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Abstract of recently accepted papers

Mass loss and rotational CO emission from Asymptotic Giant Branch stars

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We present submillimeter observations of rotational transitions of carbon monoxide from $J = 2 \rightarrow 1$ up to $7 \rightarrow 6$ for a sample of Asymptotic Giant Branch stars and red supergiants. It is the first time that the high transitions $J = 6 \rightarrow 5$ and $7 \rightarrow 6$ are included in such a study. With line radiative transfer calculations, we aim to determine the mass-loss history of these stars by fitting the CO line intensities. We find that the observed line intensities of the high transitions, including the $J = 4 \rightarrow 3$ transition, are significantly lower than the predicted values. We conclude that the physical structure of the outflow of Asymptotic Giant Branch stars is more complex than previously thought. In order to understand the observed line intensities and profiles, a physical structure with a variable mass-loss rate and/or a gradient in stochastic gas velocity is required. A case study of the AGB star WX Psc is performed. We find that the CO line strengths may be explained by variations in mass-loss on time scales similar to those observed in the separated arc-like structures observed around post-AGB stars. In addition, a gradient in the stochastic velocity may play a role. Until this has been sorted out fully, any mass loss determinations based upon single CO lines will remain suspect.

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A Model for the Dust Envelope of the Proto-planetary Nebula LSIV-12°111

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The spectral energy distribution of the proto-planetary nebula LSIV-12°111 from near-UV to far-IR is fitted using the dust radiative transfer model for a spherically symmetric envelope. The luminosity of the central star was adopted to be 6300 $L_\odot$, and the effective temperature is equal 23750 K. The model of the dust envelope was calculated using the DUSTY (version 2.0) code. For the grain size distribution we adopted the standard MRN model. The dust composition was accepted to be the warm silicate, and the grain number density $n(r) \propto r^{-2}$. The derived parameters of this model are: the optical depth of the dust envelope at wavelength 0.55 micron, 0.072; the inner envelope radius, 5.6×10^{16} cm; the temperature of the dust at inner radius, 124 K; the distance, 3.8 kpc. To estimate the parameters of the stellar wind we used the gas-dynamical mode of the DUSTY code. The formal estimation of the total mass-loss rate is 1.0×10^{-5}M$_\odot$ yr^{-1}. However the small optical thickness of the envelope and, as a consequence, the weak gas-dust interaction makes this result to be questionable.

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IRAS 08544-4431 : a new post-AGB star in a binary system surrounded by a dusty disc.

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We present an analysis of our extensive data-set on IRAS 08544-4431. It is the first object we discuss of our newly defined sample of stars, selected for their position in the 'RV Tauri' box in the IRAS [12] − [25], [25] − [60] two-color diagram. Moreover, our selection criteria included an observed excess in the L-band, indicative of a dusty disc. The SED of IRAS 08544-4431 shows a broad IR excess starting already at H. Our optical photometric data reveal some evidence for deep and shallow minima in the light curve and a pulsation time-scale of around 100 days with a small amplitude (ΔV peak-to-peak = 0.17 mag). Our CORALIE radial velocity measurements show that IRAS 08544-4431 is a binary system with a period of 499 ± 3 days and a mass function of 0.02 M$_\odot$. Moreover, IRAS 08544-4431 is detected in both the CO (2-1) and (1-0) mm-wave emission lines. The triangular shape of the weak CO profile confirms that part of the circumstellar material is not freely expanding but resides probably in a dusty circumbinary disc. Our chemical abundance analysis of a high resolution spectrum of high S/N reveals that a depletion process has modified the photospheric abundances to a moderate extent ([Zn/Fe]=+0.4). All these findings confirm that the F-type IRAS 08544-4431 is another good example of a binary Post-AGB star surrounded by a dusty disc. The Halfa, P-Cygni profile shows ongoing mass-loss with a very high outflow velocity, the origin of which is not understood. The strength and velocity of the Halfa-absorption are modulated with the orbital motion; the maxima of both quantities (∼ 400 km s−1, 5 Å respectively) occur at superior conjunction.

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The Abundance Evolution of Oxygen, Sodium and Magnesium in Extremely Metal-Poor Intermediate Mass Stars: Implications for the Self-Polution Scenario in Globular Clusters

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We present full stellar evolution and parametric models of the surface abundance evolution of ^{16}O, ^{22}Ne, ^{23}Na, and the magnesium isotopes in an extremely metal-poor intermediate mass star ($M_{\rm ZAMS} = 5{\rm M}_{\odot}$, $Z = 0.0001$). ^{16}O and ^{22}Ne are injected into the envelope by the third dredge-up following thermal pulses on the asymptotic giant branch. These species and the initially present ^{24}Mg are depleted by hot bottom burning (HBB) during the interpulse phase. As a result, ^{23}Na, ^{25}Mg and ^{26}Mg are enhanced. If the HBB temperatures are sufficiently high for this process to deplete oxygen efficiently, ^{23}Na is first produced and then depleted during the interpulse phase. Although the simultaneous depletion of ^{16}O and enhancement of ^{23}Na is possible, the required fine tuning of the dredge-up and HBB casts some doubt on the robustness of this process as the origin of the O–Na anti-correlation observed in globular cluster stars. However, a very robust prediction of our models are low ^{24}Mg/^{25}Mg and ^{24}Mg/^{26}Mg ratios whenever significant ^{16}O depletion can be achieved. This seems to be in stark contrast with recent observations of the magnesium isotopic ratios in the globular cluster NGC 6752.

