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Abstract of recently accepted papers

The 1995-1996 Decline of R Coronae Borealis – High Resolution Optical Spectroscopy

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A set of high-resolution optical spectra of R CrB acquired before, during, and after its 1995-1996 decline is discussed. All of the components reported from earlier declines are seen. This novel dataset provides new information on these components including several aspects not previously seen in declines of R CrB and other RCBs. In the latter category is the discovery that the decline's onset is marked by distortions of absorption lines of high-excitation lines, and quickly followed by emission in these and in low excitation lines. This 'photospheric trigger' implies that dust causing the decline is formed close to the star. These emission lines fade quickly. After 1995 November 2, low excitation narrow (FWHM $\sim$ 12 km s^{-1}) emission lines remain. These appear to be a permanent feature, slightly blue-shifted from the systemic velocity, and unaffected by the decline except for a late and slight decrease of flux at minimum light. The location of the warm dense gas providing these lines is uncertain. Absorption lines unaffected by overlying sharp emission are greatly broadened, weakened, and red-shifted at the faintest magnitudes when scattered light from the star is a greater contributor than direct light transmitted through the fresh soot cloud. A few broad lines (FWHM $\simeq$ 300 km s^{-1}) are seen at and near minimum light with approximately constant flux: prominent among these are the He I triplet series, Na I D, and [N II] lines. These lines are blue-shifted by about 30 km s^{-1} relative to the systemic velocity with no change in velocity over the several months for which the lines were seen. It is suggested that these lines, especially the He I lines, arise from an accretion disk around an unseen compact companion, which may be a low-mass white dwarf. If so, R CrB is similar to the unusual post-AGB star 89 Her.

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On the formation of hydrogen-deficient post-AGB stars

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We present an evolutionary sequence of a low mass star from the Asymptotic Giant Branch (AGB) through its post-AGB stage, during which its surface chemical composition changes from hydrogen-rich to strongly hydrogen-deficient as consequence of a very late thermal pulse, following the so-called *born-again scenario.* The internal structure and abundance changes during this pulse are computed with a numerical method which allows the physically consistent calculation of stellar layers where thermonuclear and mixing time scale are comparable — a situation which occurs when the helium flash driven convection zone extends to the hydrogen-rich surface layers during the pulse peak. The final surface mass fractions are [He/C/O]=[0.38/0.36/0.22], where the high oxygen abundance is due to diffusive overshoot employed during the AGB evolution. These models are the first to achieve general agreement with the surface abundance pattern observed in hydrogen-deficient post-AGB stars — e.g. the PG 1159 stars or the WR-type central stars of planetary nebulae —, confirming the born-again scenario with a physically consistent calculation and supporting the occurrence of convective overshooting in thermally pulsing AGB stars.

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Sodium production in asymptotic giant branch stars

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A new scenario is presented for the production of ^{23}Na in asymptotic giant branch (AGB) stars. The scenario takes advantage of the periodic third dredge-up episodes characterizing those stars, which mix primary ^{12}C from their intershell layers to their surface. Two successive interpulse/pulse/dredge-up sequences are then required to produce ^{23}Na. During the first sequence carbon and oxygen are converted into ^{14}N by the hydrogen burning shell, and subsequently transformed into ^{22}Ne by the helium burning shell. During the second sequence, ^{22}Ne is converted into ^{23}Na by the hydrogen burning shell, which is brought to the surface by the subsequent dredge-up episode. The ^{23}Na produced by this scenario is thus primary.

The efficiency of this scenario is analyzed through standard evolutionary AGB model predictions combined with synthetic calculations for the surface chemical evolution. It is shown that primary ^{23}Na can efficiently be produced as soon as the surface C+N+O abundance enhancement reaches a certain level depending on the stellar metallicity. The required surface C+N+O abundance enhancement amounts to $\sim$0.4 dex in solar metallicity stars, and to $\sim$0.8 dex at a metallicity five times less than solar.

An *analytical* study of Na production further reveals that the surface ^{23}Na abundance asymptotically evolves to a 'line of primary sodium enrichment' (LOPSE) in the [C+N+O]−[^{23}Na] diagram. That LOPSE represents the ^{23}Na abundance evolution predicted in zero metallicity AGB stars experiencing third dredge-up episodes. An analytical relation for the surface ^{23}Na abundance evolution as a function of the surface C+N+O abundance is provided.

