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Abstracts of recently accepted papers

Infrared giants vs. supergiants II. CO Observations

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We report systematic observations of millimeter CO emission from a sample of 109 oxygen–rich evolved stars (AGB and supergiants), colour–selected from the IRAS Point Source Catalog ($0.69 < S_{25\mu m}/S_{12\mu m} < 1.20$). CO(1–0) has been searched with good sensitivity in 81 sources (74% of the sample). CO(1–0) is detected in 54 sources and a significant upper limit has been achieved in 27 sources.

In our previous paper we reported on the statistical results of these observations. We showed that in almost 50% of the sources, the ratio of the IRAS 60μm flux to CO intensity, $\mathcal{R} = S_{60}/T_{mb}(1-0)$, is larger by a factor of 3 to more than 10 than what is expected according to the correlation found by Nyman et al. (1992). Supergiants only exhibit very high values ($\gtrsim$200). In most cases, the observed spread in the values of this ratio can be explained by a large range of luminosities. This leads to a new criterion to identify AGB stars: an object with $\mathcal{R} < 150$ must have a low mass progenitor.

Here we study the correlations between $\mathcal{R}$ and various physical properties of the sources. Most sources with high values of $\mathcal{R}$ also have low galactic latitudes, small IRAS variability indices, and early spectral types (typically M1–M5). Conversely, there is no dependence on the IRAS colours, nor on the intensity of silicate 10μm emission. However, a few AGB stars exhibit large $\mathcal{R}$; other factors than luminosity are required to explain these values. Different hypotheses, such as the possible presence of a chromosphere, a low ^{12}C abundance or a variable mass–loss rate, are examined. Considering the global high OH detection rate ($\sim$ 67%), we studied the correlations with CO and OH emission. The detection of OH seems to be a useful discriminator of mechanisms that enhance $\mathcal{R}$.

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Preprints can be obtained by contacting josselin@iap.fr *or via WWW on http://ww.iap.fr/users/josselin/*

The stability of late-type stars close to the Eddington limit

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The opacity-modified Eddington limit has been computed for hydrogen-deficient model atmospheres. The R Coronae Borealis (R CrB) stars are found to be located strikingly close to the limit, which suggests that the unknown trigger mechanism for their visual declines of the stars are instabilities in connection with the stars encountering the Eddington limit in their evolution. It also points to a similarity between the eruptive behaviour of the R CrB stars and the Luminous Blue Variables (LBVs).

Super-Eddington luminosities in hydrostatic model atmospheres manifest themselves by the presence of gas pressure inversions. Such inversions are not an artifact of the assumption of hydrostatic equilibrium but can also be present in hydrodynamical model atmospheres. Only for very large mass loss rates hardly realized in supergiants will the inversions be removed. Instabilities may, however, still be present in such inversions, which is investigated for both H-rich and H-deficient late-type supergiant model atmospheres. Dynamically instabilities may occur in surface ionization zones, which might lead to ejections of gas. A local, non-adiabatic, linear stability analysis reveals that sound waves can be amplified due to the strong radiative forces. However, despite the super-Eddington luminosities, the efficiency of the radiative instabilities is fairly low compared to for early-type stars with growth rates of $10^{-5}\,\mathrm{s}^{-1}$.

Accepted by A&A

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Excitation of Far-Infrared lines of OH and maser pumping efficiency in circumstellar envelopes.

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We present the results obtained with a radiative transfer model to investigate the excitation of OH molecules. Fluxes of far-infrared rotational lines of OH are calculated in terms of a radiatively excited envelope and of a radiative transfer model including collisional and radiative excitation. The agreement with the OH far-infrared lines observed with ISO is satisfactory. The 34.6 μm line is found to be in absorption as observed. We also predict that the 53.3 μm line should be seen in absorption and also contributes to the maser pumping process. Maser pumping efficiencies are estimated from the model and compared to the values determined from recent OH far-infrared observations with ISO and OH maser data.

Accepted by A&A.

Preprints can be obtained by contacting trung@mesiom.obspm.fr

On the determination of carbon isotopic ratios in cool carbon stars

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We discuss the determination of carbon isotopic ratios ^{12}C / ^{13}C in N-type Galactic carbon stars. Ohnaka & Tsuji (1996) reported ^{12}C / ^{13}C ratios smaller by a factor 2 or 3 than the determinations of Lambert et al. (1986). Using synthetic spectra of carbon stars, we analyse systematic errors in their *iso-intensity* method. It is found to be rather sentitive to model parameters and blends. Furthermore, there are large discrepancies between the effective temperatures adopted by these two studies (mean discrepancy close to 260 K for the 20 stars in common). That, together with uncertainties due to model atmospheres, to carbon enrichments and effects of the blends, could explain most of the discrepancies between these two studies. The LGEH86 analysis is, on the other hand, rather insentitive to model parameters. We therefore conclude that large ^{12}C / ^{13}C ratios in cool Galactic carbon stars should be favoured.

