MAD Science Demonstration Proposal

Title: Deep-high spatial resolution HK_s observations of “giant” proplyds

Investigators	Institute	EMAIL
Sílvia Vicente	Faculty of Sciences of Lisbon University	smvicente@fc.ul.pt
Isamu Matsuyama	Carnegie Institution of Washington	matsuyama@dmt.ciw.edu

Abstract:

We propose to perform deep-high spatial resolution HK_s MAD observations of a sample of 8 “giant” photo-evaporating protoplanetary disks detected in different cluster environments (age, distance, number of OB stars). Our goal is to resolve and characterize with detail their circumstellar structures by comparison with HST/ACS optical images and to test if the models of protoplanetary disk evaporation for Orion are applicable in more extreme regions.

Scientific Case:

Externally illuminated photoevaporating protoplanetary disks or *proplyds* (O’Dell et al. 1993) are a special class of YSO found embedded within or near a HII region. They are usually identified as teardrop shaped photoionized envelopes with bright ionization fronts facing the source of UV radiation, visible in optical emission lines (Hα, [OIII], [SII]), and extended tails pointing away from it. Infrared images show the presence of central stars in most proplyds. The disk dust component is seen in some objects as dark silhouettes in front of the bright nebular background or inside the proplyd ionization front and coincides with emission in [OI] and H_2 (Chen et al. 1998). Proplyd appearance can be explained by the interaction of EUV (LyC; $h\nu \geq 13.6$ eV) and FUV (6 eV$\leq h\nu < 13.6$ eV) radiation emitted by the OB stars, with a circumstellar disk and envelope. The establishment of the proplyds as a well defined class of objects resulted in several theoretical models proposed in the literature (Johnstone et al. 1998; Richling & Yorke 1998, 2000; Storzer & Hollenbach 1999; Matsuyama et al. 2003; Hollenbach & Adams 2004; Throop & Bally 2005). The *Hubble Space Telescope (HST)* provided the first direct images of proplyds in the core of the Orion Nebula (NGC 1976, M42), the nearest, young (450 pc; 1 Myr) and best studied HII region in its stellar content and proplyd quest. Over half of the 300 YSO in the Trapezium cluster observed within the HST images were classified as proplyds and their head diameters vary from 70 to 2520 AU (Vicente & Alves 2005). In addition, several microjets are associated with proplyds (Bally at al. 2000) indicating that the embedded stars are still surrounded by active accretion disks.

More recently, several proplyds were found in the outskirts of the Orion Nebula (O’Dell 2001; Smith et al. 2005; Bally et al. 2005) and in other cluster regions: the Lagoon Nebula (Stecklum et al. 1998), NGC 3603 (Brandner et al. 2000), the Trifid Nebula (Yusef et al. 2000), the Carina Nebula (Smith et al. 2003) and IC 1396, NGC 2244, NGC 2264 (Balog et al. 2006, 2007) and they are several times larger than the typical-size proplyds found in Orion, which raise questions about their true nature as bona-fide proplyds. Some of these ”giant” globules have been detected in the optical with HST and others in the mid-IR with *Spitzer*, but none has been detected in the NIR with high spatial resolution. MAD represents an unique opportunity to observe these objects in the NIR with an unpredecented sensitivity and resolution.

As a science demonstration program for MAD, we propose to observe, in H and K_s, a sample of 8 “giant” proplyds and proplyd candidates detected in different cluster environments (age, distance, and number of OB stars) and located at different distances from their external ionizing sources. Different cluster ages, densities and UV radiation fields may strongly affect proplyd characteristics. We will be able to investigate these systems in more detail and study their morphology by comparison with existing HST/ACS optical images. We also be able to test theories of photoevaporation and investigate the effects of the evaporation on the characteristic emission features of the dust. Are the models for protoplanetary disk evaporation in Orion applicable in more extreme regions?

For “real” proplyds, we expect to detect the embedded stars, the silhouette dusty disks if near edge-on, outflows and jets and possibly shocks originated from wind-wind collisions.

The PI has extensive experience in reducing and analyzing AO near-IR data from the ESO NAOS-CONICA instrument and the CoI, Isamu Matsuyama is an expert on the theory of protoplanetary disk photoevaporation.

