IAUS 329: The Lives and Death-throes of Massive Stars

10$^{\text{th}}$ IAU Symposia on Massive Stars
Auckland, New Zealand

Poster Abstracts

November 28$^{\text{th}}$ to December 2$^{\text{nd}}$, 2016

Contents

Death Throes: Supernovae, Stellar Deaths and Progenitors

Is the link between the observed velocities of neutron stars and their progenitors a simple mass relationship?

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Neutron stars (NS's) are observed with much higher spacial velocities than their accepted OB star progenitors, some with measured velocities in excess of 1500km/s. While it is widely accepted that these extreme velocities are a result of the supernovae that create them, the exact mechanism responsible is still not fully understood. We propose the primary source of these extreme velocities is the asymmetric ejection of the outer envelope during the supernovae, with the resulting conservation of momentum imparting a velocity "kick" the the newly created neutron stars. Using the binary stellar evolution models from BPASS and our proposed mass ratio relationship, we are able to show that the observed neutron star velocity is primarily determined by the range of ejecta masses that arise in the supernova progenitors due to binary evolution.

RADFLAH: A New, Open Numerical Framework to Model Supernova Light Curves with the FLASH Code

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Poster 12

We present the newlyincorporated gray radiation hydrodynamics capabilities of the FLASH code based on a radiation fluxlimiter aware hydrodynamics numerical implementation designed specifically for applications in astrophysical problems. The newly incorporated numerical methods consist of changes in the pristine unsplit hydrodynamics solver using operator splitting and adjustments in the fluxlimited radiation diffusion unit. Our method can treat problems in both the strong and weak radiationmatter coupling limits as well as transitions between the two regimes. Appropriate extensions in the "Helmholtz" equation of state are implemented to treat twotemperature astrophysical plasmas involving the interaction between radiation and matter. A set of radiationhydrodynamics test problems is presented aiming to showcase the new capabilities of FLASH and to provide direct comparison to similar codes like CASTRO. To illustrate the capacity of FLASH to simulate phenomena occurring in stellar explosions, such as shock breakout, radiative precursors and ejecta heating due to the decays of radioactive nickel and cobalt, we also present an 1D supernova simulation yielding a model gray light curve. The latest public release of FLASH with these enhanced capabilities is freely available for download and use by the broader astrophysics community.

The Variety of Gamma-Ray Burst Supernovae and Their Progenitors

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Observing the supernovae (SNe) associated to the different types of gamma-ray bursts (GRBs) is one of the few means to study their progenitors. In the past years, it has become clear that the GRB-like events are more heterogeneous than previously thought. Moreover, the SNe associated with different sub-types of GRBs are seen to differ, especially those associated with ultra-long duration GRBs. To address this issue in a systematic way we started in 2010 an observing programme at the 10.4m GTC telescope.In this talk I will present the results of our observational programme, including the detection of 12 new GRB-SNe, and will discuss them in the context of all known GRB-SNe. Highlights of our sample are the discovery of the first SN associated with a hyper-energetic burst (GRB 130427A), the study of the SN associated with the shock-breakout GRB 140606A, or the SN associated to the peculiar ultra-long GRB 101225A at $z = 0.85$. I will also present new, unpublished photometric and spectroscopic observations of the SNe of GRB 150518A and 150818A.

The Progenitor-Remnant Connection of Neutrino-Driven Supernovae Across the Stellar Mass Range

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We perform hydrodynamic supernova (SN) simulations in spherical symmetry for progenitor models and metallicities to explore the progenitor-explosion and progenitor-remnant connections based on the neutrino-driven mechanism. We use an approximative treatment of neutrino transport and replace the high-density interior of the neutron star (NS) by an inner boundary condition based on an analytic proto-NS core-cooling model, whose free parameters are chosen.Our models are calibrated to reproduce the observables of SN 1987A and the Crab SN for theoretical models of their progenitor stars. Judging the fate of a massive star, either a neutron star (NS) or a black hole (BH), solely by its structure prior to collapse has been ambiguous. Our work and previous attempts find a non-monotonic variation of successful and failed supernovae with zero-age main-sequence mass. We identify two parameters based on the "critical luminosity" concept for neutrino-driven explosions, which in combination allows for a clear separation of exploding and non-exploding cases. Continuing our simulations beyond shock break-out, we are able to determine nucleosynthesis, light curves, explosion energies, and remnant masses. The resulting mean remnant masses are 1.4 solar masses for NS and 9 solar masses for BH if only the helium core implodes.

Diversified Core-Collapse Supernovae Through A Jet-Feedback Mechanism

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I propose that the energy output of explosions following massive stellar core-collapse is regulated through a jet-feedback mechanism. This scenario advocates for jet-powered central engines producing different outcomes depending on the efficiency of the interaction between the jets and their surrounding. An efficient coupling of the jets with the infalling material will result in the halt of material accretion and the central engine shutting down early-on, resulting in a regular energy supernova. A lower efficiency will allow a longer accretion period and a higher energy output from the central engine, possibly resulting in black hole formation and superluminous supernovae or gamma-ray bursts. I demonstrate these concepts on models of massive stars with the aid of analytic approximations and numerical codes, and discuss potential consequences of this model.

Wolf-Rayet Stars in M81: Detection and Characterization Using GTC/OSIRIS Spectra and HST/ACS Images

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Poster 25

We here report the properties of Wolf-Rayet (W-R) stars in 14 locations in the nearby spiral galaxy M81. These locations were found serendipitously while analysing the slit spectra of a sample of $\sim$ 150 star-forming complexes, taken using the long-slit and Multi-Object spectroscopic modes of the OSIRIS instrument at the 10.4m Gran Telescopio Canarias. Colours and magnitudes of the identified point sources in the Hubble Space Telescope images compare well with those of individual W-R stars in the Milky Way. Using templates of individual W-R stars, we infer that the objects responsible for the observed W-R features are single stars in 12 locations, comprising of 3 WNLs, 3 WNEs, 2 WCEs and 4 transitional WN/C types. In diagrams involving bump luminosities and the width of the bumps, the W-R stars of the same sub-class group together, with the transitional stars occupying locations intermediate between the WNE and WCE groups, as expected from the evolutionary models. However, the observed number of 4 transitional stars out of our sample of 14 is statistically high as compared to the 4% expected in stellar evolutionary models.

Time Lapse Spectropolarimetry: Constraining the Nature and Progenitors of interacting CCSNe

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SNe Type IIn are among the brightest supernova explosions due to strong circumstellar interaction, but the category is not well defined. The heterogeneous nature of the class, in addition to a wide range of time dependence of the interaction behavior, implies that any number of different progenitors can give rise to a IIn event so long as there is appreciable mass loss prior to explosion. Serendipitously, an examination of the geometric and optical properties of the circumstellar material (CSM) can help to identify the progenitors of individual IIn SNe. Polarimetry is the optimal method for constraining CSM characteristics as polarimetric signals depend on and preserve geometric information from unresolved sources.

We present results of an ensemble of three-dimensional simulations of the polarized H alpha emission-line profiles of interacting SNe using a Monte Carlo radiative transfer code called SLIP. A novel feature of these simulations is their ability to emit photons from a distributed shock region as well as from a central source. This allows us to examine two separate scenarios that can potentially produce IIn events: one where the SN photosphere is completely obscured and all emission is generated from shocked CSM, and one in which the central photosphere is visible and only weakly interacts with CSM. We present results for how these different models best match multi-epoch observed polarized spectra of the IIn SNe 1997eg, 1998S, 2000P, 2009ip, 2010jl, 2011cc, 2011ht, and 2012ab obtained from the SNSPOL collaboration database. I will use the results to investigate relationships among SNe IIn based on viewing angle and consider whether the category should be subdivided based on physical properties of the CSM and/or progenitor.

The VLT/X-shooter GRB afterglow legacy survey

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The Swift satellite allows us to use gamma-ray bursts (GRBs) to peer through the hearts of star forming galaxies through cosmic time. Our open collaboration, representing most of the active European researchers in this field, builds a public legacy sample of GRB X-shooter spectroscopy while Swift continues to fly. To date, our spectroscopy of about 100 GRB afterglows covers a redshift range from 0.059 to about 8, with more than 20 robust afterglow-based metallicity measurements (over a redshift range from 1.7 to 5.9). With afterglow spectroscopy (throughout the electromagnetic spectrum from X-rays to the sub-mm) we can hence characterize the properties of star-forming galaxies over cosmic history in terms of redshifts, metallicities, molecular contents, ISM temperatures, UV-flux densities, etc.. These observations provide key information on the final evolution of the most massive stars collapsing into black holes, with the potential of probing the epoch of the formation of the first (very massive) stars.

Pre-Supernova Neutrino Emissions From ONe Cores in the Progenitors of Core-Collapse Supernovae

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We focus on the neutrinos emitted from the stellar core in the late phase before core bounce, called "pre-supernova neutrinos". These neutrinos have relatively lower-energy than usual supernova neutrinos in PNS neutrino cooling phase. So, it has not been much attention to observe pre-SN neutrinos. However, they come into our sight because of the development of observational technique such as low threshold and backgrounds at several detectors in the world, for instance, Super-Kamikande, KamLAND. If we can observe these neutrinos, much information about the progenitor structure is given to us such as composition, convection properties and nuclear-burning features. This will have great important roles to confirm the stellar evolution theory. Moreover, the detection of pre-SN neutrinos becomes the alert for other observational detectors, gravitational waves and magnetic waves. So, the prediction about the propertied of pre-SN neutrinos theoretically is strongly needed for SN explosions in the future.The main purpose of our research is to distinguish 2 types of progenitors of SNe, iron-core collapse supernovae (FeCCSNe) and electron capture supernovae (ECSNe) predicted by stellar evolution theory. So, we calculate the neutrino luminosity and spectrum about these progenitors and estimate the number of events at the several detectors. Finally, we will be able to distinguish the two types of progenitors by the detection ornon-detection of the pre-supernova neutrinos if they are close enough ($<$ 1kpc).

Proper Motions of Eta Carinae's Outer Ejecta and Its Eruptive History

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Eta Carinae, the most extreme LBV in our Galaxy, underwent a Great Eruption in the 1800s and ejected significant mass into the well-known bipolar Homunculus. But Eta Car's outer ejecta, a spread of dense, nitrogen-rich knots outside the Homunculus, have led to suspicion that the Great Eruption was not this star's first major mass-loss event. We have measured proper motions for nearly 800 distinct features in the outer ejecta using 21 years of HST WFPC2 and ACS imaging. With motions measured across sixteen baselines, we find that the outer ejecta are expanding ballistically and belong to three age groups: one dating to the mid-1200s, another to the mid-1500s, and a third to the early 1800s, associated with but perhaps predating the peak of the Great Eruption. These three age groups are separated in space and radial velocity. There is no evidence for interaction between the dense ejecta that could be powering Eta Car's soft X-ray shell, which is instead likely driven by fast, rarefied ejecta from the Great Eruption striking the older dense ejecta. The thirteenth-century event was strikingly asymmetric, ejecting mass almost entirely to one side of the star. The sixteenth-century event displays bipolar symmetry, but along a different axis than the current Homunculus. These observations provide constraints on theoretical models of Eta Car's behavior, as models must explain the repetition, timescale, and asymmetry of these major mass-loss events.

Uncovering supernovae in luminous infrared galaxies

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Poster 44

A substantial number of core-collapse supernovae (CCSNe) are expected to be hosted by luminous infrared galaxies (LIRGs) due to the intense star formation rate (SFR) of these galaxies, but very few have been found. This makes these very dusty LIRGs prominent hunting grounds to resolve the so called "Supernova Rate problem", where up to half of the CCSNe expected from the measured cosmic SFR are not observed. In the SUNBIRD (Supernovae UNmasked By InfraRed Detection) project we aim to uncover dust-obscured supernovae by monitoring over 25 LIRGs, using near-infrared Laser Guide Star Adaptive Optics imaging on the Gemini South and Keck telescopes. Such discoveries are vital for determining the fraction of all supernovae which will be missed as a result of dust obscuration by current and future optical surveys. I present the first results of SUNBIRD, which includes both supernova detections very close to galactic nuclei as well as in surprisingly isolated regions of these LIRGs.

Dissecting a SN Impostor's Circumstellar Medium: MUSEing About the SHAPE of η-Car's Outer Ejecta

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Eruptive and episodic mass-loss events have a key impact on the fate of massive stars. The involved physics creates large-scale circumstellar nebulae that are often spatially resolved. The nebula's kinematics, spatial symmetry, element abundance, and the presence of density inhomogeneities all provide insight into the dominant mass-loss mechanism at play. We carried out the first large-scale integral field unit observations of η-Car in the optical with the Multi Unit Spectroscopic Explorer (MUSE) at the Very Large Telescope (VLT). The observations cover a field of $1' \times 1'$ centered on the star and attain a spectral resolution of R $\sim$ 3000. We perform a three-dimensional morpho-kinematic analysis with the code SHAPE of the ejecta outside of η-Car's famous Homunculus nebula. This analysis reveals the detailed three-dimensional structure of the outer ejecta. The kinematics measured with MUSE and modeled with SHAPE establish unequivocally the spatial cohesion of the outer ejecta and their correlation with the soft X-ray emission. Our modeling and the MUSE observations constitute an invaluable dataset to be confronted with future radiation-hydrodynamics simulations. Such a comparison may shed light on the yet elusive physical mechanism responsible for η-Car-like eruptions.