The predicted surface ^{23}Na enhancements can exceed 0.5 dex depending on the level of surface ^{12}C enrichment, and increases with decreasing stellar metallicity. The quantitative prediction of ^{23}Na surface abundances, however, is presently subject to a high level of uncertainty, partly due to the still poor quantitative prediction of the structural evolution of AGB stars (dredge-up episodes in particular), and partly due to the uncertainties still affecting some nuclear reaction rates (such as ^{23}Na destruction by proton capture).

The case of massive AGB stars in which hot bottom burning occurs is also discussed. The production of secondary sodium in those stars is a natural consequence of ^{22}Ne burning in their envelope, if the temperature at the base of the envelope exceeds 70 million K. It requires, however, many interpulses to be significant. The production of primary sodium from the dredge-up of primary ^{22}Ne and its subsequent burning in the envelope, on the other hand, is estimated not to be very efficient, expect maybe in low-metallicity stars.

An eventual detection of high Na overabundances in carbon stars or related objects would support the scenario of primary sodium production in AGB stars. Such an observational evidence may have been found in at least one post-AGB star. Further observations of those objects are called for. Observations of ^{23}Na in planetary nebulae are also encouraged. Finally, the production of primary ^{23}Na by AGB stars, if confirmed observationally, may have played a non-negligible role in the chemical evolution of our Galaxy.

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Stability and energetics of mass transfer in double white dwarfs

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The donor star in an interacting double white dwarf lies deep within the potential well of the accretor, a condition which both alters the minimum mass transfer rate needed to generate an Eddington luminosity, and limits the fraction of matter which can be driven from the binary in a super-Eddington wind. That mass loss itself alters the threshold condition for the onset of dynamical instability of the donor star. We show that, unless the mass of the accreting star is extremely near the Chandrasekhar limit, a significant fraction (exceeding 0.5 for accretors of mass $< 1M_{\odot}$) must be retained, even when the nominal accretion luminosity far exceeds the Eddington limit. In super-Eddington accretion, the accreted envelope almost certainly extends beyond the orbit of the donor, and will trigger white dwarf merger in a common envelope.

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Tip-AGB stellar evolution in the presence of a pulsating, dust-induced "superwind"

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We present selected "superwind" mass-loss histories and the related tip-AGB stellar evolution models, which have been computed according to the characteristics of a dust-induced, carbon-rich wind, and which include several recent improvements as compared to Schröder et al. (1998). We discuss the (initial) stellar mass-range of 1 to 2.5 $M_{\odot}$, with a nearly solar composition (X=0.28, Y=0.70, Z=0.02). In each time-step, mass-loss rates

are used, which are consistent with the actual stellar parameters, and which are based on our pulsating, dust-induced wind models for carbon-rich stars (Fleischer et al. 1992), including a detailed and consistent treatment of dust formation, radiative transfer and radiative wind acceleration.

The resulting "superwind" mass-loss rates reach 2 to $3 \cdot 10^{-5} M_{\odot} \mathrm{yr}^{-1}$. For this reason, they become an influential factor of tip-AGB stellar evolution – but also vice versa, since our mass-loss rates vary strongly with effective temperature ($\dot{M} \propto T_{\rm eff}^{-8}$ (roughly), see Arndt et al. 1997), reflecting the temperature sensitivity of the dust formation process on a macroscopic scale.

With all tip-AGB models of an initial stellar mass $M_i > 1.3 M_{\odot}$ we find superwinds with a total mass outflow of 0.26 to $> 0.55 M_{\odot}$ during their final $3 \cdot 10^4$ yrs, just as required for PN-formation. Furthermore, a thermal pulse leads to a very short (100 to 200 yrs) interruption of the "superwind" of these models.

A critical (Eddington-like) luminosity L_c is required for the radiation driven wind models, which our evolution models fail to reach for $M_i < 1.1 M_{\odot}$. With slightly larger stellar masses, $L_{\rm tAGB}$ is near L_c and thermal pulses can trigger very short "superwind" bursts, as already pointed out by Schröder et al. (1998). We find good agreement between our improved models and the mass-loss characteristics of the thin CO shells found by Olofsson et al. (1990, 1993, 1996, 1998) around some carbon-rich Mira stars.

