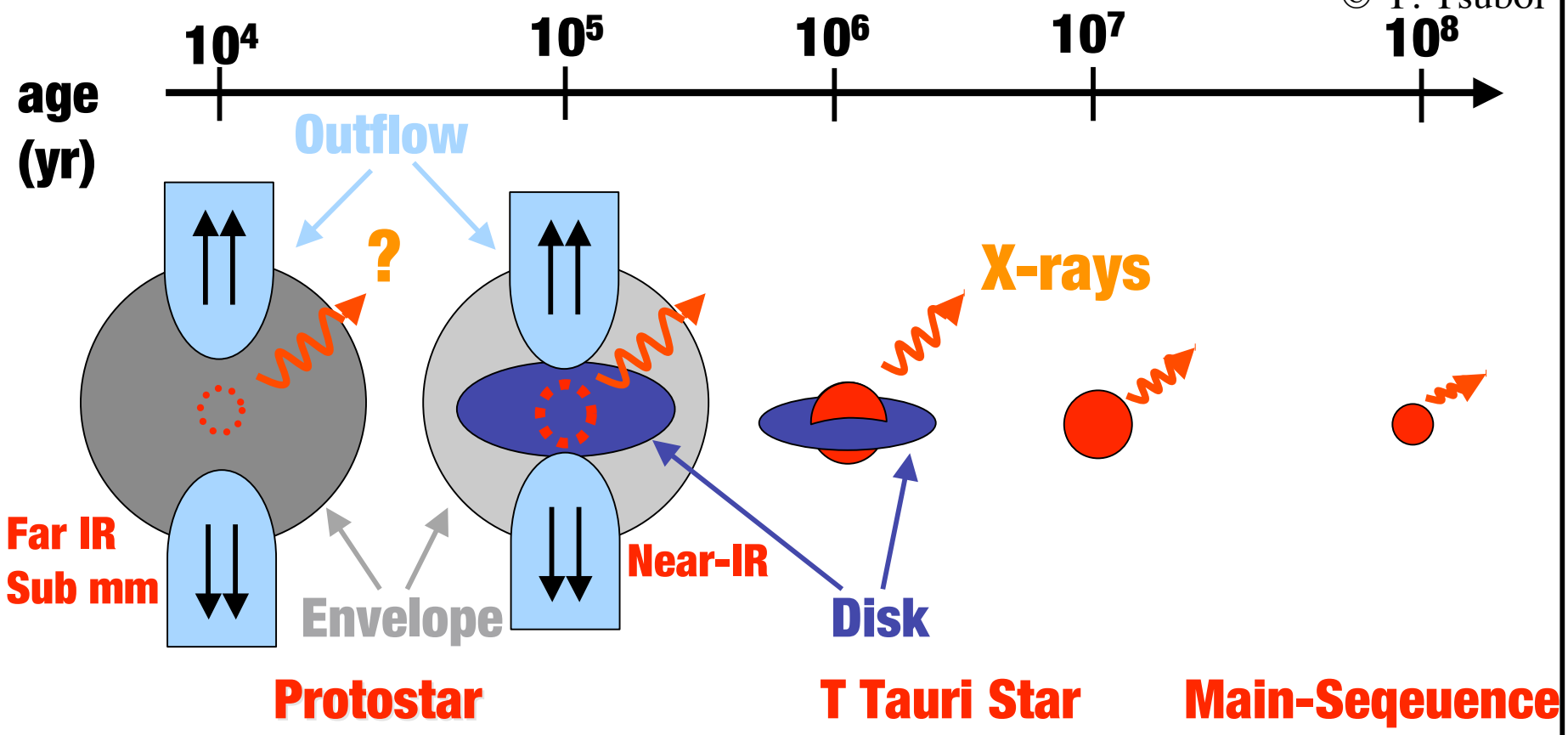
The First Definite Detection of X-rays from an Extremely Young Protostar

K. Hamaguchi, M.F. Corcoran (NASA/GSFC, USRA)
R. Petre, N.E. White (NASA/GSFC)
B. Stelzer (INAF)
K. Nedachi, N. Kobayashi (Tokyo Univ.)
A.T. Tokunaga (Hawaii Univ.)