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Exploring the Explosion Mechanism of Core-Collapse Supernovae in Three Dimensions

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Poster 54

We present the first successful simulations of neutrino-driven supernova explosions in three dimensions (3D) using the VERTEX-PROMETHEUS code including sophisticated energy-dependend neutrino transport. The simulated models of 9.6 and 20 solar mass iron-core stars demonstrate that successful explosions can be obtained in self-consistent 3D simulations where previous models have failed. New insights into the supernova mechanism can be gained from these explosions.The first 3D model explodes at the same time but more energetically than its axially symmetric (2D) counterpart. Turbulent energy cascading reduces the kinetic energy dissipation in the cooling layer and therefore suppresses neutrino cooling. The consequent inward shift of the gain radius increases the gain layer mass, whose recombination energy provides the surplus for the explosion energy.The second explosion is obtained through a moderate reduction of the neutral-current neutrino opacity motivated by strange-quark contributions to the nucleon spin. A corresponding reference model without these corrections failed, which demonstrates how close current 3D models are to explosion. The strangeness adjustment is meant as a prototype for remaining neutrino opacity uncertainties.

Light-Curve and Spectral Properties of Ultra-Stripped Core-Collapse Supernovae

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Poster 57

We discuss light-curve and spectral properties of ultra-stripped core-collapse supernovae. Ultra-stripped supernovae are supernovae with ejecta masses of only $\sim 0.1 M_\odot$ whose progenitors lose their envelopes due to binary interactions with their compact companion stars. We follow the evolution of an ultra-stripped supernova progenitor until core collapse and perform explosive nucleosynthesis calculations. We then synthesize light curves and spectra of ultra-stripped supernovae based on the nucleosynthesis results. We show that ultra-stripped supernovae synthesize $\sim 0.01 M_\odot$ of the radioactive ^{56}Ni, and their typical peak luminosity is around 1×10^{42} erg/s or -16 mag. Their typical rise time is 5-10 days. By comparing synthesized and observed spectra, we find that SN 2005ek and some of so-called calcium-rich gap transients like PTF10iuv may be related to ultra-stripped supernovae.

The Progenitor Masses of ~ 100 Core-Collapse SNe

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Poster 94

By age-dating the stellar populations in the vicinity of supernova remnants (SNRs), we derive the progenitor masses for more than 200 core-collapse SNe. With this large statistical sample, we are able to characterize the distribution of progenitor masses. Using Bayesian statistical inference, we find that the minimum mass of SNR progenitors is 7.2 ± 0.3 solar masses, the maximum mass is 33^{+17}_{-6} solar masses, and the power law slope in between is 2.8 ± 0.5, consistent with the Saltpeter IMF. The accuracy of the minimum mass may provide interesting constraints on stellar evolution. With regard to the maximum mass, either the most massive of massive stars are not exploding, or there is severe bias against forming SNRs by the explosions of the most massive stars.

Analytic Conditions for Core-Collapse Supernova Explosions

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Poster 95

We derive an integral condition for core-collapse supernova explosions and use it to construct a new diagnostic of explodability. The fundamental challenge in core-collapse supernova theory is to explain how a stalled accretion shock revives to explode a star. In this talk, we assume that shock revivalis initiated by the delayed-neutrino mechanism and derive an integral condition for shock expansion, $v_s > 0$. In general, there are five parameters in the core-collapse problem: the neutrino luminosity, the temperature of neutrinos, the neutron star radius, the neutron star mass, and the accretion rate onto the stalled shock. The integral condition represents an explosion condition that incorporates these five parameters, and this integral condition is represented by a single equation, which is characterized by a single dimensionless parameter, $\Psi > 0$. $\Psi = 0$ defines a critical five-dimensional hypersurface, below this surface, stalled-shock solutions exists, and above this hypersurface only $v_s > 0$ solutions exist. Therefore, $\psi = 0$ defines a critical hypersurface forexplosion, and we show that the critical neutrino luminosity curve proposed by Burrows & Goshy 1993 is a projection of this more generalcritical condition. Finally, we propose and verify with 1D simulations that $\Psi > 0$ is a reliable and accurate explosion diagnostic.

Multi-Messenger Signals From Core-Collapse Supernovae

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Poster 59

The next Galactic supernova is expected to bring great opportunities for the direct detection of gravitational waves (GW), full flavor neutrinos, and multi-wavelength photons. To maximize the science return from such a rare event, it is essential to have established classes of possible situations and preparations for appropriate observations. To this end, we use a long-term numerical simulation of the core-collapse supernova (CCSN) of a 17 solar-mass red supergiant progenitor to self-consistently model the multi-messenger signals expected in GW, neutrino, and electromagnetic messengers. This supernova model takes into account the formation and evolution of a protoneutron star, neutrino-matter interaction, and neutrino transport, all within a two-dimensional shock hydrodynamics simulation. With this, we separately discuss three situations: (i) a CCSN at the Galactic Center, (ii) an extremely nearby CCSN within hundreds of parsecs, and (iii) a CCSN in nearby galaxies within several Mpc. These distance regimes necessitate different strategies for synergistic observations. In a Galactic CCSN, neutrinos provide strategic timing and pointing information. We explore how these in turn deliver an improvement in the sensitivity of GW analyses and help to guarantee observations of early electromagnetic signals. To facilitate the detection of multi-messenger signals of CCSNe in extremely nearby and extragalactic distances, we compile a list of nearby red supergiant candidates and a list of nearby galaxies with their expected CCSN rates. By exploring the sequential multi-messenger signals of a nearby CCSN, we discuss preparations for maximizing successful studies of such an unprecedented stirring event.

New Radio Observations of Supernova 1978K

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Poster 79

SN 1978K in the southern late-type galaxy NGC 1313 is the closest (4.6 Mpc) and oldest-known example of a Type IIn supernova. It was only discovered in 1991 on the basis of its prodigious radio and X-ray luminosity, and remains bright to this day. We report new radio observations of SN 1978K at high frequency and high spatial resolution. SN 1978K has been detected at 34 and 94 GHz with the ATCA, leading to the exciting prospect that it will be the first extragalactic supernova remnant after SN 1987A to be detected with ALMA. VLBI observations at 8.4 GHz have allowed us to derive the past average expansion velocity, which indicates significant deceleration as the blast wave interacts with the dense circumstellar medium characteristic of Type IIn supernovae.

The Berkeley Sample of Stripped-Envelope Supernovae: 20+ Years of Spectroscopy and Photometry

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Poster 81

Stripped-envelope supernovae (SNe of types IIb/Ib/Ic, as well as some rarer subtypes) are associated with the core collapse of some of the most massive stars in the universe. These SNe exhibit heterogenous properties in their spectral and photometric evolution, the study of which is confounded by the scarcity of well-observed examples (these subtypes, on average, are both less luminous and less volumetrically common than SNe of types II and Ia). I will present the ongoing effort at Berkeley to analyze, understand, and make public the large sample of stripped-envelope SNe observations accumulated by the Filippenko group - data both previously published and as-yet unpublished, including 700+ spectra of 250+ SNe.

CFHT/Sitelle Observations of the Ejected WR Nebula M1-67

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I will present observations of the ejected WR nebula M1-67 obtained with the newly commissioned Sitelle Fourier transform spectrograph at the CFHT. The datacubes we have obtained are of unprecedented spatial and spectral resolution and allow us to determine abundances, temperature, densities and kinematics at each point of the entire nebula. From this dataset, we will be able to disentangle the origin of the two components of the nebula, the relatively spherical shell and the bipolar outflow, through comparison with theoretical predictions. This way, we will be able to determine if they originated in an RSG, LBV or WR phase and will allow to shed more light on the evolutionary path of this star.

Spectropolarimetry of the Broad Line Type Ic SN 2014ad

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Poster 83

The connection between Gamam-Ray Bursts (GRBs) and broad line Type Ic Supernovae (SNe), makes these SNe targets of interest in order to better understand the mechanisms by which they explode and produce GRBs. To this end, spectropolarimetry is a very powerful tool, allowing us to determine the 3 dimensional geometry of the ejecta of spatially unresolved SNe. Here we present 7 epochs of spectropolarimetry of the broad line Type Ic SN 2014ad, and compare our results to Type Ic SNe associated with GRBs, such as 1998bw, 2003dh and 2006aj.

Exploring the Physics of Core-Collapse Supernovae With Multidimensional Simulations: From Axisymmetry to Three Dimensions

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Multi-dimensional effects are essential for the success of the neutrino-driven explosion mechanism of core-collapse supernovae. Although astrophysical phenomena in nature involve three spatial dimensions, the huge computational demands still allow only for a few self-consistent, three-dimensional (3D) simulations focusing on specific aspects of the explosion physics, whereas systematic studies of larger sets of progenitor models or detailed investigations of different explosion parameters are restricted to the axisymmetric (2D) modeling approach at the moment. Employing state-of-the-art neutrino physics, we present the results of self-consistent core-collapse supernova simulations performed with the Prometheus-Vertex code in 2D and 3D. The 2D study of 18 successfully exploding pre-supernova models in the range of 11 to 28 solar masses shows the progenitor dependence of the explosion dynamics: if the progenitor exhibits a pronounced decline of the density at the Si/Si-O composition shell interface, the rapid drop of the mass-accretion rate at the time the interface arrives at the shock induces a steep reduction of the accretion ram pressure. This causes a strong shock expansion supported by neutrino heating and thus favors an early explosion. In case of a more gradually decreasing accretion rate, it takes longer for the neutrino heating to overcome the accretion ram pressure and explosions set in later. By considering the effects of turbulent pressure in the gain layer, we derive a generalized condition for the critical neutrino luminosity that captures the explosion behavior of all models very well. We show that this concept can also be extended to describe the behavior of recent 3D simulations and that the conditions necessary for the onset of explosion can be defined in a similar way. Finally, we discuss the effects of stellar rotation on the explosion physics in 2D and 3D and place our results into the context of observed neutron star spin and kick velocities.

Core-Collapse Supernovae in the Early Universe: Radiation Hydrodynamics Simulations of Multicolor Light Curves

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Poster 87

The properties of the first generation of stars and their supernova (SN) explosions remain unknown due to the lack of their actual observations. Pop III stars may have been very massive and predicted to be exploded as pair-instability SNe, but the observed metal-poor stars show the abundance patterns which are more consistent with yields of core-collapse SNe.We study the multicolor light curves for a metal-free core-collapse SN models (massive stars of 25-100 solar mass range) to determine the indicators for the detection and identification of first generation SNe. We use mixing-fallback supernova explosion models which explain the observed abundance patterns of metal poor stars. Numerical calculations of the multicolor light curves are performed using the multigroup radiation hydrodynamic code STELLA. The calculated light curves of metal-free SNe are compared with our calculations of non-zero-metallicity models and observed SNe. We have found that the color evolution is especially helpful for estimating the metallicity of the SN progenitor. Our results could be used to identify first-generation SNe in the current (Subaru/HSC) and future transient surveys (LSST, James Webb Space Telescope). They are also suitable for identifying of the low-metallicity SNe in the nearby Universe (PTF, Pan-STARRS, Gaia).

The Impacts of Pre-Collapse Structures In CCSNe Theory

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Poster 92

The main topic of CCSNe theory is now starting to pay attention to what is exact condition of powerful explosion and particularly what kind of pre-collapse structure expedite to obtain the canonical explosion, i.e. "initial problem". So far the practical stellar evolution calculations of massive stars are, however, still in progress due to the complicated convection theory, the effect of rotation, the presence of mass loss events and the resolution dependence. In Yamamoto et al. (2016), we studied the influence of the progenitor structure on the dynamics systematically by constructing progenitor models parametrically instead of employing realistic models provided by stellar evolution calculations. The mass of the iron core and that of silicon plus surfer (Si+S) layer are chosen as the parameters and dynamical evolutions after collapse are calculated in one and two dimensions. We found that the explosion energy is tightly correlated with mass accretion rate at shock revival irrespective of dimension and the lighter iron cores but with rather high entropies, which are yet to be produced by realistic stellar evolution calculations, may produce the more energetic explosions and the larger amounts of nickel masses. Our simulation confirmed necessity of early time explosion to reproduce 1051 erg.The authors further studied the parametric pre-collapse structures by altering the entropy distributions in core so as to see the difference in the time evolution of mass accretion rates. Furthermore, the models are also extended to shellular rotation stars by employing an approach in Fujisawa et al. (2015). These additional effects will be demonstrated and discussed in the conference.