Accepted by A&A main journal

Preprints can be obtained by contacting laverny@astro.uu.se

Eccentric binary model for off-center planetary nebulae nuclei

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We examine the influence of eccentric binary progenitors on the morphologies of their descendant planetary nebulae. In particular we consider how mass loss via a stellar wind by an asymptotic giant branch star in an eccentric binary can lead to the displacement of the central star in the equatorial plane. We postulate that the mass loss rate from the asymptotic giant branch star varies systematically with orbital phase. Such variations may be due to several effects, including a tidal enhancement of the stellar wind near periastron, and a cessation of the stellar wind when the Roche lobe of the asymtotic giant branch star encroaches on its extended atmosphere. Our results may pertain to binary systems with semimajor axes in the range of $a \simeq 7$ AU to 80 AU, which correspond to orbital periods in the range of $P \simeq 15 - 500$ years. We apply the results to planetary nebulae in general, and including MyCn 18 (the Hourglass Nebula), in particular, for which the central star was recently found by HST to be displaced from the center of the nebula. The results of this paper may be applied to circumstellar matter around more massive stars, such as progenitors of supernovae, by rescaling the physical properties of the binary stars and the wind velocities.

Accepted by ApJ

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Instabilities in moving planetary nebulae

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We apply recent theoretical results of gas dynamic instabilities to interpret observations of 34 planetary nebulae moving through, and interacting with, the interstellar medium. We show that the Rayleigh-Taylor instability can play an important role not only in shaping the outskirts of the nebulae, but in shaping the inner regions as well, since it allows the interstellar medium to flow into the nebular inner parts by fragmenting the halo.

This is nicely demonstrated, we claim, in the interacting planetary nebulae A 35 and IC 4593, which have bow shocks well inside their almost spherical, but very filamentary, halos. The fragmentation by the Rayleigh-Taylor instability relaxes the need to assume non-homogeneous mass ejection by these planetary nebulae progenitors. We also apply recent results which suggest that the interstellar medium magnetic field makes the Rayleigh-Taylor instability very efficient for nebulae close to the galactic plane, and breaks the cylindrical symmetry of Rayleigh-Taylor and Kelvin-Helmholtz instability modes. The deviation from axisymmetry in the interaction process forms what we term "Rayleigh-Taylor rolls" (or stripes), instead of "fingers" or "blobs" in the unmagnetized flow.

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Knots, filaments, and turbulance in radiative shocks

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We study the structure and stability of asymmetric colliding flows for the case where one shock is oscillating due to the radiative cooling overstability and the interaction zone undergoes no global acceleration. 2D high-resolution numerical simulations reveal a new structure formation mechanism in the wake of such shocks which has been suppressed in previous simulations due to a too coarse numerical mesh. Small scale structures – filaments and knots – are inevitably formed in such shocks. Downstream of the knots a turbulent zone establishes where cold and hot gas are mixed, probably leading to efficient X-ray emission. The bulk of the cooled gas forms a layer of irregular shape and temporally and spatially variable size. The gas in its interior is in mildly supersonic turbulent motion, having a large density and velocity dispersion. Some observed peculiarities in the optical and UV-spectra may be partly due to these characteristics. This mechanism may also contribute to the appearance of knots and filaments in PNe (e.g. in the Helix nebula), in WR ring nebulae, in other circumstellar nebulae like symbiotics, and in SNR. It has consequences for the dynamics of the ISM.

Video animations are available at http://www.astro.phys.ethz.ch/staff/walder.html

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Preprints can be obtained by contacting walder@astro.phys.ethz.ch *or via WWW on* http://www.astro.phys.ethz.ch/papers/walde
or via anonnymous ftp on ftp://saturn.ethz.ch/pub/walder/knots.ps.gz.

Circumstellar shells and mass loss rates: Clues to the evolution of S stars

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It is the purpose of this paper to rediscuss the circumstellar properties of S stars and to put these properties in perspective with our current understanding of the evolutionary status of S stars, in particular the intrinsic/extrinsic dichotomy. Accordingly, an extensive data set probing the circumstellar environment of S stars (IRAS flux densities, maser emission, CO rotational lines) has been collected and critically evaluated. This data set combines new observations (9 stars have been observed in the CO $J = 2 - 1$ line and 3 in the CO $J = 3 - 2$ line, with four new detections) with existing material (all CO and maser observations of S stars published in

the literature). The IRAS flux densities of S stars have been re-evaluated by co-adding the individual scans, in order to better handle the intrinsic variability of these stars in the IRAS bands, and possible contamination by Galactic cirrus.