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Optical properties of carbon grains: Influence on dynamical models of AGB stars

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For amorphous carbon several laboratory extinction data are available, which show quite a wide range of differences due to the structural complexity of this material. We have calculated self-consistent dynamic models of circumstellar dust-shells around carbon-rich asymptotic giant branch stars, based on a number of these data sets. The structure and the wind properties of the dynamical models are directly influenced by the different types of amorphous carbon. In our test models the mass loss is not severely dependent on the difference in the optical properties of the dust, but the influence on the degree of condensation and the final outflow velocity is considerable. Furthermore, the spectral energy distributions and colours resulting from the different data show a much wider spread than the variations within the models due to the variability of the star. Silicon carbide was also considered in the radiative transfer calculations to test its influence on the spectral energy distribution.

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An HST Snapshot Survey of Proto-Planetary Nebulae Candidates: Two Types of Axisymmetric Reflection Nebulosities

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We report the results from an optical imaging survey of proto-planetary nebula candidates using the *Hubble Space Telescope* (*HST*). The goals of the survey were to image low surface brightness optical reflection nebulosities around proto-planetary nebulae and to investigate the distribution of the circumstellar dust, which scatters the star light from the central post-asymptotic giant branch star and creates the optical reflection nebulosities.

We exploited the high resolving power and wide dynamic range of *HST* and detected nebulosities in 21 of 27 sources. The reduced and deconvolved images are presented along with photometric and geometric measurements. All detected reflection nebulosities show elongation, and the nebula morphology bifurcates depending on the degree of the central star obscuration. The Star-Obvious Low-level-Elongated (SOLE) nebulae show a bright central star embedded in a faint, extended nebulosity, whereas the DUst-Prominent Longitudinally-EXtended (DUPLEX) nebulae have remarkable bipolar structure with a completely or partially obscured central star. The intrinsic axisymmetry of these proto-planetary nebula reflection nebulosities demonstrates that the axisymmetry frequently found in planetary nebulae predates the proto-planetary nebula phase, confirming previous independent results. We suggest that axisymmetry in proto-planetary nebulae is created by an equatorially enhanced superwind at the end of the asymptotic giant branch phase. We discuss that the apparent morphological dichotomy is caused by a difference in the optical thickness of the circumstellar dust/gas shell with a differing equator-to-pole density contrast. Moreover, we show that SOLE and DUPLEX nebulae are physically distinct types of proto-planetary nebulae, with a suggestion that higher mass progenitor AGB stars are more likely to become DUPLEX proto-planetary nebulae.

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Predicting Stellar Angular Sizes

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Reliable prediction of stellar diameters, particularly angular diameters, is a useful and necessary tool for the increasing number of milliarcsecond resolution studies being carried out in the astronomical community. A new and accurate technique of predicting angular sizes is presented for main sequence stars, giant and supergiant stars, and for more evolved sources such as carbon stars and Mira variables. This technique uses observed K and either V or B broad-band photometry to predict $V = 0$ or $B = 0$ zero magnitude angular sizes, which are then readily scaled to the apparent angular sizes with the V or B photometry. The spread in the relationship is 2.2% for main sequence stars; for giant and supergiant stars, 11-12%; and for evolved sources, results are at the 20-26% level. Compared to other simple predictions of angular size, such as linear radius-distance methods or black-body estimates, zero magnitude angular size predictions can provide apparent angular sizes with errors that are 2 to 5 times smaller.

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The composition and nature of the dust shell surrounding the binary AFGL 4106

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We present infrared spectroscopy and imaging of AFGL 4106. The 2.4-5 μm ISO-SWS spectrum reveals the presence of a cool, luminous star ($T_{\rm eff} \approx 3750$ K) in addition to an almost equally luminous F star ($T_{\rm eff} \approx 7250$ K). The 5 – 195 μm SWS and LWS spectra are dominated by strong emission from circumstellar dust. We find that the dust consists of amorphous silicates, with a minor but significant contribution from crystalline silicates. The amorphous silicates consist of Fe-rich olivines. The presence of amorphous pyroxenes cannot be excluded but if present they contain much less Fe than the amorphous olivines. Comparison with laboratory data shows that the pure Mg-end members of the crystalline olivine and pyroxene solid solution series are present. In addition, we find strong evidence for simple oxides (FeO and Al_2O_3) as well as crystalline H_2O ice. Several narrow emission features remain unidentified.

