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Abstract of recently accepted papers

Water vapor absorption in early M-type stars

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The spectrometers onboard the Infrared Telescope in Space (IRTS) reveal water vapor absorption in early M-type stars, as early as M2. Previous observations detected H_2O vapor absorption only in stars later than M6, with the exception of the recent detection of H_2O in β Peg (M2.5 II-III). In our sample of 108 stars, 67 stars have spectral types earlier than M6. The spectral types are established by means of their near-infrared colors on a statistical basis. Among the 67 stars of spectral types earlier than M6, we find water vapor absorption in six stars. The observed absorption features are interpreted using a local thermodynamic equilibrium model. The features are reasonably fitted by model spectra with excitation temperatures of 1000–1500 K and water column densities of 5×10^{19} to 1×10^{20} cm^{-2}. These numbers imply that the H_2O molecules are present in a region of the atmosphere, located above the photosphere. Furthermore, our analysis shows a good correlation between the H_2O absorption band strength, and the mid-infrared excess due to the circumstellar dust. We discuss the relation between the outer atmosphere and the mass loss.

Accepted by Astronomy and Astrophysics

Preprints can be obtained by contacting mikako@astro.isas.ac.jp

Investigating the Near-Infrared Properties of Planetary Nebulae II. Medium Resolution Spectra

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We present medium-resolution (R $\sim$ 700) near-infrared (λ = 1 - 2.5 μm) spectra of a sample of planetary nebulae (PNe). A narrow slit was used which sampled discrete locations within the nebulae; observations were

obtained at one or more positions in the 41 objects included in the survey. The PN spectra fall into one of four general categories: H I emission line-dominated PNe, H I and H_2 emission line PNe, H_2 emission line-dominated PNe, and continuum-dominated PNe. These categories correlate with morphological type, with the elliptical PNe falling into the first group, and the bipolar PNe primarily in the H_2 and continuum emission groups. The categories also correlate with C/O ratio, with the O-rich objects generally falling into the first group and the C-rich objects in the other groups. Other spectral features were observed in all categories, such as continuum emission from the central star, C_2, CN, and CO emission, and warm dust continuum emission towards the long wavelength end of the spectra.

Molecular hydrogen was detected for the first time in four PNe. An excitation analysis was performed using the H_2 line ratios for all of the PN spectra in the survey where a sufficient number of lines were observed. From the near-infrared spectrum, we determined an ortho-to-para ratio, the rotational and vibrational excitation temperatures, and the dominant excitation mechanism of the H_2 for many objects surveyed. One unexpected result from this analysis is that the H_2 is excited by absorption of ultraviolet photons in most of the PNe surveyed, although for several PNe in our survey collisional excitation in moderate velocity shocks plays an important role. The correlation between bipolar morphology and H_2 emission has been strengthened with the new detections of H_2 in this survey. We discuss the role of winds and photons to the excitation of H_2 in PNe, and consider some implications to the utility of H_2 as a nebular diagnostic and to our understanding of PNe structure and evolution.

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Preprints can be obtained by contacting jhora@cfa.harvard.edu
or via WWW on http://xxx.lanl.gov/abs/astro-ph/9904202

Optical and infrared observations of the bipolar proto-planetary nebula Hen 401

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Based on optical and near infrared ground-based spectroscopy and optical and near infrared HST images we confirm the classification of Hen 401 as a bipolar proto-planetary nebula. HST images reveal a highly elongated morphology which consists of two main bipolar lobes of unequal surface brightness separated by a dark lane of dust with a total extension of $28''x3''$ superimposed on a much fainter background emission with elliptical shape extending over $\sim 10''x5''$.

The simultaneous detection of spectral lines formed under very different density conditions, together with the strong obscuration observed along the equatorial plane, is interpreted as the signature of a circumstellar disk, which would be responsible for the strong collimation observed. We conclude that the emission observed is mainly due to scattering of the light originated in the fluorescence excited inner region of the circumstellar disk.

In addition, we also report the detection of strong molecular H_2 emission in the near infrared, confirming that the onset of the H_2 emission occur in proto-PNe after the bipolar structure has developed, but before photoionization takes place.

