# 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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## From the editor

**The Wolf-Rayet bibliography** is continuously being updated by Karel van der Hucht. In particular, the files for 1995 through 1999 have been updated in August. They can be found on the *Hot Massive Star* Web site in Mexico `http://www.astro.ugto.mx/∼eenens/hot/`
or on its mirror in London `http://www.star.ucl.ac.uk/∼hsn/index.html`
or directly from `ftp://saturn.sron.nl/pub/karelh/UPLOADS/WRBIB/`
Comments and additions emailed to K.A.van.der.Hucht@sron.nl will be appreciated.

This newsletter brings the announcement of three more **meetings for the year 2000** (see last pages). For more information, please refer to our Web site.

| | | |
|---|---|---|
| March 15-18 | Chile | Star, gas and dust in galaxies: exploring the links |
| July 10-14 | Québec | Interacting winds from massive stars |
| August 10 | England | Massive star birth (IAU General Assembly) |
| August 21-23 | Ireland | P Cygni 2000: 400 years of progress |
| August 24-26 | Sweden | eta Car & other mysterious stars: a hidden opportunity for emission spectroscopy |

Accepted Papers

## Spatial wavelet analysis of line-profile variations

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The technique of wavelet analysis is discussed in the context of line-profile variations in rapidly-rotating stars undergoing non-radial pulsation. This technique may be used to determine the harmonic degree $l$ of the pulsation using isolated residual spectra; it is able to handle spectra with relatively low signal-to-noise levels, and is well suited to extracting previously unobtainable information from-low quality, patchy data. A demonstration of the technique is presented using data generated from a spectral synthesis code.

**Accepted by MNRAS**
*Preprints from* `rhdt@star.ucl.ac.uk`
*or by anonymous ftp to* `ftp://star.ucl.ac.uk/pub/rhdt/wavelets.ps.gz`

## A near infrared study of the HII/photodissociation region DR 18 in Cygnus

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Near infrared observations of DR 18, a HII region in the Cygnus X molecular complex, are presented in this paper. These observations reveal DR 18 as an arc-shaped nebula in the 2.2 $\mu$m region, with a central star of $V = 15.6$ obscured by $A_V \simeq 8$ magnitudes. Visible and near-infrared spectroscopy and photometry indicate a spectral type around B0.5V for this star, while a near-infrared color-color diagram of the stars in the area shows that the central star is the most luminous one of a loose aggregate. Analysis of the narrow band imaging in the $K$ band suggests that the arc nebulosity is principally due to emission by small grains, heated by the central star, in a photodissociation region. We interpret the arc nebula as the interface between a molecular cloud that is being eroded by the central star and the resulting HII region. Using published models of photodissociation regions, we estimate the density in the arc nebula to be a few times $10^3$ cm$^{-3}$. We briefly discuss the possible relation of the structures observed in the near infrared with the source IRAS 20333+4102, which has been included in several far infrared and radio studies of the area. We conclude that IRAS 20333+4102 is not directly related to any of the structures that we describe here, and could be an intermediate mass protostar embedded deeper in the molecular cloud.

The emission associated to ionized gas in DR 18 has a morphology fairly different from that of the arc nebula, being brighter near the position of the central star. A crescent-shaped peak is observed beside the central star and facing the arc nebula, suggesting an interaction between a stream of ionized gas from the nebula and the wind from the central star. We present two dimensional gas dynamical simulations which successfully reproduce such gas stream, the bow shock ahead of the central star, and the overall appearance of the nebula. An essential component of our model is the existence of an

outward-decreasing density stratification in the cloud being eroded, as is commonly observed in dense molecular clumps.

The simple geometry of the nebula and the observability of the central star at short wavelengths make the derivation of the physical conditions of the region and the modeling of its dynamical evolution comparatively easier than in other, similar regions. DR 18 thus provides a good case study of several features associated to the interaction of an early B star with a molecular cloud.

**Accepted by Astronomy and Astrophysics**
*Preprints from* fcomeron@eso.org
*or on the web at* http://www.eso.org/∼fcomeron/publicat.html

## An Explanation of Observed Trends in the X-ray Emission from Single Wolf-Rayet Stars

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The O and early B star winds show empirical correlations between X-ray ($L_{\rm x}$) and Bolometric ($L_{\rm Bol}$) luminosity as well as wind properties such as wind momentum and wind kinetic energy. Wolf-Rayet stars do not. We discuss scaling relations to qualitatively explain this lack of correlation among the WR winds and to quantitatively reproduce the observed ratio of X-ray luminosities between the N-rich WN types and C-rich WC types. If (a) the filling factor of hot X-ray emitting gas varies as $(\dot{M}/v_\infty)^{-1}$ for stars of different mass loss and terminal speed and (b) the ambient Wolf-Rayet wind component is optically thick to the hot gas X-rays, then a lack of correlation between $L_{\rm x}$ and wind parameters is to be expected. The emergent X-ray emission then depends only on factors relating to relative abundances and ionization. The observed ratio $L_{\rm X}({\rm WN})/L_{\rm X}({\rm WC})$ is consistent with our scaling analysis using typical WN and WC abundances.

