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Dense circumstellar nebulae in wide binary central stars

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Detection of close binary central stars with periods of less than a day is now well-tested and routinely possible via photometric monitoring. For wide binary central stars with periods of weeks to years detection techniques are still in their infancy. Radial velocity monitoring programs are yet to be applied to very large samples and the method suffers from large systematic errors as well as intrinsic wind variability. One alternative we are exploring is the detection of dense circumstellar nebulae residing around a wide companion. The archetype of this class is EGB6 as revealed by *HST* imaging (Bond 2009). Here we present spectroscopic evidence for other EGB6-like central stars and discuss their relationship to symbiotic stars. A probable 12.5-day irradiated binary is also presented to demonstrate the limits of the photometric monitoring technique.

Dense circumstellar nebulae in wide binary central stars★

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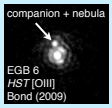
★Based on observations made with the VLT at Paranal Observatory [079.D-0764(A), 081.D-0748(A), 083.D-0654(A)], the NTT at La Silla Observatory [079.D-0764(B)], and Gemini South [GS-2009A-Q-35]. ☺b.miszalski@herts.ac.uk

INTRODUCTION



Identification of close binary central stars (CSPN) with periods ≤ 1 day via photometric monitoring is now routine and they make up ~17±5% of all CSPN (Bond 2000; Miszalski et al. 2009a). At orbital periods larger than ~10 days the irradiation effect becomes very weak (see **MPA 1508-6455** panel at right). Besides NGC 2346 and Ciardullo et al. (1999) binaries there is essentially *no information* about binaries at P ≥ 10 days, so for convenience we group them under *wide binaries*. In this regime (P~10-10^3 days) periods can be measured with radial velocity (RV) monitoring, but current studies are problematic. Targets are bright and under-sampled, while sensitivity is reduced by large systematic errors and intrinsic wind variability. The statistics are thus unreliable, e.g. De Marco et al. (2004) claimed 98% probability of variability in the *single* ionising star of the non-PN PHL 932 (Frew et al. 2010). Identification of wide binaries must be improved to properly gauge their role in the overall binary fraction.

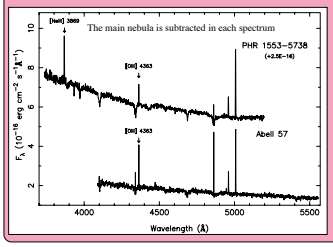
We propose a **new method** that uses high spatial resolution longslit or integral field unit (IFU) spectroscopy to identify ***circumstellar nebulae arising from wide binary interactions***.
In 4/5 of the examples given here additional evidence rules out a close binary.

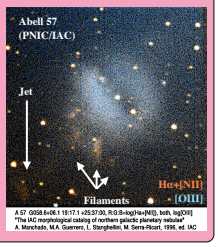
Frew & Parker (2010) noted dense cores in a few PNe and called them 'EGB 6-like' after the archetype of this class, EGB 6 (Ellis et al. 1984; Liebert et al. 1989; Su et al., these proc.). EGB 6 is an old PN 13' across with a dense inner nebula (n_e ~10^{6-7} cm^{-3}). The strong [OIII] 4363 and [NeIII] 3869 in the inner nebula appears identical to those in D'-type symbiotic stars (Schmid & Nussbaumer 1993) and is co-located with a resolved companion ~120 AU from the CSPN (Bond 2009; inset). Only He 2-428 has a close binary *and* a dense nebula but the densities appear to be > 10^{10} cm^{-3} and mass transfer might be active (Rodriguez et al. 2001; Santander-Garcia et al. these proc.). A cool T~300 K dust component is purported to be a remnant accretion disk, whose ionisation sustains the nebula, but it is unclear if it can survive 10^5 yrs. Higher dust temperatures and variability would be expected if accretion were still occurring.

