EUROPEAN SOUTHERN OBSERVATORY

Organisation Européenne pour des Recherches Astronomiques dans l'Hémisphère Austral
Europäische Organisation für astronomische Forschung in der südlichen Hemisphäre

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APPLICATION FOR OBSERVING TIME PERIOD: **83A**

Important Notice:

By submitting this proposal, the PI takes full responsibility for the content of the proposal, in particular with regard to the names of CoIs and the agreement to act according to the ESO policy and regulations, should observing time be granted

1. Title Category: **C–4**

Effects of UV radiation from massive stars on the evolution of circumstellar disks in NGC 6611

2. Abstract / Total Time Requested

Total Amount of Time:

Our aim is to investigate the influence of environment on the evolution of circumstellar disks and accretion timescale in NGC 6611. This young open cluster is very rich of massive stars, and therefore it offers a very good opportunity to derive the effects of their UV radiation on circumstellar disks of cluster members. We plan to determine spectral types for selected pre-main sequence members of the star forming region NGC 6611, for which we have infrared (2MASS and Spitzer) and optical BVI photometry, complete down to V $\sim$ 23. Our immediate goal is to derive accurate effective temperatures, ages and individual extinctions of cluster members to study the evolutionary status and the properties of the circumstellar disks by SED modeling. In addition, we want to find the stars characterized by strong accretion from emission in the Hα line. We ask for a total of 28 840 sec (abour 8 hours) for VIMOS spectroscopic program and 16 080 sec (about 4.5 hours) for GIRAFFE-FLAMES

3. Run	Period	Instrument	Time	Month	Moon	Seeing	Sky Trans.	Obs.Mode
A	83	VIMOS	1h	apr	n	n	CLR	s
B	83	VIMOS	2h	jul	n	n	CLR	s
C	83	VIMOS	2h	jul	n	n	CLR	s
D	83	VIMOS	2h	jul	n	n	CLR	s
E	83	VIMOS	2h	jul	n	n	CLR	s
F	83	FLAMES	3h	jul	n	n	CLR	s
G	83	FLAMES	3h	jul	n	n	CLR	s

4. Number of nights/hours	Telescope(s)	Amount of time
a) already awarded to this project:		
b) still required to complete this project:		

5. Special remarks:

“ ”

6. Principal Investigator: mguarce

CoI(s): L. Prisinzano (1344), G. Micela (1344), F. Damiani (1344), S. Sciortino (1344), G. Peres (1883)

