THE HOT STAR NEWSLETTER

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

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From the editor

Continuing the series of *commentaries*, and following the well-rated commentary on the photospheric connection (previous issue), we present here an excellent commentary on *massive binaries* by Tony Moffat. Who volunteers for the next one?

We have plenty of news: on the **discovery** of OB/x-ray binaries in the Galaxy (IAUC 6285), of a possible LBV star in NGC 2363 (IAUC 6294) and of OB supergiants, LBV candidates and WR stars in M33 (see page 12, Phil Massey et al.). Also, a call for an observing **campaign** of η Carinae in coordination with XTE scheduled observations, an update on the proposed ROSAT/ASCA campaign and a note on the **coordinates** of WR 130 and WR 132. A **special topic session** at the next AAS meeting (Madison, June 12) is scheduled on: disks and bipolar outflows from *hot* stars.

Contents of this newsletter

Commentary

Massive Binaries

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Binaries have always served as the main source for deriving the least model-dependent estimates of basic stellar parameters, such as the mass and radius. This is no less the case for massive stars, where even good old classical Keplerian orbits are still desperately needed. Nevertheless, a lot is happening in this area, as well as in the study of wind collisions between stars in massive binaries. Let's have a closer look at what's up currently in these areas.

Until recently, the most massive known star based on a Keplerian binary orbit remained at around 60 $M_\odot$. Thus, it was a (pleasant!) surprise when Rauw et al. (1996) announced the most massive star so far "weighed" to be the WR component in HD 92740 = WR22, at 72 $M_\odot$. This is an 80.35-day system originally studied with photographic spectra by Moffat & Seggewiss (1978) and Conti et al. (1979). Located in the greater Carina Nebula, WR22 is a single-eclipsing (because of its elliptical orbit!) system with an H-rich WN7 spectrum, suggesting that it is in the early WNL stage, and hence more likely than its H-poor WNL cousins to be very massive (Langer et al. 1994). But no-one thought that a WR star could be **this** massive!

The most massive known Main Sequence star may still well be in HD 93205, which Conti and Walborn (1976) originally found, based again on photographic plates, to consist of an O3V and an O8V star in a 6-day elliptical orbit. Like HD 92740, this system is also located in the Carina Nebula – a known hotbed of luminous, potentially massive stars. Although not eclipsing, HD 93205 does show phase-dependent light variations of amplitude 0.02 mag, which are due mainly to tidal distortion (Antokhina et al. 1996). Despite the large quantity of good photoelectric data, the precision of the light curve is **still** not good enough (0.003 mag per data point, with 186 independent points) to yield a useful estimate of the orbital inclination. At the same time, others are working on improving the RV orbit (Bertrand et al. 1996a; Morrell et al. 1996), which shows apsidal motion. Equally interesting is that HD 93205 is one of only four O + O systems known so far that shows clear phase-dependent X-ray variability (Corcoran 1996).

In a more systematic approach, Bertrand et al. (1996b) are using multi-object spectroscopy to search for binaries among the ~ 120 potentially most massive (early O, WNL) stars in 30 Dor. Once found, they will attempt to obtain radial velocity orbits, constrain the inclinations using light variations, and estimate the masses.

Beyond Keplerian orbits, other methods of mass determination are model dependent. For example, spectral line analyses of O-star spectra have led to masses that are significantly less than those obtained from stellar evolution (the so-called mass discrepancy problem). It is possible now that new, more accurate metallic line blanketting corrections may increase the spectroscopic masses into the range of those from evolution (Lanz et al. 1996). However, ultimately it seems that the only sure way of getting truly reliable masses will be via Keplerian orbits of massive stars in binaries. Stay tuned to the Hot-Star Newsletter for rapid (!?) developments.

As far as stellar radii are concerned, the WR stars are the biggest challenge, since we cannot even see their hydrostatic core surfaces (i.e. $\tau = 1$ even in continuum emission occurs in the wind). Nevertheless, one can approach this problem best using WR + O binaries, especially if they exhibit eclipses. Marchenko, Moffat, and collaborators have been using large numbers of high S/N, medium dispersion CCD spectra to study a few key cases (Marchenko et al. 1994, 1995, 1996; Moffat & Marchenko 1996). Most importantly, they are finding that WR hydrostatic core radii may be systematically smaller than predicted by the "standard model" for WR stars. Smaller radii are more compatible with the notion that most WR stars are approaching (or have reached) the He Main Sequence. They also alleviate problems with finding a suitable radiative acceleration mechanism (Pistinner & Eichler 1995).

The more massive a hot star, the higher its luminosity and thus also its mass-loss rate, given that the winds are radiatively driven for the most part. Thus, colliding winds can become quite important in massive binaries, especially in the case of WR + O (or even WR + WR, if such should exist) systems. The recent workshop at La Plata (Argentina; 21-24 November 1995) dealt uniquely with this subject ("Colliding Winds in Binary Stars") in honour of Jorge Sahade at his 80th birthday. This followed quite closely on the heels of IAU Symposium 163 in Elba (May 1994) on "Wolf-Rayet Stars: Binaries, Colliding Winds, Evolution".

