Chandra Observation of the Trifid Nebula: X-ray emission from the exciting O star Complex and Pre-main sequence stars

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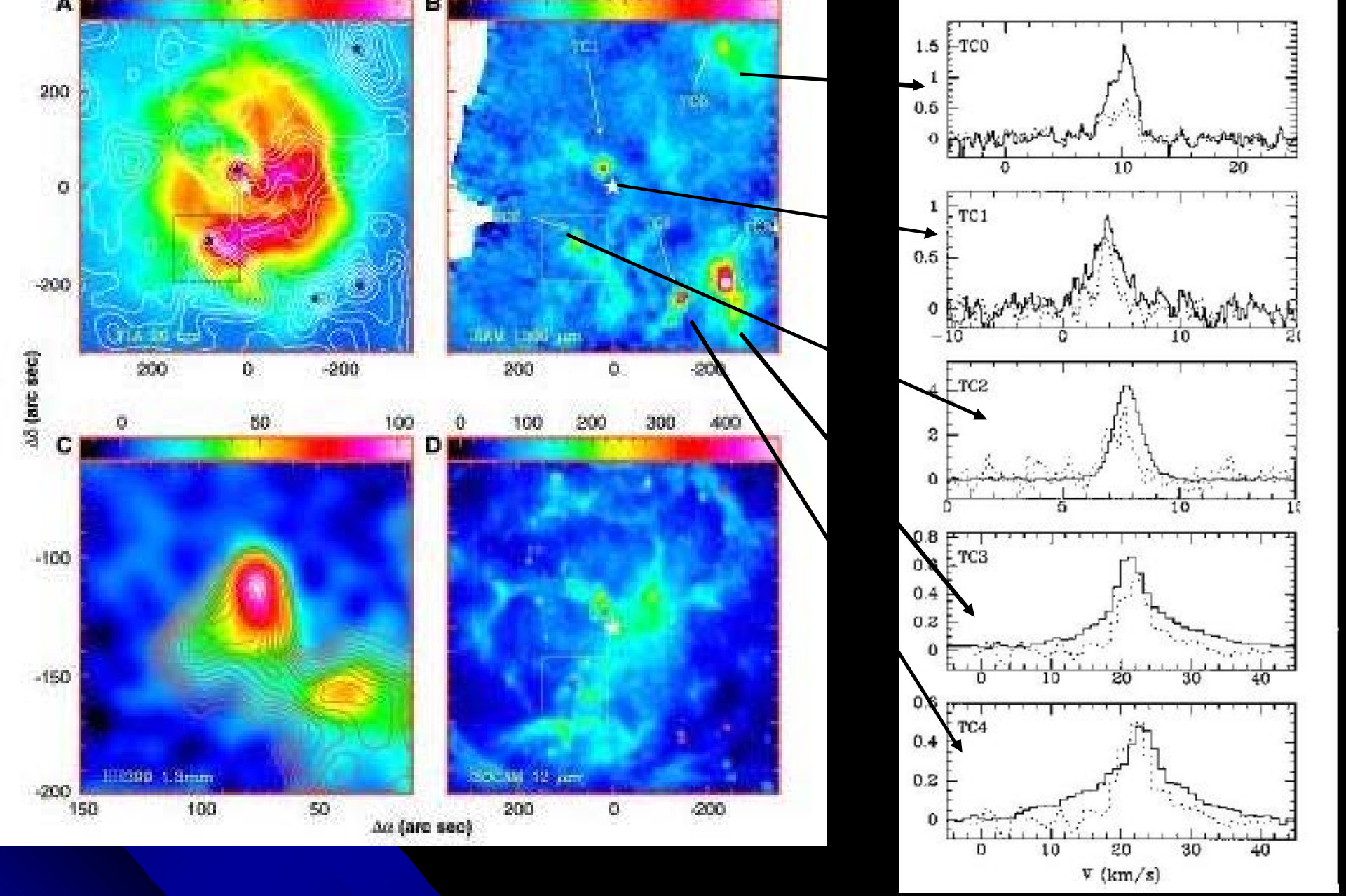
Introduction: Trifid Nebula

- Textbook optical picture of classical HII region: red ionized gas from O7 star, trisected by dark dust lanes
- Recent studies show
- A youngest HII region with 3×10^5 yr
- Active star forming region showing HH399, 4 massive protostars, ~85 TTS and YSO

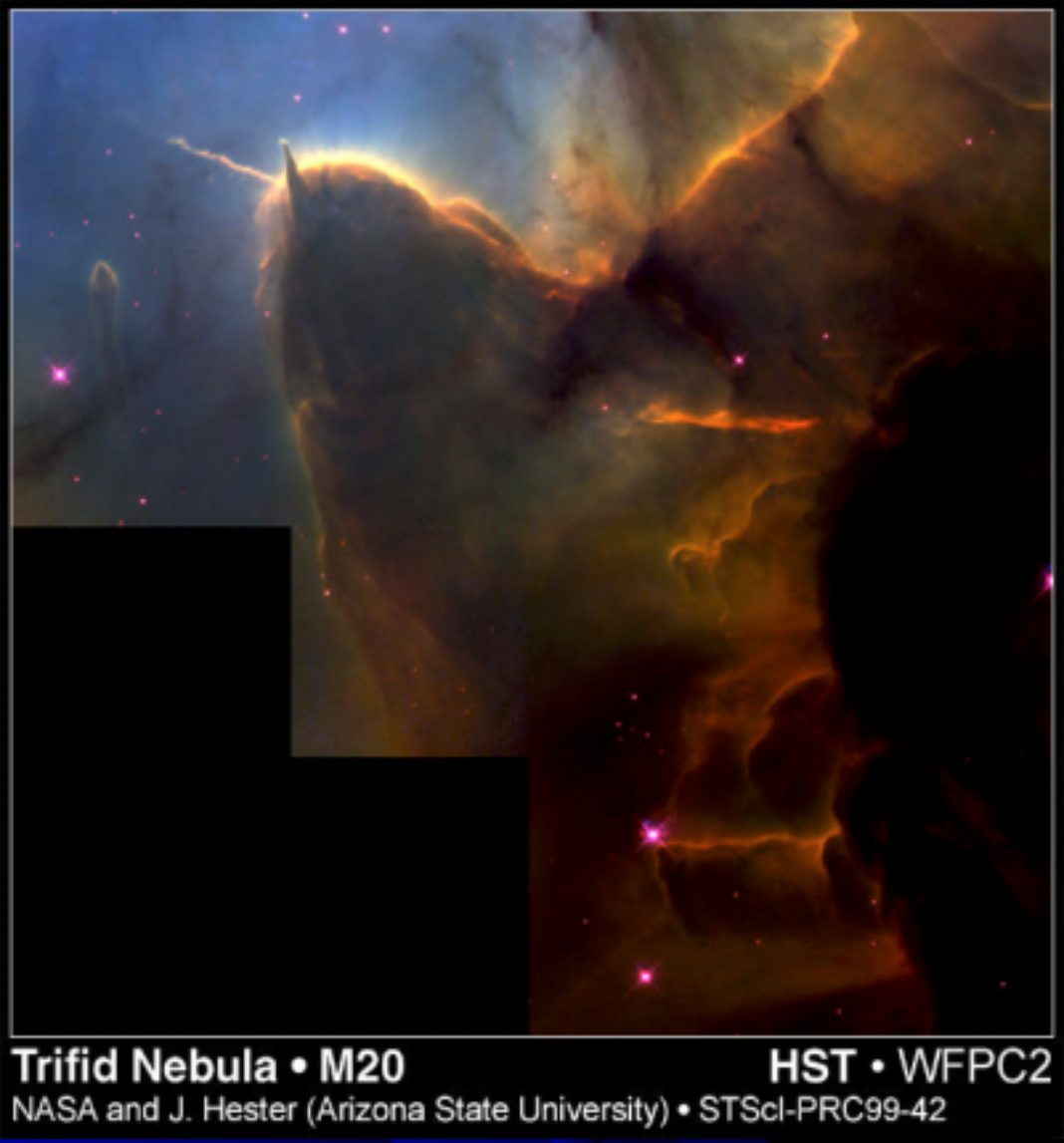


1300um IRAM bolometer observation: dust continuum map

⇒4 massive protostars,HCO+, SiO (J=2-1) show broad bipolar wings, Masses of 17-60 $M_?$

