MAD Science Demonstration Proposal

A new census of 4 young associations: Trapezium, $\lambda-$Ori, $\sigma-$Ori and NGC2362

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Abstract:

We propose to use the unique capabilities of MAD to perform a comprehensive study of the IMF and multiplicity in 3 nearby young associations: $\lambda-$Ori, $\sigma-$Ori, and the Trapezium, and the cluster NGC 2362. This study will complement our previous work in these associations and will allow us to: (1) improve and/or extend the study of the IMF down to the planetary mass regime; (2) for the first time, perform a systematic search for multiple systems over the whole mass range, from massive O-type stars to T-dwarfs and isolated planetary mass objects (IPMOs); (3) correct the IMF from binarity; (4) compare the IMF and the properties of multiplicity of the 4 associations. The proposed study will provide straightforward constraints on the models of formation of stars, brown dwarfs and IPMOs, by providing us with a global overview of star formation (i) in 4 different environments; (ii) over the whole mass range. Additionally, the observations will provide important calibration datasets for the technical development of MCAO at ESO.

Scientific Case:

There are four major observational methods to test and constrain the theory of stellar and sub-stellar formation and evolution: a) via the properties of multiplicity; b) via the shape of the IMF, and its dependence on the age and the environment; c) via the occurrence of disks and their properties; d) via the kinematics of young objects.

We propose to perform a systematic and comprehensive study of both the multiplicity and the IMF in 4 young associations, over the whole range of masses. **In one shot, the proposed program will provide for the first time a global overview of the formation of astrophysical objects, from massive stars to isolated planetary-mass objects (IPMOS)**. The team members have previously worked on the proposed associations. Complemented by our previous studies of disks (optical spectroscopy & Spitzer mid-IR photometry), substellar objects (optical, IR photometry & spectroscopy) and activity (optical spectroscopy & X-rays), the MAD observations will contribute to create the most complete and extensive dataset over the modest area covered in this study of the 4 star forming regions (SFR) described below. We have included the expected K-mag for 10 M_{Jup} members in each cluster, based on Baraffe et al. (2002) evolutionary tracks:

The Trapezium cluster: Using the Public Data Release of MAD first run, we have reported the detection of 12 new faint sources, extending the Ks luminosity function to lower-mass objects **(Bouy, Kolb, Marchetti et al., submitted to A&A, available at http://arrakeen.free.fr/work/madorion.pdf)**. These new detections demonstrate that, in spite of the numerous surveys performed in the Trapezium (age=1 Myr, d=400 pc), the bottom end of the luminosity function of the Trapezium still remains to be discovered, and that MAD at VLT is the perfect instrument to perform such a study. The public data were obtained under moderate atmospheric conditions. The new and twice deeper observations will allow to reach unprecedented sensitivities. The estimated K-mag [10 M_{Jup}]= 16.7 mag.

The $\sigma-$Orionis cluster: This region (d = 350 pc; age = 3–8 Myr; K-mag [10 M_{Jup}]= 17.8 mag) 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 surveys by Béjar et al. (1999) and Zapatero-Osorio et al. (2000) complemented by near-IR photometry and optical/infrared spectroscopy by members of our team (Martin et al. 2001; Barrado y Navascués et al. 2003) have revealed a large population of young BDs and IPMOs. MAD will allow us to extend and improve the IMF on its very low/planetary mass end, and for the first time, to study the multiplicity of young L, T dwarfs and IPMOs.

The $\lambda-$Orionis cluster: The O8 III star $\lambda-$Ori commands a SFR which includes the 5 Myr Collinder 69 (C69) cluster, two 3 Myr associations (Barnard 30 and 35) and another much younger dark clouds (LDN1588 and 1603), all located at 400 pc. The star formation might have been triggered by a supernova (Dolan & Mathieu 2001). The accretion properties and disk frequencies are different in each association and several substellar objects have been detected (Barrado y Navascués et al. 2004, 2005, 2007). Are the multiplicity properties different in each group? Is the dependency with the primary mass the same? We wan to address these questions and to improve the IMF down to IPMOs by observing members of C69, B30 and B35. The K-mag [10M_{Jup}] =18.0 mag.

NGC 2362: Despite its youth (5Myr; d=1.5 Kpc; K-mag [10 M_{Jup}] = 21 mag), this 'Trapezium-like' cluster does not show signatures of circumstellar disks or rests of the parental nebula. The pre-main sequence population is extremely active in X-rays and several substellar objects have been detected (Moitinho et al. 2001, 2003; Huélamo et al. 2003; Damiani et al. 2006).

