# A deep Chandra observation of the S254-S258 star forming complex


**Paola Mucciarelli & Thomas Preibisch**

Universitäts-Sternwarte München, Excellence Cluster Universe, Germany

http://www.usm.uni-muenchen.de/ys/ e-mail: pmuccia@usm.uni-muenchen.de



In the S254-S258 region a dense cluster of very young stellar objects is sandwiched between two HII regions. This remarkable configuration led to conjectures that the two B stars exciting the HII regions may have been dynamically ejected from the central cluster, or, alternatively, that the current star formation activity in the central cloud is triggered by the two expanding HII regions. In the second case, the two B stars should belong to a slightly (few Myr) older stellar generation, but, interestingly, no associated young low-mass stars could be identified so far around them; this let arise speculations of a case of isolated formation of massive stars.

In order to solve this puzzle, we have performed a deep Chandra X-ray observation of this extraordinary star forming region and detected more than 360 X-ray sources. This yields, for the first time, a reasonably complete sample of all young stars in the observed region, and detects a scattered distribution of the young star population around the dense cluster S255-2. Here we present the first results of our ongoing analysis.


## The S254-S258 star forming complex at a glance

- contains the five diffuse HII regions S254-S258 (D~ 2.0-2.5 kpc).
- S255 and S257 are each powered by an apparently single B0 star, have radii of ~1pc, and a projected separation of ~3pc.
- S255-2 (Heyer et al., 1989) is a dense dusty molecular cloud filament with several hundreds embedded infrared sources (estimated age ~ 1 Myr) and clear evidence of very recent and ongoing star formation activity (Howard et al 1997; Miralles et al 1997; Itoh et al 2001; Chavarria et al 2008).

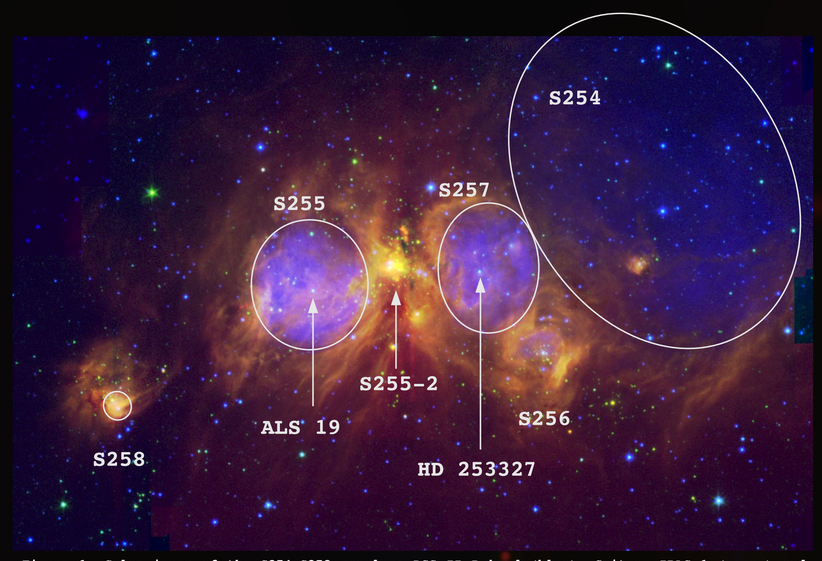


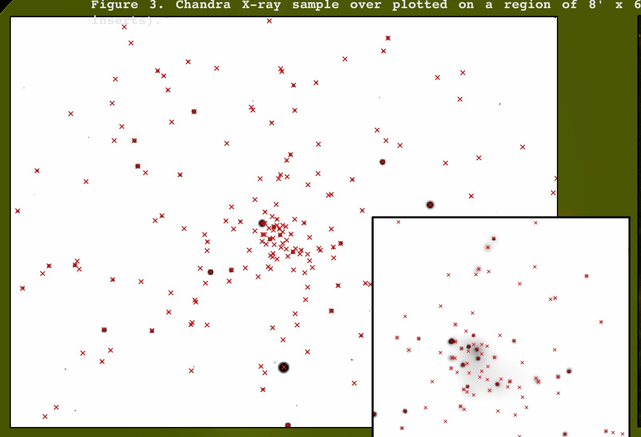

Figure 1. Color image of the S254-S258 complex: DSS II R band (blue), Spitzer IRAC 1 (green) and IRAC 4 (red). White circles enclose the five HII regions. The two ionizing stars of S255 and S257 are also indicated, along with the central cluster S255-2.