X-rays (Quiescent) Stronger

	Class 0	Class I	Class II	Class III	Sun
kT (keV)	?	2-4	1-3		0.1-0.3
log *Lx* (ergs s^{-1})		29-30.2	28-30.5		27.3

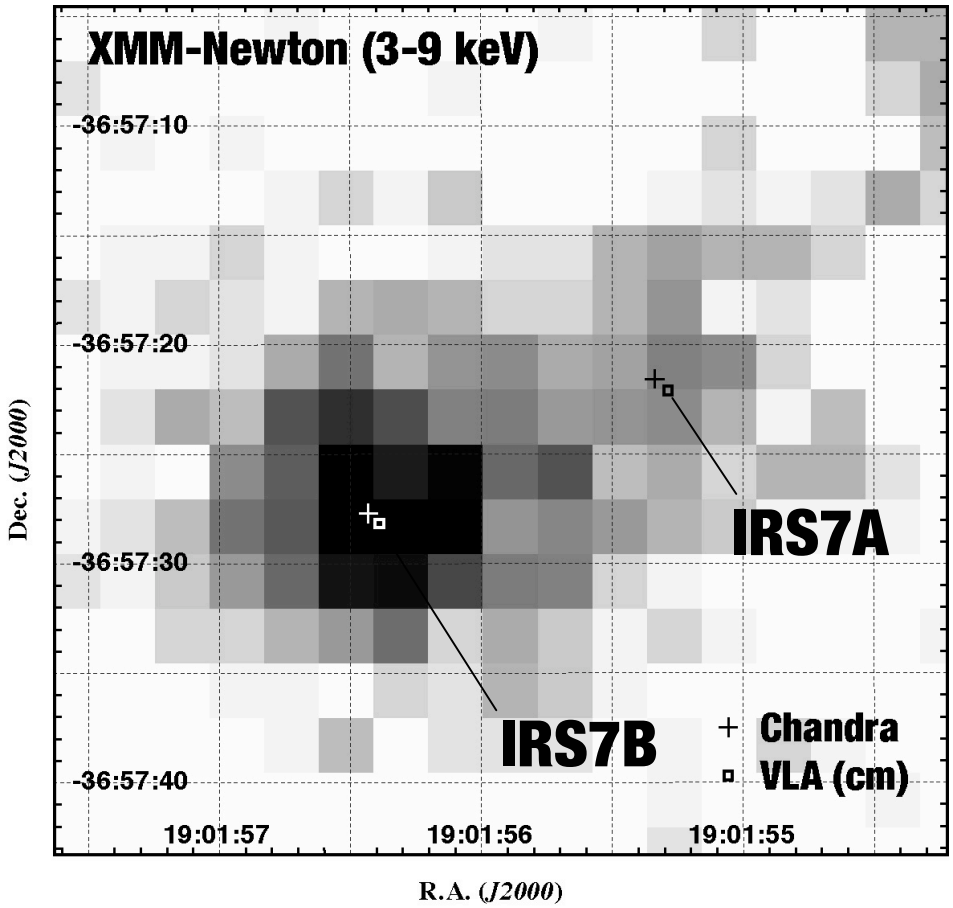
R Oph, Imanishi et al. ApJ, 557, 747

Gudel, Guinan and Skinner 1997, ApJ, 483, 947

