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Abstracts of recently accepted papers

A first optical spectroscopic monitoring of the post–AGB star SAO 96709 = IRAS 07134+1005: pulsation and shock waves.

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We have performed a spectroscopic monitoring of the F5 I "post–AGB" star SAO 96709 on the Hα and NaD spectral regions in order to study atmospheric motions that could be associated with shock wave propagation throughout the stellar atmosphere. Twenty–one Hα spectra and seventeen NaD spectra were obtained as regularly as possible, over a 14 month interval. We find that the Hα, NaD, and other line profiles are strongly variable on a timescale of a few days. The 5853.688 Å Ba II and 6587.622 Å C I lines also reveal a variation in their radial velocities. Fourier analysis of these variations yields one main period of 27.3 days and three secondary ones of 32.9, 11.9 and 7.1 days. The Hα profiles and the velocity variations are good evidence for complex atmospheric dynamics that are related to shock wave propagation throughout the atmospheric layers. These observed spectral features are in good agreement with the recently found photometric variability and point to a pulsating nature for SAO 96709 = HD 56126 = IRAS 07134+1005.

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Detection of C_2, CN, and NaI D absorption in the AGB remnant of HD 56126

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We present the detection of molecular absorption lines in the optical spectrum of the post-AGB star HD 56126. The C_2 Phillips $A^1\Pi_u - X^1\Sigma_g^+$ (1,0), (2,0), and (3,0); Swan $d^3\Pi_g - a^3\Pi_u$ (0,0) and (1,0); and CN Red system $A^2\Pi - X^2\Sigma^+$ (1,0), (2,0), (3,0), and (4,0) bands have been identified. From the identification of the molecular bands we find an expansion velocity of 8.5 ± 0.6 km s^{-1} independent of excitation condition or molecular specie.

On the basis of the expansion velocity, rotational temperatures, and molecular column densities we argue that the line-forming region is the AGB remnant. This is in agreement with the expansion velocity derived from the CO lines. We find column densities of $\log N_{C_2} = 15.3 \pm 0.3$ cm^{-2} and $\log N_{CN} = 15.5 \pm 0.3$ cm^{-2}, and rotational temperatures of $T_{rot} = 242 \pm 20$ K and $T_{rot} = 24 \pm 5$ K respectively for C_2 and CN.

By studying molecular line absorption in optical spectra of post-AGB stars we have found a new tracer of the AGB remnant. From comparison with the results of CO and IR observations it is possible to obtain information on non-spherical behavior of the AGB remnant. Using different molecules with different excitation conditions it should be possible to study the AGB remnant as a function of the distance to the star, and thus as a function of the evolutionary status of the star on the AGB.

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Mid-IR and radio images of IC 418: dust in a young planetary nebula

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We present three new images of the young, carbon rich planetary nebula, IC 418: 11.3μm dust emission, a [NeII] 12.8μm line emission and 6 cm free-free continuum. All three images show different morphologies. In order to investigate these spatial differences and the mechanisms of dust emission in IC 418, we compare our data to two radiative transfer models with different radial density distributions. Model 1 has a thin shell that drops off as r^{-3}, resulting in a high density ionized region surrounded by an ionized halo. While, model 2 has a thicker shell that drops off as r^{-2} resulting in the ionization front stopping in the thick shell and a high density ionized region immediately surrounded by a neutral shell. Both models use a mixture of silicon carbide (SiC) and amorphous carbon (AC) dust grains with dust to gas ratios of $\sim 2 \times 10^{-5}$ and $\sim 6 \times 10^{-4}$, respectively and the standard power law distribution in sizes ($a^{-3.5}$; $0.005\mu m < a < 0.25\mu m$). Both models reproduce our mid–IR images and mid–IR spectra well suggesting that, while IC 418 has emission features attributed to polycyclic aromatic hydrocarbons (PAHs), the SiC feature and not the PAH feature probably dominates the 11.3μm emission. Comparison of our images with broad-band J, H and K images of IC 418 by Hora et al. (1993), suggest that dust emission processes may contribute more near–IR emission than previously thought and that this near-IR "dust" emission is contained within the ionized gas region. Both models reproduce the observed spatial distributions of the 11.3μm, [NeII], and 6cm emissions which differ because they have different radial excitation gradients in the nebula. However, model 1 better explains all of the many previous observations of IC 418 at different wavelengths. We suggest a three layer onion model for IC 418: a $\sim 6''$ radius high density ionized region surrounded by a $\sim 20''$ radius low density ionized halo, enclosed by a completely photodissociated neutral halo extended beyond a $\sim 80''$ radius. This structure may suggest a mass loss history for IC 418 in which its progenitor AGB star experienced a superwind ($\dot{M} \sim 4 \times 10^{-5}$ $M_\odot$ yr^{-1}, v$\sim$11 km s^{-1}) just before departing the AGB.

