THE MASSIVE STAR NEWSLETTER

formely known as *the hot star newsletter*

⋆

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http://www.astroscu.unam.mx/massive_stars
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Accepted Papers

Can single O stars produce non-thermal radio emission?

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We present a model for the non-thermal radio emission from presumably single O stars, in terms of synchrotron emission from relativistic electrons accelerated in wind-embedded shocks. These shocks are associated with an unstable, chaotic wind. The main improvement with respect to earlier models is the inclusion of the radial dependence of the shock velocity jump and compression ratio, based on one-dimensional time-dependent hydrodynamical simulations. The decrease of the velocity jump and the compression ratio as a function of radius produces a rapidly decreasing synchrotron emissivity. This effectively prohibits the models from reproducing the spectral shape of the observed non-thermal radio emission. We investigate a number of "escape routes" by which the hydrodynamical predictions might be reconciled with the radio observations. We find that the observed spectral shape can be reproduced by a slower decline of the compression ratio and the velocity jump, by the re-acceleration of electrons in many shocks or by adopting a lower mass-loss rate. However, none of these escape routes are physically plausible. In particular, re-acceleration by feeding an electron distribution through a number of shocks, is in contradiction with current hydrodynamical simulations. These hydrodynamical simulations have their limitations, most notably the use of one-dimensionality. At present, it is not feasible to perform two-dimensional simulations of the wind out to the distances required for synchrotron-emission models.

Based on the current hydrodynamic models, we suspect that the observed non-thermal radio emission from O stars cannot be explained by wind-embedded shocks associated with the instability of the line-driving mechanism. The most likely alternative mechanism is synchrotron emission from colliding winds. That would imply that all O stars with non-thermal radio emission should be members of binary or multiple systems.

Reference: to appear in A&A
Status: Manuscript has been accepted

Weblink: http://arxiv.org/abs/astro-ph/0603127

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Star Formation in Space and Time: The Orion Nebula Cluster

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UC Berkeley

We examine the pattern of star birth in the Orion Nebula Cluster (ONC), with the goal of discerning the cluster's formation mechanism. Outside of the Trapezium, the distribution of stellar masses is remarkably uniform, and is not accurately described by the field-star initial mass function. The deconvolved, three-dimensional density of cluster members peaks at the Trapezium stars, which are truly anomalous in mass. Using theoretical pre-main-sequence tracks, we confirm the earlier finding that star formation has accelerated over the past 10 Myr. We further show that the rate of acceleration has been the same for all masses. Thus, there is no correlation between stellar age and mass, contrary to previous claims. Finally, the acceleration has been spatially uniform throughout the cluster.

Our reconstruction of the parent molecular cloud spawning the cluster shows that it had a mass of 6700 solar masses prior to its destruction by the Trapezium. If the cloud was supported against self-gravity by mildly dissipative turbulence, then it contracted in a quasi-static, but accelerating manner. We demonstrate this contraction theoretically through a simple energy argument. The mean turbulent speed increased to its recent value, which is reflected in the present-day stellar velocity dispersion.

The current ONC will be gravitationally unbound once cloud destruction is complete, and is destined to become a dispersing OB association. We hypothesize that similarly crowded groups seen at the centers of distant OB associations are also unbound, and do not give rise to the Galactic population of open clusters. Finally, accelerating star formation implies that most clumps within giant molecular complexes should have relatively low formation activity. Sensitive infrared surveys could confirm this hypothesis.

Reference: ApJ preprint doi:10.1086/'503357'
Status: Manuscript has been accepted

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Variable Unidentified Emission Near 6307 AA in Eta Carinae

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[4] Astronomisches Institut, Ruhr-Universitat Bochum

We have discovered a conspicuous unidentified variable feature near 6307 AA in the spectrum of Eta Carinae which is spatially unresolved from the central star and its wind (r ¡ 200–300 AU). It is significant for two reasons: such prominent unidentified lines are now rare in this object, and this feature varies strongly and systematically. It exhibits a combination of characteristics which, so far as we know are unique in Eta Carinae's spectrum. It may provide insights into the recurrent spectroscopic events and the star's long-term brightening.