The R Corona Australis Cloud

d **~170 pc**

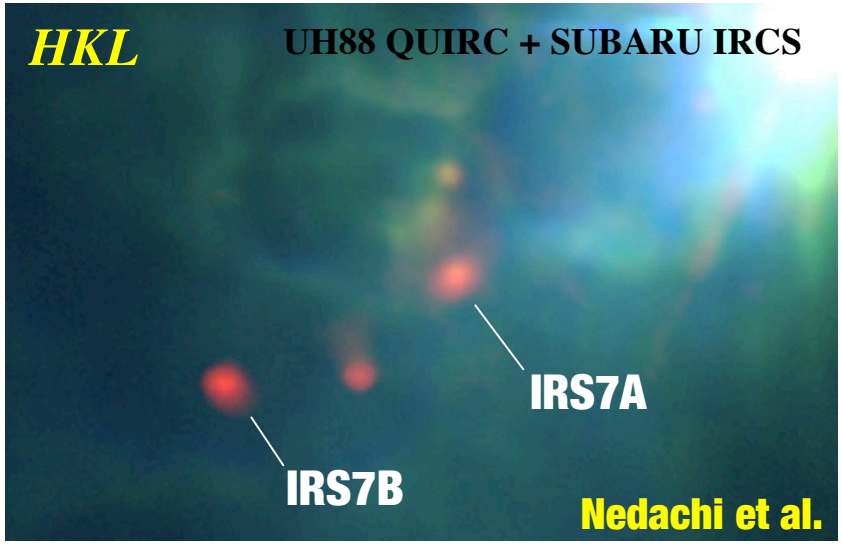
Counterpart of the hard X-ray Source



cm radio Src. IRS7B

IR

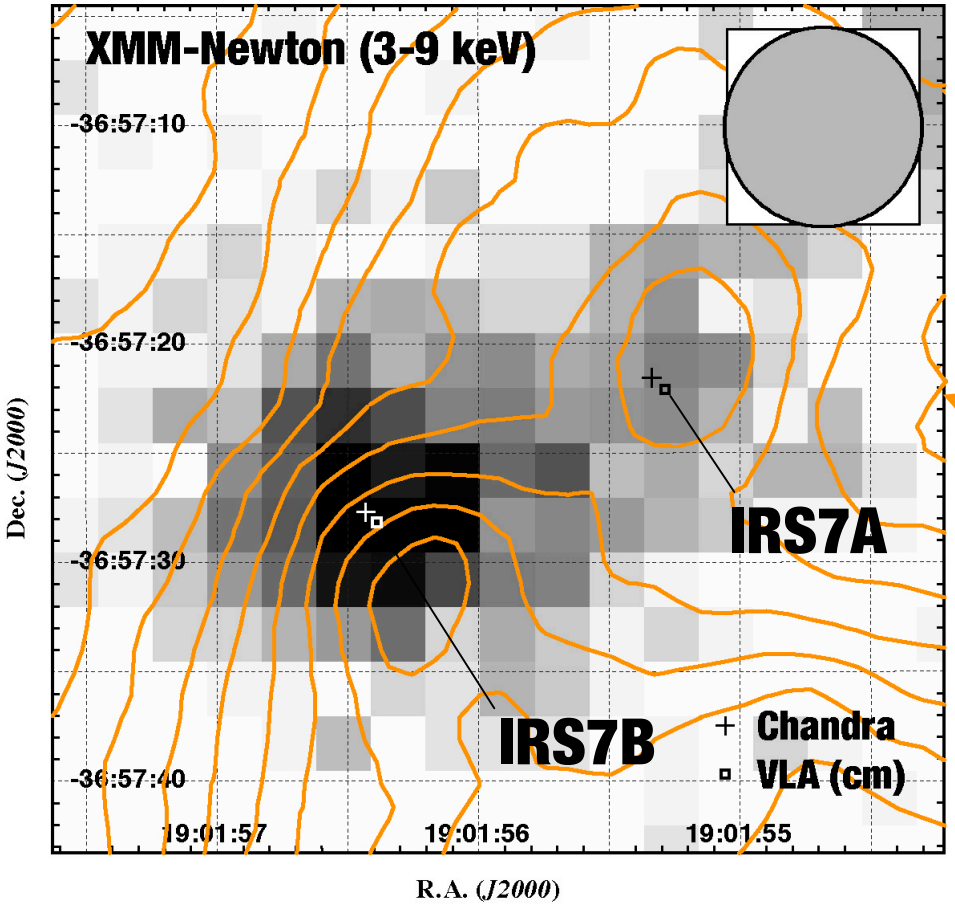
- **K (2.2 μm): no (<19.4^m)**
- **L', M, N, Q (> 3.8 μm): yes**