Colliding hot winds provide a means to explain why binary systems emit slightly higher X-ray fluxes than the sum of their individual components. But the enhancement is often not as much as thought originally, since no allowance was made for radiative wind "inhibition" (Stevens & Pollock 1994) or, more likely, radiative wind braking, before the collision (Owocki & Gayley 1995; Gayley & Owocki 1996). In certain WC + O systems, wind collisions also can lead to excess (episodic) dust and non-thermal radio emission (Williams 1996). Wind collisions also furnish a strong source of instability and hence turbulence, that can be seen as extra small-scale bumps on certain emission lines in WR stars. When X-ray satellites become sensitive enough (and X-ray TACs allow us literally to sit on some sources for a *decent* interval of time!), we may even be able to carry out reliable abundance analyses (simpler in the X-ray domain!) of the excess emission and perhaps settle the WR abundance problem definitively.

Once thought to be due to some kind of Roche-lobe overflow in massive hot stars, the phase-dependent spectral variations seen in some binary systems can now in most cases be nicely explained by excess emission arising in the shock zone between the colliding winds. Details on how this excess emission varies have now been analysed by Luehrs (1996) in the case of WR + O winds. From this analysis, one can extract information on the orbital inclination, the shock-cone opening angle and the mean flow speed along the shock surface. Such inclinations are sorely needed to obtain definitive masses of the stars. Those spectral lines which do not vary (normally those of the highest ionization level, which are formed closest to the star), on the other hand, can be used with greater confidence to determine the radial velocity orbits.

Detailed analyses are just starting to be done for WR + O (and some O + O) wind interactions. Perhaps the most spectacular case is the WR + WR (Niemela 1988; or possibly more like Of + Of: Moffat 1996) SMC system HD 5980. One of its components has undergone an LBV-like erruption recently and may only now be returning to its original state. Before the eruption, a large fraction of most emission lines in the spectrum probably arose in the wind collision zone, which is almost like a flat, rotating sheet for these two nearly equal-wind stars. Even if the orbit in this case is elliptical (e = 0.3), the circular-orbit model of Luehrs can be modified and fitted to the line variations. The results appear to be quite convincing (e.g. the same inclination as obtained from polarization and light curve studies of this eclipsing system).

In short, massive binaries appear to be returning to the forefront. No wonder: short of obtaining interferometrically resolved images (in the next decade or so?), they offer the only true way to get a viable, nearly model-independent handle on the basic properties of massive stars. It's a tricky business, though, because you have to first deal with the interaction effects, which anyway are interesting in their own right!

I thank Nicole St-Louis for a critical reading of this text.

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News

OB and X-Ray Binary Candidates

C. Motch and M. Pakull, CNRS, Observatoire Astronomique de Strasbourg; F. Haberl and K. Dennerl, Max-Planck-Institut fur Extraterrestrische Physik, report the discovery of several new galactic OB/x-ray binary candidates: "These massive systems were selected from a cross-correlation of the ROSAT all-sky survey ($| b |< 20°$) with OB star catalogues, and display significant excess x-ray emission (range 0.1–2.4 keV) over the expected stellar level. Follow-up optical and ROSAT observations yield four very likely new massive x-ray binaries: the O star LS 5039 (RX J1826.2-1450) and the Be stars BSD 24-491 (RX J0440.9+4431), LS 992 (RX J0812.4-3114) and LS 1698 (RX J1037.5-5647). LS 992 exhibited an x-ray outburst during survey observations (1990 Oct. 28.5-31.1 UT; x-ray luminosity 1.3 $\times 10^{35}$ erg/s, assuming d = 9.2 kpc), and LS 1698 is probably identical to the hard x-ray transient 4U 1036-56. The new candidates have x-ray luminosity $> 6 \times 10^{33}$ erg/s, indicating the presence of an accreting neutron star or black hole. Two further Be/x-ray binary candidates, HD 161103 and SAO 49725 require confirmation of their x-ray excess (x-ray luminosity 1-5 $\times 10^{32}$ erg/s) and could be Be + accreting white dwarf systems."

(IAU Circular No. 6285)

The brightest star in NGC 2363

L. Drissen, J.-R. Roy and C. Robert, Departement de Physique, Universite Laval, Quebec, communicate: "We report the discovery of an unusually bright new object in the middle of the giant H II region NGC 2363, based on Hubble Space Telescope WFPC2 images obtained on Jan. 8. Preliminary reductions indicate V = 17.95, B-V roughly 0 for the new object. This point source, which was then the brightest star in NGC 2363 (absolute V about -10.0), was not visible on groundbased CCD images obtained in Jan. 1991 and Oct. 1992 at the Canada-France-Hawaii telescope; although crowding is severe in groundbased images, no point source brighter than V about 22 was visible at that location. WFPC2 images indicate that this object is a strong H alpha point source, surrounded by a small (radius 0".09, or 1.5 pc at a distance of 3.5 Mpc) H alpha shell. We suspect that this object is a Luminous Blue Variable star in eruption (a la η Car). The coordinates of this star, from our WFPC2 images, are R.A. = 7h28m43s.4, Decl. = +69d11'24" (equinox 2000.0). This is 0".5 west and 1".3 north of the 'eastern knot' of NGC 2363 (Fig. 2 in Drissen et al. 1993, A.J. 106, 1460). NGC 2363 is the brightest star-forming region in the Magellanic irregular NGC 2366, a member of the M81 group."