ApJ Letters, in press

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The *s*-Process in Rotating AGB Star

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We model the nucleosynthesis during the thermal pulse phase of a rotating, solar metallicity Asymptotic Giant Branch (AGB) star of $3\,{\rm M}_{\odot}$, which was evolved from a main sequence model rotating with 250km/s at the stellar equator. Rotationally induced mixing during the thermal pulses produces a layer ($\sim 2\cdot 10^{-5}\,{\rm M}_{\odot}$) on top of the CO-core where large amounts of protons and ^{12}C co-exist. With a post-processing nucleosynthesis and mixing code, we follow the abundance evolution in this layer, in particular that of the neutron source ^{13}C and of the neutron poison ^{14}N. In our AGB model mixing persists during the entire interpulse phase due to the steep angular velocity gradient at the core-envelope interface, thereby spreading ^{14}N over the entire ^{13}C-rich part of the layer. We follow the neutron production during the interpulse phase, and find a resulting maximum neutron exposure of $\tau_{\rm max} = 0.04{\rm mbarn}^{-1}$, which is too small to produce any significant *s*-process. In parametric models, we then investigate the combined effects of diffusive overshooting from the convective envelope and rotationally induced mixing. Just adding the overshooting and leaving the rotational mixing unchanged results also in a small maximum neutron exposure ($0.03{\rm mbarn}^{-1}$). Models with overshoot and weaker interpulse mixing — as perhaps expected from more slowly rotating stars — yield larger neutron exposures. A model with overshooting without any interpulse mixing obtained up to $0.72{\rm mbarn}^{-1}$, which is larger than required by observations. We conclude that the incorporation of rotationally induce mixing processes has important consequences for the production of heavy elements in AGB stars. While through a distribution of initial rotation rates, it may lead to a natural spread in the neutron exposures obtained in AGB stars of a given mass in general — as appears to be required by observations — it may moderate the large neutron exposures found in models with diffusive overshoot in particular. Our results suggest that both processes, diffusive overshoot and rotational mixing, may be required to obtain a consistent description of the s-process in AGB stars which fulfils all observational constraints. Finally, we find that mixing due to rotation within our current framework does increase the production of ^{15}N in the partial mixing zone. However, this increase is not large enough to boost the production of fluorine to the level required by observations.

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Self-consistent modeling of the outflow from the O-rich Mira IRC –20197

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We present a self–consistent time–dependent model for the oxygen–rich Mira variable IRC –20197. This model includes a consistent treatment of the interactions among hydrodynamics, thermodynamics, radiative transfer, equilibrium chemistry, and heterogeneous dust formation with TiO_2 nuclei. The model is determined by the stellar parameters, stellar mass $M_\star = 1.3\,M_\odot$, stellar luminosity $L_\star = 1.4\,10^4\,L_\odot$, stellar temperature $T_\star = 2400\,K$, and solar abundances of the elements. The pulsation of the star is simulated by a piston at the inner boundary where the velocity varies sinusoidally with a period of $P = 636\,d$ and an amplitude of $\Delta v_p = 8\,km\,s^{-1}$. Based on the atmospheric structure resulting from this hydrodynamic calculation at different phases, we have performed angle– and frequency–dependent continuum radiation transfer calculations, which result in the spectral energy distributions at different phases of the pulsation cycle and in synthetic light curves at different wavelengths. These are in good agreement with the infrared observations of IRC –20197. The model yields a time averaged outflow velocity of $11.9\,km\,s^{-1}$ and an average mass loss rate of $7.3\,10^{-6}\,M_\odot yr^{-1}$ which are in good agreement with the values derived from radio observations. Furthermore, the chemical composition of the resulting grains is discussed.

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Three-dimensional photoionization modelling of the hydrogen-deficient knots in the planetary nebula Abell 30

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We have constructed a photoionization model, using the 3-D Monte Carlo code MOCASSIN for one of the hydrogen-deficient knots (J3) of the born-again planetary nebula Abell 30. The model consists of spherical knots, comprising a cold, dense, hydrogen-deficient core with very high metal abundances. The inner core, occupying 9.1% of the total volume of the knot, is surrounded by a less dense hydrogen-deficient and metal-enriched gas envelope, with less extreme abundances. The envelope of the knot might have been formed by the mixing of the knot material with the surrounding nebular gas.

This bi-chemistry, bi-density model did not produce enough heating to match the fluxes of the collisionally excited emission lines (CELs) and of the optical recombination lines (ORLs) observed in the spectrum of the knot. We therefore included heating by photoelectric emission from dust grains in the thermal equilibrium calculations, and found that dust-to-gas ratios of 0.077 and 0.107 by mass for the central core and the envelope of the knot, respectively, are sufficient to fit the spectrum. Surprisingly, photoelectric emission from grains is the dominant source of heating in the hot envelope of the knot, while heating by photoionization of helium and heavy elements dominates in the cold core.

We obtain a good fit with the observations for most of the significant emission lines treated in our model. The two major discrepancies occurred for the [O II] 3727,29 Å doublet and the [N II] 6548, 6584 Å lines, which are severely underestimated in our model. Recombination contributions could be significant and we included them for the O II transitions. However, this was not sufficient to resolve the discrepancy, due to the high collisional de-excitation rates in the dense core, where most of the recombination lines would be produced. This possibly highlights a weakness using a discontinuous density distribution like ours, where in reality one might expect an intermediate phase to exist.

The chemical abundances inferred from our modelling of the central core region and of the envelope of the knot are, at least qualitatively, in agreement with the abundances derived by the empirical analysis of Wesson et al. (2003), although the discrepancies between the core and the envelope abundances that we find are less dramatic than those implied by the ORL and CEL empirical analysis. Our models also indicate, in agreement with the empirical analysis of Wesson et al. (2003), that the C/O ratio in the two regions of the knot is less than unity, contrary to theoretical predictions for born-again nebulae (Iben 1983, Herwig 2001).