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Preprints can be obtained by contacting pgarcia@iso.vilspa.esa.es

On the formation of warm molecular layers

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The levitation of the outer atmospheres of AGB stars by pulsations is proposed as possible mechanism to form "warm molecular layers". We compare the amounts of CO, H_2O, CO_2 and SO_2 molecules found in an oxygen-rich dynamical model atmosphere with the values derived from recent ISO observations. In the model, the molecules are present in a layered structure behind shock waves which leads to a substantial increase of the column densities in comparison with static models. By additional non-LTE investigations, we calculate the vibrational and rotational excitation temperatures of these molecules and discuss the respective deviations from the kinetic gas temperature in view of the interpretation of the observations.

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Preprints can be obtained by contacting woitke@physik.tu-berlin.de
or via WWW on http://export.physik.tu-berlin.de/~woitke/arbeiten.html

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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The circumstellar envelope of AFGL 4106

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We present new imaging and spectroscopy of the post-red supergiant binary AFGL 4106. Coronographic imaging in Hα reveals the shape and extent of the ionized region in the circumstellar envelope (CSE). Echelle spectroscopy with the slit covering almost the entire extent of the CSE is used to derive the physical conditions in the ionized region and the optical depth of the dust contained within the CSE.

The dust shell around AFGL 4106 is clumpy and mixed with ionized gas. Hα and [N II] emission is brightest from a thin bow-shaped layer just outside of the detached dust shell. On-going mass loss is traced by [Ca II] emission and blue-shifted absorption in lines of low-ionization species. A simple model is used to interpret the spatial distribution of the circumstellar extinction and the dust emission in a consistent way.

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Preprints can be obtained by contacting jacco@ast.cam.ac.uk

[FeII] Bubbles in the Young Planetary Nebula Hubble 12

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We have obtained narrowband images of the young planetary nebula Hubble 12 showing [FeII] line emission in bipolar bubbles near the core. Bright [FeII] emission is strong evidence for shocks, suggesting the presence of a high-velocity wind emanating from the central star. We compare our data to previously published images of Hubble 12—finding similar structures in hydrogen recombination and free-free emission—and we propose three possible interpretations of the data: that the bubbles indicate the inner shock of the fast wind, that the [FeII] emission is evidence of the outer shock an episodic wind, or that the emission is cooling line radiation from a photodissociation region (PDR). We argue that the first two interpretations are more likely, because the [FeII] emission must be shock-excited.

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Preprints can be obtained by contacting carl@astro.pas.rochester.edu
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SiO Maser Survey of the Galactic Disk IRAS Sources. I. $15° < l < 25°$, Near End of the Galactic Bar

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A survey has been made in the SiO J =1-0, v =1 and 2 transitions ($\sim$ 43 GHz) for the color-selected IRAS sources in the galactic disk area of $15^\circ < l < 25^\circ$ and $|b| < 3^\circ$ with the Nobeyama 45-m telescope. We have detected 67 out of 119 observed sources in SiO masers. Distances to the sources are deduced by the IRAS 12 and 25 μm flux densities and range approximately from 2 kpc to 12 kpc. The lines of sight of this region cross the location of the near end of the bar in the Galaxy. Radial velocities of the detected sources spread between -100 km s^{-1} and 200 km s^{-1}. The range slightly exceeds the possible limits expected from the galactic rotation. A comparison of the SiO with the CO and HI velocity-longitude (v-l) diagrams reveals that the overall distribution of the SiO maser sources on the v-l diagram resembles to the molecular ring feature. Observational data are compared with the theoretical results of the bar models.

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VLBA Observation of SiO Masers in the M giant IRC-10414

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We have mapped the M-giant star, IRC$-$10414, in the SiO J=1–0 v=1 line at 43.1 GHz with the VLBA with a spatial resolution of better than 0.5 mas. The maser spots spread over on a circle of a radius of about 7.1 mas. A velocity gradient in the east-west direction of $\sim$0.7 km s^{-1} mas^{-1} is found. Monitoring observations with Nobeyama 45-m telescope have shown that the intensity ratio of the SiO J =1–0 v =1 to v =2 maser line was quite unusual (5–40) for the period of 1997–1999 in this object; this ratio was known to be close to unity in many late-type stellar objects, but was known to deviate strongly from unity in young stellar objects. The unusual line intensity ratio of this star may suggest an chemical or geometrical anomaly of the envelope of IRC-10414. A possible ring/disk model is discussed in order to explain the distribution of the maser spots in this object.

