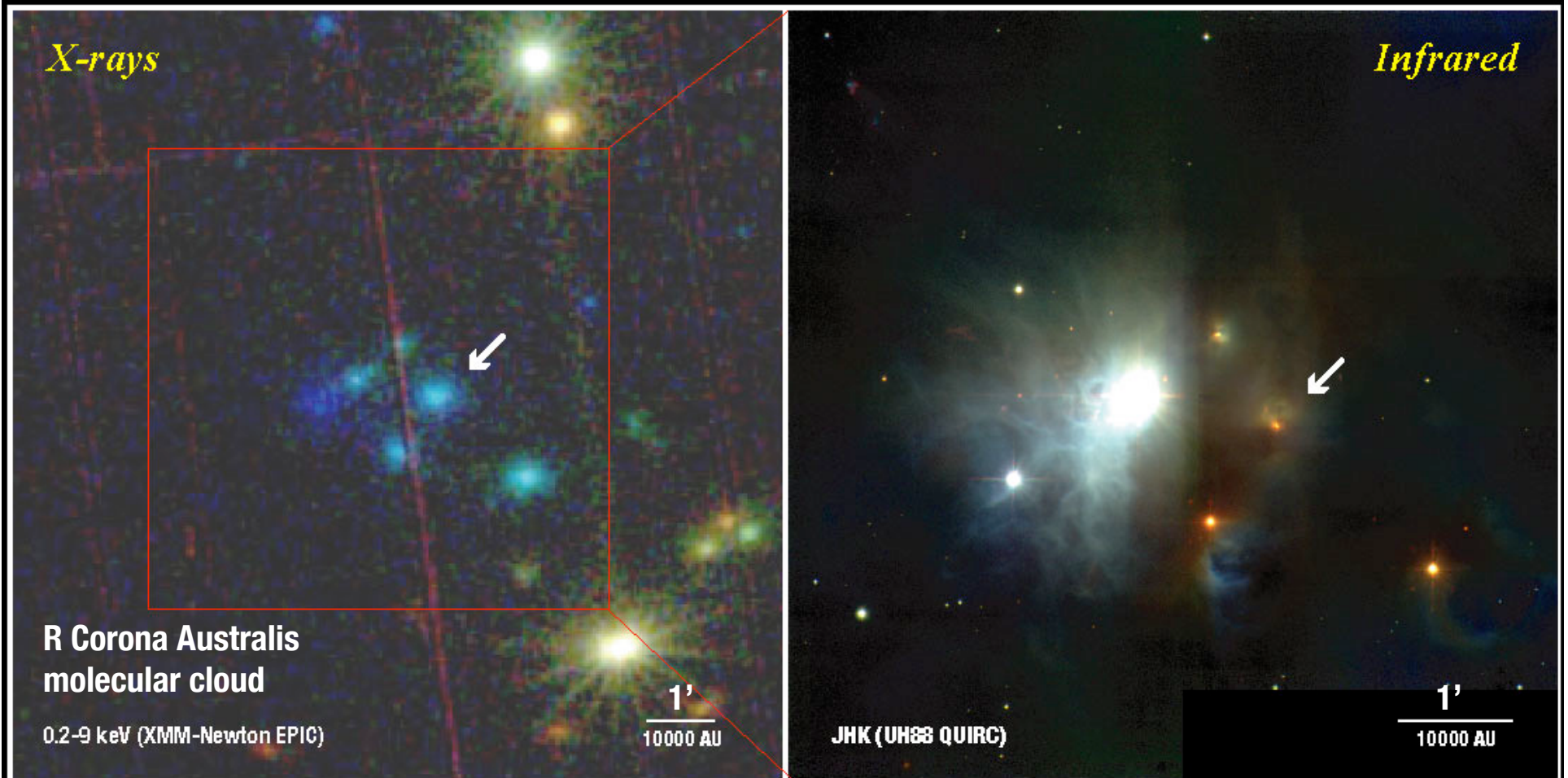


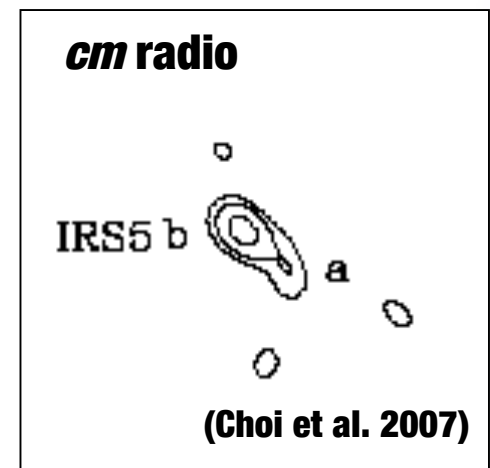
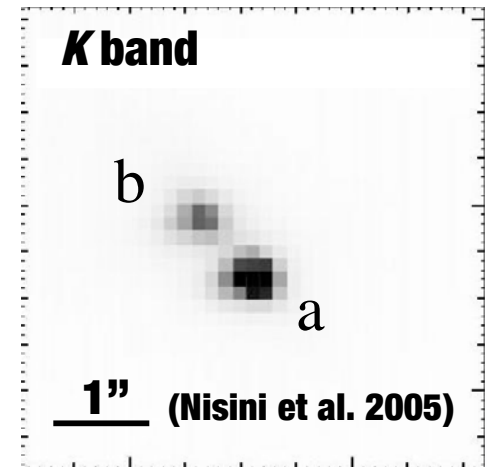
Spatially resolving X-ray emission from a Class I Pre-Main Sequence Binary System



Kenji Hamaguchi (CRESST & NASA/GSFC, USRA), Minho Choi, Ken'ichi Tatematsu, Chul-Sung Choi, Rob Petre, Michael F. Corcoran

Young Binary System R CrA IRS5

- **Binary stars are born at the same time**
 - ◆ **Useful probe to study stellar evolution**
- **R CrA IRS5**
 - ◆ **Class I pre-main sequence (PMS) star**
 - ◆ **X-ray variable (Forbrich et al. 2006, 2007)**
 - ◆ **Variable *cm* continuum radio emission with circular polarization (Suters et al. 1996, Feigelson et al. 1998)**
 - ◆ **Spatially resolved in IR and radio**
 - ➔ **Which of the binary stars emits X-rays?**