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Models of the Dust Envelope of the Unique Object FG Sagittae

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We use JHKLM photometric data obtained in 1998-2001 to model the dust envelope of the unique object FG Sge, which formed around the star after several consecutive cycles of dust condensation beginning in Autumn 1992. Models with a spherically symmetric, extended envelope consisting of a mixture of spherical particles of amorphous carbon and silicon carbide with the MRN size distribution were fitted to match the mean observed spectral energy distributions of FG Sge during brightness maximum and minimum after 1998 for two values of the luminosity and effective temperature of the central star. The stellar-wind parameters and mass-loss rate have been estimated in each case. The observational data for the brightness maximum and minimum cannot be described by models with a fixed luminosity or fixed distance to the star. This is a consequence of the object's unusual behavior, with synchronous flux decreases in all the observed bands. The inability of the model to adequately describe the minimum-brightness state is probably associated with the abrupt disruption of the spherical symmetry of the envelope due to the formation of a small, dense dust cloud in the line of sight.

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Mass-loss from dusty, low outflow-velocity AGB stars I. Wind structure and mass-loss rates

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We present the first results of a CO(2-1), (1-0), and 86 GHz SiO maser survey of AGB stars, selected by their weak near-infrared excess. Among the 65 sources of the present sample we find 10 objects with low CO outflow velocities, $v_{\rm exp} \leq 5\,{\rm km\,s^{-1}}$. Typically, these sources show (much) wider SiO maser features. Additionally, we get 5 sources with composite CO line profiles, i.e. a narrow feature is superimposed on a broader one, where both components are centered at the same stellar velocity. The gas mass-loss rates, outflow velocities and velocity structures suggested by these line profiles are compared with the results of hydrodynamical model calculations for dust forming molecular winds of pulsating AGB stars. The observations presented here give support to our recent low outflow-velocity models, in which only small amounts of dust are formed. Therefore, the wind generation in these models is dominated by stellar pulsation. We interpret the composite line profiles in terms of successive winds with different characteristics. Our hydrodynamical models, which show that the wind properties may be extremely sensitive to the stellar parameters, support such a scenario.

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The Chemical Evolution of Magnesium Isotopic Abundances in the Solar Neighbourhood

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The abundance of the neutron-rich magnesium isotopes observed in metal-poor stars is explained quantitatively with a chemical evolution model of the local Galaxy that considers—for the first time—the metallicity-dependent contribution from intermediate mass stars. Previous models that simulate the variation of Mg isotopic ratios with metallicity in the solar neighbourhood have attributed the production of ^{25}Mg and ^{26}Mg exclusively to hydrostatic burning in massive stars. These models match the data well for [Fe/H] > -1.0 but severely underestimate ^{25,26}Mg/^{24}Mg at lower metallicities. Earlier studies have noted that this discrepancy may indicate a significant role played by intermediate mass stars. Only recently have detailed calculations of intermediate mass stellar yields of ^{25}Mg/^{24}Mg and ^{26}Mg/^{24}Mg become available with which to test this hypothesis. In an extension of previous work, we present a model that successfully matches the Mg isotopic abundances in nearby Galactic disk stars through the incorporation of nucleosynthesis predictions of Mg isotopic production in asymptotic giant branch stars.

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Detection of elements beyond the Ba-peak in VLT+UVES spectra of post-AGB stars

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In this letter, we report on our successful systematic search for lines of elements beyond the Ba-peak in spectra of s-process enriched post-AGB stars. Using newly released atomic data from both the VALD database and the D.R.E.A.M. project, we could derive abundances for several elements heavier than europium for three objects, on the base of high quality VLT+UVES spectra. The abundances of these elements are of particular interest since they turn out to be powerful constraints for chemical evolutionary AGB models. Their high abundances indicate that, also in only moderately metal deficient AGB stars, production of lead is expected to be significant.

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Automated Isotopic Measurements of Micron-Sized Dust: Application to Meteoritic Presolar Silicon Carbide

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We report the development of a new analytical system allowing the fully automated measurement of isotopic ratios in micrometer-sized particles by secondary ion mass spectrometry (SIMS) in a Cameca ims-6f ion microprobe. Scanning ion images and image processing algorithms are used to locate individual particles dispersed on sample substrates. The primary ion beam is electrostatically deflected to and focused onto each particle in turn, followed by a peak-jumping isotopic measurement. Automatic measurements of terrestrial standards indicate similar analytical uncertainties to traditional manual particle analyses (e.g., ∼30/amu for Si isotopic ratios). We also present an initial application of the measurement system to obtain Si and C isotopic ratios for ∼3,300 presolar SiC grains from the Murchison CM2 carbonaceous chondrite. Three rare presolar Si_3N_4 grains were also identified and analyzed. Most of the analyzed grains were extracted from the host meteorite using a new chemical dissolution procedure. The isotopic data are broadly consistent with previous observations of presolar SiC in the same size range (~0.5–4μm). Members of the previously identified SiC AB, X, Y and Z sub-groups were identified as was a highly unusual grain with an extreme ^{30}Si enrichment, a modest ^{29}Si enrichment and isotopically light C. The stellar source responsible for this grain is likely to have been a supernova. Minor differences in isotopic distributions between the present work and prior data can be partially explained by terrestrial contamination and grain aggregation on sample mounts, though some of the differences are probably intrinsic to the samples. We use the large new SiC database to explore the relationships between three previously identified isotopic sub-groups mainstream, Y and Z grains all believed to originate in asymptotic giant branch stars. The isotopic data for Z grains suggest that their parent stars experienced strong CNOcycle nucleosynthesis during the early AGB phase, consistent with either cool bottom processing in low-mass (M<2.3M$_\odot$) parent stars or hot-bottom burning in intermediate mass stars (M>4M$_\odot$). The data provide evidence for a sharp threshold in metallicity, above which SiC grains form with much higher ^{12}C/^{13}C ratios than below. Above this threshold, the fraction of grains with relatively high ^{12}C/^{13}C decreases exponentially with increasing ^{29}Si/^{28}Si ratio. This result indicates a sharp increase in the maximum mass of SiC parent stars with decreasing metallicity, in contrast to expectations from Galactic chemical evolution theory.