(IAU Circular No. 6294)

A Comment on the Coordinates of WR130 and WR 132

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More than a year ago, I was told by L.J. Smith and P. Crowther that the coordinates for WR130 (=AS 374) given in the 6$^{\text{th}}$ WR catalogue (van der Hucht *et al.*, 1981) were incorrect. As pointed out by K. van der Hucht, the coordinates given in the SIMBAD database are not the same as in the WR catalogue. However, the SIMBAD coordinates are obviously also incorrect. Since I was partly responsible for supplying the finding charts and coordinates in the WR catalogue, I have tried to resolve this matter.

In a preliminary version of our finding charts we had marked a star $\approx 1'$ east and slightly north of the star finally indicated in the catalogue. This was our best guess from the quite unclear chart given by Iriarte and Chavira (1956). Since the identification for this (and some of the other WR stars) was uncertain, we asked Peter Conti to check our markings. He then made corrections to our finding charts for WR130 and WR132, based on his (and Phil Massey's) observations. Those corrections were then introduced in the final finding charts.

In September 1995 I made spectroscopic observations of WR130, using the Nordic Optical Telescope at La Palma. I could then confirm that the finding chart in the WR catalogue is correct. Regarding the coordinates, the most reasonable explanation is, that we first measured the position of the wrongly identified star, and forgot to remeasure them once the finding chart had been corrected.

Fortunately, it turns out that this star has been included in the Guide Star Catalogue (=GSC 2670 1448), which gives the coordinates (2000.0):

α: $19°59^{m}12.70^{s}$ δ: $+31°27'09.7''$

The corresponding 1950.0 coordinates are then:

α: $19°57^{m}14.5^{s}$ δ: $+31°18'05''$

There are then still some uncertainties regarding the coordinates for WR 132. Note the remark on the misidentification of this star given by Massey (1984). Assuming that the finding chart is correct, a comparison with GSC shows that the WR catalogue coordinates corresponds to the star indicated on the finding chart (=GSC 2674 1901). However, the declination given in GSC deviates by $8''$ from the declination given in the WR catalogue. Thus the best coordinates for WR132 are:

α: $20°01^{m}39.76^{s}$ δ: $+32°34'18.4''$ (2000.0)
α: $19°59^{m}42.9^{s}$ δ: $+32°25'54''$ (1950.0)

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Editor's note: Similarly, for correct coordinates of WR 146, see MNRAS 252, 300 (1991).

XTE Observations of η Carinae - Request for Coordinated Observations

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η Carinae has recently been seen to undergo strong variability in its radio (White et al., 1995, ApJ 450, 435) and X-ray (Corcoran et al. 1995, ApJ 445, L121) emission, probably correlated with the 5.52-year cycle of "shell events" reported recently (Damineli, 1995, ApJ & Hot Star News 15). The X-ray Timing Explorer (XTE) will be monitoring the hard X-ray emission from η Car throughout 1996. Ground-based coordinated observations would be extremely useful. In the NIR and optical spectral ranges, the largest variations are expected to be found in the H-band and in the higher excitation lines. The best lines to survey are: [NeIII] 3869, HeI 10830, 6678, 7065, 20580, [ArIII]7135, [NII]5754, [FeIII]4658 and 4701.

The times of the XTE observations (as they currently appear in the XTE long-term timeline) are given in the table on the *last* page of this newsletter. Note that these times are subject to change. Updates will be posted in following editions of the Hot Star Newsletter. WWW users can check
http://lheawww.gsfc.nasa.gov/users/corcoran/bio.html
for updates as well.

For more information, contact Michael F. Corcoran, `corcoran@barnegat.gsfc.nasa.gov`

The massive star X-ray observing campaign

29 people have expressed interest in participating in the massive star X-ray observing campaign currently being organized. If you missed the original announcement (Hot Star Newsletter 15) and would like to participate, please contact Mike Corcoran (corcoran@barnegat.gsfc.nasa.gov) to get your name on the distribution list and to receive future updates.

Accepted Papers

Multi-colour photometric and spectroscopic monitoring of the WN5 star EZ Canis Majoris

M.F.J. Duijsens[1], K.A. van der Hucht[2], A.M. van Genderen[1], H.E. Schwarz[3], H.P.J. Linders[1] and O.M. Kolkman[4]

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We present and analyse photometric and spectroscopic observations of the WN5 star EZ Canis Majoris obtained over a period of 7 years. We discuss the changing light curve, the shift in phase of the maxima and point to flare type variability seen in one night. Small amplitude variations are reported in another night. We have investigated the change of the average visual magnitude over a total period of 18 years and found a possible cyclic variation with a timescale of 2425^d (6.6 y) and a range of $\sim 0.^m07$. A precession phenomenon may offer an explanation. The trend of the maximum light amplitude of the $3.^d766$ cycle is also investigated and it shows a saw-tooth character with a timescale of $\sim 400^d$.