In an externally irradiated environment, the object circumstellar gas is heated and ionized creating an ionization front that is bright in hydrogen recombination lines like Hα (0.656 μm), Paβ (1.282 μm, J), Paα (1.875 μm), Brγ (2.1654 μm, K_s) and Brα (4.05 μm, L') and other highly ionized species like [OIII] (0.502 μm), [NII] (0.658 μm) and [SII] (0.673 μm) in the optical. Jets and outflows produce shock-excited NIR emission lines of [FeII] (1.26 μm, J; 1.64 μm, H) and H_2 (1-0)S(1) (2.12 μm, K_s). In addition, the evaporating gas drags small particles of dust into the proplyd photoevaporative flow that will be heated and eventually destroyed by EUV and FUV stellar radiation and trapped Lyα photons. These small particles will emit in the NIR and are also entrained in the outflows and jets.

Our targets are located in the South of the Orion Nebula (450 pc, O6 star, ~ 1 Myr), NCG 2244 (1.5 Kpc, O5 star, 4 Myr), NGC 2264 (800 pc, O7 star, 4 Myr), NGC 3372 (2.8 Kpc, several O stars, 1-3 Myr) and NGC 3603 (6-7 Kpc, several O stars, 2-3 Myr). In Orion are 3 giant proplyds and their associated Herbig-Haro flows: 181-826 + HH540, 253-1536 + HH668, 216-0939 + HH667 (sizes from 800 to 1200 AU) and a small pure silhouette disk 295-606 which is included in this list because of its good MAD GS asterism. They are described in detail in Smith et al. 2005 and Bally et al. 2005. The proplyds in NCG 2244 and NCG 2264 were discovered by Balog et al. 2006 in *Spitzer* 8 and 24 μm images which are still the only images published of these objects. In the target list, I have included a second field (field 2) for each one of these clusters, which are potential "proplyd" regions as described in Balog et al. 2007. The proplyd in NGC 3372 is in Smith et al. 2003 list and NGC 3603 field holds the proplyd 1 and proplyd 2 objects described in Brandner et al. 2000.

For the most interesting objects, with close enough bright guide stars, a follow-up study using narrow-band imaging and spectroscopy with NACO, SINFONI and VISIR is planned.

Targets and integration time

Target	**RA**	**DEC**	**Filter**	**Magnitudes**	**Total integration time** (sec)	**Field** (arcmin)
181-826 + HH540	05 35 18.1	-05 28 26	H Ks	Ks=13-20	1350 each	1
253-1536 + HH668	05 35 25.3	-05 15 35	H Ks	Ks=13-20	1350 each	1
216-0939 + HH667	05 35 21.6	-05 09 39	H Ks	Ks=13-20	1200 each	1
295-606 (silhouette)	05 35 29.5	-05 26 06	H Ks	Ks=13-20	1200 each	1
NGC 2244 - prop	06 31 54.7	04 54 25	H Ks	Ks=13-20	1350 each	1
NGC 2244 - field 2	06 31 55.6	04 56 34	H Ks	Ks=13-20	630 each	1
NGC 2264 - prop	06 41 01.9	09 52 39	H Ks	Ks=13-20	1350 each	1
NGC 2264 - field 2	06 40 58.5	09 53 57	H Ks	Ks=13-20	630 each	1
NGC 3372	10 46 32.8	-60 03 53	H Ks	Ks=13-20	1500 each	1
NGC 3603	11 15 15	-61 15 56	H Ks	Ks=13-20	1200 each	1

Guide stars list and positions

Target: 181-826 + HH540			
	RA$''_{rel}$	**DEC$''_{rel}$**	**V Mag**
GS1	+49	+115	12.4
GS2	+122	-31	8.53
GS3	+124	+45	11.22
SKY	-60	-180	
Target: 253-1536 + HH668			
	RA$''_{rel}$	**DEC$''_{rel}$**	**V Mag**
GS1	+17	+ 25	11.55
GS2	+83	-88	7.58
GS3	-102	-63	13.0
SKY	-140	+150	

Target: 216-0939 + HH667

	RA$''_{rel}$	**DEC$''_{rel}$**	**V Mag**
GS1	-5	+25	9.79
GS2	+73	+64	12.03
GS3	+81	-89	12.74

Target: 295-606 (silhouette)