Reference: Accepted to appear in May 2006 PASP
Status: Manuscript has been accepted

Weblink: http://arxiv.org/abs/astro-ph/0603168

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Microlensing of Circumstellar Envelopes. III. Line profiles from stellar winds in homologous expansion

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This paper examines line profile evolution due to the linear expansion of circumstellar material observed during a microlensing event. This work extends our previous papers on emission line profile evolution from radial and azimuthal flow during point mass lens events and fold caustic crossings. Both "flavours" of microlensing were shown to provide effective diagnostics of bulk motion in circumstellar envelopes. In this work a different genre of flow is studied, namely linear homologous expansion, for both point mass lenses and fold caustic crossings. Linear expansion is of particular relevance to the effects of microlensing on supernovae at cosmological distances. We derive line profiles and equivalent widths for the illustrative cases of pure resonance and pure recombination lines, modelled under the Sobolev approximation. The efficacy of microlensing as a diagnostic probe of the stellar environs is demonstrated and discussed.

Reference: A&A, in press
Status: Manuscript has been accepted

Weblink: xxx.lanl.gov/abs/astro-ph?papernum=0511551

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The Effective Temperatures and Physical Properties of Magellanic Cloud Red Supergiants: The Effects of Metallicity

Emily M. Levesque (1, 2), Philip Massey (1), K. A. G. Olsen (3), Bertrand Plez (4), George Meynet (5), and Andre Maeder (5)

(1) Lowell Observatory; (2) MIT; (3) CTIO/NOAO; (4) GRAAL CNRS, Univ de Montpellier II; (5) Geneva Observatory

We present moderate-resolution optical spectrophotometry of 36 red supergiants (RSGs) in the LMC and 39 RSGs in the SMC. Using the MARCS stellar atmosphere models to fit this spectrophotometry, we determine the reddenings, effective temperatures and other physical properties, such as bolometric luminosity and effective stellar radii, and compare these to stellar evolutionary models. As a self-consistency check, we also compare the broad-band colors $(V\text{-}K)_0$ and $(V\text{-}R)_0$ with the models. The $(V\text{-}R)_0$ results are in good agreement with those from fitting the optical spectrophotometry, but

the $(V\text{-}K)_0$ results show metallicity-dependent systematic differences, amounting to 3-4% in effective temperature, and 0.2 mag in bolometric luminosity, at the metallicity of the SMC; we conclude that this is likely due to the limitations of static 1D models, as spectra of RSGs in the optical and IR may reflect different atmospheric conditions due to the large surface granulation present in these stars. We adopt the scales indicated by the optical spectrophotometry and $(V\text{-}R)_0$ colors, but accept that there is still some uncertainty in the absolute temperature scales. We find that the effective temperature scales for the LMC and SMC K-type supergiants agree with each other and with that of the Milky Way, while for M-type supergiants the scales are cooler than the Galactic scale by 50 K and 150 K, respectively. This is in the sense that one would expect: since the spectral classification of RSGs is based on the line strengths of TiO, stars with lower abundances of these elements have to be cooler in order to have the same strength. However, this effect is not sufficient to explain the shift in average RSG spectral type between the three galaxies. Instead, it is the effect that metallicity has on the coolest extent of the evolution of a star that is primarily responsible. Our new results bring the RSGs into much better agreement with stellar evolutionary theory, although the SMC RSGs show a considerably larger spread in effective temperatures at a given luminosity than do the LMC stars. This is expected due to the larger effects of rotational mixing in lower-metallicity stars, as higher helium abundance at the surface would lead to higher effective temperatures in the RSG phase. We also find that the distribution of reddening of RSGs in the Clouds is skewed significantly towards higher values, consistent with our recent finding that Galactic RSGs show extra extinction due to circumstellar dust.

Reference: ApJ, in press
Status: Manuscript has been accepted

Weblink: http://www.lowell.edu/users/massey/MCRSG.pdf.gz

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Implications of the metallicity dependence of Wolf-Rayet winds

John J. Eldridge, Jorick S. Vink

Queen's University Belfast and Keele University.