Rising from the Ashes: Mid-Infrared Re-Brightening of the Impostor SN 2010da in NGC 300

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We present multi-epoch mid-infrared (IR) photometry and the optical discovery observations of the "impostor" supernova (SN) 2010da in NGC 300 using new and archival Spitzer Space Telescope images and ground-based observatories. The mid-IR counterpart of SN 2010da was detected as SPIRITS 14bme in the SPitzer InfraRed Intensive Transient Survey (SPIRITS), an ongoing systematic search for IR transients. A sharp increase in the 3.6 μm flux followed by a rapid decrease measured $\sim$150 d before and $\sim$80 d after the initial outburst, respectively, reveal a mid-IR counterpart to the coincident optical and high luminosity X-ray outbursts. At late times after the outburst ($\sim$ 2000 d), the 3.6 and 4.5 μm emission increased to over a factor of 2 times the progenitor flux. We attribute the re-brightening mid-IR emission to continued dust production and increasing luminosity of the surviving system associated with SN 2010da. We analyze the evolution of the dust temperature, mass, luminosity, and equilibrium temperature radius in order to resolve the nature of SN 2010da. We address the leading interpretation of SN 2010da as an eruption from a luminous blue variable (LBV) high-mass X-ray binary (HMXB) system. We propose that SN 2010da is instead a supergiant (sg)B[e]-HMXB based on similar luminosities and dust masses exhibited by two other known sgB[e]-HMXB systems. Additionally, the SN 2010da progenitor occupies a similar region on a mid-IR color-magnitude diagram (CMD) with known sgB[e] stars in the Large Magellanic Cloud. The lower limit estimated for the orbital eccentricity of the sgB[e]-HMXB ($e > 0.82$) from X-ray luminosity measurements is high compared to known sgHMXBs and supports the claim that SN 2010da may be associated with a newly formed HMXB system.

A New Prescription for the Mass-Loss Rates of Hydrogen-Free Wolf-Rayet Stars and Its Implications for Massive Star Evolution

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Poster 88

We present a new empirical prescription for the mass-loss rates of hydrogen-free Wolf- Rayet stars as a function of their luminosity, surface chemical composition, and initial metallicity. The prescription provides an improvement in describing the mass-loss rates of WC and WO stars compared to the often used Nugis & Lamers (2000; NL00) prescription, in particular during the later stages of Wolf-Rayet evolution. Compared to NL00, the prescription has a shallower dependence on both luminosity and surface chemical composition, implying higher mass-loss rates at low luminosities and low surface helium abundances. We obtain a weak metallicity dependence for the wind strength of WC and WO stars, implying that if these stars are formed in low-metallicity environments, their winds are relatively strong. We discuss the implications of the new mass-loss rates for the immediate pre-supernova evolution of massive stars.

Observations and Surveys of Massive Stars: Hot Stars, Cool Stars, Transition Objects and Binaries

The Potential of Using KMOS for Multi-Object Massive Star Spectroscopy

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Earth

Poster 91

KMOS, the "K-Band Multi-Object Spectrometer", was built by a British-German consortium as a second generation instrument for the ESO Paranal Observatory. It is available to the user community since its successful commissioning in 2013Although the main science driver for KMOS was to enable the study of galaxy formation and evolution through multiplexed observations of high-redshift galaxies and the majority of ongoing programs actually are addressing this task. We therefore aim at presenting the excellent capabilities of KMOS to a wider community and indicate potential applications in massive star spectroscopy. are quite a few applications beyond that. This includes, for example, stellar spectroscopy of blue and red supergiants in and beyond the Local Group (e.g. Gazak et al., 2015). (Sharples et al., 2013). As a multi-object integral field spectrometer for the near infrared, KMOS offers 24 deployable IFUs of 2.8×2.8 arcsec and 14×14 spatial pixels each, which can either be placed individually within a 7.2 arcmin field of view or combined in a mosaic mode in order to map contiguous fields on sky. The instrument covers the whole range of NIR atmospheric windows (0.8...2.5μm) with 5 spectral bands and a resolution of R$\sim$3000...4000.

Difference Frequencies in Pulsating Be Stars and Their Relation to Mass Loss

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Poster 5

Classical Be stars are B stars suffering discrete outbursts with cadences from weeks to years. Be stars are the most rapid rotators among non-degenerate stars. Nevertheless, viscosity is needed to redistribute angular momentum such that 1% of the ejecta do reach Keplerian orbits and form a disk. In the local Universe, about 5% of all core-collapse supernovae should have Be stars as their progenitors. Their pulsations have diagnostic potential in two different areas: For the exploration of the stellar density, rotation, and chemical profiles and for the identification of the energy supply of the outbursts. Spectroscopy and ground-based photometry have mapped not even the tips of these icebergs. But the motivation these observations provided has been brought to rich fruition by the advent of dedicated space photometers (BRITE, CoRoT, Kepler, MOST, SMEI, etc.) as reported in this contribution: 1. Outbursts may occur with frequencies corresponding to the difference between pulsation frequencies. 2. The associated stellar variations seem to take on the nature of variabilities in their own right: They are not just frequency differences but difference frequencies. 3. The amplitudes associated with difference frequencies may be similar to, or even larger than, the amplitude sum of the parent frequencies, suggesting strong non-linear mode coupling. 4. In some cases, the mass loss appears modulated with the difference frequencies, which could be powering outbursts. 5. Especially close to outbursts, dense groups of incoherent frequencies arise, which, as groups, exhibit harmonic relations. Spectroscopy suggests that they are not stellar but reside in the star-disk transition region. They may be due to large-scale eddies in the circumstellar gas flow. The objects discussed include prominent names such as 27 and 28 ω CMa, γ Cas, η and μ Centauri, and 28 Cygni.

Investigating the Detectability of Wolf-Rayet Stars Beyond the Local Group

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Poster 8

The supernova zoo still remains very much a mystery for many classifications of SNe. For example, the progenitors of Type Ib/c SNe are predicted to be either massive WR stars, low-mass stripped helium cores or a combination of both, however this has not yet been confirmed. For Type Ib/c SNe, efforts to identify the progenitor star have been hindered by either the lack of pre-imaging at sufficient depth (e.g. SN 2003jg) or insufficient resolution to identify a single star (e.g SN 2007gr). We use narrow-band imaging of M33, which spatially resolves individual Wolf-Rayet stars to investigate the detectability of WR stars in both nearby ($\sim$ 5Mpc) and distant ($\sim$ 30Mpc) galaxies. By artificially degrading the images to represent more distant galaxies we find that (i) the faintest WR stars are no longer detected and (ii) the HeII emission from WR stars in crowded regions is diluted by surrounding stars, becoming unresolvable. Consequently, the detectability of WR stars is significantly affected by over 50% at the greatest distances and as such our ability to identify SNe progenitors suffers for more distant populations.

Near-Infrared Photometric Properties of Red Supergiant Stars in Extragalactic Galaxies NGC 4449, NGC 5055 (M63) and NGC 5457 (M101)

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Poster 13

We present near-infrared photometric properties of red supergiant stars (RSGs) in three extragalactic galaxies NGC 4449, NGC 5055 and NGC 5457. The near-infrared imaging data were obtained from WFCAM UKIRT, and optical imaging archive data (CFHT and Subaru) were also used to remove foreground Galactic stars. We identified RSGs of galaxies from the Galactic stars using (i-K, r-i) colour-colour diagram. The effective temperature and luminosities of the identified RSGs were derived from broadband JHK photometry using MARCS synthetic fluxes. We found that all three galaxies have the majority of RSGs between $\log L/L_{\odot} = 4.8$ and 5.7, and their effective temperature and luminosities agree well with the current evolutionary tracks with masses in the range $9 - 30 M_{\odot}$. In the spatial distribution of RSGs with the HII regions, the RSGs of NGC 4449 and NGC 5457 show spatial correlation with the HII region, which however is not the case for NGC 5055. We do not find a clear metallicity dependance on the RSG effective temperature in the three galaxies, but the maximum luminosity of the three galaxies is constant at $\log L/L_{\odot} \sim 5.6$. Failure to confirm the metallicity effect on the location of RSGs in an H-R diagram is likely to be attributed to the inaccuracy of the colour-dependent identification of RSGs and the uncertainty in circumstellar extinction. Additional spectroscopy data, including photometry are essential to examine whether the physical properties of RSGs change with metallicity.

Disentangling Rotational Velocity Distribution of Stars

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Poster 15

Rotational speed is an important physical parameter of stars: knowing the distribution of stellar rotational velocities is essential for understanding stellar evolution. However, rotational speed cannot be measured directly and is instead the convolution between the rotational speed and the sine of the inclination angle — $v\sin(\alpha)$. The problem itself can be described via a Fredhoml integral of the first kind. A new method (Curé et al. 2014) to deconvolve this inverse problem and obtain the cumulative distribution function for stellar rotational velocities is based on the work of Chandrasekhar & M$\acute{'}$unch (1950). Another method to obtain the probability distribution function is Tikhonov regularization method (Christen et al. 2016, submitted).The proposed methods can be also applied to the mass ratio distribution of extrasolar planets and brown dwarfs (in binary systems, Curé et al. 2015).For stars in a cluster, where all members are gravitationally bounded, the standard assumption that rotational axes are uniform distributed over the sphere is questionable. On the basis of the proposed techniques a simple approach to model this anisotropy of rotational axes has been developed with the possibility to "disentangling" simultaneously both the rotational speed distribution and the orientation of rotational axes.

Assessing the Possible Existence of Co-Rotating Bright Spots On OB Stars

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Poster 17

OB stars exhibit various types of spectral variability associated with wind structures, including the apparently ubiquitous discrete absorption components (DACs) seen in the absorption troughs of their UV resonance lines. They are thought to be caused by either magnetic fields or non-radial pulsations. Current models using ad hoc co-rotating bright spots on the surface of these stars successfully reproduce the qualitative properties of DACs, but the existence of such spots remains speculative. Following the first claimed detection of such spots in the light curve of the O giant xi Persei, a suite of observational diagnostics is developed to assess the validity of this "bright spot paradigm" (BSP). Using optical photometry and time-resolved spectroscopy, we search for signatures consistent with the BSP, while also deriving constraints which allow us to evaluate the role of both magnetism and pulsations in producing this phenomenon.

Photometric Variability of Luminous Blue Variables in M33 on Short Timescales

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Poster 22

We used SDSS r-band aperture photometry and astrometry of ∼500 000 stellar-like objects in the M33 galaxy performed by the CASU (Cambridge Astronomy Survey Unit) Astronomical Data Centre in the Institute of Astronomy, University of Cambridge. The observations were carried out with the 2.6m VISTA telescope at the Cerro Paranal, Chile. More than 500 images in that passband were obtained with the OmegaCAM, a large format (16k×16k pixels) CCD camera, and each of them covers a field of view of $1^\circ \times 1^\circ$. The current time span of the data is 2.1 yrs until the end of 2014. The structure function analysis (Hughes et al. 1992) was applied in order to study the variability of ~ 30 known or suspected LBVs in the M33 galaxy (Massey et al. 2007) on different time scales. In some cases like Var C the time resolution of the data allows us to confirm an enhanced weekly variations Dm ~ 0.3m which is somehow shorter than the previously know typical monthly variations with the same maximum amplitude thought to be caused by non-radial pulsations.

Ages of High-Mass X-ray Binaries in M33

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Poster 23

We present initial results on a study of high-mass X-ray binaries (HMXBs) in the nearby, star-forming spiral galaxy M33. We identify and characterize HMXB candidates in M33 using a combination of deep Chandra X-ray imaging and archival Hubble Space Telescope (HST) observations. We determine ages for the HMXBs in our sample to ∼5 Myr precision from fits to the color-magnitude diagrams of the surrounding stars and the resultant star formation histories (SFHs). In addition to measuring ages for the HMXBs in our M33 sample, we identify candidate optical counterparts as probable supergiants or OB stars from HST photometry. Previous studies of HMXB populations in NGC300, the Small Magellenic Cloud, and NGC2403 have revealed HMXBs to have a preferred age of ∼30-60 Myr, implying large fractions of HXMBs contain Be donor stars, which may constrain binary formation channels in these galaxies. Our sample of HMXBs in M33 is now well-characterized with both measured ages and optically identified candidate donor stars. Our measurements add M33 to the handful of galaxies with well-described HMXB populations. Together, these galactic hosts provide improved characterization of the interplay between host galaxy properties, such as metallicity and SFH, and the evolution of massive binary stars.

The Yellow and Red Supergiants of M31/M33 and Post-Red Supergiant Evolution

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Poster 26

From surveys of luminous star populations in nearby galaxies, we have selected a sample of yellow and red supergiant candidates in M31 and M33 for study of their spectral characteristics and spectral energy distributions to place them on an HR Diagram. As the position of intermediate and late-type supergiants on the color-magnitude diagram can be heavily contaminated by foreground dwarfs, we used spectral classification and multi-band photometry from optical and near-infrared surveys to confirm membership, in addition to careful measurements of the extinction along the line-of-sight to each source to determine bolometric luminosities. Based on spectroscopic evidence for stellar winds and mass loss and the presence of circumstellar dust in their SEDs, we find that 30-40% of the yellow supergiants in M31 and M33 are likely in a post-red supergiant state. Comparison with evolutionary tracks suggests that these mass-losing, post-RSGs have initial masses between $20 - 40 M_{\odot}$. More than half of the observed red supergiants are producing dusty circumstellar ejecta, and thus may be more likely to evolve back to warmer temperatures due to their high mass loss.

The O-Supergiant Binary Star HD166734: A New Study

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Poster 28

The O7.5If + O9I binary star HD166734 presents a period around 34.5 d and a high eccentricity. The minimum masses are both around 30 solar masses. Well studied O-supergiant binaries are not frequent objects. Despite the interest of HD166734, the determination of the orbit dates back to 1982. We present here the results of modern spectroscopic campaigns leading to a new determination of the orbit and to a disentangling of the spectra opening the possibility to perform an individual CMFGEN analysis of both components. We also present a new estimation of the masses thanks to a detailed study of the visible lightcurve and to the discovery of an eclipse.

