X-ray properties of sources detected in the DROXO survey

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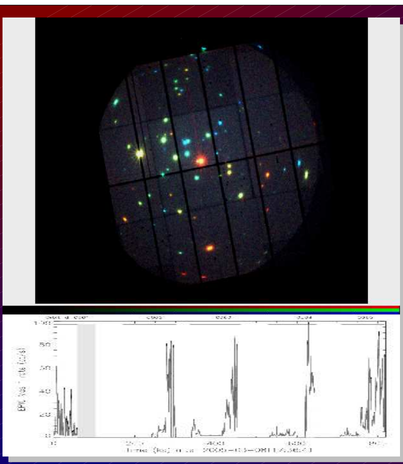
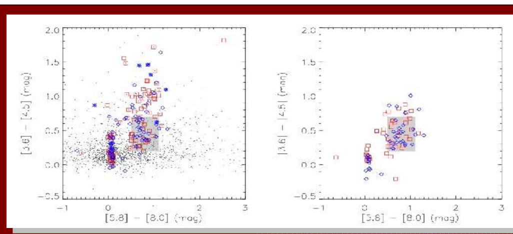
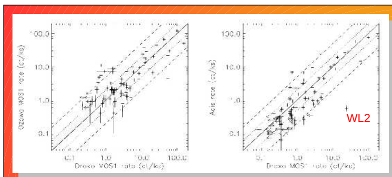


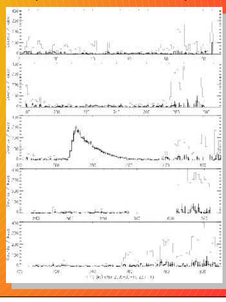
DROXO is a large program for the XMM-Newton AO7 aimed to observe for ~500 ks the dense core F of the Rho Ophiuchi Cloud. With DROXO it is possible to explore the time variability on time scale of a week and to study the interplay of X-ray YSO emission and circumstellar disk in the first stages of star formation.
The observation was affected by high background variability, especially at the end of each satellite revolution, and one of the MOS1 chips stopped to work. The bottom panel on the left shows the light curve (0.3-10 keV band) of the MOS1 events. To reach the deepest sensitivity, we filtered out high background intervals (net exposure: 190 ks) and performed source detection with PWXDETECT code that allows us to analyze together PN and MOS images . We found 111 X-ray sources.
The molecular cloud density changes across the field of view, being more dense in the upper right corner. The pseudo-color image on the left shows the image of the sum of EPIC images, red sources are softer than blue ones, whose spectra are harder and/or more absorbed (N_H up to ~10^{23} cm^{-2}). By fitting the spectra with absorbed thermal models we find that most of plasma temperatures are comprised in ~0.7-6.0 keV with a median of 2.5 keV.
DROXO offers to date the deepest survey of fluorescent Fe line at 6.4 keV in PMS stars. This line has been studied in details in Elias29 (Giardino et al., 2007), YLW16A and IRS43 (cf. talk of E. Flaccomio at this conference).



Spitzer counterparts of DROXO sources. We matched the DROXO sources with the final release of the catalog of the C2D survey (Evans et al., 2003). The above plots show the IRAC colors in 3.6, 4.5, 5.8 and 8.0 μm bands. On the left, dots represent all objects in the field of view. DROXO source counterparts are marked with red squares. Blue diamonds are ISOCAM objects not detected in DROXO, Ozawa et al. (2005) XMM-Newton survey and Chandra survey. The gray area is where Class II YSO should lie while Class 0-I YSO should be found at [3.6]-[4.5] > 0.7 (Allen et al. 2004). We applied a reddening correction based on A_V, A_J or N_H.(reddening law as for Flaherty et al. 2007) On the right, the dereddened points from both samples are shown. Almost all stars for which we have reddening information fall in the region were Class II should lie (gray area). It is plausible that the Core F of Rho Oph exhibits a lower fraction of very embedded Class I YSO thus confirming what recently reported for the entire Rho Oph region by Jorgensen et al. (2008).