References

IR: Pontoppidan et al. (2003), Hamaguchi et al. (2005), Nedachi et al. (2005)

Counterpart of the hard X-ray Source



Radio Src. IRS7B

IR

- K (2.2 μm): no (<19.4^{m})
- L', M, N, Q (> 3.8 μm): yes

Radio

contour

- submm (450,850 μm): yes
- mm (6.9 mm): yes?
- cm (2,6 cm): yes

X-rays

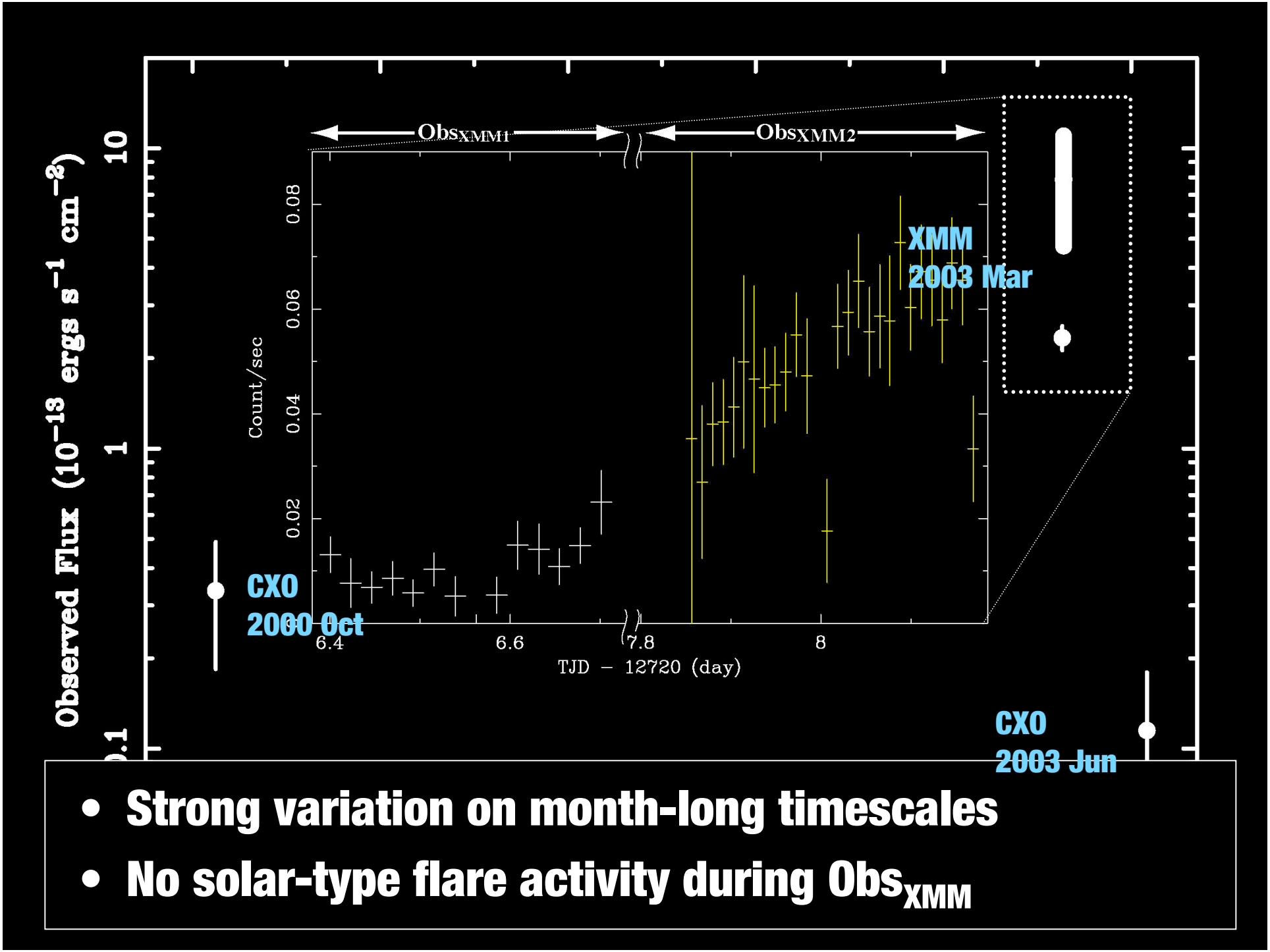
- N_H~2.8x10^{23} cm^{-2} (Av ~180^{m})