Chandra Observations & Analysis

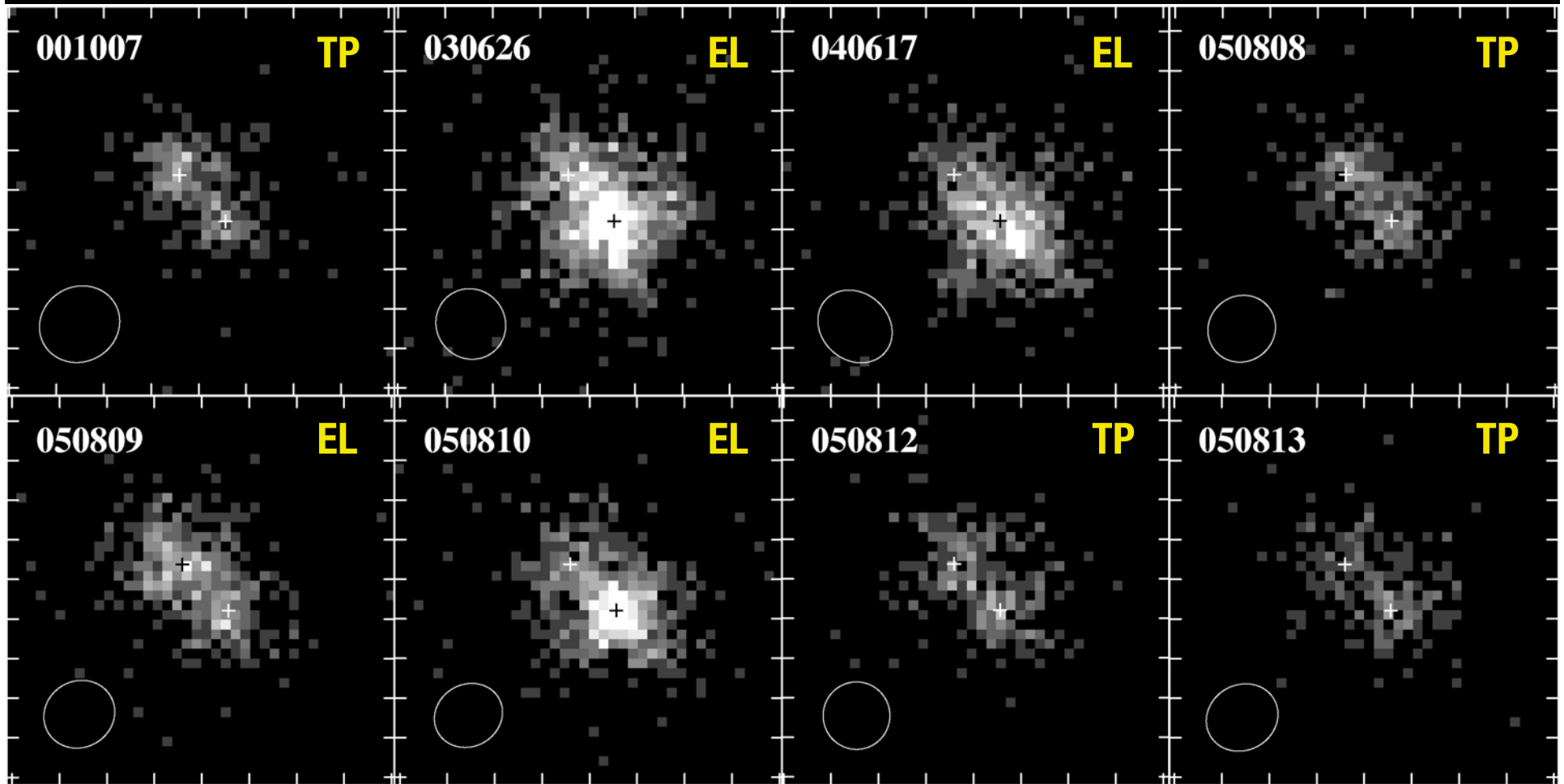
- **8 Chandra archival observations in 2000-2005**
 - ◆ **IRS 5 was at 1-2' off-axis**
- **Utilize the Sub-pixel Event Repositioning technique**
 - ◆ **Tsunemi et al. (2001), Li et al. (2003, 2004)**
- **Absolute astrometry**
 - ◆ **Measure positions of surrounding bright X-ray sources with the *wavedetect* tool**
 - ◆ **Cross-correlate them with 2MASS infrared sources.**
 - ◆ **Astrometry of each X-ray data frame $< \sim 0.2''$**

X-ray Images

0.125'' pixel⁻¹ (Tick marks shown by 0.5'')