Unlike a D' symbiotic, a main-sequence companion must be present as more evolved stars are too luminous for such a close and evolved PN (no IRAS detection also rules out dust obscuration of a giant). From Fulbright & Liebert (1993) near-infrared photometry we find J-H=1.1-1.3, H-K=0.82-0.84 and J-K=2.0-2.1 for the companion after subtracting WD and HI continuous emission contributions. These colours are redder than previously found and resemble either a reddened M7V star with E(B-V)~1.6 or an unreddened > L3 star. At M_K~7.2 the star is brighter than expected (M_K~10.6, Hawley et al. 2002) so we can rule out an L-type. The colours are likely influenced by cool dust of uncertain origin. Atmospheric ablation (Dopita & Liebert 1989) may allow dust to form in the wake of the companion or a mismatched interacting wind could work if the contact point coincides with the companion (Kenyon et al. 1993; Nussbaumer 2000). Wide binary interactions are poorly understood, but an accretion disk is not necessarily required in either scenario as dust could indeed be *continuously replenished*.

Abell 57 (PN G058.6+06.1) and PHR 1553-5738 (PN G325.3-02.9)

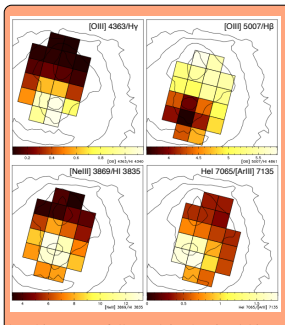
Abell 57 was observed with VLT FORS (Appenzeller et al. 1998) and found to be EGB 6-like with [OIII] 4363/Hγ > 1. Miszalski et al. (these proc.) rule out a close irradiated binary.
PHR 1553-5738 is a diffuse MASH PN ~130" across (Parker et al. 2006). Targeted during an unbiased VLT FORS survey of 18 mostly MASH PN, this was the only EGB 6-like CSPN.





A 57 G058.6+06.1 19:17.1 +25:37.00, R:G:B=log(Hα+[NII]), both, log[OIII]
©The IAC morphological catalog of northern galactic planetary nebulae
A. Manchado, M.A. Guerrero, L. Stanghellini, M. Serra-Ricart, 1996. ed. IAC

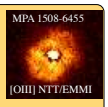
M 2-29 (PN G004.0-03.0)



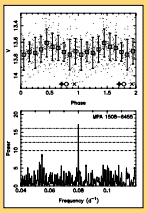
Long considered a halo PN for its low O abundance of 7.3 dex (Pena et al. 1991), Miszalski et al. (2010) measured **8.3 dex** based on VLT FLAMES IFU spectroscopy of the outer regions of this *bulge PN*. The huge discrepancy is caused by ground based longslit observations averaging over the high spatial variation of [OIII] 4363/Hγ that can reach 1.1 in the core (Torres-Peimbert et al. 2007; Miszalski et al. 2009a). Miszalski et al. (2010) also find stronger [NeIII] and HeI lines (inset).

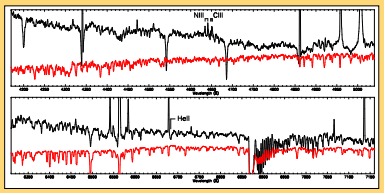
The most intriguing aspect of M 2-29 is its lightcurve which shows an NGC 2346-like fading event (Hajduk et al. 2008). Hajduk et al. proposed a complex circumbinary disk model but this was not fully explained. Miszalski et al. (2010) rule out a close binary from periodogram analysis but do find an increase in V-I colour of 0.7-0.9 mag during eclipse (a G-type companion). The lightcurve can be reproduced entirely by dust formation and evaporation models of R Coronae Borealis stars (e.g. Goeres & Sedlmayr 1992; Clayton 1996) where an eccentric wide companion may trigger dust formation. Hajduk et al. confused pulsation-driven variations at light max. with a secondary eclipse to propose a *spurious* 18 yr orbital period.