Aims: Recent theoretical predictions for the winds of Wolf-Rayet stars indicate that their mass-loss rates scale with the initial stellar metallicity in the local Universe.We aim to investigate how this predicted dependence affects the models of Wolf-Rayet stars and their progeny in different chemical environments. Methods: We compute models of stellar structure and evolution for Wolf-Rayet stars for different initial metallicities, and investigate how the scaling of the Wolf-Rayet mass-loss rates affects the final masses, the lifetimes of the WN and WC subtypes, and how the ratio of the two populations vary with metallicity. Results: We find significant effects of metallicity dependent mass-loss rates for Wolf-Rayet stars. For models that include the scaling of the mass-loss rate with initial metallicity, all WR stars become neutron stars rather than black holes at twice the solar metallicity; at lower Z, black holes have larger masses. We also show that our models that include the mass-loss metallicity scaling closely reproduce the observed decrease of the relative population of WC over WN stars at low metallicities.

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Status: Manuscript has been accepted

Weblink: http://www.arxiv.org/abs/astro-ph/0603188

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Spectroscopy of massive stars

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Although rare, massive stars, being the main sources of ionizing radiation, chemical enrichment and mechanical energy in the Galaxy, are the most important objects of the stellar population. This review presents the many different aspects of the main tool used to study these stars, i.e. spectroscopy. The first part consists in an introduction on these objects and their physical properties (mass, wind, evolution, relation with their environment). Next, the spectral behaviour of single massive stars is investigated, in the visible as well as in the X-ray domain. Finally, the last part of this paper deals with massive binaries, especially those exhibiting a colliding wind phenomenon.

Reference: Bulletin de la Societe Royale des Sciences de Liege, v75, 20-61 (2006)
Status: Manuscript has been accepted

Weblink: http://www.chimiefs.ulg.ac.be/SRSL/newSRSL/modules/
FCKeditor/upload/File/75_2006/Naze-V75-2006-p20-61.pdf

Comments: Based on lectures given at Padova University (Italy)

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Bringing VY Canis Majoris Down to Size: An Improved Determination of Its Effective Temperature

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The star VY CMa is a late-type M supergiant with many peculiarities, mostly related to the intense circumstellar environment due to the star's high mass-loss rate. Claims have been made that would suggest this star is considerably more luminous ($L \sim 5 \times 10^5 L_\odot$) and larger ($R \sim 2800 R_\odot$) than other Galactic red supergiants (RSGs). Indeed, such a location in the H-R diagram would be well in the "Hayashi forbidden zone" where stars cannot be in hydrostatic equilibrium. These extraordinary properties, however, rest upon an assumed effective temperature of 2800-3000 K, far cooler than recent work have shown RSGs to be. To obtain a better estimate, we fit newly obtained spectrophotometry in the optical and NIR with the same MARCS models used for our recent determination of the physical properties of other RSGs; we also use $V-K$ and $V-J$ from the literature to derive an effective temperatures. We find that the star likely has a temperature of 3650 K, a luminosity $L \sim 6 \times 10^4 L_\odot$, and a radius of $\sim 600 R_\odot$ These values are consistent with VY CMa being an ordinary evolved $15 M_\odot$ RSG, and agree well with the Geneva evolutionary tracks. We find that the circumstellar dust region has a temperature of 760 K, and an effective radius ∼130 AU, if spherical geometry is assumed for the latter. What causes this star to have such a high mass-loss, and large variations in brightness (but with little change in color), remains a mystery at present, although we speculate that perhaps this star (and NML Cyg) are simply normal RSGs caught during an unusually unstable time.

Reference: ApJ, in press
Status: Manuscript has been accepted

Weblink: http://www.lowell.edu/users/massey/VY.pdf.gz

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Discovery of magnetic fields in the β Cephei star ξ^1 CMa and in several Slowly Pulsating B stars

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We present the results of a magnetic survey of a sample of eight β Cephei stars and 26 Slowly Pulsating B stars with FORS 1 at the VLT. A weak mean longitudinal magnetic field of the order of a few hundred Gauss is detected in the β Cephei star ξ^1 CMa and in 13 SPB stars. The star ξ^1 CMa becomes the third magnetic star among the β Cephei stars. Before our study, the star ζ Cas was the only known magnetic SPB star. All magnetic SPB stars for which we gathered several magnetic field measurements show a field that varies in time. We do not find a relation between the evolution of the magnetic field with stellar age in our small sample. Our observations imply that β Cephei stars and SPBs can no longer be considered as classes of non-magnetic pulsators, but the effect of the fields on the oscillation properties remains to be studied.