**Accepted to Astronomy & Astrophysics Letters**
*Preprints from* rico@astro.gla.ac.uk

## Simultaneous Radio and X-ray Observations of the Wolf-Rayet Star WR 147

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We present results of simultaneous ASCA/VLA observations of the Wolf-Rayet star WR 147 (= AS 431). This WN8 star is an optical double and may be a WR + OB colliding wind binary system. The new observations place tight constraints on the origin of its X-ray and radio emission. The X-ray emission is due to a multi-temperature optically thin thermal plasma with the dominant contribution coming from plasma at kT $\approx$ 1 keV. The absorption column density derived from the X-ray spectrum is $N_H = 2 \times 10^{22}$ cm$^{-2}$ which agrees well with estimates based on the visual extinction but is too large to explain by wind absorption alone. The X-ray temperature structure is consistent with colliding

wind shock emission but the unabsorbed X-ray luminosity $L_x = 10^{32.55}$ ergs $s^{-1}$ (0.5 - 10 keV) is several times smaller than predicted from colliding wind shock models.

The VLA data provide the most complete picture ever obtained of the radio spectral energy distribution of a WR star and consist of near-simultaneous observations at five different wavelengths (1.3, 2, 3.6, 6, and 21 cm). The radio emission consists of a thermal free-free component from the WR wind and a nonthermal component. If the nonthermal emission is due to relativistic particles accelerated by the Fermi mechanism in wind shocks then the flux is expected to decline at high frequencies according to $S_\nu \propto \nu^{-0.5}$. However, the observed falloff is much steeper and cannot be reproduced by a simple power-law or by synchrotron models which assume power-law electron energy distributions. A surprising result is that the nonthermal emission can be accurately modeled as synchrotron radiation from relativistic electrons that are nearly monoergetic.

**Accepted by ApJ**
*Preprints from* `ftp mambo.colorado.edu, cd pub/data, get wr147*.ps`

## Radio Detections of Stellar Winds from the Pistol Star and Other Stars in the Galactic Center Quintuplet Cluster

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VLA images of the Sickle and Pistol H II regions near the Galactic center at 3.6 and 6 cm reveal six point sources in the region where the dense Quintuplet stellar cluster is located. The spectral indices of five of these sources between 6 cm and 3.6 cm have values of $\alpha = +0.5$ to $+0.8$, (where $S_\nu \propto \nu^\alpha$), consistent with the interpretation that the radio sources correspond to ionized stellar winds of the massive stars in this cluster. The radio source associated with the Pistol Star shows $\alpha = -0.4 \pm 0.2$, consistent with a flat or slightly non-thermal spectrum.

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*Preprints from* `clang@nrao.edu`
*or on the web at* http://xxx.lanl.gov/astro-ph/9907176

## Wolf-Rayet nebulae as tracers of stellar ionizing fluxes: I. M1-67

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We use WR124 (WN8h) and its associated nebula M1–67, to test theoretical non-LTE models for

Wolf-Rayet (WR) stars. Lyman continuum ionizing flux distributions derived from a stellar analysis of WR124, are compared with nebular properties via photo-ionization modelling. Our study demonstrates the significant role that line blanketing plays in affecting the Lyman ionizing energy distribution of WR stars, of particular relevance to the study of H II regions containing young stellar populations.

We confirm previous results that non-line blanketed WR energy distributions fail to explain the observed nebular properties of M1–67, such that the predicted ionizing spectrum is too hard. A line blanketed analysis of WR124 is carried out using the method of Hillier & Miller (1998), with stellar properties in accord with previous results, except that the inclusion of clumping in the stellar wind reduces its wind performance factor to only ∼2. The ionizing spectrum of the line blanketed model is much softer than for a comparable temperature unblanketed case, such that negligible flux is emitted with energy above the He I $\lambda$504 edge. Photo-ionization modelling, incorporating the observed radial density distribution for M1–67 reveals excellent agreement with the observed nebular electron temperature, ionization balance and line strengths. An alternative stellar model of WR124 is calculated, following the technique of de Koter et al. (1997), augmented to include line blanketing following Schmutz et al. (1991). Good consistency is reached regarding the stellar properties of WR124, but agreement with the nebular properties of M1–67 is somewhat poorer than for the Hillier & Miller code.