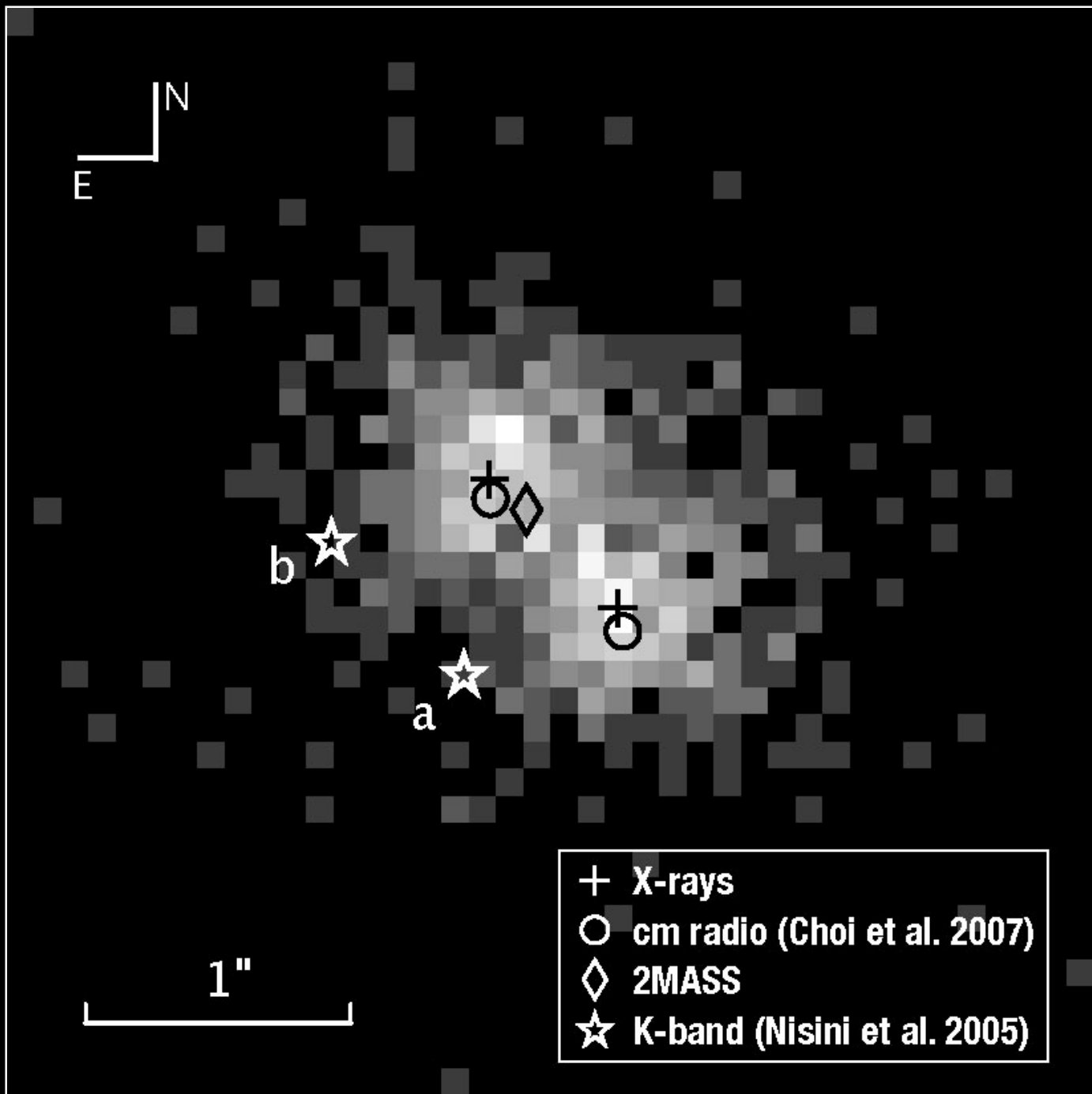
Numbers: YYMMDD of the observation dates