	RA$''_{rel}$	**DEC$''_{rel}$**	**V Mag**
GS1	+40	+52	8.18
GS2	+45	-67	6.40
GS3	-61	-101	11.22

Target: NGC 2244 - prop

	RA$''_{rel}$	**DEC$''_{rel}$**	**V Mag**
GS1	+60	+86	9.91
GS2	+43	-92	9.13
GS3	-106	-10	11.18
GS4	-38	+110	11.36

Target: NGC 2244 - field 2

	RA$''_{rel}$	**DEC$''_{rel}$**	**V Mag**
GS1	0	0	6.69
GS2	-5	-43	11.61
GS3	-45	-21	11.36
GS4	-41	+32	11.50
GS5	+53	-16	10.79
GS6	-52	-40	9.13
GS7	+51	-57	9.91
GS8	+ 33	+76	10.95

Target: NGC 2264 - prop

	RA$''_{rel}$	**DEC$''_{rel}$**	**V Mag**
GS1	0	+10	8.71
GS2	-27	-23	9.73
GS3	+37	-46	12.07
GS4	+6	-48	12.40
GS5	-48	+72	4.69

Target: NGC 2264 - field 2

	RA$''_{rel}$	**DEC$''_{rel}$**	**V Mag**
GS1	0	-23	4.69
GS2	+47	-80	8.71
GS3	+11	+60	11.98
GS4	+90	+37	9.73
GS5	+85	+30	10.13

Target: NGC 3372

	RA$''_{rel}$	**DEC$''_{rel}$**	**V Mag**
GS1	0.0	-33	9.62
GS2	0.0	+15	11.91
GS3	+7	-95	11.67

Target: NGC 3603 - prop1 + prop2

	RA$''_{rel}$	**DEC$''_{rel}$**	**V Mag**
GS1	-43	-10	11.43
GS2	-55	+15	6.11
GS3	+60	+58	10.87

Science observations

Target	**Template** (arcsec)	**Box Square**	**DIT** (sec)	**NDIT**	**NINT**	**Total time per target (+ overheads, in min)**
181-826 + HH540	auto-jitter	10	1.5	60	15	65 (H and Ks filters)
sky	auto-jitter	10	1.5	60	5	35 (H and Ks filters)
253-1536 + HH668	auto-jitter	10	1.5	60	15	65 (H and Ks)
sky	auto-jitter	10	1.5	60	5	35 (H and Ks)
216-0939 + HH667	auto-jitter	10	1	60	20	60 (H and Ks)
295-606 (silhouette)	auto-jitter	10	10	24	5	60 (H and Ks)
NGC 2244 - prop	auto-jitter	20	15	4	25	65 (H and Ks)
NGC 2244 - field2	auto-jitter	20	0.7877	100	8	41 (H and Ks)
NGC 2264 - prop	auto-jitter	20	1	60	25	65 (H and Ks)
NGC 2264 - field2	auto-jitter	20	0.7877	100	8	41 (H and Ks)
NGC 3372	auto-jitter	10	1	60	25	70 (H and Ks)
NGC 3603	auto-jitter	20	1	60	20	60 (H and Ks)

Time Justification:

Listed in the table above are the technical specifications for each science target. They are ordered accordingly to their observability in 1 night of January 2008 and not their priority. The auto-jitter mode was chosen and, for the 1st two crowded fields a sky offset position was selected. Sky offset positions can be included for the other fields if necessary. The increasing overheads would be compensated by a smaller number of targets observed. In this case, I will provide a target priority list. Most of the targets have good guide star asterims. For the less optimal, but still feasible asterisms, I agree on a degradation of the typical correction performance.

We expect each extended target to be very faint (Ks > 14) in a bright nebular background, and because we want to resolve structures and morphology in these objects we need high spatial resolution and contrast translated in a significant S/N ratio. Assuming a limiting magnitude of Ks ~ 20.5 for a SNR = 3 and for an equivalent exposure time of 600s and an average FWHM of 100 mas, we have considered an exposure time of 1200s on average per target and per filter, accounting for bad seeing conditions. The exceptions are NGC 2244 and NGC 2264-field 2 targets which are "proplyd survey" fields and include a very bright O-type star at their centers. For most of the targets, the GS are out of the CAMCAO 1' x 1' FOV.

Adding overheads, a total observing time of ~ 11h in January 2008 is required for this project.

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