Reference: MNRAS
Status: Manuscript has been accepted

Weblink: http://www.arxiv.org/abs/astro-ph/0604283

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Bright OB stars in the Galaxy - III. Constraints on the radial stratification of the clumping factor in hot star winds from a combined Halpha, IR and radio analysis

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Recent results strongly challenge the canonical picture of massive star winds: various evidence indicates that currently accepted mass-loss rates, Mdot, may need to be revised downwards, by factors extending to one magnitude or even more. This is because the most commonly used mass-loss diagnostics are affected by "clumping" (small-scale density inhomogeneities), influencing our interpretation of observed spectra and fluxes.

Such downward revisions would have dramatic consequences for the evolution of, and feedback from, massive stars, and thus robust determinations of the clumping properties and mass-loss rates are urgently needed. We present a first attempt concerning this objective, by means of constraining the radial stratification of the so-called clumping factor.

To this end, we have analyzed a sample of 19 Galactic O-type supergiants/giants, by combining our own and archival data for Halpha, IR, mm and radio fluxes, and using approximate methods, calibrated to more sophisticated models. Clumping has been included into our analysis in the "conventional" way, by assuming the inter-clump matter to be void. Because (almost) all our diagnostics depends on the square of density, we cannot derive absolute clumping factors, but only factors normalized to a certain minimum.

This minimum was usually found to be located in the outermost, radio-emitting region, i.e., the radio mass-loss rates are the lowest ones, compared to Mdot derived from Halpha and the IR. The radio

rates agree well with those predicted by theory, but are only upper limits, due to unknown clumping in the outer wind. Halpha turned out to be a useful tool to derive the clumping properties inside r ¡ 3...5 Rstar. Our most important result concerns a (physical) difference between denser and thinner winds: for denser winds, the innermost region is more strongly clumped than the outermost one (with a normalized clumping factor of 4.1 +/- 1.4), whereas thinner winds have similar clumping properties in the inner and outer regions.

Our findings are compared with theoretical predictions, and the implications are discussed in detail, by assuming different scenarios regarding the still unknown clumping properties of the outer wind.

Reference: Astronomy and Astrophysics
Status: Manuscript has been accepted

Weblink: http://www.usm.uni-muenchen.de/people/puls/papers/clpaper.pdf

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Rotational and Cyclical Variability in γ Cassiopeia

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γ Cas is an unusual classical Be star for which the optical-band and hard X-ray fluxes vary on a variety of timescales. We report results of a 9 year monitoring effort on this star with a robotic ground-based (APT) telescope in the B, V filter system as well as simultaneous observations in 2004 November with this instrument and the *Rossi X-ray Timing Explorer (RXTE)* satellite. Our observations disclosed no correlated optical response to the rapid X-ray flares in this star, nor did the star show any sustained flux changes any time during two monitored nights in either wavelength regime. Consistent with an earlier study by Robinson et al. (2002), optical light curves obtained in our new APT program revealed that γ Cas undergoes $\sim$3%-amplitude cycles with lengths of 50–91 days. Our observations in 2004 showed a similar optical cycle. Over the nine days we monitored the star with the *RXTE*, the X-ray flux varied in phase with its optical cycle and with an amplitude predicted from the data in Robinson et al. In general, the amplitude of the V magnitude cycles are 30–40% larger than the corresponding B amplitude, suggesting that the production site of the cycles is circumstellar. The cycle lengths constantly change and can damp or grow on timescales as short as 13 days. We have also discovered a coherent period of 1.21581$\pm$0.00004 days in all our data, which appears consistent only with rotation. The full amplitude of this variation is 0.0060 in both filters, and, surprisingly, its waveform is almost sawtooth in shape. This variation is likely to originate on the star's surface. This circumstance hints at the existence of a strong magnetic field with a complex topology and a possible heterogeneous surface distribution of metals.

Reference: The Astrophysical Journal
Status: Manuscript has been accepted

Weblink:

Email: msmith@stsci.edu

Ionization structure in the winds of B[e] supergiants II. Influence of rotation on the formation of equatorial Hydrogen neutral zones

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2-Astronomical Institute, Utrecht University

Context: B[e] supergiants are known to possess non-spherical winds, and the existence of disks which are neutral in Hydrogen already close to their stellar surface has recently been postulated. A suitable mechanism to produce non-spherical winds seems to be rapid rotation, and at least for three B[e] supergiants in the Magellanic Clouds rotation velocities at a substantial fraction of their critical velocity have been found.