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*Preprints from* `pac@star.ucl.ac.uk`
*or by anonymous ftp to* `ftp.star.ucl.ac.uk, in pub/pac/m167/paper.ps.gz`
*or on the web at* `http://http://xxx.lanl.gov/abs/astro-ph/9908200`

## On the nature of the bi-stability jump in the winds of early-type supergiants

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We study the origin of the bi-stability jump of the terminal velocity of the winds of supergiants near spectral type B1. Here, the ratio $v_\infty/v_{\rm esc}$ drops steeply from about 2.6 at types earlier than B1 to a value of $v_\infty/v_{\rm esc}$=1.3 at types later than B2. To this purpose, we have calculated wind models and mass-loss rates for early-type supergiants in a $T_{\rm eff}$ grid covering the range between $T_{\rm eff}$ = 12 500 and 40 000 K. These models show the existence of a bi-stability jump in mass loss around $T_{\rm eff}$ = 25 000 K for normal supergiants, with $\dot{M}$ increasing by about a factor five from $T_{\rm eff} \simeq$ 27 500 to 22 500 K for constant luminosity. The wind efficiency number $\eta = \dot{M} v_\infty/(L_*/c)$ also increases drastically by a factor of 2 - 3 near that temperature.

We argue that the jump in mass loss is accompanied by a decrease of the ratio $v_\infty/v_{\rm esc}$, which is the observed bi-stability jump in terminal velocity. Using self-consistent models for two values of $T_{\rm eff}$, we have derived $v_\infty/v_{\rm esc}$ = 2.4 for $T_{\rm eff}$ = 30 000 K and $v_\infty/v_{\rm esc}$ = 1.2 for $T_{\rm eff}$ = 17 500 K. This is within 10 percent of the observed values around the jump.

Up to now, a theoretical explanation of the observed bi-stability jump was not yet provided by radiation driven wind theory. To understand the origin of the bi-stability jump, we have investigated the line acceleration for models around the jump in detail. These models demonstrate that $\dot{M}$ *increases around the bi-stability jump due to an increase in the line acceleration of Fe* III *below the sonic point.*

This shows that the mass-loss rate of B-type supergiants is very sensitive to the abundance and the ionization balance of iron.

Furthermore, we show that the elements C, N and O are important line drivers in the *supersonic* part of the wind. The *subsonic* part of the wind is dominated by the line acceleration due to Fe. Therefore, CNO-processing is expected *not* to have a large impact on $\dot{M}$, but it might have impact on the terminal velocities.

Finally, we discuss the possible role of the bi-stability jump on the mass loss during variations of Luminous Blue Variable stars.

**Accepted by A&A**
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## What heats the bright HII regions in I Zw 18?

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We have used the radiation field from a starburt population synthesis model appropriate for the brightest HII region of I Zw 18 to perform a photoionization model analysis of this object. We have investigated whether, with the observed nebular density distribution as revealed by the *HST* images and a total stellar radiation compatible with the observed UV flux, one could reproduce the constraints represented by the observed ionization structure, the He II $\lambda$4686/H$\beta$ ratio, the H$\alpha$ flux and the electron temperature indicated by the [O III] $\lambda$4363/5007 ratio.

We have found that, even taking into account strong deviations from the adopted spectral energy distribution of the ionizing radiation and the effect of additional X-rays, the photoionization models yield too low a [O III] $\lambda$4363/5007 ratio by about 30%. This discrepancy is significant and poses an interesting problem, which cannot be solved by expected inaccuracies in the atomic data. The missing energy may be of the same order of magnitude as the one provided by the stellar photons or lower, depending on the way it acts on the [O III] $\lambda$4363 line.

Elemental abundance determinations in I Zw 18 are affected by this problem. Before the nature of the missing heating source and its interactions with the nebular gas are better understood it is, however, not possible to estimate the typical uncertainties by which standard empirical methods are affected.

Several side-products of our photoionization analysis of I Zw 18 are the following:

- We have been able to reproduce the intensity of the nebular He II $\lambda$4686 using a stellar radiation field consistent with the observed Wolf-Rayet features in I Zw 18.
- We have shown that the bright NW HII region in I Zw 18 does not absorb all the ionizing photons from the central star cluster, and that about half of them are available to ionize an extended diffuse envelope.
- The [O I] emission can easily be accounted for by condensations or intervening filaments on the line of sight.
- The intrinsic H$\alpha$/H$\beta$ ratio is enhanced by collisional excitation to a value of 3. Previous estimates of the reddening of I Zw 18 are therefore slightly overestimated.

- We give ionization correction factors appropriate for I Zw 18 that can be used for more accurate abundance determinations in this object once the electron temperature problem is better understood.

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*Preprints from* schaerer@obs-mip.fr
*Also on the web at* http://webast.ast..obs-mip.fr/people/schaerer/

## An Investigation of the Large-scale Variability of the Apparently Single Wolf-Rayet Star WR 1

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In recent years, much studies have focused on determining the origin of the large-scale line-profile and/or photometric patterns of variability displayed by some apparently single Wolf-Rayet stars, with the existence of an unseen (collapsed?) companion or of spatially extended wind structures as potential candidates.