Targets and integration time

We will observe the 6 fields for 30 min (with DITxNDIT of 0.787x15 sec) in each of the J, H and K filters, jittering between the individual exposures. From our experience with the Trapezium MAD data (Bouy et al. 2007, submitted), this will allow us to reach a limit of sensitivity of ∼20 mag in each filter. The expected K-magnitudes (based on evolutionary tracks by Baraffe et al. 2002) for cluster members with Mass=10 M_{Jup} are: 16.7, 17.8, 18.0 and 21 mag for the Trapezium, σ-Ori, λ-Ori and NGC 2362, respectively. Hence, we will go down to the substellar regime in all the clusters and to the planetary-mass regime in (at least) three of them. We will also obtain a short BrG image (300 s) in order to study the multiplicity of the bright OB stars which will be saturated in the broad band images. Accounting for 20 min of overheads to point and close the loop, the total exposure time per field adds up to: 20min + 30 min x 3 filters + 5 min x BrG filter = 155 min or 2.58 h. For the 6 fields, we therefore request a total of 6 x 2.58h = 15.5h.

We have performed detailed simulations of these observations using the YAO simulator (**all the details can be found at http://www.eso.org/∼jkolb/download/MAD/MAD_proposal_Bouy_additionnal_info.pdf**). These simulations prove the feasibility but also that the Strehl ratio is expected to range between 15-30% in the K-band.

Since we see this program as a service for the community, we will provide the reduced datasets and complete catalogues for on-line retrieval no later than 6 months after the data have been obtained.

Target	**RA**	**DEC**	**Filter**	**Magnitudes**	**Total integration time** (sec)	**Field** (arcmin)
$\lambda-$Ori field 1	05 35 05	+09 56 00	J,H,Ks	Ks=8-20	1800,1800,1800	1
$\lambda-$Ori field 1			BrG	Ks=3-9	300	1
$\lambda-$Ori field 2	05 35 08	+10 00 58	J,H,Ks	Ks=8-20	1800,1800,1800	1
$\lambda-$Ori field 2			BrG	Ks=3-9	300	1
$\sigma-$Ori field 1	05 38 45	-02 35 58	J,H,Ks	Ks=8-20	1800,1800,1800	1
$\sigma-$Ori field 1			BrG	Ks=3-9	300	1
$\sigma-$Ori field 2	05 38 31.5	-02 33 33	J,H,Ks	Ks=8-20	1800,1800,1800	1
$\sigma-$Ori field 2			BrG	Ks=3-9	300	1
Trapezium	05 35 16.3	-05 23 13.8	J,H,Ks	K=8-20	1800,1800,1800	1
Trapezium			BrG	K=3-9	300	1
NGC 2362	07 18 42.5	-24 57 15.7	J,H,Ks	K=8-20	1800,1800,1800	1
NGC 2362			BrG	K=3-9	300	1

Guide stars list and positions

Target: Trapezium			
	RA$''_{rel}$	**DEC**$''_{rel}$	**V Mag**
TCC-53	05 35 16.0	-05 23 52.9	12.5
TCC-104	05 35 17.9	-05 22 45.4	11.2
Theta Ori E	05 35 15.8	-05 23 09.8	11.1
Target: $\lambda-$Ori field 1			
HD36861C	05 35 08.1	09 55 34.9	11.0
HD245168	05 35 03.0	09 56 05.2	9.6
$\lambda-$Ori A	05 35 08.2	09 56 03.2	3.3
$\lambda-$Ori B	05 35 08.4	09 56 06.0	5.6
Target: $\lambda-$Ori field 2			
TYC 705-860-1	05 35 06.0	+09 59 58.8	10.5
2MASSJ0535+1000	05 35 06.1	+10 00 19.7	12.8
HD245185	05 35 09.6	+10 01 51.5	10.0
GSC 00705-00822	05 35 09.5	+10 00 38.	12.7
Target: $\sigma-$Ori field 1			
HD37525	05 39 01.5	-02 38 56.3	8.1
BD-02 1326D	05 38 45.6	-02 35 58.8	6.6
BD-02 1326C	05 38 44.0	-02 36 04	8.8
ADS 4241 ABC	05 38 44.3	-02 36 00	3.8
GSC04771-01147	05 38 38.3	-02 34 55.2	12.24
Target: $\sigma-$Ori field 2			
HD294272	05 38 34.4	-02 34 15.9	8.7
HD294271	05 38 36.5	-02 33 12.7	7.9
GSC04771-01147	05 38 38.35	-02 34 55.2	12.24
Target: NGC 2362			
TYC6541-4233	07 18 43.1	-24 57 15.9	9.77
TYC6541-4219	07 18 46.2	-24 57 47.7	10.45
TYC6541-4221	07 18 41.9	-24 58 12.0	9.49
GSC0654104203	07 18 46.5	-24 56 33	8.17