7. Is this proposal linked to a PhD thesis preparation? State role of PhD student in this project

Yes / Guarcello M. G., Data important for Ph.D. thesis. / mid-course

8. Description of the proposed programme

A) Scientific Rationale: In the last years, several works have been devoted to study the properties of circumstellar disks in young pre-main sequence stars, their evolution, the conditions for the formation of planetary systems, and the effects of environment in which disks evolve. Theoretical studies and observations of protoplanetary disks in the ONC have shown as different environments can play an important role in the evolution of circumstellar disks. Incident UV radiation from massive stars (e.g. Hollenbach, 1994, NASA STI/Recon Technical Report N, 1, 47002; Johnstone, 1998, ApJ, 499, 758; Storzer & Hollenbach, 1999, ApJ, 515, 669) heats the disks of nearby stars to thousand degree, inducing the photoevaporation of the gas. This process consumes the disks from the outer region inward on timescale smaller than the normal evolution. When the outer region of the disks is affected by this process, the accretion cannot drain material in the inner region. The loss of the outer disk then implies that also the inner disk cannot be replenished, as suggested in the study on the young open cluster NGC 6611 of Guarcello et al., 2007 (A&A, 462, 245).
Target: a suitable target to study these processes is the young open cluster NGC 6611 in the Eagle Nebula. This cluster is characterized by a large number of massive stars (56 stars with spectral classes earlier than B5), distributed irregularly in the central region. Stars associated to these cluster show an age spread from $\sim 10^5$ years to about 5 million of years.
Several investigations have been devoted to NGC 6611 since the work of Walker (1961, ApJ, 133, 438). In Guarcello et al. (2007, A&A, 462, 245) and in Guarcello et al. (2008, submitted, available on *http://www.astropa.unipa .it/~mguarce/articolo_1.ps*), we used X-ray data (from the ACIS/CHANDRA observation ID:978, Linsky), WFI observations in BVI bands down to V=23^m (spectral type M2), 2MASS data and Spitzer/IRAC data from GLIMPSE survey, to compile a multi band catalog with 60 158 stars in a FOV of $33' \times 34'$ centered on the cluster (X-ray data were available in a smaller field of $17' \times 17'$, also centered on the cluster, about on $\alpha = 274.65$ and $\delta = -13.8$).
Our adopted membership criterion is based on detection of X-ray emission and infrared excesses. The advantage of our approach is that the X-ray based criterion allowed us to find an unbiased list of disk less members (Weak-line T-Tauri Stars), that cannot be simply identified using IR observations; while with infrared excesses we identified members with circumstellar disks. With these methods, we identified a total of 251 stars with circumstellar disk and 790 without disk in NGC 6611, within to the ACIS FOV. *We found that in NGC 6611 the disk frequency decreases for smaller distances from massive stars, indicating that the evolution of circumstellar disks is influenced by OB stars.* This is shown in the histogram in Fig. 1, where the disk frequency varies from $31\% \pm 4\%$ for the bin with lowest UV flux, to $16\% \pm 3\%$ for the highest one. Fig. 2 shows the spatial distributions in the WFI FOV of the stars with infrared excesses and the X-ray sources, with V magnitude brighter than 20^m. The box delimited by thick black lines is the central ACIS FOV.
In the outer region of the nebula, outside the ACIS FOV, we detected 207 stars with infrared excesses. The presence of a significant number of stars with disk well outside from the center of the nebula, where NGC 6611 is located, suggests that star formation is active in all the Eagle Nebula. The YSOs associated with these outer regions could have been formed in environmental condition different from those formed in NGC 6611, where all the massive stars are found. For this reason we obtained 2 additional CHANDRA/ACIS pointings (PI: Guarcello) to cover the regions of the nebula at east and north-east respect to the cluster, in order to study this young population quite distant from the massive stars of NGC 6611. The preliminary analysis of these X-ray observations revealed a large number of candidate disk-less PMS stars associated to these regions and embeddeded PMS stars with disk, whose evolution was not affected by the presence of massive stars. In Fig. 2 the FOVs of the CHANDRA pointings are delimited by dotted lines.
The comparison of disk properties in the inner and outer regions of the nebula, will allow us to obtain a complete picture of the effects of UV flux on disk evolution in the Eagle Nebula. This goal require spectroscopic observation with VIMOS and FLAMES of the selected candidate members, to derive their fundamental parameters.

B) Immediate Objective: Our main purpose is to study the effects of UV radiation from massive stars on the evolution of nearby circumstellar disks in NGC 6611. In order to address this issue, we will study the physical parameters of disks at different values of incident UV flux, comparing the results that we will obtain for the stars near and distant from the massive members. We need the requested spectroscopic observations of about 600 candidate pre-main sequence members of the cluster down to V $\sim$ 20 (spectral type K5), selected from X-ray emission or infrared excesses, to reach the following crucial objectives.

1) we will determine masses and ages of these stars to investigate about possible sequential star formation and bias introduced by mass effects that could to affect our main results about photoevaporation; 2) we want to confirm the membership using lithium line and the radial velocities from the requested spectra.

3) we want to determine projected rotational velocities in order to derive the $vsin(i)$ distribution for stars with and without circumstellar disk, to verify if a fast photoevaporation of disks alters angular momentum evolution of stars nearby strong UV sources;

4) we want to determine spectral types of our targets, in order to derive the effective temperatures and the individual extinctions, which are crucial to properly disentangle the photospheric and disk contributions in the

8. Description of the proposed programme (continued)

observed SED. This will allow us to estimate disk physical parameters using the models of Robitaille et al. (2007);

5) we want to identify the accreting stars from the Hα line profile, which in these stars is broad compared to the narrow Hα emission from the Nebula emission. We will evaluate whether the spatial distribution of stars with accretion suggests that the radiation from OB stars also affects accretion timescale. Targets, for this study, will be selected among members with disk that present blue excess, or among stars with SEDs compatible with disk models with large $\dot{M}$;

