Proposal for observations **Category: C** ☐ **ToO**

Period AOT16 (Ago07–Jan08) **Dead-line: May 10th 2007** **Submit using: www.tng.iac.es/submit.html**

1. Title

Deep IR photometry of the Cygnus OB2 young globular cluster

2. Abstract

Since first stellar population studies, Cygnus OB2 (Cyg OB2) has been characterized as one of the most rich OB associations in the galaxy. Recent optical photometric/spectroscopic studies have revealed a total stellar mass of $\sim 10^5$ $M_\odot$ and about 2600 OB stars belonging to this region. However, the extreme reddening in and around Cyg OB2 hampers the detection of low- and even some massive stars. Fortunately, the use of TNG optical and IR photometric cameras, combined with a deep *Chandra*, X-ray observation offers an excellent opportunity to: *i*) Identify the cluster stellar population and how it correlates with observations at different wavelengths; *ii*) Evaluate the total cluster mass and its initial mass function (IMF), with special emphasis on the low mass regime; *iii*) Explore the star formation history of the cluster; *iv*) Improve the knowledge of the physical processes related with the evolution of massive stars; *v*) Estimate the influence of massive stars on the formation of low mass stars and circumstellar disks evolution *vi*) Determine the fraction of disk- and accretion- objects and their statistical optical, IR and X-ray properties.

3. Number of requested nights, or hours, per each instrument (total time = sum of the single entries)

TNG							WHT	
OIG	DOLORES	DOLORES + MOS(1)	SARG	NICS	AdOpt(2)	Speckle Camera	PF ima/fibers	ISIS UV/pol
				9.0 hr.				

(1) MOS programs cannot be scheduled in queuing and are bound to strict contraints on the number of masks and on the time necessary to design/manufacture them.

(2) Observations with AdOpt may have large overheads. For more information please contact the instrument responsible.

4a. Preferred months

first choice: August second choice: September

4b. Other scheduling constraints (use also box 17)

Oct., Nov., Dec,m and Jan: impossible

5. Moonlight constraints

No restriction ☐

Max. # of days from new moon 7

6a. Past and future of the project

a) Nights already awarded to the project: 14

b) Night foreseen to complete the project: 0

6b. Long term status request* ☐

**Please read the TAC policy for long-term programs*

7. Service/queueing observing

Desirable ☐ Acceptable ☒ Impossible ☐

8. Principal investigator

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F. Damiani — OA Palermo
S. Sciortino — OA Palermo

Title of proposal **Completion (%)**

Dates **Awarded time** **Time lost (%)** **Reason(s)**

11. Brief description of the status of the project(s), including publications based on the observations.

This proposal (including Dolores and NICS) was accepted in AOT12, but only in July 2006 Dolores observations were performed. Dolores images analysis in ongoing.

12a. If this proposal is a part of a PhD thesis, write here the name of the student, the thesis title and briefly describe the relevance of these observations for the thesis goals.

M. G. Guarcello, *Effects of the environment on the evolution of circumstellar disks*, Cyg OB2 offers an unique environment to reach the thesis objective.

12b. Is this, or a similar application submitted to other time allocation committees (e.g. ESO, TNG-CAT, ITP)? If yes, please specify which and explain if and why the proposals should be considered complementary.

NO

to star formation processes and its efficiency, characterization of its initial mass function (IMF), evolution of massive stars and their influence on the formation of low mass stars, etc. In this sense, Cyg OB2 is one of the best places to address these subjects, being an outstandingly rich galactic OB association (Reddish et al. 1966). Considering its mass (~4-10×10^4 $M_\odot$), density (~40-150 $M_\odot pc^{-3}$) and size, it is tempting to classify Cyg OB2 as young globular cluster (Knödlseder 2000). An optical photometric/spectroscopic study of the stellar population of Cyg OB2 has been performed by Massey & Thompson (1991), locating it at a distance of 1700 pc (DM=11.17), behind the Great Cygnus Rift, with large non uniform visual extinction A_v ranging from 4 to 15 magnitudes.