Promising Class 0 or close to the Class 0 source

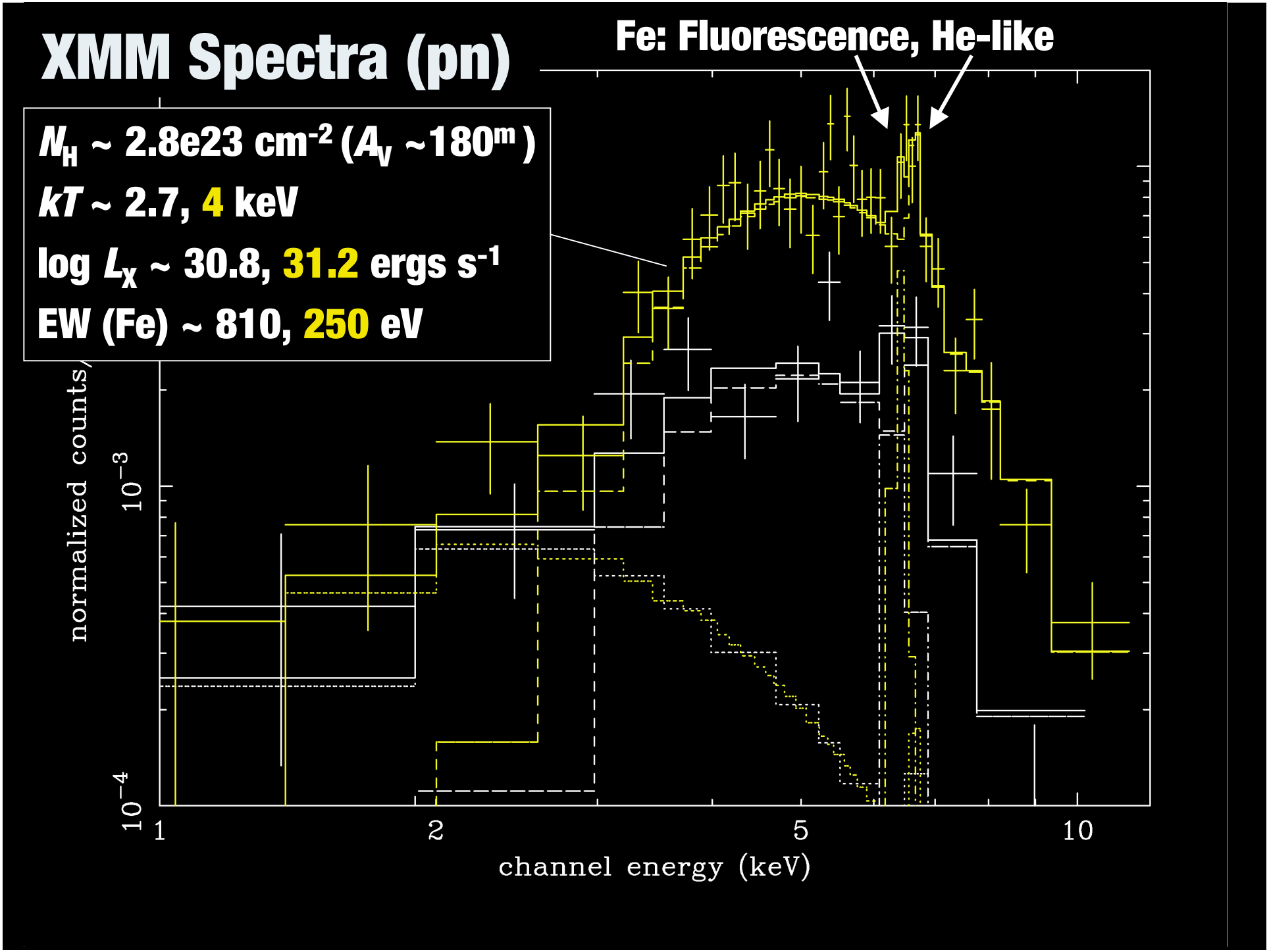
References

IR: Pontoppidan et al. (2003), Hamaguchi et al. (2005), Nedachi et al. (2005)

Radio: Brown (1987), Feigelson et al. (1998), van den Ancker (1999), Choi & Tatematsu (2004), Nutter et al. (2005)


Observed Flux (10^{-13} ergs s^{-1} cm^{-2})
10
1
0.1
Obs$_{XMM1}$
Obs$_{XMM2}$
Count/sec
0.08
0.06
0.04
0.02
6.4
6.6
7.8
8
TJD − 12720 (day)
XMM
2003 Mar
CXO
2000 Oct
CXO
2003 Jun
• Strong variation on month-long timescales
• No solar-type flare activity during Obs$_{XMM}$

XMM Spectra (pn)



