

THE HOT STAR NEWSLETTER

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

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editor: Philippe Eenens

eenens@tonali.inaoep.mx

From the editor

If the present rate of abstracts continues, we intend to publish the newsletter MONTHLY. The deadline for the next issue is August 31. If possible, when submitting an abstract, please use the template found at the end of this file.

Please note the new address of the editor, who is starting a new position at the INAOE, near Puebla (Mexico): *eenens@tonali.inaoep.mx*

Abstracts: theory

On the origin of strange modes and the mechanism of related instabilities

W. Glatzel¹

¹ Universitäts – Sternwarte Göttingen, Geismarlandstr. 11, 37083 Göttingen

An attempt to explain the origin of strange modes and the mechanism of related instabilities in terms of a simplified intuitive physical model is presented. The model is based on the requirement of a vanishing luminosity perturbation and investigation of the limit of dominant radiation pressure. Responsible for the existence of strange modes is the run of opacity, which is found by considering a properly defined sound speed. Opacity peaks acoustically decouple different parts of the stellar envelope each of them generating a spectrum of sonic modes some of which were addressed as strange modes in previous investigations. Reexamining the classical work integral instabilities are interpreted in terms of a phase shift between pressure and density perturbation. Provided the fraction of gas pressure is small enough, instability is caused for a finite range of wavenumbers by the differential character of the diffusion equation for energy transport. It is emphasized that the instability mechanism being essentially independent of opacity is not related to the classical κ - mechanism or any other Carnot type process.

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Multiple resonance line scattering and the “momentum problem” in Wolf-Rayet star winds

Uwe Springmann¹

¹ Institut für Astronomie und Astrophysik der Universität München, Scheinerstr. 1, 81679 München, Germany

The possibility of driving the dense winds of Wolf-Rayet stars via multiple scattering of photons in resonance lines is examined. To answer the question as to whether this process can in principle account for the observed high *performance numbers* (Also called wind efficiencies) $\eta = \dot{M}v_\infty/(L_*/c)$ a simple model with a logarithmic frequency distribution of spectral lines is treated by both analytical and numerical (Monte-Carlo) methods. For the case of many overlapping lines it is found that the diffuse radiation arising from the multiple scattering process leads to an even larger radiative acceleration g_{rad} than the previously used *unattenuated flux models* where each line is assumed to interact separately with the unattenuated radiative flux coming directly from the stellar photosphere. The reason for the larger multiple scattering acceleration is shown to result from (1) the diffusive behaviour of the photons which undergo many scatterings before escaping to infinity or being backscattered onto the stellar core and (2) the dependence of the Sobolev length, over which photons interact with a resonance line, on direction. The so-called hemisphere scattering in which a photon bounces back and forth between opposite hemispheres is thereby ruled out as a source of the effectivity of multiple scattering.

The radial dependence of g_{rad} in the outer parts of the wind is now weaker than r^{-2} , in the limiting case of only optically thick lines being proportional to r^{-1} , which leads to a steeper rise in the velocity field. A dynamically consistent model for a WN5 model star wind indicates that performance numbers considerably higher than unity are possible provided that a large number of overlapping lines in the spectral regions where most of the flux is emitted is present throughout the wind. The performance number is shown to be roughly equal to the number of effectively thick lines per overlap interval $\Delta\nu_\infty$.

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Abstracts: observations

On the relative luminosities of the stars in the Wolf-Rayet binary V444 Cygni

A.M.Cherepashchuk¹, G.Koenigsberger², S.V.Marchenko^{2,3} and A.F.J.Moffat⁴

¹ ¹ Sternberg Astronomical Institute, Universitetskij Prospect 13, 117234, Moscow

² Instituto de Astronomía, UNAM, Apartado Postal 70-264, C.P. 04510, México, D.F., México

³ Main Astronomical Observatory of the Ukrainian Academy of Sciences, Goloseevo, 252127 Kiev, Ukraina

⁴ Département de physique, Université de Montréal, C.P. 6128, Succursale A, Montréal, Québec, H3C 3J7 Canada and Observatoire du Mont Mégantic

