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Abstracts of recently accepted papers

Determination of Miras temperatures from TiO and VO bands. Estimates of distances

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Effective temperatures are determined for a sample of 165 oxygen-rich Miras using indices related to molecular band strength of titanium oxide and vanadium oxide computed from narrow-band photometry observations. We find a clear although very scattered period–temperature relation which agrees with a previous one. Using a theoretical evolutionary track on AGB and assuming that the scatter around the period–temperature relation is due to mass differences, we can obtain a period–luminosity relation similar to the one observed in the LMC if the mass range is 0.8 to 2.6 $\mathcal{M}_{\odot}$. Effects of metallicity are discussed. The determined luminosities are used to calibrate distances that are compared to several other estimations.

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Millimeter-wave observations of CO in Planetary Nebulae

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We present NRAO 12-meter observations of CO (J=1-0 and J=2-1) in 6 planetary nebulae, including the first confirmed detection of a molecular outflow in K 3-35 and the first observations of J=1-0 emission from NGC 2440. The J=2-1 spectrum towards K 3-35 shows a strong peak at $\sim$ 10 km s^{-1} (V_{lsr}) and a $\sim$ 40 km s^{-1} wide, lower excitation, high velocity component. The strong peak is narrow ($<$ 5 km s^{-1}) and is probably associated with a galactic molecular cloud; the high velocity emission feature indicates an outflow velocity of about 17 km s^{-1}. The CO lines towards NGC 2440 are broad and double-peaked, and indicate an expansion velocity of $\sim$ 29 km s^{-1}. The emission lines from IC 5117 are bright, "two-horned" and suggest an expansion velocity of 17 km s^{-1}. Observations towards AFGL 915 show narrow and single-peaked emission lines which have $\sim$ 20 km s^{-1} wide wings. The 115 GHz observation towards IC 418 shows a broad emission line, which we believe is the H38α recombination line. To confirm this, we also observed the H39α recombination line at 106.7 GHz. A comparison of the two lines suggests that there is no significant molecular emission at 115 GHz. We estimate the contribution from the H38α recombination line in each of our sources, to avoid overestimating the molecular emission. Using estimates of the distance (from the literature), we calculate or obtain limits to the total amount of molecular gas in our sources.

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The Structure and Kinematics of the Unusual Bipolar Outflow NGC 7026

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We have undertaken detailed high and low resolution spectroscopy, together with narrow and broad band imaging of the unusual outflow source NGC 7026. As a consequence, we find evidence for appreciable changes in excitation, and a highly variable emission structure, consistent in part with observed variations in electron density. The mean electron density is found to be $n_e = 2.05\ 10^3\ cm^{-3}$, whilst the mean extinction is $A_v = 2.0\ mag$. The outflow kinematics match the optical structure in suggesting an extremely complex flow, not readily explainable using simple prescriptions. We find, however, that the overall characteristics of the outflow may be explained in terms of a more complex model, in which up to four separate outflow centres are distributed at the extremities of an inner spheroidal shell. Such structures may constitute an advanced phase in the break-up of the primary shell, and eventually lead to the formation of a more typical bipolar outflow structure.

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Proper motions of water vapour masers and bipolar outflow from NML Cygni

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MERLIN observations of the 22-GHz H_2O masers in the circumstellar envelope of the supergiant NML Cyg show an irregular ring of emission 200 mas across, plus a pair of outlying features to the NW and SE nearly 600 mas apart. Comparison with maps at previous epochs reveals proper motions of these outlying features, of 1.9 ± 0.4 mas yr^{-1}. This corresponds to a transverse velocity of 19 ± 4 km s^{-1} at a distance of 2 kpc, which is consistent with the radial velocity range of the 22-GHz emission. The remaining masers which form the irregular ring are modelled as an expanding and accelerating thick shell. The NW-SE symmetry axis of the H_2O masers is aligned with a NW-SE asymmetry which occurs in the OH 1612-MHz masers on a larger scale of 3 arcsec. It appears that this is an internally driven effect, most likely a bipolar outflow which is more highly collimated near the star (H_2O masers) and becomes less collimated at greater distances (OH masers). The results are compared with bipolar outflows seen in other evolved objects.

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Preprints can be obtained by contacting Anita Richards (amsr@jb.man.ac.uk) *or via WWW on* http://www.jb.man.ac.uk/ amsr/ *or via anonymous ftp on* ftp.jb.man.ac.uk then cd /pub/amsr

Hubble Space Telescope and Ground-Based Imaging of the Bipolar Proto-Planetary Nebula M1-92: Evidence for a Collimated Outflow

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We present ground-based and Hubble Space Telescope optical narrow-band images of M1-92. M1-92 is a bipolar proto-planetary nebula currently undergoing the transition from asymptotic giant branch star to planetary

nebula. Previous spectropolarimetry of this object revealed that the line emission produced in the bipolar lobes is dominated by shock emission. The goal of the current observations is to determine the morphology of the shock heated gas in order to better understand the origin of this emission.