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The central star of the planetary nebula N 66 in the Large Magellanic Cloud: A detailed analysis of its dramatic evolution 1983 – 2000

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The central star of the planetary nebula N 66 (alias WS 35, SMP 83 and HV 5967) in the Large Magellanic Cloud enhanced its brightness dramatically in 1993 and 1994. Within the subsequent four years it returned to the previous level. Its spectrum resembles that of a Wolf-Rayet star of the nitrogen sequence (WN4.5). We monitored the object intensively from ground and with the Hubble Space Telescope. Now we present the complete set of spectroscopic observations from the different epochs before, during and after the brightness outburst of N 66. The stellar spectra from the different epochs are analyzed in detail by means of most advanced non-LTE models for expanding stellar atmospheres. The main results are: the luminosity, $\log L/L_\odot = 4.6$, before and after the outburst is exceptionally high for a central star of a planetary nebula. During the outburst in 1994, it even climbed up to $\log L/L_\odot = 5.4$ for about one year. The effective temperature of about 112 kK remained roughly constant, i.e. the luminosity mainly increased because of a larger effective stellar radius. The mass loss rate increased from $10^{-5.7} M_\odot \mathrm{yr}^{-1}$ in the quiet state to $10^{-5.0} M_\odot \mathrm{yr}^{-1}$ during the outburst. The chemical composition of the stellar atmosphere is that of incompletely CNO-processed matter: it is dominated by helium with a rest of hydrogen, nitrogen being slightly enhanced and carbon strongly depleted. We extensively discuss possible scenarios for the nature and evolutionary origin of N 66, which should explain the exceptional stellar parameters, the atmospheric composition, the outburst mechanism, and the existence of the bipolar nebula which was ejected only a few thousand years ago and contains about 0.6 solar masses of hydrogen-rich matter. If being a single star, N 66 might be (i) a low-mass star after the Asymptotic Giant Branch, as usually adopted for central stars of planetary nebulae, (ii) a massive, i.e. non-degenerate star, or (iii) a merger produced from two white dwarfs. Although there are no direct indications for binarity, we alternatively discuss whether N 66 might be (iv) a massive star which lost its hydrogen envelope in a recent common-envelope phase with a less massive companion, or (v) a white dwarf accreting mass from a companion with a high rate. None of the sce-

narios is free of any contradiction to at least one of the observational facts. However, the binary scenarios pose less severe problems. If N 66 is a white dwarf accreting matter in a close-binary system, its present accretion rate would bring it to the Chandrasekhar limit within a few hundred thousand years. Thus N 66 might be a candidate for a future type Ia supernova explosion in our cosmic neighborhood.

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The evolution of V4334 Sgr (Sakurai's object) in the Mid- Infrared

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Since Sakurai's object (V4334 Sgr) underwent a late helium flash in 1995, its fast evolution has been monitored with great effort. We present TIMMI and TIMMI 2 photometric observations covering a spectral range from 5 to 20 μm with a total of 8 filters. We found drastic changes in the spectral energy distribution indicating a drop of temperature in the dust envelope from 1000 to 600 K in half a year only. Combined with optical observations reported elsewhere, we conclude that the phase of dust formation has probably stopped in mid-2001 and that the dusty envelope has been expanding only, ever since. An expansion velocity of about $1000\,\mathrm{km\,s^{-1}}$ is required to explain the rapid cooling. Other optical and near-infrared observations support the existence of such high velocity flows in the envelope of V4334 Sgr. An estimate for the bolometric luminosity of $\approx 2000\mathrm{L}_\odot$ is derived for a distance of 1 kpc. Taking into account theoretical models a distance of 2 ± 1 kpc to V4334 Sgr is suggested. As a consequence of its fast final helium flash evolution, Sakurai's object may start to destroy its surrounding dust in the not too distant future.

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Light Neutron-Capture Elements in Planetary Nebulae

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Intermediate-mass stars synthesize many trans-iron nuclei during the Asymptotic Giant Branch (AGB) phase, via slow neutron capture reactions during the evolutionary stage marked by periodic He-shell burning episodes called "thermal pulses." When the stellar envelope is expelled and ionized, comprising an observable planetary nebula (PN), it retains the compositional imprint of the thermal pulses and subsequent convective dredge-up processes. I present results from ultraviolet, optical, and infrared spectroscopy of PNe that demonstrate the presence of enhanced abundances of several of the lightest n-capture elements, created by the first few n-captures on the seed nuclei, in particular, Ge ($Z = 32$), Se ($Z = 34$), and Kr ($Z = 36$). In contrast, Zn ($Z = 30$) is not found to be enriched. These results constrain models of this poorly understood phase of stellar evolution, and clarify the role of PN-producing stars in the chemical enrichment of the Galaxy.

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Preprints can be obtained by contacting harriet@astro.as.utexas.edu

Near-Infrared spectroscopy of (Proto)-Planetary Nebulae: molecular hydrogen excitation as an evolutionary tracer

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We present an in-depth analysis of molecular excitation in 11 H_2-bright planetary and proto-planetary nebulae (PN and PPN). From newly-acquired K-band observations we extract a number of spectra at positions across each source. H_2 line intensities are plotted on "Column Density Ratio" diagrams so that we may examine the excitation in and across each region. To achieve this we combine the shock models of Smith et al. (2003) with the PDR models of Black & van Dishoeck (1987) to yield a *shock-plus-fluorescence* fit to each data set.

