THE HOT STAR NEWSLETTER

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

ed. Philippe Eenens

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Discussion Forum

The ad-hoc Working Group on Hot Massive Stars.

Thank you for your suggestions of candidates for the committee. The number of answers (over 40) shows the interest of the Hot Star community, from students to retired astronomers. Many messages contained words of strong support.

A recurrent suggestion was that the Working Group should promote a closer interaction between observers and theoreticians. We shall look for ways to achieve this. Other goals of the WG are to foster collaborations (e.g. observing campaigns), to foment the exchange of information (e.g. on interesting objects) and to help organize activities and meetings. It is hoped it can serve as a link with the IAU Executive Committee, the relevant IAU commissions and other Working Groups (e.g. on B Stars).

The merged list of candidates, together with details about the election procedure, will be sent in a separate message.

Contents of this Newsletter

Accepted

O-Star Mass-Loss and Wind Momentum Rates in the Galaxy and the Magellanic Clouds. Observations and Theoretical Predictions

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A new, very fast approximate method is presented to determine mass-loss rates of O-stars from H_α line profiles. The method uses H and HeII departure coefficients from unified model atmospheres parametrized in a simple way as function of wind velocity together with photospheric NLTE line profiles as the inner boundary condition for a numerically exact radiative transfer solution to derive a wind contaminated H_α –profile. The method is also applied to H_γ to determine stellar gravities corrected for wind emission.

A detailed analytical discussion of H_α line formation in O-star winds is given and it is demonstrated that former very simple approaches considering only optically thin wind emission lead to significant systematic errors. Scaling relations and generalized curves of growth are presented that connect mass-loss rate, terminal velocity, stellar parameters and H_α equivalent width.

The method is applied to samples of O-stars in the Galaxy, LMC and SMC and mass-loss rates are derived from H_α in combination with terminal velocities measured from IUE and HST spectra. The results reveal that a tight empirical relation exists between the radius modified stellar wind momentum rate $\dot{M}v_\infty\ R_*^{0.5}$ and the stellar luminosity. The variations of this relationship between the Galaxy, LMC and SMC are explained in terms of different abundances. Furthermore, for almost all objects with dense winds (mostly supergiants), the commonly used velocity field exponent β could be *derived*, indicating a typical value of $\beta \approx 1$.

A comparison with the improved theory of radiation driven winds (as presented recently by Pauldrach et al. 1994) shows that the observed wind momentum-luminosity relationship can be understood qualitatively in terms of the theory. However, there exist significant systematic discrepancies as a function of effective temperature, luminosity class and wind performance number $\eta = \dot{M}v_\infty\ c/L$. We stress that these discrepancies would not have been detected with previous simplified H_α –approachs.

The deficiencies of the theory are discussed and suggestions for future improvements are made.

Accepted by A & A *For preprints, contact* uh101aw@hpmail.lrz-muenchen.de

X-ray and γ-ray emission in open clusters

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We have studied a number of galactic open clusters that lie in the error boxes of COS B sources. These clusters belong to complexes in which similar star formation processes occur. They have similar ages, stellar population and contain peculiar stars (Of, WR and LBV's) with very high-velocity stellar winds. We propose that a system of shock fronts, set up at the interfaces between the hypersonic wind of the peculiar stars and the other cluster members, generates acceleration of cosmic ray particles, whose interactions with the inter-cluster gas concentrations would be responsible for the observed γ-ray emission. We find various observational evidences (including CGRO data, strongly supporting the association of the γ-ray source J 2021+37=2CG075+00 with Berk 87, containing the WO star Sand 5) for the presence of such shock fronts in some of these clusters. We show that the diffuse hard X-ray emission from the clusters regions is consistent with the geometric scenario inferred from the data and with the assumed mechanism of cosmic ray acceleration.