Circles: the half of the peak intensity of PSF



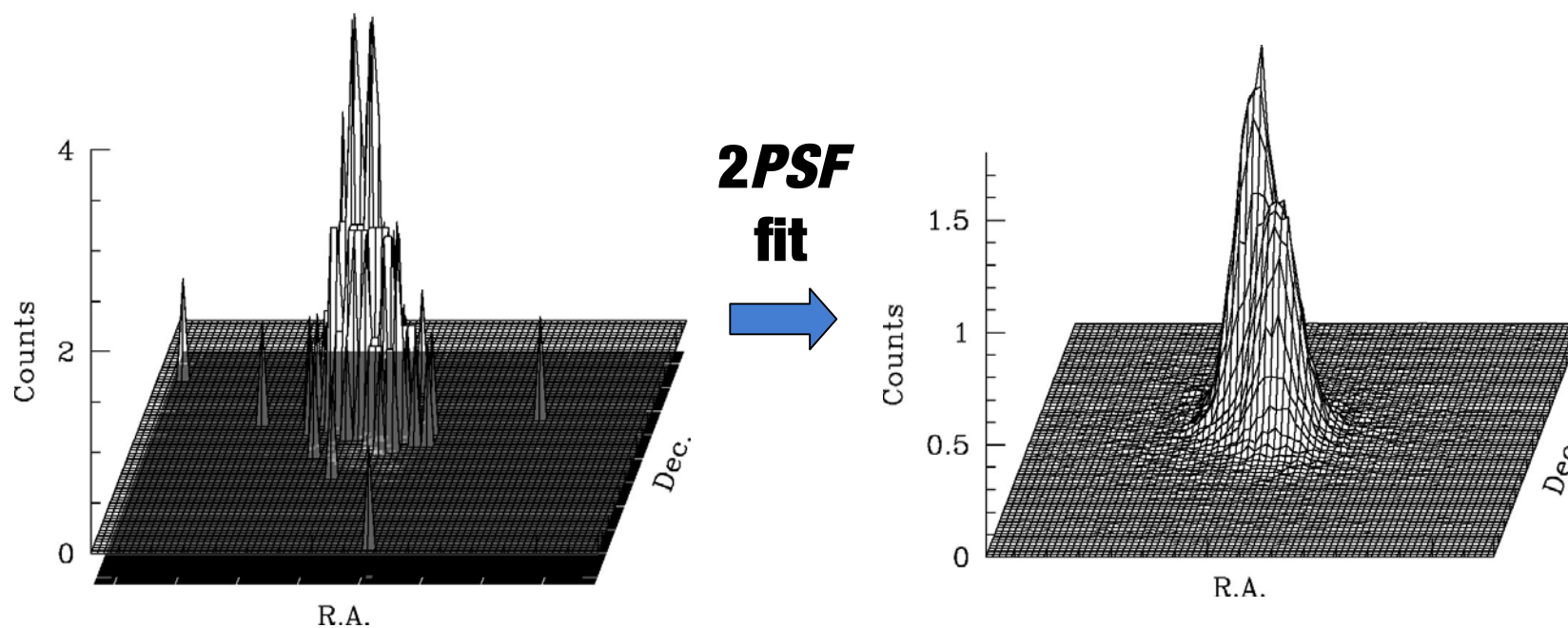
- There appears two peaks (TP) or NE-SW elongation (EL).

Composite of 4 Images with Two Clear Peaks (TP)



