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Accepted Papers

The most massive stars in the Arches cluster

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We study a sample composed of 28 of the brightest stars in the Arches cluster. We analyze K-band spectra obtained with the integral field spectrograph SINFONI on the VLT. Atmosphere models computed with the code CMFGEN are used to derive the effective temperatures, luminosities, stellar abundances, mass loss rates and wind terminal velocities. We find that the stars in our sample are either H-rich WN7-9 stars (WN7-9h) or O supergiants, two being classified as OIf+. All stars are 2-4 Myr old. There is marginal evidence for a younger age among the most massive stars. The WN7-9h stars reach luminosities as large as $2 \times 1^6 L_\odot$, consistent with initial masses of $\sim 120 M_\odot$. They are still quite H-rich, but show both N enhancement and C depletion. They are thus identified as core H-burning objects showing products of the CNO equilibrium at their surface. Their progenitors are most likely supergiants of spectral types earlier than O4-6 and initial masses $> 60 M_\odot$. Their winds follow a well defined modified wind momentum - luminosity relation (WLR): this is a strong indication that they are radiatively driven. Stellar abundances tend to favor a slightly super solar metallicity, at least for the lightest metals. We note however that the evolutionary models seem to under-predict the degree of N enrichment.

Reference: A&A accepted

On the web at: `http://arxiv.org/abs/0711.0657`
Preprints from: `martins@mpe.mpg.de`

Bright OB stars in the Galaxy -IV. Stellar and wind parameters of early to late B supergiants

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Context. B-type supergiants represent an important phase in the evolution of massive stars. Reliable estimates of their stellar and wind parameters, however, are scarce, especially at mid and late spectral subtypes. *Aims.* We apply the NLTE atmosphere code FASTWIND to perform a spectroscopic study of a small sample of Galactic B-supergiants from B0 to B9. By means of the resulting data and incorporating additional datasets from alternative studies, we investigate the properties of OB-supergiants and compare our findings with theoretical predictions. *Methods.* Stellar and wind parameters of our sample stars are determined by line profile fitting, based on synthetic profiles, a Fourier technique to investigate the individual contributions of stellar rotation and "macro-turbulence" and an adequate approach to determine the Si abundances in parallel with micro-turbulent velocities. *Results.* Due to the combined effects of line- and wind-blanketing, the temperature scale of Galactic B-supergiants needs to be revised downwards, by 10 to 20%, the latter value being appropriate for stronger winds. Compared to theoretical predictions, the wind properties of OB-supergiants indicate a number of discrepancies. In fair accordance with recent results, our sample indicates a gradual decrease in vinf over the bi-stability region, where the limits of this region are located at lower Teff than the predicted ones. Introducing a distance-independent quantity Q' related to wind-strength, we show that this quantity is a well defined, monotonically increasing function of Teff *outside* this region. *Inside* and from hot to cool, Mdot changes by a factor (in between 0.4 and 2.5) which is (much) smaller than the predicted factor of 5. *Conclusions.* The decrease in vinf over the bi-stability region is *not* over-compensated by an increase of Mdot, as frequently argued, provided that wind-clumping properties on both sides of this region do not differ substantially.

Reference: A&A, in press

On the web at: `http://www.usm.uni-muenchen.de/people/puls/papers/GalBSg.pdf`
Preprints from: `nmarkova@astro.bas.bg`

Evolution towards the critical limit and the origin of Be stars

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More and more evidence lead to consider classical Be stars as stars rotating close to the critical velocity. If so, then the question which naturally arises is the origin of this high surface velocity. We determine which are the mechanisms accelerating the surface of single stars during the Main Sequence evolution. We study their dependence on the metallicity and derive the frequency of stars with different surface

