

Telescope Time Awarded to N. Law in the last 2 years.

Include upcoming awarded time. Give date, number of nights, telescope, instrument, program title, and briefly list status, results, and publications

2006B, 3 nights, NTT (La Silla, Chile), LuckyCam, “Southern Very Low Mass Binaries”. Little data taken due to terrible weather.

2005B, 3 nights, Nordic Optical Telescope (La Palma), LuckyCam, “X-Ray Emitting Very Low Mass Stars”. Paper in final draft.

2005A, 2 nights, Nordic Optical Telescope (La Palma), LuckyCam, “Large Sample of Very Low Mass Binaries”. Published in MNRAS 368, 2006, and Astron.Nachr. 326, 2005.

List of Publications of N. Law over the past 2 years.

Include only refereed and invited papers published or in press within two years prior to due date of application. List facilities used for each paper.

N. Law, S. Hodgkin, C. Mackay, 2006, “Discovery of five very low mass close binaries, resolved in the visible with Lucky Imaging.”, MNRAS 368, 1917. Nordic Optical Telescope.

N. Law, C. Mackay, J. Baldwin, 2006, “Lucky Imaging: High Angular Resolution Imaging in the Visible from the Ground”, A&A 446, 739. Nordic Optical Telescope.

N. Law, S. Hodgkin, C. Mackay, J. Baldwin, 2005, “10 New Very Low Mass Close Binaries Resolved in the Visible”, Astron.Nachr. 326 1024. Nordic Optical Telescope.

Object List for this Proposal

Run	Object	RA	DEC	Mtype	Mag
1	AG Dra	16 01 41	+66 48 10	V	9.8
1	Hen 3-1341	17 08 37	-17 26 31	V	13.0
1	HM Sge	19 41 57	+16 44 40	V	11.0
1	Z And	23 33 40	+48 49 06	V	10.5
1	CH Cyg	19 24 33	+50 14 29	V	8.8
1	HBV 475	20 51 01	+35 34 54	V	12.1
1	RS Oph	17 50 13	-06 42 28	V	4.3
1	V1016 Cyg	19 57 05	+39 49 36	V	10.0
1	V1329 Cyg	20 51 01	+35 34 54	V	12.1
1	FN Sgr	18 53 55	-18 59 40	V	9.0

Is this proposal part of an approved thesis program? Not part of a thesis program.

High-angular-resolution Imaging of Outflows and Bipolar Jets from Symbiotic Binaries N. Law, R. Dekany & C. Mackay

1. Introduction

Symbiotic binaries contain an evolved red giant star that transfers material to a hotter, more compact component, usually a white dwarf (Kenyon 1986). The systems are distinguished from other interacting binaries by their large orbital periods, on the order of tens to hundreds of years. Because of the wide separation, the mass transfer to the hot component occurs by Bondi-Hoyle capture of the red giant wind. However, this steady-state situation often enters a dramatic new state. On timescales of years or decades, the hot component enters an outburst phase defined by a large mass loss (Kenyon & Webbink 1984; Fernandez-Castro et al. 1995) and sometimes bipolar jets (Brocksopp et al. 2004, Sokoloski & Kenyon 2003). The Southern Crab nebula (figure 1, Corradi et al. 2001) is an excellent example of the resulting complex nebulosity.

These outbursts are of particular interest because the white dwarfs in symbiotic binaries may accrete enough mass to approach the Chandrasekhar mass limit and explode as Type 1a supernovae. The average accretion rate of the white dwarf clearly depends on the amount of mass lost during outbursts. We must therefore determine the frequency and intensity of these events to predict the fate of these systems.