The availability of the 2MASS data have encouraged several investigations related to the morphology and stellar content of galactic OB regions, and CygOB2 was not the exception (Knödlseder 2000, Hanson 2003). In the last years, optical and 2MASS photometry and optical objective prism surveys of Cygnus OB2, have characterized the high-mass OB population of this region (Massey et al. 1995, Knödlseder 2000; Comeron et al. 2002), leading to an estimation of 2600±400 OB stars, with the largest number of O-type stars ever found in a galactic massive association (~ 120±20). However, the high extinction of this region, in combination with the limiting magnitude of the 2MASS J, H, and K_s bands, makes low-mass and pre-MS star populations to still remain partially or totally unexplored to date. The study of completeness of low mass stars is very important for the characterization of the total mass and initial mass function, because the IMF seems to be universal at high masses and differences only appear with the inclusion of low mass-stars (Kroupa 2002). Fortunately, at X-ray wavelengths the absorbing photoelectric cross section decreases rapidly as a function of energy, thus objects that appear strongly absorbed or even completely obscured in the optical, can be also observed at these energies. Furthermore, from first *Einstein* and *Rosat* X-ray observations is widely accepted that different physical processes like, dynamical instabilities in the radiatively driven stellar wind of the O- and B- stars (Lucy & White 1980, Owocki & Cohen 1999), solar-like magnetic dynamo activity in late-type stars (Parker 1955), and perhaps the interaction between stellar magnetosphere and the surrounding environment of Pre-MS object like Classical T-Tauri Stars (CTTS) (Shu & Shang 1997) can produce X-ray emission. This implies that almost all stars are X-rays emitters.

The combination of IR and X-ray observations is a valuable method to reveal highly embedded objects in star forming regions or OB associations. We mention two major reasons supporting this idea: at the distance of Cyg OB2 we expect a large number of foreground field stars. By the use of combined optical/IR and X-ray observation, and because of the much higher X-ray luminosity of PMS stars with respect to older field stars, we get an effective method to distinguish (highly absorbed) young members from non members (e.g. throughout f_x vs. R-I diagram);

In our deep (~100 ksec) ACIS-I *Chandra* X-ray observation at the core of Cyg OB2 region (Albacete Colombo et al., 2007), we have detected about 1000 X-ray sources in the 17'×17' field of view centered at α_{2000}=20:33:12.1 and δ_{2000}=+41:14:59.6 (see Fig. 1). For an initial analysis, we have used the 2MASS near-IR photometry of the ~3100 IR sources falling in the same field. We only considered the sources with K_s magnitude errors lower than 0.1. The 2MASS completeness limit is 16.6, 15.5 and 14.8 in the J,H,K_s bands, respectively. As we can observe in the K_s vs. H-K_s color-magnitude diagram (CMD, Fig. 2), the magnitude limits result in a serious incompleteness at the low mass end. In fact, the cross-identification between 2MASS sources and our ~1000 detected X-ray sources, produce only about 500 coincidences.

B) Scientific aim We proposed for AOT12 to perform V,R,I,H_α optical and J,H,K' IR CCD observations of Cyg OB2, using the Dolores (FOV 9.4'×9.4') and NICS (FOV 4.2'×4.2') imaging cameras respectively. The proposed was accepted, but we achieved only the optical observations (see Box 11). The analysis of obtained data is in progress. For AOT16 we ask again the J,H,K' observations, needed for the presence of significant reddening in the region and bacause of the expected large number of stars with disk. We need 16 NICS different pointing directions (see Fig. 1 and box 14) to cover the 17'×17' ACIS field. To identify a much larger sample of X-ray sources we need IR photometry from TNG-NICS camera, reaching much deeper than 2MASS, more exactly 19.6, 18.2 and 17.4 for the J,H,K' bands respectively. Assuming an average visual extinction (A_v) of 5.5, these magnitudes correspond a completeness limit for stellar masses as low as 0.2-0.3 $M_\odot$.