(Lefloch et al. 2000, 2001, 2002)

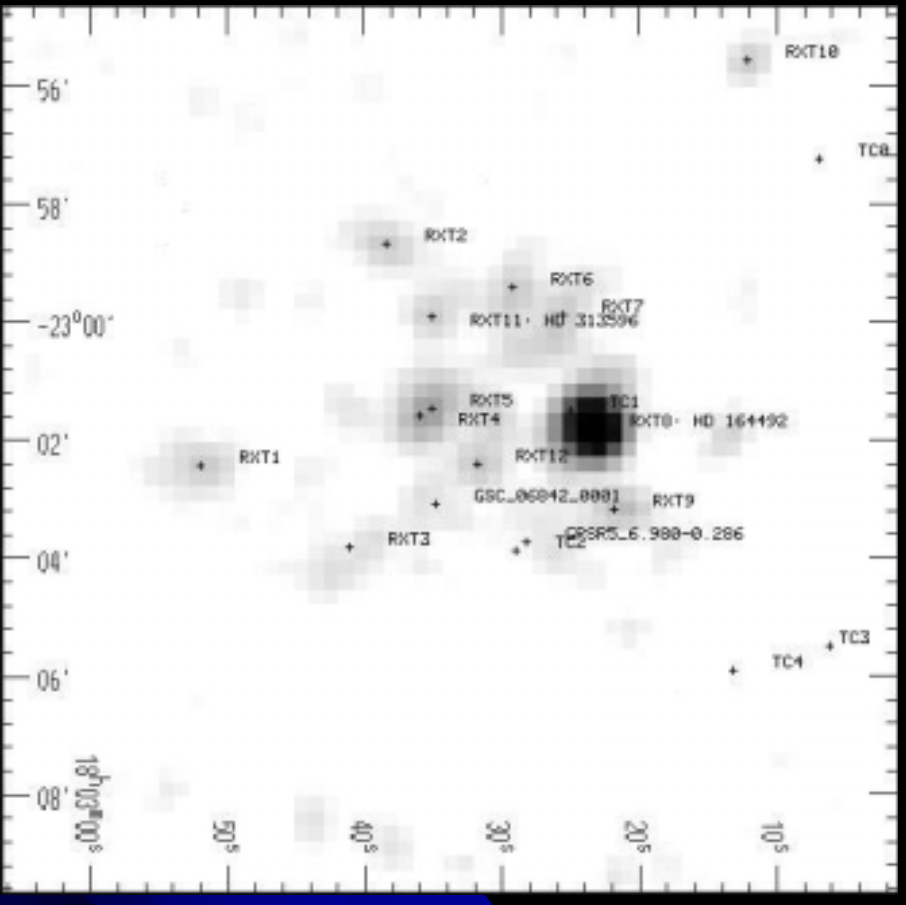
HST Observation

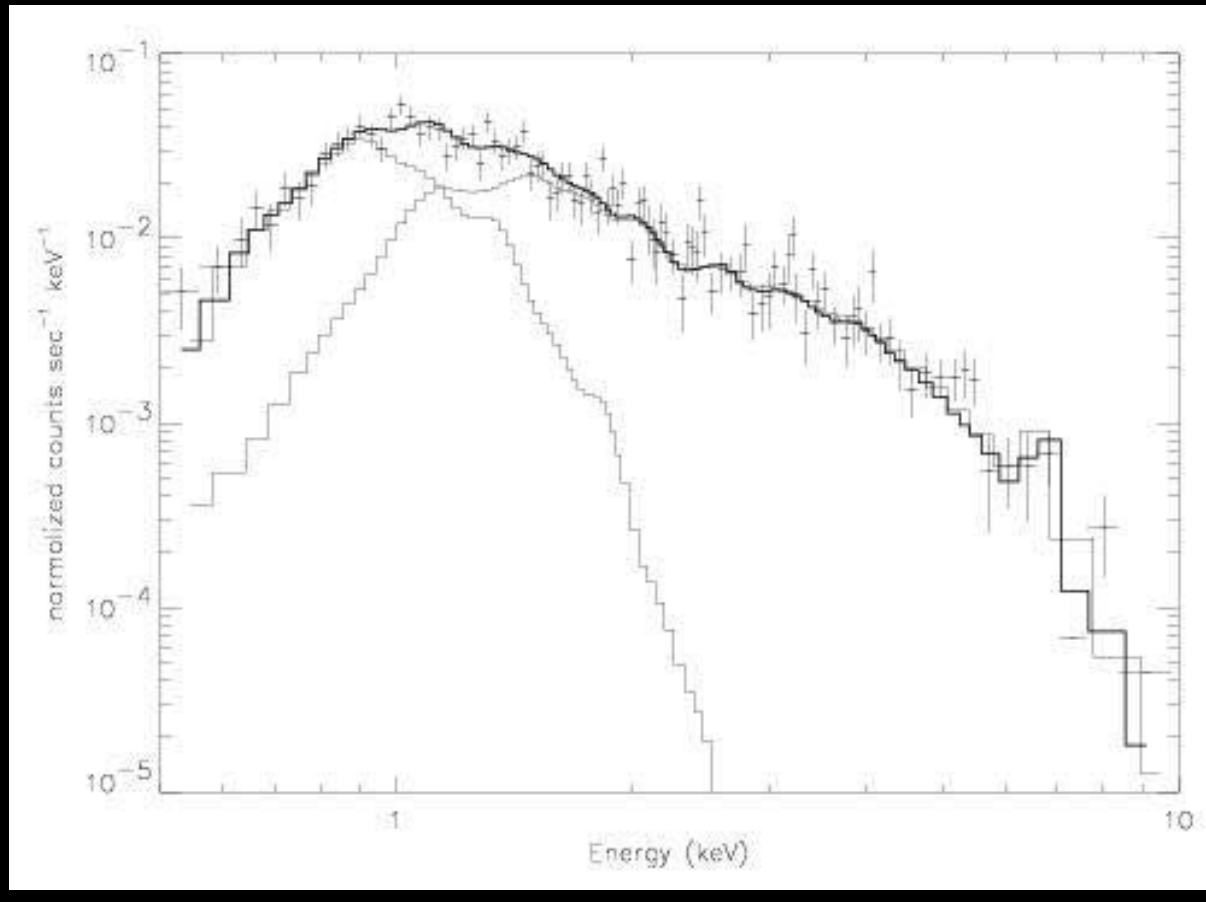


- Complex of ionization fronts: photoionized photoevaporative interfaces
- Evaporating gaseous globules (EGGs)
- HH 399: ~300km/s jet
  Jet is very knotty structure
- Young stars undergoing episodes of violent mass ejections

(Hester et al. 1999)

