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

Please note the **employment opportunity** offered by the Université de Montréal (near the end of this newsletter).

New Catalogue: The catalogue of $v_e \sin i$ measurements of OB stars published by Howarth et al. (MNRAS **284**, 265, 1997) is now available through the 'Catalogues and Atlases' section of the Hot Newsletter Web sites. The catalogue gives measurements for 373 O-type stars and B supergiants, based on IUE spectroscopy, with a typical uncertainty believed not to exceed $14\,\mathrm{km\,s^{-1}}$, or 8% of the observed value (whichever is greater). Corrected versions of the terminal-velocity measurements reported by Prinja et al. (ApJ **361**, 607, 1990; **383**, 466, 1991) are included for convenience, together with new determinations for many of the B supergiants.

Contents of this newsletter

Accepted Papers

Quantitative Spectroscopy of the HeI Cluster in the Galactic Center

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We present results on quantitative infrared spectroscopy of the brightest He I emission line stars in the Galactic center. The observed He I and H broad emission lines are caused by extremely strong stellar winds ($\dot{M} \sim 5$ to $80 \times 10^{-5}\,M_\odot\,yr^{-1}$) with relatively small outflow velocities ($V_\infty \sim 300$ to $1000\,km\,s^{-1}$). The effective temperatures of the objects range from 17,000 K to 30,000 K with corresponding stellar luminosities of 1 to $30 \times 10^5 L_\odot$. Strongly enhanced helium abundances ($N_{He}/N_H > .5$) are found. These results indicate that the He I emission line stars are evolved blue supergiants close to the evolutionary stage of Wolf-Rayet stars. They power the central parsec and belong to a young stellar cluster of massive stars which formed a few million years ago.

Accepted by A& A
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A spectroscopic investigation of P Cygni I. H and HeI lines.

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We present a detailed spectroscopic analysis of the H and He I spectrum of the Luminous Blue Variable (LBV) P Cygni. The observational constraints for our investigation are given by the mean optical and near-IR spectra obtained by Stahl et al. (1993) and published UV, optical, IR and radio continuum measurements of the star.

Within the parameter domain of interest we have investigated how line strengths, line shapes and the emergent energy distribution behave as a function of stellar parameters such as temperature, luminosity, wind density, etc. The sensitivity of the H and He I line profiles to model parameters allows a quantitative spectroscopic analysis of P Cygni to be performed. The derived parameters for P Cygni place it near a regime where two classes of models exist — those in which H remains fully ionized in the wind, and those in which H eventually recombines in the wind. The transition between the two classes of models is dramatic — a 5% change in luminosity or mass-loss is sufficient. The shape of the P Cygni absorption on the Hα profile and the radio variability indicates that H must recombine in P Cygni's wind.

As for Wolf-Rayet (W-R) stars we find that we can generate a set of homologous models which are capable of explaining, within observational errors, the flux distribution and the line profiles equally well. Scaling relations for the homologous models have been determined, but to first order they have the same T_{eff} and the same wind density parameter ($\dot{M}/R_*{}^{1.5}$). Consequently it is impossible to derive R_* from a spectroscopic analysis.

Assuming R_*=75 $R_\odot$, the following stellar parameters for P Cygni are derived:

$L_*=5.6\times10^5\,L_\odot$	(T_{eff}=1.82 kK)
$n_{He}/n_H=0.3$	$\dot{M}=3.0\times10^{-5}\,M_\odot\,yr^{-1}$
V_∞= 185 km s^{-1}	$\beta = 2.5$
$\log g_{eff}$=1.20.	

These imply a stellar distance of 1.7±0.1 kpc, which is consistent with determinations in the literature.

Continuum fluxes and the observed optical and near-infrared H and He I line profiles are well reproduced by the model. The derived stellar parameters and the high helium abundance indicates that P Cygni is highly evolved.

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Near Infrared Spectroscopy of G29.96−0.02: The First Spectral Classification of the Ionizing Star of an Ultracompact HII Region

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We have obtained the first classification spectrum and present the first direct spectral classification of the ionizing star of an ultracompact HII region. The ultracompact HII region is G29.96−0.02, a well-studied object with roughly twice solar metallicity. The near infrared K-band spectrum of the ionizing star exhibits CIV and NIII emission and HeII absorption, but lines of HI and HeI are obliterated by nebular emission. We determine that the star has a spectral type of O5 to O7 or possibly O8. We critically evaluate limits on the properties of the star and find that it is compatible with zero-age main-sequence properties only if it is binary and if a significant fraction of the bolometric luminosity can escape from the region. G29.96−0.02 will now be an excellent test case for nebular models, as the properties of the ionizing star are independently constrained.

