X-rays from the Power Sources of the Cepheus A Star-Forming Region[1]

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Chandra's First Decade of Discovery

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(see also Pravdo et al. 2009, ApJ, 704, 1495)

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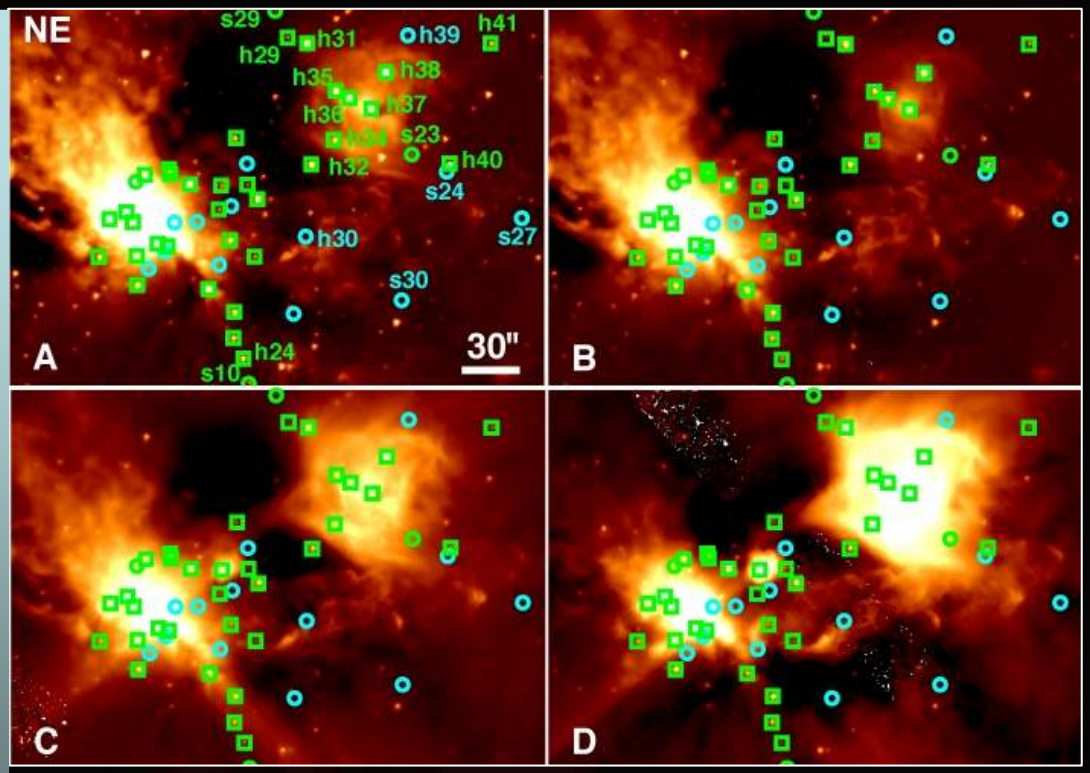
The Cepheus A Star-Forming Region