Previous X-ray observations



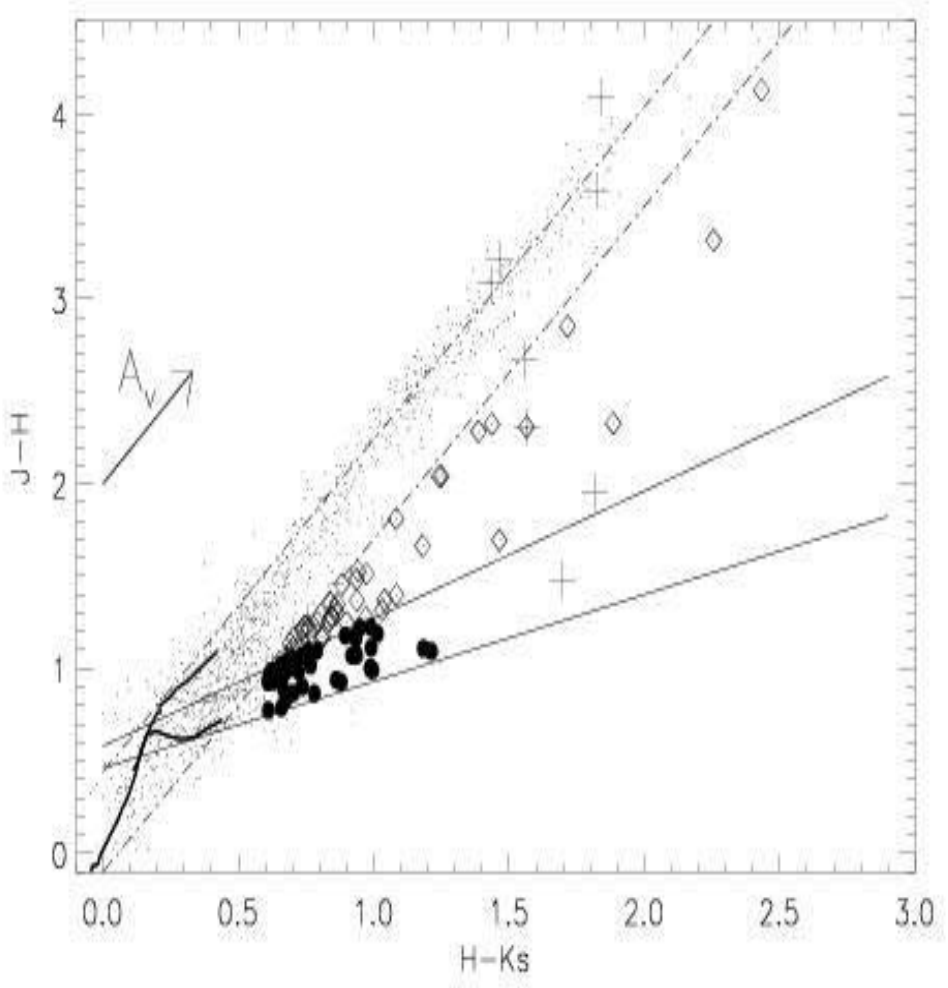


First X-ray image and spectra for the Trifid (Rho et al. 2001)

Images: a dozen of X-ray sources including the exciting O star HD 164492 and a few TTS and YSO (identified from near-IR)

Spectroscopy: hard X-ray photons- two T thermal models with $T=1.2\times10^6$ K and 4×10^7 K (Rho et al. 2001)

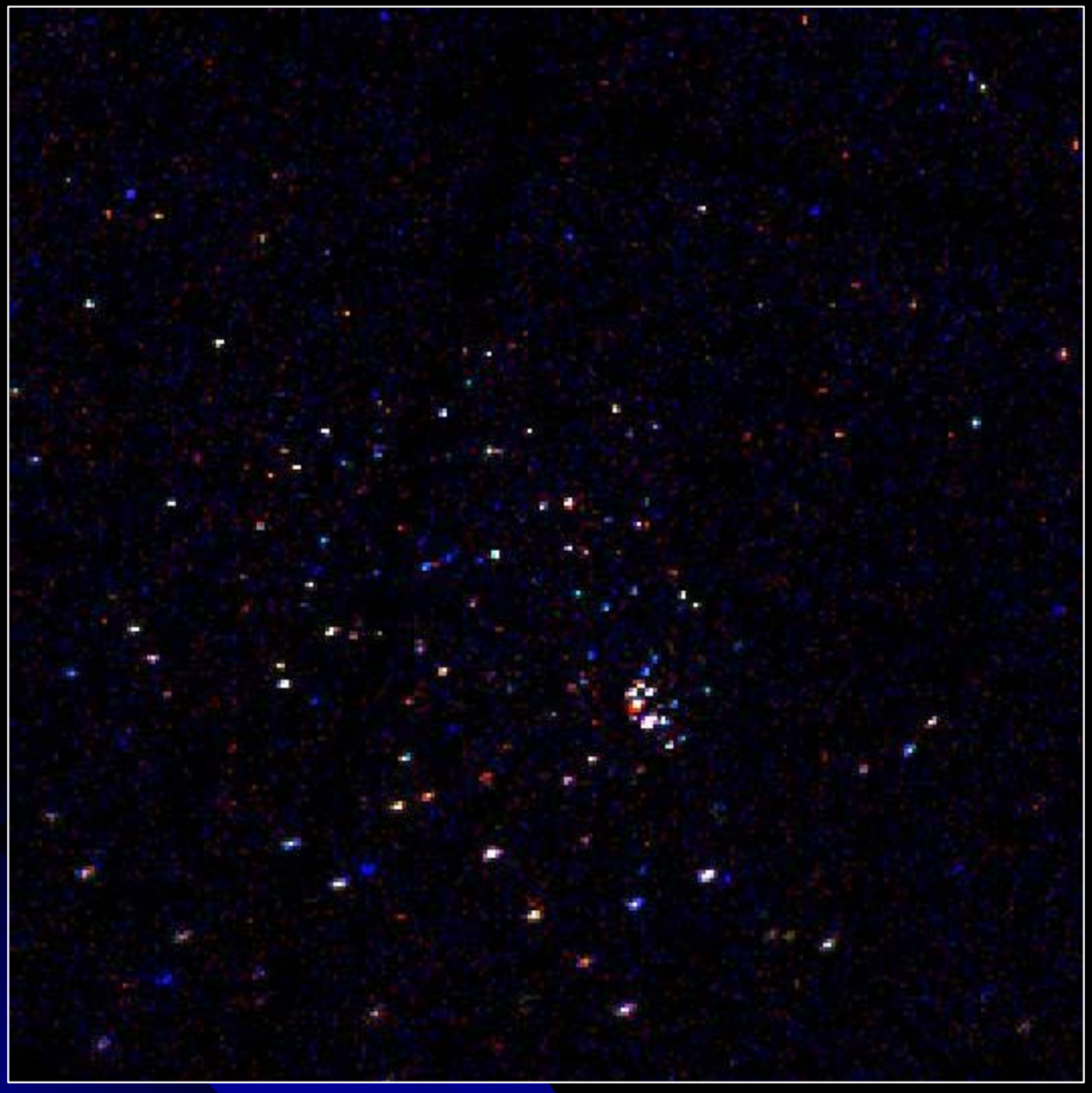
2MASS near-IR Observation



2MASS: JHK diagram
IR excess (Lada & Adams 1992) => 85 PMS candiates of TTS/YSO

Chandra Observation

- ACIS-I observation: FOV is 17’ square resolution of 1arcsec.
- The data are taken on June 13, 2002
- Standard data reduction (CIAO) with charge inefficiency transfer (CIT) correction package by Towsley et al. (2001)
- Astrometry: correlation with 2MASS source catalog: 72 sources are coinciding.



Chandra image: 14’ FOV
Red (soft 0.5-1 keV), green (1-2 keV)
and blue (hard 2-8 keV) sources