Although the combined shock+fluorescence model is needed to explain the low and high-energy H_2 lines in most of the sources observed (fluorescence accounts for much of the emission from the higher-energy H_2 lines), the *relative* importance of shocks over fluorescence does seem to change with evolutionary status. We find that shock excitation may well be the dominant excitation mechanism in the least evolved PPN (CRL 2688 - in both the bipolar lobes and in the equatorial plane) as well as in the most evolved PN considered (NGC 7048). Fluorescence, on the other hand, becomes more important at intermediate evolutionary stages (i.e. in "young" PN), particularly in the inner core regions and along the inner edges of the expanding post-AGB envelope. Since H_2 line emission seems to be produced in almost all stages of post-AGB evolution, H_2 excitation may prove to be a useful probe of the evolutionary status of PPN and PN alike. Moreover, shocks may play an important role in the molecular gas excitation in (P)PN, in addition to the low and/or high-density fluorescence usually attributed to the excitation in these sources.

Accepted by MNRAS, 2003

Preprints can be obtained by contacting Chris Davis (c.davis@jach.hawaii.edu) or via the WWW at http://www.jach.hawaii.edu/~cdavis/papers.html

Infrared Colors and Variability of Evolved Stars from COBE DIRBE Data

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For a complete 12 micron flux-limited sample of 207 IRAS sources, we have extracted light curves in seven infrared bands between 1.25 − 60 microns using the database of the DIRBE instrument on the COBE satellite. Using previous infrared surveys, we filtered these light curves to remove datapoints affected by nearby companions. In the time-averaged DIRBE color-color plots, we find clear segregation of semi-regulars, Mira variables, carbon stars, OH/IR stars, and red giants without circumstellar dust and with little or no visual variation. The DIRBE 1.25 − 25 micron colors become progressively redder and the variability in the DIRBE database increases along the oxygen-rich sequence non-dusty slightly varying red giants −> SRb/Lb −> SRa −> Mira −> OH/IR and the carbon-rich SRb/Lb −> Mira sequence. This supports previous assertions that these are evolutionary sequences involving the continued production and ejection of dust. Carbon stars are redder than oxygen-rich stars for the same variability type, except in the F(12)/F(25) ratio. Of the 28 sources in the sample not previous noted to be variable, 18 are clearly variable in the DIRBE data, with amplitudes of variation of ∼0.9 magnitudes at 4.9 microns and ∼0.6 magnitudes at 12 microns, consistent with them being very dusty Mira-like variables. The light curves of the semi-regular variable L2 Pup are particularly remarkable. The maxima at 1.25, 2.2, and 3.5 microns occur 10 - 20 days before those at 4.9 and 12 microns, and, at 4.9 and 12 microns, another maximum is seen between the two near-infrared maxima. This extra mid-infrared maximum is likely due to the formation of a new dust layer.

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or via WWW on http://lanl.arXiv.org/abs/astro-ph/0305067

Chemistry and clumpiness in planetary nebulae

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We study the chemistry in the slow wind during the transition from AGB star to pre-planetary nebula (PPN) and planetary nebula (PN). We show that there is a very rich chemistry of degradation products created by photoprocessing, driven by the gradually hardening radiation field of the central star. Most of these products are, however, photodissociated during the PPN phase if the wind is smooth. By contrast, if the wind is clumpy, possibly because of clumpiness in the AGB atmosphere, then many of these degradation products survive into the PN phase. Thus, chemistry may be used to infer the existence of clumpiness in the AGB phase. We identify potential molecular tracers, and we note that, in the case of clumpiness, large molecules may survive the transport from the stellar atmosphere to the interstellar medium. We compare between our model results with observations of three objects at differing evolutionary stages: CRL618, NGC 7027 and the Helix nebula (NGC 7293).

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Preprints can be obtained by contacting mpr@star.ucl.ac.uk or via WWW on astro-ph/0308098

‘Thermal’ SiO radio line emission towards M-type AGB stars: a probe of circumstellar dust formation and dynamics

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An extensive radiative transfer analysis of circumstellar SiO ‘thermal’ radio line emission from a large sample of M-type AGB stars has been performed. The sample contains 18 irregulars of type Lb (IRV), 7 and 34 semiregulars of type SRa and SRb (SRV), respectively, and 12 Miras. New observational data, which contain spectra of several ground vibrational state SiO rotational lines, are presented. The detection rate was about 60% (44% for the IRVs, and 68% for the SRVs). SiO fractional abundances have been determined through radiative transfer modelling. The abundance distribution of the IRV/SRV sample has a median value of 6×10^{-6}, and a minimum of 2×10^{-6} and a maximum of 5×10^{-5}. The high mass-loss rate Miras have a much lower median abundance, $\lesssim 10^{-6}$. The derived SiO abundances are in all cases well below the abundance expected from stellar atmosphere equilibrium chemistry, on average by a factor of ten. In addition, there is a trend of decreasing SiO abundance with increasing mass-loss rate. This is interpreted in terms of depletion of SiO molecules by the formation of silicate grains in the circumstellar envelopes, with an efficiency which is high already at low mass-loss rates and which increases with the mass-loss rate. The high mass-loss rate Miras appear to have a bimodal SiO abundance distribution, a low abundance group (on average 4×10^{-7}) and a high abundance group (on average 5×10^{-6}). The estimated SiO envelope sizes agree well with the estimated SiO photodissociation radii using an unshielded photodissociation rate of $2.5\times10^{-10}\,\mathrm{s}^{-1}$. The SiO and CO radio line profiles differ in shape. In general, the SiO line profiles are narrower than the CO line profiles, but they have low-intensity wings which cover the full velocity range of the CO line profile. This is interpreted as partly an effect of selfabsorption in the SiO lines, and partly (as has been done also by others) as due to the influence of gas acceleration in the region which produces a significant fraction of the SiO line emission. Finally, a number of sources which have peculiar CO line profiles are discussed from the point of view of their SiO line properties.