A possible relation with the magnetic activity of the star is discussed. We conclude that the line emission variability can be caused by both a single star model with an everchanging wind and a binary (WN+NS) model.

Accepted for publication in A & A S *For preprints, contact* genderen@strw.LeidenUniv.nl
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Elemental abundances in normal late-B and HgMn stars from co-added IUE spectra. IV. Gallium

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An analysis is presented of the ultraviolet gallium resonance lines in *International Ultraviolet Explorer* (*IUE*) spectra of 40 normal, superficially normal, and HgMn-type late-B stars. Gallium abundances are derived by fitting the Ga II λ1414, and Ga III $\lambda\lambda$1495, 1534 lines with synthetic spectra computed under the conventional assumptions of local thermodynamic equilibrium (LTE) and atmospheric chemical homogeneity. We find that the derived upper limits on the gallium abundances of the normal and superficially normal stars are consistent with the solar value. However, gallium is overabundant in essentially *all* HgMn stars, including the cooler examples such as HR 4072, χ Lup, and ι CrB, where the enhancements are relatively moderate and unambiguous identification of the resonance lines depends critically on newly available laboratory wavelengths. Furthermore, the gallium overabundances in the HgMn stars exhibit a loose correlation with effective temperature, similar in most respects to those identified for manganese and copper in the same stars except for the presence of the anomalously Ga-rich, cool HgMn star HR 7775.

We show that a systematic discrepancy between the abundances derived from the Ga^+ and Ga^{2+} ions in the hotter HgMn stars ($T_{\rm eff} \geq 12\,000\,$K) can be explained by radiative transfer effects in the presence of a stratification of gallium at optical depths above $\log \tau_0 \approx 0$. This 'stratification model' can also account for the anomalously shaped Ga III λ1495 profiles observed in the extreme cases of μ Lep, HR 2844, and HR 7143 (as demonstrated in a previous paper), and is consistent with published predictions of radiative diffusion theory for non-magnetic stars.

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Exact Analytic Solutions for Stellar Wind Bow Shocks

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Stellar wind bow shocks have been seen in association with a wide variety of stellar objects from pulsars to young stars. A new solution method is presented for bow shocks in the thin-shell limit, stressing the importance of the conserved momentum within the shell. This method leads to exact analytic solutions to the classical problem of Baranov, Krasnobaev & Kulikovskii (1971). Simple formulae are given for the shell shape, mass column density and velocity of shocked gas at all points in the shell. These solutions will facilitate detailed comparison between observed sources and bow shock models.

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Non-LTE line formation for S II and S III. I. Model atoms and first results

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Detailed model atoms for S II and S III are presented. As a test and first application of these models, the sulphur abundance of the B type stars HR 1923, HR 2928 and HR 5285 is derived. Results based on LTE computations are compared with those from a non-LTE analysis. For the three stars in the test sample, new values of effective temperature $T_{\rm eff}$, gravities log$g$ and microturbulent velocities $v_{\rm turb}$, based on the latest Kurucz model atmospheres are also given. A new grid of H profiles and Si equivalent widths for these models is presented.

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Diffusive mixing by shears in rotating stars

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We show that the Richardson criterion, even in its improved form found recently, is insufficient by itself to describe the occurrence of shear instabilities in rotating stars. The coupling between the shears and their effects on the T–gradient must be accounted for. When this is done, we obtain a new more complete criterion, in which the shear properties essentially depend on one critical dimensionless number θ.

We must distinguish the cases of radiative and semiconvective zones. For a radiative zone, the stability criterion becomes

$$\frac{1}{4}\left(\frac{dU}{dz}\right)^2 < \frac{g\varphi\nabla_\mu}{H_p}.$$

If this condition is not realized, we show that there is always a range of scales in the turbulent spectrum where shear instabilities occur. The corresponding diffusion coefficient, depending only on θ, is given.

In a semiconvective zone, the stability criterion, with respect to shears, is

$$\frac{1}{4}\left(\frac{dU}{dz}\right)^2 < \frac{g\varphi\nabla_\mu}{H_p} - \frac{1}{1+2\sqrt{6}}\ \frac{g\delta}{H_p}\ (\nabla_{\rm rad}-\nabla_{\rm ad})\,.$$

We also derive the appropriate diffusion coefficient when the above criterion is not satisfied. Different ranges of turbulent scales may also exist, depending on θ. Interestingly enough, we may notice that the above criterion is also that expressing the transition from shear to semiconvective instabilities.

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The hydrodynamic evolution of circumstellar gas around massive stars II. The impact of the time sequence O star → RSG → WR star

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We investigate the interaction of a 35 $M_{\odot}$ star with its circumstellar medium over the entire stellar life time, combining an implicit hydrodynamic code for the calculation of the massive stellar evolution, and an explicit hydrodynamic code for the treatment of the circumstellar gas. The final supernova phase is not included.

The 35 $M_{\odot}$ stellar model has three well defined evolutionary phases: main sequence, red supergiant and Wolf-Rayet stage. It provides a realistic test for the three-wind model of Wolf-Rayet bubbles. We find the velocity of the red supergiant wind to be a key parameter affecting the formation and detectability of a ring nebula in the Wolf-Rayet stage. We investigate systematic differences of wind shells and nebulae around post-RSG WR stars compared to those of post-LBV WR stars.

