A Blast from the Past:
How Circinus X-1 Became the youngest known X-ray Binary

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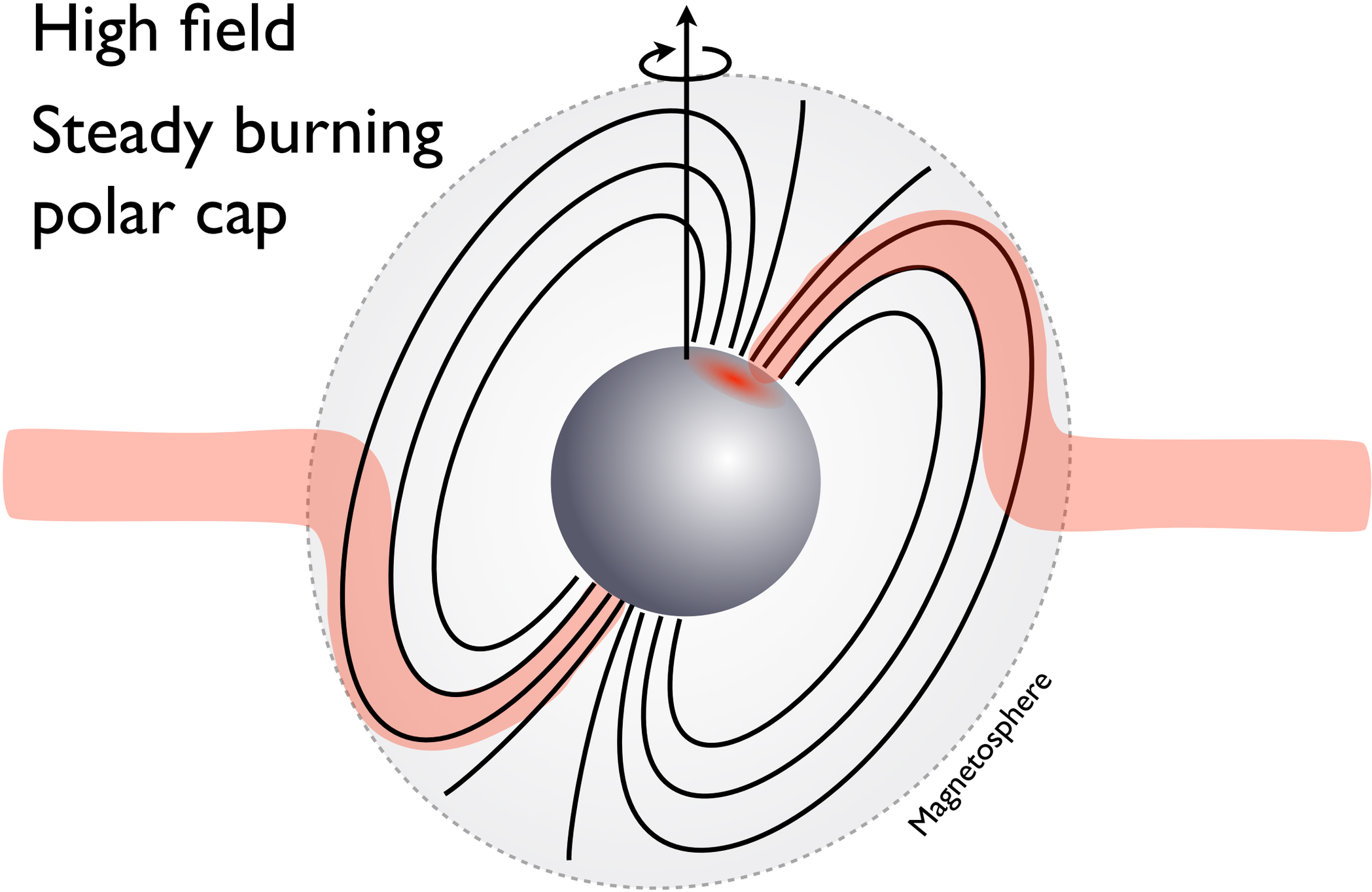
Michiel VanDer Klis (Amsterdam)
Paolo Soleri (formerly Amsterdam)