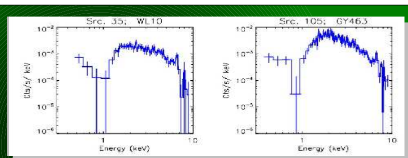


Sensitivity of the survey. The faintest detected source has a MOS equivalent rate of $8.3 \cdot 10^{-2}$ ct/ks; it yields $5 \cdot 10^{-15}$ erg s^{-1} cm^{-2} in flux and ~10^{28} erg s^{-1} in luminosity (0.3-10 keV band, at a distance of 140 pc) if we assume a spectrum with kT=2.5 keV and $N_H = 2.3 \cdot 10^{22}$ cm^{-2} (mean values derived from spectral fits). By assuming a lighter aborption of ~10^{21} cm^{-2} the limit luminosity would be $L_X = 2 \cdot 10^{27}$ erg s^{-1}. Recent X-ray surveys of the same region were obtained with Chandra (Imanishi et al., 2001) and XMM (Ozawa et al. 2005).

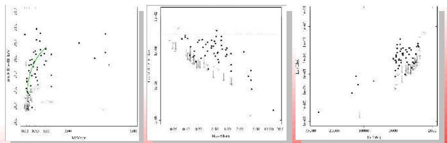


In the above plots we compare the rates from DROXO and those from Ozawa for XMM et al. (2005) and Flaccomio et al. (2006) obtained from ACIS on *Chandra* (efficiency similar to MOS). The Chandra survey shows a level of sensitivity similar to that attained in DROXO. Most of the sources show rates differing less than a factor 5. However, some sources with good statistics (rates > 1 ct/ks) are found clearly variable. For example, in the case of WL2/GY128 a big flare is observed varying in DROXO observation (PN data light curve on the right: total rate is the thin line, background subtracted rate is the bold line).

Quick summary of our findings:
Detected sources 111, 88 counterparts in 2MASS, 67 in ISOCAM, 95 in Spitzer C2D survey, for a total of 94 identified X-ray sources.
2MASS objects in the FoV: 1056
ISOCAM (Bontemps et al., 2001) objects in the FoV: 100
Spitzer (C2D survey, Evans et al. 2003) objects in the FoV: 3910

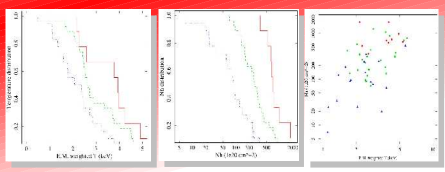


Soft excess in X-ray spectra. In 9 cases we observe a soft excess below 1.0 keV in spectra not fitted with a multi-temperature model absorbed with a single value of N_H column. A better fit is obtained with a model with 2 thermal emission components with two distinct N_H column values. Here we show two examples. WL10 is a class II star, the soft component has a kT = 0.11 keV and it is absorbed by $N_H = 3.7 \cdot 10^{21}$ cm^{-2} (kT = 4.6 keV and $N_H = 2.8 \cdot 10^{22}$ cm^{-2} are the parameters of the warm main component). On the right, GY463 shows a soft component with kT ~0.1 keV, $N_H = 1.7 \cdot 10^{21}$ cm^{-2} (kT= 3.2 keV and $N_H = 2.5 \cdot 10^{22}$ cm^{-2} are the parameters of the main component). The soft component can be interpreted as emission due to jet shocks seen under favourable source geometry conditions. Similar cases have been reported by Guedel et al. (2007) in the XEST survey of the Taurus Cloud, and explained as soft jet emission occurring far away from the dense absorbing material surrounding the YSO.



X-ray luminosities. From left to right, X-ray luminosities and Lx/Lbol versus masses and Teff. Upper limits are calculated for the ISOCAM sample (Bontemps et al., 2001). Lx vs. mass shows a trend consistent whith Lx - mass relation found for Orion (Preibisch et al. 2005, green line), valid where saturation of Lx/Lbol is present. Lx/Lbol saturation occurs at 0.7 M/M⊙ and at Teff ~ 5000.

We used the slope-SED classification given by Bontemps et al. (2001) based on ISOCAM survey of Rho Oph.The distributions of plasma temperatures (weighted mean through Emission Measure) and N_H for the stars of Class I (red), II (green) and III (blue) show that Class I stars are on average hotter than Class III stars and, marginally, also than Class II stars. Two sample tests result in a difference between Class I vs. Class III distribution at a level of 98%; for Class I vs. Class II the difference is at 75% level of significance. At the same time absorption toward Class I YSOs is larger than toward Class II and III YSOs (central panel). Panel on the right shows the scatter plot of kT and N_H for the different SED classes.



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