## The Chandra observation

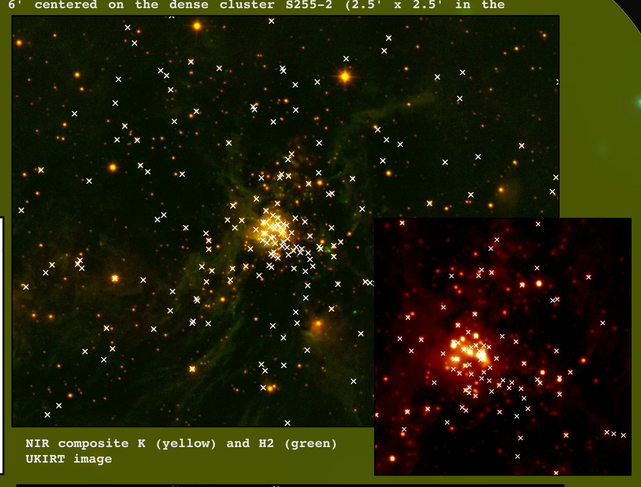
X-rays observations can provide a sample of the populations of low-mass stars association members, unbiased toward stars with circumstellar disk and free from field stars contamination.

Our Chandra observation was performed on November 21/23 2009 (PI T. Preibisch) and last of two pointings for a total exposure time of about 75 Ks. **A total of 364 sources were detected** in the 17'x 17' Chandra field (ACIS EXTRACT, Broos et al 2010), centered in the dense young cluster S255-2 (Fig.2). The sensitivity limit of our data is $F_{x,lim}$~$10^{-15}$erg/cm$^2$/sec, corresponding to a X-ray luminosity of $L_{x,lim}$~$5x10^{29}$erg/sec and stellar masses of ~0.5 Msun (Preibisch et al 2005). About 20% of the X-ray sources are concentrated within 1' of this central cluster, but the remaining 80% are scattered in a wider distribution around the cluster (Fig. 3).

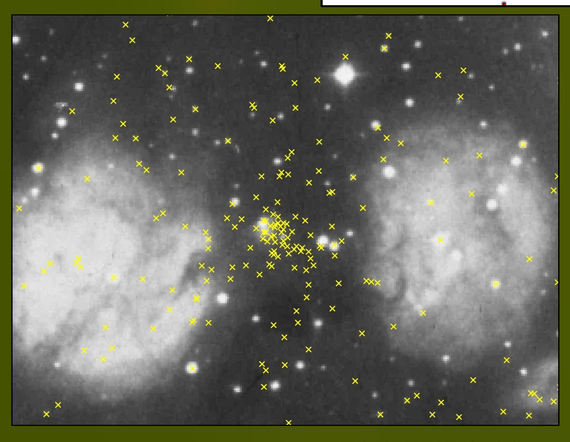
Figure 3. Chandra X-ray sample over plotted on a region of 8' x 6' centered on the dense cluster S255-2 (2.5' x 2.5' in the



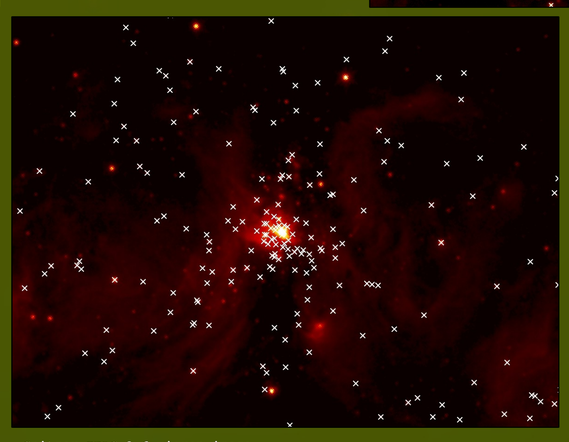
Chandra smoothed image in the [0.5-8.0]keV band