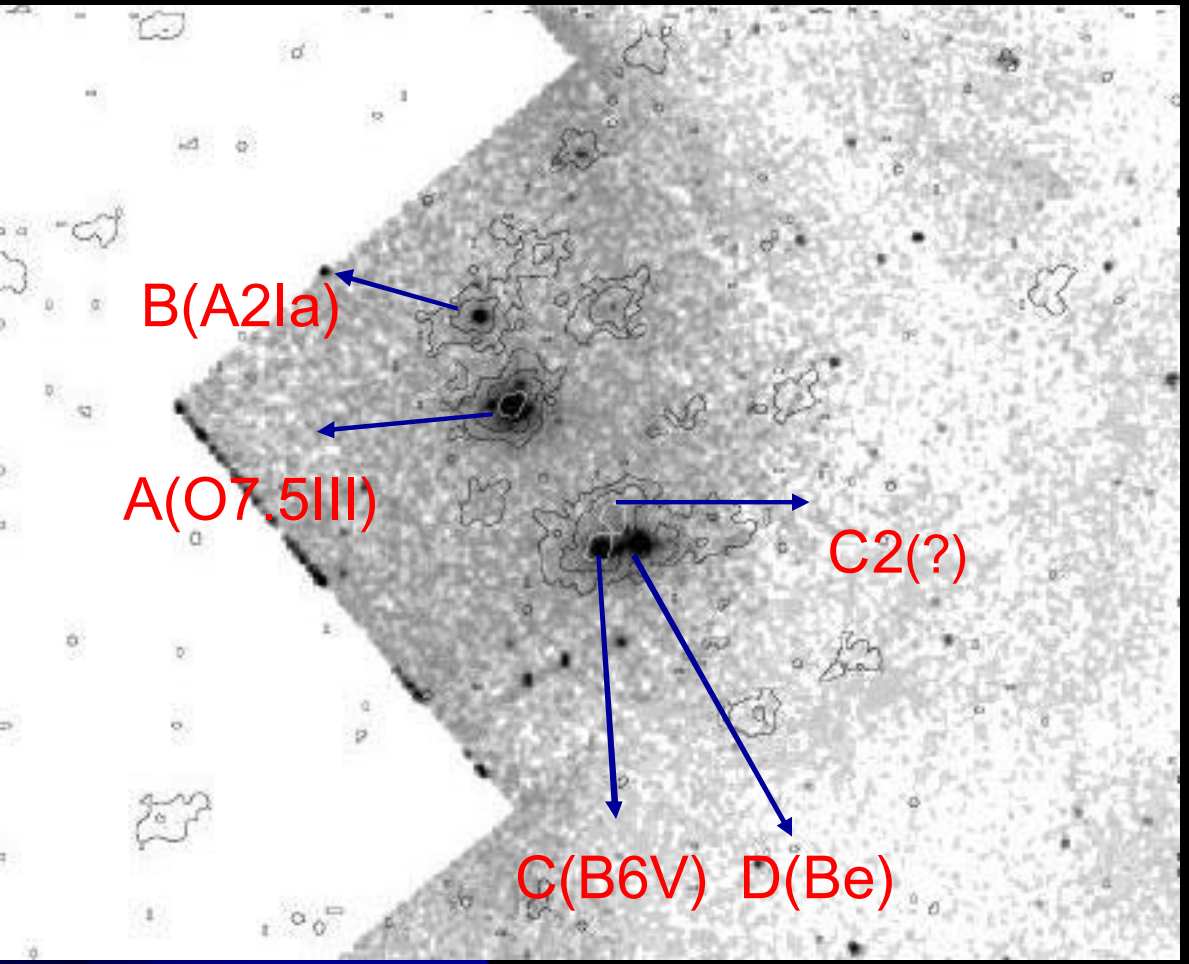
Chandra Image

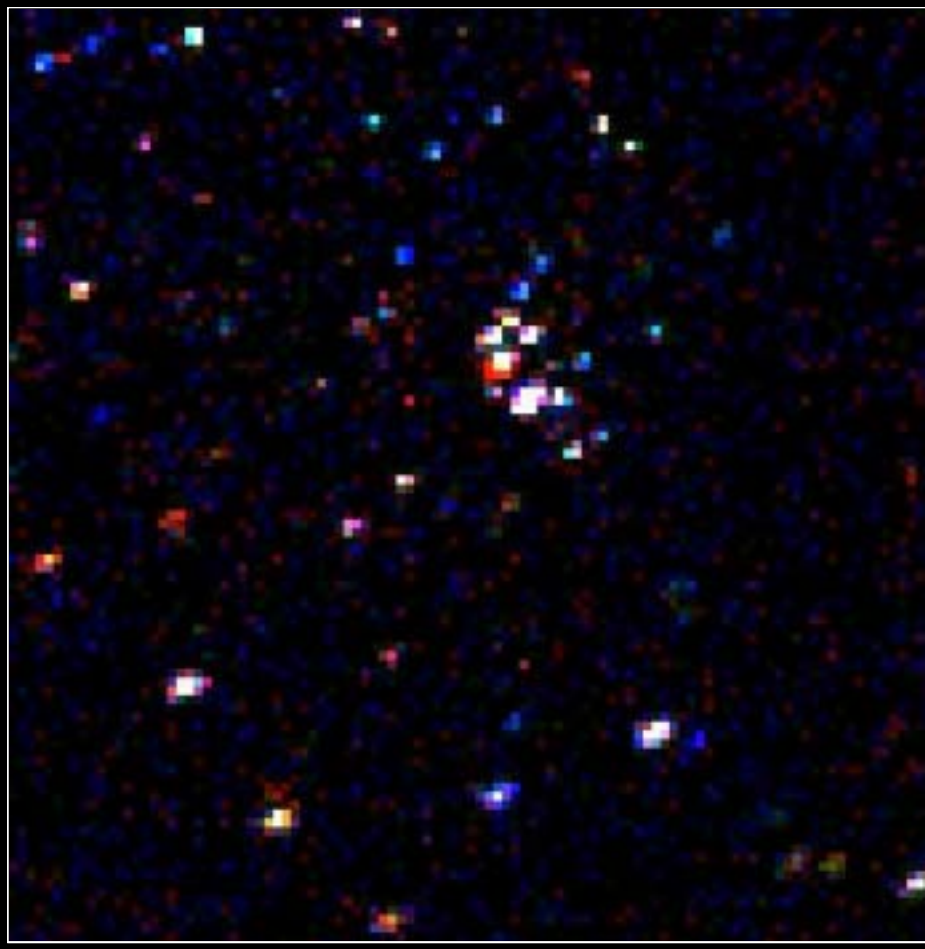
- 304 sources in the Trifid using wavelet method
- One-thirds are hard sources (embedded)
- Multiple sources around the O star
- Two-thirds have 2MASS counterparts

Chandra Image after adaptive filters

(FOV: 7.5’x7,5’)

Sources around HD164492: components A-F



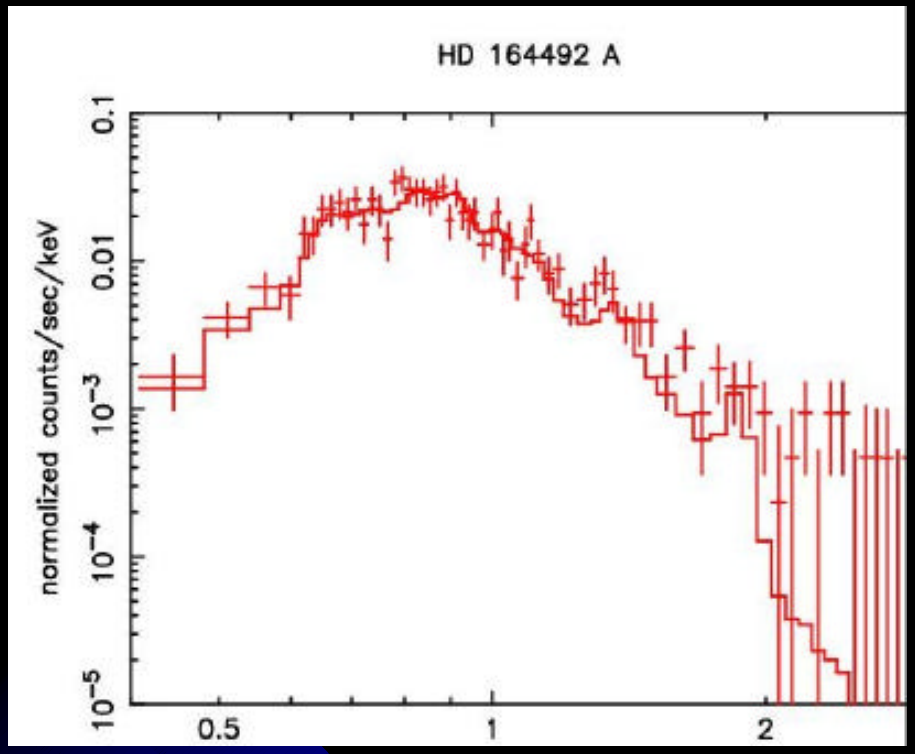


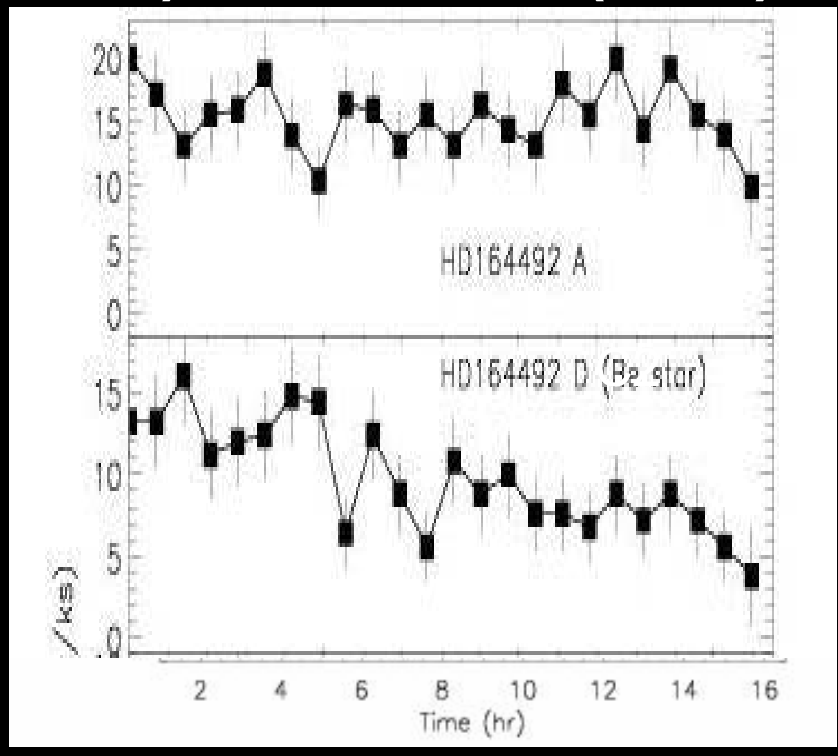
X-ray contours superposed on HST image.