A new spectroscopic estimate of the luminosity ratio $q = L_{WR}/L_{O6}$ is obtained from the dilution of the absorption lines of the O6V-III component in the WR eclipsing binary V444 Cygni (WN5+O6). We find $q = 0.60 \pm 0.06$ for the range $\lambda\lambda 4000 - 6000\text{\AA}$ and $q = 0.56 \pm 0.13$ from IUE spectra. This clearly indicates that the light of the O6 dominates the combined light of V444 Cyg. This result is in

strong contradiction with the value $q = 3.1$ derived from the light curve solution for V444 Cyg (model with $T_{eff} = 40000$ K for the O-star component) by Hamann & Schwarz (1992), but agrees with the light curve solutions obtained previously by Cherepashchuk (1975) and Cherepashchuk et al. (1984). The discrepancy can be explained if the model of a *homogeneous* extended atmosphere for WR stars applied by Hamann & Schwarz for the determination of q from the emission lines of HeI and HeII is not applicable. Clumpy structure of WR winds proposed in earlier papers (Cherepashchuk et al. 1984; Moffat et al. 1988) should be more applicable.

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High-speed photometry of Wolf-Rayet stars

S. V. Marchenko^{1*}, I. I. Antokhin², J.-F. Bertrand³, R. Lamontagne³, A. F.J. Moffat³,
A. Piceno⁴ and J. M. Matthews⁵

¹ Instituto de Astronomía, UNAM, Apartado Postal 70-264, C.P. 04510, México, D.F., México

* On leave from Main Astronomical Observatory of the Ukrainian Academy of Sciences, Goloseevo, 252127 Kiev, Ukraina

² Sternberg Astronomical Institute, Universitetskij Prospect 13, 117234, Moscow, Russia

³ Département de physique, Université de Montréal, C.P. 6128, Succursale A, Montréal, Québec, H3C 3J7 Canada, and Observatoire du mont Mégantic

⁴ Instituto Nacional de Astrofísica, Óptica y Electrónica, Apdos. Postales 216 y 51, Puebla 72000, Pue., México

⁵ Department of Geophysics and Astronomy, University of British Columbia, 129-2219 Main Mall, Vancouver, BC, V6T 1Z4, Canada

We have monitored 10 bright WR stars at ultra-high (0.005 or 0.01 sec) and/or high (1 or 5 sec) time resolution. Only EZ Cma = WR6 (WN5, periodically variable, non WR + O) shows evidence for a possible period in the range expected for a spun-up pulsar: $P \sim 0.11$ sec. We did not confirm the 10.5 min periodicity recently announced in the WN8 star HD 96548 = WR40.

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A dusty nebula around the luminous blue variable candidate HD168625

D. Hutsemékers¹, E. Van Drom¹, E. Gosset¹, and J. Melnick²

¹ Institut d'Astrophysique, Université de Liège, 5 av. de Cointe, B-4000 Liège, Belgium

² European Southern Observatory, La Silla, Casilla 19001, Santiago 19, Chile

On the basis of narrow-band visible and near-infrared imagery as well as high-resolution spectroscopy, we report the discovery of a new LBV-type nebula around the B supergiant HD168625. We find that it essentially consists of a dusty expanding shell from which seems to emerge a bipolar emission nebula, the whole embedded in a reflection nebulosity. The inner shell is stratified: the continuum emission arises beyond the ionized gas, and is possibly due to scattering of stellar light by large dust grains or to non-equilibrium dust emission. The unexpected presence of unidentified infrared emission bands (UIRs) in the spectrum of this object is also discussed. We finally report the non-detection of a comparable nebula around the nearby LBV HD168607.

Accepted by A & A For preprints, contact hutsemek@astra.astro.ulg.ac.be Electronic copies are available on machine 139.165.20.4 through the anonymous ftp, file /pub/preprints/hd625.ps.Z (compressed postscript)

Excitation of the inner pc of the Galactic Center: results from near-infrared spectroscopy

D. Lutz¹, R. Gentzel¹, A. Krabbe¹, M. Blietz¹,
S. Drapatz¹, P. P. van der Werf¹, F. Najarro² and D. J. Hillier²

¹Max-Planck-Institut für extraterrestrische Physik, Giessenstr., D-85748 Garching bei München, Germany

²Universitätsternwarte München, Scheinerstr. 1, D-81679 München, Germany

We present near-infrared spectroscopy and line imaging of the central 0.5 pc of the Galaxy. The “mini-cavity” region south-west of SgrA* is a source of bright 2.217 μm emission now identified as due to [Fe III]. We infer that iron is released from grains in shocks triggered by fast wind blowing into the Galactic Center gas streamers. After cooling the shocked streamer gas is maintained at about 7000 K by the central UV field. Morphology and dynamics can be explained either by models invoking HeI emission line stars as a local wind source or by models in which a jet from SgrA* acts as an external wind source.