We present observations of WR 1 which highlight the unusual character of the variations in this object. Our narrowband photometric observations reveal a gradual increase of the stellar continuum flux amounting to $\Delta v \approx 0.09$ mag followed by a decline on about the same timescale (3-4 days). Only marginal evidence for variability is found during the 11 following nights. Strong, daily line-profile variations are also observed but they cannot be easily linked to the photometric variations. Similarly to the continuum flux variations, *coherent* time-dependent changes are observed in 1996 in the centroid, equivalent width and skewness of He II $\lambda$4686.

Despite the generally coherent nature of the variations, we do not find evidence in our data for the periods claimed in previous studies. While the issue of a cyclical pattern of variability in WR 1 is still controversial, it is clear that this object might constitute in the future a cornerstone for our understanding of the mechanisms leading to the formation of largely anisotropic outflows in Wolf-Rayet stars. **Accepted by A&A**
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## The nature of strings in the nebula around $\eta$ Carinae

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$\eta$ Carinae is one of the most extreme cases of a Luminous Blue Variable star. A bipolar nebula of $17''$ size surrounds the central object. Even further out, a large amount of filamentary material extends

to a distance of 30″ or about 0.3 pc. In this paper we present a detailed kinematic and morphological analysis of some outer filaments in this nebula which we call *strings*. All strings are extremly long and narrow structures. We identified 5 strings which have sizes of 0.058 to 0.177 pc in length and a width of only 0.002 pc. Using high-resolution long-slit echelle spectroscopy it was found that the strings follow a Hubble law with velocities increasing towards larger distances from the star. With these unique properties, *high collimation* and *linear increase* of the radial velocity the strings represent a newly found phenomena in the structure and evolution of nebulae around LBVs. Finally, we show that morphologically similar strings can be found in the planetary nebula NGC 6543, a possible PN-counterpart to this phenomenon.

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*Preprints from* kweis@ita.uni-heidelberg.de
*or on the web at* http://www.ita.uni-heidelberg.de/~kweis/publications.html

## A Large HI Shell Surrounding the Wolf-Rayet Star HD191765

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We have surveyed a $2.6^\circ \times 2.6^\circ$ field centered on the Wolf-Rayet (WR) star HD 191765 (=WR 134) in the H I 21 *cm* line and in the 1420 and 408 $MHz$ radio continuum, using the Synthesis Telescope of the Dominion Radio Astrophysical Observatory (DRAO), in order to search for direct evidence of the interaction between the WR star wind and the interstellar medium.

An arc shaped structure is present in the 1420 $MHz$ continuum image, which perfectly matches the optical nebula Anon (MR 100). This gas is not visible on our 408 $MHz$ map, hinting at the thermal nature of the source. This ionized gas could be associated with Luminous Blue Variable (LBV) or red supergiant (RSG) ejectae swept-up by the WR wind and photoionized by the strong ultraviolet (UV) flux from the star. However, this suggestion needs to be confirmed by clear CNO enrichment measurements in the north-west region of the nebula.

Our H I maps reveal the existence of a nearly complete shell at a velocity of $v_{sys} = -11.44\ km\ s^{-1}$ ($R_s \approx 20.9\ pc, v_{exp} \approx 9.9\ km\ s^{-1}, M_{HI} \approx 1830\ M_\odot$) which, mainly for morphological reasons, we associate with HD 191765 (although a contribution from the nearby WR star HD192103 cannot be totally excluded). The dynamical age of this bubble ($\sim 1.3 \times 10^6\ yr$) suggests that it was mainly blown during the main sequence progenitor O-star phase. The kinematic distance corresponding to a Local Standard of Rest (LSR) velocity of $-11\ km\ s^{-1}$ is approximately 5 $kpc$, which is incompatible with the association distance of HD191765 of 2.1 kpc. Therefore, we conclude that the H I bubble we have detected was blown in gas already in movement with respect to normal Galactic rotation for this region. There is independent evidence that gas at this velocity is present in this line of sight.

Recent Hipparcos data analyzed by Moffat *et al.* (1998) give a supersonic proper motion for HD 191765 (projected velocity $\sim 52\ \ km\ s^{-1}$ at a position angle on the sky of PA=$-38^\circ$). This velocity vector points away from a position very close to the center of the H I bubble, which strengthens the hypothesis of a physical link with the WR star. The supersonic velocity of the star with respect to the interstellar medium might have generated some compression of the interstellar medium in the south-west region, rendering the H$\alpha$ gas brighter in that direction with respect to the surroundings.

**Accepted by The Astronomical Journal**
*Preprints from* stlouis@astro.umontreal.ca

# On the nature of the H I infrared emission lines of $\tau$ Scorpii

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We present H$\alpha$, He I $\lambda$ 2.058 $\mu$m and 6 hydrogen Brackett and Pfund lines of $\tau$ Sco (B0.2V) obtained using the ground-based INT and UKIRT instruments as well as satellite data from ISO. The infrared lines all show core emission. We have investigated the formation of these lines using sophisticated non-LTE models.