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The inhomogeneous circumstellar envelope of Rigel (β Orionis A)

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We report on time series Hα profiles of the late B-type supergiant Rigel (β Orionis A). Our observations indicate the presence of variable and asymmetric outflows and infalls of matter. We have recorded a blue-shifted high-velocity absorption component in Hα almost simultaneously with Kaufer et al. (1996b). The final part of this extraordinary event has been observed. We found that blue-shifted high-velocity aborption has completely disappeared in one month and another, red-shifted strong absorption appeared at 50 km s^{-1}. Based on our observations and those reported in the literature we propose extended rotating magnetic structures (closed loops) in the mantle of Rigel. The fundamental parameters of the star are discussed.

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Spectral analyses of late-type [WC] central stars of planetary nebulae: more empirical constraints for their evolutionary status

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The optical spectra of the five recently observed late-type Wolf-Rayet central stars He 2–459 ([WC8]), M 2–43 ([WC8]), SwSt 1 ([WC9]), PM 1–188 and IRAS 21282+5050 (both [WC11]) are analyzed by means of spherically expanding model atmospheres. The stellar parameters T_* (effective temperature), v_∞ (final velocity of the wind), R_* (stellar radius) and $\dot{M}$ (mass loss rate) are determined by NLTE simulations which account for the elements hydrogen, helium, carbon and oxygen. With two exceptions (SwSt 1 and IRAS 21282) the results presented here fit into the sample of already examined [WCL]-type objects. Altogether 13 out of 17 known [WCL]-CSPN have been analyzed so far. The presence of hydrogen in the atmospheres of [WC11] and [WC12] stars becomes more and more evident. In five out of seven analyzed objects of these subtypes hydrogen emission features of stellar origin can be identified.

The spectra of the latest subtypes ([WC11], [WC12]) show rather narrow lines and thus allow to detect features of nitrogen (N II, N III), neon (Ne I) and silicon (Si III, Si IV). For the first time we present model calculations accounting for these elements and perform abundance estimates for the eight narrow-lined stars (all [WC11] and [WC12] plus SwSt 1). The obtained surface compositions are discussed in the light of recent evolutionary calculations which account for diffuse mixing during thermal pulses at the Asymptotic Giant Branch.

Accepted by Astronomy & Astrophysics

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The Hourglass Nebulae of Sher 25 and SN 1987 A: Two of a Kind?

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We have performed a detailed study of the morphology and kinematics of the hourglass-shaped nebula around the blue supergiant Sher 25 in the galactic giant HII region NGC 3603. Near-infrared high resolution adaptive optics images in the Brγ line and HST/NICMOS images in the HeI 1.08μm line were compared with iso-velocity maps in the Hα and [NII] lines.

The adaptive optics observations clearly resolved the width of the ring (0$''$.9, i.e., 0.027 pc), yielding δR/R=1:8. We show that the Hα and [NII] lines trace the entire silhouette of the hourglass. The bipolar lobes of the hourglass expand at 70 km s^{-1}, whereas the ring around the waist of the hourglass expands at 30 km s^{-1}. Both the ring and the bipolar lobes have about the same dynamical age, indicating a common origin and a major outburst and mass-loss event 6630 yr ago. The ionized mass within the hourglass is between 0.3 M$_\odot$ and 0.6 M$_\odot$ - quite comparable to the total mass suggested for the expanding (pre-supernova) shell around SN 1987 A.

The hourglass structure around Sher 25 is similar to that of SN 1987 A in spatial extent, mass, and velocities. The major differences between these two nebulae might arise from environmental effects. Both internal and external ionization sources are available for Sher 25's nebula. Furthermore, Sher 25 and its hourglass-shaped nebula appear to be moving to the south-west with respect to the ambient interstellar medium, and ram pressure has apparently deformed the hourglass. We conclude that the circumstellar nebulae around SN 1987 A and Sher 25 are very similar and define a new class of nebulae around blue supergiants in their final evolutionary stage.