velocities in clusters of various ages and metallicities. We have computed 112 stellar models of four different initial masses between 3 and 60 $M_\odot$, at four different metallicities between 0 and 0.020, and with seven different values of the ratio $\Omega/\Omega_{\rm crit}$ between 0.1 and 0.99. For all the models, computations were performed until either the end of the Main Sequence evolution or the reaching of the critical limit. The evolution of surface velocities during the Main Sequence lifetime results from an interplay between meridional circulation (bringing angular momentum to the surface) and mass loss by stellar winds (removing it). The dependence on metallicity of these two mechanisms plays a key role in determining for each metallicity, a limiting range of initial masses (spectral types) for stars able to reach or at least approach the critical limit. Present models predict a higher frequency of fast rotating stars in clusters with ages between 10 and 25 Myr. This is the range of ages where most of Be stars are observed. To reproduce the observed frequencies of Be stars, it is necessary to assume first that the Be star phenomenon occurs already for stars with $\mathrm{v/v_{crit}} \geq 0.7$ and second, that the fraction of fast rotators on the Zero Age Main Sequence is higher at lower metallicities. Depending on the stage at which the star becomes a Be star, the star at this stage may present more or less important enrichments in nitrogen at the surface.

Reference: Astronomy and Astrophysics

On the web at: http://arxiv.org/abs/0711.1735
Preprints from: sylvia.ekstrom@obs.unige.ch

XMM-Newton X-ray study of early type stars in the Carina OB1 association

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X-ray properties of the stellar population in the Carina OB1 association are examined with special emphasis on early-type stars. Their spectral characteristics provide some clues to understanding the nature of X-ray formation mechanisms in the winds of single and binary early-type stars. A timing and spectral analysis of five observations with XMM-Newton is performed using various statistical tests and thermal spectral models. 235 point sources have been detected within the field of view. Several of these sources are probably pre-main sequence stars with characteristic short-term variability. Seven sources are possible background AGNs. Spectral analysis of twenty three sources of type OB and WR 25 was performed. We derived spectral parameters of the sources and their fluxes in three energy bands. Estimating the interstellar absorption for every source and the distance to the nebula, we derived X-ray luminosities of these stars and compared them to their bolometric luminosities. We discuss possible reasons for the fact that, on average, the observed X-ray properties of binary and single early type stars are not very different, and give several possible explanations.

Reference: Accepted by Astronomy and Astrophysics
Status: Manuscript has been accepted

On the web at: http://arxiv.org/abs/0711.3612

Preprints from: igor@sai.msu.ru

Phase-dependent X-ray observations of the beta Lyrae system: No eclipse in the soft band

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We report on observations of the eclipsing and interacting binary beta Lyrae from the Suzaku X-ray telescope. This system involves an early B star embedded in an optically and geometrically thick disk that is siphoning atmospheric gases from a less massive late B II companion. Motivated by an unpublished X-ray spectrum from the Einstein X-ray telescope suggesting unusually hard emission, we obtained time with Suzaku for pointings at three different phases within a single orbit. From the XIS detectors, the softer X-ray emission appears typical of an early-type star. What is surprising is the remarkably unchanging character of this emission, both in luminosity and in spectral shape, despite the highly asymmetric geometry of the system. We see no eclipse effect below 10 keV. The constancy of the soft emission is plausibly related to the wind of the embedded B star and Thomson scattering of X-rays in the system, although it might be due to extended shock structures arising near the accretion disk as a result of the unusually high mass-transfer rate. There is some evidence from the PIN instrument for hard emission in the 10-60 keV range. Follow-up observations with the RXTE satellite will confirm this preliminary detection.

Reference: to appear as a Letter in A&A

On the web at: astroph/0711.3954
Preprints from: ignace@etsu.edu

Carbon abundances of early B-type stars in the solar vicinity. Non-LTE line-formation for C II/III/IV and self-consistent atmospheric parameters

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Precise determinations of the chemical composition in early B-type stars consitute fundamental observational constraints on stellar and galactochemical evolution. Carbon is one of the most abundant metals in the Universe but analyses in early-type stars show inconclusive results, like large discrepancies between analyses of different lines in C II, a failure to establish the C II/III ionization balance and the derivation of systematically lower abundances than from other objects. We present a comprehensive and robust C II/III/IV model for non-LTE line-formation calculations based on carefully selected atomic data. The model is calibrated with high-S/N spectra of six apparently slow-rotating early B-type dwarfs and giants, which cover a wide parameter range and are randomly distributed in the solar neighbourhood. A self-consistent quantitative spectrum analysis is performed using an extensive iteration scheme to determine stellar atmospheric parameters and to select the appropriate atomic data used for the derivation of chemical abundances. We establish the carbon ionization balance for all sample stars based on a unique set of input atomic data, achieving consistency for all modelled lines. Highly accurate atmospheric parameters and a homogeneous carbon abundance with reduced systematic errors are derived. This results in a present-day stellar carbon abundance in the solar neighbourhood, which is in good agreement with recent determinations of the solar value and with the gas-phase abundance of the Orion H II region. The homogeneous present-day carbon abundance also conforms with predictions of chemical-evolution models for the Galaxy. The present approach allows us to constrain the effects of systematic errors on fundamental parameters and abundances. (abridged)

Reference: A&A

On the web at: http://arxiv.org/abs/0711.3783
Preprints from: nieva@sternwarte.uni-erlangen.de

Neglecting the porosity of hot-star winds can lead to underestimating mass-loss rates

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Context: The mass-loss rate is a key parameter of massive stars. Adequate stellar atmosphere models are required for spectral analyses and mass-loss determinations. Present models can only account for the inhomogeneity of stellar winds in the approximation of small-scale structures that are optically thin. Compared to previous homogeneous models, this treatment of “microclumping” has led to reducing empirical mass-loss rates by factors of two to three. Further reductions are presently discussed in the literature, with far-reaching consequences e.g.for stellar evolution and stellar yields. Aims: Stellar wind clumps can be optically thick in spectral lines. We investigate how this “macroclumping” influences theradiative transfer and the emergent line spectra and discuss its impact on empirical mass-loss rates. Methods: The Potsdam Wolf-Rayet (PoWR) model atmosphere code is generalized in the “formal integral” to account for clumps that are not necessarily optically thin. The stellar wind is characterized by the filling factor of the dense clumps and by their average separation. An effective opacity is obtained by adopting a statistical distribution of clumps and applied in the radiative transfer. Results: Optically thick clumps reduce the effective opacity. This has a pronounced effect on the emergent spectrum. Our modeling for the O-type supergiant zeta Puppis reveals that the optically thin Halpha line is not affected by wind porosity, but that the PV resonance doublet becomes significantly weaker when macroclumping is taken into account. The reported discrepancies between resonance-line and recombination-line diagnostics can be resolved entirely with the macroclumping modeling without downward revision of the mass-loss rate. In the case of Wolf-Rayet stars, we demonstrate for two representative models that stronger lines are typically reduced by a factor of two in intensity, while weak lines remain unchanged by porosity effects. Conclusions: Mass-loss rates inferred from optically thin emission, such as the Halpha line in O stars, are not influenced by macroclumping. The strength of optically thick lines, however, is reduced because of the porosity effects. Therefore, neglecting the porosity in stellar wind modeling can lead to underestimating empirical mass-loss rates.

Reference: DOI: 10.1051/0004-6361:20066377

On the web at: astro-ph/0704.2390

Preprints from: lida@astro.physik.uni-potsdam.de

The cool supergiant population of the massive young star cluster RSGC1

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We present new high-resolution near-IR spectroscopy and OH maser observations to investigate the population of cool luminous stars of the young massive Galactic cluster RSGC1. Using the 2.293micron CO-bandhead feature, we make high-precision radial velocity measurements of 16 of the 17 candidate Red Supergiants (RSGs) identified by Figer et al. We show that F16 and F17 are foreground stars, while we confirm that the rest are indeed physically-associated RSGs. We determine that Star F15, also associated with the cluster, is a Yellow Hypergiant based on its luminosity and spectroscopic similarity to ρ Cas. Using the cluster's radial velocity, we have derived the kinematic distance to the cluster and revisited the stars' temperatures and luminosities. We find a larger spread of luminosities than in the discovery paper, consistent with a cluster age 30% older than previously thought (12±2Myr), and a total initial mass of $(3 \pm 1) \times 10^4 M_\odot$. The spatial coincidence of the OH maser with F13, combined with similar radial velocities, is compelling evidence that the two are related. Combining our results with recent SiO and H_2O maser observations, we find that those stars with maser emission are the most luminous in the cluster. From this we suggest that the maser-active phase is associated with the end of the RSG stage, when the luminosity-mass ratios are at their highest.

Reference: astro-ph/0711.4757
Comments: Accepted for publication in ApJ

On the web at: http://arxiv.org/abs/0711.4757v1
Preprints from: davies@cis.rit.edu

The periodicity of the eta Carinae events

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Extensive spectral observations of eta Carinae over the last cycle, and particularly around the 2003.5 low excitation event, have been obtained. The variability of both narrow and broad lines, when

combined with data taken from two earlier cycles, reveal a common and well defined period. We have combined the cycle lengths derived from the many lines in the optical spectrum with those from broad-band X-rays, optical and near-infrared observations, and obtained a period length of P=2022.7±1.3 d.

Spectroscopic data collected during the last 60 years yield an average period of P=2020±4 d, consistent with the present day period. The period cannot have changed by more than $\Delta P/P = 0.0007$ since 1948. This confirms the previous claims of a true, stable periodicity, and gives strong support to the binary scenario. We have used the disappearance of the narrow component of HeI 6678 to define the epoch of the Cycle 11 minimum, T_0=JD 2,452,819.8. The next event is predicted to occur on 2009 January 11 (±2 days). The dates for the start of the minimum in other spectral features and broad-bands is very close to this date, and have well determined time delays from the HeI epoch.

Reference: MNRAS

Preprints from: `damineli@astro.iag.usp.br`

Dynamical Simulations of Magnetically Channeled Line-Driven Stellar Winds: II. The Effects of Field-Aligned Rotation

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Building upon our previous MHD simulation study of magnetic channeling in radiatively driven stellar winds, we examine here the additional dynamical effects of stellar em rotation in the (still) 2-D axisymmetric case of an aligned dipole surface field. In addition to the magnetic confinement parameter η_* introduced in Paper I, we characterize the stellar rotation in terms of a parameter $W \mathrm{equiv} V_{\rm rot}/V_{\rm orb}$ (the ratio of the equatorial surface rotation speed to orbital speed), examining specifically models with moderately strong rotation $W =$~0.25 and 0.5, and comparing these to analogous non-rotating cases. Defining the associated Alfvén radius $R_{\rm A} \approx \eta_*^{1/4} R_*$ and Kepler corotation radius $R_{\rm K} \approx W^{-2/3} Rstar$, we find rotation effects are weak for models with $R_{\rm A} < R_{\rm K}$, but can be substantial and even dominant for models with $R_{\rm A} \gtrsim R_{\rm K}$. In particular, by extending our simulations to magnetic confinement parameters (up to $\eta_* = 1000$) that are well above those ($\eta_* = 10$) considered in Paper I, we are able to study cases with $R_{\rm A} \gg R_{\rm K}$; we find that these do indeed show clear formation of the em rigid-body disk predicted in previous analytic models, with however a rather complex, dynamic behavior characterized by both episodes of downward infall and outward breakout that limit the buildup of disk mass. Overall, the results provide an intriguing glimpse into the complex interplay between rotation and magnetic confinement, and form the basis for a full MHD description of the rigid-body disks expected in strongly magnetic Bp stars like σ Ori E.

Reference: MNRAS (in press)

On the web at: `http://shayol.bartol.udel.edu/massivewiki-media/publications/rotation.pdf`
Preprints from: `asif@bartol.udel.edu`

