THE YOUNG OPEN CLUSTER AROUND 25 ORI

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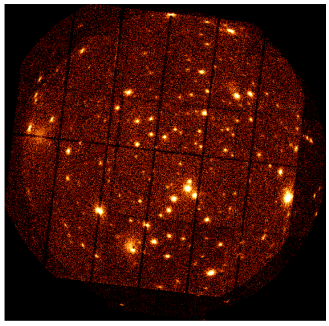
1. The 25 Ori cluster

The 25 Ori cluster consists of a group of bright stars and ~200 pre-main sequence (PMS) stars located around the B1Vpe star 25 Orionis in the Orion OB1a association (age ~ 7 - 10 Myr, d = 330 pc, E(B - V) = 0.09). The cluster was recently discovered by Kharchenko et al. (2005) from the analysis of the spatial distribution and proper motions of bright stars, and by Briceño et al. (2005, 2007) from an optical variability survey and follow-up spectroscopy of PMS stars. The cluster includes the Herbig Ae star V346 Ori, and has a very low fraction (6 - 7%) of stars with disks (Hernández et al. 2006, 2007), consistent with the expected decrease of the fraction of circumstellar disks with age.

2. Observations and source detection

The cluster was observed with XMM-Newton for 63 ks on March 1-2, 2009, using the EPIC cameras. The pointing direction was intermediate between the cluster centers derived by Briceño et al. (2007) and Kharchenko et al. (2005), 9.6 arcmin southeast of 25 Ori, to maximize the number of known members falling in the field of view.

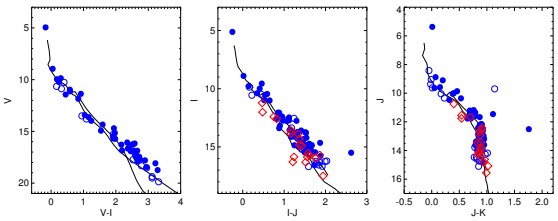
Source detection was performed on the individual and merged MOS1+MOS2+PN datasets using the Wavelet Detection algorithm developed at INAF-OAPa (Damiani et al. 1997). We detected a total of 187 sources above a significance threshold of 5σ, including two extended sources.



Composite EPIC image of the field

We searched for counterparts within 4″ of the X-ray positions, finding that:

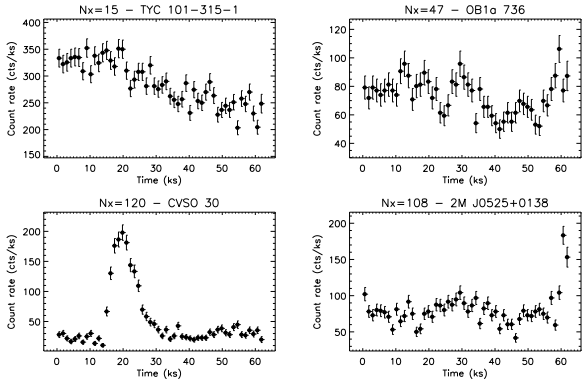
- 62 sources are identified with known cluster members. For the 38 undetected members we computed 3σ upper limits at the optical positions. Detection rates are ~50% for M > $M_\odot$, ~75% for M = 0.25 - 1 $M_\odot$, and ~30% for lower-mass objects. The Herbig Ae star V346 Ori was not detected.
- 19 sources have counterparts in the 2MASS and Denis catalogues with photometry consistent with membership, therefore they might be new cluster candidates.
- 3 sources, including the 2 extended ones, are identified with extragalactic radio sources, and 31 sources are identified with known or possible non-members, or with objects without membership information.
- The remaining 71 sources have no catalogued counterpart. Most of them have hardness ratios consistent with an extragalactic origin.



Colour-magnitude diagrams for objects in the XMM-Newton field of view. Blue circles: detected (filled) and undetected (open) known members; red diamonds: detected new possible candidates. The solid lines are 20 Myr isochrones from Siess et al. (2000) and Baraffe et al. (1998)

3. Variability

Using the Kolmogorov-Smirnov test, we find that ~45% of the cluster members and ~25% of the new candidates are variable at the 99% confidence level. Flares were observed in 10 sources.