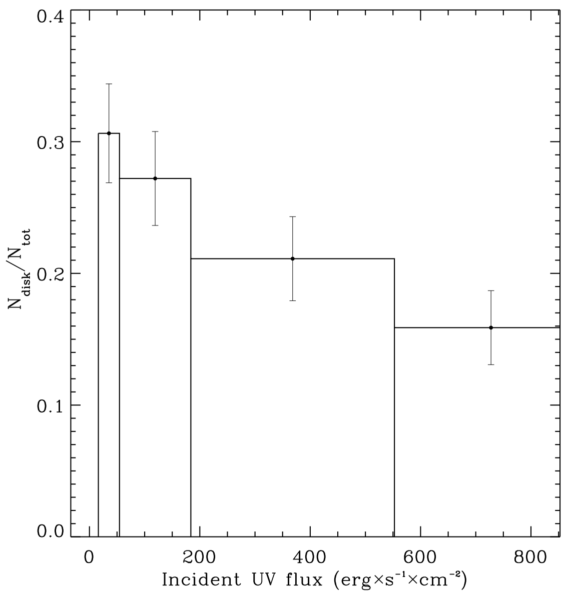
Spectra necessary for spectral classification can be obtained with the spectrograph VIMOS (objectives 1,4) available at the VLT. Using VIMOS in the Multi-Object Spectroscopy (MOS) mode and the high resolution (HR) Orange setup (spectral resolution $R \sim 2150$, with a slit width of 1 arcsec), covering the spectral range [5200-7600]Å, we can achieve, with one exposure of 4000 sec, a S/N≥30 for our faintest stars (V ∼ 20). To observe all the selected targets, at different values of incident UV flux, we need 4 pointings: the ones corresponding to the Field1 and Field3 cover the central region of NGC 6611, where are all the massive stars; those corresponding to Field2 and Field4 cover the outer region, that will be observed with CHANDRA, where there are no known massive stars associated with the nebula (see Fig. 2).
The simultaneous observation of Hα and Lithium lines can be performed with GIRAFFE-FLAMES with the Medusa fibre system in the setup HR15N, with a spectral resolution R=17000 in the wavelength range [6470-6790] Å(objectives 2,3,5). To observe our faintest targets (V ∼ 18) with a S/N≥30, useful to have radial velocities accurate to 2 km s^{-1}, it is necessary an observation time of 6000 sec.
Note: VIMOS data in the ESO archive of NGC 6611 (program 073.C-0470) cannot be used to address our issues, since the sample selection is inadequate to our goal. Specifically, the selection in the archival data is based on photometry alone. On the contrary, we have a much more efficient X-ray + disk based membership criterion. Besides, we plain to observe stars in a wide range of spectral classes (from late B to K stars). For such sample of targets, Orange setup is more efficient for spectral classification respect to the setup in archive data. Available FLAMES observations (program 072.C-0463 published in Evans et al., 2005) are limited to a sample of very bright sources (V≤13), while we propose to observe many more stars down to V ∼ 18.

C) Telescope Justification: The spectrograph VIMOS in the Multi-Object Spectroscopy mode with the high resolution (MOS HR Orange) setup, together with the high capability of the VLT UT3 telescope allows us to obtain up to 150 × 4 spectra simultaneously with suitable resolution and a S/N to accurately derive the spectral classification of our stars, down to 0.8 solar masses.
The spectrograph FLAMES/GIRAFFE will allow us to obtain spectra of a sub-sample of about 100 targets down to V ∼ 18 in a wavelength range that includes both the Hα and the Lithium lines, with a S/N ≥ 30, useful to recognize the Classical T-Tauri Stars, to evaluate the rotational velocities and to verify the cluster membership.

D) Observing Mode Justification (visitor or service): the required observing run can be best done in service mode.