Aims: The aim ouf our research is to find recombination distances in the equatorial plane of rapidly rotating stars that are suitable to explain the observed huge amounts of neutral material in the vicinity of especially B[e] supergiants.

Methods: We perform ionization structure calculations in the equatorial plane around rapidly rotating luminous supergiants. The restriction to the equatorial plane allows us to treat the ionization balance equations 1-dimensionally, while the stellar radiation field is calculated 2-dimensionally, taking into account the latitudinal variation of the stellar surface parameters. The stellar parameters used correspond to those known for B[e] supergiants. The assumptions made throughout the computations have all in common that the total number of available ionizing photons at any location within the equatorial plane is overestimated, resulting in upper limits for the recombination distances.

Results: We find that despite the drop in equatorial surface density of rapidly rotating stars (neglecting effects like bi-stability and/or wind compression), Hydrogen and Helium recombine at or close to the stellar surface, for mass loss rates $\dot{M} \gtrsim 5 \times 10^{-5} \mathrm{M}_{\odot} \mathrm{yr}^{-1}$ and rotation speeds in excess of $v_{\mathrm{rot,eq}}/v_{\mathrm{crit}} \simeq 0.8$.

Reference: Astronomy & Astrophysics
Status: Manuscript has been accepted

Weblink: http://arxiv.org/abs/astro-ph/0605153

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Models of Forbidden Line Emission Profiles from Axisymmetric Stellar Winds

Richard Ignace and Adam Brimeyer

East Tennessee State University

A number of strong infrared forbidden lines have been observed in several evolved Wolf-Rayet star winds, and these are important for deriving metal abundances and testing stellar evolution models. In addition, because these optically thin lines form at large radius in the wind, their resolved profiles carry an imprint of the asymptotic structure of the wind flow. This work presents model forbidden line profile shapes formed in axisymmetric winds. It is well-known that an optically thin emission line formed in a spherical wind expanding at constant velocity yields a flat-topped emission profile shape. Simulated forbidden lines are produced for a model stellar wind with an axisymmetric density distribution that treats the latitudinal ionization self-consistently and examines the influence of the ion stage on the profile shape. The resulting line profiles are symmetric about line centre. Within a given

atomic species, profile shapes can vary between centrally peaked, doubly peaked, and approximately flat-topped in appearance depending on the ion stage (relative to the dominant ion) and viewing inclination. Although application to Wolf-Rayet star winds is emphasized, the concepts are also relevant to other classes of hot stars such as luminous blue variables and Be/B[e] stars.

Reference: To appear in MNRAS
Status: Manuscript has been accepted

Weblink: http://www.etsu.edu/physics/ignace/pubs.html

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Submitted Papers

Particle Re-Acceleration in Colliding Winds Systems? Radio, X-ray, and Gamma-ray Emission Models of WR 140

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NRC/HIA, Dominion Radio Astrophysical Observatory, Penticton, Canada

We present calculations of the spatial and spectral distribution of the radio, X-ray and gamma-ray emission from shock accelerated electrons in the wind-collision region (WCR) of WR140. Our calculations are for orbital phase 0.837 when the observed radio emission is close to maximum. Using the observed thermal X-ray emission at this phase in conjunction with the radio emission to constrain the mass-loss rates, we find that the O-star mass-loss rate is consistent with the reduced estimates for O4-5 supergiants by Fullerton et al. (2005), and the wind momentum ratio, eta = 0.02.

The observed low frequency turnover at approximately 3 GHz in the radio emission is due to free-free absorption, since models based on the Razin effect have an unacceptably large fraction of energy in non-thermal particles. A key result is the index of the non-thermal electron energy distribution is flatter than the canonical value for diffusive shock acceleration (DSA), namely p¡2. It is argued that this requires re-acceleration of non-thermal particles in multiple wind-embedded shocks, which are then injected as seed particles for further acceleration at the global shocks bounding the WCR.