The observed emission in the most pronounced hydrogen lines, such as Br$\alpha$ and Pf$\alpha$, is stronger than predicted by our models. The velocities of peak emission are blue-shifted by 5-10 kms$^{-1}$ with respect to the stellar velocity. This together with the surprisingly strong width of Br$\alpha$ and the peculiar profile of He I $\lambda$ 2.058 suggests that shock-induced turbulent velocity fields may be present in or somewhat above the stellar photosphere, as has already been suggested from analysis of optical and ultraviolet data. We derive $T_{\rm eff}$ = 32$\pm$2 kK from the infrared data alone, a value consistent with previous optical analysis. The good agreement indicates that quantitative analysis of infrared lines alone (e.g. for hot stars in regions of high extinction) can be used to characterize photospheres accurately. We also investigate the mass loss of $\tau$ Sco and find an upper-limit of 6 $10^{-9}$ $M_{\odot}$yr$^{-1}$.

A parameter study of the infrared hydrogen and helium lines indicates that emission may be expected in Br$\alpha$ and Pf$\alpha$ for stars with $T_{\rm eff} \gtrsim 16$ kK and will dominate the profiles of these lines for $T_{\rm eff} \gtrsim 31$ and 26 kK, respectively. He I $\lambda$ 2.058 will be in emission for $20 \lesssim T_{\rm eff} \lesssim 33$ kK and He II line profiles will contain emission at $T_{\rm eff} \gtrsim 33$ kK. The effect of surface gravity on these values is small.

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*or by anonymous ftp to* `helios.astro.uva.nl:/pub/peer`

# Three-dimensional spectral classification of WN stars: One too many?

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A "three-dimensional" classification for WN stars has been introduced by Smith, Shara, and Moffat (MNRAS 281, 163, 1996). In addition to the well known "one-dimensional" ionization subclasses (e.g., WN6, WN7, WN8, etc.) they have added subscripts of "h", "a", "b" and "o" to refer, respectively, to the connotation of *h*ydrogen being present (from the Balmer/Pickering emission line decrement), the presence of *a*bsorption lines, the appearance of *b*road emission lines, or n*o* evidence of hydrogen (in stars without a "b"). I will critically evaluate the appropriateness of the latter two subscripts, utilizing the observed distribution functions of line width and line strength for Galactic and LMC WN

stars. A "two-dimensional" classification, providing information about the hydrogen in addition to the ionization is probably warranted.

**To appear in New Astronomy**
*Preprints from* pconti@jila.colorado.edu

## Hard X-Rays Emitted by Starbursts as Predicted by Population Synthesis Models Including a Realistic Fraction of Interacting Binaries

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We combine our population number synthesis code where the effects of interacting close binaries are included in detail, with the formation mechanism of X-radiation in young supernova remnants and in high mass X-ray binaries, to predict the hard X-ray luminosity emitted by starbursts. We demonstrate that the role of interacting close binaries is very large. Therefore, observations of hard X-rays with energies larger than 2 keV of starburst regions may highlight the importance of close binary evolution in understanding properties of active starformation regions.

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*Preprints from* dvbevere@vub.ac.be

## Implications of massive close binaries for black hole formation and supernovae

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The progenitor evolution of the massive X-ray binary Wray 977 is investigated using new models of massive close binary evolution. These models yield constraints on the mass limit for neutron star/black hole formation in single stars, $M_{\rm BH}$. We argue for quasi-conservative evolution in this system, and we find $M_{\rm BH} > 13..21\,{\rm M}_\odot$ from the existence of a neutron star in Wray 977, with the uncertainty being due to uncertainties in the treatment of convection. Our results revise earlier published much larger values of $M_{\rm BH}$ derived from the parameters of Wray 977.

Then, on the basis of a grid of 37 evolutionary models for massive close binaries with various initial masses, mass ratios and periods, we derive primary initial-final mass, initial mass-final helium core mass, and initial mass-final CO-core mass relations for the various mass transfer cases of close binary evolution. From these models we derive for single stars that $M_{\rm BH} \lesssim 25\,{\rm M}_\odot$, independent of whether most black hole binaries formed through the Case A/B or the Case C binary channel. Using our grid of binary models, we obtain a consistent scenario for the formation of black holes in binary systems.

We emphasize that in binaries the critical initial mass limits for neutron star/black hole formation and for white dwarf/neutron star formation are very different from the corresponding values in single stars. While the first may well be above $100\,{\rm M}_\odot$ in Case A/B binaries, the latter is found to be in the range $12...15\,{\rm M}_\odot$ instead of the canonical value of $8...10\,{\rm M}_\odot$ usually quoted for single stars. This effect should not be neglected in population synthesis studies of massive binary systems. Also, neutron

star and black hole mass functions obtained for single stars can not per se compared to the masses of compact objects in binary systems.

