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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editor: Philippe Eenens
eenens@andromeda.inaoe.mx

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Accepted Papers

Detection of Wolf-Rayet stars of WN and WC subtype in Super Star Clusters of NGC 5253

Daniel Schaerer[1,2], Thierry Contini[3,4], Daniel Kunth[5] and Georges Meynet[2]

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

[2] Geneva Observatory. CH-1290 Sauverny, Switzerland

[3] UMR 5572, Observatoire Midi-Pyrénées, 14 avenue E. Belin, F-31400 Toulouse, France

[4] Present address: School of Physics and Astronomy, Tel Aviv University, 69978 Tel Aviv, Israel

[5] Institut d'Astrophysique de Paris, 98 bis Bd. Arago, F-75014 Paris, France

We present spectroscopic observations of the central star clusters in NGC 5253 the aim of which is to search for WC stars. Our observations show the presence of Wolf-Rayet (WR) stars not only of WN but also of WC subtype in two star forming regions corresponding to the maximum optical and UV emission. The massive star population we derive is consistent with young bursts of $\sim$ 3 and 4 Myr. The region of maximum optical emission is found to provide the dominant contribution of the ionizing flux as opposed to the less extinguished region of maximum UV brightness. The presence of WR stars near the N-enriched regions found by Walsh & Roy (1987, 1989) and Kobulnicky et al.

(1997) suggests they are a possible source of N. It is presently unclear whether or not our detection of WC stars is compatible with the normal observed He/O and C/O abundance ratios.

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A Compact, Variable Radio Nebula Around P Cygni

C. J. Skinner[1], K. M. Exter[2], M. J. Barlow[3], R. J. Davis[4] and M. F. Bode[5]

[1] Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD21218, USA
[2] School of Physics & Astronomy, University of St. Andrews, North Haugh, St. Andrews, Fife KY16 9SS, UK
[3] Department of Physics & Astronomy, University College London, Gower Street, London WC1E 6BT, UK
[4] Nuffield Radio Astronomy Laboratories, Jodrell Bank, Macclesfield, Cheshire SK11 9DL, UK
[5] School of Chemical and Physical Sciences, Liverpool John Moores University, Byrom Street, Liverpool L3 3AF, UK

We present high spatial resolution images, at a wavelength of 6 cm, of the Luminous Blue Variable star P Cygni. The images fully resolve the core of the stellar wind, and show that it is very clumpy. Two images were taken, separated in time by approximately a month, during which the structure in the wind has changed radically. The total flux observed has also changed significantly. We show that the clump sizes and electron densities are consistent with the radio variability being due to recombination of the ionized gas within the clumps, after key cooling lines become optically thin, causing the free-free emission to disappear. This is the first time that resolved radio images of a hot star wind have been obtained. It also represents important confirmation of a previous observation that thermal free-free wind emission can vary rapidly in a hot stellar wind.

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The LMC transition star R 84 and the core of the LH 39 OB association

M. Heydari-Malayeri[1], F. Courbin[2], G. Rauw[2], O. Esslinger[3], and P. Magain[2]

[1] DEMIRM, Observatoire de Paris, 61 Avenue de l'Observatoire, F-75014 Paris, France
[2] Institut d'Astrophysique, Université de Liège, 5, Avenue de Cointe, B-4000 Liège, Belgium
[3] Department of Physics and Astronomy, University of Wales, College of Cardiff, CF2 3YB, Cardiff, UK

On the basis of sub-arcsecond imaging obtained at the ESO NTT with SUSI and the ESO ADONIS adaptive optics system at the 3.6 m telescope, we resolve and study the core components of the LMC OB association LH 39. The central star of the association, the rare transition object R 84, is also investigated using CASPEC echelle spectroscopy at the ESO 3.6 m telescope. A new, powerful image restoration code that conserves the fluxes allows us to obtain the magnitudes and colors of the components. We bring out some 30 stars in a $\sim 16'' \times 16''$ area centered on R 84. At a resolution of $0''.19$ (FWHM), the closest components to R 84 are shown to be stars #21 and #7 lying at $1''.1$ NW and $1''.7$ NW respectively of the transition star. The former is possibly a blue star of $V = 16.7$ mag and the latter with its $V = 17.5$ mag is the reddest star of the field, after R 84. Star #7 turns out to be too faint to correspond to the red M2 supergiant previously reported to contaminate the spectrum

of R 84. If the late-type spectrum is due to a line-of-sight supergiant with a luminosity comparable to R 84, it should lie closer than $0''.12$ to R 84. The transition star shows spectral variability between 1982 and 1991. We also note some slight radial velocity variations of the Of emission lines over timescales of several years. Furthermore, we derive the spectral types of two of the brightest stars of the cluster, using long slit spectra obtained at the NTT telescope equipped with EMMI, and discuss the apparent absence of O type stars in this association.