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Outmoving Clumps in the Wind of the Hot O-Supergiant ζ Puppis

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We present time-series of ultra-high signal-to-noise, high resolution spectra of the HeII 4686 Å emission line in the O4I(n)f supergiant ζ Puppis, the brightest early-type O-star in the sky. These reveal stochastic, variable substructures in the line, which tend to move away from the line-center with time. Similar scaled-up features are well established in the strong winds of Wolf-Rayet stars (the presumed descendants of O stars), where they are explained by outward moving inhomogeneities (e.g., blobs, clumps, shocks) in the winds. If all hot-star winds are clumped like that of ζ Pup, as is plausible, then mass-loss rates based on recombination-line intensities will have to be revised downwards. Using a standard 'β' velocity law we deduce a value of $\beta = 1.0 \ldots 1.2$ to account for the kinematics of these

structures in the wind of ζ Pup. In addition to the small-scale stochastic variations we also find a slow systematic variation of the mean central absorption reversal.

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Inference of steady stellar wind $v(r)$ laws from optically thin emission lines II. Occultation effects and the determination of intrinsic stellar properties

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This paper extends previous work on the inversion of line profiles to obtain wind velocity laws to a case that includes the occultation of light from the far side of the star. The velocity law $v(r)$ is assumed to be from a wind that is steady and spherically symmetric. The wind is also assumed to be optically thin in the emission line profile. The major result here is the derivation of an *analytic* inversion formula. The effects of stellar occultation are shown to produce a significant change in the analysis from paper I, and by accounting for the occultation, the red-shifted emission of P Cygni profiles can be used to obtain $v(r)$. Using simulated line profiles as generated from a radiation transport code to test the procedure, the inversion technique based on optically thin lines successfully recovers $v(r)$ distributions for weak LTE H_α profiles from hot star winds. Even in the case of NLTE H_α lines, the technique is seen to reproduce the model velocity distribution quite well. Our inversion technique thus remains robust outside the scope of our assumptions, owing primarily to an empirical approach for applying the method. An important aspect of our empirical approach is the possibility of estimating intrinsic stellar and wind properties, such as the mass-loss rate $\dot{M}$, photospheric radius R, and the stellar distance D. As an example, photospheric stellar radii are derived from the model profiles and found to be in good agreement with the input values, with typical errors of about 5%. Even in the NLTE case, the photospheric radii are underestimated by only 10–20%.

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On the Origin of the UV Upturn in Elliptical Galaxies. I. Sensitivity of UV Population Synthesis to Various Input Parameters

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We present models of the late stages of stellar evolution intended to explain the "UV upturn" phenomenon in elliptical galaxies. Such models are sensitive to values of a number of poorly-constrained physical parameters, including metallicity, age, stellar mass loss, helium enrichment, and the distribution of stars on the zero age horizontal branch (HB). We explore the sensitivity of the results to values of these parameters, and reach the following conclusions.

Old, metal rich galaxies, such as giant ellipticals, naturally develop a UV upturn within a reasonable time scale - less than a Hubble time - without the presence of young stars. The most likely stars to dominate the UV flux of such populations are low mass, core helium burning (HB and evolved HB) stars. Metal-poor populations produce a higher ratio of UV-to-V flux, due to opacity effects, but only metal-rich stars develop a UV upturn, in which the flux increases towards shorter UV wavelengths.

Model color-magnitude diagrams and corresponding integrated spectra (for various values of age, metallicity, helium enrichment, mass loss efficiency, initial mass function, and the HB mass dispersion factor) are available on S.Y.'s world wide web site http://shemesh.gsfc.nasa.gov/model.html.

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The discovery of a new massive O-type close binary: τ CMa (HD 57061), based on Hipparcos and Walraven photometry

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We present an interpretation of Hipparcos Hp and Walraven $VBLUW$ photometry of the brightest star in the open cluster NGC 2362 (although not necessarily associated with this cluster), HD 57061 (30τ CMa, HR 2782, HIP 35415). In this multiple system the central component consist of a visual double star, two O-type stars separated by 0.″151, which is also known to be a 154.9 d period single lined spectroscopic binary. It is now shown that this system also contains a massive close binary with a period of 1.282122 d, most probably as the main component of the spectroscopic binary. This system therefore contains both the longest period spectroscopic binary and the shortest period eclipsing binary known for O-type stars. The shape of the light curve is characteristic for heavily distorted double star components. An estimate has been made for various physical parameters of the system. The system seems to be typical for some binary interaction results obtained in N-body simulations for open clusters. Improved ephemeris are provided for two similar stars that were observed around the same time as HD 57061: HD 57060 and HD 167971.