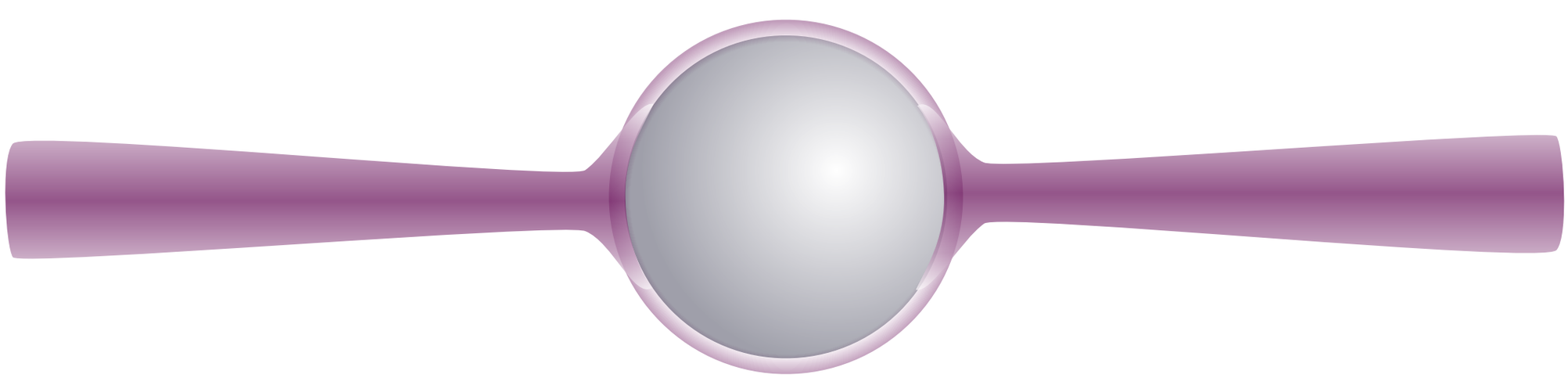
Young: X-ray Pulsar

- High field
- Steady burning polar cap

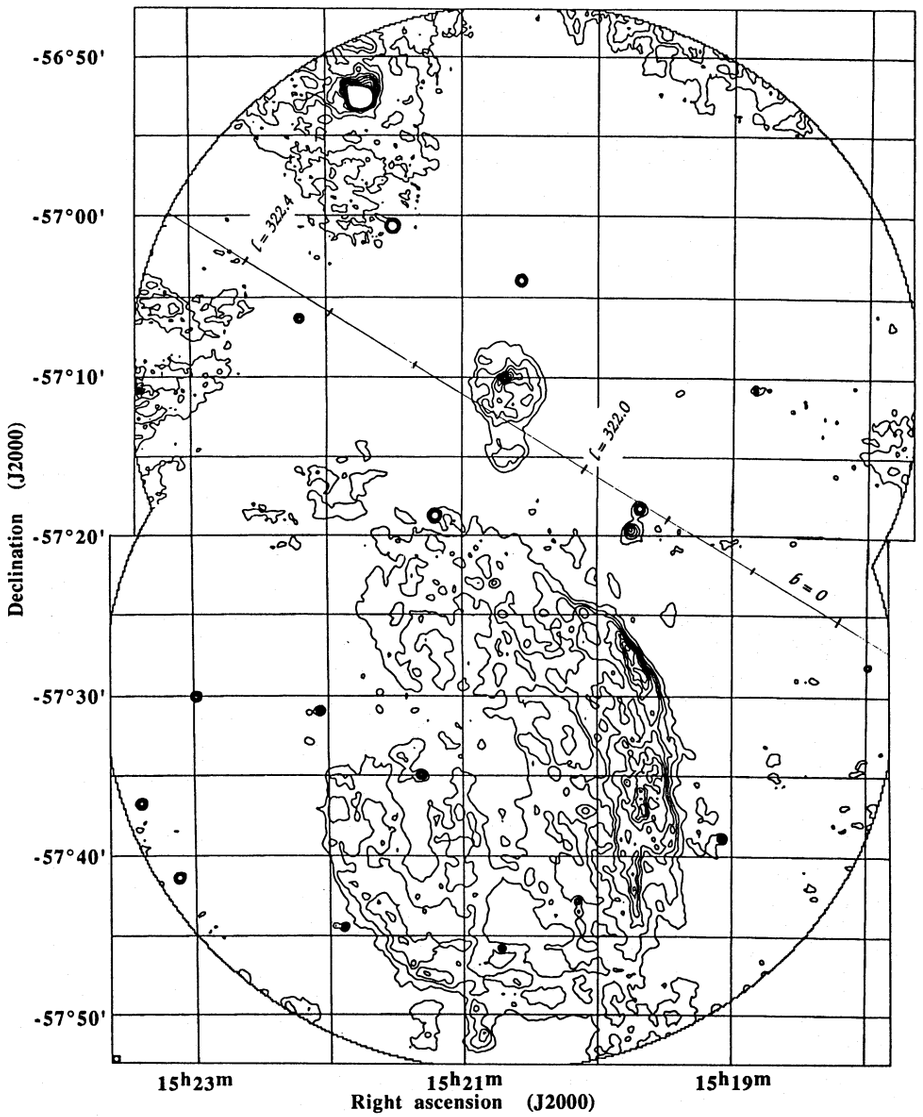


Old: X-ray Transients

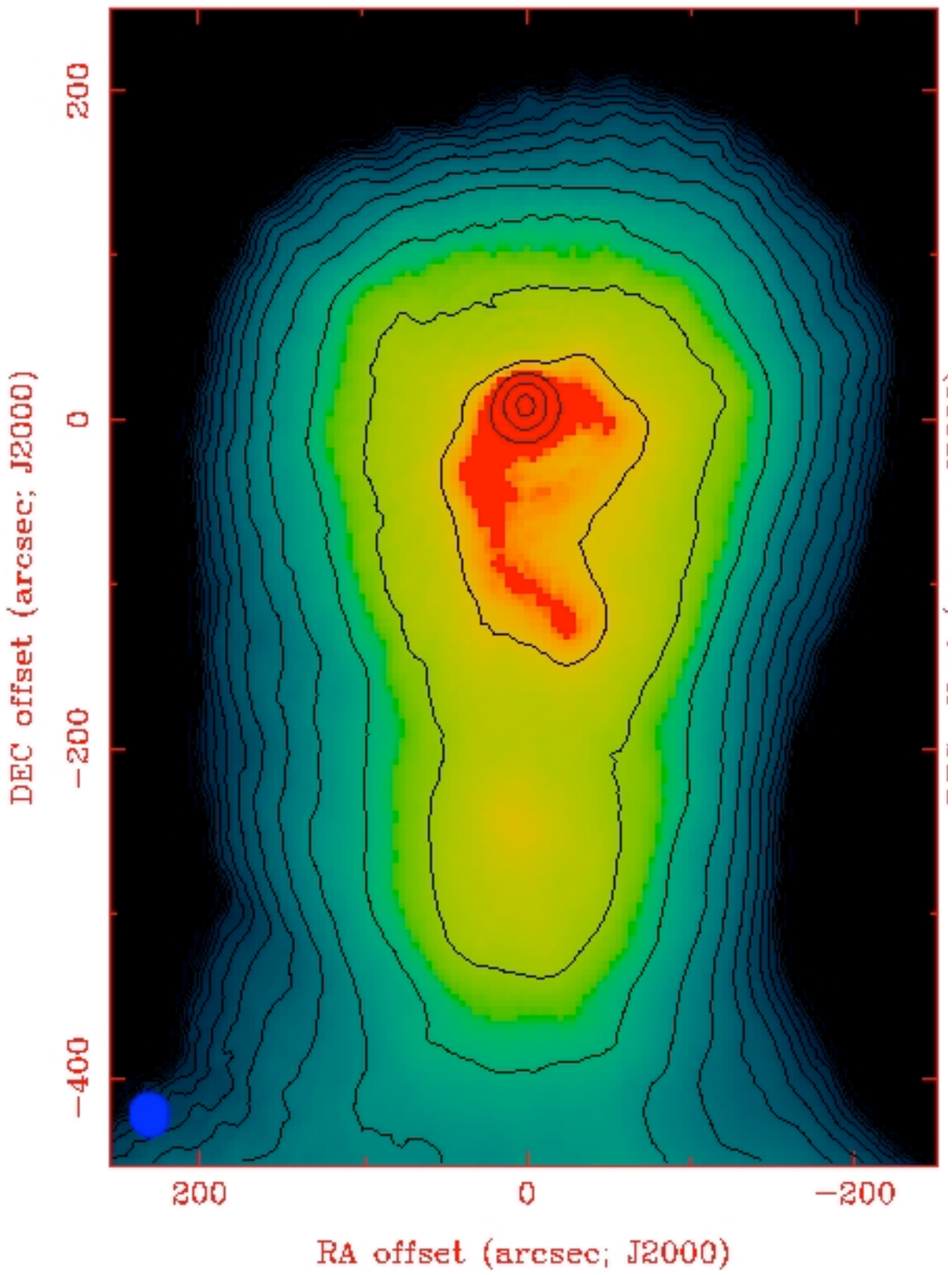
- Low field
- Regular accretion
- Unsteady burning (nuclear flashes)



Circinus X-1



Stewart+'93



Tudose+'06

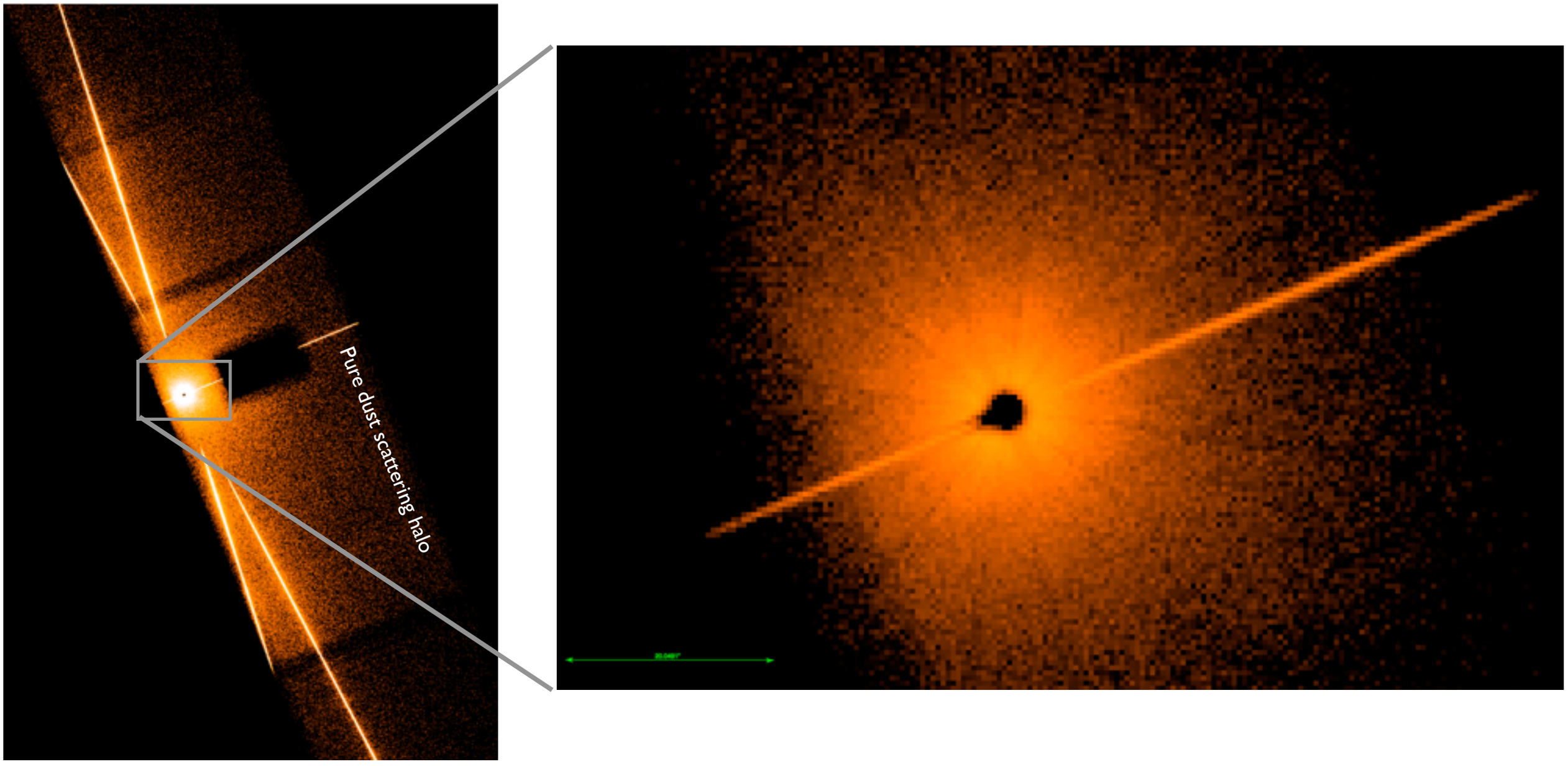
Circinus X-1 Vital Stats

- Orbit:
  - ⋆ 16.5 day orbit
  - ⋆ Eccentricity e~0.45
  - ⋆ X-ray dips
  - ⋆ $P/\dot{P}$ ~ 3,000 yrs!
- Extinction:
  - ⋆ $9 < A_V < 12$
  - ⋆ $N_H \sim 2 \times 10^{22}$ cm^{-2}
- Neutron star XRB (Linares+'10)
  - ⋆ Type I bursts
  - ⋆ No pulsations
  - ⋆ Jets
  - ⇒ Low field LMXB
- Companion (Jonker+'07)
  - ⋆ A5-B0 Ia - HMXB?
  - ⋆ Or: 0.4 $M_\odot$?