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β Pic light variations: I. The planetary hypothesis

A. Lecavelier des Etangs[1,2] A. Vidal-Madjar[1] G. Burki[3]
H.J.G.L.M. Lamers[4] R. Ferlet[1] C. Nitschelm[1] F. Sèvre[1]

[1] Institut d'Astrophysique de Paris, CNRS, 98 bis boulevard Arago, F-75014 Paris, France

[2] NCRA, TATA Institute of Fundamental Research, Post Bag 3, Ganeshkhind, Pune University Campus, Pune 411 007, INDIA

[3] Observatoire de Geneve, CH-1290 Sauverny, Switzerland

[4] Astronomical Institute and SRON Laboratory for Space Research, University of Utrecht, Utrecht, The Nederland

The β Pic disk is probably a young planetary system in the clearing-out phase and similar to ours 4 billion years ago. The understanding of that system may shed light on the origin and evolution of our own planetary system. A very important question is related to the presence of large bodies, from kilometer size to planets. It is shown that many indirect arguments seem to indicate that even large planets must be already formed within the system.

Because it is seen nearly edge-on, photometric observations of the star were carried on in order to detect some signatures of inhomogeneities within the dust disk. This edge-on geometry is also very favorable to detect an eventual occultation by an object orbiting the star. An exceptional and significant photometric event was observed on Julian Day 2444918 (Nov 10, 1981), when the lightcurve shows a brightening during about 10 days with a central dip during less than one day. We discuss several possible explanations. The two most likely ones are: (1) occultation by a planet that is located in the dust disk, with an dust-free area around the planet, (2) the passage of a large cloud of dust with a highly forward peaked scattering in front of the star.

In this paper we model the predicted lightcurve for the occultation by a planet in a dust ring. The model takes into account the partial occultation phase and the limb-darkening effect. Even fine details of the light curve can be explained by this model. We find that the planet is of about Jupiter size and orbits the star at a distance of about 5 AU. We discuss the strong and the weak points of this model. The model of the forward scattering dust cloud is studied in a separate paper.

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Preprints from hennyl@sron.ruu.nl

β Pic light variations: II. Scattering by a dust cloud

H.J.G.L.M. Lamers[1,2] A. Lecavelier des Etangs[3,4] A. Vidal-Madjar[3]

[1] Astronomical Institute, University of Utrecht, Princetonplein 5, NL-3584 CC, Utrecht, The Netherlands

[2] SRON Laboratory for Space Research, Sorbonnelaan 2, NL-3584 CA, Utrecht, The Netherlands

[3] Institut d'Astrophysique de Paris, CNRS, 98 bis boulevard Arago, F75014 Paris, France

[4] NCRA, Tata Institute of Fundamental Research, Post Bag 3, Ganeshkhind, Pune University Campus, Pune 411 007, India

We explain the observed photometric variations of the star β Pic of November 1981 (Lecavelier et al. 1995) in terms of scattering and occultation by a dust cloud that is orbiting the star. The calculations were made for different phase functions for scattering and diffraction. We derived the parameters of the cloud that are compatible with the observed light curve: in particular the distance from the star (between 0.45 and 4 AU) and the effective scattering surface (a few times 10^{24} cm^2). However a spherical dust cloud is inconsistent with the observed photometric variations because its large size cannot explain the short duration of the dip in the light curve. A model consisting of a flat cloud, that is elongated in the orbital plane and has a pointed shape with the largest optical depth closest to the star, can explain the light curve. We suggest that such a cloud could be the result of one large comet that passes the line of sight to the star near periastron, or of a fragmented comet of the type as the Shoemeker-Levi fragments. The model suggests that the comet passes the star at a distance of about 0.4 AU and a dust mass of about 2×10^{21} g. The crucial test of these models is the possible presence (in the case of an orbiting dust cloud) or absence (in the case of a comet) of periodic recurrences of the short time photometric variations.