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Hipparcos photometry of 24 variable massive stars (α Cyg variables)

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The photometric variability of 24 α Cyg variables, i.e. variable super–and hypergiants, observed by the Hipparcos satellite is described. Three of the selected stars are situated in the SMC, 12 in the LMC and the remaining 9 in the Galactic plane. Four of them are hot S Dor–type variables, or LBVs (luminous blue variables) and two are possible members of this class. Light curves are presented for all stars. For five stars, among which one LBV, the variability was discovered from the Hipparcos

photometric data. Results of period searches are presented and, when relevant, folded light curves are shown. The linear ephemeris of two variables was revised.

For most of the program stars the Hipparcos magnitude scale (Hp) differs from the V of the UBV system by $\lesssim 0\overset{\mathrm{m}}{.}1$. For all variables temperatures and M_{bol} are given. Galactic foreground reddening for the objects in the Magellanic Clouds are given based on IRAS maps.

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Submitted Papers

Wolf-Rayet Stars and O-Star Runaways with HIPPARCOS. I. Kinematics

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Reliable systemic radial velocities are almost impossible to secure for Wolf-Rayet stars, difficult for O stars. Therefore, to study the motions - both systematic in the Galaxy and peculiar - of these two related types of hot, luminous star, we have examined the Hipparcos proper motions of some 70 stars of each type. We find that (a) both groups follow Galactic rotation in the same way, (b) both have a similar fraction of "runaways", (c) mean kinetic ages based on displacement and motion away from the Galactic plane tend to slightly favour the cluster ejection over the the binary supernova hypothesis for their formation, and (d) those with significant peculiar supersonic motion relative to the ambient ISM, tend to form bow shocks in the direction of the motion.

Submitted to A&A
Preprints from `sergey@astro.umontreal.ca`

Wolf-Rayet Stars and O-Star Runaways with HIPPARCOS. II. Photometry

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Abundant *HIPPARCOS* photometry over 3 years of 141 O and Wolf-Rayet stars, including 8 massive X-ray binaries, provides a magnificent variety of light curves at the $\sigma \sim$1-5% level. Among the most interesting results, we mention: optical outbursts in HD 102567 (MXRB), coinciding with periastron passages; drastic changes in the light curve shape of HD 153919 (MXRB); previously unknown long-term variability of HD 39680 (O6V:[n]pe var) and WR 46 (WN3p); unusual flaring of HDE 308399 (O9V); ellipsoidal variations of HD 64315, HD 115071, HD 160641; rotationally modulated variations in HD 66811=ζ Pup (O4Inf) and HD 210839=λ Cep (O6I(n)fp); dust formation episode in WR 121 (WC9). In a statistical sense, the incidence of variability is slightly higher among the WR stars, which partially can be explained by higher percentage of binary systems. Among the presumably single WR stars, the candidate runaways appear to be more variable then the rest.

Submitted to A&A
Preprints from `sergey@astro.umontreal.ca`

Discovery of Candidate Luminous Blue Variables in M31

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Luminous Blue Variables (LBV's) constitute a short-lived, eruptive phase in the evolution of some of the most massive stars. Only a handful have yet been identified in the Galaxy and in each of the nearby galaxies; there are four known in M31. We have found an extremely efficient method to identify candidate LBV stars in nearby galaxies. The candidates are identified in a pair of deep, continuum subtracted narrow-band Hα and [S II] images as objects with extremely low [S II] to Hα ratios, and with coincident stellar objects in continuum images. Five of the most promising new candidates identified by these criteria in the NE half of M31 were subsequently confirmed by optical spectroscopy to show spectra similar to the previously identified M31 LBV, HS var 15. These five

also have much in common with B[e] stars, of which none were known in M31. They are bright Hα sources, (120 $L_\odot < L_\alpha < 1300\ L_\odot$), with no detectable [S II] emission, large Hα equivalent widths (-60 – -400 Å) and broad wings on the Hα profiles (FWZI = 1200 – 2000 km/sec). Most candidates have Fe 2 emission. We discuss the environments of the candidates and find that most objects are likely older than several million years because they tend not to be located inside bright H II regions. We predict, based on the current results that at least 20 LBV/B[e] candidates may be present in M31.