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The Light Curve and Evolutionary Status of the Carbon Star V Hya

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V Hya, an evolved carbon star with a complex circumstellar envelope, has two variability periods, 530d and 6000d (17 years). We analyze recent light curve data and show that both variations have been present for at least 100 years and have been regular over this time. The 530d period and its 1.5 - 2 magnitude amplitude show that V Hya is a Mira variable. We suggest that the star is in a binary system (as also suspected from the structure of the circumstellar envelope) and that the 17-year variation is due to extinction by circumstellar dust orbiting with the companion. The properties of the envelope found from molecular line observations: the

fast molecular wind, the relatively small size of the dense circumstellar envelope, and the high mass loss rate, all suggest that V Hya has entered its 'superwind' phase. However, its spectral type, period, colors, and lack of ionizing radiation show that the star is still on the AGB. These properties add to the evidence that the complex structures of many planetary nebulae, including fast stellar winds, originate during the final phases of mass loss on the AGB.

Preprints can be obtained by contacting gk@astro.princeton.edu *or* http://www.astro.princeton.edu/~library/prep.html, Preprint 808 *or* at ftp://astro.princeton.edu/gk/VHYA/aaa.ps.gz

Infrared emission of hot water in the atmosphere of Mira

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The ISO/SWS spectrum of *o* Cet taken at its maximum exhibits an absorption-like feature between 3.5 and 4.0 μm. We present evidence that the feature is due to emission of H_2O and SiO molecules, in a layer extended to about two stellar radii with an excitation temperature of 2000 K. These hot molecules are also observed in a spectrum of Z Cas near minimum, but this time in absorption. A simple plane-parallel model is used to fit the spectra of these two stars. The H_2O column densities and excitation temperatures in the layers are found to be similar in both stars. The difference of the H_2O band is thus primarily due to the layer size. The H_2O layers seem to be more extended at visual maximum, probably related to the stellar pulsation. The estimated lower limit to the local gas density in the layers of $\sim 10^{11}$ cm^{-3} is in good agreement with theoretical predictions from dynamical model atmospheres.

Accepted by A&A Letter

Preprints can be obtained by contacting yamamura@astro.uva.nl
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Spectroscopy of the post-AGB star HD 101584(IRAS 11385-5517)

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From an analysis of the spectrum (4000Å to 8800Å) of HD 101584 it is found that most of the neutral and single ionized metallic lines are in emission. The forbidden emission lines of [OI] 6300Å and 6363Å and [CI] 8727Å are detected, which indicate the presence of a very low excitation nebula. The Hα, FeII 6383Å, NaI D_1, D_2 lines and the CaII IR triplet lines show P-Cygni profiles indicating a mass outflow. The Hα line shows many velocity components in the profile. The FeII 6383Å also has almost the same line profile as the Hα line indicating that they are formed in the same region. From the spectrum synthesis analysis we find the atmospheric parameters to be T_{eff}=8500K, log g=1.5, V_{turb}=13km s^{-1} and [Fe/H]=0.0. ¿From an analysis of the absorption lines the photospheric abundances of some of the elements are derived. Carbon and nitrogen are found to be overabundant. ¿From the analysis of Fe emission lines we derived T_{exi} = 6100K$\pm$200 for the emission line region.

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Mid-infrared colors as a diagnostic tool of circumstellar envelopes in AGB stars

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New observations of AGB circumstellar envelopes made with the mid-IR imaging camera CAMIRAS are presented. Diagnostic tools based on mid-IR colors are proposed for the analysis of the observed objects, and tested against a larger sample of AGB sources derived from IRAS observations. Radiative transfer modelling is used to calibrate our diagnostic procedures, in order to investigate the physical and chemical characteristics of both samples. The different chemical signatures of C-rich and O-rich envelopes are put in evidence by mid-IR color-color diagrams, and correlations are found between the observed colors and a mass loss parameter derived by radio observations. Evidences for possible temporal variations in the mass loss rates are also suggested. The possibility to derive direct information on the spatial structure and symmetry of the envelopes is finally investigated, and the image of the O-rich star WX Psc, as an example of a spatially resolved axisymmetric envelope, is presented.