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Two Ring Nebulae around Blue Supergiants in the Large Magellanic Cloud

K. Weis[1,2], Y.-H. Chu[2], W.J. Duschl[1,3] and D.J. Bomans[2]

[1] Institut für Theoretische Astrophysik, Tiergartenstr. 15, D-69121 Heidelberg, Germany

[2] University of Illinois, Department of Astronomy, 1002 W. Green Street, Urbana, IL 61801, USA

[3] Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, D-53121 Bonn, Germany

Ring nebulae are often found around massive stars such as Wolf-Rayet stars, OB and Of stars and Luminous Blue Variables (LBVs). In this paper we report on two ring nebulae around blue supergiants in the Large Magellanic Cloud. The star Sk−69 279 is classified as O9f and is surrounded by a closed shell with a diameter of 4.5 pc. Our echelle observations show an expansion velocity of 14 km s^{-1} and a high [NII]λ6583Å/Hα ratio. This line ratio suggests nitrogen abundance enhancement consistent with those seen in ejectas from LBVs. Thus the ring nebula around Sk−69 279 is a circumstellar bubble.

The star Sk−69 271, a B2 supergiant, is surrounded by an Hα arc resembling an half shell. Echelle observations show a large expanding shell with the arc being part of the approaching surface. The expansion velocity is $\sim$ 24 km s^{-1} and the [NII]λ6583Å/Hα is not much higher than that of the background emission. The lack of nitrogen abundance anomaly suggests that the expanding shell is an interstellar bubble with a dynamic age of 2×10^5 yr.

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The AG Carinae nebula: abundant evidence for a red supergiant progenitor?

L.J. Smith,[1] M.P. Stroud,[1] C. Esteban[2] and J.M. Vílchez[2]

[1]Department of Physics and Astronomy, University College London, Gower Street, London, WC1E 6BT

[2]Instituto de Astrofísica de Canarias, E-38200 La Laguna, Tenerife, Spain

AG Car is a massive, evolved supergiant which is thought to be in transition from an O star to a Wolf-Rayet (WR) star and is currently identified as a Luminous Blue Variable (LBV) with $\log L/L_\odot = 6.0$. We present an abundance study of the ejecta-nebula surrounding AG Car with the aim of elucidating the evolutionary history of the central star. Physical parameters and abundances are derived for five regions across the nebula from high spatial resolution spectroscopy obtained at the AAT. We derive an average T_e of 6350 ± 400 K, a n_e of $820 \pm 170\,\mathrm{cm}^{-3}$, and find that N is enhanced by a factor of 4.5 ± 1.3 and that O is deficient by a factor of 15.1 ± 7.2. The derived abundances are compared with those determined for ejecta-type nebulae around WR stars and those predicted by hydrodynamical calculations and stellar evolutionary models. We find that the AG Car nebula is composed of mildly processed material which has not reached the CNO-equilibrium abundances predicted for LBV nebulae. The similarity of the AG Car nebular nitrogen abundance to WR nebulae leads us to suggest that the nebulae were ejected at the same evolutionary point, and have undergone no further chemical modification. For AG Car, this point appears to have occurred before the LBV phase because of the observed low nitrogen enrichment. Comparison of the observed nitrogen abundance with evolutionary model predictions indicates that the AG Car nebula may represent the H-rich envelope of a red supergiant (RSG). The problem of a RSG progenitor for AG Car is discussed and it is found that the LBV model of Stothers & Chin (1993, 1996), incorporating a brief unstable RSG phase, is capable of explaining the observations. We conclude that despite its high luminosity, AG Car has probably experienced a brief RSG phase where it ejected its outer layers to form the currently observed nebula.