Modelling of the dust emission using a dust radiation transfer code shows that large grains ($\approx 1\mu$m) must be present and that the abundance of the crystalline silicates is between 7 and 15% of the total dust mass, depending on the assumed enstatite to forsterite ratio, which is estimated to be between 1 and 3. The amorphous and crystalline dust components in the shell do not have the same temperature, implying that the different dust species are not thermally coupled. We find a dust mass of $\approx 3.9 \cdot 10^{-2}$ $M_\odot$ expelled over a period of $\approx 4 \cdot 10^3$ years for a distance of 3.3 kpc. The F-star in the AFGL 4106 binary is likely a post-red-supergiant in transition to a blue supergiant or WR phase.

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or via WWW on http://www.astro.uva.nl/ frankm/papers.html

Six years of short-spaced monitoring of the v=1 and v=2 J=1–0 ^{28}SiO maser emission in evolved stars

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We present the results from a monitoring of the v=1 and v=2 J=1–0 ^{28}SiO maser emission in 21 objects, covering all types of known SiO maser emitters: 13 Mira variables, 2 long period semiregulars (SRGs), 3 variable supergiants (SGs), 2 OH/IR stars, and one young stellar object. This study has been carried out with the 13.7 meter radiotelescope of the Centro Astronómico de Yebes (Guadalajara, Spain), from July 1984 to May 1990, and represents the longest and most tightly sampled monitoring of SiO masers ever published.

Our data show that for Mira-type (i.e. regular) variables, the SiO and optical light curves agree in period, and that the maxima of the SiO emission lag the optical ones by about 0.1–0.2 periods. Since a similar lag characterizes the near infrared (NIR) emission variability from these stars, we conclude that for regular variables SiO and NIR vary in phase. This result was confirmed in three objects for which NIR variability curves are available. For SRGs and SGs, we found a less systematic behavior, but when the SiO emission is periodic, its variability curve agrees with the optical one, also showing a lag between maximum epochs similar to that of Mira-type stars. The data clearly reveal other interesting details on the SiO maser variability, such as the strong intensity differences between different maxima and changes in the velocity distribution of the emission. Finally, the SiO masers associated to the young stellar object Orion IRc2 showed a double peaked spectrum with low amplitude, aperiodic variations.

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Observations of Water Masers Associated with the Proto-Planetary Nebula Candidate IRAS 19296+2227

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We present the first VLBI observations of the $6_{16} - 5_{23}$, 22-GHz H_2O maser emission associated with a proto-planetary nebula candidate. We obtained three epochs of observation of the water masers associated with IRAS 19296+2227 using the Very Long Baseline Array operated by the National Radio Astronomy Observatory. These observations show that the water masers are distributed over a 50 mas arc-like structure covering a limited velocity range of $\sim$9 km s^{-1}. The masers most likely reside in an AGB-like circumstellar shell, although we cannot rule out the possibility that they lie in a shocked region. Over the 40 days spanning the epochs of observation, we have measured an error weighted average proper motion of 6.16 ± 1.31 km s^{-1}, indicating that the masers are not in a high velocity outflow.

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SN 1987A's Circumstellar Envelope, II: Kinematics of the Three Rings and the Diffuse Nebula

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We present several different measurements of the velocities of structures within the circumstellar envelope of SN 1987A, including the inner, equatorial ring (ER), the outer rings (ORs), and the diffuse nebulosity at radii $\leq$ 5 pc, based on CTIO 4m and *HST* data. A comparison of STIS and WFPC2 [N II]λ6583 loci for the rings show that the ER is expanding in radius at (10.5$\pm$0.3) km s^{-1} (with the northern OR expanding along the line of sight at $\sim$26 km s^{-1}, and for the southern OR, $\sim$23 km s^{-1}). The best fit to CTIO 4m/echelle spectra of the [N II]λ6583 line show the ORs expanding at $\sim$23 km s^{-1} along the line of sight. Accounting for inclination, the best fit to all data for the expansion in radius of both ORs is 26 km s^{-1}. The ratio of the ER to the OR velocity is nearly equal to the ratio of the ER to the OR radius, so the rings are roughly homologous, all having been created $\sim$20,000 yr before the SN explosion. This makes the previously reported, large compositional differences between the ER and ORs difficult to understand. Additionally, a grid of longslit 4m/echelle spectra centered on the SN shows two velocity components over a region roughly coextensive with the outer circumstellar envelope extending $\sim$5 pc (20 arcsec) from the SN. One component is blueshifted $\sim$10 km s^{-1} relative to the systemic velocity of the SN, while the other is redshifted by a similar amount. These features may represent a bipolar flow expanding from the SN, in which the ORs are propelled 10-15 km s^{-1} faster than that of the surrounding envelope into which they propagate. The kinetic timescale for the entire nebula is $\geq$350,000 yr (and probably more since material may be accumulating in an outer contact discontinuity). The kinematics of these different structures constrain possible models for the evolution of the progenitor and its formation of a mass loss nebula.