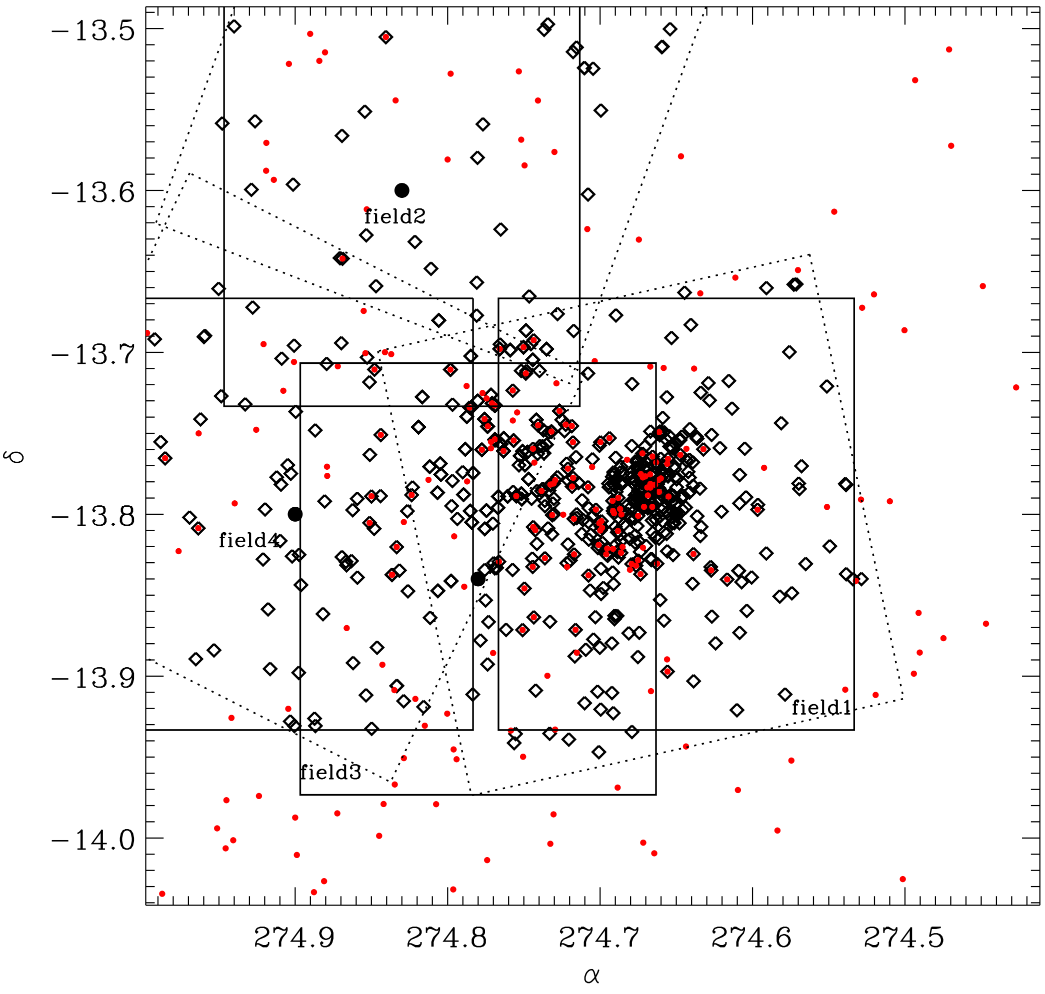
E) Strategy for Data Reduction and Analysis: The reduction of data will be done using the VIMOS pipeline Data Reduction Software (Version 2.1.11) provided by ESO, while the extraction and analysis of the data will be performed using the IRAF software and hardware available at INAF-OA Palermo. The spectral classification will be done by comparing final calibrated spectra to spectral types known from the library of Pickles(1998, PASP, 110-863).
The GIRAFFE data will be reduced using the Base-Line Data Reduction Software (Version 1.13.1) developed at Geneva Observatory and relative calibration files. The radial and rotational velocities will be computed using the cross-correlation function (task `FXCOR` of IRAF) and the ATLAS9 (Kurucz,1993) synthetic spectra at different velocities, and the equivalent width of the Lithium line will be computed with the IRAF task `SPLOT`, after performed the continuum normalization in the region around the Li I 6707.8 Å line with the IRAF task `CONTINUUM` . The analysis will be performed by the P.I. with the collaboration of the CoIs.

8. Attachments (Figures)



Frequencies of stars with disk, in the CHANDRA FOV of $17' \times 17'$ centered on NGC 6611, vs. the incident UV flux emitted by massive members with spectral classes earlier than B5. The disk frequencies in the four bins, from highest to lowest UV incident fluxes, are equal to: $16\% \pm 3\%$, $21\% \pm 3\%$, $27\% \pm 4\%$ and $31\% \pm 4\%$.

8. Attachments (Figures)



Spatial distribution of stars with excesses (red points) and of X-ray sources (diamonds) inside the WFI FOV ($33' \times 34'$) with $V \leq 20^m$. The boxes delimited by dotted lines are the ACIS FOVs. The thin lines delimit the fields that we want to observe with VIMOS: Field1 and Field3 explore the central region, where massive members of the cluster are found, Field2 and Field4 explore the outer regions. Also the two FLAMES pointings, not shown here, cover respectively the central region (Field5) and the outer region (Field6).

9. Justification of requested observing time and lunar phase

Lunar Phase Justification: Any lunar phase can be allowed for our observations.