The Massive Star Content of NGC 3603

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We investigate the massive star content of NGC 3603, the closest known giant H II region. We have obtained spectra of 26 stars in the central cluster using the Baade 6.5-m telescope (Magellan I). Of these 26 stars, 16 had no previous spectroscopy. We also obtained photometry of all of the stars with previous or new spectroscopy, primarily using archival HST ACS/HRC images. The total number of stars that have been spectroscopically classified in NGC 3603 now stands at 38. The sample is dominated by very early O type stars (O3); there are also several (previously identified) H-rich WN+abs stars. We derive E(B-V)=1.39, and find that there is very little variation in reddening across the cluster core, in agreement with previous studies. Our spectroscopic parallax is consistent with the kinematic distance only if the ratio of total to selective extinction is anomalously high within the cluster, as argued by Pandey et al. Adopting their reddening, we derive a distance of 7.6 kpc. We discuss the various distance estimates to the cluster, and note that although there has been a wide range of values in the recent literature (6.3-10.1 kpc) there is actually good agreement with the apparent distance modulus of the cluster—the disagreement has been the result of the uncertain reddening correction. We construct our H-R diagram using the apparent distance modulus with a correction for the slight difference in differential reddening from star to star. The resulting H-R diagram reveals that the most massive stars are highly coeval, with an age of 1-2 Myr, and of very high masses (120 Mo). The three stars with Wolf-Rayet features are the most luminous and massive, and are coeval with the non-WRs, in accord with what was found in the R136 cluster. There may be a larger age spread (1-4 Myr) for the lower mass objects (20-40Mo). Two supergiants (an OC9.7 I and the B1 I star Sher 25) both have an age of about 4 Myr. We compare the stellar content of this cluster to that of R136, finding that the number of very high luminosity ($M_{\rm bol} < -10$) stars is only about 1.1-2.4x smaller in NGC 3603. The most luminous members in both clusters are H-rich WN+abs stars, basically "Of stars on steroids", relatively unevolved stars whose high luminosities results in high mass loss rates, and hence spectra that mimic that of evolved WNs. To derive an initial mass function for the massive stars in NGC 3603 requires considerably more spectroscopy; we estimate from a color-magnitude diagram that less than a third of the stars with masses above 20 Mo have spectral types known.

Reference: AJ, in press

On the web at: `http://www.lowell.edu/users/massey/n3603final.pdf`
Preprints from: `Phil.Massey@lowell.edu`

The circumstellar medium around a rapidly rotating, chemically homogeneously evolving, possible gamma-ray burst progenitor

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Rapidly rotating, chemically homogeneously evolving massive stars are considered to be progenitors of long gamma-ray bursts. We present numerical simulations of the evolution of the circumstellar medium around a rapidly rotating 20 Msol star at a metallicity of Z=0.001. Its rotation is fast enough to produce quasi-chemically homogeneous evolution. While conventionally, a star of 20 Msol would not evolve into a Wolf-Rayet stage, the considered model evolves from the main sequence directly to the helium main sequence. We use the time-dependent wind parameters, such as mass loss rate, wind velocity and rotation-induced wind anisotropy from the evolution model as input for a 2D hydrodynamical simulation. While the outer edge of the pressure-driven circumstellar bubble is spherical, the circumstellar medium close to the star shows strong non-spherical features during and after the periods of near-critical rotation. We conclude that the circumstellar medium around rapidly rotating massive stars differs considerably from the surrounding material of non-rotating stars of similar mass. Multiple blue-shifted high velocity absorption components in gamma-ray burst afterglow spectra are predicted. As a consequence of near critical rotation and short stellar evolution time scales during the last few thousand years of the star's life, we find a strong deviation of the circumstellar density profile in the polar direction from the $1/R^2$ density profile normally associated with stellar winds close to the star.

Reference: Accepted for publication in Astronomy & Astrophysics

On the web at: http://lanl.arxiv.org/abs/0711.4807
Preprints from: marle@udel.edu

Proceedings

Quantitative analysis of resolved X-ray emission line profiles of O stars

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By quantitatively fitting simple emission line profile models that include both atomic opacity and porosity to the Chandra X-ray spectrum of ζ Pup, we are able to explore the trade-offs between reduced mass-loss rates and wind porosity. We find that reducing the mass-loss rate of ζ Pup by roughly a factor of four, to $1.5 \times 10^{-6} M_{\odot}$/yr, enables simple non-porous wind models to provide good fits to the data. If, on the other hand, we take the literature mass-loss rate of 6 times $10^{-6} M_{\odot}$/yr, then to produce X-ray line profiles that fit the data, extreme porosity lengths – of $h_{\infty} \sim 3R_*$ – are required. Moreover, these porous models do not provide better fits to the data than the non-porous low optical depth models. Additionally, such huge porosity lengths do not seem realistic in light of 2-D numerical simulations of the wind instability.

Reference: Appearing in "Clumping in Hot Star Winds," eds. Hamann, Feldmeier, & Oskinova, Potsdam: Univ.-Verl., 2007

On the web at: http://astro.swarthmore.edu/∼cohen/Papers/cohen_potsdam.pdf
Preprints from: cohen@astro.swarthmore.edu