Chandra image at the central part of HD164492 complex

A : O star
B: B6V star
CD: Brightest star – B/Be (B6V and Be) stars
C2: new X-ray source new Components CD-blend, highly variable

HD 164492 A (O star) and B (A2)





Component A: O star (O7.5III)

• Spectrum is soft emission (kT of 0.5 keV); stellar wind

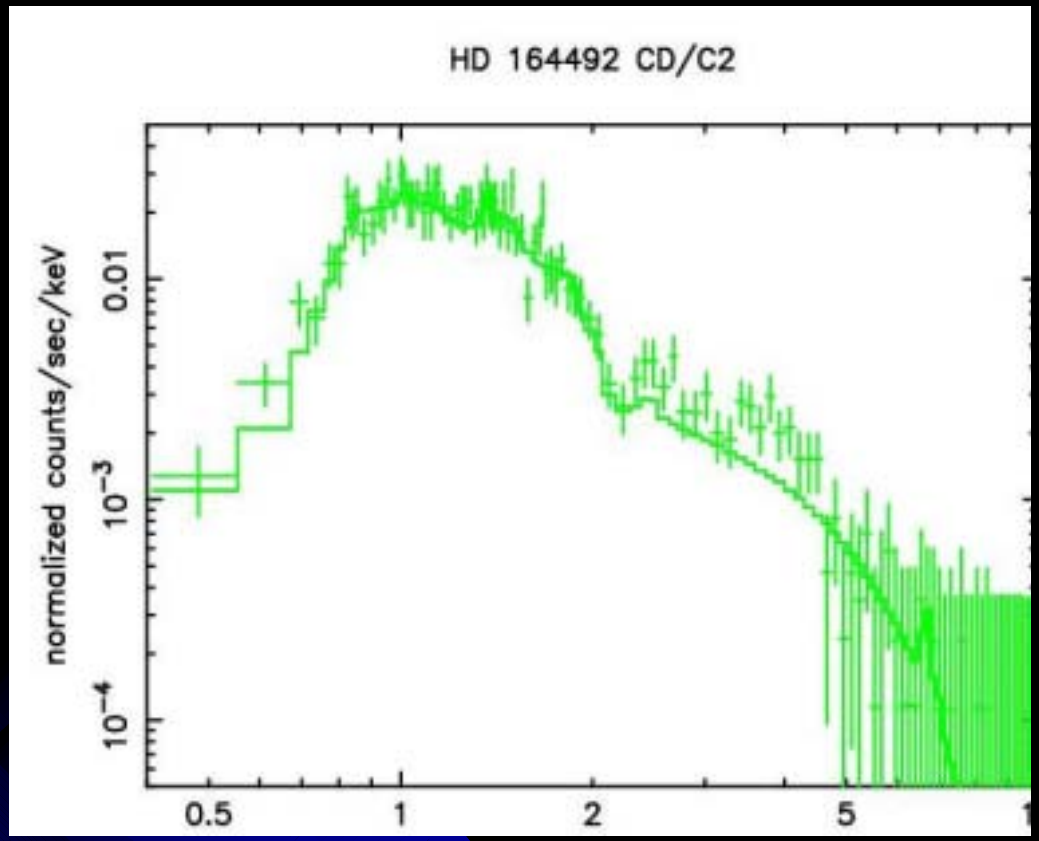
=>Lack of high temperature seen in theta Ori A, C, E suggests a magnetically confined wind shock was not developped.

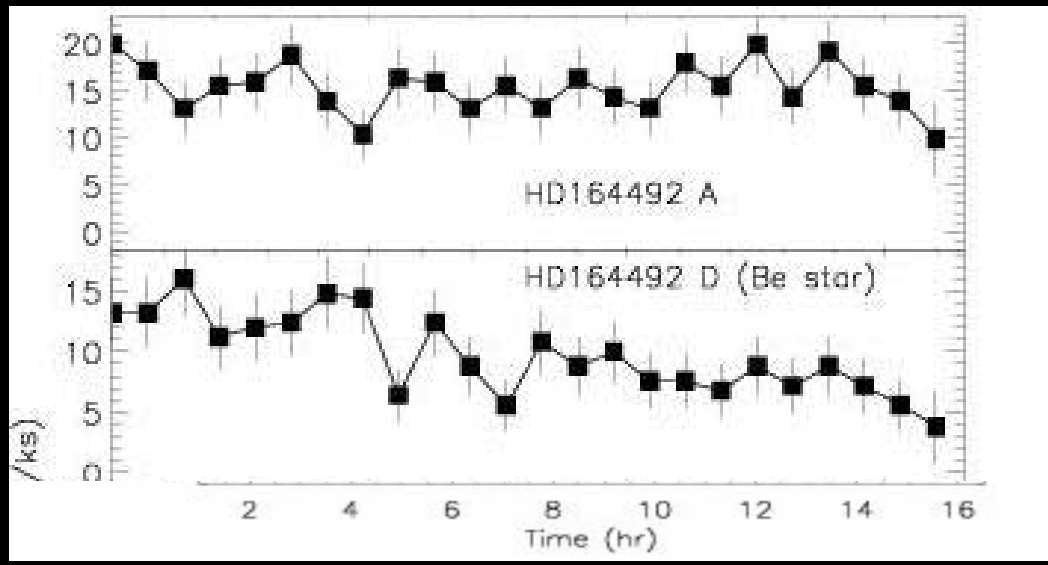
• 20% time variability, while theta Ori A shows 50% variability.

Component B: A2Ia

rare to have X-ray emission from A star

CD-C2 blend (B/Be stars)





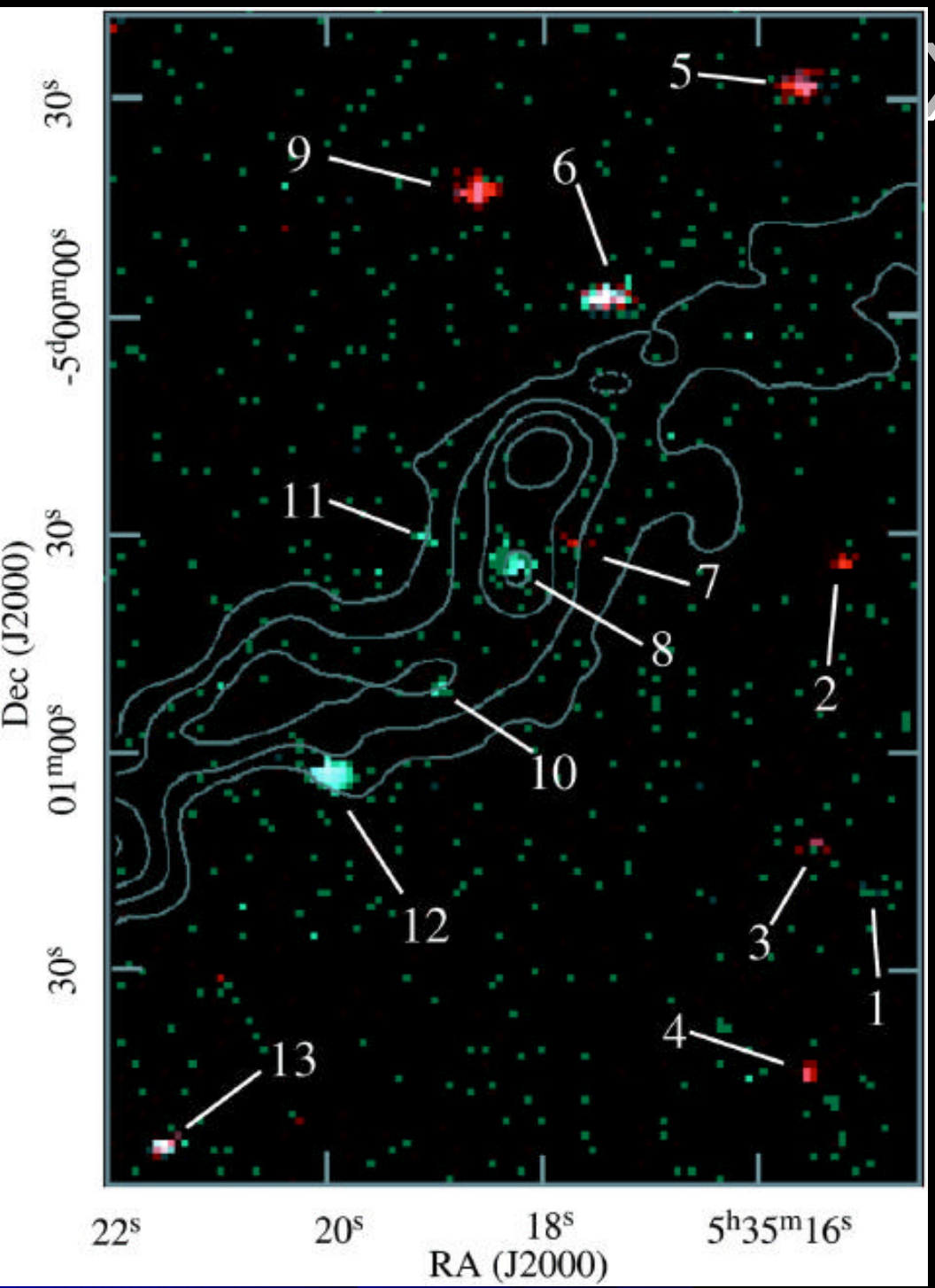
CD-C2 blend (B/Be star)