The Wolf-Rayet star WR 136 is located on our evolutionary track in the HR diagram, and the computed circumstellar gas distribution at the time our stellar model hits the position of WR 136 is in good agreement with its observed nebula NGC 6888. The ring nebula Sh 308 around WR 6 can be explained when the RSG wind has higher velocity than in the case of NGC 6888. Our results support the interpretation of the H II regions Sh 303 and Sh 304 as parts of the fossil swept-up main sequence shell surrounding Sh 308, in accord with the three-wind model.

Finally, we obtain constraints on the initial mass of the progenitor of the supernova remnant Cassiopeia A. We find that in order to explain the existence of quasi-stationary flocculi, the stellar progenitor should have an initial mass of ~ 30 $M_{\odot}$, just above the lower initial-mass limit for WR star formation.

Accepted by A & A *For preprints, contact* `ggs@astroscu.unam.mx, ntl@ipp-garching.mpg.de` (manuscript is available by anonymous ftp machine 130.183.83.33 pub/ntl)

The Discovery of Hot Stars near the Galactic Center Thermal Radio Filaments

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We report the discovery of a highly unusual cluster of stars at G0.121+0.017 near the Arched (thermal) Filaments, $\sim 10'$ northeast of the Galactic Center. H (1.65 μm) and K$'$(2.1 μm) images are used to estimate a distance to the cluster consistent with a Galactic Center location. K$'$ band spectroscopy reveals that the cluster contains 13 stars with Brγ (2.166 μm) emission, 12 of these stars also have He I (2.112/3 μm) emission, and 2 show fainter He II (2.189 μm) emission. Based on a spectral comparison with optically classified stars, we suggest the new emission stars are late WN stars. If the classification is correct, the cluster contains $\sim$14% of all known galactic WN stars.

Observations of emission line stars near G0.15–0.05, the 'Pistol', are also presented. There are four stars near the Pistol which contain emission lines. Three of these stars differ spectroscopically from the stars in the new cluster; one has a spectrum similar to the new cluster stars. Together with the cluster stars, these newly discovered hot young stars provide evidence for recent star formation and the stellar ionization of the thermal radio emission regions in the vicinity of the Galactic Center.

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The calculation of line polarization due to scattering by electrons in multi-scattering axisymmetric envelopes

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Previously we developed a numerical method to solve the continuum polarized radiative transfer equation for the case of scattering by particles with a Rayleigh phase matrix in axisymmetric geometries. Here we extend the method to compute polarized line profiles in stars with extended and expanding envelopes, but with the restriction that the polarization in the line and continuum arises entirely from electron scattering. The method, extensively tested using Monte-Carlo calculations, treats optically thick lines, allows for extension of the line formation area relative to that of the continuum, and incorporates the frequency redistribution of photons caused by the thermal and bulk motions of the electrons. Test calculations are used to illustrate the effect that thermal broadening, line absorption, stratification, and inclination have on the emergent polarized line profile.

Accepted by A & A *For preprints, contact* `jdh@magpie.phyast.pitt.edu`

Wind Inhomogeneities in Wolf-Rayet Stars. I. Search for Scaling Laws Using Wavelet Transforms.

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We describe a new technique involving wavelet transforms for analyzing discrete stochastic components like those found on the tops of emission lines in Wolf-Rayet stars. A *wavelet power spectrum* is used to characterize the variable component of the emission line we believe to arise from the superposition of many individual gaussian-like subpeaks. This was applied to emission line spectra of eight Wolf-Rayet stars obtained at CFHT and ESO. Where the data show the most power, we identify a *dominant scale*, which is found to be very similar in all but one of the stars in our sample.

We present a phenomenological model where the variable structure on top of the emission line is represented by a sum of individual subpeaks of the same simple shape (gaussian or triangular) and various scales. This model is used to introduce the idea of *scaling laws*. The amplitude A and number density N of subpeaks on a given scale are related to their characteristic width σ (i.e. velocity dispersion) by scaling relations, of which the simplest form is a power law: $A \sim \sigma^{\alpha}$ and $N \sim \sigma^{\beta}$. The wavelet power spectrum is used to verify the consistency of this model with the data. Synthetic signals are generated, and their wavelet spectra are compared to those of the data. This provides a constraint on the value of $2\alpha+\beta$, which is found to be $\sim 2.7 \pm 0.5(\sigma)$ for the model involving gaussians, or $\sim 3.4 \pm 0.6(\sigma)$ for the model involving triangles. The implications provided by this new constraint are discussed.