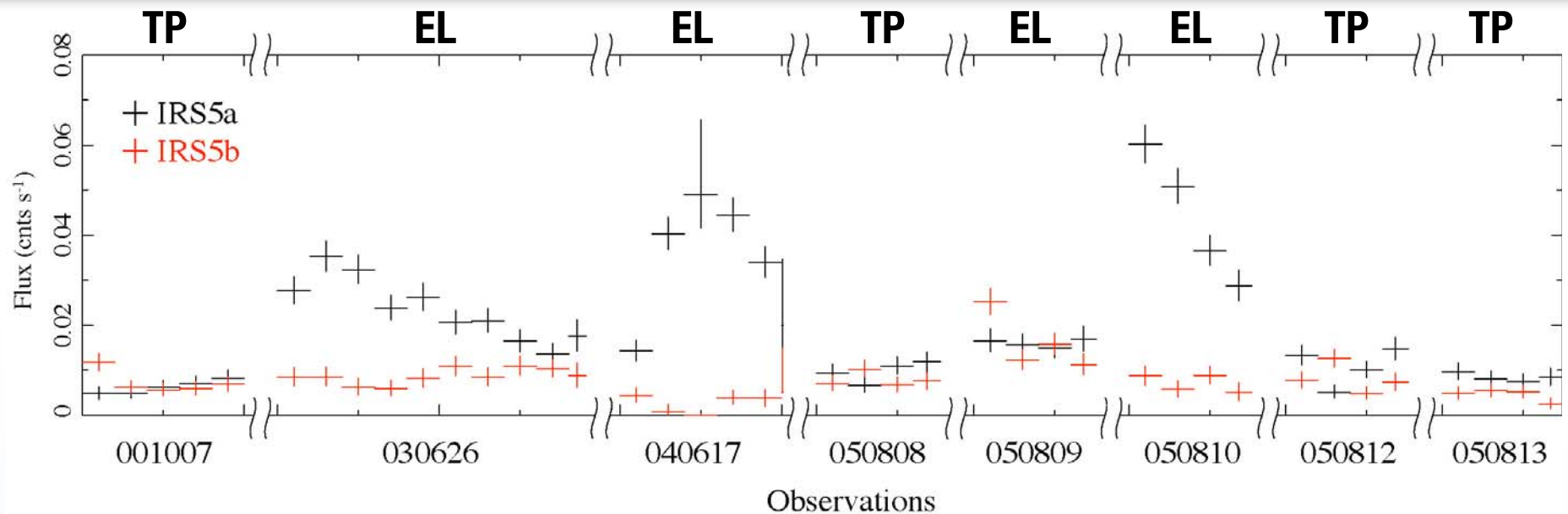
Generate Light Curves and Spectra

- **Fit time/energy restricted images with 2 *PSFs***
 - ◆ **Sherpa (Cash stat., Powell meth., error: projection)**
 - ◆ **PSF: ChaRT + MARX**



1st 4ksec image in the 050809 observation

Light Curves (1-8 keV)



IRS5a: significant time variation

- ◆ 3 typical stellar flares in 156 ks (1 flare per ~50 ks)

IRS5b: stable

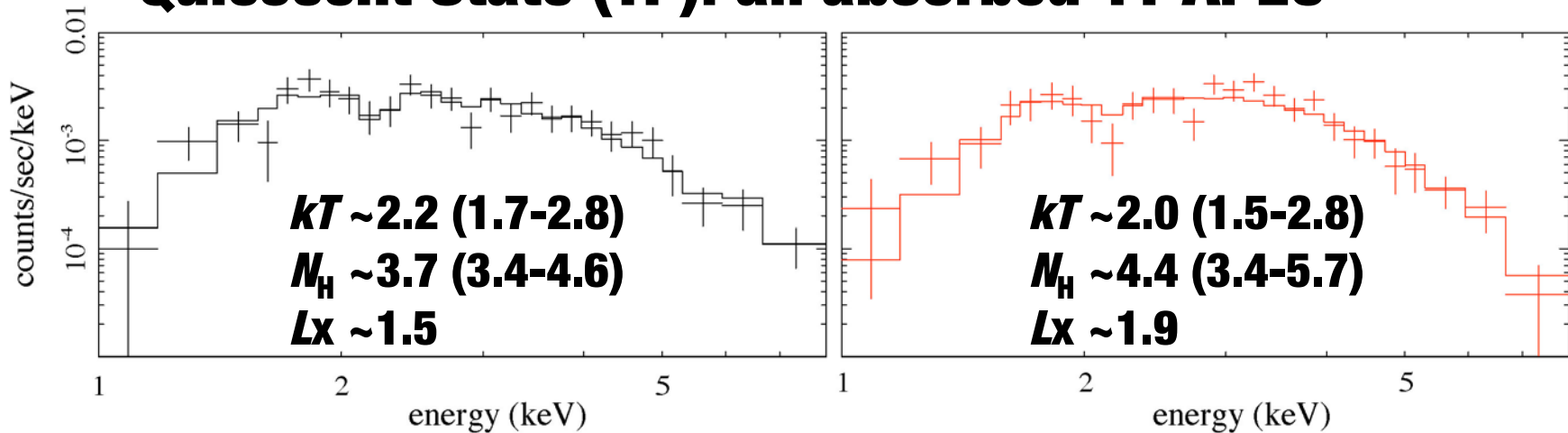
- ◆ an apparent enhancement in 2005-08-09