The ground-based images suggest that the shock emission is concentrated in diffuse knots in the bipolar lobes. Our high spatial resolution Wide Field Planetary Camera 2 images demonstrate that the shock emission is the result of a collimated outflow that originates near the central star and impacts the bipolar lobes. The outflow axis appears to be inclined with respect to the bipolar axis of M1-92, suggesting the presence of a precessing or wobbling jet. We discuss these findings in the context of the current models that seek to explain the planetary nebula formation process.

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M2–9: moving dust in a fast bipolar outflow.

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Using optical images and spectra of the bipolar nebula M2–9 we show that, in addition to the well–known bright inner nebula, the object has fast, highly collimated outflows reaching a total extent of 115 arcsec. These radially opposed and point–symmetric outer lobes are *both* redshifted, leading us to model the radiation from them in terms of light reflected from moving dust, rather than intrinsic emission. Our polarization images show that the lobes are 60% linearly polarized in a direction perpendicular to the long axis of M2-9. This high polarization indicates optically thin scattering, and lends weight to our dust scattering model. Another indication that reflected light is involved is that the Hα line in the central object and in the brightest outer lobe both show large wings.

Use of this model then allows us to determine the distance to M2–9 directly from the measured proper motions on images taken over a period of more than 16 yrs. The physical and geometrical parameters of the nebula then follow. M2–9 is at a distance of 650 pc, is 0.4 pc long, has a luminosity of 550 $L_\odot$, and its outer nebula has a dynamical age of 1200 yrs, in round numbers.

Using the fact that the central object has been constrained to be of low luminosity but of a sufficiently high temperature to make the observed OIII, we argue that the central object of M2-9 has to contain a compact, hot source, and is therefore probably a binary.

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Two planetary nebulae in the Sagittarius Dwarf Galaxy

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Two planetary nebulae are shown to belong to the Sagittarius Dwarf Galaxy, on the basis of their radial velocities. This is only the second dwarf spheroidal galaxy, after Fornax, found to contain planetary nebulae. Their existence confirms that this galaxy is at least as massive as the Fornax dwarf spheroidal which has a single planetary nebula, and suggests a mass of a few times 10^7 solar masses. The two planetary nebulae are located along the major axis of the galaxy, near the base of the tidal tail. There is a further candidate, situated

at a very large distance along the direction of the tidal tail, for which no velocity measurement is available. The location of the planetary nebulae and globular clusters of the Sagittarius Dwarf Galaxy suggests that a significant fraction of its mass is contained within the tidal tail.

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Planetary nebulae morphologies, central star masses and nebular properties

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We have constituted a sample of about 80 PN with defined morphologies and well observed basic parameters (fluxes, angular radii, expansion velocities and magnitudes of the central stars). For these PN, we have derived the central star masses by comparing the observed set of parameters with those predicted by a simple evolutionary model of a PN, expanding at the same velocity as the observed one. We have then examined the relations between the PN morphological types and other properties, linked to the central star mass.

Bipolar PN are shown to have a wider distribution of central star masses than the rest of PN, and shifted towards higher values. They lie closer to the Galactic plane and tend to have larger N/O ratios.

Point symmetric PN, which have not been much studied so far, are found to constitute an outstanding class. They show an almost perfect $M_* - v_{exp}$ correlation. They correspond to a rather short evolutionary stage of PN. They lie, on average, further from the Galactic plane than bipolar PN and tend to have lower N/O.

Globally, PN with higher central star masses are found closer to the Galactic plane, and the observed relation between N/O and M_* is roughly consistent with the predictions from evolutionary models for AGB stars.

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Observations of the central star and nebula of Abell 65

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Imaging and spectrophotometry of the low surface brightness planetary nebula Abell 65 and its eclipsing binary central star are presented. The spectrum of the central star is remarkable in showing H and He lines *in emission*, similar to the spectra of cataclysmic variables. This is the second PN central star, after HFG 1, to show such stellar line emission. The central star is of high temperature ~80000K and the nebula of high excitation, optically thin, and with a high He abundance. The morphology is unusual with a central dark lane (not dust) and high excitation outer filaments. The relation between the close binary nucleus and the nebular morphology is discussed.

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Dust particle size distribution around oxygen-rich mass losing red giants

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We investigate the size distributions of circumstellar grains around 7 oxygen-rich mass-losing red giants by using published data for the spatial extents of the circumstellar OH masers to compare with measures of the near infrared sizes and thus to constrain the circumstellar extinction curves between the ultraviolet and the infrared. We find that the extinction increases toward the ultraviolet with the implication that a large fraction of the grains must be ejected with radii $<< 0.3$ μm. For an assumed size distribution of circumstellar particles similar to that in the interstellar medium such that $n(a)da$ varies as $n_0 a^{-3.0} exp(-a/a_0)$, where a is the radius of a spherical grain, two different arguments show that the upper limits or inferred values of a_0 are comparable to 0.14 μm, the value of this parameter which describes the size distribution of interstellar grains in diffuse clouds. These results are consistent with the standard hypothesis that interstellar grains grow and evolve from circumstellar dust.

Around IRC+10420, there appears to be an additional population of big grains, with radii ≥ 0.5 μm and carrying $\sim$20% of the dust mass. These large particles may be formed because they have time to grow in the rotating equatorial disk postulated to exist around this star, and they may be similar to some of the isotopically-anomalous inclusions found in meteorites.

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