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Submitted Papers

The UV-Brightest Stars of M 33 and its Nucleus: Discovery, Photometry, and Optical Spectroscopy

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We investigate the UV-brightest sources in the nearby galaxy M 33. Our catalog of 356 sources is constructed from FUV (1500Å) and NUV (2400Å) images obtained with the Ultraviolet Imaging Telescope (UIT) matched with ground-based UBV data. We find that our survey is limited by the FUV flux and is complete to $F_{\lambda 1500} = 2.5 \times 10^{-15}$ ergs cm^{-2} s^{-1} Å^{-1}, other than in the most crowded regions; this corresponds roughly to $M_{bol} = -9.2$ to -10.0 (or masses of 40-60 $\mathcal{M}_{\odot}$), for T_{eff} =50,000° to 10,000°. We use *HST* WFPC2 images of several M 33 fields to conclude that at least half of our sample is uncontaminated by unresolved neighbors, at least at the $0.1''$ (0.4 pc) level, a resolution similar to that achieved in the LMC from the ground. Spectral types have been obtained for 131 of our objects. We discuss the spatial distribution of the UIT sources, finding that they provide an excellent tracer of the spiral arm pattern and confirm that star formation continues in the nuclear region to the the present day. Our survey has found a large number of O and early B-type supergiants, including stars as early as O6, but the optical spectroscopic sample is dominated by later-type B supergiants, as these are the visually brighter. Among the brightest stars (both at 1500Å and at V) are the "superluminous" Wolf-Rayet stars first discovered by Conti & Massey in M 33's largest HII regions; these objects are now known to be small groups of stars in modest analog to R 136 in 30 Dor. In general, our survey has failed to detect the known WR stars as they are too faint, but we did find several new late-type WN stars and composite systems, which are brighter. Two stars of high absolute visual magnitude ($M_V \approx -9.0$) are found to be B I+WN binaries, similar to HDE 269546 in the LMC;

one of these is multiple at *HST* resolution. Most interesting, perhaps, is our finding six Ofpe/WN9 "slash" stars, five of them newly discovered. These stars show properties intermediate between those of Of and WN stars, and are believed to be a quiescent form of Luminous Blue Variables (LBVs). Our spectroscopy found five additional stars which are spectroscopically similar to the known LBVs of M 33. One of these stars has recently been shown to be spectroscopically variable, and we suggest that all of these stars deserve continued scrutiny. The nucleus of M 33 is the visually brightest object in our survey, and its UV colors are indicative of a hotter component than its optical photometry or spectral type would suggest. We discuss the possibility that the point-like nucleus may contain a few interesting hot stars that dominate the light in the UV, and make the comparison to the cluster of He I emission-line stars found near the Milky Way's center. We comment on which color-magnitude and color-color plots make the best diagnostic tools for studying the hot, massive star population of a galaxy like M 33.

Submitted to the ApJ *For preprints, contact* `massey@noao.edu`

The effect of binary evolution on the theoretically predicted distribution of WR and O-type stars in starburst regions and in star birth stop regions

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The present paper critically investigates the influence of massive close binary evolution on the variation of the massive star content in starburst regions. We also introduce the concept of regions where star formation suddenly ceases (a star birth stop region) and we show that as far as the WR/O number ratio is concerned very similar results are obtained as with a starburst. The most important conclusion of the study is that within our present knowledge of observations of massive stars, massive close binary evolution plays an ESSENTIAL role in the evolution of starbursts and star birth stop regions.

Submitted to A & A *For preprints, contact* `wvanrens@vnet3.vub.ac.be`

The number of OB and WR type runaways with and without a compact companion, predicted by close binary evolution.

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Using a detailed model of massive close binary evolution, accounting properly for the effects of assymmetric supernova explosions (SN) and using recent observations of pulsar runaway velocities, we determine the theoretically expected number of OB-type runaways. Comparison with the observed frequency forces us to conclude that at least 50% of the OB-type runaways must have been formed by a mechanism different from the SN mechanism in close binaries, cluster ejection being a plausible alternative. The evolution of the set of OB runaways formed through the binary scenario is followed further up to a possible WR runaway phase, i.e. single OB runaways follow a single star evolutionary scenario, OB + compact companion binaries evolve through a common envelope phase for which we

use the spiral-in description. We conclude that the theoretically expected number of WR+compact companion systems is very low, i.e. if Cyg X-3 is a WR+CC, it may be the only one. However our results reveal a significant fraction of single WR runaways but with a binary history. We also predict the existence of 'weird' WR stars with a compact star in the centre of the WR (descendants of Thorne-Zytkow objects).

Submitted to A & A *For preprints, contact* `wvanrens@vnet3.vub.ac.be`

In Proceedings

Analyses of Wolf-Rayet Ultraviolet Spectra

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The ultraviolet spectra of population I WR stars obtained from IUE archive are used to determine fundamental stellar parameters. Terminal velocities for 85 galactic and LMC Wolf-Rayet stars were obtained by means of the empirical relation between easily measured in low resolution spectra quantities and high-resolution terminal velocity measurements. Temperatures and so-called transformed radii were derived based on available contour plots of spectral characteristics for a grid of NLTE models. The effect of the reddening law on stellar far UV continua is emphasized and the revised extinction curve towards WR stars is used for dereddening. For the sample of stars attributed to open clusters or associations we construct the stellar distance scale and adopt it for the other WR stars. The remaining fundamental parameters are derived and HR diagram for population I WR stars is presented.