[?]XMB

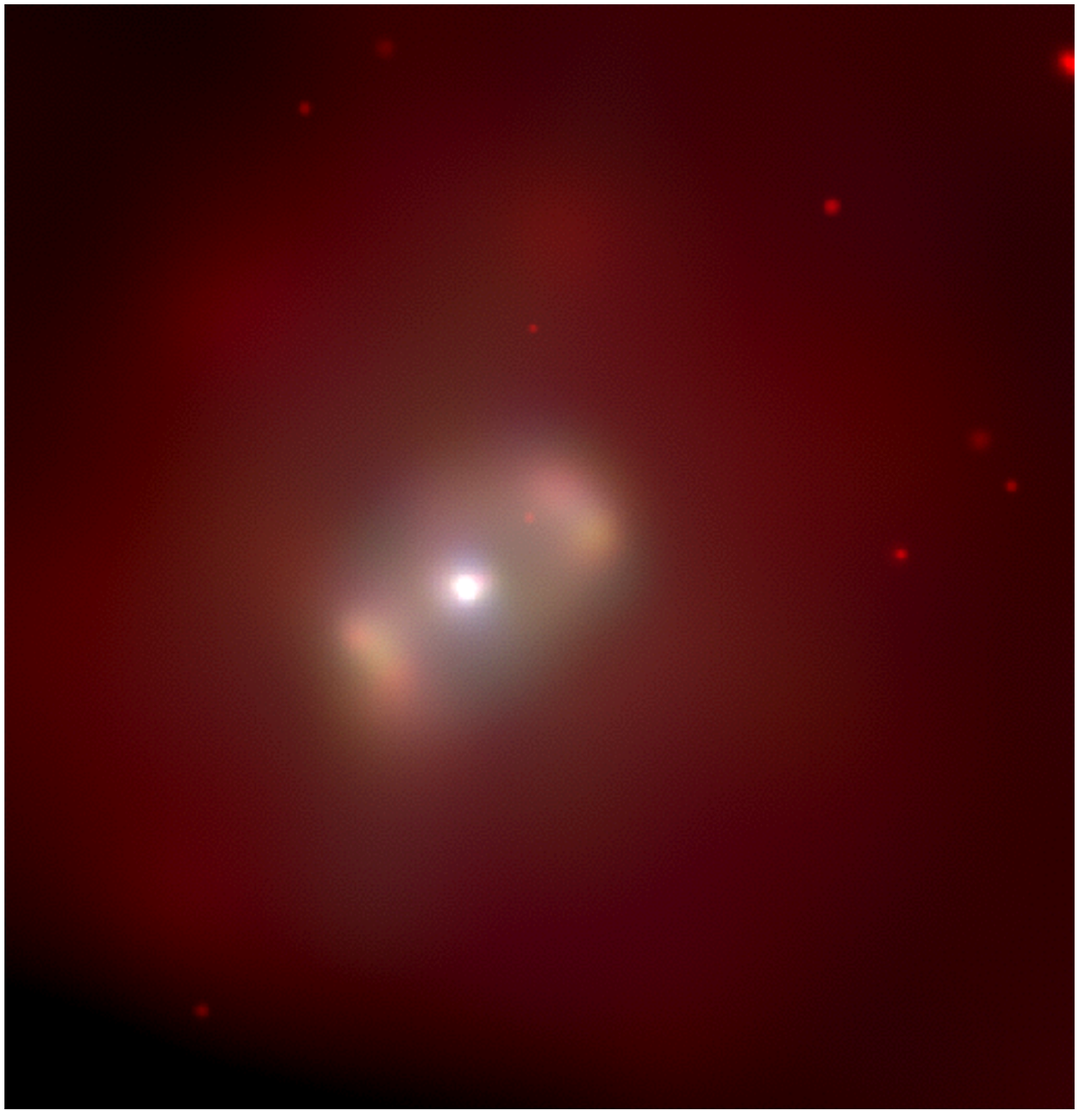
Properties	HMXB - young	LMXB - old
Donor	O-B (M > 5M	K-M or WD
Optical spectrum	Star-like	Reprocessed
Accretion disk	small	yes
Orbital Period	1-100d	10min - 10d
X-ray Eclipses	common	rare
B-field	Strong (B>10	Weak (B~10
X-ray pulsations	common (0.1-1000s)	rare (0.001-100s)
Type I X-ray Bursts	absent	common
QPOs	rare (0.001-1Hz)	common (1-1000Hz)
Jets	No	Yes