These observations will permit: *i*) Identify the nearly total cluster stellar population and the cross-identification between optical, IR and X-ray observations, considering the importance of such multi-wavelength studies of young- and stellar OB associations; *ii*) Evaluate the total cluster mass and its initial mass function (IMF) across the entire mass spectrum, with an important expected contribution from low mass stars; *iii*) Explore the star formation history of the cluster; *iv*) Study the influence of massive stars on the low mass star formation rate **and disk evolution**; *v*) Improve the knowledge of the physical processes related with the evolution of massive stars and the interaction with their environment; *vi*) Investigate the fraction of disk- and accretion- objects, and their statistical optical, IR and X-ray characteristics, in order to reveal the underlying physical processes behind their observed multi-wavelength emission.

Albacete Colombo J. F. et al., 2007, A&A, 464, 211
Comeron F. et al. 2002, A&A, 389, 874
Hanson M. M. 2003, AJ, 597, 957
Hunt L. K. et al. 1998, AJ, 115, 2594
Kenyon S. J. & Hartmann L. 1995, ApJS, 101, 117
Knödlseder J. 2000, A&A 360, 539
Kroupa P. 2002, Science, 295, 82
Lucy L. B. & White R. L. 1980, ApJ 241, 300
Massey P., & Thompson A. B. 1991, AJ, 101, 1408
Massey P., Johonson K. E & Degioia-Eastwood K. 1995, ApJ, 454, 151
Owocki S. P. & Cohen D. H. 1999, ApJ 520, 833
Parker E. N. 1955, ApJ 122, 293
Reddish V. C., Lawrence L. C., & Pratt N. M. 1966, Pub. R. Obs. Edinburgh, 5, 111
Shu F. H., & Shang H. 1997, IAU Symp. 182, 225
Siess L., Dufour E., & Forestini M. 2000, A&A, 358, 593
Stelzer B. & Neuhäuser R. 2001, A&A, 377, 538

Figure 1: *Chandra* X-ray observation and Dolores/NICS pointing at the CygOB2 region.