Mass loss rates or upper limits have been derived for all S stars observed in the CO rotational lines, and range from $< 2\ 10^{-8}$ $M_\odot$ y^{-1} for extrinsic S stars to 10^{-5} $M_\odot$ y^{-1}. These mass-loss rates correlate well with the K - [12] color index, which probes the dust loss rate, provided that the mass loss rate be larger than 10^{-8} $M_\odot$ y^{-1}. Small mass-loss rates are found for extrinsic S stars, consistent with their not being so evolved (RGB or Early-AGB) as the Tc-rich S stars. This result does not support the claim often made in relation with symbiotic stars that binarity strongly enhances the mass-loss rate.

Accepted by Astronomy & Astrophysics Supplements.
Preprints can be obtained by contacting ajorisse@astro.ulb.ac.be
or via WWW on http://astro.ulb.ac.be/Htm/ps.htm

The Structure of the Prototype Bipolar Protoplanetary Nebula CRL2688 (Egg Nebula): Broad-Band, Polarimetric, and H_2 Line Imaging with NICMOS/HST

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High resolution near-infrared ($1.65 - 2.1$ μm) images and 2 μm polarimetric images of the inner $19\farcs5 \times 19\farcs3$ region of the bipolar protoplanetary nebula, CRL2688, taken using the newly installed Near Infrared Camera and MultiObject Spectrometer (NICMOS) aboard the Hubble Space Telescope, are reported. The NICMOS images reveal a wealth of structure also seen in HST/WFPC2 images, but not detected in previous, ground-based near-infrared imaging studies. In particular, we detect a system of concentric arcs centered on, and twin "searchlight beams" emanating from, the obscured central star. The images also show two sharply bounded spindle-shaped polar cavities with point-symmetric structure, and the 2.122μm H_2 S(1) v=1-0 emission line image clearly resolves the sharp interface between the high-velocity outflow that produces these polar cavities and the surrounding slow outflow that forms the extended nebula. The H_2 image also resolves the bright equatorial H_2 emission into distinct components and elucidates their detailed morphologies. We have discovered, within the dark lane that bifurcates the bipolar lobes of CRL2688, a compact source of unpolarized light. Our imaging polarimetry shows that this source is not the post-AGB star which illuminates the nebula - we conclude that the compact source is a companion star.

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Preprints can be obtained by contacting sahai@grandpa.jpl.nasa.gov *or via WWW on* http://wfpc2.jpl.nasa.gov/ idt/sahai.html

Nucleosynthesis in Low- and Intermediate-Mass Stars: An Overview

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Invited review to appear in: *Tours Symposium on Nuclear Physics III*, Ed. H. Utsunomiya, AIP, 1997

An overview of the main phases of the evolution of low- and intermediate-mass stars is presented, and the different types of nucleosynthesis operating from the pre-main sequence up to and including the asymptotic

giant branch phase described. The surface abundance modifications brought by each nucleosynthesis process is also briefly discussed.

Preprints can be obtained by contacting Nami.Mowlavi@obs.unige.ch
or via anonnymous ftp on obsftp.unige.ch, *file* /pub/mowlavi/nuclgen.ps.gz

Discovery of CO_2 emission in AGB stars with the 13 μm dust feature

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We have detected strong emission lines at 13.48, 13.87, 14.97, 15.40 and 16.28 μm in the ISO/SWS spectra of O-rich AGB stars. These lines are only found in the spectra of Miras and semi-regular variables when they also show the 13 μm dust emission feature. The lines appear just resolved in the high-resolution (AOT06, resolution $\sim$ 1500) SWS spectra that we recently obtained.

Here we report the identification of these emission lines as the Q-branches of ro-vibrational (bending mode) transitions in CO_2 molecules. This identification is corroborated by our SWS Fabry-Perot observation of the 13.87 μm line in W Hya where individual Q-branch components of the $10^00\,\Sigma_g^+ - 01^10\,\Pi_u$ transition of CO_2 have been detected. The 15.40 μm line is probably due to $^{13}CO_2$.

We speculate that the simultaneous occurence of the 13 μm dust feature and the CO_2 emission lines indicates the existence of a warm ($\sim$ 650-1400 K) gas layer close to the star where both the 13 μm dust and the CO_2 emission lines are formed.