Accepted by A & A *For preprints, contact* polcaro@saturn.ias.fra.cnr.it

The ultraviolet spectrum of η Carinae II. 1980 IUE observations of the Homunculus

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We analyze the ultraviolet observations of the circumstellar nebula of η Car (the *Homunculus*) obtained in December 1980 with *IUE*. A high resolution spectrum was obtained with the IUE large aperture from 6″ to 17″ NW of η Car, near the H condensation (the *head*). The measured flux appears two orders of magnitude larger than that expected from the instrumentally scattered light (stray light). The high resolution 2295 to 3200 Å spectrum of the nebula is given in the form of Atlas to provide a quantitative ground for a detailed comparison with the UV spectrum of the stellar core discussed by Viotti et al. (1989). The terminal velocities of the P Cygni absorption components are similar in the stellar core and in the nebula, but the blue side of the emission appears less absorbed in the latter. The high excitation Fe II emission lines, such as the 2507-08 Å blend, appear sharp and very prominent in emission. A terminal velocity of $\geq$1000 km s^{-1} is derived from the analysis of the stellar and nebular Mg II doublet. We have also identified Fe I emission lines at 2823 and 2844 Å which are fluorescence excited by the Mg II *k* line. The low resolution *IUE* spectrum of the condensations H (8″ NW of η Car), D (5″ E) and S (11″ SW), is also analyzed, and the spatial physical structure of the nebula near D and S is discussed. The long-wave spectrum is dominated by broad emission blends

of Fe II and Mg II. The short-wave spectrum of the X-ray emitting S condensation displays a high temperature spectrum with strong emissions of He II, N III], N IV], N V, Si III], Si IV, Fe III, and of the fluorescence Fe II 1785–88 Å lines. C II 1335 Å is also weakly present, while C III] 1907 Å and C IV 1550 Å are absent. An *interstellar* extinction of $E_{B-V} \simeq 0.4$ is derived from the 2200 Å i.s. band in the nebular spectra.

Accepted by A&A. *For preprints, contact* viotti@alpha1.ias.fra.cnr.it

The manuscript is available on request to the authors at the above addresses, or from anonymous ftp–server alpha1.ias.fra.cnr.it in the directory /pub/uvspace/preprint. The extracted spectrograms of the different nebular regions and of η Car, and the line lists of Papers I and II are available in the directory /pub/uvspace/spectra.

A spectroscopic orbit for the O8 If star 9 Sge

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We performed a period search of the 109 published radial velocities of 9 Sge (HD 188001) obtained since 1921 and found a dominant period of 78.74 day plus its first harmonic. We confirm earlier suggestions that the O8 If star 9 Sge is an SB1 binary of small amplitude ($K \sim 11$ km/s). Our improved set of orbital elements indicate the companion may be a small star whose mass is probably in the range $1.2 - 1.9 M_{\odot}$. This permits a non-degenerate dwarf companion as early as A-type, which would not be detectable in contrast with the bright primary star.

Accepted by PASP *For preprints, contact* matthews@astro.ubc.ca

Triggered Star Formation and the Dynamics of a Superbubble in the LMC: the OB Association LH47/48 in DEM 152

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We examine the stellar population of an OB association, LH47/48, which is associated with a superbubble H II region, DEM 152 in the N44 nebular complex of the Large Magellanic Cloud. With CCD photometry and spectroscopy of the massive stars, we find no evidence that an unusual stellar population gave rise to the shell morphology of the gas. The slope of the initial mass function, $\Gamma = -1.3 \pm 0.2$, is consistent with that of other OB associations in the LMC, and there is no significant difference in the IMF internal or external to the supershell. The inferred stellar ionizing flux is consistent with the observed nebular Hα flux. We do find evidence for triggered star formation: the H-R diagram suggests an age of $\gtrsim 10$ Myr for the population interior to the bubble with more recent, $\lesssim 5$ Myr, star formation on the exterior. Using the detailed data on the stellar population, we compare a numerical form of the Weaver *et al.* (1977) evolutionary model for wind-driven bubbles with the observed shell kinematics, finding a substantial discrepancy: the observed shell radius is too small, and/or expansion velocity too large to be explained with this version of the model. We discuss possible explanations for the inconsistency.