Massive close binaries produce also Type Ib and Ic supernovae. We find two different types of supernova progenitor structure in our models, one with remaining helium masses of the order of $1\,M_\odot$ which stems from an intermediate progenitor initial mass range (about $16...25\,M_\odot$), and another with one order of magnitude smaller remaining helium masses from initial masses above and below this. A possible connection to the distinction of Type Ib and Type Ic supernovae, and implications from the Type Ic supernova SN1998bw and its associated $\gamma$-ray burst are discussed.

**Accepted by A&A**
*Preprints from* stephan, ntl@astro.physik.uni-potsdam.de
*or on the web at* http://www.astro.physik.uni-potsdam.de/abstracts/bh.html

## New catalogue of Wolf-Rayet galaxies and high-excitation extra-galactic H II regions

**Daniel Schaerer[1], Thierry Contini[2,3], Maximilien Pindao[4]**

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The recently published catalogue of Wolf-Rayet galaxies and high-excitation extra-galactic H II regions (Schaerer et al., 1999, A&A, 136, 35) is now available on the Web at
http://webast.ast.obs-mip.fr/people/schaerer/wrcat/.

We aim at providing periodic updates of the catalogue based on the literature and other data communicated to us. Contributions from the community will greatly be appreciated.

*Communicated by* schaerer@obs-mip.fr

# Submitted Papers

## The relative figure of merit of optical interferometry as compared to spectroscopy. Example of parameter estimates for the circumstellar envelope of P Cyg.

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When planning new facilities, one is interested to know whether and by how much the new technique is superior to already existing ones. We describe a general approach permitting to evaluate the

relative merits of various techniques used in astrophysical observations, following the theory of model parameter estimation. It is applied to compare two-aperture optical long baseline interferometry to classical spectroscopy, both used to define the model parameters of the P Cyg wind. The wind modeling was done using an efficient approximation for computation of the line source function; it allowed to analyse about $10^5$ points in the parametric space of P Cyg envelope models. It is shown that interferometry offers no real advantage if the object can be described by stationary spherically symmetric models with a priori fixed thermal structure. However, if the object must be described by a model with a large number of free parameters, e.g. when the thermal structure of the envelope is not fixed a priori, then the interferometric measurements can reduce the error in model parameters determination by an order of magnitude. In the case of P Cyg, the reduction of errors provided by interferometry is highest for the baseline lengths in the range 45–90 m. This illustrates the capacity of the proposed method to be used for optimization of interferometric configurations. The simplifications adopted for this first trial application are critically analyzed, and future improvements are indicated.

**Submitted to A & A**
*Preprints from* `Almas.Chalabaev@obs.ujf-grenoble.fr`
*or by anonymous ftp to* `ftp.laog.obs.ujf-grenoble.fr/toutlemonde/chalabae/mbac9906.ps`
*or on the web at* `ftp://laog.obs.ujf-grenoble.fr/toutlemonde/chalabae/mbac9906.ps`

## Radiative Torque and Partial Spindown of Winds from Rotating Hot Stars

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We examine the degree to which the azimuthal component of the line-driving force can remove angular momentum from the equatorial wind of a rapidly rotating hot star, using a straightforward extension of the standard CAK formalism. We illustrate how even in a wind that is azimuthally symmetric, such a net azimuthal line-force results from the prograde/retrograde velocity gradient asymmetries that are inherent to a non-rigidly rotating outflow. In particular, we show that the sense of the associated line torque always acts *against* the rotation whenever (as is generally the case) the azimuthal velocity falls below the linear outward increase ($v_\phi \sim r$) associated with rigid rotation. Through a parameter study based on 2D numerical hydrodynamical simulations, we find that the net loss of wind angular momentum is significant but generally quite moderate, about 30-40%, for a wide range of conditions. We then present an extensive analytic analysis that further illuminates the physical nature of the wind spindown and its robust net magnitude. This emphasizes the inherent dynamical feedback between line driving and flow acceleration, which allows the radiative force to effectively magnify the coriolis force in the rotating frame, and so cause the rotation speed to decrease even more steeply with radius than required to conserve angular momentum. A general conclusion is that, while the moderate net spindown of the wind is not likely to have a major impact on the overall wind dynamics, it should be observable from emission line diagnostics, and that doing so would provide an independent test of line-driven wind theory.