To appear in the proceedings of the Ven workshop on "Planetary Nebulas with WR Type Nuclei". *For preprints, contact* `kroch@astri.uni.torun.pl`

Quantitative spectroscopy of Wolf-Rayet stars and related objects

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We discuss recent analyses of luminous, post-main sequence, emission line stars based on stratified, extended non-LTE atmospheric models. We will address our knowledge of such objects, focusing in particular on Wolf-Rayet stars, LBVs, Of/WN stars, Of supergiants, and low mass [WC] central stars of Planetary Nebulae. Derived stellar wind properties and chemistries are discussed, which allow the exact evolutionary sequences followed by the most massive stars to be identified, revealing limitations of the standard evolutionary theory. We also discuss future requirements of the Standard Model, including line blanketing and clumping.

Invited paper from JENAM-95 'Progress in European Astrophysics' to be published in Mem. Soc. Astron. Ital.

For preprints, contact `pac@star.ucl.ac.uk` (paper available by anonymous ftp)

The Stellar Content of Giant H II Regions in NGC 2403

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We present some results of a study on the stellar population of two giant H II regions in the nearby galaxy NGC 2403, based on *Hubble Space Telescope* images. The emphasis is put on the distribution of the Wolf-Rayet and red supergiant stars and the information they provide about the star-forming history of these large complexes. We also discuss the presence of a luminous, compact stellar cluster at the core of both regions, and the overall morphology of the star-forming regions.

To appear in "From Stars to Galaxies" (Crete95 Symposium), ASP Conf. Series, ed. C. Leitherer, U. Fritze-von Alvensleben and J. Huchra
For preprints, contact `ldrissen@phy.ulaval.ca`

Wolf-Rayet Stars and Stellar Winds

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Wolf-Rayet (W-R) stars are evolved O stars showing unusual composition, and severe hydrogen depletion. Recent spectroscopic analyses that provide insights into the nature of W-R winds, and their similarity to O star winds are discussed. While it has been convincingly demonstrated that O star stellar winds are driven by radiation pressure, it is unclear whether the same mechanism can explain the much higher mass-loss rates of W-R stars.

Possible explanations for the high efficiency of radiation driven winds in W-R stars are reviewed. These solutions involve ionization effects, missing opacity sources, and the possibility that the required driving efficiencies have been strongly overestimated. Uncertainties in the present theory of radiation driven winds arising from the effects of rotation and inhomogeneities are also discussed.

Many of the uncertainties in our understanding of W-R stars could be clarified if reliable stellar models, which included the effects of non-LTE line blanketing, were available. Progress towards implementing non-LTE line blanketing is discussed. Preliminary model comparisons are made with recent HST observations of LMC WC stars.

For publication in Hydrogen Deficient Stars, 2nd International Colloquium, eds S. Jeffery, U Heber *For preprints, contact* `jdh@magpie.phyast.pitt.edu`

Meetings

Disks and Bipolar Outflows from Hot Stars

Agenda for a special topics session at the American Astronomical Society meeting
June 9-13, 1996 in Madison, Wisconsin

Disks and Bipolar Outflows from **hot stars** is a new research topic in Astronomy. An all day topical session has been organized to introduce the new subject, identify areas that need further study, and provide a sense of direction for the field. The topic is related to the disks and bipolar outflows that occur during the formation of cool stars, but there are some major differences. For hot stars the disks and bipolar outflows may occur during more than one phase of evolution. Also, the environmental conditions during the accretion phases are much different. There are two general classes of disks/bipolar outflows from hot stars: 1) Those that occur around hot stars that are on, or have evolved from, the Main Sequence. 2) Those that occur around massive pre-main-sequence stars.

We can trace some of the major developments that have precipitated the emergence of this new field of study. It has been realized recently that winds from rotating stars can lead directly to the formation of circumstellar disks. The wind compressed disk (WCD) model has recently been developed by J. Bjorkman and others. It may explain many properties of the emission line Be stars. Even mild stellar rotation rates of about 20 percent breakup lead to significant equatorial concentrations of material as a result of orbital focusing of winds from B stars, hypergiant stars and Wolf Rayet stars. Also in the last several years Adam Frank has shown that winds, disks, and bipolar outflows are three coupled components of the planetary nebula shaping process. Similar bipolar structures in evolved hot stars have been revealed by Kris Davidson's HST observations of eta Carinae and other hypergiant stars. We call the above classes of disks and bipolar outflows "star originated."

The subject of star formation is not nearly as well developed for hot, massive stars as it is for cool, low-mass stars. However, several examples of high-velocity molecular outflows associated with high-mass star formation regions have been investigated, and recently Churchwell and his colleagues have demonstrated that their occurrence may be common. There are strong indications that the large-scale molecular flows are generally bipolar and that they are driven by small-scale outflows powered by accretion, as in the low-luminosity objects. Direct observational clues to the properties of the small-scale flows and to the presence of infalling gas and circumstellar disks have been analyzed during the last few years, particularly for the intermediate-mass Herbig Ae/Be stars. Although the existence of accretion disks is still controversial and the effect of the stellar wind and radiation field on these flows has not yet been fully explored, we are motivated by the analogy with the low-mass objects to refer to this class of disks and outflows as "accretion originated."