ALMA Observation of Mass-Loss Rates From Massive Stars

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Poster 29

There are sufficient evidence that points to an over-estimation of the currently accepted mass-loss rates from massive stars as shown by inconsistencies in results derived using different diagnostics, attributed to wind clumping. Potential downward revisions of mass-loss rates of massive stars have a profound effect on the stars' evolution. In this poster we present the results of the ALMA continuum observations of a selection of massive stars. The ALMA bands provide the necessary sub-millimeter and millimeter information to constrain the density/clumping structure in the intermediate wind zone, in which the wind is extremely sensitive to clumping. Our ultimate goal is to combine analysis of all diagnostics from the Far-UV to the radio domain with consistency, to derive the clumping properties throughout the entire wind and help to constrain the physical origin of wind clumping.

The origin of the dusty Mass loss of Betelgeuse

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Poster 31

The origin of red supergiant mass loss still remains to be unveiled. Characterising the formation loci and the dust distribution in the first stellar radii above the surface is key to understand the initiation of the mass loss phenomenon. With its angular diameter of about 43 mas in the near-infrared, Betelgeuse makes an ideal target to study the inner structures that represent potential signatures of dust formation.SPHERE/ZIMPol observations reported in Kervella et al. 16 revealed that Betelgeuse shows an asymmetric dust environment in the 3 inner stellar radii. Depending on their characteristics and composition, these grains could interact with the stellar radiation and trigger mass loss via a dust wind.The power of polarimetric interferometry, already demonstrated in Norris et al., Nature 2012, was applied to Betelgeuse using the NACO/SAMPol instrument at ESO/VLT.These observations allowed us to detect an inner dust atmosphere located only 0.4 stellar radius above the photosphere. With a Mie scattering modelling, we estimated dust grain sizes and densities for various dust composition. Extrapolating to the visible wavelengths, we compare our radiative transfer modelling to the SPHERE/ZIMPol data reported in Kervella+16 and conclude on the nature of the two dust distributions.

MASGOMAS: Building a Bona-Fide Catalog of Galactic Massive Star Clusters

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Poster 33

MASGOMAS (MAssive Stars in Galactic Obscured MAssive clusterS) is a project aiming at discovering obscured Galactic OB stars forming massive clusters. We started searching for the clusters by eye in surveys like 2MASS. Since then, the project has gone through different phases of increasing automatization, that have allowed us to discover some massive clusters, like MASGOMAS-1 (with more than 20,000 solar masses), MASGOMAS-4 and MASGOMAS-6 (with a few thousands).Here we present the latest advances in our project, designed to build up a catalog of bona-fide candidates, minimizing the spurious selections. We apply the method to the region around the $l = 33$ region, where we found MASGOMAS-1 and present some preliminary observations.

Quantitative Spectroscopic Analysis of O Stars in the IACOB+OWN Project: Massive Stars in the Galaxy With the Imminent GAIA information.

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Poster 35

Massive stars are luminous beacons that help us to extract information about the star formation history and the chemodynamical evolution of galaxies in the Universe. They are also one of the agents suggested to trigger the re-ionization of the Universe. Our Galaxy is full of massive stars, which expend their short-lived existence within bright star-forming regions, depositing huge amounts of mechanical and radiative energy to the interstellar medium before they explode as energetic supernovae event.The IACOB and OWN projects have collected a large database of high-resolution multi-epoch spectra of Galactic O and B-type stars, $\sim$10000 spectra for more than 700 stars. This unique spectroscopic dataset, once analyzed and interpreted with state-of-the-art tools and techniques will provide a new, global overview of the physical and evolutionary properties of massive stars in their early phases.In this contribution, I will present the results from the quantitative spectroscopic analysis of $\sim$280 likely single O stars targeted by the IACOB and OWN surveys (implying the largest sample of O Galactic O stars analyzed homogeneously, using modern automatized tools). I will put special emphasis on the subsample of $\sim$130 O stars included in the recently revised (by the GOSSS project) grid of standards for spectral classification. Finally I will also highlight the impact of the GAIA mission in the determination of physical parameters of massive stars, both in the IACOB project and in future Multi-Object Spectroscopy Surveys.

Revealing the structure of the outer disks of Be stars

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Poster 42

Classical Be stars possess self-ejected gaseous circumstellar disks governed by viscous forces. The structure of the inner parts (< 20 stellar radii) of these disks is well explained by the viscous decretion disk model (VDD), which is able to reproduce multi-technique observable properties of most of the so-far studied objects.

The IR and radio continuum excess in Be stars arises from free-free emission from the ionized disk. As the free-free opacity increases with wavelength, fluxes at longer wavelengths originate from progressively larger areas of the disk. Therefore, the outer parts of the disks are observable at radio wavelengths only. However, the structure of the outer parts has not been observationally constrained for more than a handful of targets. A steepening of the spectral slope somewhere between infrared and radio wavelengths was reported for the handful of Be stars that were actually observed in radio, but the physical reason for this feature remains mostly unknown. The most straightforward explanation is offered by unseen secondary companions tidally influencing the disk.

New radio flux measurements of several Be stars from APEX/LABOCA ($\lambda = 0.87$mm), CARMA ($\lambda = 3$mm) and JVLA ($\lambda = 0.7 - 6$cm) will be presented. The compiled spectral energy distributions covering the interval from ultraviolet to radio are modeled with the Monte Carlo radiative transfer code HDUST. Change of the disk structure in the form of a faster than expected density fall-off in its outer parts ($\sim 20 - 100$ stellar radii) is confirmed by the physical model. The change in the density regime is the same for known binaries (γ Cas) as well as for Be stars that are almost certainly isolated (EW Lac). Therefore, another mechanism besides the effect of binarity seems to be at play in the outer disks.

The Next Possible Outburst of P Cygni

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Poster 43

On the basis of long-term UBV observations of P Cygni, which were made by Eugene Kharadze and Nino Magalashvili between 1951-1983, is evident that P Cygni undergone reddening during those observations. P cygni is a LBV and a supernova impostor. Corrected on the reddening B-V color has values between about -0.4 (at the beginning of 1950-ies) and -0.1 (for the 1980-ies). It means that the star probably had earlier spectral type at the beginning of 20-th century and accordingly, we are witnesses of its evolutionary changes. It means also that on the HR diagram the star moves gradually to the instability strip of "LBVs in Outburst" (see N.Smith, Vink and De Koter, ApJ, 2004.). So, if the rate of the reddening of the P Cygni will the same in near future then the star will have the next eruption (or even supernova explosion) after approximately 80-120 years. According to the new photometric observations of 2014 the star continues reddening. The long (approximately 1500 d, 1160 d, 760 d, 580 d) quasi-periods and the shorter ones (approximately 130 d, 68 d and 15-18 days) were revealed using the above observations. We suggest that P Cygni pulsates.

Photometric Variability of the Be Star Population With the KELT Survey

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Poster 46

Be stars are main sequence, rapidly rotating B-type stars with emission lines in their spectra attributed to a gaseous circumstellar disk. Variability across a wide range of timescales (from hours to decades) is observed in this class of objects, including stellar pulsations, outbursts, oscillations in the circumstellar disk, and the total disappearance (or reappearance) of the disk. Using data from the KELT survey (Kilodegree Extremely Little Telescope; a wide-field photometric survey designed to find transiting exoplanets with high precision of $\sim$ 1% and baselines up to 10 years for $\sim$3 million objects), we investigate the light curves of hundreds of Be stars and find many systems exhibiting the aforementioned types of variability. Many of these Be stars also have existing spectra simultaneous with the KELT photometry, providing a unique look into the correlation between spectroscopic features and photometric variability, and allowing us to study how these observables relate to the underlying physical processes present in Be stars.

Massive Stars in M31

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Poster 49

Massive stars are intrinsically rare and therefore present a challenge to understand from a statistical perspective, especially within the Milky Way. We recently conducted follow-up observations to the Panchromatic Hubble Andromeda Treasury (PHAT) survey that were designed to detect more than 10,000 emission line stars, including WRs, by targeting regions in M31 previously known to host large numbers of young, massive clusters and very young stellar populations. Because of the existing PHAT data, we are able to derive an effective temperature, bolarimetric luminosity, and extinction for each of our detected stars. We report on preliminary results of the massive star population of our dataset and discuss how our results compare to previous studies of massive stars in M31.

The Circumstellar Environment of B[e] Supergiants

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Poster 51

Massive stars affect strongly the insterstellar medium through their intense stellar winds and their rich chemically processed material as they evolve. This interaction becomes substantial in short-lived transition phases of massive stars (e.g. B[e] Supergiants, Luminous Blue Variables, Yellow Hypergiants) in which mass-loss is more enhanced and usually eruptive. A complex environment, combining atomic, molecular and dust regions, is formed around these stars. In particular, the circumstellar environment of B[e] Supergiants is not well understood. To address that, we have initiated a campaign to investigate these environments for a sample of Galactic and Magellanic Cloud sources. Using high-resolution optical and near-infrared spectra (using MPG-ESO/FEROS, GEMINI/Phoenix and VLT/CRIRES, respectively), we examine a set of emission features ([OI], [CaII], CO bandheads) to trace their physical conditions and kinematics in their formation regions. We find that the B[e] Supergiants are surrounded by a series of single and/or multiple equatorial rings, of different physical conditions (temperature, density), a probable result of previous mass-loss events. In many cases the CO forms very close to the star, while we notice also an alternate mixing of densities and temperatures (which give rise to the different emission features) along the equatorial plane.

Machine Learning Approaches to Selecting Wolf-Rayet Candidates

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Poster 52

WR stars are excellent tracers of recent star formation. A map of Galactic star forming regions is key to understanding the history of the Milky Way, in context with the stellar demographics and the high-mass end of the stellar initial mass function (IMF). This task is made difficult by dust obscuration along the Galactic plane. In the last decade, infrared searches have significantly increased the number of confirmed WR stars, thanks to the lower obscuration by dust at infrared wavelengths compared to the visible. The current census of 727 WR stars is smaller than the lowest predicted limit from previous survey estimates. The WR stellar population can be distinguished, at least partially, from other stellar populations by broad-band IR colour selection. We discuss the use of machine learning classifiers to quantitatively improve the selection of WR candidates. These methods are used also to separate the other stellar populations which have similar IR colours, e.g., young stellar objects (YSOs), asymptotic giant branch (AGB) stars, Herbig Ae/Be objects, etc. In particular, we show the results of the classifications obtained by using the 2MASS J, H and K photometric bands, and the Spitzer/IRAC bands at 3.6, 4.5, 5.8 and 8.0 μm, as reported in the GLIMPSE catalog. One method has been used to select new WR candidates for observational follow-up. A few candidates have been observed with the 3-meter InfraRed Telescope Facility (IRTF). The preliminary tests and new observations are very promising, suggesting that a detection rate of 50% can be easily achieved, and our work indicates that up to $\sim 80\%$ is also a realistic objective. Once completeness is quantitatively understood based on candidacy success rates, varying by region and WR class, we can project the population again by region and class with error bars.

WR 148 and the Not So Compact Companion

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Poster 58

WR 148 (WN8h) is a single lined spectroscopic binary with an established period of 4.3174d suspected to harbour either a low mass B star or a black hole. We obtained two nights of spectra from the Keck Observatory at both quadratures complemented with several other spectra from l'Observatoire du Mont-Megantique in the summers of 2014 and 2015. The high resolution and high signal-to-noise Keck spectra reveal the long time hidden companion's absorption lines. Moving in anti-phase to the WR emission lines at similar amplitudes, the mass ratio appears to be in the order of unity. Considering an orbital inclination of 67° derived from previous polarimetry observations, its total mass would be a mere $2-3M_{\odot}$; an unprecedented result for a thought to be massive binary. We apply the shift and add technique to disentangle the spectra and obtain a companion spectra compatible with an O5 spectral type. Assuming a typical mass for an O5V type, we obtain anew orbital inclination of 18° in contrast with past results. We review the previous polarimetric technique to conclude WR 148 is indeed a low inclination, high mass binary system

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X-Ray Lightcurves of Colliding-Wind Binaries

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Poster 61

Massive binaries harbour two supersonic stellar winds doomed to collide, which may generate high energy emission. In the few systems where this is the case, monitoring the X-ray emission provide crucial information on the wind and binary properties (such as relative wind strengths, wind densities, or binary geometries). In this contribution, the results obtained with Swift and XMM observatories will be examined, emphasizing the unique constraints provided by such data.

Observational Signatures of Hot-Star Magnetospheres

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Poster 64

The presence of a magnetic field can have an enormous effect on the dynamics of the stellar winds of OB stars. Interaction between the field and the wind within the circumstellar environment creates a magnetosphere, with observable consequences, such as rotational modulation of hydrogen emission features in the Balmer lines in the optical. Recently, we have begun to explore magnetospheres via infrared spectroscopy. Infrared evidence of magnetospheric material has several important advantages over other diagnostics, and can be used to discover and study magnetic stars inaccessible in optical wavelengths. The various types and dynamics of hot-star magnetospheres will be presented, with a focus on the benefits of multi-wavelength studies to determine the characteristics and dynamics of the magnetospheric material.