Velocity-resolved spectroscopy of the brightest HeI emission line star in the Galactic Center has been used to constrain atmospheric models. The star is found to be similar to evolved massive stars of type Ofpe/WN9, undergoing heavy mass loss. Helium is overabundant in the atmosphere. Extrapolating from this star it is likely that the Galactic Center HeI stars contribute a large fraction of the total luminosity and a significant fraction of the Lyman continuum luminosity of the central parsec. Hotter stars are needed to provide the HeI ionizing flux.

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The distance to the Wolf-Rayet star HD 50896

Ian D. Howarth¹ and Werner Schmutz²

¹ Department of Physics & Astronomy, University College London, Gower Street, London WC1E 6BT, UK

² Institut für Astronomie, ETH-Zentrum, CH-8092 Zürich, Switzerland

We present high-resolution observations ($R \simeq 10^5$) of the interstellar NaI D lines in the spectra of 23 stars which are close to HD 50896 on the plane of the sky, plus HD 50896 itself. The results are parameterized by using simple cloud models. We confirm that HD 50896 lies beyond the cluster Cr 121 (which is in the same line of sight), and estimate $D \simeq 1.8$ kpc.

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Stellar-wind variability in IUE spectra of 68 Cygni

Ian D. Howarth¹ and Keith C. Smith¹

¹ Dept. Physics & Astronomy, University College London, Gower Street, London WC1E 6BT, UK

We construct an empirical noise model for fully-processed high-resolution, short-wavelength IUE spectra which takes crude account of the spatial variations of the camera response as well as the ripple-correction factors. We use this model to examine the velocity range over which statistically significant variability can be detected in the UV P-Cygni profiles of the O7.5 III: star 68 Cyg, on timescales from days to years. On short timescales, significant absorption-component variability at levels in excess of

$\sim 4\%$ (r.m.s.) of the continuum level is not detected at velocities below $|v| \simeq 800 \text{ km s}^{-1}$ ($\sim 0.34v_\infty$), in Si IV. Over the full dataset (152 spectra spanning 5 years), variability at the 2% level is detected down to $0 \pm 50 \text{ km s}^{-1}$, in C IV. These differences may simply be due to the lower statistical sensitivity of the smaller subsets of data taken over shorter periods, rather than being an indication of long-term variations. The data therefore provide strong evidence on \sim year timescales, and tentative evidence on \sim day timescales, for variability to the very base of the flow.

The emission components of the major resonance-line P-Cygni profiles are effectively constant, with r.m.s. variations not exceeding 4% of the continuum level (with $\sim 98\%$ confidence); the C IV absorption trough is saturated over a velocity range of 530 km s^{-1} ; and the width of the blue edge of the P-Cygni profiles indicates that 68 Cyg has a highly structured wind containing shocks with velocity jumps of at least $\sim 600 \text{ km s}^{-1}$.

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Multi-frequency variations of the Wolf-Rayet system HD 193793 II. Observations of the 1991–92 radio maximum

P.M. Williams¹, K.A. van der Hucht², T.A.Th. Spoelstra³

¹ Royal Observatory, Blackford Hill, Edinburgh EH9 3HJ, Scotland, U.K.

² SRON-Utrecht, Sorbonnelaan 2, NL-3584 CA Utrecht, The Netherlands

³ Netherlands Foundation for Research in Astronomy, P.O. Box 2, NL-7990 AA Dwingeloo, The Netherlands

New observations of the colliding wind Wolf-Rayet WC7+O4-5 binary HD 193793 (WR 140) at 6 cm and 21 cm with the Westerbork Synthesis Radio Telescope are presented. They show that the 21 cm flux, in particular, rose to a sharp maximum in 1992, lagging about a year behind the 6 cm flux. After maximum, both fell simultaneously. The data are interpreted in terms of the varying circumstellar extinction to a non-thermal source where the WC and O winds collide. The rising branch of the flux curve is determined mostly by extinction in the WC stellar wind and the fading branch mostly by that in the O star wind.