MPA 1508-6455 (PN G316.7-05.8)



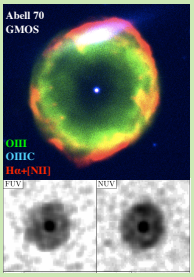
Variability amplitudes for periods of days to weeks quickly reach << 0.1 mag (De Marco et al. 2008). To emphasise this Miszalski (2009) found the MASH-II PN **MPA 1508-6455** (Miszalski et al. 2008) to have a significant period of **12.5 days** in ASAS (Pojmanski 2002). Our deep ANU 2.3m spectrum shows CIII/NIII emission lines typical of irradiated close binaries (Pollacco & Bell 1993,1994) on top of a clearly composite spectrum. The 70 mmag amplitude variations must be due to irradiation variability at the edge of expected observable and theoretical limits.



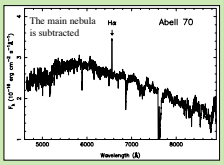


Black: MPA 1508-6455, Red: A K2V star for reference (Bagnulo et al. 2003). In this case the companion may be evolved to explain the roughly equal luminosities of each component.

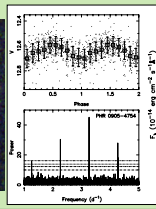
Abell 70 (PN G038.1-25.4) and PHR 0905-4754 (PN G268.9-00.4)

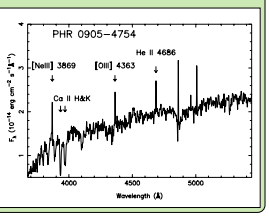


Abell 70 (Miszalski et al. in prep) is a little studied PN 45" across. Miszalski (2009) noticed odd 2MASS colours and took 30 min exposures with the B1200 and R400 GMOS gratings (Hook et al. 2004). The HRV= -95±2 km/s measured from MgI absorption lines of the V=17.4 G8IV star agrees with the nebula (-90±2 km/s) so this is no superposition. The ionising star is only seen in GALEX UV observations (Morrissey et al. 2007) from which we estimate V=19.8. Excess Hα emission is present from a low density circumstellar nebula. Miszalski et al. (these proc.) rule out a close binary so it is a likely wide binary.



PHR 0905-4754 (Frew et al. 2010, in prep.) is a MASH PN with an atypical F giant CSPN. Miszalski (2009) found a period of 0.31 days from ASAS, but to avoid breakup of the F giant we must rule out a close binary or rotation as the cause of variability. The companion appears to show Delta Scuti pulsations and the ANU 2.3m spectrum reveals a dense circumstellar nebula. Like Abell 70, the ionising star is not seen because of the high luminosity of the F giant and/or its intrinsic faintness.





Discussion

The frequency of EGB 6-like behaviour is uncommon (max 5% of all PNe or ~150 PNe). This is too high for all of them to have L-type companions (Farihi et al. 2005). They can occur where evolved companions (PHR 0905-4754) or very late M types (EGB 6) are present.
Low-ionisation structures (LIS, Gonçalves et al. 2001; Miszalski et al. 2009b) are prominent in Abell 57, Abell 70 and *especially* PHR 0905-4754. This suggests LIS may form before the common-envelope phase started or the common-envelope phase further widened or kicked-out the companion (e.g. Farihi et al. 2006). Kinematic ages of polar outflows also suggest LIS form before the main nebula is ejected (Corradi et al., these proc.).
The presence of circumstellar nebulae implies symbiotic-like wide binary interactions. Evolved companions are increasingly being found in PNe (Abell 70, PHR 0905-4754, MPA 1508-6455; De Marco 2009) forcing us to reconsider the very small likelihood of catching brief evolutionary stages inside PNe ejected by the hot component (Corradi 2003). He 2-104 has a large ionised mass of 0.1 Msun but also contains a Mira (Santander-Garcia et al. 2008). Indeed, outer nebulae are also quite common in D'-type symbiotics (e.g. Jorissen et al. 2005).
A mixed origin for multiple nebula components may help resolve the debate (Corradi 2003).

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