When Cir X-1 is bright…



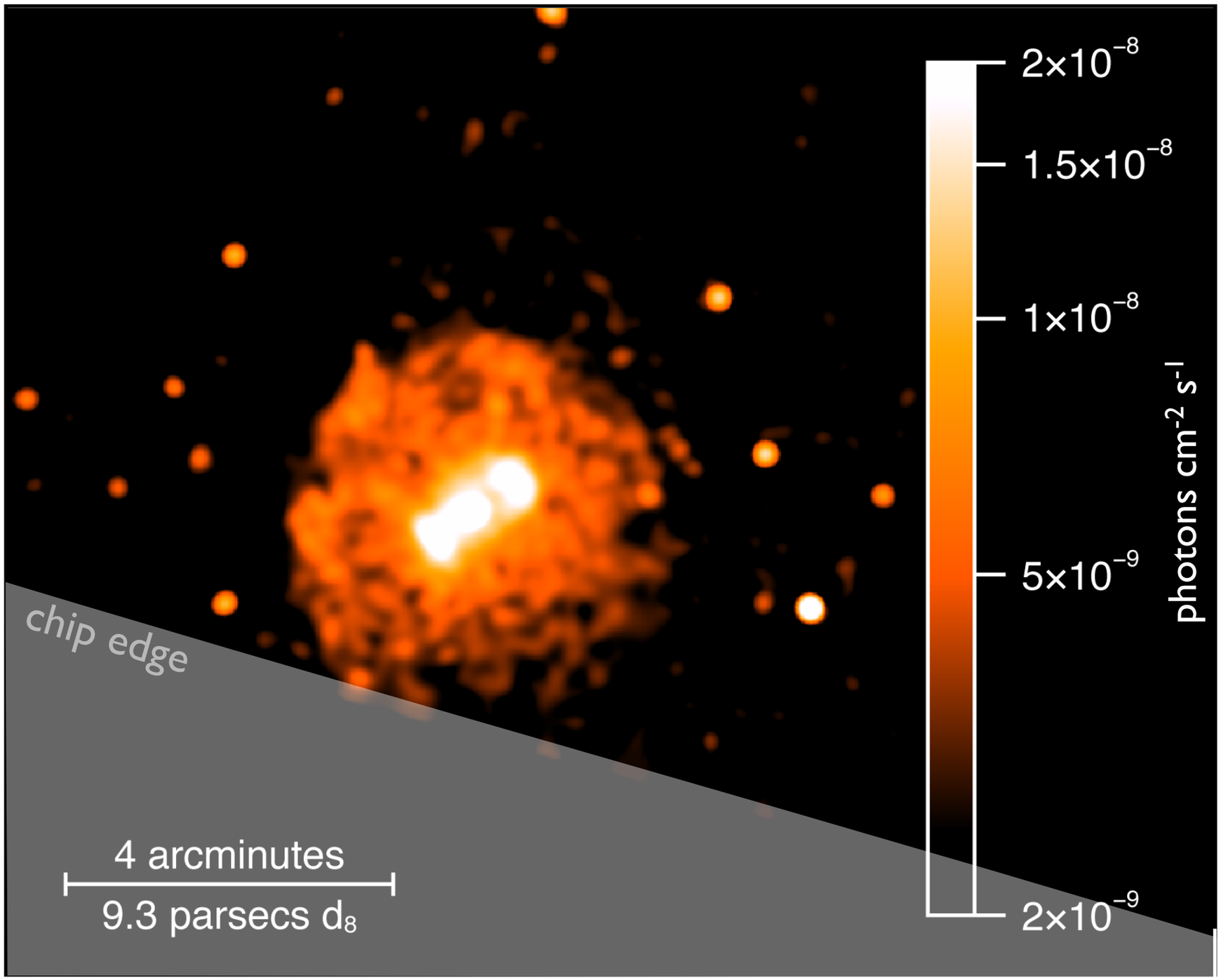
Brandt+'01

When Cir X-1 is dim…



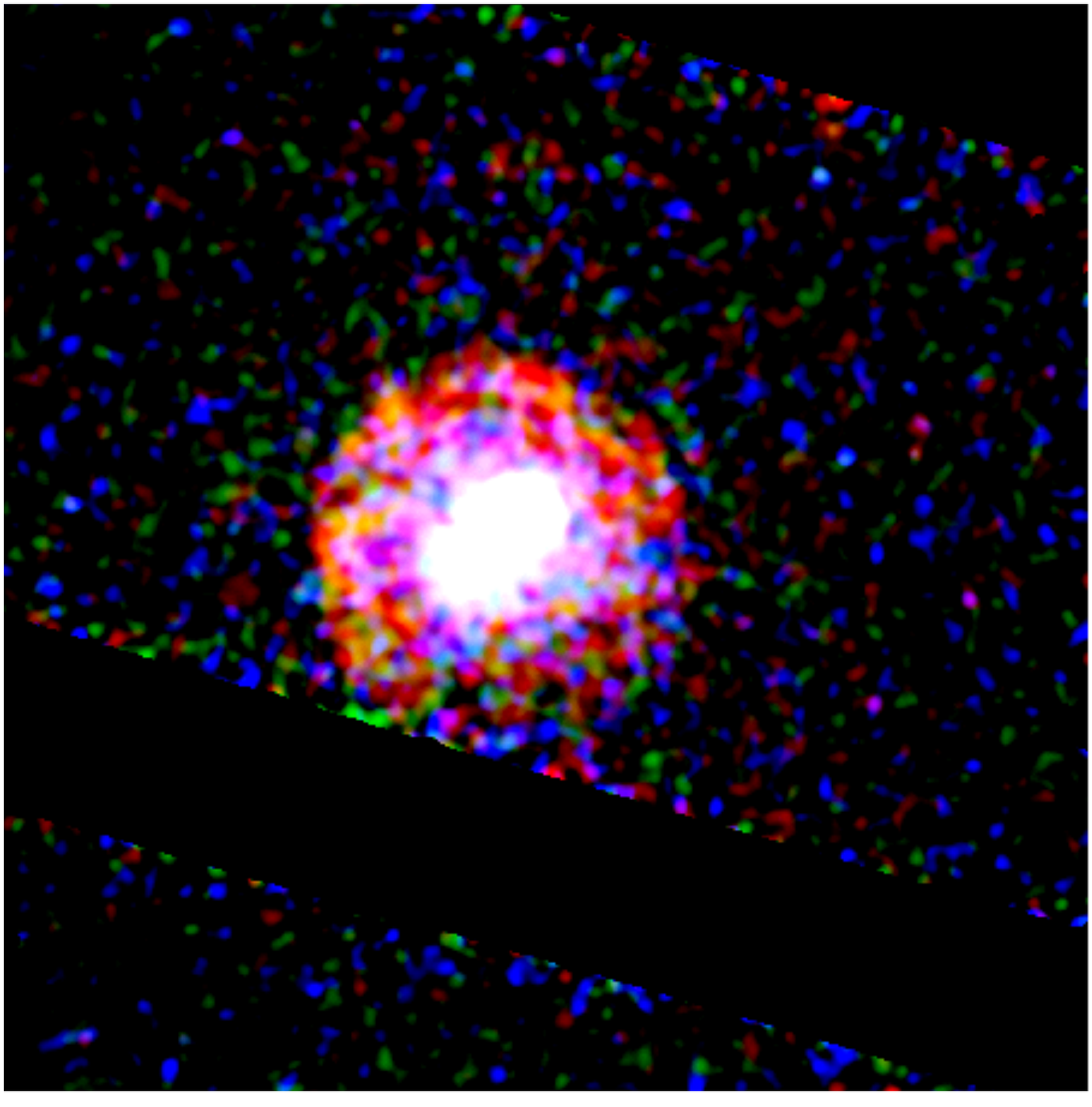
(Sell et al. 2010)

Circinus X-1 X-ray Nebula



Heinz+'13

Circinus X-1 X-ray Nebula



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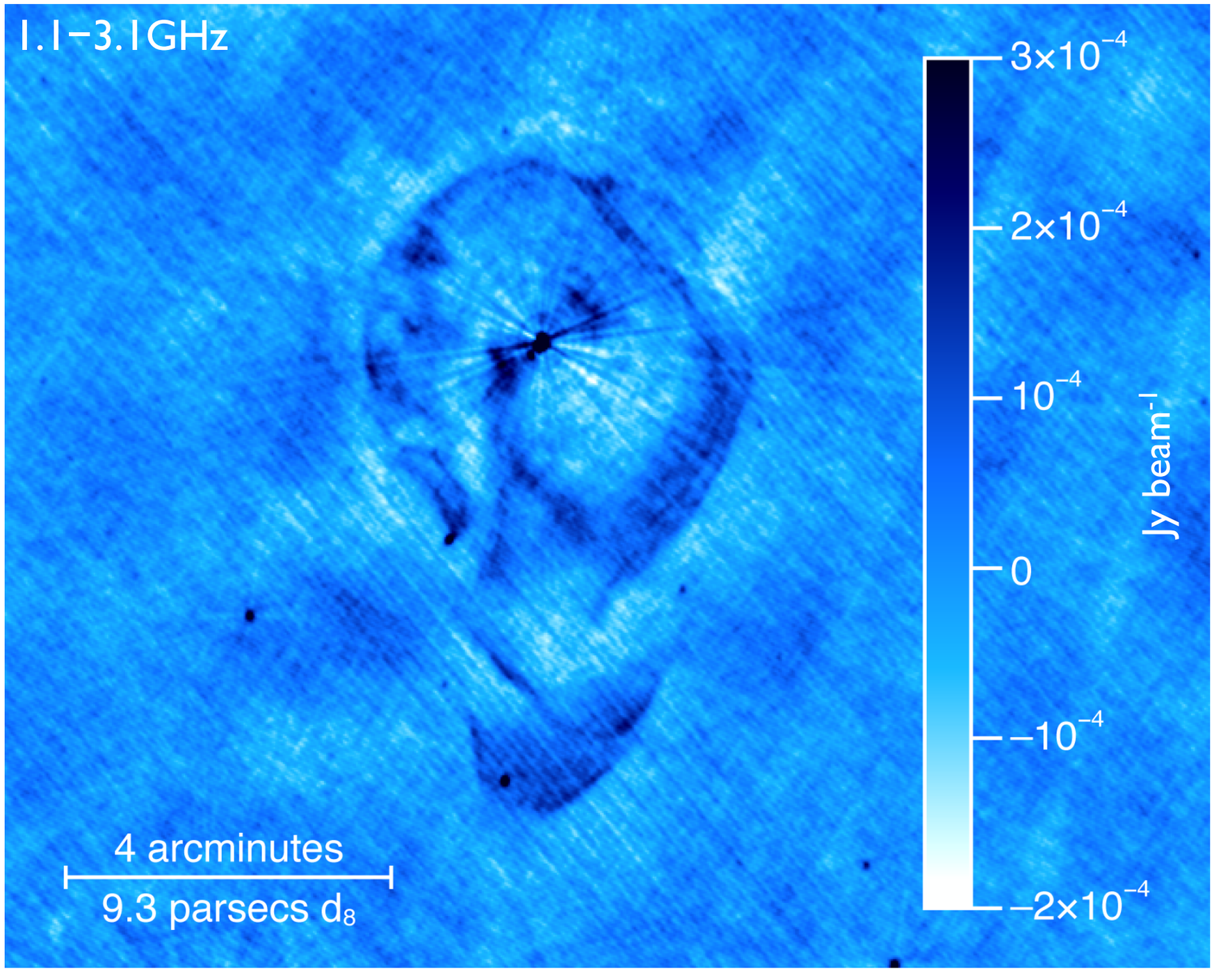
ATCA radio



