Chandra **Observations of Soft Gamma-ray Repeaters**

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Spin, Magnetism and Cooling of Young Neutron Stars
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Observations:

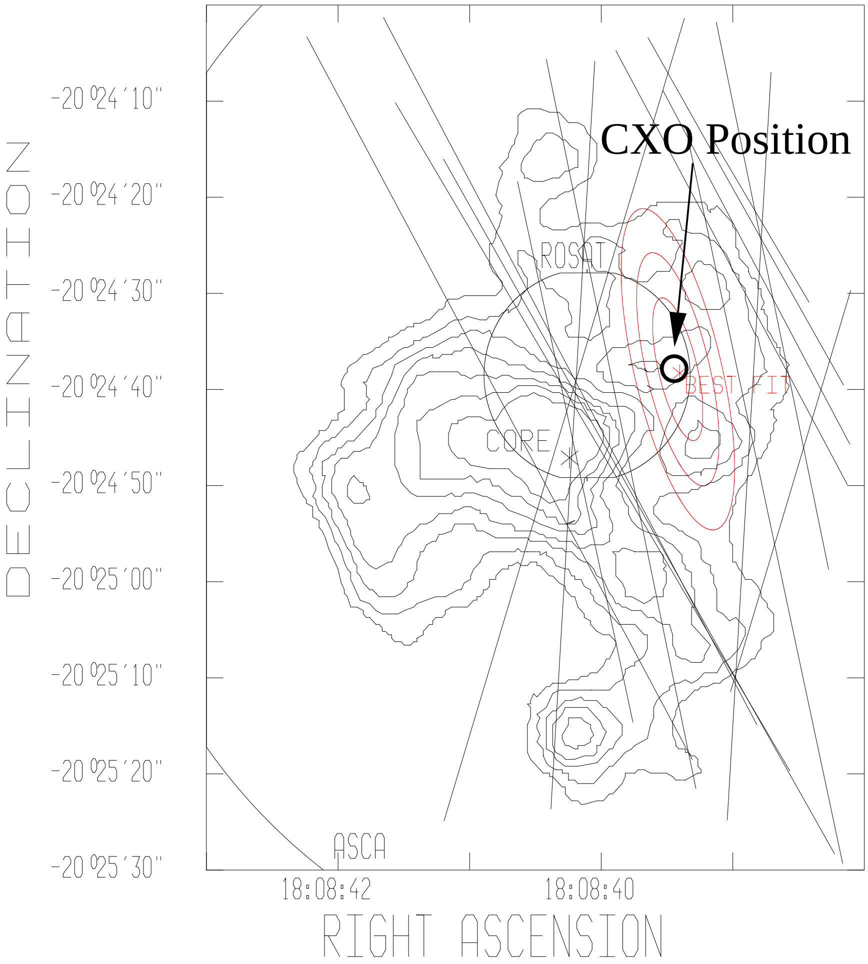
- SGR 0525−66:
  - 30 ksec with ACIS-S3 in 1/8 subarray mode (0.4 s resolution)
  - HST WF/PC-2, with 4 colors
- SGR 1806−20:
  - 5 ksec with ACIS-S (full chip)
  - 31 ksec with ACIS-S3 in 1/4 subarray mode (0.8 s resolution) — right after recent burst

Background:

- SGR 0525−66
  - 5 March 1979 burst
  - Located in SNR N49 in LMC
  - No optical/radio counterparts (Dickel *et al.* 1995)
  - X-ray counterpart: RX J0525−6607 (Marsden *et al.* 1996)
  - 8 s periodicity (burst only)
- SGR 1806−20
  - Associated with SNR G10.0−0.3 (Kulkarni & Frail 1993)
  - Quiescent X-ray source, with photon index $\Gamma \sim 2.2$
  - Non-thermal expanding radio source at core of SNR (Frail *et al.* 1997); could be from LBV (van Kerkwijk *et al.* 1995)
  - 7.5 s periodicity, with (mostly) steady spindown (Woods *et al.* 2000)
  - Bursts repeatedly (*e.g.* