THE HOT STAR NEWSLETTER

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An electronic publication dedicated to A, B, O, Of, LBV and Wolf-Rayet stars
and related phenomena in galaxies

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Accepted Papers

^{26}Al Yields from Rotating Wolf–Rayet Star Models

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We present new ^{26}Al stellar yields from rotating Wolf–Rayet stellar models which, at solar metallicity, well reproduce the observed properties of the Wolf-Rayet populations. These new yields are enhanced with respect to non–rotating models, even with respect to non–rotating models computed with enhanced mass loss rates. We briefly discuss some implications of the use of these new yields for estimating the global contribution of Wolf-Rayet stars to the quantity of ^{26}Al now present in the Milky Way.

Accepted by New Astronomy Reviews
or on the web at http://arXiv.org/abs/astro-ph/0311091

Massive Stars: Their Birth Sites and Distribution

Pavel Kroupa[1]

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The stellar IMF has been found to be an invariant Salpeter power-law (alpha=2.35) above about 1 $M_{\odot}$, but at the same time a massive star typically has more than one low-mass companion. This constrains the possible formation scenarios of massive stars, but also implies that the true, binary-star corrected stellar IMF should be significantly steeper than Salpeter, alpha > 2.7. A significant fraction of all OB stars are found relatively far from potential birth sites which is most probably a result of dynamical ejections from cores of binary-rich star clusters. Such cores form rapidly due to dynamical mass segregation, or they are primordial. Probably all OB stars thus form in stellar clusters together with low-mass stars, and they have a rather devastating effect on the embedded cluster by rapidly driving out the remaining gas leaving expanding OB associations and bound star clusters. The distributed population of OB stars has a measured IMF with alpha about 4, which however, does not necessarily constitute a different physical mode for isolated star formation. A steep field-star IMF is obtained naturally because stars form in clusters which are distributed according to a power-law cluster mass function.

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E-mail: `pavel@astrophysik.uni-kiel.de`
URL: `http://arxiv.org/abs/astro-ph/0309598`

The Ofpe/WN9 stars in M 33

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We present HST/STIS Ultraviolet spectra of the six known Ofpe/WN9 stars ("slash stars") in M 33. These stars were selected for showing the characteristics of the Ofpe/WN9 class from previous optical ground-based spectroscopy. The UV spectra are rich in wind lines, whose strength and terminal velocity vary greatly among our target sample. We analyse the STIS spectra with non-LTE, line blanketed, spherical models with hydrodynamics, computed with the WM-basic code. We find C to be underabundant and N overabundant, respect to the solar values, with a ratio (by mass) of C/N between 0.02 to 0.9 across the sample. Some stars show very conspicuous wind lines (P Cygni profiles), while two stars have extremely weak winds. The mass-loss rates thus vary greatly across the sample. The mass-loss rates of the hottest stars are lower than typical values of WNL stars, but higher than expected for normal population I massive stars. There is indication that the mass-loss rates may be variable in time. The C/N ratio, and the other physical parameters derived by the spectral modeling (T_{eff} , Lbol, mass), are consistent with evolutionary calculations for objects with moderately high initial masses ($\approx$30-50 $M_{\odot}$), evolving towards the WNL stage through an enhanced mass-loss phase.

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Preprints from `bianchi@pha.jhu.edu`
or on the web at `http://dolomiti.pha.jhu.edu`

The catalogue of OB associations in IC 1613

J. Borissova, R. Kurtev, L. Georgiev, M. Rosado

We present a catalogue of OB associations in IC 1613. Using an automatic and objective method (Battinelli's 1991 technique) 60 objects were found. The size distribution reveals a significant peak at about 60 parsecs if a distance modulus of 24.27 mag is assumed. Spatial distributions of the detected associations and H II regions are strongly correlated.

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E-mail: `jborisso@astro.puc.cl`
URL: `http://arxiv.org/abs/astro-ph/0310282`

Minimizing Strong Telluric Absorption in Near Infra-red Stellar Spectra

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We have obtained high resolution spectra (R = 25000) of an A star over varying airmass to determine the effectiveness of telluric removal in the limit of high signal to noise. The near infra-red line HeI at 2.058 microns, which is a sensitive indicator of physical conditions in massive stars, supergiants, HII regions and YSOs, resides among pressure broadened telluric absorption from carbon dioxide and water vapor that varies both in time and with observed airmass.

Our study shows that in the limit of bright stars at high resolution, accuracies of 5% are typical for high airmass observations (greater than 1.9), improving to a photon-limited accuracy of 2% at smaller airmasses (less than 1.15). We find that by using the continuum between telluric absorption lines of a ro-vibrational fan a photon-limited 1% accuracy is achievable.

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Preprints from `mkenworthy@as.arizona.edu`
or on the web at `http://xxx.lanl.gov/abs/astro-ph/0310588`

Physical limits to the validity of synthesis models: The Lowest Luminosity Limit

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In this paper we establish a necessary condition for the application of stellar population synthesis models to observed star clusters. Such a condition is expressed by the requirement that the total luminosity of the cluster modeled be larger than the contribution of the most luminous star included in the assumed isochrones, which is referred to as the Lowest Luminosity Limit (LLL). This limit is independent of the assumptions on the IMF and almost independent of the star formation history. We have obtained the Lowest Luminosity Limit for a wide range of ages (5 Myr to 20 Gyr) and metallicities (Z=0 to Z=0.019) from the Girardi et al. (2002) isochrones. Using the results of evolutionary synthesis models, we have also obtained the minimal cluster mass associated with the LLL, $\mathcal{M}^{min}$, which is the mass value below which the observed colors are severely biased with respect to the predictions of synthesis models. We explore the relationship between $\mathcal{M}^{min}$ and the statistical properties of clusters, showing that the magnitudes of clusters with mass equal to $\mathcal{M}^{min}$ have a relative dispersion of 32% at least (i.e., 0.35 mag) in all the photometric bands considered; analogously, the magnitudes of clusters with mass larger than $10 \times \mathcal{M}^{min}$ have a relative dispersion of 10% at least. The dispersion is comparatively larger in the near infrared bands: in particular, $\mathcal{M}^{min}$ takes values between 10^4 and 10^5 $M_\odot$ for the K band, implying that severe sampling effects may affect the infrared emission of many observed stellar clusters. As an example of an application to observations, we show that in surveys that reach the Lowest Luminosity Limit the color distributions will be skewed toward the color with the smallest number of effective sources, which is usually the red, and that the skewness is a signature of the cluster mass distribution in the survey. We also apply our results to a sample of Globular Clusters, showing that they seem to be affected by sampling effects, a circumstance that could explain, at least partially, the bias of the observed colors with respect to the predictions of synthesis models. Finally, we extensively discuss the advantages and the drawbacks of our method: it is, on the one hand, a very simple criterion for the detection of severe sampling problems that bypasses the need for sophisticated statistical tools; on the other hand, it is not very sensitive, and it does not identify all the objects in which sampling effects are important and a statistical analysis is required. As such, it defines a condition necessary but not sufficient for the application of synthesis models to observed clusters.

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Classical Be stars

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Recent results on classical Be stars are reviewed and links to general astrophysics are presented. Classical Be stars are B type stars close to the main sequence which exhibit line emission over the photospheric spectrum. The excess is attributed to a circumstellar gaseous component which is commonly accepted to be in the form of an equatorial disc. Since 1988, when the last such review was published, major progress has been made. The geometry and kinematics of the circumstellar environment can be best explained by a rotationally supported relatively thin disc with very little outflow, consistent with interferometric observations. The presence of short-term periodic variability is restricted to the earlier type Be stars. This variation for at least some of these objects have been shown to be due to nonradial pulsation. For at least one star, evidence for a magnetic field has been observed. The mechanisms responsible for the production and dynamics of the circumstellar gas are still not constrained. Observations of nonradial pulsation beating phenomena connected to outbursts point towards a relevance of pulsation, but this mechanism cannot be generalized. Either the evidence that Be stars do not form a homogeneous group with respect to disc formation is growing, or the short-term periodic variability is less important than previously thought. The statistics of Be stars investigated in open clusters of the Milky Way and the Magellanic Clouds have re-opened the question of the evolutionary status of Be stars. The central B star is a fast rotator, although theoretical developments have revived the question of how high rotational rates are, so that the commonly quoted mean value of about 70 to 80the critical velocity may just be a lower limit. Be stars are in an unique position to make contributions to several

important branches of stellar physics e.g. asymmetric mass-loss processes, stellar angular momentum distribution evolution, astroseismology, and magnetic field evolution.

Review in PASP October 2003 issue (Vol. 115, No. 812, Page 1153) *on the web at* http://www.journals.uchicago.edu/cgi-bin/resolve?PASP203118

Characteristics and classification of A-type supergiants in the Small Magellanic Cloud

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We address the relationship between spectral type and physical properties for A-type supergiants in the SMC. We first construct a self-consistent classification scheme for A supergiants, employing the calcium K to Hϵ line ratio as a temperature-sequence discriminant. Following the precepts of the 'MK process', the same morphological criteria are applied to Galactic and SMC spectra with the understanding there may not be a correspondence in physical properties between spectral counterparts in different environments. We then discuss the temperature scale, concluding that A supergiants in the SMC are systematically cooler than their Galactic counterparts at the same spectral type, by up to $\sim$10%. Considering the relative line strengths of Hγ and the CH G-band we extend our study to F and early G-type supergiants, for which similar effects are found. We note the implications for analyses of extragalactic luminous supergiants, for the flux-weighted gravity-luminosity relationship and for population synthesis studies in unresolved stellar systems.

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On the photometric variability of blue supergiants in NGC 300 and its impact on the Flux-weighted Gravity-Luminosity Relationship

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We present a study of the photometric variability of spectroscopically confirmed supergiants in NGC 300, comprising 28 epochs extending over a period of five months. We find 15 clearly photometrically variable blue supergiants in a sample of nearly 70 such stars, showing maximum light amplitudes ranging from 0.08 to 0.23 magnitudes in the V band, and one variable red supergiant. We show their light curves, and determine semi-periods for two A2 Ia stars. Assuming that the observed changes correspond to similar variations in the bolometric luminosity, we test for the influence of this variability on the Flux-weighted Gravity–Luminosity Relationship and find a negligible effect, showing that the calibration of this relationship, which has the potential to measure extragalactic distances at the Cepheid accuracy level, is not affected by the stellar photometric variability in any significant way.

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E-mail: bresolin@ifa.hawaii.edu

URL: http://arxiv.org/abs/astro-ph/0309336

Instabilities of captured shocks in the envelopes of massive stars

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The evolution of strange mode instabilities into the non linear regime has been followed by numerical simulation for an envelope model of a massive star having solar chemical composition, $M = 50M_{\odot}, T_{\rm eff} = 10^4K$ and $L = 1.17 * 10^6 L_{\odot}$. Contrary to previously studied models, for these parameters shocks are captured in the H-ionisation zone and perform rapid oscillations within the latter. A linear stability analysis is performed to verify that this behaviour is physical. The origin of an instability discovered in this way is identified by construction of an analytical model. As a result, the stratification turns out to be essential for instability. The difference to common stratification instabilities, e.g., convective instabilities, is discussed.

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E-mail: `mgrott@gwdg.de`
URL: `http://arxiv.org/abs/astro-ph/0309708`

O stars effective temperature and HII regions ionization parameter gradients in the Galaxy

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Extensive photoionization model grids are computed for single star HII regions using stellar atmosphere models from the WM-basic code. Mid-IR emission line intensities are predicted and diagnostic diagrams of [NeIII]/[NeII] and [SIV]/[SIII] excitation ratio are build, taking into account the metallicities of both the star and the HII region. The diagrams are used in conjunction with galactic HII region observations obtained with the ISO Observatory to determine the effective temperature $T_{\rm eff}$ of the exciting O stars and the mean ionization parameter U. $T_{\rm eff}$ and U are found to increase and decrease, respectively, with the metallicity of the HII region represented by the [Ne/Ne$_{\odot}$] ratio. No evidence is found for gradients of $T_{\rm eff}$ or U with galactocentric distance $R_{\rm gal}$. The observed excitation sequence with $R_{\rm gal}$ is mainly due to the effect of the metallicity gradient on the spectral ionizing shape, upon which the effect of an increase in $T_{\rm eff}$ with Z is superimposed. We show that not taking properly into account the effect of metallicity on the ionizing shape of the stellar atmosphere would lead to an apparent decrease of $T_{\rm eff}$ with Z and an increase of $T_{\rm eff}$ with $R_{\rm gal}$.

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E-mail: `morisset@astroscu.unam.mx`
URL `http://arxiv.org/abs/astro-ph/0310275`

The Angular Momentum Evolution of 0.1-10 $M_{\odot}$ Stars From the Birthline to the Main Sequence

S.C. Wolff, S.E. Strom, L.A. Hillenbrand

(Abridged for astro-ph) Projected rotational velocities (vsini) have been measured for a sample of 145 stars with masses between 0.4 and > 10 $M_{\odot}$ (median mass 2.1 $M_{\odot}$) located in the Orion star-forming

complex. These measurements have been supplemented with data from the literature for Orion stars with masses as low as 0.1 $M_\odot$. The primary finding from analysis of these data is that the upper envelope of the observed values of angular momentum per unit mass (J/M) varies as $M^{0.25}$ for stars on convective tracks having masses in the range 0.1 to 3 $M_\odot$. This power law extends smoothly into the domain of more massive stars (3 to 10 $M_\odot$), which in Orion are already on the ZAMS. This result stands in sharp contrast to the properties of main sequence stars, which show a break in the power law and a sharp decline in J/M with decreasing mass for stars with $M < 2\ M_\odot$. A second result of our study is that this break is seen already among the PMS stars in our Orion sample that are on radiative tracks, even though these stars are only a few million years old. A comparison of rotation rates seen for stars on either side of the convective-radiative boundary shows that stars do not rotate as solid bodies during the transition from convective to radiative tracks.

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E-mail: lah@astro.caltech.edu
URL: http://arxiv.org/abs/astro-ph/0310280

Direct measurement of the size and shape of the present-day stellar wind of Eta Carinae

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We present new high angular resolution observations at near-IR wavelengths of the core of the Luminous Blue Variable Eta Carinae, using NAOS-CONICA at the VLT and VINCI at the VLT Interferometer (VLTI). The latter observations provide spatial information on a scale of 5 milli-arcsec or 11 AU at the distance of Eta Carinae. The present-day stellar wind of Eta Carinae is resolved on a scale of several stellar radii. Assuming spherical symmetry, we find a mass loss rate of $1.6 \times 10^{-3}\ M_\odot/yr$ and a wind clumping factor of 0.26. The VLTI data taken at a baseline of 24 meter show that the object is elongated with a de-projected axis ratio of approximately 1.5; the major axis is aligned with that of the large bi-polar nebula that was ejected in the 19th century. The most likely explanation for this observation is a counter-intuitive model in which stellar rotation near the critical velocity causes enhanced mass loss along the rotation axis. This results from the large temperature difference between pole and equator in rapidly rotating stars. Eta Carinae must rotate in excess of 90 per cent of its critical velocity to account for the observed shape. The large outburst may have been shaped in a similar way. Our observations provide strong support for the existence of a theoretically predicted rotational instability, known as the Omega limit.

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E-mail: mschoell@eso.org
URL: http://arxiv.org/abs/astro-ph/0310399

The Nature of the Massive Young Stars in W75 N

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We have observed the W75 N massive star forming region in SiO(J=2-1 & J=1-0) at 3″- 5″resolution and in 6 cm, 2 cm, and 7 mm continuum emission at 1.4″- 0.2″resolution. The abundance ratio of [SiO]/[H2] is roughly 5-7 x 10^{-11} which is typical for what is expected in the ambient component of molecular clouds with active star formation. The SiO morphology is diffuse and centered on the positions of the ultracompact HII regions - no collimated, neutral jet was discovered. The ionized gas surrounding the protostars have emission measures ranging from 1-15 x 10^6 pc cm^{-6}, densities from 0.4-5 x 10^4 cm^{-3}, and derived spectral types of the central ionizing stars ranging from B0.5 to B2. Most of the detected sources have spectral indicies which suggest optically thin to moderately optically thick HII regions produced by a central ionizing star. The spread in ages between the oldest and youngest early-B protostars in the W75 N cluster is 0.1-5 x 10^6 years. This evolutionary timescale for W75 N is consistent with that found for early-B stars born in clusters forming more massive stars (Mstar > 25 $M_\odot$).

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E-mail: `dshepher@aoc.nrao.edu`
URL: `http://arxiv.org/abs/astro-ph/0310418`
URL: `http://www.aoc.nrao.edu/~dshepher/science.shtml`

Chandra and HST Confirmation of the Luminous and Variable X-ray Source IC 10 X-1 as a Possible Wolf-Rayet, Black-Hole Binary

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We present a Chandra and HST study of IC 10 X-1, the most luminous X-ray binary in the closest starburst galaxy to the Milky Way. Our new hard X-ray observation of X-1 confirms that it has an average 0.5-10 keV luminosity of 1.5e38 erg/s, is strongly variable (a factor of 2 in > 3 ks), and is spatially coincident (within 0.'23 +/-0.'30) with the Wolf-Rayet (WR) star [MAC92] 17A in IC 10. The spectrum of X-1 is best fit by a power law with photon index of 1.8 and a thermal plasma with kT 1.5 keV, although systematic residuals hint at further complexity. Taken together, these facts suggest that X-1 may be a black hole belonging to the rare class of WR binaries; it is comparable in many ways to Cyg X-3. The Chandra observation also finds evidence for extended X-ray emission co-spatial with the large non-thermal radio superbubble surrounding X-1.

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E-mail: `feb@ast.cam.ac.uk`
URL: `http://arxiv.org/abs/astro-ph/0310039`

Submitted Papers

A CNO Dichotomy among O2 Giant Spectra in the Magellanic Clouds

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From a survey of the 3400 Å region in the earliest O-type spectra, we have found that two of the four O2 giants observed in the Large Magellanic Cloud have the O IV lines there stronger than the N IV, while the other two have the opposite. A Small Magellanic Cloud counterpart also has the N IV stronger than O IV. Inspection of the blue spectra of these stars shows that the former pair have weaker N lines in all ionization states (III, IV, V) present as well as lines of C IV λ4658, while the latter three have stronger N lines and greater He/H. Space ultraviolet observations of two of the N-strong stars show N V wind profiles substantially stronger than those of C IV, while in the N-weak stars the C IV features are equal to or stronger than the N V. The N-strong stars are now reclassified as ON2 III(f*), newly defining that category. These characteristics strongly suggest a larger fraction of processed material in the atmospheres of the ON2 stars, which we confirm by modeling the optical spectra. In the context of current models, it is in turn implied that the ON2 stars are in a more advanced evolutionary state than the others, and/or that they had higher initial rotational velocities. The recent formulation of the effects of rotation on massive stellar evolution introduces an additional fundamental parameter, which the CNO abundances are in principle able to constrain. We present some illustrative comparisons with current Geneva evolutionary models for rotating massive stars. It is possible that these very hot, nitrogen-rich objects are products of homogeneous evolution. Our results will provide motivation for further physical modeling of the atmospheres and evolutionary histories of the most massive hot stars.

Submitted to The Astrophysical Journal
Preprints from walborn@stsci.edu

Another single hydrogen-rich Wolf-Rayet Star in the SMC?

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A 12th Wolf-Rayet star in the SMC has recently been discovered by Massey et al. (2003). In order to determine its spectral type and a preliminary binary status, we obtained 3 high signal-to-noise spectra separated in time at the ESO-NTT. Compared to other WR stars in the SMC, SMC-WR12 appears to belong to the subgroup of faint, single and hydrogen-rich WN stars. We discuss the evolutionary

status of WR12 and show that relatively low mass *rotating* progenitors can better account for the properties of single hydrogen-rich WN stars in the SMC.

Submitted to A&A
Preprints from `cfoellmi@eso.org`
or on the web at `http://arxiv.org/abs/astro-ph/0310153`

Jobs

Post-doctoral Research Position at The Johns Hopkins University, USA

A post-doctoral research position is available to work with Dr. Luciana Bianchi at The Johns Hopkins University, Center for Astrophysical Sciences, Baltimore, MD, USA. The research program involves modeling spectra of hot massive stars in Local Group galaxies with state of the art non-LTE codes. The program includes reduction and analysis of HST-STIS (UV and visual) spectra, ground-based (VLT) and FUSE far-UV spectra of early type stars (and CSPN) in the Local Group. Experience with codes for synthetic spectra calculations is required. Experience in reducing spectroscopic data is a desirable plus.

The candidate should have a PhD in Astronomy or closely-related degree. The position is available immediately (one year, renewable) and will be filled as soon as a suitable candidate is found. Applications including curriculum vitae, statement of interest and relevant work experience, publications, and three letters of reference should be sent to:

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JHU encourages applications from women and minority candidates. AAE/EOE

Opportunity for Graduate Student (Dissertation Work) Johns Hopkins University, Dept. of Physics and Astronomy

Immediately available: graduate student position to work with Dr. Luciana Bianchi (bianchi@pha.jhu.edu). Research program: study of young massive stellar populations and stellar clusters in nearby galaxies and the MW, with multi-band imaging from HST (WFPC2, STIS, ACS), ESO-VLT, GALEX, SDSS. Experience with IDL and IRAF, and with common photometry packages/techniques highly desirable. Knowledge of stellar evolution is a desirable plus. Graduate students who have passed all the exams, from JHU or abroad, will be considered. Visiting graduate students from foreign universities will be employed for a minimum of one year (typically 3 years). Send statement of interest and relevant experience, curriculum vitae and references, to :

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