A revised magnetic topology for the magnetic O-type star θ^1 Ori C

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Poster 67

θ^1 Orionis C was the first O-type star to be measured to host a magnetic field at its surface, through circular polarization induced by the Zeeman effect. Since then, the discovery and systematic characterization of magnetic fields in OB stars by the new generation of powerful spectropolarimeters has enabled a new understanding of the influence of magnetism on their radiation-driven stellar winds, and on their observed spectral characteristics at all wavelengths. However θ^1 Orionis C, the usual benchmark of magnetic O-type stars, has yet to be characterized with modern spectropolarimetric observations. We present a new ESPaDOnS monitoring of this poster-child object and a new determination of its surface field topology.

Properties of the O-type giants and supergiants in 30 Doradus

O. H. Ramirez-Agudelo, H. Sana, A. de Koter, N. Langer, C. Evans, and the VFTS consortium

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Poster 72

Spectroscopic single O-type stars are powerful cosmic engines that strongly impact their surroundings. Stellar winds, rotation, and possible former binary interaction are key parameters that affects their evolution, chemical yields, ionising photon budget, and the final fate as supernovae and long-duration gamma-ray burst.

By using ground-based optical spectroscopy obtained in the framework of the VLT-FLAMES Tarantula Survey (VFTS) and the non-LTE stellar atmosphere code FASTWIND, we determine stellar, photospheric and wind properties of 72 presumably single O-type giants, bright giants and supergiants located in the 30 Doradus region. This unmatched sample offers an opportunity to test models describing their main-sequence evolution and mass-loss properties.

In this work we confront their stellar characteristics with evolutionary tracks for single stars. In the HRD, our sample stars are found to occupy the region predicted for the core hydrogen-burning phase by Brott et al. (2011) and Köhler et al. (2015). Except for 5 stars, the helium abundance of our sample stars are in agreement with the initial LMC composition. Interestingly the few helium enriched stars present moderate rotational velocity (i.e., $vsini < 200\,\mathrm{km/s}$) and thus it may challenge the role of rotational mixing. We also compare the derived spectroscopic and evolutionary masses and find that are in fair agreement, though the scatter is sizeable. Finally, the wind-strength of our stars is higher than theoretical predictions. This may be interpreted as an effect of the wind being clumped.

Young massive clusters using the VVV Survey

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Poster 73

Young massive stellar clusters (age $<$ 10Myr, M$\sim$1.000-10.000 solar masses) are good laboratories to observe massive stars and test stellar evolution theories. Because these clusters are very young, we need near infrared data to access their stellar population. In this talk we will present the massive clusters discovered by our group using the ESO public survey Vista Variables in the Via Lactea (VVV). Our cluster database includes new clusters with spectroscopically confirmed OB-stars, massive young stellar objects and Wolf-Rayet. This database allows to homogeneously derive a cluster physical characterization and, with them, we can begin to explore relations between the cluster stellar population, their intrinsic parameters and the Milky Way (distance to the Galactic center or spiral arm structure, for example).

Massive Pre-Main Sequence Stars in M17

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Poster 74

The formation process of massive stars is poorly understood, mainly due to the difficulties observing the early phases of the formation process. Massive young stellar objects (mYSOs) are rare and thus distant, and they are deeply embedded in their parental clouds, challenging the analysis of the highly reddened photospheric spectra. M17 is one of the most prominent HII regions in the sky, is relatively nearby, and hosts a young stellar population. Using X-shooter on the ESO Very Large Telescope we have obtained high quality spectra of a sample of candidate mYSOs and some OB stars classified by Hanson et al. (1997). In most cases, we are able to analyse the spectra and fit FASTWIND models to the photospheres of the stars obtaining accurate values for their effective temperatures, surface gravities, rotational velocities and radii. We measure the extinction towards our sources by fitting their spectral energy distribution to Kurucz models which allow us obtain a good estimate of their luminosity. Additionally, the observed infrared excess and the double-peaked emission lines provide the opportunity to probe the physical structure of the disk. We present a unique sample of massive pre-main sequence stars and substantiate the earlier results by Ochsendorf et al. (2011) that these objects are bloated, young massive stars contracting towards the main sequence, still surrounded by a (remnant?) disk. We compare the observed properties of our targets with evolutionary tracks of massive protostars by Hosokawa et al. (2010), and demonstrate that these mYSOs near the western edge of the HII region are on their way to become OB main-sequence stars ($\sim 8 - 25 M_{\odot}$). The initial mass-accretion rates should have been high ($\sim 10^{-4} - -10^{-3} M_{\odot}$/yr) and the mYSOs likely represent a second generation of massive star formation, possibly triggered by the O stars present in the center of the HII region.

LBV Binarity: HR Car and Its Interacting Companion

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Poster 75

The Luminous Blue Variable (LBV) HR Car has recently been identified as a binary, with interferometric data from the VLTI. Although the orbit is not yet fully constrained, it is sufficiently well known to put it in the same class as eta Car, HR Car's far more famous neighbour. I will introduce and review the evidence derived from the interferometric instruments AMBER and PIONIER, and, by the time of the meeting, possibly as well GRAVITY. The results so far indicate that HR Car is a binary with a period of a few years, although we cannot discard as yet larger periods up to several decades. The eccentricity is still not constrained, but is greatly dependent on the period, as the periastron is fixed for all solutions, with a value of about 11 au. At least during periastron the two components are sufficiently close to have strong wind-wind interaction; the companion passes through the Br-gamma formation region of the LBV. In fact, the first AMBER observations were taken during such a phase. The situation may dramatically differ from mere wind-wind interaction when a periastron passage happens during the maximum of an S Dor cycle. The primary could then be large enough to fill its Roche-lobe, and maybe even large enough for the secondary to pass through the extended outer layers or the very dense inner wind of the LBV, giving reason to expect some fireworks.

Low metallicity Wolf-Rayet stars are rarely formed via mass transfer

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Poster 80

Massive stars may reach the Wolf-Rayet (WR) phase, characterized by powerful, radiation-driven stellar winds and hydrogen deficiency. Hypothetically, they can form either as single stars or via mass-transfer in binary systems. WR stars in the low metallicity environment of the Megallanic Clouds were long believed to form primarily via the binary channel because of their relatively low mass-loss rates. To test this hypothesis, we use state-of-the-art Potsdam Wolf-Rayet (PoWR) model atmospheres to perform a non-LTE spectral analysis of known multiple WR systems in the Magellanic Clouds, including the complete WR population in the Small Magellanic Cloud. Together with auxiliary polarimetric and wind-collision analyses, our results enabled us to constrain the evolutionary paths of our objects.We find that, in contrast to the single WR stars, the majority of analyzed systems did not undergo homogeneous evolution, and did experience mass-transfer. However, the implied initial masses are large enough for the primaries to have entered the WR phase as single stars. Our results suggest that mass transfer in binaries contributes little, if at all, to the formation of WR stars at low metallicity. In my talk, I will discuss the tools, analysis methods, and results which lead to this fundamental conclusion.

Stellar Wind Measurements for Colliding Wind Binaries Using X-Ray Observations

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Poster 84

We report the results of the stellar wind measurement for colliding wind binaries. Mass-loss is one of the most important and uncertain parameters in the evolution of a massive star. We have reported an approach of stellar wind measurement for colliding wind binary WR140 using X-ray observations (Sugawara et al. 2015). The X-ray spectrum is the best measure of conditions in the hot postshock gas. By monitoring the changing of the the X-ray luminosity and column density along with the orbital phases, we derive the mass-loss rates of these stars. In this paper, we show the results of X-ray observations of five colliding wind binaries using archived data, and present these mass-loss rates.

The search for Wolf-Rayet stars in IC10

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Poster 86

We present a deep imaging and spectroscopic survey of the Local Group starburst galaxy IC10 using Gemini North and GMOS to unveil its global Wolf-Rayet population. It has previously been suggested that for IC10 to follow the WC/WN versus metallicity dependence seen in other Local Group galaxies, a large WN population must have previously been unaccounted for. Our search revealed 3 new WN stars, and 10 candidates awaiting confirmation, providing little evidence to support this claim. Since the metallicity of IC10 resides intermediate between the LMC and SMC, we also provide a comparison between IC10 and Magellanic Cloud WR properties. We find that the range of emission line widths and strengths of IC10 WR stars are more similar to their LMC counterparts, and average line luminosities were also in better agreement with the LMC. We investigate the number of binary systems in IC10 and find the binary fraction to be $41 \pm 10\%$, which is consistent with other Local Group galaxies.

The Carina High-contrast Imaging Project (CHIP)

Alan Rainot et al.

Poster 71

The formation of massive stars remains one of the most intriguing questions in astrophysics today. The main limitations result from the difficulty to obtain direct observational constraints on the formation process itself. Several formation theories have been proposed such as stellar collisions, merging, competitive accretion and monolithic collapse among others. In this context, the Carina High-contrast Imaging Project aims to observe all 80+ O stars in the Carina nebula using the new VLT 2nd-generation extreme-AO instrument SPHERE. This instrument offers unprecedented imaging contrast allowing us to detect the faintest companions around massive stars. These novel observational constraints will help to discriminate between the different formation scenarios. Here, we present the first results of the ongoing observational campaign.

The X-Ray Origin of the Be Star Gamma Cassiopeiae and the Implication to Its Stellar Evolution

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Poster 30

Gamma Cassiopeiae is an enigmatic Be star with unusually hard, strong X-ray emission compared with normal main-sequence B stars. The origin is controversial for decades between two theories: mass accretion onto a hidden compact companion and magnetic dynamo driven by the star-Be disk differential rotation. There has been found no decisive signature that support either theory, such as a pulse in X-ray emission or the presence of large-scale magnetic field. In a ~ 100 ksec duration observation of the star with the Suzaku X-ray observatory in 2011, we detected six rapid X-ray spectral hardening events called "softness dips". All the softness dip events show symmetric softness ratio variations, and some of them have flat bottoms apparently due to saturation. The softness dip spectra are best described by either $\sim 40\%$ or $\sim 70\%$ partial covering absorption to kT $\sim$ 12 keV plasma emission by matter with a neutral hydrogen column density of $\sim 2 - 8 \times 10^{21}\mathrm{cm}^{-2}$, while the spectrum outside of these dips is almost free of absorption. This result suggests that two distinct X-ray emitting spots in the gamma Cas system, perhaps on a white dwarf companion with dipole mass accretion, are occulted by blobs in the Be stellar wind, the Be disk, or rotating around the white dwarf companion. The formation of a Be star and white dwarf binary system requires mass transfer between two stars; gamma Cas may have experienced such activity in the past. We discuss the gamma Cas type Be stellar evolution, based on this result.

Toolkit to analysis and fit of stellar spectra using a mega-database of CMFGEN models

Celia Rosa Fierro, Janos Zsargó , Santiago Alfredo Díaz-Azuara, Jaime Klapp, Anabel Arrieta Ostos, Lorena Arias Montaño

Poster 93

Models of stellar atmospheres are valuable tools for studying the chemical composition and physical conditions of the gas present in the atmosphere of stars. The numeric codes that incorporate most of the physical processes and atomic data are microprocessor time-consuming and require a lot of memory. A grid of models allows analyzing a large number of stars with similar characteristics; however, the number of models in the grid increases exponentially when several input parameters are taken into account. Using the ABACUS I supercomputer and the CMFGEN code (Hillier & Miller 1998, ApJ, 496, 407), we generated a mega-grid of 15 000 atmosphere models (Zsargó et al., in preparation), covering in the H-R diagram, the region of the main sequence stars between 9 and 120 solar masses. Find the best models to fit a observed spectrum within this mega-database is unthinkable without the aid of computing tools. We present a computing toolkit which perform this task efficiently.

Observations of Bright Massive Stars Using Small Size Telescopes

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Poster 6

The size of a telescope determines goals and objects of observations. It becomes more and more difficult to get photometric data of bright stars during the latest decades because most of telescopes of small sizes do not operate already. But there are rather interesting questions connected to the properties and evolution ties between different types of massive stars. Multi-wavelength photometric data are needed for solution of some of them. We are presenting our observational plans of bright Massive X-ray binaries, WR and LBV stars using a 48 cm Cassegrain telescope.

Searching for self-enrichment in Cyg-OB2

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Poster 76

One of the main objectives of the future WEAVE Cygnus Survey is to obtain accurate abundances and spatial abundance patterns for early-type stars in the Cygnus X star-forming region. As a preparatory step, we are conducting a whole spectroscopic study of the complete O-type population in Cyg OB2, whose results will be used to optimize the survey sample and will add an additional epoch useful to identify stellar multiplicity. Part of this study, is to determine whether Cyg OB2 has been subject to self-enrichment processes. Cyg OB2 is a rich OB association in our Galaxy located only at $\sim$ 1.4kpc from us, and it represents an ideal testbed to check theories about star formation in Young Super-massive extragalactic Clusters (YMCs), exploring the evidence for self-enrichment due to successive generations of stars formed out of gas enriched by the previous ones.We have checked whether the age spread observed in Cyg OB2, whose distribution of stellar ages extends beyond 10 Myr, might be associated with a chemical composition spread that could evidence star formation from self-enrichment processes. For this purpose, we have performed a spectroscopic analysis of a sample of slow rotators in Cyg OB2 (which have been chosen so as to cover the observed age spread) using FASTWIND atmosphere models and determined their fundamental parameters as well as the He, Si and O surface abundances, whose results we present and discuss in this contribution.

