MAD Science Demonstration Proposal

Stellar formation in the cores of SFR: Lupus III

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Abstract:

The IMF and the properties of multiplicity **and their dependence on the age and environment** are two of the most important observational constraints used to study stellar formation. While a large number of studies have been performed in SFR, none of them were successful at studying the cores of associations because of the presence of dazzling bright massive stars. Except in isolated cases (such as the Trapezium, 400pc, studied with HST by variuous authors and with MAD by our team: Bouy et al., 2008, A&A, 477, 681) the output of stellar formation in the direct vicinity of these central stars remains largely unknown. Taking advantage of the novel capabilities of MAD we propose to continue our study of stellar formation in the vicinity of intermediate/massive stars down to the planetary mass domain in the core of a young nearby association.

Scientific Case:

While numerical simulations of stellar formation have reached a high level of sophistication (e.g Bate et al., 2003, 2005), observations have so far failled to provide definite constraints on the mass function in the core of young associations. Most seeing limited surveys indeed tend to avoid the central parts of young associations because of the presence of dazzling massive stars filling the cameras with their heavy persistence effects on the detector resulting from saturation. To date little is known about the presence or absence of faint objects close to young massive/intermediate mass stars. In that context, adaptive optics offers several advantages. It provides a much sharper PSF but also **a much higher contrast**, allowing to obtain **very deep** images even in the direct vicinity of bright stars. It also allows to resolve the structures of the nebulosities commonly found in SFR, increasing the sensitivity to faint objects as illustrated in Fig. 1.

We propose to use MAD to perform an innovative study of stellar, substellar and planetary formation. The high spatial resolution and high dynamic range achieved by MAD on an unprecendented large field of view will allow us to search for very low mass, substellar and planetary mass objects in the unstudied core of the Lupus III association, where previous seeing limited surveys were dazzled by the bright massive stars. Our previous experience with MAD in the core of SFR succesfully lead to the discovery of 5 confirmed brown dwarfs and 1 confirmed planetary mass object in the $\sigma-$Orionis association (http://arrakeen.free.fr/work/madsori.pdf; submitted to A&A), and an even larger number of candidates.

The Lupus association: is only ≈150 pc away and about 1 Myr old. It is one of the prime locations for the study of young low-mass stars and brown dwarfs (BDs), and the determination of the IMF. Deep optical and near-IR surveys revealed a large population of TTauri and young BDs (Comeron et al., 2003, A&A, 406, 1001; Lopez Martí et al., 2005, A&A, 440, 139). Spitzer surveys showed that a number of them harbour disks (Chapman et al., 2007, ApJ, 667, 288; Allen et al., 2007, ApJ, 655, 1095). Because of the high extinction and of the presence of dazzling Herbig Ae stars (HD 144667 and HD 144668, Fig. 2), the above mentioned surveys did not study the core of the association. The projected field of view of MAD at 150 pc corresponds to ≈9000 AU, which is of the order of the Oort cloud around the Sun. The minimum separation probed with MAD (≤0.1") corresponds to 15 AU, which is of the same order as Saturn's orbit around the Sun (10 AU). While this resolution is similar to the minimum separation probed by Ghez et al. (1997, ApJ, 481, 378) in the same association using speckle interferometry, the dynamic range probed by the MAD observations will be much greater reaching 21 mag in each filter, **corresponding to a limiting mass of 2 M_{Jup} at the age and distance of the association**.

Our team has complementary expertise in observation, data analysis and MCAO instrumentation, and we are well prepared to observe, analyze and interpret the data, and publish them in a timely manner.