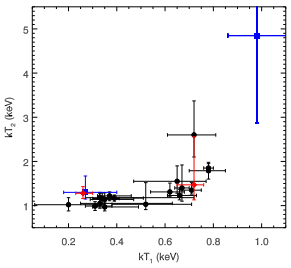


Examples of variable late-type members and candidates. Note the very strong flare of NX120, identified with the M3 star CVSO 30. The new candidate NX108 shows modulated emission with a period of ~35 ks, likely due to rotational modulation.

4. Spectral analysis of bright sources

We performed joint PN+MOS spectral fits for 21 members and 2 new candidates with at least 500 cts in the PN or MOS, using 2-T or 1-T APEC models with variable global abundances. Since all selected sources are diskless, we kept the interstellar absorption fixed to $N_H = 2.4 \times 10^{20}$ cm^{-2}, derived from the average cluster reddening.

- We find temperatures $T_1 \sim 0.2$-0.8 keV and $T_2 \sim 0.8$ - 2 keV, and subsolar abundances ($Z \sim 0.1$ - $0.3\ Z_\odot$), in agreement with the results found for other young clusters and star-forming regions.
- The two new candidates (red diamonds) have similar temperature structure as cluster members.
- For NX120 (blue squares) we fitted separately the spectrum in quiescence and at the flare peak, finding that during the flare both temperatures and emission measures increase significantly, reaching $T_2 \sim 5$ keV.

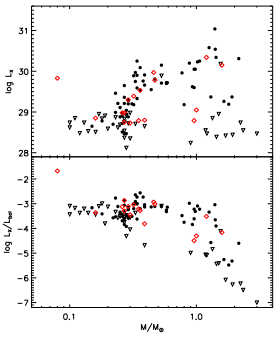


X-ray temperatures derived from 2-T spectral fits

5. X-ray luminosities

X-ray luminosities in the 0.3-8.0 keV band were computed using a conversion factor CF = 7.8×10^{-12} erg cm^{-2} cnt^{-1} derived from the spectral fits. The sensitivity in the center of the field is $L_X \sim 2 \times 10^{28}$ erg s^{-1}.

- L_X shows a rapid increase with mass up to ~0.8 $M_\odot$, then a large scatter is present at higher masses. 25 Ori (not shown in the figure) has $L_X = 1.6 \times 10^{29}$ erg s^{-1} and $L_X/L_{bol} \sim -8.4$.
- For late-type stars $L_X/L_{bol} \sim -3.5$, similar to what found for the λ Ori and σ Ori clusters (Franciosini et al. 2006; Franciosini & Sacco 2011) and for other young clusters of comparable age (e.g. Flaccomio et al. 2003; Preibisch et al. 2005; Telleschi et al. 2007).
- New candidates follow the cluster trends, except one with a very low estimated mass but high luminosity, which is very likely to be a contaminant.

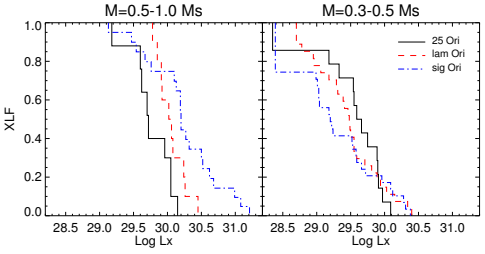


L_X and L_X/L_{bol} vs mass. Triangles indicate upper limits. Red diamonds indicate the new candidates.

6. Comparison with the λ Ori and σ Ori clusters

We compared the X-ray luminosity functions of spectroscopically-confirmed members with those of the younger clusters λ Ori (1-8 Myr, Franciosini & Sacco 2011) and σ Ori (2-4 Myr, Franciosini et al. 2006).

We found that stars with M = 0.5 - 1 $M_\odot$ in 25 Ori are less luminous by a factor of 2 - 3 than those in the younger clusters λ Ori and σ Ori, with a confidence level of 90%, indicating a decrease of X-ray emission with age, as observed in Orion and Taurus (Preibisch & Feigelson 2005; Telleschi et al. 2007). λ Ori also appears to be slightly less luminous than σ Ori, but the differences are not significant. On the other hand, no significant difference is observed for lower masses.



Comparison of the XLFs of the 25 Ori cluster with those of λ Ori and σ Ori. The apparent lower luminosity of σ Ori stars with M = 0.3 - 0.5 $M_\odot$ is due to the lower detection rate.

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