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ROSAT PSPC Observations of 27 Near-Main-Sequence B Stars

D. H. Cohen[1,2], J. P. Cassinelli[1], and J. J. MacFarlane[1,2]

[1] University of Wisconsin – Madison, Department of Astronomy, 475 N. Charter Street, Madison, WI 53706

[2] University of Wisconsin – Madison, Fusion Technology Institute, 1500 Johnson Drive, Madison, WI 53706

In this paper we report on *ROSAT* PSPC observations of 27 near-main-sequence B stars made with unprecedented sensitivity. Contrary to the results of previous surveys, it is found that 75 percent of the sample stars are X-ray sources, albeit most at modest levels. The X-ray luminosities of the program stars range from 5.6×10^{27} ergs s^{-1} up to 2.2×10^{32} ergs s^{-1}. We find that $L_{\mathrm{X}}/L_{\mathrm{Bol}}$ decreases abruptly

beyond about B0 and stabilizes at $L_X/L_{Bol} \approx 10^{-8.5}$ by about B2, with seven non-detections at B2 and later. For the B0 and B1 stars our modeling suggests wind attenuation of the X-ray photons is significant, so that the emitted X-ray luminosity, corrected for this attenuation, actually exceeds 10^{-7} L_{Bol} in some cases. Presumably this situation is even more severe for O stars, thus the well known $L_X/L_{Bol} \approx 10^{-7}$ law may simply be an artifact of the neglect of wind attenuation. The *ROSAT* PSPC observations of most of the B stars are very soft, with the notable exception of τ Sco (B0 V). The wind emission measure filling factors we find for the very early B stars are rather large (roughly 0.1 to 1). This could be brought into line with theoretical calculations of the line-force instability wind-shock mechanism if the mass loss rates of these stars are a few times higher than theory currently predicts. However the X-rays from stars later than B2 require filling factors greater than unity and so cannot be produced by any radiation-driven wind-shock mechanism because there is simply not enough wind material to produce the observed X-rays. It is possible that mid- to late-B stars represent some kind of transition to, or hybrid of, wind and coronal X-ray mechanisms.

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ASCA X-ray Spectroscopy of the Unusual B0 V Star τ Scorpii

D. H. Cohen[1,2], J. P. Cassinelli[1], and W. L. Waldron[3]

[1] University of Wisconsin – Madison, Department of Astronomy, 475 N. Charter Street, Madison, WI 53706

[2] University of Wisconsin – Madison, Fusion Technology Institute, 1500 Johnson Drive, Madison, WI 53706

[3] Applied Research Corporation, 8201 Corporate Drive, Suite 1120, Landover, MD 20785

We have obtained a high quality *ASCA* spectrum of the MK standard B0 V star τ Sco in order to test the standard wind-shock picture of OB star X-ray production. The fluxes in three line complexes from ions indicative of hot plasma – Mg^{+10}, Si^{+12}, and S^{+14} – are measured, and we also present a global spectral fit using a fairly standard multi-temperature, optically thin, collisional equilibrium model. We were able to achieve a statistically good fit, but only by using the MeKaL plasma emission code (Mewe, Kaastra, & Liedahl 1995) and fixing the elemental abundances at the photospheric values as determined by optical spectroscopy. The parameters of the model are: $T_1 = 7$ MK, $EM_1 = 3.5 \times 10^{54}$ cm^{-3}, $T_2 = 12$ MK, $EM_2 = 8.1 \times 10^{53}$ cm^{-3}, $T_3 > 27$ MK, $EM_3 > 3.0 \times 10^{53}$ cm^{-3}. The quantity of material with temperature in excess of 10^7 K on τ Sco is comparable to that with temperature in excess of 10^6 K on most other early B stars.

The data cannot be explained by the standard line-force instability wind-shock mechanism. However more unusual shock mechanisms involving magnetically confined wind shocks or interactions between infalling matter and the ambient stellar wind cannot be ruled out. Alternately, a dynamo driven by differential rotation could be powering coronal plasma. If magnetic fields are involved in any way then the star's extreme youth could play a role.