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The optical nebulae around the symbiotic Miras He 2–147, HM Sge and V1016 Cyg

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We present narrowband images and [N II]λ658.3 nm spectra, obtained under sub–arcsec seeing conditions, of the extended nebulae around the symbiotic Miras He 2–147, HM Sge, and V1016 Cyg. The main results of this study are:

- The nebula around He 2–147 is a ring expanding with a velocity of $\sim$100 km s^{-1} which is inclined at $\sim$ 55° to the line of sight. The kinematical age of the ring is between 220 and 340 yrs, depending on the adopted distance, and its size is of the order of 10000 a.u.
- The bulk of the [N II] core emission of HM Sge is produced in an extended circumbinary region which, along the North-South direction, has a size of 0″.4, much larger than the binary orbit.
- HM Sge possesses a curved, collimated string of knots extending out to a distance of about 9″, with a fainter counterpart on the other side of the central star. We discuss the possibility that it is the result of a fast collimated wind from the white dwarf and (precessing) accretion disc. If so, its age would be $\sim 500 \cdot D_{kpc}$ yrs, where D_{kpc} is the (poorly known) distance to HM Sge in kpc.

- The [N II] core emission of V1016 Cyg is resolved into two blobs separated by 59± 5 km s^{-1} and by $0''.40 \pm 0''.06$ (extrapolated to P.A.=+80°), which are identified with the kinematical features found by Solf (1983) in 1982. We compute an upper limit to their proper motions in the last 15 yrs, and show that they are not ejecta from the 1965 outburst.
- V1016 Cyg is surrounded by a $20''$ elongated nebula, whose major axis is at P.A.=+45°. Along this direction, we find an extended kinematical feature with projected velocities of about ±30 km s^{-1} which extends $3''$ from the centre, ending on the SW side in a low–ionization knot.

These data provide unique information on the occurrence, geometry and dynamics of ancient mass loss events from these systems, which are likely to be related to unrecorded outbursts of their hot components. We set constraints on the recurrence time between outbursts and the accretion rates of the hot components, using the observed high incidence of nebulae among symbiotic Miras, the observed multiple nebulae, and the maximum observed age of the nebulae. We also discuss the implications of the observations of these nebulae for the theories of formation of aspherical planetary nebulae.

Accepted by Astronomy & Astrophysics

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Si isotopic ratios in mainstream presolar SiC grains revisited

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Although mainstream SiC grains, the major group of presolar SiC grains found in meteorites, are believed to have originated in the expanding envelope of asymptotic giant branch (AGB) stars during their late carbon-rich phases, their Si isotopic ratios show a distribution that cannot be explained by nucleosynthesis in this kind of stars. Previously, this distribution has been interpreted to be the result of contributions from many AGB stars of different ages whose initial Si isotopic ratios vary due to the Galactic chemical evolution of the Si isotopes. This paper presents a new interpretation based on local heterogeneities of the Si isotopes in the interstellar medium at the time the parent stars of the mainstream grains were born. Recently, several authors have presented inhomogeneous chemical evolution models of the Galactic disk in order to account for the well known evidence that F and G dwarfs of similar age show an intrinsic scatter in their elemental abundances.

First we report new calculations of the *s*-process nucleosynthesis of the Si and Ti isotopes in four AGB models (1.5, 3, and 5 $M_\odot$ with $Z = 0.02$; 3 $M_\odot$ with $Z = 0.006$). These calculations are based on the release of neutrons in the He intershell by the ^{13}C source during the interpulse periods followed by a second small burst of neutrons released in the convective thermal pulse by the marginal activation of the ^{22}Ne source. In the 1.5 and 3 $M_\odot$ models with solar metallicity the predicted shifts of the Si isotopic ratios in the stars' envelope are much smaller (< 30 ‰ for the ^{29}Si/^{28}Si ratio and < 40 ‰ for the ^{30}Si/^{28}Si ratio; the two ratios are normalized to solar) than the range observed in the mainstream grains (up to 180 ‰). Isotopic shifts are of the same order as in the SiC grains for the 5 $M_\odot$ and $Z = 0.006$ models but the slope of the ^{29}Si/^{28}Si vs. ^{30}Si/^{28}Si correlation line is much smaller than that of the grains. We also show that none of the models can reproduce the correlations between the Ti and Si isotopic ratios measured in the mainstream grains as the result of *s*-process nucleosynthesis only.