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Spectroscopy of selected pulsating stars : the anomalous variable V351 Cep

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The physical parameters: effective temperature T_{eff}, surface gravity log g, microturbulent velocity ξ_t, abundances of 26 chemical elements, radial velocity V_r - were obtained for 5 phases of the variable star V351 Cep using CCD echelle spectra with spectral resolution R = 25000 in the region $\lambda\lambda 5100 - 8000\AA$. The chemical composition of V351 Cep coincides within the errors with the solar chemical composition and, except for the CNO elements, it coincides with the chemical composition of the young supergiant α Per. It is shown that the massive supergiant α Per has an essential overabundance of N and deficiency of C, O in comparison with the solar abundances, which is in good agreement with evolutionary status of α Per. At the same time, no considerable modifications of the CNO abundances for V351 Cep were found. It evidences for absence of dredge-up H-burning products to the surface of the star.

The luminosity of V351 Cep, $M_v = -3^m$, was obtained using the intensity of the infrared triplet OI (near 7774 Å). This value is not consistent with the luminosity obtained from the P-L relation.

The combination of the physical parameters of V351 Cep allows to classify V351 Cep as an anomalous cepheid.

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On the growth of carbonaceous grains in circumstellar envelopes

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We present a phenomenological description of relevant aspects of the grain surface chemistry on pre-existing carbonaceous seed particles. The production of radical surface sites is calculated by means of modified analogous gas-phase thermodynamic and reaction kinetic data. Our results suggest that surface growth processes mainly take place at sp^3 bonded carbon atoms rather than at the edges of graphitic plates or polycyclic aromatic hydrocarbons and that the resulting grain material will be amorphous diamond-like carbon. Furthermore, we argue that the sticking efficiency of the key growth species C_2H_2 at radical sites is high even for significant grain drift velocities. The dust growth rate will generally be proportional to the radical surface coverage.

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The Unusual Circumstellar Environment of the Evolved Star, U Equ

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In the course of a spectroscopic survey to identify cold IRAS stars, we discovered that the evolved star, U Equ, has a very peculiar optical spectrum indicating an unusual circumstellar environment. The moderate resolution (62 Å mm^{-1}) spectrum has deep, yet unusually thin, *molecular absorption* features that must arise in cold gas at a large distance from the star. The optical spectrum also has striking *molecular emission* lines of TiO, AlO, VO possibly due to a fluorescence mechanism. Although the IRAS 25/12 μm colors of U Equ are typical of optically thin circumstellar envelopes, the LRS spectrum displays a strong 10 μm silicate absorption band, indicating a thick, dusty envelope. Comparing our H_2O and OH maser observations with profiles in the literature taken in

1987 (H_2O) and 1990 (OH), we have found a variable velocity pattern and profile shape. We suggest that the star is of a warm spectral type, G to early K, and that it has an edge-on dusty disk or torus and an inner warm molecular circumstellar shell. The luminosity criteria in our moderate-resolution spectra are consistent with that of an evolved giant. The velocity and Galactic latitude are not consistent with an early pre-main sequence evolutionary stage; however, the line-of-sight proximity of U Equ and a bright ribbon of IRAS Galactic cirrus suggest further investigation into the interstellar environment is needed. We present optical spectra, profiles of the H_2O and OH masers, and J and K band images and photometry.

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Distances to Planetary Nebulae BD +30°3639 and NGC 6572

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Third-epoch Very Large Array proper-motion measurements on the planetary nebulae $BD + 30°3639$ and NGC 6572 have been made. Combining these measurements with simple models for the nebulae and using improved analysis, it has been determined that the distance to $BD + 30°3639$ is $1.5 \pm 0.4\,kpc$ and NGC 6572 is $1.2 \pm 0.4\,kpc$. These measurements are consistent with the distances determined from the previous epoch. However, the errors are significantly smaller and are now dominated not by the measurements but by the modeling and the uncertainty in the flux variation. The distances are significantly higher than those determined by statistical methods, with important consequences for calculation of the nebular masses and luminosities.

In addition to their distances, the observations have elucidated the dynamical properties of the objects. First, the expansion of a shell is consistent with the self-similar expansion that is usually assumed for these objects, with the magnitude of the proper motion of a portion of a shell being linearly related to its distance from the center of symmetry. Second, the proper-motion measurements have directly yielded the ages for the nebulae, which are determined to be $900 \pm 200\,yr$ for $BD + 30°3639$ and $1000 \pm 200\,yr$ for NGC 6572.