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A ring nebula surrounding evolved massive stars in the post-starburst galaxy NGC 1569

Laurent Drissen¹ and Jean-René Roy²

¹ Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218, USA

² Département de Physique, Université Laval, Québec (Qué.), G1K 7P4, Canada

Broad stellar emission lines have been detected in the optical spectrum of a small cluster in the post-starburst galaxy NGC 1569. These lines, He I 5876, H α and He I 6678, have a full width at half maximum of 600 km s^{-1} , and are attributed to a late-type WN star. The cluster, located in the outskirts of the galaxy, is surrounded by a large (radius = 30 pc) ring nebula. This detection of a Wolf-Rayet star is a *direct* evidence of recent ($\leq 5 \text{ Myrs}$) massive ($M_i \geq 40M_\odot$) star formation in NGC 1569.

Accepted by P.A.S.P. *For preprints, contact* drissen@stsci.edu

The Variability of Three O-type Stars: ζ Ophiuchi; ζ Puppis and HD 93521.

Andy Reid¹

¹ Department of Physics & Astronomy, University College London, Gower Street, London WC1E 6BT, UK

Analysis of time-resolved optical spectroscopy of the rapidly rotating O-stars: ζ Ophiuchi (O9.5 V); ζ Puppis (O4 I(n)f); and HD 93521 (O9.5 V), is presented. Extensive datasets were acquired for the first two stars, including coordinated, multi-site observations; these stars represent the principal subjects for investigation. For HD 93521, the data are more fragmentary; however, the echelle nature of the spectra and the similar spectral classification to ζ Oph, justify their inclusion.

For all three stars, the optical observations show line profile variations (lpv) in the form of ‘bumps’ and ‘dips’ migrating from blue to red on typical timescales of several hours. Strong changes in line shape and equivalent width are also observed for ζ Pup. The strength of these variations is dependent upon line species and line strength in all cases. For the two principal stars, the morphology of the lpv is investigated by using a Fourier time-series technique which incorporates the CLEAN deconvolution algorithm. The lpv of the HD 93521 is investigated by comparison with synthetic data generated by a non-radial pulsation (NRP) stellar model. The origin of the lpv in O-stars is controversial; a major aim of this work is to discriminate between photospheric non-radial pulsation, rotational modulation, and variability at the base of the stellar wind, as the cause of the optical variability.

In addition to the optical spectroscopy, narrow-band photometry was available for the primary stars, and, for all three stars, time-resolved IUE ultraviolet spectroscopy (some simultaneous with the optical data). The simultaneous UV data are of particular importance as they allow an investigation of a possible ‘photospheric connection’ between the lpv and the development of enhancements in optical depth within the stellar wind seen as discrete and narrow absorption components in the UV resonance lines.

As a collateral study, the analysis techniques which have been applied to the optical data have been tested on a series of synthetic profiles generated by NRP stellar models. The results from the synthetic data allow a comparison with those obtained on observational data, both given here and in previous studies.

For details of obtaining a copy, contact ahnr@star.ucl.ac.uk

News

Observing Campaign on O-stars

From 14–23 October 1994 we will conduct one more extensive campaign of UV and optical spectroscopy (now including the instrumentation to detect magnetic fields) on O stars, with main targets Xi Per, 68 Cyg, Lambda Cep, 19 Cep, Zeta Ori, and Lambda Ori. H-alpha + He II 4686 that are the most important lines to cover, to test the possible correlation between excess H-alpha emission and the

appearance of a new discrete absorption component in the UV wind lines. Here is the list of the telescopes involved so far. The other participants include Lex Kaper, John Telting, David Bohlender, John Landstreet, Grant Hill, Vilppu Piirola, Ted Kennelly, Yiman Jiang, David McDavid, Huilai Cao, and Yulian Guo.

Telescope	Instrument	Dates	Nights	Remarks
IUE	High res spectroscopy	17 - 21 Oct	5.5	Scheduled
CFHT 4m	UWO polarimeter	17 - 21 Oct	4	Scheduled
OHP 1.5m, France	H alpha spectroscopy	14 - 21 Oct	7	Scheduled
JKT 1m, La Palma	red spectroscopy	14 - 23 Oct	10	Scheduled
NOT 2.5m La Palma	polarimeter, photometer	14 - 23 Oct	10	Applied
TBD Canada	Halpha spectroscopy	14 - 21 Oct	7	Applied
Texas, D. McDavid	polarimetry, photometry	14 - 21 Oct	7	Scheduled
Xinglong China .6m	photometry	14 - 21 Oct	7	Scheduled
Yunnan 1m China	Halpha spectroscopy	14 - 21 Oct	7	Scheduled

We are especially interested in North American observers. Please contact me for more information (I will be out of town between 19 July and 13 August 1994).

Huib Henrichs / huib@astro.uva.nl