> Being a young field there are more questions than answers. Each speaker is being asked to formulate 2 or 3 incisive questions that can guide the future development of their subject area.
> We will have a one day meeting on Wednesday, June 12. The morning session will be concerned with the theory and observations of disks and bipolar outflows that are "star originated," and the afternoon will deal with those that are "accretion originated."
> Scientific Organizing Committee: J. Cassinelli (chair of the SOC), Ed Churchwell, Kris Davidson, Adam Frank, Lee Hartmann, Arieh Konigl, Debra Shepherd.

List of Speakers and Topics.

Session I. Star Originated Disks and Bipolar Outflows

Jon Bjorkman (U of Wisconsin) Wind Compressed Disks around Early-Type Rotating Stars.

Adam Frank (U of Minnesota) Models for the Production of Bipolar Outflows around Planetary Nebulae Nuclei.

Rens Waters (U of Amsterdam) Observations of Disks and Wind Compressions around Hot Luminous Stars.

Kris Davidson (U of Minnesota) The Bipolar Outflows from eta Carinae and other Hypergiants.

Session II. Accretion Originated Disks and Bipolar Outflows

Arieh Konigl (U of Chicago) Theory of Massive Bipolar Outflows Formed During Stellar Accretion.

Ed Churchwell (U of Wisconsin) Bipolar Outflows from Pre-MS Massive Stars.

Joe Cassinelli (U of Wisconsin) The Effects of the Winds and Ionizing Radiation Fields on Massive Star Formation

Lee Hartmann (Cntr for Astrophys) Contrasts between the accretion flows of low mass and high mass stars.

For further information please contact Joe Cassinelli (608-255-2073) `cassinelli@astro.wisc.edu`

Table 1: Schedule of XTE observations of η Car (see page 6)

MET	Time	Type	Observation ID	Target
3002745600	02/26/96 00:00:00	GO	10004-01-27-00	η Car
3002832000	02/27/96 00:00:00	GO	10004-01-30-00	η Car
3002832000	02/27/96 00:00:00	GO	10004-01-38-00	η Car
3003091200	03/01/96 00:00:00	GO	10004-01-35-00	η Car
3003091200	03/01/96 00:00:00	GO	10004-01-37-00	η Car
3003091200	03/01/96 00:00:00	GO	10004-01-39-00	η Car
3006979200	04/15/96 00:00:00	GO	10004-01-20-00	η Car
3006979200	04/15/96 00:00:00	GO	10004-01-28-00	η Car
3006979200	04/15/96 00:00:00	GO	10004-01-29-00	η Car
3006979200	04/15/96 00:00:00	GO	10004-01-31-00	η Car
3006979200	04/15/96 00:00:00	GO	10004-01-33-00	η Car
3007584000	04/22/96 00:00:00	GO	10004-01-34-00	η Car
3007584000	04/22/96 00:00:00	GO	10004-01-36-00	η Car
3011472000	06/06/96 00:00:00	GO	10004-01-15-00	η Car
3011472000	06/06/96 00:00:00	GO	10004-01-18-00	η Car
3011472000	06/06/96 00:00:00	GO	10004-01-32-00	η Car
3012076800	06/13/96 00:00:00	GO	10004-01-22-00	η Car
3012076800	06/13/96 00:00:00	GO	10004-01-25-00	η Car
3012076800	06/13/96 00:00:00	GO	10004-01-40-00	η Car
3012422400	06/17/96 00:00:00	GO	10004-01-16-00	η Car
3012422400	06/17/96 00:00:00	GO	10004-01-19-00	η Car
3016051200	07/29/96 00:00:00	GO	10004-01-12-00	η Car
3016051200	07/29/96 00:00:00	GO	10004-01-14-00	η Car
3016051200	07/29/96 00:00:00	GO	10004-01-21-00	η Car
3016051200	07/29/96 00:00:00	GO	10004-01-24-00	η Car
3016051200	07/29/96 00:00:00	GO	10004-01-26-00	η Car
3016656000	08/05/96 00:00:00	GO	10004-01-11-00	η Car
3016656000	08/05/96 00:00:00	GO	10004-01-13-00	η Car
3016656000	08/05/96 00:00:00	GO	10004-01-17-00	η Car
3016656000	08/05/96 00:00:00	GO	10004-01-23-00	η Car
3020889600	09/23/96 00:00:00	GO	10004-01-04-00	η Car
3020889600	09/23/96 00:00:00	GO	10004-01-06-00	η Car
3020889600	09/23/96 00:00:00	GO	10004-01-08-00	η Car
3020889600	09/23/96 00:00:00	GO	10004-01-09-00	η Car
3020889600	09/23/96 00:00:00	GO	10004-01-10-00	η Car
3021753600	10/03/96 00:00:00	GO	10004-01-05-00	η Car
3021840000	10/04/96 00:00:00	GO	10004-01-03-00	η Car
3021840000	10/04/96 00:00:00	GO	10004-01-07-00	η Car
3022185600	10/08/96 00:00:00	GO	10004-01-02-00	η Car
3023395200	10/22/96 00:00:00	GO	10004-01-01-00	η Car