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Preprints can be obtained by contacting kay@sron.rug.nl

A ^{12}CO $(J = 1 \rightarrow 0)$ and $(J = 2 \rightarrow 1)$ atlas of circumstellar envelopes of AGB and post-AGB stars

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We present the results of a ^{12}CO $(J = 1 \rightarrow 0)$ and $(J = 2 \rightarrow 1)$ survey on a sample of 46 objects classified as AGB and post-AGB stars. We have obtained fully sampled high resolution maps of their ^{12}CO $(J = 1 \rightarrow 0)$ emission by combining visibilities from the IRAM interferometer with short spacing observations from the IRAM 30m telescope. Properties of their circumstellar envelopes like fluxes, radii, and positions are derived from model fits to the visibilities and compared to the results obtained from ^{12}CO $(J = 2 \rightarrow 1)$ maps observed at the IRAM 30m telescope. From the ^{12}CO $(J = 1 \rightarrow 0)$ observations we have derived mass loss rates for 38 stars and established an empirical relation between the CO photodissociation radius of an envelope and the measured radius in the $(J = 1 \rightarrow 0)$ emission.

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Preprints can be obtained by contacting neri@iram.fr

Bipolar Pre-Planetary Nebulae: Hydrodynamics of dusty winds in binary systems. I. Formation of accretion disks

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Mass-losing giant stars and objects in transition to planetary nebulae often display a bipolar symmetry in their outflowing circumstellar envelopes. Here we initiate a detailed study of the hypothesis that the observational characteristics of asymmetric and bipolar preplanetary nebulae result from the effects of a detached binary companion upon the otherwise spherical wind of a single mass-losing star. We follow the gas flows in this system using 3-dimensional smoothed particle hydrodynamics models. In this first work we describe the dusty wind models and the numerical procedure employed, and we address the issue of wind accretion and the formation of accretion disks about the binary companion to the mass-losing giant, as a function of wind velocity and binary separation. In all of our models, we find that permanent, stable accretion disks of various sizes form around the binary companion. The disks are geometrically thin and their equilibrium structure has elliptical streamlines with a range of eccentricities. Our results also indicate that such disks may be susceptible to tilt or warping instabilities. We also find that wind accretion in such binaries is stable, displaying no evidence for any type of flip-flop instability.

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Preprints can be obtained by contacting mastro@astro.ucla.edu

Dissertation Abstracts

Evolution and variability of the R Coronae Borealis stars

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Thesis work conducted at: Uppsala Astronomical Observatory

Ph.D dissertation directed by: Bengt Gustafsson

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The R Coronae Borealis (R CrB) stars are characterized by their severe hydrogen-deficiency and drastic visual variability. This thesis is devoted to both these issues using theoretical, numerical and observational investigations.

A large sample of the stars has been analysed to determine their elemental abundances, which trace both their ancestry and the history of stellar nucleosynthesis. For the purpose, line-blanketed, hydrogen-deficient model atmospheres have been constructed. The peculiar compositions of the stars indicate that they are in fact born-again giants, for which two explanations have been proposed: either a merger of two white dwarfs or a final He-shell flash in a post-AGB star, which briefly re-inflates the star back to giant dimensions. According to their composition, the stars can be divided into a homogeneous majority group and a diverse minority, which might reflect two different evolutionary backgrounds or the effect of dust-gas separation. The atmospheres bear witness of H- and He-burning in different phases as well as *s*-processing, but the high Si/Fe and S/Fe ratios of in particular the minority remain unexplained. The inability of the models to reproduce the C I lines suggests that standard model atmospheres are far from adequate descriptions of supergiants such as the R CrB stars.

An analysis of Sakurai's object, which has likely recently experienced a final He-shell flash, reveals similarities with the R CrB stars as regards chemical composition. More spectacular, the star shows evidence of very rapid

evolution and nucleosynthesis, most notably a decrease in the H abundance and an increase in the Li and *s*-element contents within only five months. The star represents an impressively fast case of stellar evolution very rarely encountered.

The variability of the stars with fadings of up to 8 magnitudes is unique and not yet explained. It is probably due to obscuration events of the stars by newly formed dust clouds. Possible instabilities due to large radiative forces in the stellar atmospheres, which could be the unknown trigger mechanism for the variability by ejecting condensible material, are searched for. A connection between such instabilities and the declines is supported by the proximity of the stars to the theoretical opacity-modified Eddington limit.

Key words: Stellar evolution, stellar abundances, stellar atmospheres, instabilities, R Coronae Borealis stars, post-AGB stars.

Faraday Discussion 109, The University of Nottingham, UK, 15-17 April 1998

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