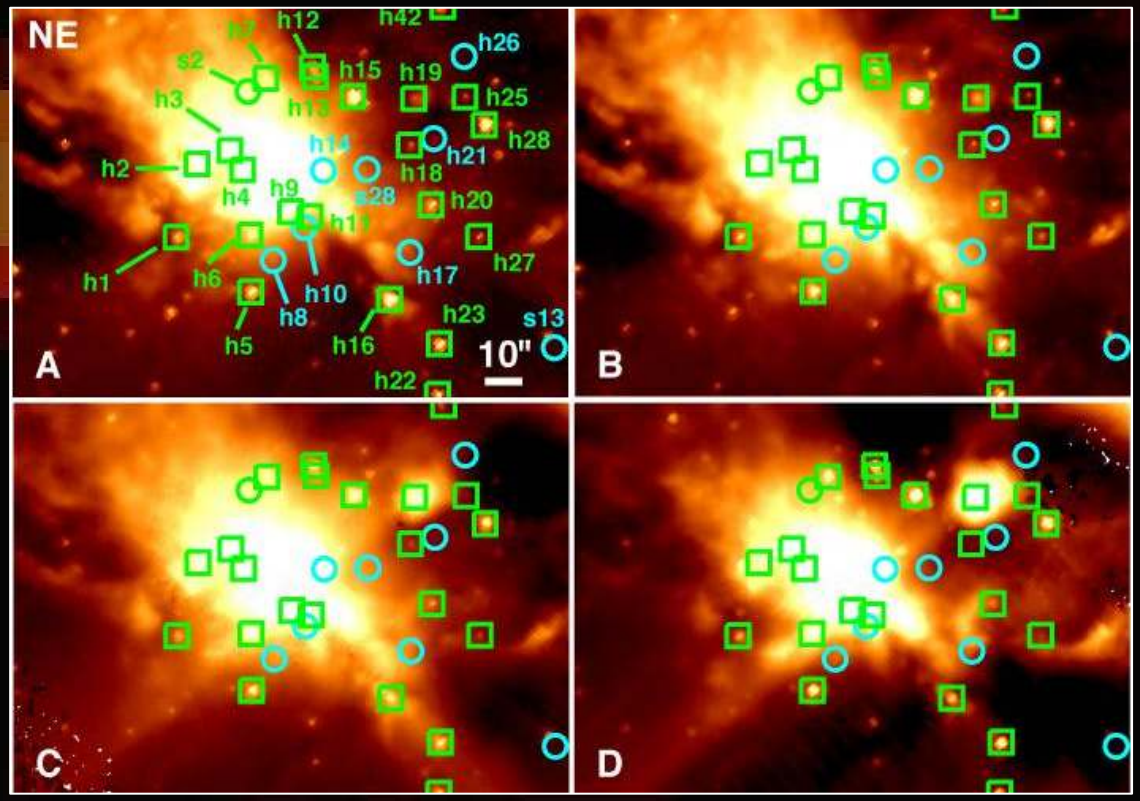
- Molecular cloud d~700 pc
- A strong radio, SMA, and mid-IR source
- Power sources are thought to be one or more massive stars in eastern lobe that show outflows and jets
- Prior lower-resolution X-ray observations showed an unresolved source, HWX (Pravdo & Tsuboi 2005), associated with one or more of the putative power sources.



Cepheus A seen with *Spitzer* Obs. at (A) 3.6, (B) 4.5, (C) 5.8, and (D) 8.0 μm. X-ray sources are indicated.

Cepheus A Stars

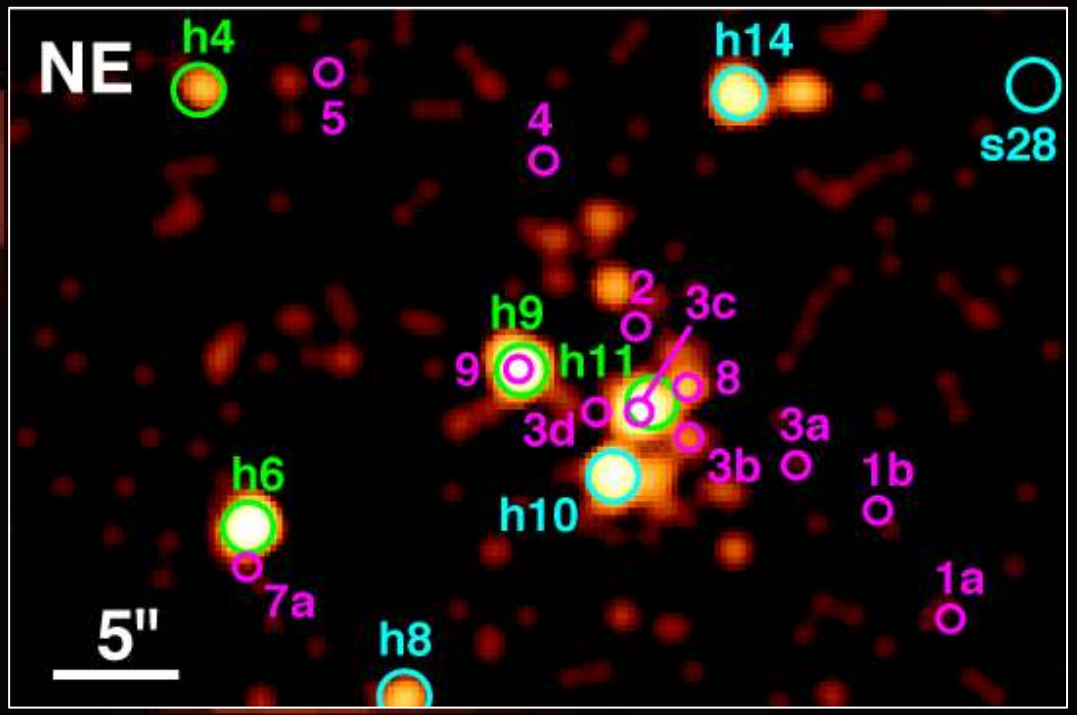
- *Chandra*/ACIS observations show X-ray sources associated with several mid-IR sources identified spectrally as 3 Class 0/I, 13 Class II, 11 Class III, and 2 flat-spectrum stars typical of a star-forming region.