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Direct Observations of the Ionizing Star in the UC HII Region G29.96−0.02: A Strong Constraint on the Stellar Birth Line for Massive Stars

Alan M. Watson[1,2], Alison L. Coil[1,3], Debra S. Shepherd[4,5], Peter Hofner[6,7], and Ed Churchwell[4]

[1] Lowell Observatory, 1400 West Mars Hill Road, Flagstaff, AZ 86001

[2] Department of Astronomy, New Mexico State University, Las Cruces, NM 88001

[3] Department of Astrophysical Science, Princeton University, Peyton Hall, Princeton, NJ 08544

[4] Department of Astronomy, University of Wisconsin – Madison, 475 North Charter Street, Madison, WI 53706

[5] Radio Astronomy, California Institute of Technology, Pasadena, CA 91125

[6] Universität zu Köln, I. Physikalisches Institut, Zülpicherstrasse 77, D-50937 Köln, Germany

[7] NAIC, Arecibo Observatory, PO Box 995, Arecibo, PR 00613

We have observed the ultracompact HII region G29.96−0.02 in the near infrared J, H, and K bands and in the Brγ line. By comparison with radio observations, we determine that the extinction to the nebula is $A_K = 2.14$ with a 3σ uncertainty of 0.25. We identify the ionizing star and determine its intrinsic K magnitude. The star does not have an infrared excess and so appears to be no longer accreting. The K magnitude and the bolometric luminosity allow us to place limits on the location of the ionizing star in the HR diagram. The 3σ upper limit on the effective temperature of the ionizing star is 42 500 K. We favor a luminosity appropriate for star with a mass in excess of about 60 $M_\odot$. The limit on the temperature and luminosity exclude stars on the ZAMS and stars within 10^6 yr of the ZAMS. Since the age of the UC HII region is estimated to be only about 10^5 yr, we suggest that this is direct evidence that the stellar birth line for massive stars at twice solar metallicity must be significantly redder than the ZAMS.

Accepted by Ap.J.

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Submitted Papers

Spectroscopic Binary Orbits from Ultraviolet Radial Velocities. Paper 26: HD 165052

D. J. Stickland[1], C. Lloyd[1] and R. H. Koch[2]

[1] Rutherford Appleton Laboratory, Chilton, UK

[2] University of Pennsylvania, USA

High-resolution IUE spectra have been used to re-examine the orbital characteristics of the double-lined O6.5V binary HD 165052. The period found previously on the basis of optical spectra is found to be incorrect and orbital elements based on the new period of 2.95505 days are presented. The low implied inclination, about 20° will be an important constraint for modelling the variability of X-rays produced in the colliding winds.

Submitted to *The Observatory*

Preprints from ds@astro1.bnsc.rl.ac.uk

The ASCA X-ray Spectrum of η Carinae

M. F. Corcoran[1,2], R. Petre[1], J. H. Swank[1], S. A. Drake[1,2]
K. Koyama[3], Y. Tsuboi [3] R. Viotti[4], A. Damineli[5,6]
K. Davidson[7], K. Ishibashi[7], S. White[8], and D. Currie[8]

[1] Laboratory for High Energy Astrophysics, Goddard Space Flight Center, Greenbelt MD 20771

[2] Universities Space Research Association, 7501 Forbes Blvd, Ste 206, Seabrook, MD 20706

[3] Dept. of Physics, Faculty of Science, Kyoto University, Sakyo-ku, Kyoto 606-01, Japan

[4] Instituto Astrofisica Spaziale, CNR, Via E. Fermi 21, 1-00044 Frascati, RM, Italy

[5] Instituto Astronomico e Geofisico da USP, CP 9638, 01065-970- Sao Paulo-Brazil

[6] Joint Institute for Laboratory Astrophysics, Boulder, CO 80309

[7] Department of Astronomy, University of Minnesota, 116 Church St., SE, Minneapolis, MN 55455

[8] Dept. of Physics and Astronomy, University of Maryland, College Park, MD 20742

