MAD Science Demonstration Proposal

Young massive star clusters in the Carina Nebula

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Abstract:

The Carina Nebula (NGC 3372) is a very spectacular feature of the Milky Way and the parent giant molecular cloud of a number of young massive clusters including a population of the most massive stars known in the Galaxy. It contains several open clusters that include not only dozens of young O- and B-type stars but also evolved Wolf-Rayet stars. The youngest and most populous clusters of the region are the open clusters Trumpler 14 and Trumpler 16 that are located in the central part of the Carina Nebula. The high-mass population of Trumpler 16, the older of the two, includes the Wolf-Rayet star HD93162 and the famous luminous blue variable star η Carinae. Trumpler 14, in contrast, shows no evolved star but several O-type stars notably the O2If* star HD93129Aa. Both clusters have an extended population of bright stars and their strong UV radiation interacts with the surrounding material triggering subsequent star formation. The proximity of the Carina Nebula and its cluster population together with the combination of high spatial resolution and the wide-field at VLT-MAD allows to resolve for the first time the dense central regions of these clusters including their most massive stellar population.

Scientific Case:

In the Milky Way today more than 90% of all stars form in dense stellar clusters (Lada & Lada 2003, ARA&A, 41, 57). Observations of giant HII regions in extragalactic systems with intense star formation activity suggest that clustered star formation is the dominant mode of star formation throughout the Universe. In distant starbursts, essentially all the light we observe originates in the most massive O- and B-type stars.

The Carina Nebula (NGC 3372), at a distance of ≈2.6 kpc (Tapia et al. 2003, MNRAS, 339, 44), is a HII region with a particular star cluster population that harbors a large concentration of O-type stars and can be considered as a smaller analog of the starburst region 30 Doradus in the LMC. The stellar content of the Carina Nebula is similar to that of 30 Doradus and Galactic massive star clusters like NGC 3603 or the Arches cluster with the difference that the open clusters of the Carina Nebula are less centrally concentrated. Nevertheless, the influence of the strong UV radiation and stellar winds on the ISM appears to trigger star formation which is already an ongoing process in the Carina Nebula (e.g. Rathborne 2002, MNRAS, 331, 85).

Trumpler 14 and Trumpler 16 (hereafter Tr 14 and Tr 16), the youngest and most populous clusters of the Carina Nebula, include a large fraction of the young and mostly unevolved high-mass star population. The stellar population of Tr 14 includes several O-type stars notably the O2If* star HD93129Aa (Smith 2006, MNRAS, 367, 763). The lack of evolved stars makes Tr 14 a very young cluster while Tr 16, in contrast, includes the Wolf-Rayet star HD93162 and the famous star η Carinae, a candidate for the most massive star of the Galaxy. The ages of the high-mass content of Tr 14 and Tr 16 are supposed to be around 1-2 Myr (Vazquez et al. 1995, A&AS, 116, 75) and 2-3 Myr (Smith 2006, MNRAS, 367, 763), respectively, while the formation of intermediate-mass stars probably started earlier. However, the ages of the clusters as well as the distances estimates remain controversy. This could be due to the anomalous extinction law observed in the clusters (e.g. Tapia et al. 2003, MNRAS, 339, 44). The initial mass functions (IMF) of Tr 14 and Tr 16 have been also derived but not for the subsolar regime (e.g. Massey&Johnson 1993, AJ, 105, 980).

Immediate aims - the high-mass population of Trumpler 14 and Trumpler 16:
The dense population of bright O- and B-type stars of Tr 14 and Tr 16 offer an ideal environment for the use of a multi-conjugate adaptive optics system. The resolution power and the wide-field at VLT-MAD allow to resolve the dense cores of the two clusters for the first time. We propose observations of four pointings in the H- and K_S-band, each pointing covers the 1-arcmin MAD field. Three fields are located in the area of Tr 14, one in the area of Tr 16. Each field includes at least three bright stars which can be used as natural guide stars (NGS). Therefore, the NGS requirements for VLT-MAD are satisfied.
Census of the stellar content: To understand the interplay between high-mass star formation on one hand and low- and intermediate-mass star formation on the other hand knowledge of the stellar content of the cluster cores is necessary. The spatial distribution of different types of stars would show a possible higher concentration of high-mass stars at the center of the cluster and, if it is observed, to reveal its origin. Furthermore, it allows to examine the influence of high-mass star formation on the formation of low- and intermediate-mass stars.
Construction of core CMD: MAD observations of the clusters in the Carina Nebula region provides the opportunity to construct the actual deepest color magnitude diagrams (CMD) of Tr 14 and Tr 16. Knowledge of the stellar content down to low mass stars and their positions in the CMD would shed more light on a probable continuous star formation. The deep CMDs also allow to apply isochrone models to improve significantly the estimates for extinction, distance and age of Tr 14 and Tr 16.
Masses of PMS stars and the IMF: By comparison of the sequence of PMS stars in the CMD with theoretical isochrones, distance, extinction and age of the low-mass cluster population can be derived. In addition, masses can be assigned to individual PMS stars, and the mass function can be derived down to the hydrogen burning limit. This will address the question of whether the Initial Mass Function (IMF) in young, massive clusters follows a Kroupa-IMF, or if a truncated IMF towards lower mass stars fits better to the observations.

Targets and integration time

Target	**RA**	**DEC**	**Filter**	**Magnitudes**	**Total integration time** (sec)	**Field** (arcmin)
Trumpler 14(a)	10 43 57.0	−59 32 46	H, K_s	H=19.0, K_s=19.5	3,600	1
Trumpler 14(b)	10 43 47.5	−59 33 46	H, K_s	H=19.0, K_s=19.5	3,600	1
Trumpler 14(c)	10 44 03.0	−59 35 32	H, K_s	H=19.0, K_s=19.5	3,600	1
Trumpler 16	10 45 05.0	−59 42 13	H, K_s	H=19.0, K_s=19.5	3,600	1

Guide stars list and positions

Target: Trumpler 14(a)			
	$\mathbf{RA}''_{rel}$	$\mathbf{DEC}''_{rel}$	**V Mag**
GSC0862602805	+2.28	−7.92	7.00
HD93128	−19.98	−11.37	8.84
GSC0862600354	+21.33	+19.26	10.04
Target: Trumpler 14(b)			
GSC0862600354	−26.57	−0.19	11.87
GSC0862602422	+9.51	+21.52	11.90
GSC0862602187	+26.49	−4.83	12.31
Target: Trumpler 14(c)			
GSC0862600285	−15.11	−13.89	11.23
GSC0862600337	−23.23	+7.46	11.46
GSC0862601368	+21.81	+20.13	11.87
Target: Trumpler 16			
GSC0862602397	+13.61	+16.38	9.57
GSC0862601092	−21.44	+11.85	10.27
GSC0862602028	+10.76	−22.82	11.50

Time Justification:
We want to study the PMS population of the two major clusters of the Carina Nebula down to a mass of 0.08 $M_\odot$ which is close to the hydrogen burning limit. A star of the Carina Nebula with a mass of 0.08 $M_\odot$ at an age of 4 Myr should have an apparent K magnitude $\approx 18.7 - 19.2$ mag (dist. 2.6 kpc, $A_V = 2.5 - 7$ mag $\leftrightarrow$ $A_K = 0.275 - 0.77$ mag). To achieve a photometric uncertainty of ± 0.05 mag, which corresponds to a S/N ≈ 20 we need 30 min integration time in both the H- and K_s-band. This means an integration time of 1.0 hr for each of the 1-arcmin MAD fields is required. With the four proposed fields to observe this leads to 4.0 hr of total integration time.