Spectrum is hard: kT1=0.6 keV and kT2=5.9 (>2) keV

C2 source is highly time variable

-CD blend and hard sources are responsible for the hard emisison seen in ASCA spectrum, not the exciting O star.

X-ray emission from Class 0

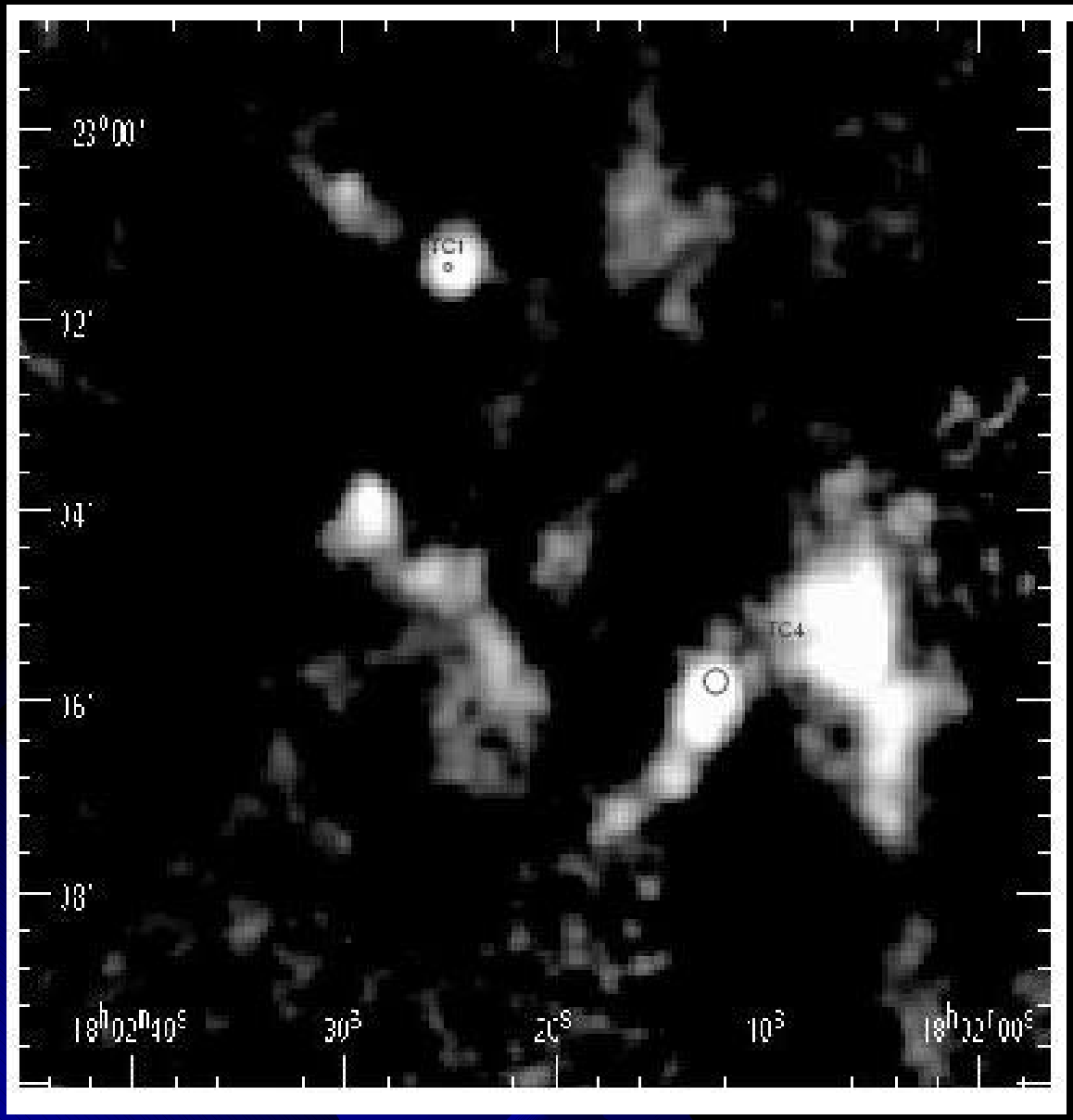


X-rays in Class 0 objects (infalling stage)

- X-ray ionization is involved in bipolar flows or X-rays from accretion from the circumstellar disk

Chandra three color image superposed on 1300um contour map in OMC-3. Source 8 and 10 are X-ray counterparts of Class 0 candidates

Discovery of X-rays from Class 0 objects in the Trifid Nebula



Two X-ray counterparts of class 0 candidates superposed on 1300um Map in Trifid Nebula

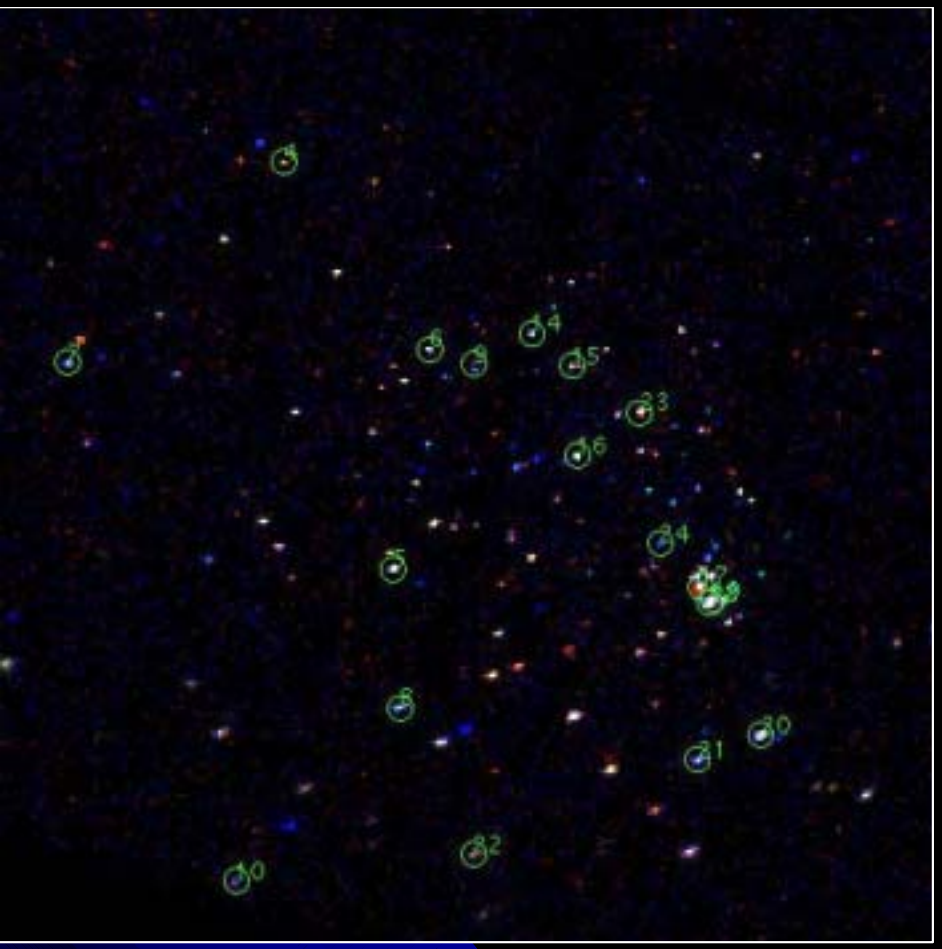
X-ray counterparts from massive Presetllar cores