Spitzer images of Cepheus A East with identified >2 keV sources (squares), <2 kev source (green circles), and blankfield X-ray sources (cyan).

Cepheus A Power Sources Region

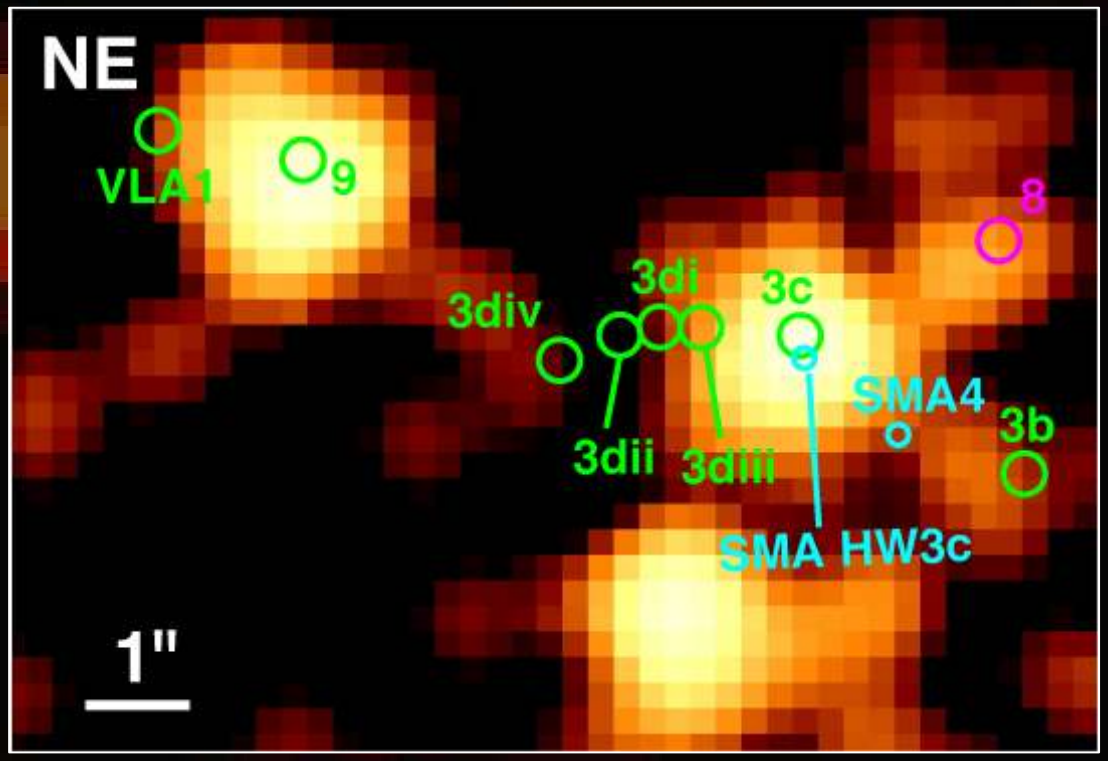
- The putative power sources of Cepheus A are associated with "HW" radio sources, esp. HW2, potentially a massive protostar (Patel et al. 2005). The *Chandra*/ACIS image shows that the previously discovered HWX is at least 3 X-ray sources, h9, h10, and h11, none of which is associated with HW2.