**Submitted to ApJ**
*Preprints from* `kenneth-gayley@uiowa.edu`
*or by anonymous ftp to* `ftp.bartol.udel.edu/owocki/spindown`

# Luminous Blue Variables, Candidate Luminous Blue Variables, and Their Neighboring OB Associations in M31: V15 and K895

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We have imaged the environments of luminous blue variables (LBVs) and candidate LBVs in M31 in U, B, R, J, H, and K bands with the WIYN 3.5-m and ARC 3.5-m telescopes to constrain the ages and progenitor masses of these objects. We find that K895 is most likely a B[e] supergiant and may possess a photometrically variable history that confirms its LBV candidacy. Luminosity and effective temperature limits from the photometry of LBV V15 and K895 lead to age and mass constraints that we compare to the constraints implied by the color-magnitude diagrams of the surrounding stars. LBV V15 appears to be much younger than its neighbors within 100 pc. An upper limit to the age of V15 is found to be 3.5 Myrs ($M_{init} \gtrsim 60$ $M_\odot$) when the luminosity is calculated using the extinction determined from the nearby stars. An age << than 1 Myr ($M_{init} = 120$ $M_\odot$) is found for V15 when the simplest of circumstellar dust models is used to account for excess extinction. The neighbors of V15 in contrast appear to be $\gtrsim 25$ Myrs old. The case for K895 is less extreme. Its age is found to be $\leq 8$ Myrs old ($M_{init} \gtrsim 20$ $M_\odot$) when the luminosity is calculated using the extinction of the neighboring stars. With the simple circumstellar dust model a younger age of $\sim 6$ Myrs ($M_{init} \sim 25$ $M_\odot$) is determined for K895. The neighbors of K895 are older than 8 Myrs.

We discuss four possible explanations for the nature of these objects and the age discrepancies with their environments.

We investigate the ages of the other nearby OB associations and large holes in the atomic hydrogen distribution to examine the stellar and ISM environments. The kinematic ages of the two HI holes are in agreement with the ages of their embedded stellar populations. The HI hole in which V15 is projected provides one more possible age constraint for V15 (10 Myrs). We note the presence of OB 102 WR-1 in the data set and find a lower limit initial mass of $15 - 24$ $M_\odot$ for it from the surrounding stars.

In the appendix we derive a new mass-loss rate estimate for V15 with the data in this paper. We use the mass-loss rate and other estimated parameters of V15 to examine its place in the distance dependent modified wind-momentum-luminosity relation of Kudritzki et al. (1996).

**Submitted to AJ**

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# WR146 - Observing the OB-type companion

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We present new observations of the colliding-wind system WR 146 aimed at understanding the nature

of the companion to the Wolf-Rayet star and the collision of their winds. A new optical spectrum indicates that the companion is an O8f star, perhaps a giant or supergiant and that the system is more luminous than had previously been believed. High-resolution radio observations from MERLIN at 5 GHz and from the VLA at frequencies up to 22 GHz are also presented. Analysis of these observations show that we have detected the radio emission from the WR star, the non-thermal wind-wind interaction region and, for the first time, the radio emission from the stellar wind of the O8f companion. This provides the unique possibility of determining the mass-loss rate and terminal wind velocity ratios of the two winds, independent of distance. Respectively, these ratios are determined to be $0.23 \pm 0.07$ and $0.48 \pm 0.14$ for the O8f star relative to the WR star.

**Submitted to MNRAS**
*Preprints from* sean.dougherty@hia.nrc.ca

Proceedings

## Nucleosynthesis in massive stars

**A. Maeder**

Geneva Observatory

We show why the chemical yields from massive stars very much depend on the initial metallicity Z, and we give the He, C, O, $\alpha$-nuclei and heavy element production as a function of Z. The production of low–mass s–elements by massive stars follows that of carbon production.
The extreme case of zero–metallicity stars is discussed, according to results by Feijoo and Meynet (1999). Despite very large differences during the H– and He–burning phases, stars of all masses finish their He phase with central conditions globally similar to those of current low Z $\simeq$ 0.001 values. Thus, we may conclude that their nucleosynthetic production is similar to that of other current low Z models.
We emphasive that Z–dependent yields are necessary to interpret the [O/Fe] vs. [Fe/H] relation, otherwise there will be an oxygen overproduction. The [C/O] vs. [Fe/H] can only be accounted for by Z–dependent yields. We finally suggest that the evidences of primary nitrogen given by the [N/O] vs. [O/H] of spiral galaxies is the result of fast rotation in stars of 10–15 $M_\odot$, where a long–living shell coexists with a He–burning core. We point out the large [N/H] excesses observed in A–type supergiants of the SMC (cf. Venn 1998).

**Review at the 35th Liege Colloquium, July 1999, "The galactic halo: from globular clusters to field stars"**
*Preprints from* andre.maeder@obs.unige.ch

## Fundamental parameters of Be stars derived from near-infrared spectra

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Because of their spectral peculiarities, stellar parameters of objects undergoing the Be phenomenon

cannot be determined in the same way as for normal B stars. In particular, the use of the first lines of the Hydrogen series is hampered by the presence of emission components. On the other end, the recently generalized use of CCD detectors, well adapted to the deep red spectral region, provides a large amount of quantitative and well calibrated flux measurements with spectral resolutions around 0.1 nm. We propose to use the shape of the continuum and line flux distribution in the range of the higher Paschen lines of Hydrogen to determine first the effective temperature and superficial gravity of Be stars where, in most cases, the photospheric spectrum is not disturbed by line or continuum emission.