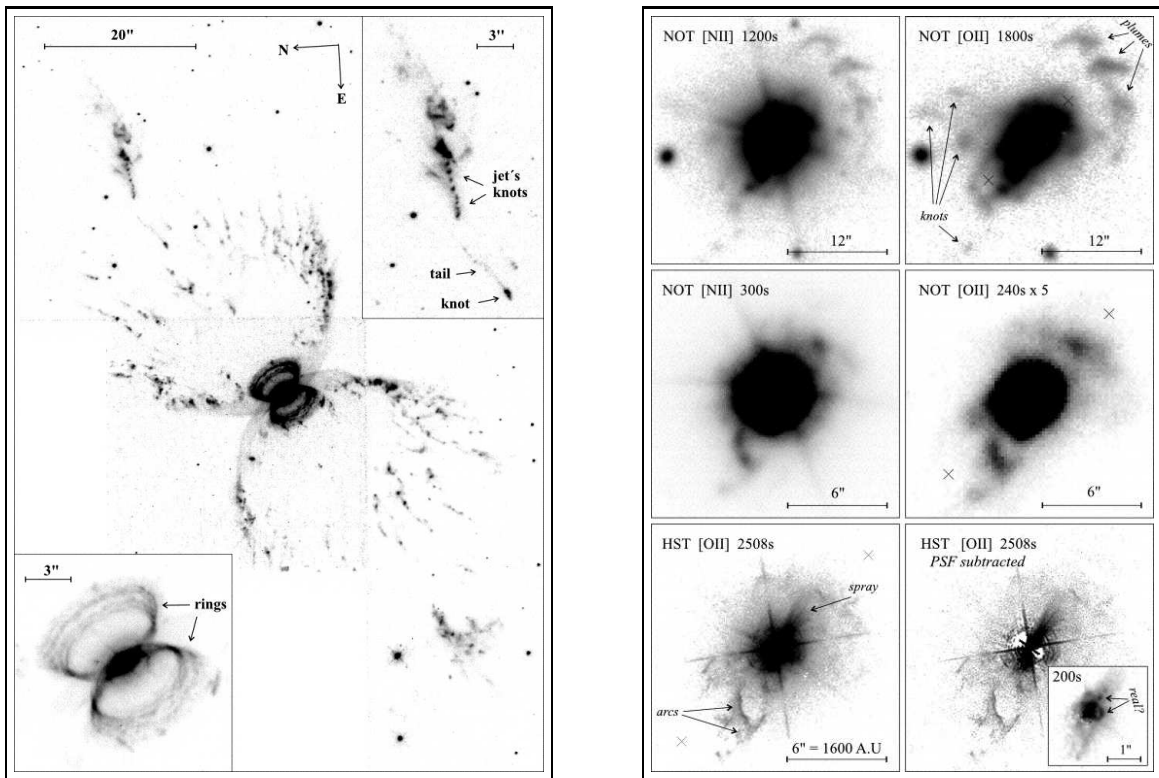


Fig. 1.— (left) He2-104, the Southern Crab in a 4000 second HST exposure from Corradi et al. 2001a. Note that resolving much of the structure requires sub-arcsecond resolution. (right) CH Cyg, log intensity scale. The top four images are seeing-limited; the bottom two are HST, illustrating the dramatic improvements from high-angular-resolution techniques. From Corradi et al. 2001b.

The occasional detection of bipolar jets from symbiotic binaries suggest that the systems can also be used to further understand the nature and cause of collimated jets. Such jets are found in a wide variety of accretion-disk phenomena, from protostellar outflows to active galactic nuclei. The origin of jets in symbiotic binaries is not well understood – few jets have been detected, and some are even found in systems not in outburst (Brocksopp, Bode & Eyres 2003).

There has been surprisingly little high-angular-resolution optical imaging of symbiotic binaries. A very short exposure HST survey of eight symbiotic binaries is presented by Brocksopp, Bode & Eyres (2003); extended emission was detected in three of the sources. Corradi et al. 2001a and 2001b present beautiful images of the symbiotic binaries He2-104 (the Southern Crab) and CH Cyg (figure 1). Complex structure is seen in the [N II] emission line on scales ranging from subarcsec to 20 arcsec. *High-angular-resolution optical imaging of a larger, more representative sample of these systems is now required to study the nature and causes of the outflows.*

2. The Proposal – A High-Angular-Resolution Survey of Symbiotic Binary Outflows

We propose a narrow-band high-angular-resolution imaging programme of a representative sample of symbiotic binaries to search for outflows and collimated jets. We will use the unique opportunity for narrow-band visible-light adaptive optics imaging afforded by the new P200 LAMP (LuckyCam with Aperture Masking at Palomar) instrument.

Bright line emission from symbiotic binaries' outflow events persists for decades or more (for example, Corradi 2006; Brocksopp, Bode & Eyres 2003). We can thus construct a detailed history of the mass-loss events from these systems using the residual nebulosities. Our sample will allow us determine outburst rates, velocities, and the presence of jets for each of the studied systems. Correlations between those properties with the nature of the symbiotic stars can then be investigated. For the large majority of our targets, this will be the first deep imaging on subarcsecond scales.

The outburst history of these sources can also be determined from publically-available photometric monitoring. Using this data, we will correlate the spacial positions of detected ejecta in our images with the outburst times, to constrain its proper motion. This will provide detail on the nature of the central engine – distinguishing between protostar-like low-velocity flows and the much faster X-Ray binary jets.

3. Detailed Observation Plan

Program Design We plan to image a representative sample of symbiotic binaries where extended nebulae in have been detected in lower-resolution imaging. These observations will allow us to determine the proper motions of previously-detected central ejecta. The proper motions are often large enough to be measured easily – 0.55 arcsec per year for CH Cyg, for example (Taylor, Seaquist & Mattei 1986). We will also search for structure on sub-arcsecond scales. In particular, Z And has just entered a major outburst stage with new jets detected in optical spectra (Skopal, ATel #882, Sep 14 2006). Those jets may be visible to our imaging by the requested observation time, giving a direct expansion velocity calibration.