Constraining Disk Properties of a Survey of Southern Be Stars

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Poster 4

Be stars represent a challenge in the study of the physical mechanism required to form and support disks around hot stars. Using different techniques, such as photometry, interferometry and spectroscopy and thanks to the development of powerful radiative codes, we can study the conditions for which disk exist as well as disk features such as the size of the emission region, inclination angle, mass, angular momentum, etc. Using `BEDISK` a non-LTE radiative transfer code and `BERAY` that solves the transfer equation throughout the disk, we studied 63 Be southern stars by modeling H_α emission line profiles. We found for early stellar *emission* types that the density structure in the surface of the disk can be modeled by a power law with base density between $\rho_0 \sim$ (4.00 - 6.30)$\times10^{-11}$ g cm^{-3} with a power-law fall of between $n \sim$ 2.0 - 2.5. We also found that outer disk radii of the H_α emitting regions are between $R_{disk} \sim$ 20 - 30$R_\star$, the angular momentum between $J_d \sim$ (1.0 - 3.1)$\times10^{-7}J_\star$ and the disk mass between $M_d \sim$ (1.0 - 3.1)$\times10^{-9}M_\star$.

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O.H. Ramirez-Agudelo, H. Sana, A. de Koter, N. Langer, C. Evans, and VFTS consortium

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Poster 72

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Chandra X-Ray Grating Spectroscopic Diagnostics of the X-Ray Emitting Plasma in the Magnetic O+O Binary Plaskett's Star

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Poster 48

Recent spectropolarimetric observations have revealed that the rapidly rotating secondary in the massive O+O binary system Plaskett's star harbors a strong magnetic field with a surface dipole field strength of ~ 3 kG (Grunhut et al. 2013), suggesting the likely presence of a centrifugally supported magnetosphere, unique among O stars. Previous X-ray observations interpreted the X-ray emission in terms of a collision between the primary and secondary wind (Linder et al. 2006),but the presence of a strong magnetic field on the secondary suggests that X-ray emission might originate from the magnetosphere or even in a wind magnetosphere collision. To distinguish between these competing hypotheses, we have obtained high resolution Chandra grating spectra of Plaskett's star, with good orbital and rotational phase coverage. The forbidden-to-intercombination line ratios of He-like Si XIII and Mg XI rule out formation of X-ray emitting plasma inside the magnetosphere of the secondary, and are consistent with formation in the region between the two stars. The lines are broad, with a Gaussian sigma of ~ 700 km/s. We surprisingly find no evidence for variability of the line shape or shift with either secondary rotational phase or orbital phase. This is contrary to expectations for either a magnetospheric or a colliding wind origin for the X-rays.

Theory of Stellar Evolution & Atmospheres: Beyond Standard Physics, Rotation, Duplicity, Mass Loss and Magnetic Fields and Instabilities

3D Hydrodynamic Simulations of O-Shell Convection

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Poster 1

I am reporting on our team's progress in investigating fundamental properties of convective shells in the deep stellar interior during advanced stages of stellar evolution. We have performed a series of 3D hydrodynamic simulations of convection in conditions similar to those in the O-shell burning phase of massive stars. We focus on characterizing the convective boundary and the mixing of material across this boundary. Results from 768^3 and 1536^3 grids are encouragingly similar (typically within 20%). Several global quantities, including the rate of mass entrainment at the convective boundary and the driving luminosity, are related by scaling laws. We investigate the effect of several of our assumptions, including the treatment of the nuclear burning driving the convection or that of neutrino cooling. The burning of the entrained material from above the convection zone could have important implications for pre-supernova nucleosynthesis.

Stellar and Wind Parameters of Massive Stars From Spectral Analysis

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Poster 3

The only way to deduce information from stars is to decode the radiation it emits in an appropriate way. Spectroscopy can solve this and derive many properties of stars. In this work we seek to derive simultaneously the stellar and wind characteristics of A and B supergiant stars. Our stellar properties encompass the effective temperature, the surface gravity, the stellar radius, the micro-turbulence velocity, the rotational velocity and, finally, the chemical composition. For wind properties we consider the mass-loss rate, the terminal velocity and the line–force parameters (α, k and δ) obtained from the standard line–driven wind theory.To model the data we use the radiative transport code FASTWIND considering the newest hydrodynamical solutions derived with HYDWIND code, which needs stellar and line–force parameters to obtain a wind solution. A grid of spectral models of massive stars is created and together with the observed spectra their physical properties are determined through spectral line fittings.These fittings provide an estimation about the line–force parameters, whose theoretical calculations are extremely complex. Furthermore, we expect to confirm that the hydrodynamical solutions obtained with a value of δ slightly larger than ~ 0.25, called δ-slow solutions, describe quite reliable the radiation line-driven winds of A and late B supergiant stars and at the same time explain disagreements between observational data and theoretical models for the Wind–Momentum Luminosity Relationship (WLR).

Analytically Constraining Angular Momentum Transport and Magnetic Field Topology in Stellar Radiative Zones

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Poster 3

The radiative core of main-sequence low-mass stars and the radiative envelope of main-sequence massive stars likely host a fossil magnetic field, namely a remnant of the field built during the star's birth. Massive stars with an observed magnetic field typically possess a non-axisymmetric oblique magnetic dipole. If a comparison is drawn between the stably-stratified regions of massive and low mass stars, given their hydrodynamical similarity, such non-axisymmetric magnetic fields may also exist within these regions for low-mass stars. Moreover, fossil magnetic fields have been proposed as an important source of angular momentum transport and mixing across the Hertzsprung-Russel diagram. In this context, the stability of axisymmetric magnetic field configurations within a quiescent, stably-stratified medium have been understood for quite some time (e.g., Tayler 1973). Such analyses indicate that only certain mixed (poloidal and toroidal) configurations of axisymmetric magnetic fields are permitted within the radiative regions of stars. We have generalized this class of global stability analysis, extending it for the first time to regions with both non-axisymmetric magnetic fields and differential rotation. Here, we present the resulting stability criteria. Such criteria help to restrict the number of magnetic field configurations that are possible within the stable regions of low-mass stars, thereby limiting the routes of angular momentum transport in the radiative interior and means of interaction with the dynamo-generated magnetic fields established in their overlying convective layers.

HDUST Inhales He: Probing the Hotter Inner Parts of Gaseous Disks by the Inclusion of Helium in the Radiative Transfer Analysis

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Poster 10

HDUST is a three-dimensional, NLTE radiative transfer code. This code was in the core of our research in the past decade or so, and its application in the field of classical Be star research allowed for relevant contributions in our understanding of the central object and its circumstellar disk. Recently, major advances were implemented in HDUST that is now capable of handling He and other elements (in addition to H) in the NLTE regime and in three-dimensional configurations. This new version of HDUST offers new and quite exciting scientific opportunities. In this contribution we study how the inclusion of He will affect the thermal structure of the disk for a broad range of disk and stellar param- eters, and how the He I and II lines can be used to probe and constrain the properties of the inner parts of Be disks.

Wind-embedded shocks in FASTWIND: X-ray emission and K-shell absorption

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Poster 11

EUV and X-ray radiation emitted from wind-embedded shocks can affect the ionization balance in the outer atmospheres of massive stars, and can also be the mechanism responsible to produce highly ionized atoms detected in the wind UV spectra. To investigate these processes, we implemented the emission from wind-embedded shocks and related physics into our atmosphere/spectrum synthesis code FASTWIND. We account also for the high energy absorption of the cool wind by adding important K-shell opacities. In this poster, we (i) present suitable tests to verify our implementation; (ii) discuss the effects from shock emission for important ions (He, C, N, O, Si and P); (iii) provide a systematic investigation on the frequency and radial dependence of the mass absorption coefficient, $\kappa_\nu(r)$. We conclude that the approximation of a *radially constant* $\kappa_\nu(r)$ is justified for wavelengths lower than 18 Angstrom and for radii larger than $1.2R_\star$.

3D MHD Simulations of Radiatively Driven Winds with Inclined Magnetic Fields

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Poster 16

We present results of 2D and 3D numerical simulations of magnetically confined, radiatively driven stellar winds of massive stars, conducted using the astrophysical MHD code Pluto, with a focus on understanding the rotational variability of radio and sub-mm emission. Radiative driving is implemented according to the Castor, Abbott and Klein theory of radiatively driven winds. Many magnetic massive stars posses a magnetic axis which is inclined with respect to the rotational axis. This misalignment leads to a complex wind structure as magnetic confinement, centrifugal acceleration and radiative driving act to channel the circumstellar plasma into a warped disk whose properties should be apparent in multiple wavelengths. Building upon work carried out by ud-Doula, Owocki and Townsend, simulating magnetically channeled radiatively outflow. Light curves in multiple wavelengths via Monte Carlo radiative transfer are presented. Parameters such as the mass-loss rate, magnetic field strength, rotational period, magnetic and rotational axis misalignment are investigated.

A Multi-Wavelength View of NGC 1624-2

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Poster 17

Large surveys such as the Magnetism in Massive Stars (MiMeS) and B-fields in OB stars (BOB) surveys have contributed to the detection of an increasing number of magnetic massive stars, and follow-up of these objects has led to the recognition of a population of magnetic massive stellar objects with distinct properties. Among these, one star holds a particular interest: NGC 1624-2, which possesses the largest magnetic field of any O-type star ($>$ 20 kG, largest by nearly an order of magnitude). Such a field exerts an overwhelming influence on the stellar wind, confining it into a circumstellar magnetosphere, the structure of which can be constrained by observations at different wavelength regimes. I will discuss how recent observations in the optical and X-rays suggest that NGC 1624-2's magnetosphere is much larger than that of any other magnetic O star. Further work is done by modeling the variations of UV resonance lines, which allows us to constrain the velocity structure of the magnetosphere, taking into account recent optical spectropolarimetric observations that raise the possibility of a more topologically complex magnetic field than previously expected. Putting all of these multi-wavelength constraints together allows us to paint a more consistent picture of NGC 1624-2 and its surprising behavior, giving us valuable insight into the very nature of massive star magnetospheres.

FASTWIND reloaded: complete comoving frame transfer for "all" contributing lines

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Poster 70

FASTWIND is a unified NLTE atmosphere/spectrum synthesis codeoriginally designed (and frequently used) for the optical/IRspectroscopic analysis of massive stars with winds. Until the previousversion (v10.1), the line transfer for background elements(mostly from the iron-group) was performed in an approximate way, bycalculating the individual line-transitions in a single-line Sobolevor comoving frame approach, and by adding up the individual opacitiesand source functions to quasi-continuum quantities that are used todetermine the radiation field for the complete spectrum.We have now updated this approach and calculate, for ALL contributinglines (from elements H to Zn), the radiative transfer in the comovingframe, thus also accounting for line-overlap effects in an "exact"way. Related quantities such as temperature, radiative accelerationand formal integral have been improved in parallel. For a typicalmassive star atmospheric model, the computation times (from scratch, and for a modern desktop computer) are 1.5 h for the atmosphere/NLTE part, and 30 to 45 minutes (when not parallelized) for the formal integral (i.e., SED and normalized flux) in the ranges 900 to 2000 and 3800 to 7000 A.We compare our new with analogous results from the alternative codeCMFGEN, for a grid consisting of 5 O-dwarf and 5 O-supergiantmodels of different spectral subtype. In most cases, the agreement isvery good or even excellent (i.e., for the radiative acceleration),though also certain differences can be spotted. A comparison withresults from the previous, approximate method shows equally goodagreement, though also here some differences become obvious. Besidesthe possibility to calculate the (total) radiative acceleration, thenew FASTWIND version will allow to investigate the UV-part of thespectrum in parallel with the optical/IR domain.

BPASS: Binary Population and Spectral Synthesis

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Poster 19

We have recently released the new results of Version 2.0 of the BPASS code. The predictions cover a broad range of theoretical predictions for individual stars, binaries, resolved and unresolved stellar populations, supernovae and their progenitors, and compact remnant mergers. We will summarize the most important results on how binary populations reproduce observations better than single star models. We will also summarize the currently publicly available data.

New Insights into the Puzzling P-Cygni Profiles of Massive Magnetic Stars

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Magnetic massive stars comprise approximately 10% of the total massive-star population, presenting a new "species" in the wider massive star zoology. Unlike their non-magnetic counterparts, modern spectropolarimetry has shown these stars to host strong, stable, large-scale, often nearly dipolar magnetic fields of 1 kG or more. Such strong global magnetic fields trap outflowing stellar wind material, inducing regions of shock-heated, X-ray-emitting gas. For the pre-shocked material, P-Cygni line profiles provide a powerful probative tool for examining the effects of magnetic channeling on such wind outflows. In stark contrast to the strong line saturation observed in non-magnetic O-stars, recent HST UV spectra of NGC 1624-2 the most magnetic O-type star observed to date show atypically unsaturated P-Cygni profiles in the CIV and NV resonance lines, as well as a distinct dependence on rotational phase. Our initial investigation focused on the role of X-rays in reducing ion fractions, but showed opposite trends for the two lines; it was thus unable to fully explain the unsaturation in both lines. This poster examines the further effect of non-radial, magnetically-channeled wind outflow on line formation, using a Sobolev Exact Integration (SEI) approach to synthesize P-Cygni lines for direct comparison with HST UV spectra of NGC 1624-2. Our study thus provides a first step toward a broader understanding of how strong magnetic fields affect the stellar wind outflow of this and other magnetic massive stars.