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Production of Aluminium and the Heavy Magnesium Isotopes in Asymptotic Giant Branch Stars

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We investigate the production of aluminium and magnesium in asymptotic giant branch models covering a wide range in mass and composition. We evolve models from the pre-main sequence, through all intermediate stages, to near the end of the thermally-pulsing asymptotic giant branch phase. We then perform detailed nucleosynthesis calculations from which we determine the production of the magnesium and aluminium isotopes as a function of the stellar mass and composition. We present the stellar yields of sodium and the magnesium and aluminium isotopes. We discuss the abundance predictions from the stellar models in reference to abundance anomalies observed in globular cluster stars.

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Preprints can be obtained by contacting akarakas@ap.stmarys.ca

Space Telescope Imaging Spectrograph slitless observations of Small Magellanic Cloud Planetary Nebulae: a study on morphology, emission line intensity, and evolution

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A sample of 27 Planetary Nebulae (PNs) in the Small Magellanic Clouds (SMC) have been observed with the Hubble Space Telescope Imaging Spectrograph (HST/STIS) to determine their morphology, size, and the spatial variation of the ratios of bright emission lines. The morphologies of SMC PNs are similar to those of LMC and Galactic PNs. However, only a third of the resolved SMC PNs are asymmetric, compared to half in the LMC. The low metallicity environment of the SMC seems to discourage the onset of bipolarity in PNs. We measured the line intensity, average surface brightness (SB), and photometric radius of each nebula in H-alpha, H-beta, [O III] (4959 and 5007 A), [N II] (6548 and 6584 A), [S II] (6716 and 6731 A) He I (6678 A), and [O I] 6300 and 6363 A. We show that the surface brightness to radius relationship is the same as in LMC PNs, indicating its possible use as a distance scale indicator for Galactic PNs. We determine the electron densities and the ionized masses of the nebulae where the [S II] lines were measured accurately, and we find that the SMC PNs are denser than the LMC PNs by a factor of 1.5. The average ionized mass of the SMC PNs is 0.3 solar masses. We also found that the median [O III]/H-beta intensity ratio in the SMC is about half than the corresponding LMC median. We use Cloudy to model the dependence of the [O III]/H-beta ratio on the oxygen abundance. Our models encompass very well the average observed physical quantities. We suggest that the SMC PNs are principally cooled by the carbon lines, making it hard to study their excitation based on the optical lines at our disposal.

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The Case for Asymmetric Dust Around a C-Rich AGB star

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$JHKL$ observations of the mass-losing carbon Mira variable IRAS 15194–5115 (II Lup) extending over about 18 years are presented and discussed. The pulsation period is 575 days and has remained essentially constant over this time span. The star has undergone an extensive obscuration minimum during this time. This is complex and, like such minima in similar objects, e.g. R For, does not fit the model predictions of a simple long term periodicity. Together with the high resolution observations of Lopez et al. the results suggest that the obscuration changes are due to the formation of dust clouds of limited extent in the line-of-sight. This is an RCB-type model. The effective reddening law at J and H is similar to that found for R For.

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or at http://arXiv.org/abs/astro-ph/0308417

Post-AGB Evolution in the Large Magellanic Cloud. A Study of the Central Stars of Planetary Nebulae

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We present medium- and broad-band Hubble Space Telescope (*HST*) photometry of a sample of 35 central stars (CSs) of Planetary Nebulae (PNs) in the Large Magellanic Cloud (LMC). The observations were made with the WFPC2 and STIS instruments on board the *HST*. By observing LMC objects, our sample is free of the distance uncertainty that is the dominate source of error in the determination of CS luminosities in Galactic PNs. By observing with the *HST*, we resolve the nebula and therefore we often detect the CSs unambiguously. We obtain core masses of 16 of the objects by comparing their positions on the HR diagram to theoretical evolutionary tracks, once we determine the stellar effective temperature through Zanstra analysis. This sample of CS masses is the largest and most reliable set obtained in an extra-Galactic environment. We find an average mass of 0.65 $M_{\odot}$, though a few of the objects have very high mass. This average value is consistent with the average mass of the white dwarf population in the Galaxy. As the immediate precursors of white dwarfs, the study of the mass distribution of PN CSs should help to constrain the initial-to-final mass relation within environments of differing metallicity. Finally, by exploring the physical connections between the star and the nebula, we establish the importance of the study of PNs in the LMC to constrain the energy input from the wind during the post-AGB phase. **Accepted by the Astrophysical Journal**

Preprints can be obtained by contacting villaver@stsci.edu
Also available from the URL http://arXiv.org/abs/astro-ph/0307250

Really Cool Stars and the Star Formation History at the Galactic Center

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We present $\lambda/\Delta\lambda = 550$ to 1200 near infrared H and K spectra for a magnitude limited sample of 79 asymptotic giant branch and cool supergiant stars in the central $\approx$ 5 pc (diameter) of the Galaxy. We use a set of similar spectra obtained for solar neighborhood stars with known $T_{\rm eff}$ and $M_{\rm bol}$ that is in the same range as the Galactic center (GC) sample to derive $T_{\rm eff}$ and $M_{\rm bol}$ for the GC sample. We then construct the Hertzsprung–Russell (HRD) diagram for the GC sample. Using an automated maximum likelihood routine, we derive a coarse star formation history of the GC. We find (1) roughly 75% of the stars formed in the central few pc are older than 5 Gyr; (2) the star formation rate (SFR) is variable over time, with a roughly 4 times higher star formation rate in the last 100 Myr compared to the average SFR; (3) our model can only match dynamical limits on the total mass of stars formed by limiting the IMF to masses above 0.7 $M_{\odot}$. This could be a signature of mass segregation or of the bias toward massive star formation from the unique star formation conditions in the GC; (4) blue supergiants account for 12 % of the total sample observed, and the ratio of red to blue supergiants is roughly 1.5; (5) models with isochrones with [Fe/H] = 0.0 over all ages fit the stars in our HRD better than models with lower [Fe/H] in the oldest age bins, consistent with the finding of Ramirez et al. (2000) that stars with ages between 10 Myr and 1 Gyr have solar [Fe/H].