Submitted to ApJ

Preprints from `nking@nmsu.edu`

In Proceedings

The Physics of Rotational Mixing in Massive Stars

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The physics of the new Geneva models of stellar evolution with rotation is shortly presented. The hydrostatic effects are treated with the Kippenhahn and Thomas method modified for shellular rotation. Surface effects of rotation (i.e. distorsion, changes of gravity, $T_{\rm eff}$ and mass loss rates) are also accounted for. Potentially the most important effects of rotation are those due to chemical mixing and transport of angular momentum. We treat explicitely the shear mixing with a new method and we also follow meridional circulation paying a great attention to the effect of μ-gradients and horizontal turbulence. The numerical method to be applied require great care, because the system of equations describing the meridional circulation and the conservation of the angular momentum is of a high order.

Will be published in the Proceedings of the Boulder-Münich Workshop II, ed. I. Howarth, ASP Conference Series

Preprints from `Andre.Maeder@obs.unige.ch`

Massive Star Models With Rotation: New Numerical Results

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We explore the consequences on stellar model outputs of the theory of rotational mixing exposed in the present volume by A. Maeder. We show the importance of a proper account of the interactions between meridional circulation and shear turbulence in rotating star. We discuss astrophysically interesting issues related to massive star evolution: shape of the tracks in the HR diagram, mass-luminosity relation, lifetimes, evolution of the surface abundances. We conclude by some remarks regarding the effects of rotation on WR star formation.

Will be published in the Proceedings of the Boulder-Münich Workshop II, ed. I. Howarth, ASP Conference Series

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Photometry, Polarimetry, and Interferometry of B[e] Stars. Variability

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B[e]– or peculiar Be stars have been distinguished by Allen & Swings (1976, A&A, 47, 293) as a group of early–type emission–line stars having infrared excess at 2–3 μm too large to be explained by circumstellar gas emission only. Most of them show forbidden lines what has caused a popular name of these objects – B[e] stars. Seventy nine such objects was found in the Milky Way by the end of 70s. During follow up studies 47 % of them have been recognized as the objects at well–understood evolutionary stages: pre–main–sequence Herbig Ae/Be stars, Luminous Blue Variables, Planetary Nebulae, symbiotic systems. The rest of these stars suggested to be B[e] supergiants similar to those found in the Magellanic Clouds (Zickgraf et al. 1986, A&A, 143, 119), binary systems consisting of a hot and a cool star, or still have uncertaint nature. The purpose of this paper is to review information obtained so far for the latter three categories of galactic B[e] stars, as well as for some recently studied objects from the Dong & Hu's (1991, Chin. A&A, 15, 275) list which can be considered as B[e] stars candidates. Main results of this review can be summarized as follows:

1. The majority of galactic B[e] stars locate outside of star forming regions and, hence, more likely are evolved stars rather than pre–main–sequence ones.

2. There is a lack of high–quality observations of galactic B[e] stars. Variability of their various characteristics requires coordinated long–term observations using different observational techniques.

3. Only for 9 B[e] stars detailed light curves can be constructed. The averaged amplitude of their optical variability is nearly $0\overset{m}{.}5$, which is significantly larger than that obtained for the Magellanic Clouds B[e] supergiants. For six of them quasi–periodic brightness variations have been found.

4. Spectral energy distributions in a range between near–UV and far–IR are available for nearly 30 B[e] stars. A wide variety of their shapes reflects different evolutionary stages they pass. A distinct group of stars with steep decrease of the IR–brightness, which could indicate recent dust formation, is found.

5. All B[e] stars observed polarimetrically display a significant degree of polarization. Mie scattering, as well as Thomson scattering, can account for the observed wavelength dependence of polarization, so that neither gaseous nor dusty component can be ignored in analysis of observations. Polarization of the objects observed many times is found to be variable. This and spectropolarimetry in some cases confirms a hypothesis of non-spherical dust distribution around B[e] stars.