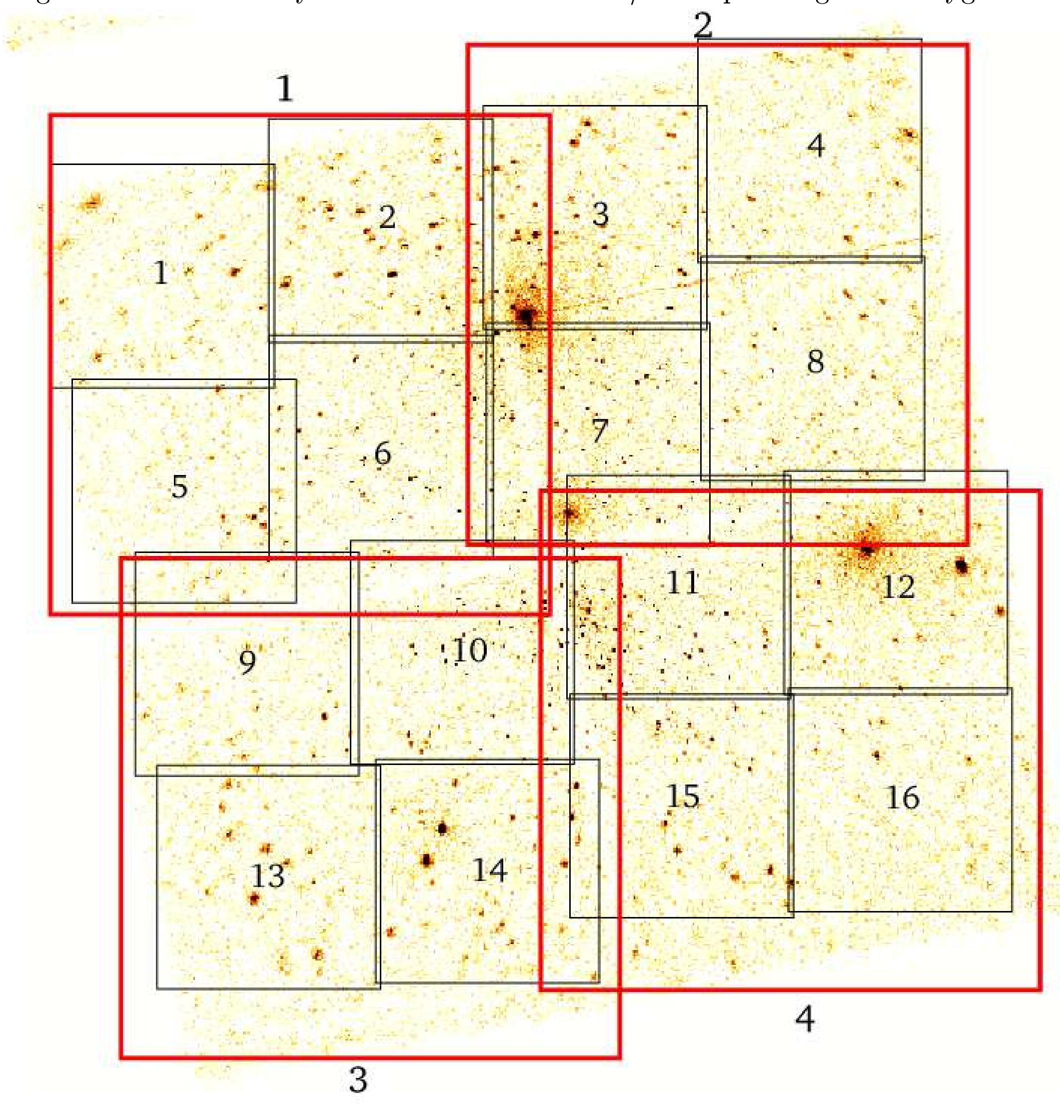

Fig. 1: X-ray image of the Cyg OB2 observed with the *Chandra* ACIS-I camera. The image, centered at α_{2000}=20:33:12.137 and δ_{2000}=+41:14:59.61, has a field of view of 17'×17'. Big boxes (thick lines) refer to the 4 fields observed with Dolores (FOV 9.4'×9.4') camera, while small boxes (thin lines) show the 16 different pointing of the NICS (FOV 4.2'×4.2') camera. The numeration is the same as that listed in box 14.

Figure 2: 2MASS near-IR K_s vs. H-K_s CMD diagram at the Cyg OB2 region.