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Preprints can be obtained by contacting rblum@ctio.noao.edu
or via WWW on http://arXiv.org/abs/astro-ph/0307291

A deep survey of heavy element lines in planetary nebulae – I. Observations and forbidden-line densities, temperatures and abundances

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We present deep optical spectrophotometry of twelve Galactic planetary nebulae (PNe) and three Magellanic Cloud PNe. Nine of the Galactic PNe were observed by scanning the spectrograph's slit across the nebula, yielding relative line intensities for the entire nebula that are suitable for comparison with integrated nebular fluxes measured in other wavelength regions. In this paper we use the fluxes of collisionally excited lines (CELs) from the nebulae to derive electron densities and temperatures, and ionic abundances. We find that the nebular electron densities derived from optical CEL ratios are systematically higher than those derived from the ratios of the infrared (IR) fine-structure (FS) lines of [O III]. The latter have lower critical densities than the typical nebular electron densities derived from optical CELs, indicating the presence of significant density variations within the nebulae, with the infrared CELs being biased towards lower density regions.

We find that for several nebulae the electron temperatures obtained from [O II] and [N II] optical CELs are significantly affected by recombination excitation of one or more of the CELs. When allowance is made for recombination excitation, much better agreement is obtained with the electron temperatures obtained from optical [O III] lines. We also compare electron temperatures obtained from the ratio of optical nebular to auroral [O III] lines with temperatures obtained from the ratio of [O III] optical lines to [O III] IR FS lines. We find that when the latter are derived using electron densities based on the [O III] $52\,\mu$m/$88\,\mu$m line ratio, they yield values that are significantly higher than the optical [O III] electron temperatures. In contrast to this, [O III] optical/IR temperatures derived using the higher electron densities obtained from optical [Cl III] $\lambda5517/\lambda5537$ ratios show much closer agreement with optical [O III] electron temperatures, implying that the observed [O III] optical/IR ratios are significantly weighted by densities in excess of the critical densities of both [O III] FS lines. Consistent with this, ionic abundances derived from [O III] and [N III] FS lines using electron densities from optical CELs show much better agreement with abundances derived for the same ions from optical and ultraviolet CELs than do abundances derived from the FS lines using the lower electron densities obtained from the observed [O III] $52\,\mu$m/$88\,\mu$m ratios. The behaviour of electron temperatures obtained making use of the temperature-insensitive [O III] IR FS lines provides no support for significant temperature fluctuations within the nebulae that could be responsible for derived Balmer jump electron temperatures being lower than temperatures obtained from the much more temperature sensitive [O III] optical lines.

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Preprints can be obtained by contacting ygt@star.ucl.ac.uk

2MASS Counterparts for OH/IR Stars: I The Arecibo Sample

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The positions of the IRAS counterparts to the 420 OH/IR stars in the Arecibo sky ($0^\circ < \delta < +38^\circ$) are usually accurate to better than $10''$. But every star has recently been observed by the 2-Micron All-Sky Survey (2MASS), which provides $\approx 0.2''$ quality positions, while those with $|\,b\,| \leq 4.5^\circ$ have also been observed by the Mid-course Space Experiment (MSX), which provides $\approx 2''$ quality positions. We use the MSX and/or IRAS

coordinates to guide us to 2MASS counterparts for the 134 Arecibo OH/IR stars with images in the second release of the 2MASS Point Source Catalog.

An unexpected byproduct of having the J-H v H-K_s plot generated from the 2MASS fluxes is the realization that most (≈84 %) of the redder OH/IR stars have detached circumstellar shells. We identify 5 objects that probably, by contrast, have "normal" shells, and confirm the status of AU Vul as a proto planetary nebula.

Accepted by Astronomical Journal

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Detection of an orbiting gas disk in the Red Rectangle

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We present interferometric maps of CO emission in the Red Rectangle, a well known protoplanetary nebula. The CO emission is found to arise from a relatively thin equatorial disk, extending about 5″ in the direction perpendicular to the symmetry axis of the optical nebula. The velocity dispersion of the emission clearly increases towards the center, in a pattern significantly coincident with that expected for a keplerian velocity field. Modeling of the CO maps confirms that the emitting gas is probably rotating around the central star(s), with a kepler-like velocity distribution (at least in the central regions) that would correspond to a central mass ~ 0.9 $M_\odot$. Other possible explanations to the observations are discussed, but are found to be unlikely. Our models also suggest that the density and temperature increase towards the center roughly proportionally to the inverse radius. The asymmetry observed in the line profile and intensity distribution (the red part being stronger) can be explained by self-absorption if, superimposed to the rotation velocity, there is a low radial expansion at a velocity of about 0.4 km s^{-1}, at least in the outer disk regions. This is the first probable detection of a gas disk in kepler-like rotation around a post-AGB star.

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or via WWW on http://www.oan.es/preprints/2003

The physical parameters, excitation and chemistry of the rim, jets and knots of the planetary nebula NGC 7009

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We present long-slit optical spectra along the major axis of the planetary nebula NGC 7009. These data allow us to discuss the physical, excitation and chemical properties of all the morphological components of the nebula, including its remarkable systems of knots and jets. The main results of this analysis are the following: *i)* the electron temperature throughout the nebula is remarkably constant, T_eOiii = 10 200 K; *ii)* the bright inner rim and inner pair of knots have similar densities of $N_e \sim 6000$ cm^{-3}, whereas a much lower density of $N_e \sim 1500$ cm^{-3} is derived for the outer knots as well as for the jets; *iii)* all the regions (rim, inner knots, jets and outer knots) are mainly radiatively excited; and *iv)* there are no clear abundance changes across the nebula for He, O, Ne, or S. There is a marginal evidence for an overabundance of nitrogen in the outer knots (ansae), but the inner ones (caps) and the rim have similar N/H values that are at variance with previous results. Our data are compared to the predictions of theoretical models, from which we conclude that the knots at the head of the jets are not matter accumulated during the jet expansion through the circumstellar medium, neither can their origin be explained by the proposed HD or MHD interacting-wind models for the formation of jets/ansae, since the densities as well as the main excitation mechanisms of the knots, disagree with model predictions.