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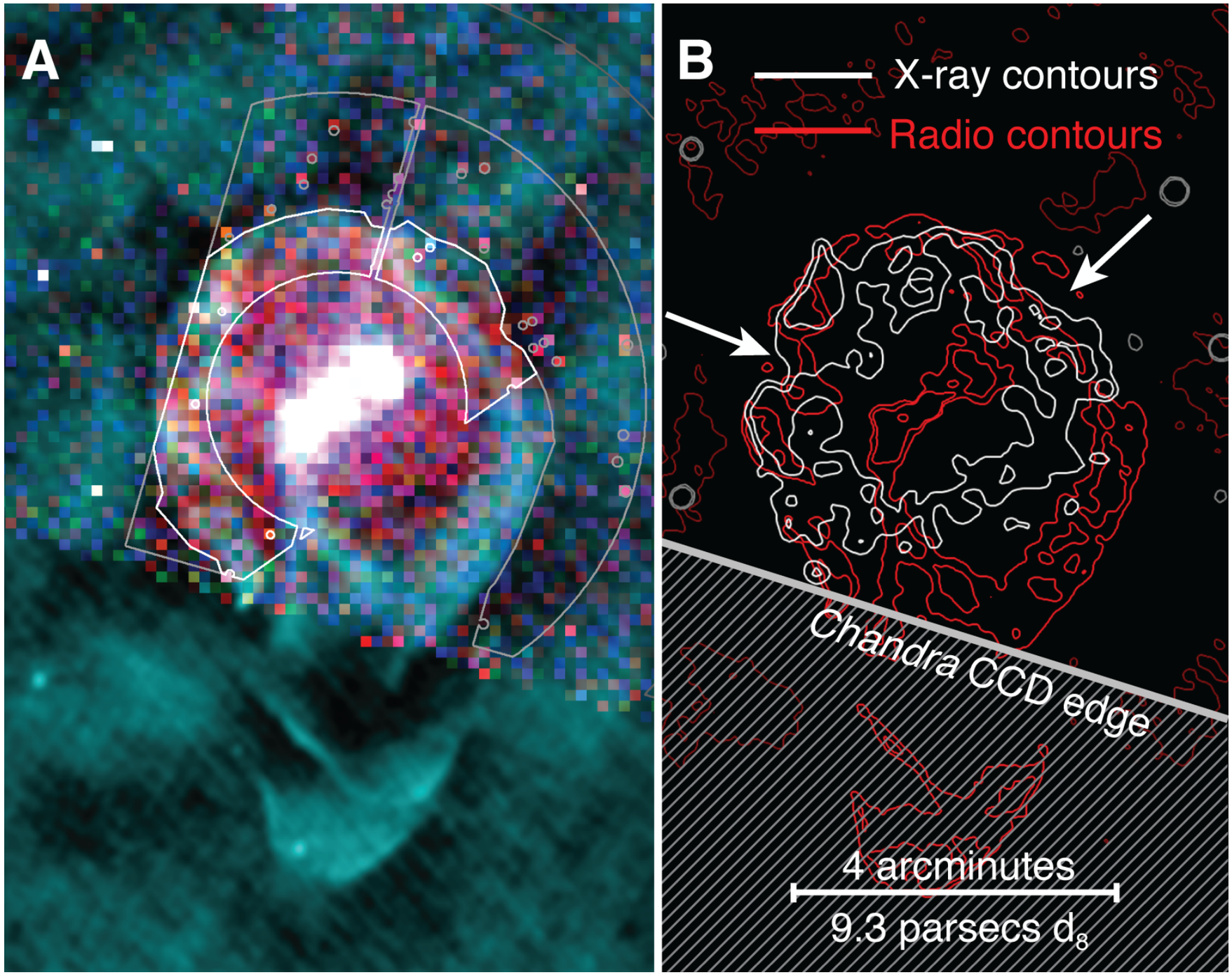
Radio/X-Ray Overlay



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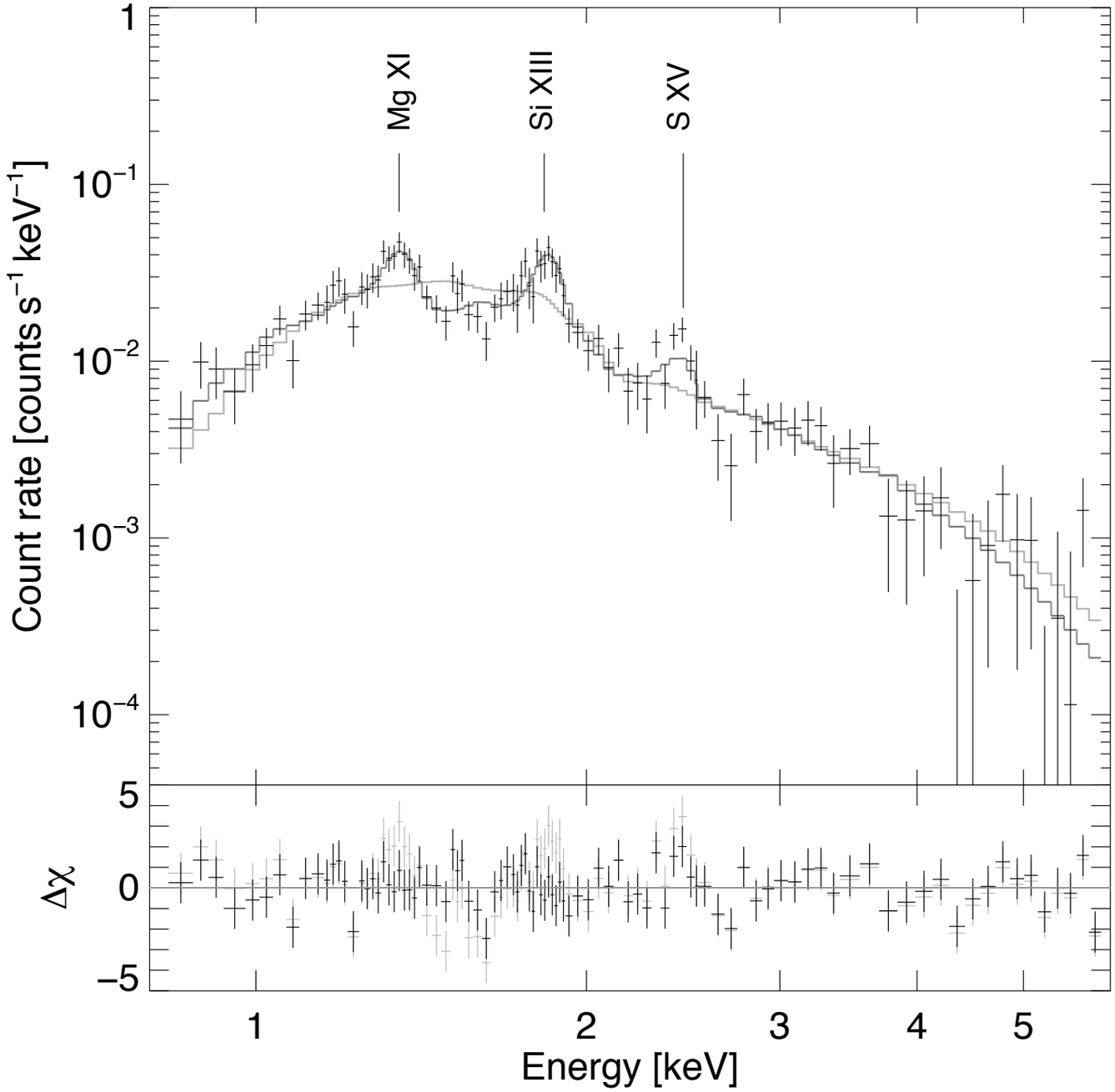
A (NE) Thermal Spectrum