Chandra/ACIS image in the 2-8 keV energy band. X-ray sources with counterparts at other wavelengths (green) and blankfield X-ray sources (cyan) are shown. Magenta circles mark the positions of the compact radio "HW" sources (Garay et al. 1996).

Cepheus A Power Sources Core

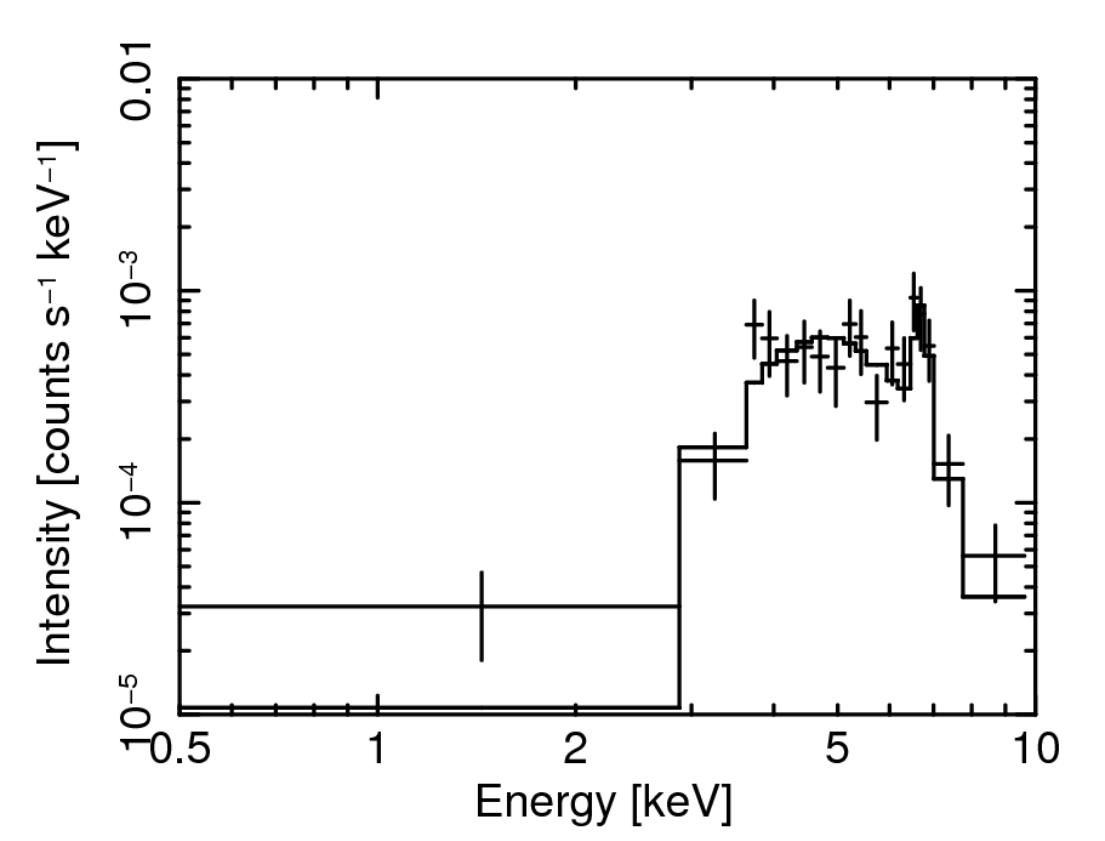
- The 3 brightest X-ray sources are associated with a variable radio source HW9, a radio and SMA source HW3c, and object not now known at any other wavelength. Other X-ray sources may be present.