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The Latitudinal Dependence of Radiatively Driven Mass Loss from Rapidly Rotating Hot-Stars

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We investigate the latitudinal variation of radiatively driven mass loss from rapidly rotating hot-stars. Previous analyses have assumed a uniformly bright stellar surface and concluded that the wind mass flux and density should increase with the increased centrifugal force toward the wind *equator*. In contrast, we show here that a gravity darkening in which the surface radiation flux scales with the effective (centrifugally reduced) gravity leads to a dramatically different wind morphology, with the strongest mass loss now occurring toward the relatively bright *poles*. We also review recent work that indicates nonradial (poleward) components of the line-driving force in such rotating winds can effectively inhibit the equatorward wind deflection needed to form an equatorial wind-compressed disk. Finally, we examine the equatorial bistability model, and show that a sufficiently strong jump in wind driving parameters can, in principle, overcome the effect of reduced radiative driving flux, thus still allowing moderate enhancements in density in an equatorial, bistability zone wind.

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New spectroscopic results for a galactic B[e]-supergiant MWC 314

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New spectroscopic and modeling results obtained for a recently suggested LBV candidate MWC 314 are presented. No photospheric lines have been found in the blue region of its spectrum with a resolution of 0.6 Å. The Balmer line modeling shows that the absence of P Cyg–type absorptions can be explained by the existence of an axi–symmetric stellar wind inclined at 50–60deg to the line of sight and having a viewing angle of 40deg. The refined stellar and wind parameters are as follows: T_*=25000 K, $R_* = 50 R\odot$, $\dot{\mathrm{M}}$ =4 $10^{-5} M \odot\ yr^{-1}$, v_∞=500 $\mathrm{km\,s^{-1}}$. As a first step to study the neutral helium lines, we present several profile calculations of the λ6678 He I line performed by means of the comoving frame method for a spherical expanding envelope to solve the radiative transfer problem.

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Preprints from `fremat@umh.ac.be`

Job Opportunities

Employment Opportunity in Astronomy or Astrophysics at the Université de Montréal

The Astronomy/Astrophysics Group in the Departement de Physique at the Universite de Montreal invites applications for a postdoctoral position in Astronomy or Astrophysics to begin preferably before the end of 1997. The appointment will initially be made for one year, with the possibility of renewal for up to a total of three years. Candidates in all areas will be considered. However, the successful candidate (Ph. D. preferably after July 1st, 1995) is expected to interact strongly with local research staff (see recent list of activities at our Web site).

Applicants should send a curriculum vitae, bibliography, statement of research interests and the names of three references to: Chairman, Astronomy/Astrophysics Group, Departement de Physique, Universite de Montreal, P.O. Box 6128, Station Centreville, Montreal (Quebec), Canada H3C 3J7, or email: moffat@astro.umontreal.ca. In accordance with immigration regulations, preference will be given to citizens or permanent residents of Canada.

The deadline for receipt of applications is: October 15, 1997.

Meetings

IAU Colloqium No. 169: Variable and Non-spherical Stellar Winds in Luminous Hot Stars

At its 70th meeting in Kyoto, the Executive Committee of the International Astronomical Union reviewed the proposals for IAU-sponsored meetings to be held in 1998. We are pleased to announce that the EC approved the proposed Colloquium "Variable and Non-spherical Stellar Winds in Luminous Hot Stars", to be held in Heidelberg, Germany, on June 15-19,1998.

Outline of Scientific Program

1. Observations of non-spherical winds
2. Theories of non-spherical winds
3. Variable winds
4. Pulsation
5. Theories of wind variations
6. Evolutionary aspects

Scientific Organizing Committee

E. Chentsov (Russia), P.S. Conti (USA), R.M. Humphreys (USA), G. Koenigsberger (Mexico), R.P. Kudritzki (Germany), H.J.G.L.M. Lamers (The Netherlands), C. Leitherer (USA),
P. McGregor (Australia), A. Maeder (Switzerland), C. Sterken (Belgium), B. Wolf (chair, Germany)

Local Organizing Committee
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LSW = Landessternwarte Koenigstuhl, Heidelberg
ITA = Institut für Theoretische Astrophysik, Universität Heidelberg
MPIA = Max Planck Institut für Astronomie, Heidelberg

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