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The nature of Hen 3-1312 : a post-AGB star in a binary system

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This work reports the low- and high-resolution spectroscopic diagnostic diagrams, radial velocity, stellar parameter and abundance analysis of the planetary nebula Hen 3-1312. The low- and high-resolution spectra reveal that Hen 3-1312 is in fact a very-low-excitation object, in a binary system with a supergiant as a cool central star. The analysis of the high-resolution spectrum shows the cool stellar component to have an effective temperature of T_{eff}=6 500±100 K and a surface gravity of log $g = 0.8 \pm 0.2$ corresponding to a spectral type of F(6-7)I. These parameters result in an estimated primary luminosity of 4 100 $L_\odot$, implying a distance of 4 400 pc which is in agreement with previous determinations. The abundance analysis reveals Hen 3-1312 to be a metal-poor object having [Fe/H]=-1.1. The mean abundances of carbon, nitrogen and oxygen are found to be solar, however the α-elements (Mg, Si and Ca) are underabundant relative to the Sun. The abundance profile of Hen 3-1312 is analyzed and compared with other classes of stars with similar atmospheric parameters.

Accepted by Astronomy & Astrophysics

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PhD Abstract

A Study of Grain Drift in C Stars.
Theoretical Modeling of Dust-Driven Winds in Carbon-Rich Pulsating Giant Stars.

Christer Sandin

Thesis work conducted at: Department of Astronomy and Space Physics, Uppsala University, Sweden

Ph.D dissertation directed by: Dr. Susanne Höfner and Prof. Bengt Gustafsson

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On-line version of the thesis can be found on: http://publications.uu.se/theses/abstract.xsql?dbid=3397

A major fraction of stars will pass through a short period of dramatic events in their final evolutionary stage. Low- to intermediate-mass stars, studied here, are stripped of their outer parts in a slow massive wind. This mass loss reshapes both the star and the surrounding medium. The formation of the wind is a consequence of the non-linear interaction of a number of physical processes. Stellar pulsations and efficient dust formation are examples of such key processes. Time-dependent theoretical models, in combination with observations, are useful tools for understanding these winds.

The main object of this thesis has been the physical improvement of a theoretical wind model. Here the coupling between the dust and gas in the wind is studied in further detail, allowing drift. The methods that have been developed earlier to describe the micro-physical interaction are overviewed and summarized. Previously dust has often been assumed to move at the same velocity as gas. New time-dependent wind models are presented where grain drift has been treated self-consistently. Specifically, the coupling between dust and gas in the wind has been modeled more realistically, with descriptions of both the modified momentum and energy balances, and drift dependent dust formation. The results of these new "drift models" have been compared with the results of non-drift models.

A general result of the study is that the effects of drift are significant and difficult to predict if a simple analytical theory is used. It has been found that dust in drift models tends to accumulate in certain dense regions, an accumulation that was not possible without drift. Moreover the new models show an increased variability in the wind structure. The use of drift in dust formation tends to markedly increase the produced dust. Some sets of model parameters lead to a wind without including drift, but a corresponding wind does not form when drift is included – and vice versa. The effects of drift are important and can probably not be ignored in realistic models.

Thesis-related publications: A&A 2003, 398, 253; A&A 2003, 404, 789; A&A 2003, submitted

Conference announcement

ASTRONOMICAL POLARIMETRY
CURRENT STATUS AND FUTURE DIRECTIONS
15-19 March 2004
Waikoloa Beach Marriott, Kailua, Hawaii
First Announcement

Dear Colleague,

We are pleased to announce the convening of a Workshop on optical-infrared-mm/submm (OIM) Astronomical Polarimetry, in the wonderful surroundings of the north Kona coast in March 2004. The aim of the Workshop is to bring together experts in all areas of OIM astronomical polarimetry to discuss the most recent results in this exciting and crucial field, and to consider the potential for polarimetry in the era of eight- and ten-metre optical and infrared telescopes. The meeting will concentrate on ground-based polarization measurements, and will include a session devoted to new and novel instrumentation. The remaining sessions will be organized according to the astronomical source rather than to wavelength regime or specific technique. Neither Radio polarimetry nor Solar polarimetry are within the conference remit, but each will be the subject of review talks which will set the scene for two of the conference sessions.

SCIENCE AREAS

Sessions will be divided into two, with approximately 80 per cent of the time guaranteed for current results and 20 per cent for presentations on future directions, facilities etc. Proceedings, including posters, will be published. The following science areas will be covered:

Techniques and Instrumentation
Interstellar Dust and Gas
Galaxies, Radio Galaxies and AGN
Star Formation
Circumstellar Disks and Extrasolar Planets
Stars, CVs, Magnetic Stars, Stellar Evolution
High-redshift and Cosmological Polarimetry
Theory and Modelling

DATES AND DEADLINES

Web site opens: 1-Jun-2003
Commencement of Registration: 1-Jun-2003
Second Announcement: 1-Oct-2003
End of Early Registration: 1-Dec-2003
Abstract Deadline: 1-Jan-2004
Late Registration Deadline: 1-Feb-2004

SPONSORING ORGANIZATIONS

Joint Astronomy Centre and Subaru Telescope

Canada-France Hawaii Telescope
Gemini Observatory
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