Equilibrium Structures of Rapidly Rotating Stars With Shellular Rotation

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Poster 21

One of the most fascinating challenge in the stellar astrophysics is understanding the structures of realistic rotating stars and their evolution. Many stellar evolution codes for rotating stars have adopted shellular rotation as one of the rotation models and calculated 1D rotating models. However, some rotating massive stars have very rapid rotations and the shapes of them are largely deformed due to the rotation. Therefore, their outer layers cannot be well described by 1D models due to their fast rotation and so multi-dimensional models are required to describe them. Recently, we have developed a new numerical method for obtaining self-consistent structures of rapidly rotating baroclinic stars (Fujisawa 2015; MNRAS 454). We used the numerical method and obtained self-consistent equilibrium structures of rapidly rotating massive stars with shellular rotation. These equilibrium structures might be useful for both evolutionary and progenitor models of rapidly rotating massive stars.

Stellar parameters of the reference O-type stars

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Poster 34

Massive stars play a key role in various fields of astrophysics. In the 70's, the two dimensional spectral classification of O stars was developed by Walborn. Standard stars have been selected to be the reference object of each stellar type / luminosity class. These standard stars are still used today for the classificationof the any newly discovered O stars. However, the stellar properties of these reference objects have never been determined in a homogeneous way. Using high-resolution, high signal-to-noise ratio from OHP and ESO and the modeling code CMFGEN, we are currently determining the properties of the standard O-type stars. During this presentation we will present the preliminary results of our study.

The 2-D rotational dynamics of massive stars' radiation zone

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Poster 37

Rotation is a key physical process to understand the evolution of massive stars from their formation to their late stages of evolution. It modify their internal structure and key properties such as their evolutionary tracks in the HR diagram, their life time, etc. In this context, asteroseismology has made great strides forward in probing their internal differential rotation. However, detecting and characterizing the differential rotation deep within the star remains quite a formidable task. Moreover, the precise nature of the dynamical interactions and couplings between the convective core and the radiative envelope is still not well understood.To build upon our current understanding of this interaction, we constructed models of the radiative zone in which we study the influence of a differentially rotating convective core upon its overall dynamics. In these models, we provide a 2D description of the hydrodynamics in the radiative zone with a self-consistent computation of the differential rotation and meridional circulation that are maintained due to the shear layer at the bottom of the radiative envelope. We choose to use results from 3D numerical simulations of the dynamics of the convective core to set the boundary condition at the bottom of the studied radiative envelope. Our computations first use the Boussinesq approximation, the results of which are then compared to a solution computed using the an elastic approximation using realistic entropy stratification computed using a stellar evolution code. Stewartson layers, which are intrinsically 2D, which arise upon the tangent to the core cylinder, appear and play a key role in the transport of angular momentum. Indeed, we show that the differential rotation is highly influenced by the shear of the convective core mainly inside the tangent to the core cylinder while the external part seems less influenced. We finally discuss the corresponding possible consequences for chemical mixing and asteroseismic signatures

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Moderation of Stellar Initial Mass by Line-Driven Ablation

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Poster 40

Mass is a key parameter in understanding the evolution and eventual fate of hot, luminous stars. Mass loss driven by UV-scattering forces is already known to reduce the mass of such stars by $10^{-10} - 10^{-4} M_{\odot}$/yr over the course of their lifetimes. However, high-mass stars already drive such strong winds while they are still in their accretion epoch. Therefore, stellar UV-scattering forces will efficiently ablate material off the surface of their circumstellar disks, perhaps even shutting off the final accretion through the last several stellar radii and onto a massive protostar. By using a fully three-dimensional UV-scattering prescription (Castor, Abbott, and Klein 1975; Cranmer and Owocki 1995), we here quantify the role of radiative ablation in controlling the disk's accretion rate onto a forming massive star. Particular emphasis is given to the potential impact of this process on the stellar upper mass limit.

Wind inhibition by X-ray irradiation in high-mass X-ray binaries

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Poster 45

The stellar wind of hot massive stars is driven radiatively by the light absorption in the lines of heavier elements.Therefore, the amount of mass lost per unit of time(mass-loss rate) depends on the wind ionization. That is why the accretion powered X-ray emission of high-mass X-ray binaries influences the radiative force and may even lead to wind inhibition. We model the effect of X-ray irradiation on the stellar wind in high-mass X-ray binaries. The influence of X-rays is given by the X-ray luminosity, by the optical depth between a given point and the X-ray source, and by a distance to the X-ray source. X-rays are negligible in binaries with low X-ray luminosities or at large distances from the X-ray source. The influence of X-rays is stronger for higher X-ray luminosities and in closer proximity of the X-ray source. There is a forbidden area in the diagrams of X-ray luminosity vs. the optical depth parameter. In the forbidden area with high X-ray luminosity and low optical depth parameter the X-ray ionization leads to the wind inhibition. We collected parameters of high-mass X-ray binaries from literature, predicted their wind parameters,and showed that there is excellent agreement between the positions of observed stars in these diagrams and our predictions. All wind-powered high-mass X-ray binary primaries lie outside the forbidden area. Many of them lie close to the border of the forbidden area, indicating that their X-ray luminosities are self-regulated.

4D Imaging and Modeling of Eta Carinae's Inner Fossil Wind Structures

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Poster 50

Eta Carinae is the most massive active binary within 10,000 light-years and famous for the largest non-terminal stellar explosion ever recorded. Observations reveal a supermassive ($\sim 120M_{\odot}$) binary, containing a highly unstable LBV and either a WR or extreme O star, undergoes dramatic changes every 5.54 years due to the stars' very eccentric orbits ($e = 0.9$). Many of these changes are due to a dynamic wind-wind collision region (WWCR) between the stars, plus expanding fossil WWCRs formed one, two, and three 5.54-year cycles ago. These fossil WWCRs can be spatially and spectrally resolved by the Hubble Space Telescope (HST)/STIS. Starting in June 2009, we used HST/STIS to spatially map Eta Carinae's innermost WWCRs across its 5.54-year orbit, following temporal changes in several forbidden emission lines (e.g. [Fe III] 4659Å, [Fe II] 4815Å), creating detailed data cubes at specific epochs. Multiple wind structures were imaged in each forbidden line, revealing important details about the binary's orbital motion, photoionization properties, and recent ($\sim 5-15$year) mass loss history. Around apastron, arcs of compressed LBV wind, photoionized by far-UV radiation from the hot secondary star, are seen in [Fe III]. Other arcs, ionized by mid-UV radiation from the LBV primary, are seen in [Fe II]. During periastron passage, when the secondary plunges into the LBV's extended wind photosphere, high-ionization [Fe III] structures fade and appear in [Fe II] emission. These observations allow us to test 3D time-dependent hydrodynamical and radiative-transfer models of massive, interacting winds. Our observations and models strongly suggest that the wind and photoionization properties of the Eta Carinae binary have not changed substantially over the past several orbital cycles. They also provide a baseline for following future changes in Eta Carinae, essential for understanding the late-stage evolution of a nearby supernova progenitor. (Paper under review, submitted to MNRAS)

Tidal Tearing of Circumstellar Disks in Be/X-Ray and Gamma-Ray Binaries

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Poster 63

A significant fraction of massive stars are thought to evolve to the state of critical rotation during their lives. Reaching the critical rotation, stars begin to eject gas from the equatorial region and become Be stars with viscous decretion disks around them. Afterwards, the excess angular momentum of the star is removed mainly via the decretion disk. At the same time, Be decretion disks are also associated with high energy emission, if they have compact companions. About half of high-mass X-ray binaries and gamma-ray binaries host a Be star as the optical counterpart. In these systems, the Be disk either supplies gas to the accreting compact object or terminates the pulsar wind, causing shocks, from which high energy emission arises. Studying the structure and evolution of Be decretion disks, by taking into account the interaction with the compact object, is therefore important to understand not only their role as the angular momentum reservoir but also the mechanisms of high energy emission in X-ray and gamma-ray binaries with Be stars.In this paper, we study how a Be decretion disk evolves under the influence of a compact object, performing 3D hydrodynamic simulations. In addition to the already known disk evolutionary features, such as the gradual development followed by the tidal truncation, we find that the tearing of Be disks cyclically occur in short period systems, if the disk is highly misaligned with the binary orbital plane. In these systems, after it is fully developed, the Be disk is torn off from the stellar surface, which is caused by the strong tidal force of the compact object, and starts precession. Due to the precession, a gap opens between the disk and the star, and a new disk forms in the equatorial plane of the star. Finally, the newly formed disk replaces the old precessing disk, and this whole cycle repeats. Such a cyclic evolution of Be disks has interesting implications for the angular momentum removal from the central star as well as the long-term behavior of high energy emission in Be/X-ray and gamma-ray binaries.

The Spectral Temperature of Light Echoes From Eta Carinaes Giant Eruption

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Poster 65

The 1840's era giant eruption of eta Carinae remains a challenge for understanding the lives and death throes of the most massive stars. In recent years the detection by Rest et al. (2012) of light echoes from this era has provided important new observational constraints on the nature of the eruption. In particular, spectra of the echoes suggest a relative cool spectral temperature of about 5500K, below the lower limit of about 7000K derived from the optically thick wind outflow analysis of Davidson (1987). This has lead to a debate about the viability of this steady wind model relative to alternative, explosive scenarios. Here we present an updated analysis of the wind outflow model using newer low-T opacity tabulations and accounting for the stronger mass loss associated with the $> 10 M_\odot$ mass now inferred for the Homunculus. A major conclusion is that, because of the sharp drop in opacity due to free electron recombination for T<6500K, a low spectral temperature of about 5000K is compatible with, and indeed expected from, a wind with the extreme mass loss inferred for the eruption. Within a spherical gray model in radiative equilibrium, we derive spectral energy distributions for various assumptions for the opacity variation of the wind, and make initial comparisons with observed light echo spectra.

Stable and Quasi-Stable Stellar Wind Accretion in High-Mass X-Ray Binaries

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Poster 68

Features of accretion from stellar winds of early-type stars in high-mass X-ray binaries will be discussed. Specifically, the regime of subsomic quasi-spherical settling accretion onto onto magnetized neutrons stars, which can be realized at low and moderate mass accretion rates ($<$ a few 10^{16}g/s) , will be considered and its observational manifestations in supergiant fast X-ray transients (SFXTs) will be discussed. We will show that properties of stellar winds from massive OB-stars (velocity and possible magnetic fields) can be responsible for the arising of powerful outbursts observed in SFXTs.

Shear-Driven Transport and Mixing in the Interiors of Massive Stars

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Poster 69

Turbulent transport and mixing generated by hydrodynamic instabilities triggered by rotation gradients are key mechanisms in the evolution of massive stars, which often rotate rapidly. They impact the chemical stratification and rotation of stars and thus fundamental properties of stellar evolution such as evolutionary tracks, life time, yields, etc. Moreover, they must be taken into account when predicting the properties of gravitational supernovae progenitors. Such shear instabilities, both in the vertical and horizontal directions, are usually taken into account in stellar evolution codes using phenomenological prescriptions that have mostly never been tested, thus hindering the predictive power of stellar evolution calculations. As a complement to the development of more precise spectroscopic and asteroseismic observations, and to help distinguish between effects of different processes for their interpretation, new local numerical simulations and theoretical prescriptions are now developed to obtain new constraints on shear-driven turbulent transport and mixing processes in stellar radiative zones. In this talk, we will present new high-resolution turbulent Cartesian simulations and theoretical prescriptions and show how they can help to improve transport models used in stellar evolution. In this context, we will discuss the hydrodynamical key parameters that should now be taken into account when drawing a dynamical picture of the evolution of stars.

The Evolutive Westerlund 1 Paradox

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Poster 77

We have spectral, photometric and polarimetric data of Westerlund1 (WD1) supercluster and we plan: a) obtain the cluster age for three mass ranges (subsolar, intermediate and high mass in Post-Main Sequence); b) use the gravity-luminosity method (FLGR - Meynet et al. 2015) in Blue Supergiant Stars (BSGs) to compare our WD1 results with other objects in the literature. Stellar models for high mass stars predicts a tight correlation between absolute magnitude and surface gravity (FGLR) of Blue Giants (BGs), BSGs and Blue Hypergiants (BHGs). This information combined with the reddening could be used to determine galactic and extragalactic distances in good precision. The FGLR method was applied to low metallicity environments (Meynet et al. 2015 and references therein), but no work was done at solar metallicities. We have derived accurate parameters for the young massive cluster Westerlund 1 (reddening and distance) and there are published determinations of age, metallicity, and binarity (Bonanos 2007, Clark et al. 2014). We are using published spectroscopic classification and our photometry data for the most luminous members of the cluster (60 stars BSGs and BHGs) and we want to add another 60 less luminous evolved blue stars, which cannot be observed in the optical window because of the high reddening ($A_{\rm V} \sim 12, V \sim 16 - 19$). They are bright in the NIR ($K_s \sim 9 - 11$) where there are spectral features useful for spectral classification. This method could also be used to there is an evolutionary paradox determine the evolutionary stage of the cluster. Westerlund 1 is an interesting case because there is an evolutionary paradox. The main sequence (MS) turn on showed a cluster with an age of $t \sim 4$ Myr (Gennaro et al. 2011). It explained the existence of Wolf-Rayets (WR) but not the Red Super Giants (RSG), since they appear only with $t \sim 7$ Myr. Other early study showed one more paradox: there is a magnetar coming of a $M < 40 M_\odot$, but in the canonical values we see that a neutron star progenitor is $9 < M/M_\odot < 25$ (Muno et al. 2006). We will use the spectral classification designed by Hanson et al. (1996) to obtain temperatures (lines: HeI 2.0581, 2.1126, HeII 2.1885, HI 2.1661, NII 2.1155), fit the wings of the lines in high S/N spectra (~ 300) and derive the surface gravity. We will use these data to supplement the data we already have for the most luminous cluster members and we will publish a paper. This project could become an important tool to test the application of FLGR method for BSGs populations in young massive clusters. This presentation will show the presents results of this work.