Accepted by ApJ *For preprints, contact* oey@as.arizona.edu

Multicomponent radiatively driven winds from A and B stars I. The metallic wind of a main sequence A star

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The multicomponent nature of the wind is a fundamental aspect of the wind of A and B stars. We first show that a radiatively driven wind can exist on main sequence A stars *only if* the wind is inhomogeneous. Using a multifluid approach, we present a model for radiatively driven winds on these objects. A detailed numerical simulation is performed for an A star, with $T_{\rm eff} = 10000$ K, on the ZAMS. We solve in a self-consistent way for the mass loss rate, for the energy balance in the wind and for the photospheric abundances. We obtain that only minor elements are expelled from the star and that H and He remain bound to the star. The mass loss rates obtained are very small, lower than $\dot{M} = 10^{-16}$ $M_{\odot}yr^{-1}$ but of metals only. These rates are in agreement with the existence of abundance anomalies on chemically peculiar (Cp) stars.

The mass loss rate depends crucially on whether or not chemical separation occurs in the photosphere. This result indicates an interesting possible difference between normal A and Ap stars. Results are also obtained for the abundance of metals in the photosphere and could give a key to abundance anomalies on Cp stars.

Another important point is on the energy balance of the wind. Our computations show that even on A stars, frictional heating is a major effect which could substantially heat the plasma and create UV or EUV excesses from these objects.

Accepted by A & A *For preprints, contact* babel@astrophysik.uni-kiel.de

A sudden Luminous Blue Variable like behavior of the Wolf-Rayet binary system HD 5980 in the Small Magellanic Cloud

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We report a sudden outburst-like behavior of the WR binary system HD 5980 in the SMC, as disclosed by spectroscopic and photometric observations performed in 1994 October and November. Our spectra show that the WR type spectrum of HD 5980 has changed drastically, now exhibiting a luminous blue variable (LBV) type spectrum with strong emissions of HI and HeI with P Cyg profiles and weaker emissions of NII, SiII, SiIII and FeIII. The previously dominant HeII 4686 Å emission has remarkably weakened and other WR type emission lines have disappeared. Our photometry of HD 5980 reveals a visual brightening of 2.3 mag. The behavior shown by HD 5980, i.e., the transformation of a WNE star in a sort of LBV star, is unprecedented.

To appear in Ap J Letters, 446, June 10
For preprints, contact rbarba@fcaglp.edu.ar
The manuscript is available by anonymous ftp: 163.10.4.1, /pub/rbarba/hd5980lbv.ps.Z

Spectroscopic Binary Orbits from Ultraviolet Radial Velocities. Paper 17: HD 206267

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High-resolution IUE spectra have been used to re-examine the orbit of the massive O-type star HD 206267. The spectrum is found to be triple, with one component, probably of type O7/O8, showing little or no velocity variation. The stronger component of the 3.7-day binary is probably of type O5 and its velocity amplitude has been greatly revised to 161 km s^{-1}. The secondary of the spectroscopic binary is very weak but proabably has an amplitude of about 289 km s^{-1}, similar to the value found in the optical. These results explain, qualitatively, the variety of amplitudes found for different ionic species by the optical observers.

Accepted by The Observatory *For preprints, contact* ds@ast.star.rl.ac.uk

Submitted

Two New Wolf-Rayet Stars and an LBV Star in the Quintuplet (AFGL2004) Near The Galactic Center

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As part of a 1800 pc^2 survey of the Galactic Center region in the lines of HeI (2.058 μm), Brγ (2.166 μm), and the HeII/CIV complex (3.09 μm), we have found two new Wolf-Rayet stars, a WN9 and a WC9, near the Galactic Center. K-band spectra of both stars show broad helium emission lines, and the WC9 shows broad carbon emission lines. A third emission-line star in the region has a spectrum and luminosity similar to an LBV. The stars are within 2 pc, in projection, of the Quintuplet cluster (AFGL2004) and are probably members of this cluster on the basis of their proximity and expected ages.

All three stars are evolved descendants of massive main sequence stars having $M_{initial} \gtrsim 50\,M_\odot$ (WC9), $\gtrsim 20\,M_\odot$ (WN9), and $\gtrsim 40\,M_\odot$ (LBV candidate). The LBV candidate has a luminosity of $L \approx 10^{6.3}\,L_\odot$, comparable to that of η Carinae ($L = 10^{6.5}\,L_\odot$), one of the most luminous stars in the local group of galaxies.