LAMP LAMP is a new ultra-low-noise, fast-frame-rate, visible-light camera to be placed behind the Palomar 200" adaptive optics system. The camera uses an L3CCD (see Mackay, Baldwin & Tubbs 2004 or

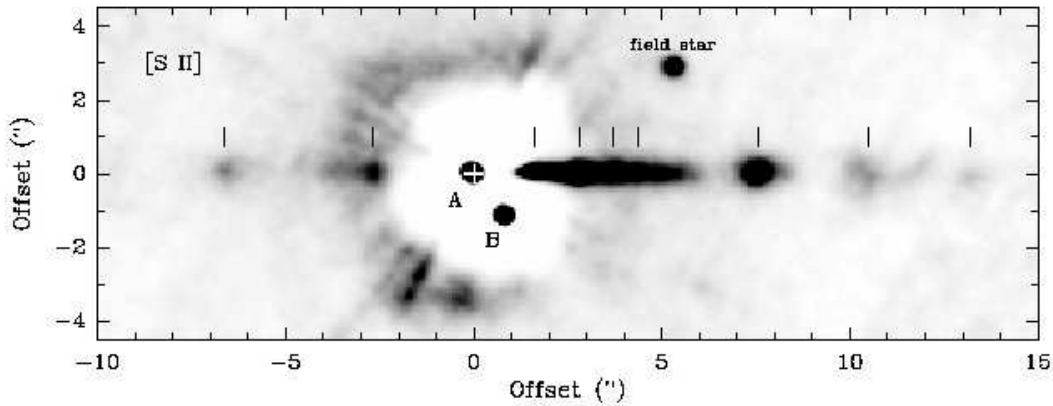


Fig. 2.— CFHT adaptive optics imaging of a classical T-Tauri jet in $H\alpha$, with ~ 0.15 arcsec resolution. Although a different type of target, the image illustrates that visible-light AO imaging can give excellent resolution images of faint nebulosity. From Dougados et al. 2000.

Law, Mackay & Baldwin 2006) to obtain images at 30 frames per second with effective 0.1 electrons read-out noise. At 600nm, images with FWHM=0.03-0.05 arcsec and Strehl ratios of 0.05-0.1 are expected to be produced by the Palomar 200" AO system and LAMP. The PI of this proposal (N. Law) is the project lead for the instrument, which has been developed specifically for the P200. More details can be found at www.astro.caltech.edu/~nlaw/lamp/.

Narrow-band, High-Contrast Imaging We will primarily image in a narrow [N II] filter ($\lambda = 658.3\text{nm}$, width $\sim 1\text{nm}$). Low-ionisation species such as [N II] are likely to be the best tracers of large-scale outflows (Corradi et al. 2001a, Corradi et al. 1999). Every ten seconds, under automated software control, a PSF will be obtained in a nearby continuum filter (where the starlight will dominate).

Requested Time Because LAMP is a new instrument for P200, detailed calibrations of sensitivity are not available. In particular, the to-be-determined final Strehl ratio sets the effective background within one arcsec of the sources. For that reason, we scale the exposure times used by other studies (Corradi et al 1999, 2001ab). In the [N II] filter, one hour exposures will be sufficient. We will also undertake more detailed studies of Z And and CH Cyg, in a variety of narrow band filters to study the evolution of the nebulae since detailed HST imaging. This will require an extra 3 hours of time. We request two nights in total.

Feasibility Spectacular emission has been detected in moderate length *seeing-limited* exposures (< 1 hour) for a large fraction of symbiotic binaries using 2-4m class telescopes (for example, Corradi et al. 2001a, 2001b, Corradi et al. 1999, Brocksopp, Bode & Eyres (2003)). Dougados et al. 2000 demonstrated the use of PSF calibration in the visible behind the 3.4m CFHT's AO system to detect nebulosity near bright stars on 0.1-0.2 arcsec scales in 1000 second integrations (figure 2). This demonstrates that low-Strehl visible-light AO imaging of nebular targets is feasible.

Name	RA	Dec	mV
AG Dra	16 01 41	+66 48 10	9.8
Hen 3-1341	17 08 37	-17 26 31	13.0
HM Sge	19 41 57	+16 44 40	11.0
Z And	23 33 40	+48 49 06	10.5
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V1329 Cyg	20 51 01	+35 34 54	12.1
FN Sgr	18 53 55	-18 59 40	9.0

Table 1: The proposed symbiotic binary targets.

4. Summary

We propose deep imaging of a representative sample of symbiotic binaries. Our sample will allow us determine outburst rates, velocities, and the presence of jets.

Bibliography

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 Fernandez-Castro et al. 1995 ApJ 442 366
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