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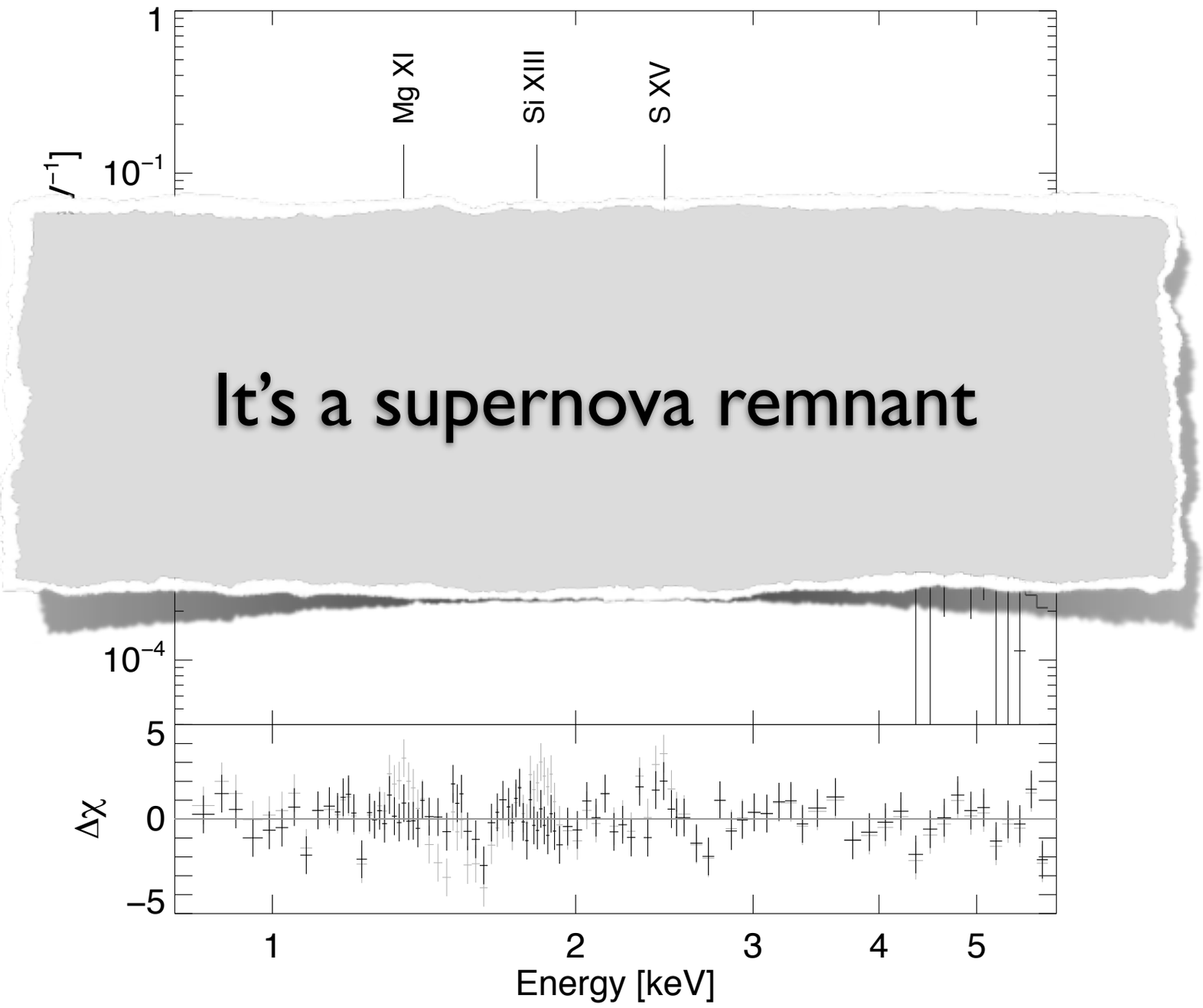
A (NE) Thermal Spectrum



It's a supernova remnant

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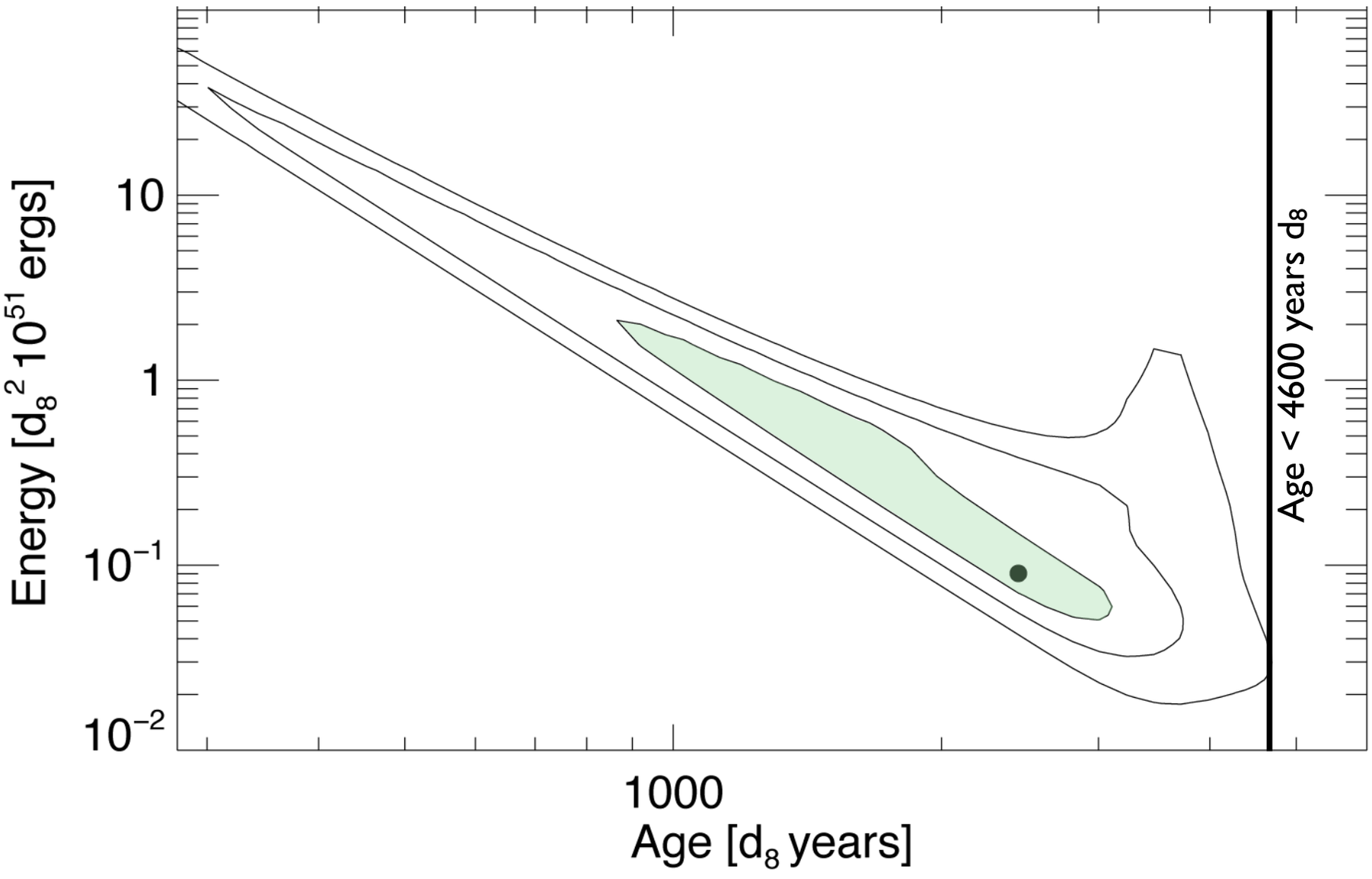
Spectral Constraints