A total of 5 emission-line stars are now known to reside in the "Quintuplet", and they collectively produce $N_{Lyc} \approx 10^{49}$ photons/s. The new LBV candidate generates enough ionizing photons to account for the "Pistol" HII region (G0.15-0.05), while the nearby "Sickle" (G0.18-0.04) may be ionized by a population of O–stars accompanying the 5 emission-line stars.

Submitted to Ap J Letters *For preprints, contact* figer@eggneb.astro.ucla.edu

Reviews

At the time, I failed to announce the following review, that most of you will have read by now. Its summary is included here for bibliographical completeness.

Massive Star Populations in Nearby galaxies

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In Section 2 we present some of the statistical properties of massive stars that can be studied individually, and consider what differences have been found between those in three relatively well–known galaxies (the Milky Way and the Magellanic Clouds). We examine the evolution models of OB stars and supergiants in Section 3, and compare them with the observations. We consider the properties of W-R stars, those highly evolved descendents of the most massive stars, in confrontation with the predicitons of stellar evolution models in Section 4. Observations and models of even more distant galaxies containing starburst phenomena are considered in Section 5. In these cases, we are usually dealing only with integrated properties of stars in galaxies. We intimate some directions for the future in Section 6.

Annual Review of A & A 1994, 32, 227–275

Observations and interpretation of Luminous Blue Variables

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The different types of variations of LBVs are discussed. The "typical LBV variations" have amplitudes of $\Delta V \simeq 0.5$ to 2.0 magnitudes and irregular time-scales of months to years. This is due to changes in the stellar radius and the effective temperature. Modelling of this variability for one star, S Dor, shows that the radius of the star varies between 100 and 380 $R_\odot$, the effective temperature between 20,000 and 9,000 K, and the luminosity between log $L_\star$ =6.10 to 5.9. The variation of the radius is not an apparent variation of the effective radius of the wind due to a variable mass loss rate (which has often been assumed) but it is a true variation of the radius of the star itself. The changes in $L_\star$ suggest that about 10^{-3} to 10^{-2} $M_\star$ takes part in the expansion of the star. The irregular microvariations with amplitudes of about $\Delta V \simeq 0.2^m$ on time-scales of weeks are probably due to non-adiabatic pulsations with mode-interaction. We argue that LBVs are close to *their* effective Eddington Limit and discuss a qualitative scenario to explain their location in the HR-diagram.

Review paper to appear in *Astrophysical Applications of Stellar Pulsation*, IAU Colloquium 155, ASP Conf Series.

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Dissertation abstracts

Hydrodynamic interactions between massive isolated stars and the interstellar medium

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Within this thesis we study the dynamics of circumstellar nebulae around massive stars which are formed by the interacting stellar winds. The thesis is conceptually divided into two main parts.

The first part explores the dynamics of ring nebula phenomena as a result of stellar ejecta. New hydrodynamic models are discussed which are able to explain most of the observed features in ring nebulae unexplained by previous models in the literature. Simple analytic and semi-analytic solutions are given as an approach to the basic dynamics. Hydrodynamic simulations are performed to take into account the non-linear behavior of the unstable swept-up shell. These simulations assume steady winds as a first approach.

In the second part we establish new steps on how to get valuable information from ring nebulae which will be useful for calculating massive stellar evolutionary models. In order to get those steps we have modeled ring nebulae by taking into account their formation and dynamic behaviors inside of the stellar evolution scenario. Hydrodynamic simulations are also performed which use more realistic mass-loss values from stellar evolution calculations as direct inputs. Two specific stellar models with 60 and 35 $M_\odot$ have been fully computed.

PhD Thesis defended on November 18th 1994, at IAC (Canary Islands)
Advisor: Mordecai-Mark Mac Low
For copies, contact ggs@astroscu.unam.mx
Available by anonymous ftp at iac.es *cd* pub/ggarcia

Meetings

The Argentine Astronomical Association, celebrating the 80th birthday of Professor Dr. Jorge Sahade, announces the workshop:

COLLIDING WINDS IN BINARY STARS

to be held at La Plata, Argentina, 21–24 November, 1995.

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