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A Survey for 22 GHz water maser emission from the Arecibo set of OH/IR stars

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We report here on our search for water masers from a set of 382 OH/IR stars identified at Arecibo from color selected IRAS sources. Maser emission with an integrated flux $\geq 10^{-21}$ W m^{-2} is detected from about half. The detection rate is highest for the bluest stars ($> 90\%$ for IRAS$(25-12) < -0.6$) and decreases to $\approx 30\%$ for the reddest. We expect multiple observations, better sensitivity and improved positions to raise the eventual detection rate from this sample to about 75%. Some of the undetected OH/IR stars are proto planetary nebulae; most of the rest are stars with very heavy mass-loss rates.

The morphological characteristics of our spectra are analyzed: this confirms our expectation that they generally evolve into double-peaked profiles at the higher mass loss rates. Emission in the velocity interval which is blue-shifted with respect to the stellar velocity is statistically stronger than emission from the red-shifted interval. The water outflow velocities reach $75 \pm 15\%$ of the circumstellar expansion velocities exhibited by OH, while flux variations are rarely larger than a factor of 10.

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Interferometric molecular line observations of the circumstellar envelope(s) around U Camelopardalis

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We have observed the circumstellar envelope of the carbon star U Cam in the $HCN(J=1\rightarrow 0)$ and $CN(N=1\rightarrow 0)$ lines using the IRAM Plateau de Bure interferometer. There is evidence of a two-envelope structure: an outer extended envelope, possibly a shell, with a radius of $\approx 7\times 10^{16}\,cm$, that expands with a velocity of $\approx 26\,km\,s^{-1}$, surrounding an inner envelope with a radius of $\approx 6\times 10^{15}\,cm$ and an expansion velocity of only $\approx 13\,km\,s^{-1}$. Mass loss rate estimates based on these data alone are uncertain, but they suggest that the mass loss rate during the formation of the outer envelope was higher than during the present mass loss epoch. Thus, we have evidence for a significant variation in the mass loss characteristics of U Cam within the last 10^3 years.

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A search for hot post-AGB stars in the IRAS Point Source Catalog

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In this paper a first step is made to search for hot post-AGB stars in the IRAS Point Source Catalog. By selecting objects that were not detected at the IRAS 12 μm passband, stars with cool dust shells were retrieved.

The selection yielded 15 objects, of which 12 have spectral type B, and would appear to be efficient in finding hot stars. However, this result does not necessarily mean that these are old evolved objects. Some stars are associated with dense galactic cirrus and are probably normal massive supergiants, a number of stars are good post-AGB candidates because of their galactic latitudes and their cool, extended infrared emission. The possibility remains that these objects are normal supergiants heating the local interstellar medium.

Three objects appear to be genuine post-AGB stars, as is attested by their spectral and photometric properties. The main conclusion derived from modelling their spectral energy distributions is that the objects evolved off the AGB about 1000 years ago, significantly longer than what is found for other post-AGB stars.

Emission lines have appeared in the spectrum of one of these objects, SAO 243756, over the last 20 years. SAO 243756 bears close resemblance to other objects that have been proposed to have entered the Planetary Nebula phase recently.

Finally, several aspects of the problem of selecting post-AGB stars in general are discussed.

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Structural and chemical evolution of intermediate-mass asymptotic giant branch stars

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The thesis studies the structural and chemical evolution of asymptotic giant branch (AGB) stars, with special emphasis on the fluorine production during the thermally pulsing AGB (TP-AGB) phase. For that purpose, a new one-dimensional stellar evolution code has been designed in order to reach the high degree of accuracy in the stellar models required to follow the nucleosynthesis during the TP-AGB phase (Chapter II). The improvements include an extensive nuclear network comprising 47 nuclides from H to S and seed nuclei in order to mimick the s-process nucleosynthesis, and new mesh distribution techniques. Special care is also exercised to correctly handle the growth of convective zones into regions of variable chemical composition.

The structural and chemical evolution of three stars with masses M and metallicities Z ($M = 3\,\mathrm{M}_\odot$,$Z = 0.02$), ($M = 6\,\mathrm{M}_\odot$,$Z = 0.02$) and ($M = 3\,\mathrm{M}_\odot$,$Z = 0.001$) have been followed in detail from the pre-main sequence up to the first dozen thermal pulses. These are described in chapter III, with particular attention to the properties during the AGB phase.

The analysis of the fluorine production in our AGB models is presented in chapter IV. The results reveal that the variations of the level of ^{19}F production during the evolution is very sensitive to the maximum temperature reached at the base of the pulse. Comparison of surface fluorine enhancements with observations is presented. Predictions of surface fluorine abundances in low-metallicity stars, for which no observations are reported yet, are also presented.

The postcript file of the thesis is available upon request at the above e-mail address.