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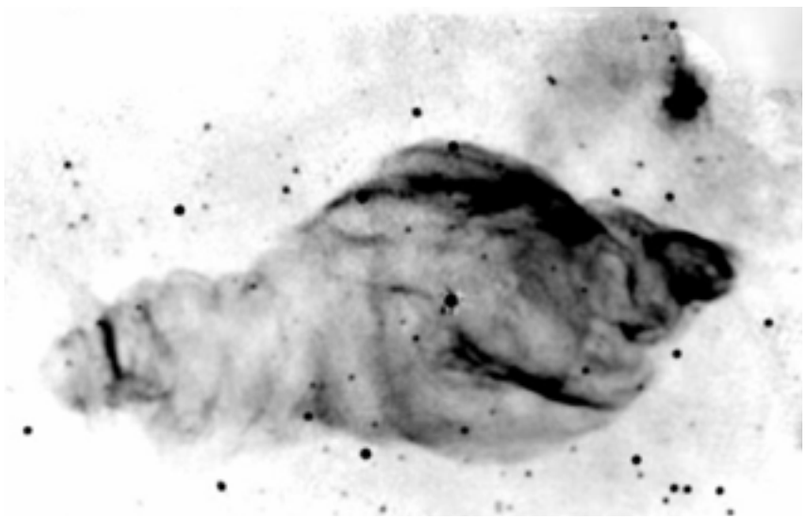
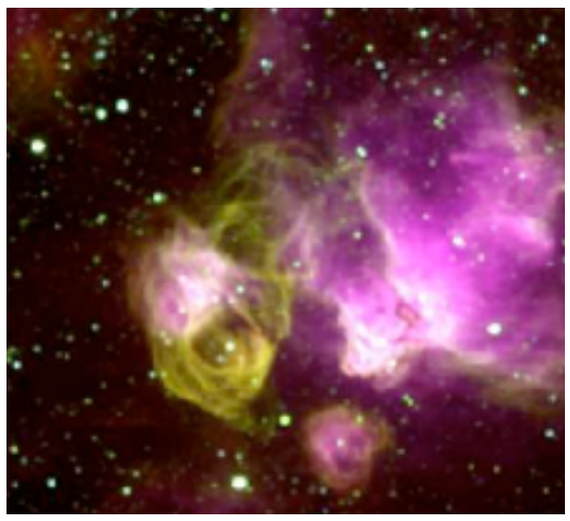
Consequences (1)

- At ~ 2,600 D_8 years, Circinus X-1 is the ***youngest*** known X-ray binary
- Only ***three*** other XRBs in Supernova remnants:



SS433

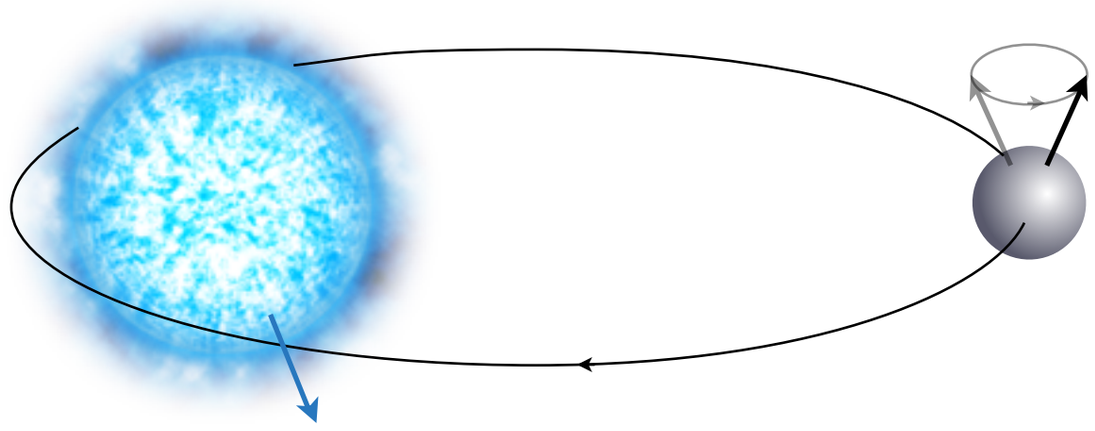
SXP 1062 (LMC)



DEM L241 (SMC)

Consequences (2)

- $P/\dot{P}$ ~ 3,000 years consistent with age
- Post-SN orbit:
  - ⋆ Orbit & spins likely misaligned - precession
- Crazy light curve



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- Post-S
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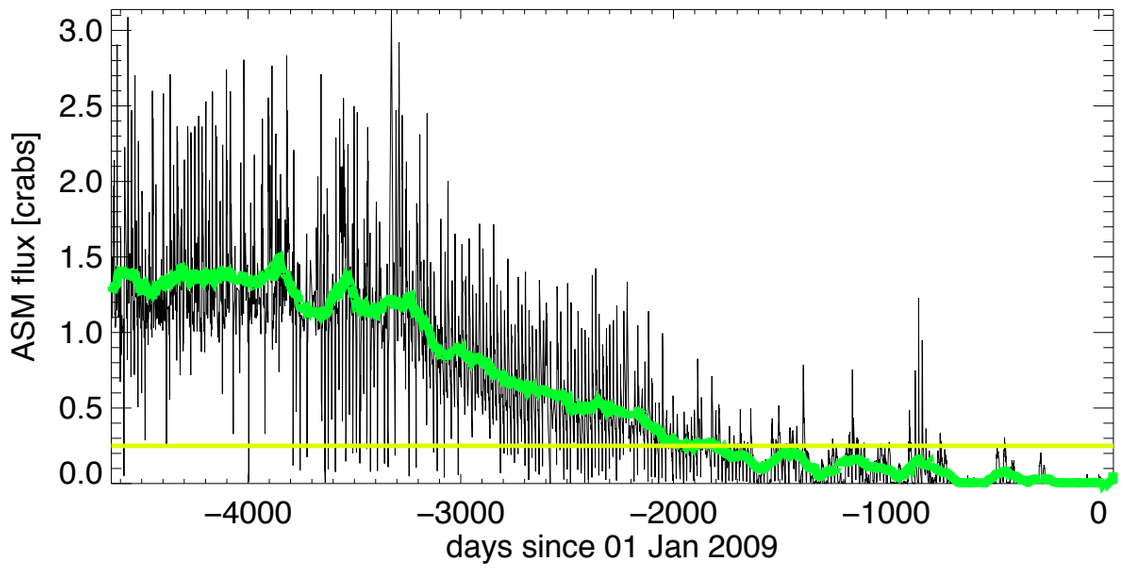
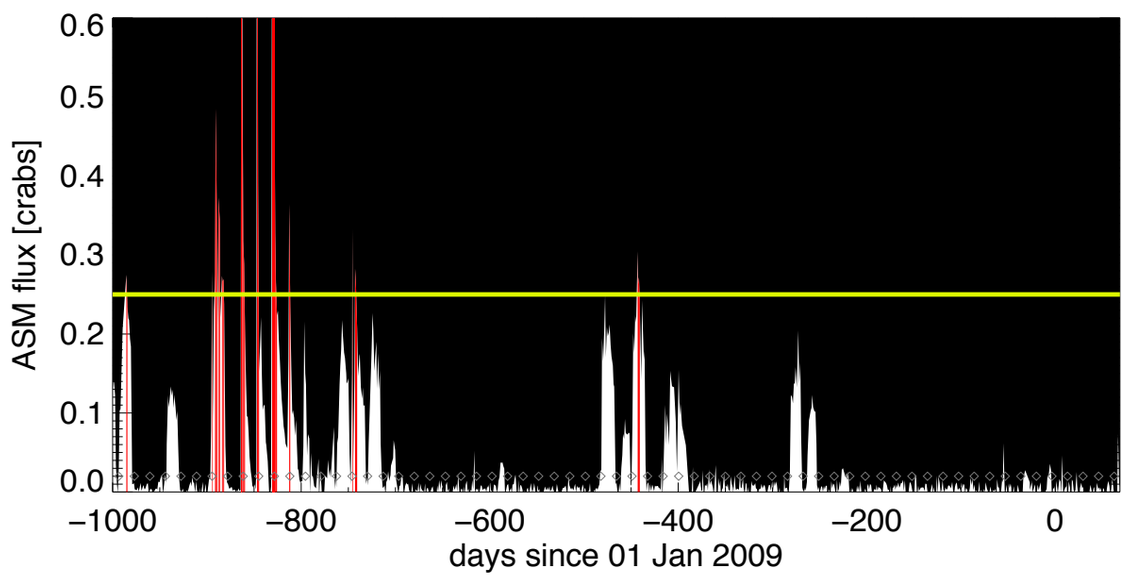
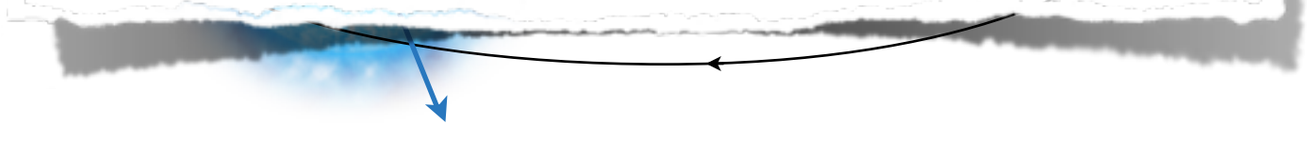