We have obtained high signal-to-noise 0.5-10 keV band X-ray spectra of the peculiar, extremely luminous star η Carinae with the *Advanced Satellite for Cosmology and Astrophysics* (*ASCA*) X-ray observatory during Cycle 4 observations in mid-1996. These data comprise the best X-ray spectra of the cool source ($kT \sim 0.3$ keV) surrounding the homunculus and of the hot source ($kT \sim 5$ keV) associated with η Car itself. We identify line emission from ions of Mg, Si and S, and numerous strong transitions of Fe in a variety of ionization stages, including the first clear identification of a fluorescent Fe line produced by photoionization of cool material by the X-ray continuum from the hot source. The line strengths are consistent with thermal equilibrium models, though abundances of some important elements are non-solar. Our analysis suggests that Fe is slightly underabundant and S and Si somewhat overabundant. Most importantly we confirm the high N enrichment derived by Tsuboi et al. (1997) from their analysis of a shorter *ASCA* observation obtained during the performance verification (PV) phase in August 1993. The O/N abundance ratio derived from the *ASCA* spectra is consistent with predictions of evolutionary models for extremely massive stars. Comparison of the Cycle 4 and PV-phase spectra shows that the X-ray luminosity increased by $\sim 50\%$ during this 3 year interval. Using the *ASCA* spectral model as a template, we re-evaluate the spectrum of η Car obtained by the *Röntgen Satelite* (*ROSAT*) in late 1992, and construct an X-ray lightcurve for the 1992.4-1996.6 interval. We present spectra from the *International Ultraviolet Explorer* (*IUE*) satellite obtained at nearly the same time as the Cycle 4 *ASCA* spectra, and show that the observed X-ray variability is reflected in changes in some important UV spectral features. Our data suggest that the X-ray emission and state of the stellar wind are intimately connected, though the exact mechanism of coupling is not known. We suggest two alternatives: an underlying photospheric change of undetermined origin in η Car itself, or a collision between a dense stellar wind from η Car and the wind or photosphere of a companion.

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or on the web at `http://lheawww.gsfc.nasa.gov/users/corcoran/bio.html`

In Proceedings

Where's the Disk?: LBV bubbles and Aspherical Fast Winds

Adam Frank[1]

[1] Department of Physics and Astronomy, University of Rochester, Rochester, NY 14627-0171;
email: afrank@alethea.pas.rochester.edu

Previous studies have explained the shapes of LBV nebulae, such as η Car, by invoking the interaction of an isotropic fast wind with a previously deposited, slow *aspherical* wind (a "slow torus"). In this work I focus on the opposite scenario where an aspherical fast wind expands into a previously deposited *isotropic* slow wind. Using high resolution hydrodynamic simulations which include the effects of radiative cooling I have completed a series of numerical experiments to test if and how aspherical fast winds effect wind blown bubble morphologies. The simulations demonstrate that aspherical fast winds can produce strongly bipolar outflows and recover some important aspects of LBV bubbles which the previous models can not.

To Appear in LBVs: Massive Stars in Transition
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Meetings

Proposal for an IAU Colloquium on

Variable and Non-spherical Stellar Winds in Luminous Hot Stars

to be held in Heidelberg (Germany), 15 - 19 June 1998

Scientific Rationale

While it is generally accepted that radiative acceleration is the main mechanism driving the winds, except for the more or less stationary mass loss of some O-stars the winds of the hot stars still retain many secrets. This applies in particular to the very strong and highly variable winds of the Luminous Blue Variable (LBV) evolutionary phase.
There have been recent important discoveries and new developments which resulted in a new view of the mass-loss properties and mechanisms. Spectroscopic time series in the satellite UV (with IUE) and in the groundbased wavelength ranges have shown that time variability is a general characteristic of mass loss of luminous hot stars and that steady state flows do not provide a good description of the observed properties. Rotation and pulsation most likely play an important role in triggering and modifying the mass loss and some observational facts can be explained only by the presence of magnetic fields. Likewise much evidence has been accumulated that the winds are (at least in many cases) non-spherical. In some spectacular cases the asymmetric outflows could be directly imaged with the HST. There are also many new theoretical contributions concerning pulsational effects and

the formation of the observed disks around luminous hot stars.

These recent new results make it desirable to have an IAU Colloquium which brings together the specialists in this field, in order to further develop the emergent concepts of wind variability and asphericity, and in order to try finding answers to these most urgent questions, with the aim of a better physical understanding of the mass loss from hot luminous stars and of the evolutionary consequences.

The Colloquium is waiting for IAU-EC approval.

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. Mc Gregor (Australia), A. Maeder (Switzerland), C. Sterken (Belgium), B. Wolf (Chair, Germany).

Further Information

Information about the planned IAU Colloquium is accessible through the web page
`http://www.lsw.uni-heidelberg.de/iaucoll/`
which will update regularly.