Time Justification: (including seeing overhead) Using VIMOS in the MOS HR mode, with the Orange setup, we can allocate up to 150 objects for each quadrant for a maximum of 600 objects with one exposure. We will observe about 600 members, selected by X-ray emission or infrared excess. We used the on-line ESO Exposure Time Calculator, Optical Spectroscopy Mode Version 3.1.0, specific for the VIMOS instrument, to estimate the observing time required for this program. Assuming 7 days from the new moon, a seeing of 1.1 arcsec and setting the condition of having $S/N \geq 30$, we have found that a pointing with 4000 sec of exposure is needed to observe our faintest targets (K5 spectral type, with $V \sim 20^m$). According to the on-line VIMOS instructions, the overheads for the spectroscopic run amount to 1560 sec per exposure, including telescope preset, MOS acquisition, instrumental setup and CCD read-out. Since the VIMOS FOV is $4{\times}7' \times 8'$, to observe all our targets we need 4 pointings (see Fig. 2). Therefore, assuming to do 2 exposures per pointing, of 2000 sec each, we require a total telescope time of 28480 sec for the VIMOS spectroscopic program (RUNs B, C, D and E).
For the PRE-IMAGING runs, we require 4 exposures each of 10 sec and 720 sec for the overheads (RUN A).
Using GIRAFFE-FLAMES with HR15N setup we can study spectra of more than about 100 targets in a wavelength range that include the Hα and the Lithium lines. By using the ESO Exposure Time Calculators for GIRAFFE-FLAMES we estimated that to observe our faintest targets ($V \sim 18$) with a $S/N \geq 30$, we need 2 exposures of 3000 sec. We need 2 pointings to observe all the selected targets, including the field that will be observed with CHANDRA. Including the overheads of 1020 sec for each exposure, we require a total telescope time of 16080 sec for the RUN F and G.

Calibration Request: Standard Calibration

10. Report on the use of ESO facilities during the last 2 years

No use, only archive WFI data used

11. Applicant's publications related to the subject of this application during the last 2 years

Guarcello M.G., Prisinzano L., Micela G., Damiani F., Peres G., Sciortino S., "Correlation between the spatial distribution of the circumstellar disks and the massive stars in the open cluster NGC 6611", 2007A&A, 462, 245

Damiani F., Prisinzano L., Micela G., Sciortino S., "The rich young cluster NGC 6530: a combined X-ray-optical-infrared study", 2006, A&A, 459, 477

Prisinzano L., Damiani F., Micela G., Pillitteri I., "VLT/Flames observations of the star forming region NGC 6530", 2007, A&A, 462, 123

Prisinzano L., Randich S., "Lithium abundances in the old open cluster NGC 3960 from VLT/FLAMES observations", 2007, A%A, 475, 539

12. List of targets proposed in this programme

Run	Target/Field	α(J2000)	δ(J2000)	ToT	Mag.	Diam.	Additional info	Reference star
A	NGC 6611-1	18 18 36	-13 48 00	0.2			Pre-IMG	
A	NGC 6611-2	18 19 19.2	-13 36 00	0.2			Pre-IMG	
A	NGC 6611-3	18 19 07.2	-13 50 24	0.2			Pre-IMG	
A	NGC 6611-4	18 19 36	-13 48 00	0.2			Pre-IMG	
B	NGC 6611-1	18 18 36	-13 48 00	1.9				
C	NGC 6611-2	18 19 19.2	-13 36 00	1.9				
D	NGC 6611-3	18 19 07.2	-13 50 24	1.9				
E	NGC 6611-4	18 19 36	-13 48 00	1.9				
F	NGC 6611-5	18 18 48	-13 48 00	2.2				
G	NGC 6611-6	18 19 24	-13 42 00	2.2				

12b. ESO Archive - Are the data requested by this proposal in the ESO Archive (http://archive.eso.org)? If yes, explain why the need for new data.

no

13. Scheduling requirements

14. Instrument configuration

Period	Instrument	Run ID	Parameter	Value or list
83	VIMOS	A	PRE-IMG	ESO filters: R
83	VIMOS	B	MOS-grisms	HR-Orange
83	VIMOS	C	MOS-grisms	HR-Orange
83	VIMOS	D	MOS-grisms	HR-Orange
83	VIMOS	E	MOS-grisms	HR-Orange
83	FLAMES	F	GIRAFFE	standard setup HR15 665.0
83	FLAMES	G	GIRAFFE	standard setup HR15 665.0