+: IRS5a
+: IRS5b

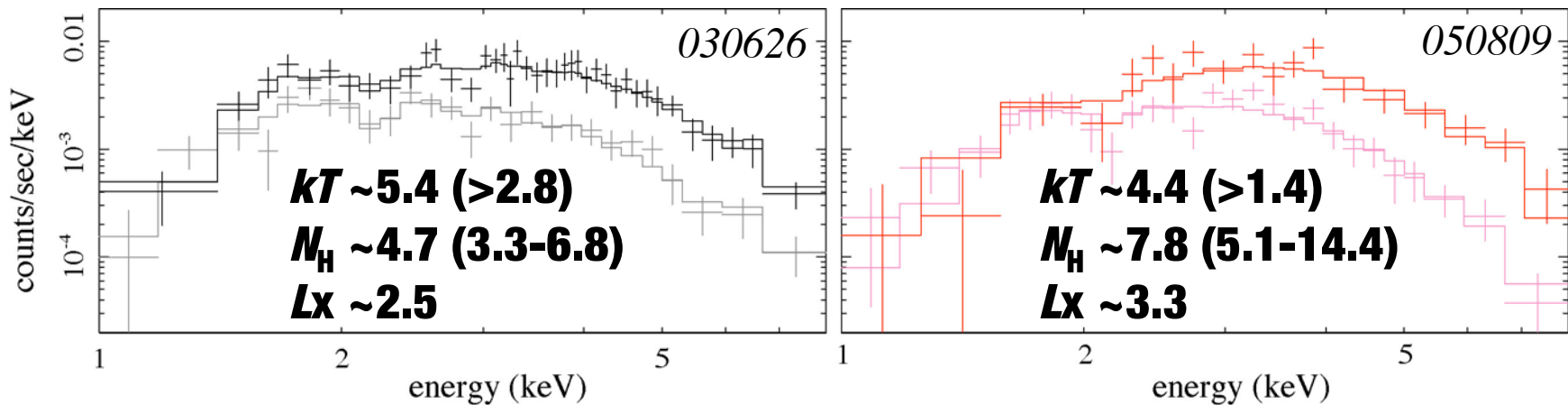
Spectra

kT : keV
 N_H : 10^{22} cm $^{-2}$
 L_x (abs cor): 10^{30} ergs s $^{-1}$

- **Quiescent State (TP): an absorbed 1T APEC**



- **Flare State (EL): Fixed QS + an absorbed 1T APEC**



X-ray Visual Young Binary System with <200 AU Projected Separation

Object	System	Separation	d (pc)	Age (Myr)
TWA5	TTS+BD	2'' (110 AU)	55	12
HD100453	A9+TTS	1.06'' (114 AU)	120	20
HD 98800	TTS+?	0.8'' (48 AU)	38	5-10
R CrA IRS5	Class I +?	0.8'' (140 AU)	170	0.3-1

TTS: T-Tauri Star, BD: Brown Dwarf

TWA5: Tsuboi et al. (2003), HD100453: Collins et al. in preparation,

HD98800: Kastner et al. (2004), R CrA IRS 5: this result

→ **IRS5 would be the youngest among known X-ray visual PMS binary systems with small separation.**

Evolutional Status

- **IRS5a and IRS5b showed similar quiescent spectra and flux.**
 - **Stars in a similar mass range may experience similar evolution of their X-ray activity.**
- **IRS 5a flared up frequently (1 flare per ~50ks)**
 - ◆ **Normal PMSs have 1 flare per 650-770 ksec (Orion: Wolk et al. 2005, Taurus: Stelzer et al. 2007)**
 - **IRS 5a might be in an active phase.**

Summary

- **We spatially resolved X-ray emission from the visual binary system IRS 5**
- **We derived light curves and spectra using a two-dimensional image fitting method.**
 - ◆ **IRS5a was active. IRS5b was stable**
 - ◆ **In the quiescent state, both stars showed similar X-ray spectra typical of Class I PMSs.**
- **More visual X-ray binary sources with small separation can be found in the *Chandra* archival data.**