Central region of the *Chandra* image with the compact radio "HW" sources (green, Torrelles et al. 1998, magenta, Garay et al. 1996) and SMA sources (cyan, Brogan et al. 2007).

X-ray Properties of the 3 Core Sources

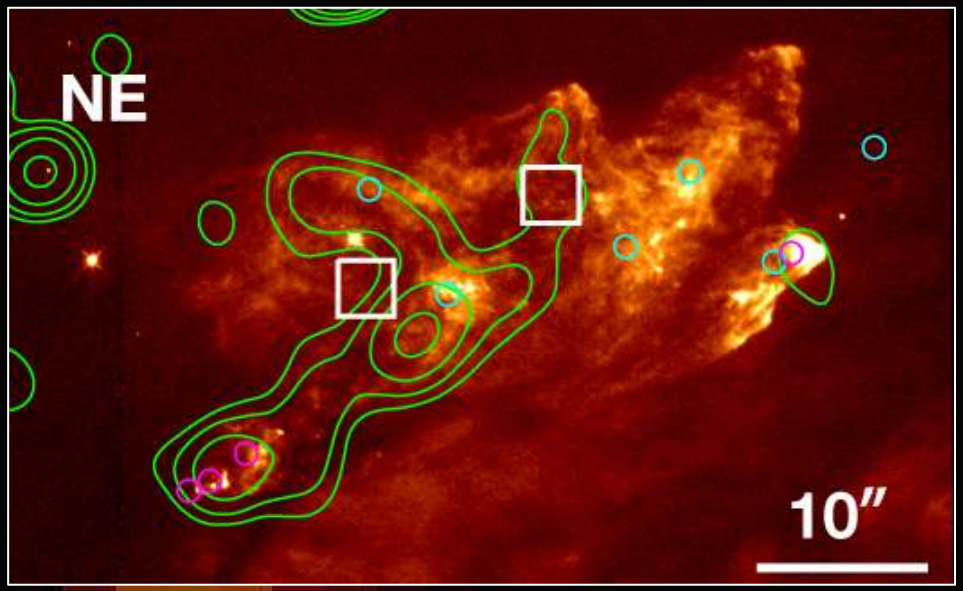
- Inferred X-ray luminosity is ≥ 10^{31} erg s^{-1} for each of the three.
- 2 of the 3 appear variable on the observation timescale (< 1 day)
- The composite X-ray spectrum is hard, T ~ 10^8 K, highly absorbed, with probable thermal Fe-line emission.



*Chandra/*ACIS composite X-ray spectrum of the core sources.

X-rays from Herbig-Haro 168

- Soft X-ray emission is confirmed from HH 168. X-ray emission peaks at objects HW and E.
- HH 168 is not as under-luminous compared with other HH objects as had been previously reported (Pravdo & Tsuboi 2005).
- The unabsorbed luminosity is 3 x 10^{30} erg s^{-1} with a temperature of 7 x 10^{6} K.



Chandra soft X-ray (<2 keV) contours of HH 168 superposed on the HST *Hα* image. Compact radio sources are shown (cyan, Hughes & Moriarty-Shieven 1990 and magenta, Garay et al. 1996). Previously reported X-ray localizations are also shows (white squares, Pravdo & Tsuboi 2005).

Conclusions

- X-ray emission from the core of the Cepheus A power region is resolved into at least 3 strong X-ray sources.
- Their radio properties are diverse from steady-state to variable to undetected.
- The most energetic source at other wavelengths is not detected.
- The X-ray sources are protostars and further observations of variability may distinguish between models of extended emission such as gyrosynchrotron regions or closer in to the stars such as strong stellar winds.
- HH 168 is not as underluminous in X-rays as previously reported.

REFERENCES

- Brogan et al. 2008, ApJ, 660, L133
- Garay et al. 1996, ApJ, 549, 193
- Hughes & Moriarty-Shieven 1990, ApJ, 360, 215
- Patel et al. 2005, Nature, 437, 109
- Pravdo & Tsuboi, 2005, ApJ, 626, 272
- Torrelles et al. 1998, ApJ, 509, 262