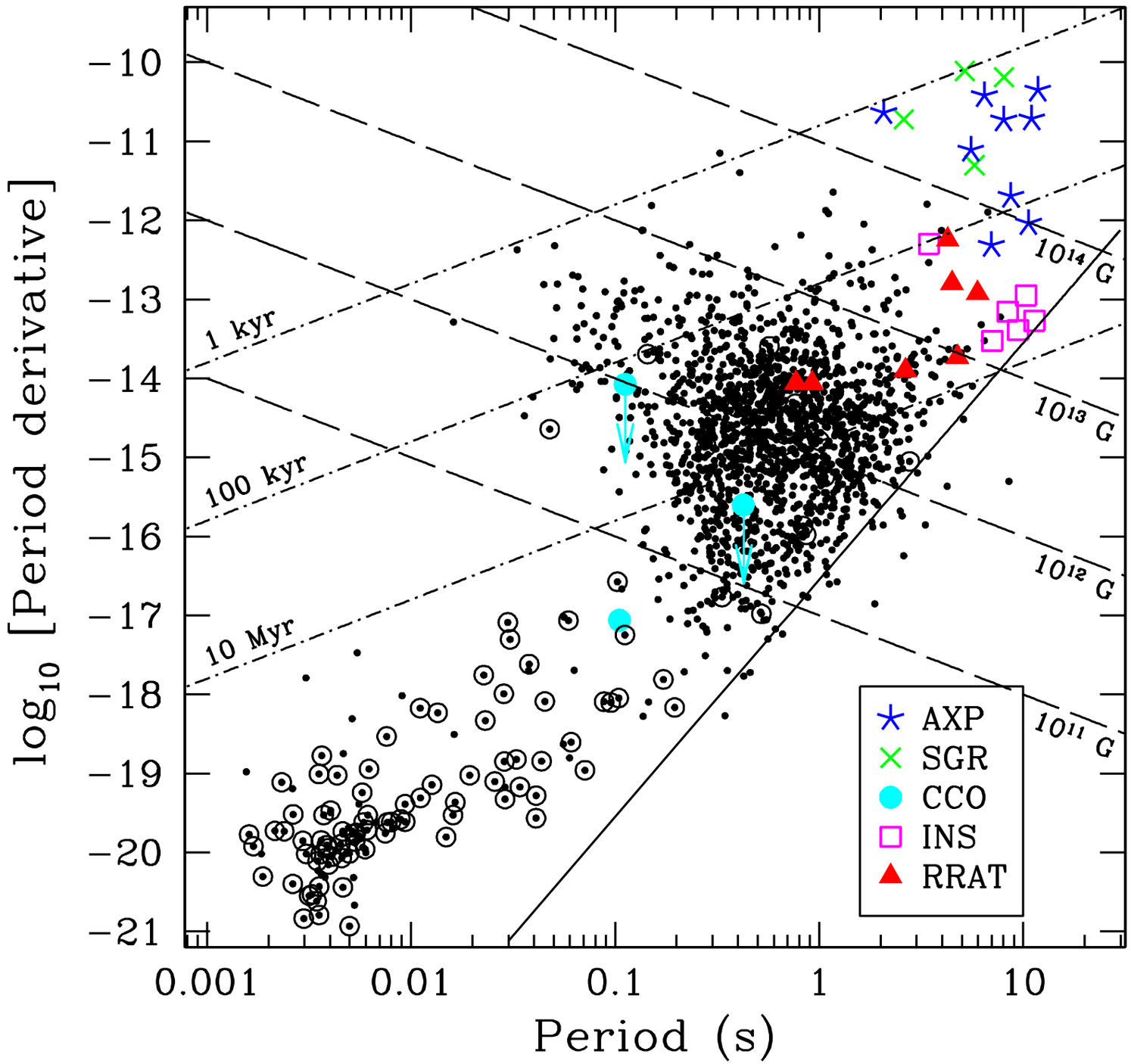




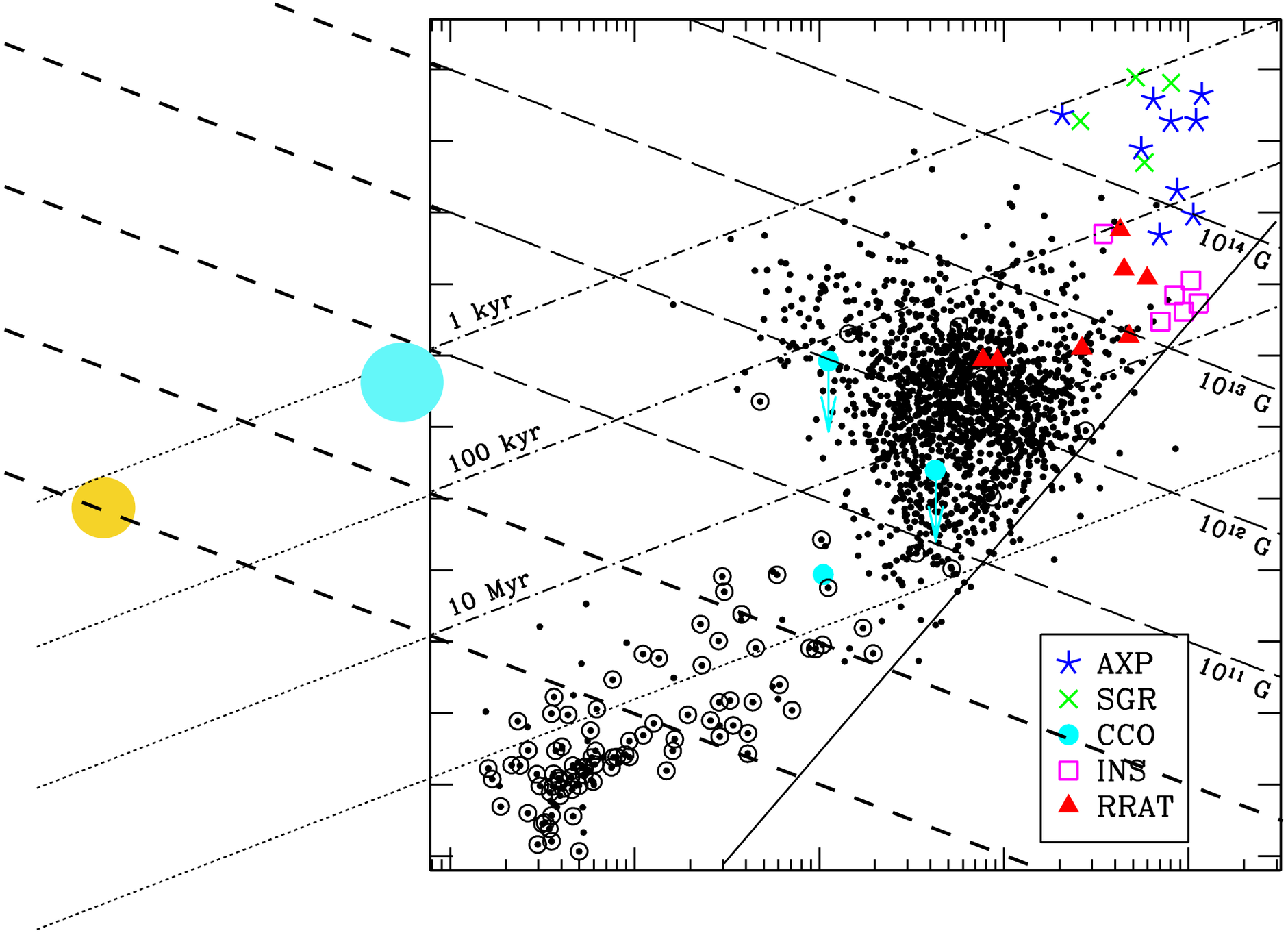
Consequences (3)

- Type I X-ray bursts, jets, lack of pulsations:
  - ⋆ $B \ll 10^{12}$ G (~ 10^9 G?)
  - ⋆ Lowest field young neutron star?
  - ⋆ Are there others?

Neutron Star B-fields



Neutron Star B-fields



Summary

- Circinus X-1 sits inside a supernova remnant
- Youngest known X-ray binary < 4,600 yrs
- Extremely low field for a young neutron star
- Orbital evolution, X-ray variability, precession: *probe post-supernova binary evolution*

Summary

Happy Anniversary, *Chandra*

and

Thank you, *Chandra* team!