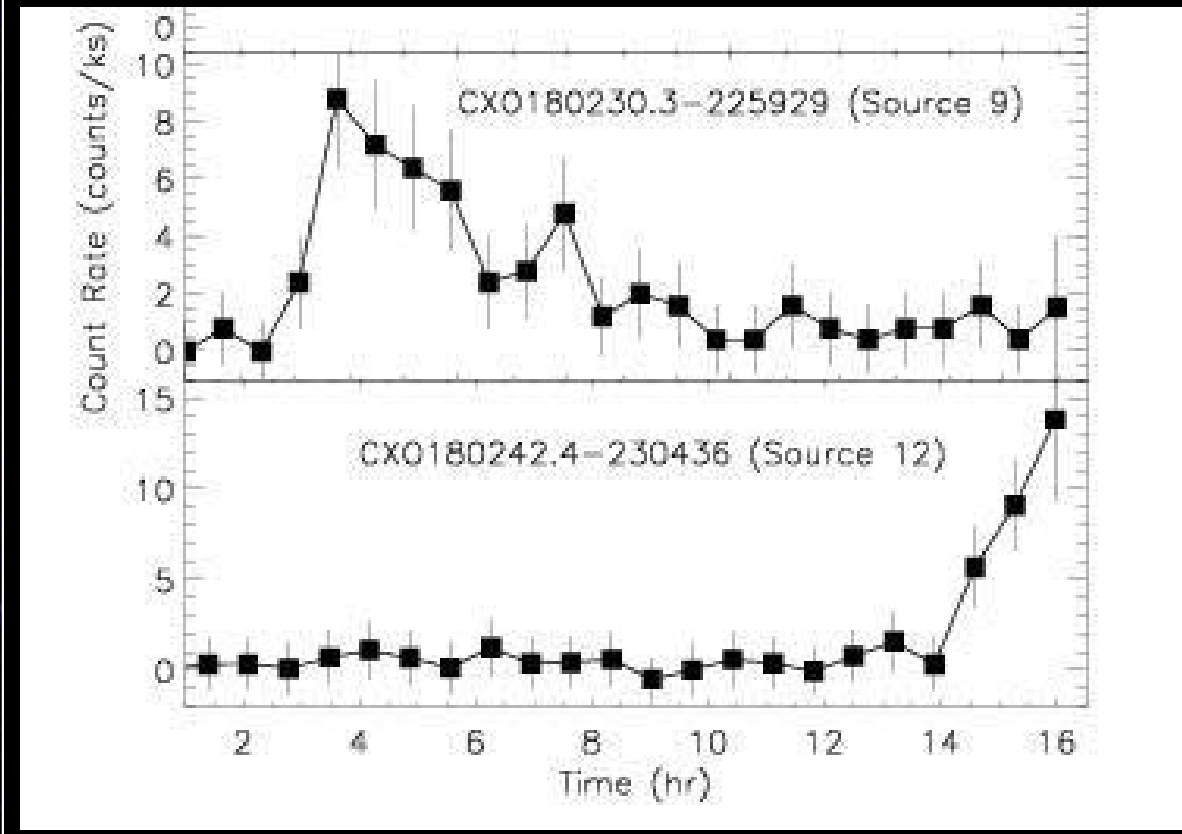
TC1: -bipolar outflow, 0.2pc,
0.16 Jy at 1300um=> 23 $M_?$
-no 2MASS counterpart
-X-ray spectrum: NH=6e22 /cm2
kT=1.7 keV, Lx=4.7e31 erg/s

TC4: -bipolar outflow, 0.29 pc,
0.6 Jy (@1300um)=> 58 $M_?$
-SED shows T of 20 K
=> Clear class 0
-Chandra psf was poor
-X-ray spectrum: NH=4e22 /cm2
kT=1.1 keV, Lx=1.9e31 erg/s

Both X-ray hardness ratios are high

Time Variable sources: flares



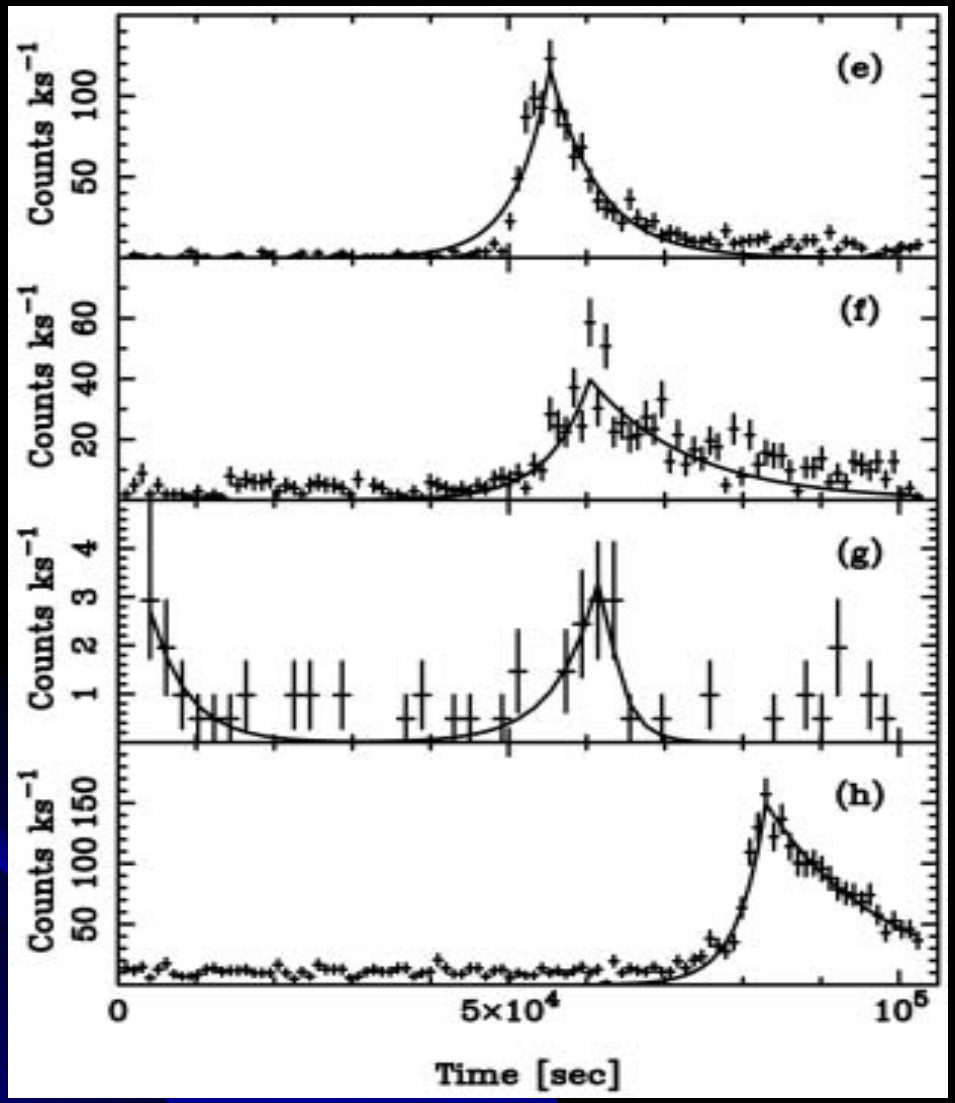


-X-ray emission from PMS: flares, magnetic dynamo processes like solar-type activities=> fast rise and slow exponential decay