There are some tantalizing hints that shock modification occurs in these systems. For example, the estimated amount of energy placed into non-thermal particles is high enough that non-linear effects should be important, and changes in the degree of shock modification with orbital phase may account for the asymmetry of the radio lightcurve and the smaller than expected variation in the X-ray lightcurve. Shock modification also results in softer X-ray emission from the post-shock plasma due to a reduction in the velocity jump across the subshock. While this is also consistent with observations, the long timescale for energy transfer between the post-shock ions and electrons may be the dominant cause.

Tighter constraints on p and the nature of the shocks in WR140 will be obtained from future observations at MeV and GeV energies, for which we generally predict lower fluxes than previous work. Since the high stellar photon fluxes prevent the acceleration of electrons beyond gamma 1e5-1e6, TeV emission from CWB systems will provide unambiguous evidence of pion-decay emission from accelerated ions. We finish by commenting on the emission and physics of the multiple wind collisions in dense stellar clusters, paying particular attention to the Galactic Centre.

Reference: MNRAS (submitted)
Status: Manuscript has been submitted

Weblink: http://xxx.lanl.gov/abs/astro-ph/0603787

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Jobs

Research Positions in Astrophysics Brussels, Belgium

Ronald Van der Linden

Royal Observatory of Belgium Ringlaan 3 B-1180 Brussels Belgium

Two tenure-track research positions in astrophysics are vacant at the Royal Observatory of Belgium (ROB), situated in Brussels, Belgium.

Applicants should have a Master degree in sciences, a degree in civil engineering or a PhD in (applied) sciences. Candidates must be citizens of a country of the European Economic Area.

The successful candidates are expected to conduct active research in stellar astrophysics. The main topics studied in this field at the ROB are: massive stars and stellar winds, post-AGB stars and planetary nebulae, variable stars and asteroseismology, binary stars and stellar groups (including astrometry).

Please note that linguistic constraints exist which must also be fulfilled (see selection criteria detailed in the links below).

The deadline for receipt of applications is May 3, 2006.

For detailed information about the application and the selection criteria, see:

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http://www.ejustice.just.fgov.be/cgi/article_body.pl?language=nl&caller=sum
  mary&pub_date=2006-03-24&numac=2006021042  (in Dutch)
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  mary&pub_date=2006-03-24&numac=2006021042  (in French)
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http://www.belspo.be/belspo/home/jobs/pages/KSB240306sel_2.pdf  (in Dutch/French)
or, contact the Director of the ROB (e-mail: ronald.vanderlinden@oma.be)
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Email: Ronny.Blomme@oma.be

Deadline: May 3, 2006

Meetings

Circumstellar Media and Late Stages of Massive Stellar Evolution

September 4-8, 2006

Venue: Ensenada, Baja California, Mexico

Weblink: http://www.astrosen.unam.mx/∼ggs/Ens2006.html

Scientific Rationale

Core collapse supernovae and many gamma-ray bursts explode in a medium which was structured by the massive and energetic pre-supernova outflows of their predecessors, e.g., Wolf-Rayet stars or Red Supergiants. How does the late stellar evolution affect the circumstellar medium structure? How is matter expelled in the explosion interacting with this circumstellar matter? And how does this affect the observable remnant or afterglow evolution? These questions are not yet well explored, but trigger an increasing interest in the community. This meeting brings together experts on stellar evolution, circumstellar medium, young supernova remnants, and gamma-ray burst afterglows, to foster productive communication amongst the theorists and observers in these fields.

Topics

1) SN/GRB progenitors and their CSM 2) Effets of binarity, binary progenitors, SNe Ib/Ic, SN1987a, ... 3) SN Ejecta and their interaction with the CSM 4) Cas A and young SNRs 5) Gamma-ray bursts and their afterglows 6) High redshift / low metallicity , Pop III & pair instability GRB hosts/environments, SN/GRB rates

Scientific Organizing Committee

N. Brickhouse, A. J. Castro-Tirado, R. Chevalier, Y.-H. Chu , D. Cox, J. Franco, C. Fransson, G. Garcia-Segura, U. Hwang, N. Langer, E. Ramirez-Ruiz, M. Rupen, R. Terlevich, J. Vink

Local Organizing Committee

G. Garcia-Segura, J. A. Lopez, M. Rozas, G. Tovmasian, L. Hernandez

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The Formation of Massive Stars

Monday, 10 September 2007 - Friday, 14 September 2007

Venue: Heidelberg/Germany

Email: beuther@mpia.de