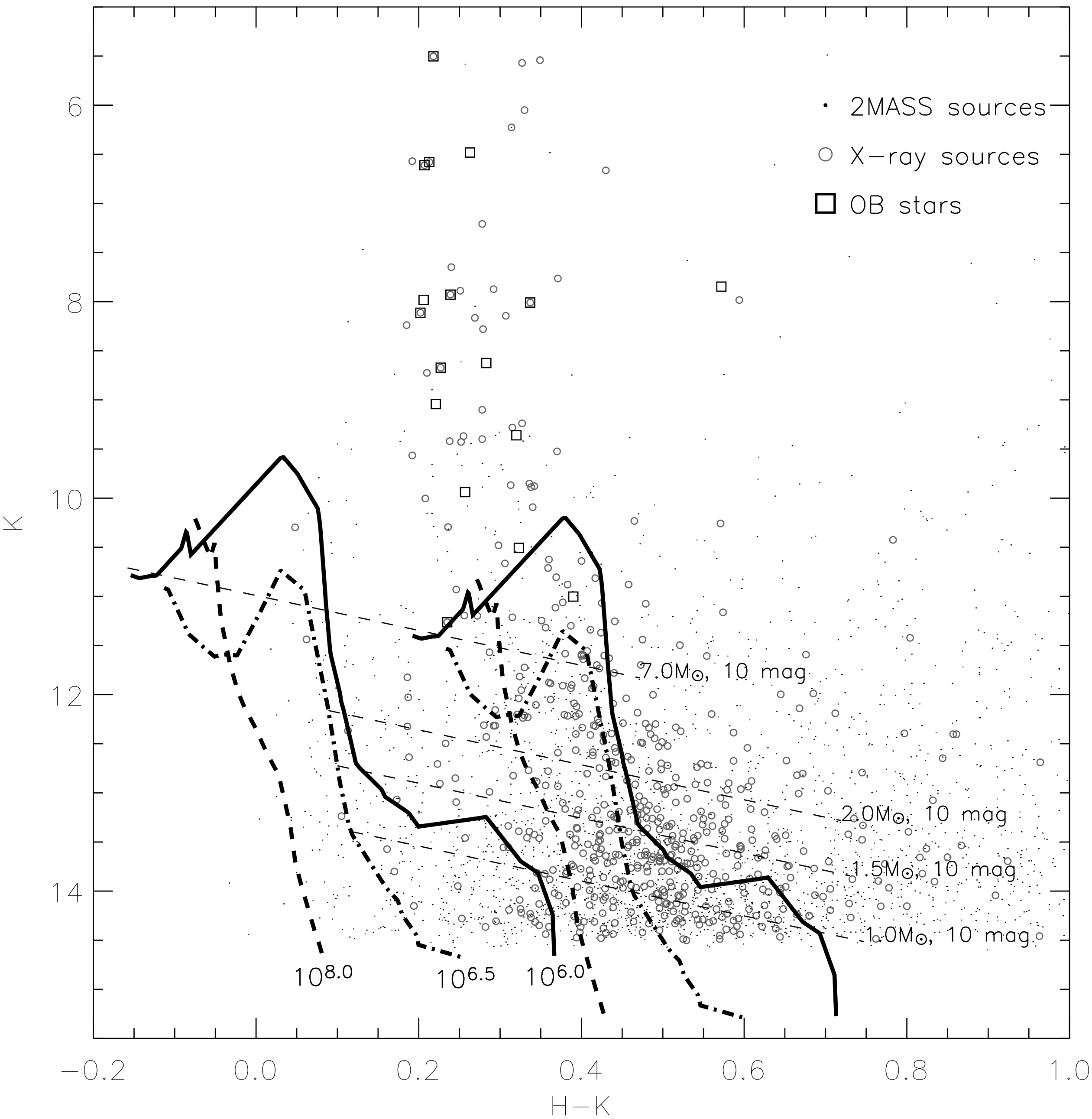

Fig. 2: Observed infrared color-magnitude diagram of the 2MASS sources (*small dots*) located in the field of view, showing X-ray sources (*open circles*), and OB stars (*open boxes*). The lines correspond to the isochrones (Siess et al. 2000) at 10^6 (*solid line*), $10^{6.5}$ (*dash-dotted lines*) and 10^8 (*dashed lines*) years, respectively. We show un-reddened (A_v=0 - left) and reddened (A_v=5.5 - right) isochrones, respectively. Reddening vectors (*thin dashed lines*) refer to different masses calculated at the age of $10^{6.5}$ years. This graph shows the need to obtain deep NICS-IR observations to reach stellar masses much below 0.9-1.0 $M_\odot$. Only half of X-ray sources have 2MASS counterparts, we expect that most of the remaining X-ray sources are low-mass and/or very absorbed members of Cyg OB2.