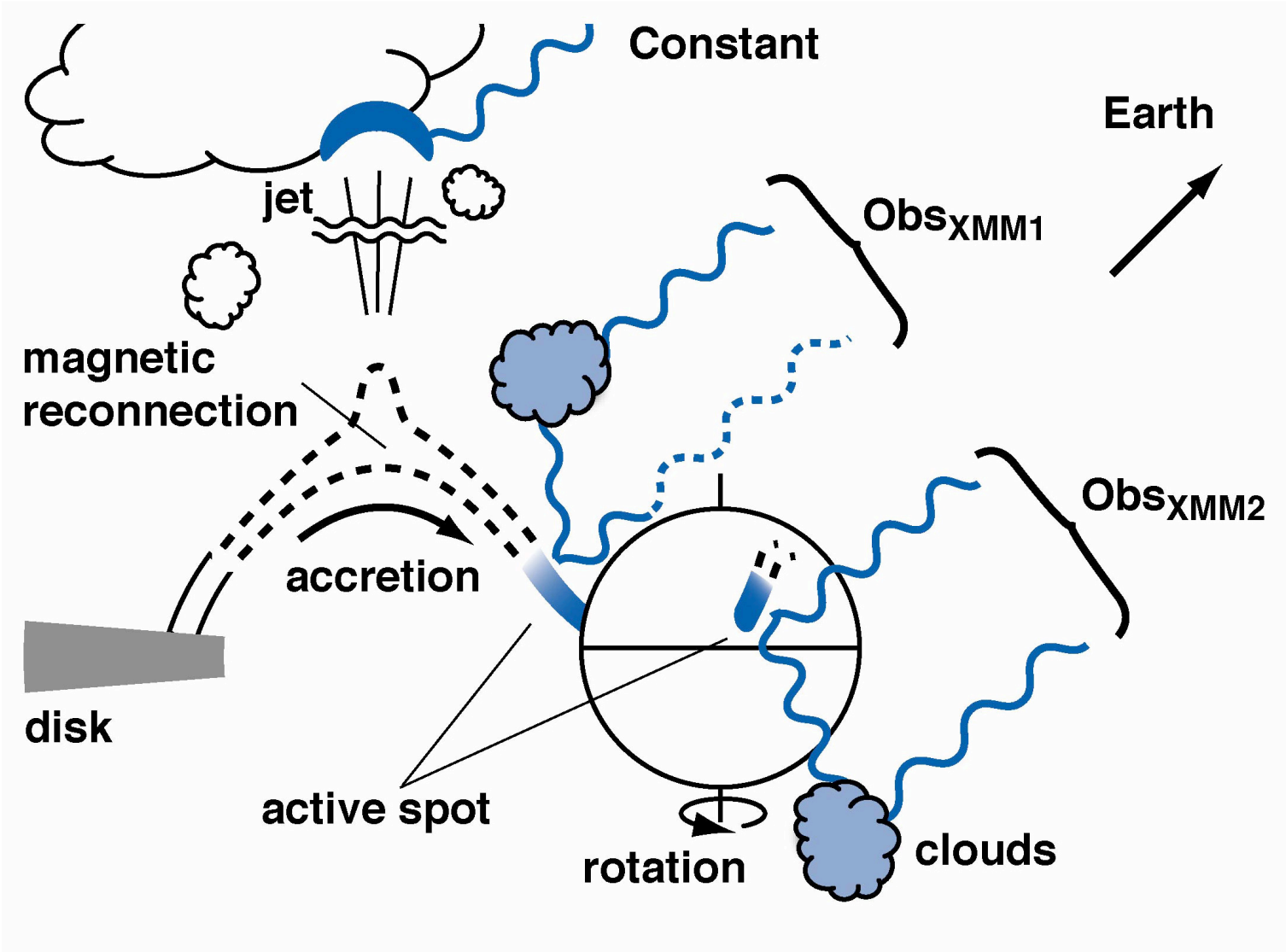
Results

- Extremely absorbed X-rays from IRS7B
  - Class 0 or very close to the class 0 phase
- X-ray activity enhanced by ~100 in 2003 Mar.
- Variable X-rays on timescales of a day
  - X-ray flux increased slowly during Obs_{XMM2}
    - No solar-type magnetic flares
  - Hot kT (~4 keV), large log L_X (~31.2 ergs s^{-1})
    - Comparable to the flare activity of Class I protostars
  - Large EW of the Fe fluorescent line
- Weak constant X-rays below 3 keV

What is the X-ray Emission Mechanism?

- Month-long flux enhancement by x10-100
  - Mass accretion outburst?
- Slow X-ray flux increase in Obs_{XMM2}
- Large EW of Fe I in Obs_{XMM1} (~800 eV)
  - Partial covering of the direct X-rays (Inoue, 1985)
  - 60% Covering ▸ log L_X ~ 31.2 ergs s^{-1}
  - ➔ No change of intrinsic L_X between Obs_{XMM1} & Obs_{XMM2}
- ➔ Rotation of an accretion spot?

Possible Geometry



P_{rot} >2.8 days

Earlier observations of Class 0 protostar candidates

- OMC-2/3 MMS 2 & 3 (Tsuboi et al. 2001)
  - N_H ~(1-3) x 10^{23} cm^{-2}
  - A shock excitation by a jet? (Tsujimoto et al. 2004)
- NGC 2024 FIR 4 (Skinner et al. 2003)
  - 4 photons
- Trifid Nebula TC1 & 4 (Rho et al. 2004)
  - N_H ~(3-6) x 10^{22} cm^{-2} (~N_H of Class I protostars)
- No detection from the others (Montmerle 2003)

→ Do Class 0 protostars have X-ray activity?