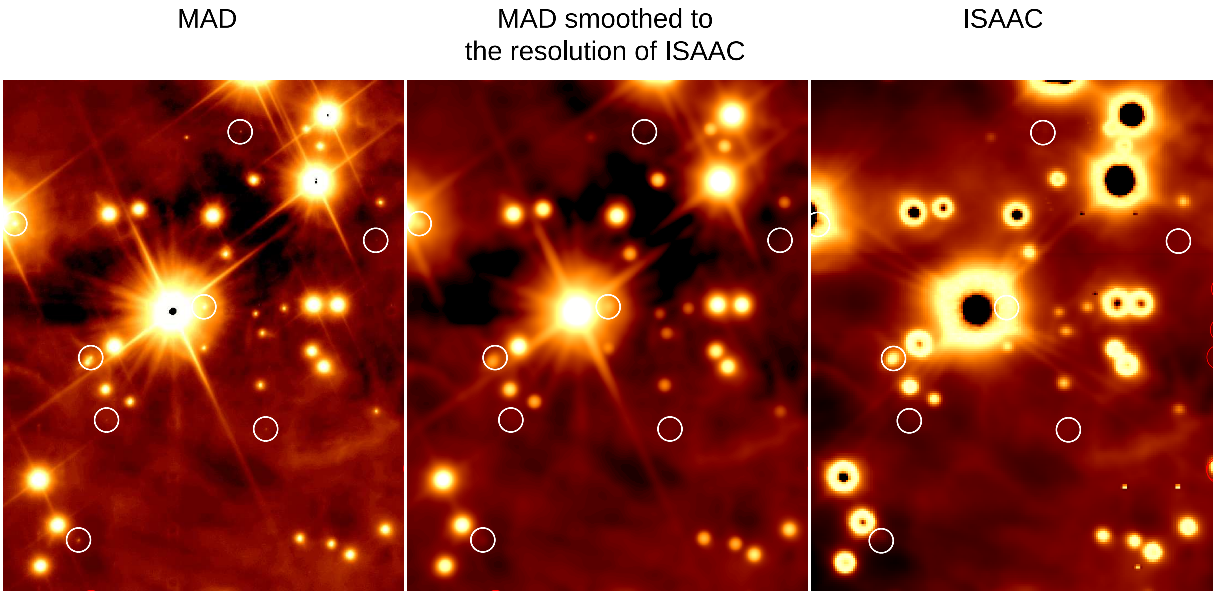

Figure 1: High dynamic range achieved by AO images: this figure shows the MAD (left panel) and ISAAC (right panel) Ks images of the same region of the Trapezium cluster. The 3-σ limit of sensitivity are similar as the exposure times were similar, but because MAD resolves the nebulosities, it was capable of detecting sources otherwise lost in the smoothed flux of the nebulosities in the seeing limited ISAAC image. This figure also shows that the better strehl ratio allows to detect close companion to bright stars that are otherwise lost in the heavily saturated PSF of the seeing limited image.

Targets and integration time

We will observe the field in each of the J, H and BrG and Ks filters. The field is made of 2 bright stars (V<8mag) and 1 faint star (V=13.1mag) forming a regular triangle shape. The faint star will be challenging for MAD and will required good ambient conditions.

Target	**RA**	**DEC**	**Filter**	**Magnitudes**	**Total integration time** (sec)	**Field** (arcmin)
Lupus	16 08 38	-39 06 04	J,H,Ks	Ks=6-20	6345	1
Lupus	16 08 38	-39 06 04	BrG		1800	1

Guide stars list and positions

Target: Lupus III			
	RA$''_{rel}$	**DEC**$''_{rel}$	**V Mag**
GS1	16 08 34.4	-39 06 16.3	7.46
GS2	16 08 34.6	-39 05 32.2	6.54
GS3	16 08 42.7	-39 06 17.0	13.1

Time Justification:

From our experience with the previous MAD observations, we estimate that exposure times of `NDIT`=32; `DIT`=0.8s; `NINT`=15 in jitter mode `NPOS`=6 will allow us to reach a limit of sensitivity of 21 mag in each filter, **corresponding to a limiting mass of 2 M_{Jup} at the age and distance of the association**. Using the overheads and formula given in Section 6.II.d of the MAD manual, the total exposure+overheads time adds up to 7560 s = 2.1h for each J, H and K filter, or 6.3h in total for the broad band filters.

We will also obtain a short BrG image (`NDIT`=32; `DIT`=0.8s; `NINT`=1; `NPOS`=1, total exposure+overheads = 0.5h) in order to study the multiplicity of the bright stars which will be saturated in the broad band images.

The total requested time to complete this proposal adds up to 7h. Lupus is observable in the beginning of august nights.

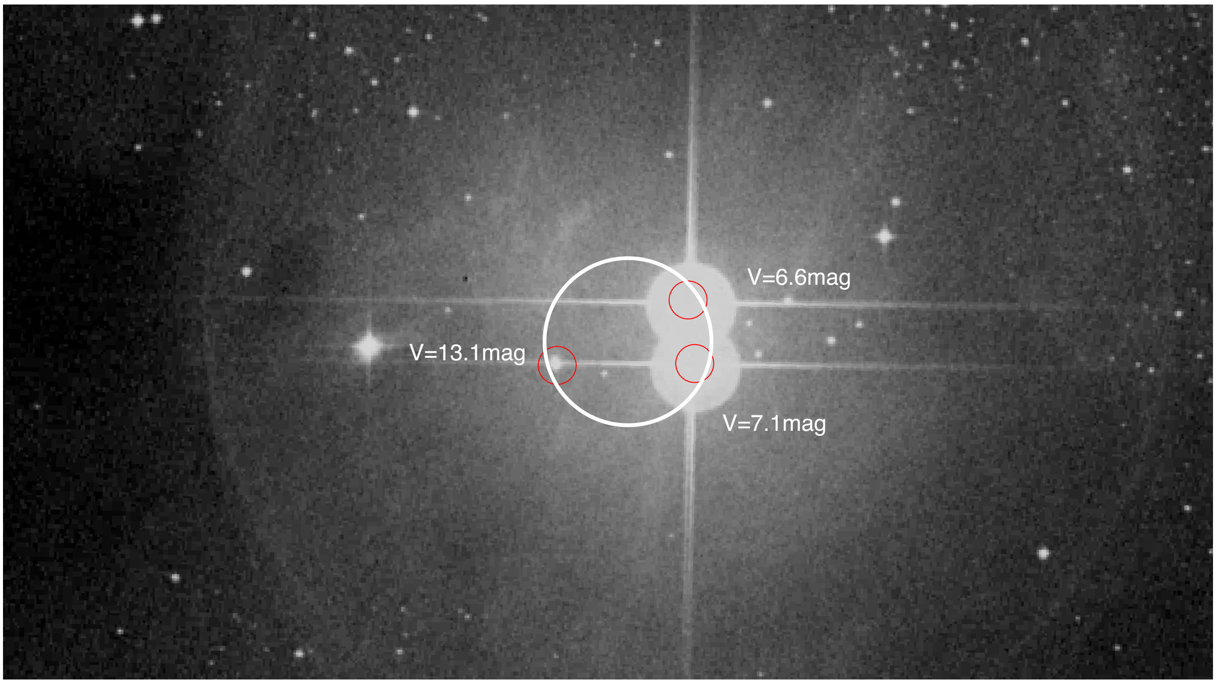

Figure 2: DSS image of the field of the proposed observations. The large bold circle represents the 2' diameter field of view of the MAD wavefront sensors. The reference stars and their V-band magnitudes are indicated.