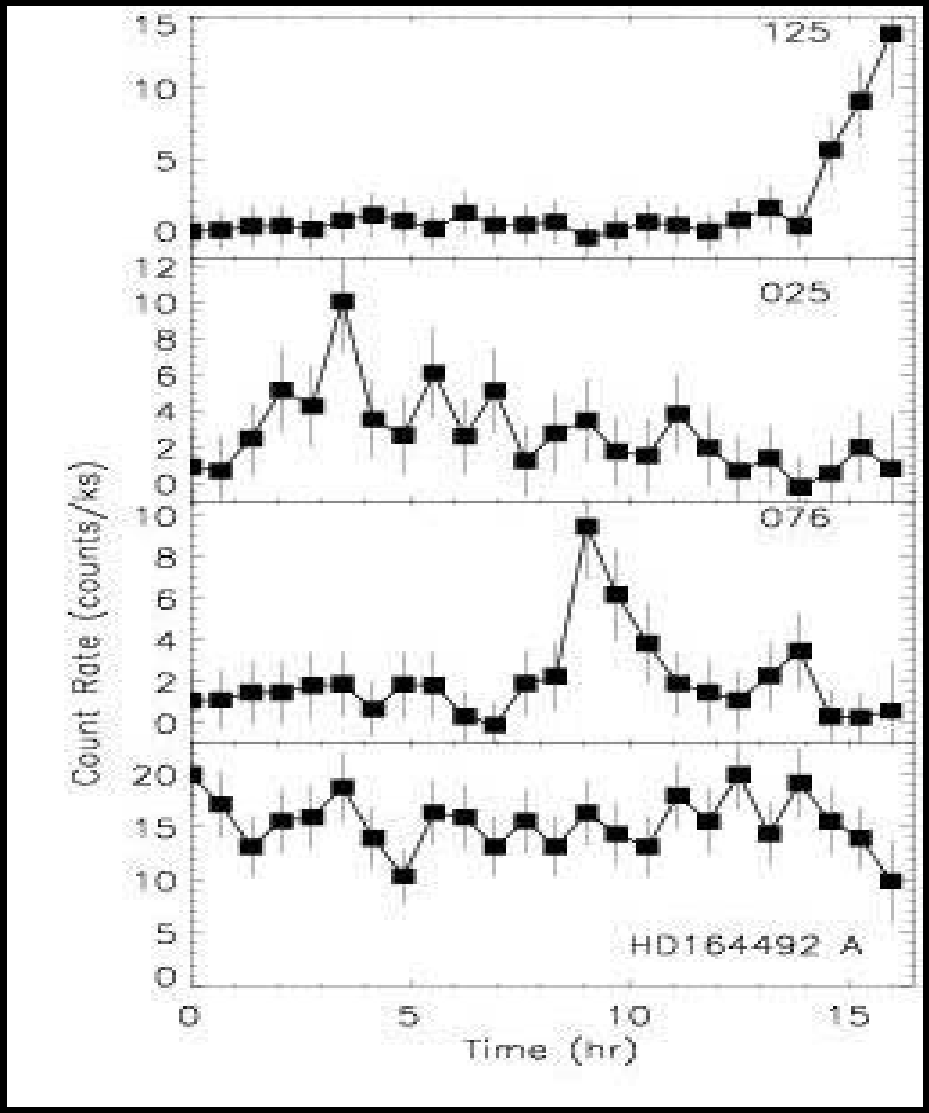
-Most of them has near-IR (classified TTS/YSO) or optical emission

-Two flare stars have no other counterparts, unstable light curve=> early stage of star formation, earlier than class I.

Class I objects & Flares

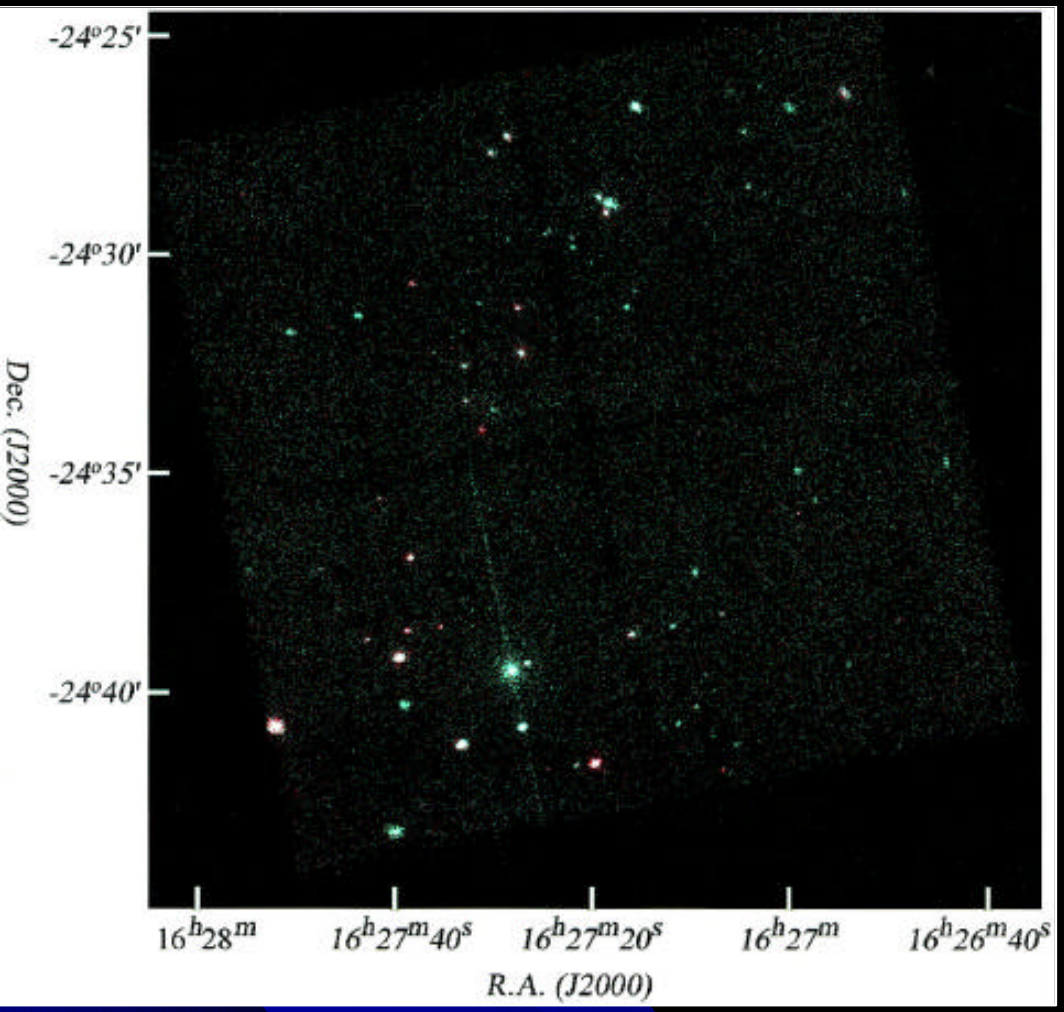


Light curves (flares) from Class I PMS in rho Oph



Light curves (flares) from PMS (first three) in Trifid Nebula

Rho Oph



- A number of flare sources from ASCA/ROSAT
- 81 sources are detected using Chandra
- 70% sources of Class I objects are X-ray emitting and a lot of them show flares=> X-rays from violent Magnetic reconnection events (Imanishi et al. 2001)
- Class I (YLW16A) shows strong fluorescent 6.4 keV Fe line: X-rays will shine upon and ionize the circumstellar disk

Conclusions

- Chandra observation detected ~304 X-ray sources; one third are hard sources, and two-thirds have near-IR counterpart.
- Central HD164492 complex shows O, B, B/Be stars: A, B, CD and C2 are detected in X-rays
- The exciting O star shows soft spectrum, from wind shock, suggesting no magnetically confined wind shock: 20% variability=> shock instabilities
- CD(B6V and Be) spectrum shows very high temperature component. New Component C2, highly variable source is revealed in the Chandra image.
- X-ray emission is detected from two prestellar cores of TC1 and TC4
- A dozen variable sources are detected: most of them have near-IR, optical counterparts. Strong PMS flare stars are likely class I candidates which light curves are similar to those in rho Oph. A few X-ray only flare stars are detected, unstable flare.