To explain the distribution of the grains' Si isotopic compositions we constructed a simple Monte Carlo model in which contributions from classic Type Ia, Type Ia sub-Chandrasekhar, and Type II supernova (SN) models of different masses were admixed in a statistical way to material with a given Si isotopic composition. For four different starting compositions (average composition of the mainstream grains corrected for AGB contributions, solar composition, 100 ‰ and 200 ‰ deficits in ^{29}Si and ^{30}Si relative to solar) we show that, with the

appropriate choice of two parameters, the distribution of the Si isotopic ratios in the mainstream grains can be successfully reproduced. The parameters to be adjusted are the total number of SN sources selected and the fraction of the material ejected from each SN that is mixed to the starting material. An upward adjustment of the supernova yield of ^{29}Si relative to the other Si isotopes by a factor 1.5 was also introduced. Using current SN yields and Galactic chemical evolution models, this increase is necessary to achieve the Si isotopic ratios of the solar system.

If most mainstream SiC grains come from AGB stars that were born within a short time span, local heterogeneities must be the dominant cause of their Si isotopic variations. However, if AGB stars of different masses and therefore different ages contributed SiC to the solar system, the Si distribution of the mainstream grains reflect both the effect of Galactic chemical evolution of the Si isotopes and of isotopic heterogeneity at the time these stars were born.

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ISOGAL-DENIS detection of red giants with weak mass loss in the Galactic Bulge

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The ISOGAL project is a survey of the stellar populations, structure, and recent star formation history of the inner disk and bulge of the Galaxy. ISOGAL combines 15 μm and 7 μm ISOCAM observations with DENIS IJK$_s$ data to determine the nature of a source and the interstellar extinction. In this paper we report an ISOGAL study of a small field in the inner Galactic Bulge ($\ell = 0.0°$, $b = 1.0°$, area = 0.035 deg^2) as a prototype of the larger area ISOGAL survey of the inner Galaxy. The ISOCAM data are two orders of magnitude more sensitive than IRAS ones, and its spatial resolution is better by one order of magnitude, allowing nearly complete and reliable point-source detection down to $\sim$ 10 mJy with the LW3 filter (12-18 μm) and $\sim$ 15 mJy with the LW2 filter (5.5-8 μm). More than 90% of the ISOCAM sources are matched with a near-infrared source of the DENIS survey. The five wavelengths of ISOGAL+DENIS, together with the relatively low and constant extinction in front of this specific field, allow reliable determination of the nature of the sources.

While most sources detected only with the deeper 7 μm observation are probably RGB stars, the primary scientific result of this paper is evidence that the most numerous class of ISOGAL 15 μm sources are Red Giants in the Galactic bulge and central disk, with luminosities just above or close to the RGB tip and weak mass-loss rates. They form loose sequences in the magnitude-colour diagrams [15]/K_s-[15] and [15]/[7]-[15]. Their large excesses at 15 μm with respect to 2 μm and 7 μm is due to circumstellar dust produced by mass-loss at low rate ($\dot{M}_{dust} \sim 10^{-11}$–a few $10^{-10} M_\odot$/yr). These ISOGAL results are the first systematic evidence and study of dust emission at this early stage (Intermediate AGB and possibly RGB-Tip), before the onset of the large mass-loss phase ($\dot{M} \geq 10^{-7} M_\odot$/yr). It is thus well established that efficient dust formation is already associated with such low mass-loss rates during this early phase.

About twenty more luminous stars are also detected with larger excess at 7 and 15 μm. Repeated ISOGAL observations suggest that the majority of these are long period variables with large amplitude, probably in the large mass-loss stage with $\dot{M} \geq 10^{-7} M_\odot$/yr.

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