NIR composite K (yellow) and H2 (green) UKIRT image



Optical DSS II R band image



Spitzer IRAC 3.6 micron image

## The case of the missing low-mass stars

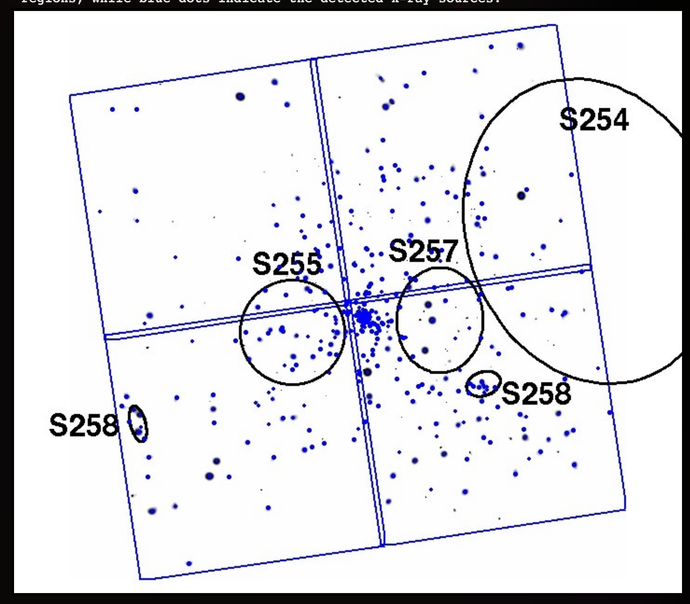
The two massive B0 stars exciting the HII regions S255 and S257 appear to be isolated (Fig.1) without any obvious co-spatial low-mass clusters (Zinnecker et al 1993) as expected according to the standard field star IMF.

**Possible solutions:**

- A bimodal star formation scenario: S254–258 would be the first observed example of isolated formation of massive stars.
- Dynamical ejection of the two B stars from the embedded cluster.
- A scenario of multiple stellar generations: the two B0 stars belong to an earlier generation of stars in the molecular cloud and their expanding HII regions may have compressed the dense cloud between them and triggered the formation of a new generation of stars, i.e. the embedded cluster of young stellar objects.

**A good discriminant between the different scenarios is the presence or absence of low-mass stars associated with these B-stars that should be present only in the last solution.**

Figure 2. Chandra smoothed image of the complex. Black circles enclose the HII regions, while blue dots indicate the detected X-ray sources.




## Spectral analysis of bright sources

Most of our sources are weak, therefore we used the median energy of each source as an indicator of the spectral shape. In our sample 35% of the sources have an hard spectrum, due to very bright plasma temperature or to absorption, as is likely in the embedded central cluster (Fig.4). Spectral analysis of 24 sources with more than 80 counts were performed. The best fit is always given by an absorbed VAPEC model, but the range of temperatures and absorbing column density is quite wide.

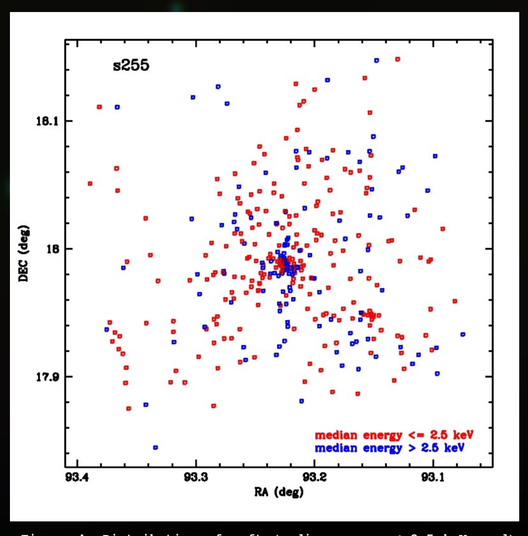



Figure 4. Distribution of soft (median energy < 2.5 keV, red) and hard (median energy > 2.5 keV, blue).


**Bibliography:**

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## CONCLUSIONS

Our Chandra observation revealed a sample of 364 X-ray sources in the S254-S258 complex field. The majority of the detected X-ray sources is widely distributed around the central cluster S255-2. Between the proposed possible scenarios, the presence of X-ray emitting low-mass stars supports the presence of multiple stellar generations.