Programs requiring adaptive optics must also specify R (or V) mag and angular distance of the guide stars

Name	α	δ	Epoch	Mag.	Additional Information
NICS-fov1	20:33:51.304	+41:19:35.34	J2000	—	Field North-East-1
NICS-fov2	20:33:29.507	+41:20:27.02	J2000	—	Field North-East-2
NICS-fov3	20:33:08.081	+41:20:41.64	J2000	—	Field North-West-3
NICS-fov4	20:32:46.570	+41:21:56.76	J2000	—	Field North-West-4
NICS-fov5	20:33:49.139	+41:15:33.24	J2000	—	Field North-East-5
NICS-fov6	20:33:29.457	+41:16:22.79	J2000	—	Field North-East-6
NICS-fov7	20:33:07.781	+41:16:36.92	J2000	—	Field North-West-7
NICS-fov8	20:32:46.294	+41:17:51.19	J2000	—	Field North-West-8
NICS-fov9	20:33:42.816	+41:12:18.27	J2000	—	Field South-East-9
NICS-fov10	20:33:21.327	+41:12:31.82	J2000	—	Field South-East-10
NICS-fov11	20:32:59.713	+41:13:45.39	J2000	—	Field South-West-11
NICS-fov12	20:32:38.020	+41:13:50.25	J2000	—	Field South-West-12
NICS-fov13	20:33:40.631	+41:08:18.35	J2000	—	Field South-East-13
NICS-fov14	20:33:18.818	+41:08:25.41	J2000	—	Field South-East-14
NICS-fov15	20:32:59.423	+41:09:38.96	J2000	—	Field South-West-15
NICS-fov16	20:32:37.601	+41:09:45.53	J2000	—	Field South-West-16
NICS-Std F.	21:52:25.30	+02 23 33.0	J2000	—	AS 36 - IR photometry Std F.

15. Observational strategy and justification of requested time, including overheads.

We propose IR observations to cover a 17'×17' region, centered at the core of the Cyg OB2 association. Infrared (J, H, K') observations will be acquired with 16 different pointing with the NICS camera (FOV 4.2'×4.2). The coordinates (J2000) in box 14 refer at the center of the NICS fields of view.
The exposure times (see TNG web page) for NICS cameras were calculated according to following conditions: *i*) all observations should reach a S/N ratio greater than 10; *ii*) we fixed the seeing to 1.2", 7 days from new moon and airmass of 1.3; *iii*) each star should appear unsaturated in at least one frame.
The exposure times for NICS IR filters were calculated to reach limit magnitudes of 19.3, 18.2 and 17.4 for the J,H,K' bands, respectively. Thus, we require 4 dithered [J,H,K'] observations of [2;2;2 sec.] covering magnitudes form [11.0:16.3; 11.0:16.0; 11.0:15.5], and 8 long exposures [60,17,13 sec.] for magnitudes ranging between [16.3:18.4; 16.0:17.3; 15.5:16.6], respectively. The total exposure time for 16 different pointing directions is about 11900 seconds, while overhead time is 16800 seconds, that means a total time of about 8 hours. In order to calibrate our instrumental J,H, K' magnitudes to the standard JHK system (Hunt et al. 1998), we also need to observe the AS 36 (see box 14) field, which include 5 standard IR sources in a FOV of 4'×4'. To observe this region we need 4 J,H,K' short exposure (2 sec.) leading to a total exposure ~24 sec, and overheads ~684 sec (about 20 minutes). We required 9 hr for the NICS camera. We need to observe standard calibration fields each night to complete both optical and IR Cyg OB2 observations.

Near Infrared photometry:
NICS imaging camera with J(1.27 μ), H(1.63 μ) and K'(2.12 μ) filters.

17. Scheduling constraints, special requirements and other remarks

August is the preferred month for the observation of Cyg OB2, because offers the best visibility time, although September is also an option. The rest of available months for the AOT16 period would produce inefficient observation runs.

18. Backup program: description or justification for none

TNG LaTeX style file vAOT16 Mar 2007.