**To appear in the proceedings of the IAU coll. 175: The Be Phenomenon in Early-Type Stars**
*Preprints from* `eolpress@skynet.be`
*or by anonymous ftp (file alicante.ps.gz) to:*
`ftp://umhsp02.umh.ac.be/pub/ftp_astro/houziaux/`

## Meetings

## First Announcement

## Stars, Gas and Dust in Galaxies:Exploring the Links

March 15- 18, 2000
La Serena, Chile

ORGANIZED BY:
Cerro Tololo InterAmerican Observatory, European Southern Observatory, Las Campanas Observatory

**Background:** Understanding the many links between the various layers of stellar populations and the various phases of the interstellar medium within galaxies is important for a wide spectrum of unsolved astrophysical problems – from developing a proper model of the ISM, to characterizing star formation on a global scale, to galaxy formation and evolution...While the links are being individually explored through different wavelength windows – from X rays to mm waves – an up-to-date overview of the mass and energy exchanges and budgets would be both timely and desirable. Therefore, we propose, as a subject of the upcoming CTIO-ESO-LCO workshop, to explore the links between stars, gas and dust within galaxies. To this end, we will bring together astronomers from many subdisciplines.

The format of a workshop will be ideal for making the best progress towards investigating the feedbacks among all the components within a galaxy. Moreover, holding the workshop in Chile – the frontier for many new facilities – and having the workshop organized by institutions which represent astronomers from both Europe and the USA will hopefully break international as well as subdisciplinary boundaries.

**Scientific program:** The 4 days of the meeting will feature:

- Reviews covering the inventory of the ISM, interactions between ISM phases, and ISM modelling tools
- Reviews on stellar populations in galaxies near and far, interaction of massive stars with the ISM, and modelling tools used in stellar populations work

- Reviews on the mass and energy budgets within galaxies and the role of feedback in galaxy structure and evolution
- Working groups to discuss key questions of galaxy physics, followed by a panel discussion

We welcome both oral and poster contributions related to these subjects.

**Registration Deadline: December 30, 1999**
For program, registration, and accomodation information, see
`http://www.eso.org/gen-fac/meetings/sgd2000/2000.html`

**Scientific Organizing Committee:** D.Alloin (ESO), N.Arimoto (U.Tokyo), C.Balkowski(O.Meudon/Paris), F.Boulanger (IAS), G.Galaz (LCO), W.Gieren(U.Concepcion), E.Hardy(NRAO), G.Hensler (U.Kiel), P.Hodge(U.Washington), R. Kennicutt (U.Arizona),J.Melnick (ESO), D.Minniti(PUC), K.Olsen (CTIO), M.Rubio(U.Chile),F.Schweizer (DTM).

**Local Organizing Committee:** D. Alloin (ESO,Chair), K. Olsen(CTIO,Co-chair), G. Galaz(LCO,Co-Chair).

## P Cygni - 2000: 400 Years of Progress

**Armagh, Northern Ireland** **21-23 August, 2000**

Preliminary Announcement

A workshop to discuss the progress towards our understanding of this peculiar hypergiant made since 1600 AD, will be held in Armagh, Northern Ireland, from 21-23 August 2000.

Scope of the workshop: P Cygni was discovered on 18th August, 1600, while in outburst. Subsequent observations of the star have now covered a time span of four centuries. Especially the more frequent and accurate observations of the 20th century have revealed much about the nature of this enigmatic object. The 400th anniversary of the discovery of P Cygni is therefore the right time to discuss the progress made towards understanding this peculiar hypergiant, to ensure that the lessons learned from its study are not lost, and that these results can be applied to the study and understanding of similar objects and of the nature and evolution of massive stars in general.

The format of the workshop will be a series of invited papers about different aspects of the research concerning P Cygni, supplemented with a number of contributed papers and posters, and ample time for discussing how the various results can best be integrated into a more complete model for the astrophysical parameters and evolution of this star. Posters and contibuted papers are invited.

The workshop will finish in good time for participants who so wish to travel to Sweden for the workshop on Eta Carinae.

Further announcements will be sent to all who respond to this first announcement and is also available on the workshop website (under construction) at http://www.arm.ac.uk/∼mdg/ and from Mart de Groot at mdg@star.arm.ac.uk

# A First Announcement for an International Workshop on "Interacting Winds from Massive Stars" (including single stars and binaries)

to be held Mon-Fr 10 - 14 July 2000
on the Magdelene Islands, Québec, Canada
will be available on the Web
after 15 October 1999, at:
http://www.astro.umontreal.ca/iwinds/
SOC:
Y.-H. Chu M.-M. Mac Low A.F.J. Moffat (chair) I.R. Stevens N. St-Louis P.M.W. Williams