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The First Stellar Abundance Measurements in the Galactic Center: the M Supergiant IRS 7

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The first measurement of the photospheric abundances in a star at the Galactic Center are presented. A detailed abundance analysis of the Galactic Center M2 supergiant IRS 7 was carried out using high-resolution near-infrared echelle spectra. The Fe abundance for IRS 7 was found to be close to solar, [Fe/H] = -0.02 ± 0.13, and nearly identical to the Fe abundances we obtained for the nearby M supergiants α Ori and VV Cep. Analysis of the first and second overtone lines of CO was used to derive an effective temperature of 3600 ± 230 K, a microturbulent velocity of 3.0 ± 0.3 km s^{-1}, and a carbon abundance log ϵ(C) = 7.78 ± 0.13, or [C/H] = -0.77. In addition, we find a high depletion of 0.74 ± 0.32 dex in O and an enhancement of 0.92 ± 0.18 dex in N. These abundances are consistent with the dredge-up of CNO-cycle products but require deep mixing in excess of that predicted by standard models for red supergiants. In light of our measured solar Fe abundance for IRS 7, we discuss other indicators of metallicity at the Galactic Center, the interpretation of low-resolution near-infrared spectra of late-type giants and supergiants, including the need for caution in using such spectra as measures of metallicity,and the evolution of massive young stars at the Galactic Center. We suggest thepossibility that rapid stellar rotation is common for stars formed under conditions in the Galactic Center, and that extra internal mixing induced by high rotation rates, rather than evolution at high metallicity, is the explanation for many of the unusual properties of the hot emission-line stars inthe Galactic Center.

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Accretion disks in pre-planetary nebulae

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A number of planetary nebulae (PNs) exhibit collimated, high-velocity outflows or jets. These hydrodynamical structures can not be easily accommodated within the classical models of evolution of post-AGB stars and understanding them has become a topical problem in PN research. One way to explain the existence of jets in PNs has been to invoke the presence of accretion disks which would presumably set the conditions for the collimation and driving of the outflows. This work investigates in detail the type of binary systems that are likely to lead to Roche lobe overflow (RLOF) and the formation of accretion disks as a consequence of common envelope evolution, and explores the expected basic physical structure of such disks. The results of the analysis show substantial restrictions in the composition of binary system that can form a disk upon accretion onto the primary. Typically, it is found that for a primary AGB core of 0.6 $M_\odot$ and envelope mass of 2-3 $M_\odot$, secondaries with $M_2 \geq 0.08$ $M_\odot$ and initial separation $a_i \geq 200$ $R_\odot$ will not lead to RLOF. For those systems that do lead to RLOF this is achieved at orbital separations < 2 $R_\odot$. We also find that dynamically stable mass transfer from secondaries with $M_2 \geq 0.08 M_\odot$ does not lead to disk formation as the circularization radius lies below the surface of the AGB core. Only lower mass companions, after a dynamically unstable mass transfer process, may lead to disk formation. Under reasonable simplifying assumptions, we estimate the resulting accretion disk properties and evolution, and discuss their potential role in driving collimated outflows.

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Kinematics of BD+30°3639

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In this paper we describe the results of the first optical kinematic study of the planetary nebula BD+30°3639. This system has a central star of the Wolf-Rayet type and is believed to be fairly young. Emission line spectra were obtained at high spectral and spatial resolution using the Utrecht echelle spectrometer at the William Herschel Telescope. These spectra indicate that the main ionized shell of BD+30°3639 appears to be evolving in a more complex way than previously thought.

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