Destruction of Be Star Disk by Large Scale Magnetic Fields

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Poster 89

Classical Be stars are rapidly rotating stars with circumstellar disks that come and go on time scale of years. Recent observational data strongly suggests that these stars lack the $\sim 10\%$ incidence of global magnetic fields observed in other main-sequence B stars. Such an apparent lack of magnetic fields may indicate that Be disks are fundamentally incompatible with a significant large scale magnetic field. In this work, using numerical magnetohydrodynamics (MHD) simulations, we show that a dipole field of only 100G can lead to the quick disruption of a Be disk. Such a limit is in line with the observational upper limits for these objects.

Ups and Downs of a Magnetic Oblique Rotator Viewed at High Resolution

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Poster 61

In 2006, the Of?p star HD191612 became the second O-star where a magnetic field was discovered. It provided a benchmark to understand the Of?p phenomenon as a whole. Ten years later, an X-ray monitoring performed at high-resolution reveals the behaviour of the hottest magnetospheric plasma, constraining its properties (position, velocity, temperature, etc).

New Solutions to Line-Driven Winds of Hot Massive Stars

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Poster 27

Massive stars are important because they enrich the ISM with their powerful stellar winds. It is important to characterise accurately the winds of these stars (called line-driven winds) because wind plays a key role aiming to understand better how massive stars will evolve through their future stages, and how they contribute with the chemical enrichment of the galaxy.Many parameterisations have been done to line-driven winds under the m-CAK theory. They have made big efforts to describe the wind, both under LTE and non-LTE conditions. However, they have not included yet self-consistent models taking in count hydrodynamics, and also neglect the effects of the ionisation density (fast solutions).In this talk, we present our solutions to the line-force parameters (k, alpha, delta) found for line-driven winds of different stars in a self-consistent performance with the wind hydrodynamics, under LTE conditions. Hydrodynamic models are provided by the code HydWind, which are generated in an iterative way. We compare these results with those ones previously found, focusing in what regions of the optical depth are used to do the calculations of the line-force multiplier. The observable wind parameters undergone from theory (terminal velocity and mass-loss rate) are also presented, in order to evaluate our calculations. We also evaluate how far change the solutions when effects of ionisation density are reckoned in (delta-slow solutions).And finally, we also present our first approaches to calculate alfa, k and delta under non-LTE environments.

Massive Stars and Their Supernovae as Galactic Building Blocks and Engines: Milky Way, Nearby Galaxies and the Early Universe

B Supergiants in IC1613: Testing Low-Z Massive Stars Physics and Evolution

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Poster 9

The chemical evolution of galaxies is strongly determined by the evolution of massive stars. Particularly important is the evolution at low Z that links our Local Universe with the conditions in early times. Because of their intrinsic brightness and relatively advanced evolutionary status, B supergiants are ideal targets to test our theories about the physics and evolution of these stars at low Z, and their impact on its host galaxy.We present results on 7 early B-type stars in the dwarf irregular galaxy IC1613, obtained with VLT-VIMOS. Non-classical automated analyses were performed to the data, using an efficient grid of models designed with FASTWIND. We determine the stellar photospheric and wind parameters, and abundances of He, C, N, O, Si, and Mg. These results will significantly improve our knowledge on the evolution of massive stars at low-Z by i) firmly establishing the metal content of the galaxy, previously inferred from HII regions and assuming a Solar chemical mixture, ii) providing new points to the WLR of metal-poor stars and iii) building the HRD of B supergiants in a metal-poor environment, with reliable stellar parameters and surface abundances.

Connecting Nuclear Physics and Massive Star Models to Galactic Chemical Evolution

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Poster 14

Modeling the chemical evolution of the Milky Way and Local galaxies represents a significant challenge, as it contains several sources of uncertainties and ideally requires multidisciplinary collaborations. Nuclear physics provides nuclear reaction rates, stellar models provide the composition of stellar ejecta, galaxy models and simulations follow the evolution of chemical species driven by multiple stellar populations, and observations provide constraints to test and improve numerical recipes. Continuous communication and feedback between all these fields is a key component in improving our understanding of how, where, and when elements have been created and recycled across cosmic time. We built a numerical pipeline that connects NuGrid stellar yields to galactic chemical evolution models, going from a classical one-zone model to a multi-zone model able to post-process cosmological hydrodynamical and dark-matter-only simulations. During this talk, I will present how we used this pipeline, in a circular way, to probe the impact of nuclear astrophysics and massive star evolution assumptions on the chemical signatures predicted by chemical evolution models. I will highlight the importance of core-collapse nucleosynthesis and how the uncertainties associated with the stellar remnant mass and black hole formation prescriptions in massive star models affect our ability to provide reliable numerical predictions in the Milky Way and in dwarf spheroidal galaxies.

Feedback by Massive Stars and the Self-Regulation of Star Formation

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Poster 32

Although star formation (SF) in action becomes directly noticeable in galaxies by various observational signatures, its process, its empirical relations to gas properties, and the reason for a much lower SF rate than expected are still far from being understood in detail. Most importantly, massive stars act as the main driver of galaxy evolution by various modes of stellar feedback, energy, mass and element releases, the first regulating the SF and energizing the interstellar medium (ISM), the last one enriching the ISM with heavier elements. For cosmological and galaxy evolutionary models the “star-formation efficiency” is an essential parameter to describe which fraction of star-forming gas is really converted into stars. Instead as being assumed temporally and empirically constant, this parameter depends not only on the stellar energy release, but also on the conditions of the formed star cluster and its surrounding gas. The formation of extremes like super star clusters as those in starburst galaxies and required previously for Globular Clusters as well as SF in low-surface brightness galaxies prove this conclusion. From our former numerical models of radiation-driven and wind-blown HII regions around single massive stars (Freyer et al.) we evaluate the energy transfer efficiency and found much lower values than those generally assumed in galaxy evolution modeling. Moreover, ongoing numerical studies of lacking massive stars at very low SF rates has also strong consequences for our understanding of feedback and SF self-regulation. Both will be discussed in our presentation.

Discovery of an Extraordinary Number of Red Supergiants in the Inner Galaxy

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Poster 55

Red supergiants (RSGs) are infrared bright massive stars easily detectable at a distance of a few megaparsecs. Their complex evolution is dominated by mass-loss and rotation that strongly affect their final fate.Even though the Milky Way is the closest laboratory of resolved stellar populations, only a thousand Galactic RSGs are currently known. This is due to our location on the Disk, dust observation, and uncertain distances.We like to present at this conference results from our recent search for Galactic RSGs in the direction of the inner Galaxy (Messineo et al. 2016). About hundred targets selected from the 2MASS and GLIMPSE I North catalogs were spectroscopically observed at infrared wavelengths, and an extraordinary large number of new RSGs were confirmed. They are mostly isolated stars with distances from 3.5 to 8.5 kpc. The newly discovered RSGs are a key ingredient for a novel modeling of Galaxy formation and evolution. An overdensity of RSGs is located between 25 and 30 degrees of Galactic longitude, where the near-side of the Bar ends and meets the spiral arms.

Mass of Dust in Core-Collapse Supernovae as Viewed From Energy Balance in the Ejecta

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Poster 62

Core-collapse supernovae (CCSNe) are considered to be one of the major sources of interstellar dust. Recent far-infrared (FIR) observations revealed the presence of freshly formed dust above $0.1 M_{\odot}$ in young supernova remnants such as SN 1987A and Cassiopeia A. However, dust masses estimated from near- to mid-infrared (N/MIR) observations of CCSNe a few years after explosions are a few orders of magnitude lower than those from FIR. In this study, we try to explain this big difference in estimated dust mass by invoking energy balance between photon absorption and thermal emission by dust. That is, as long as the heating source of newly formed dust is the radiation from the SN, the expected IR luminosity should not exceed the optical luminosity of the SN. From this constraint, we can naturally show that the mass of dust which can be heated up to a few hundred kelvin is only on the order of $10^{-4} - 10^{-2} M_{\odot}$. This means that, even if dust grain of $0.1 M_{\odot}$ already formed in the ejecta a few hundred days post-explosion, only a part of them have temperatures high enough to emit N/MIR emission. This indicates that the majority of the dust grains forms deep inside dense gas clumps so that their temperatures are too low to be detected at N/MIR wavelengths.

A Very Luminous Rosetta Stone to Decipher Massive Stellar Evolution: Linking LBVs, SN Impostors, Bright Radio Emitters and ULXs

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Poster 66

The subject of this talk is a previously unknown, very luminous ($M_{\mathrm{V}} \sim -10$) evolved star embedded in a supergiant HII region in the nearby dwarf galaxy NGC 5408. Hα has a HWZI of $\sim$ 5000km/s and the equivalent width is presently 2000Å. It displays non-thermal radio emission which is 8 times more powerful than the Cas A SNR, and long-slit spectra reveal a large surrounding HeIII region (300 pc diameter) with intense HeII 4686 and [NeV]3426 emission (ionisation potential 54 and 97 eV, respectively). This points to the presence of an ultraluminous X-ray source ($L_{\mathrm{X}} \sim$ several $10^{4}0$ erg/s, hereafter referred to as "NGC 5408 X-2"), whereas Chandra only detected a 3 orders of magnitude lower flux level. Curiously, this object is very close to, but not identical with the famous ULX NGC 5408 X-1, which is currently being studied in much detail in the literature. I will present ESO/VLT medium resolution spectra of "X-2" revealing variable P Cygni profiles of H, HeI and various ionisation stages of (forbidden) metal lines, suggesting a hot LBV nature. However, its optical continuum level appears to be constant whereas the Hα emission had increased tenfold over the last 30 years. The system appears to be in a very rapid stage of stellar evolution with currently ongoing huge mass-loss/mass-transfer between the binary components. LBV/ULX NGC 5408 X-2 appears to be a Rosetta stone worthwhile to be deciphered for a better understanding of the latest phases of massive (binary) stars.

Modeling the Colliding Winds of 30 Wolf-Rayets to Explain the Galactic Center's Thermal X-Ray Emission

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Poster 78

The Galactic center is a hotbed of astrophysical activity influenced by massive stars. ~ 30 Wolf-Rayet (WR) stars orbit within $10''$(0.4pc) of the super-massive black hole (SMBH), injecting wind material that dominates the SMBH accretion. A Chandra X-ray Visionary Program (XVP) that observed the Galactic center for 3 Ms showed spatially resolved, thermal emission around the SMBH, which was thought to be from the collision of these WR winds. We confront this theory by comparing these Chandra observations with X-ray emission from a series of hydrodynamic simulations of the 30 colliding WR winds. The simulations produce a complex density and temperature structure of cold wind material shocking with the ambient medium, thereby creating large reservoirs of hot, X-ray-emitting gas. The major success of this modeling is that, with the exception of the IRS13E cluster, the thermal emission from the hydrodynamic simulations reproduces the spectral shape and flux of the Chandra XVP observations to better than the uncertainty in the WR mass-loss rates and wind speeds used in the simulations. Furthermore, the SMBH feedback mechanisms we explore in the series of hydrodynamic simulations suggest a moderate-strength outburst that clears out some hot gas from the central parsec, thus decreasing the thermal X-ray emission. The presentation will conclude with the planned future work of incorporating the more numerous O stars and their winds, as well as a group of B stars called the "S" stars that orbit the SMBH with periods as short as ~ 10 years, and therefore influence the SMBH accretion.

The Upper Initial Mass Function in Nearby Dwarf Galaxies

J. Andrews, D. Calzetti, D. Cook, D. Dale, and M. Krumholz

Poster 2

Dwarf galaxies are likely the building blocks of all galaxies observed today, but star formation is still poorly-understood in these unevolved systems. We have obtained ground-based optical spectroscopy with the MMT and Palomar-200 inch for a sample of young, H-alpha bright clusters in ~ 20 dwarfs within ~ 3.5 Mpc; our targets all have extensive HST broad-band coverage as well. By comparing these extinction corrected spectra to stochastic stellar synthesis models we can obtain ages and masses of the clusters and associations and determine whether the dearth of ionizing photons in dwarfs is an effect of deficiency in the production of massive stars. Here we will present the results of those observations, and show that stellar clusters with massive stars are not as rare as generally thought, and are commonly found in smaller clusters in the low metallicity dwarfs.

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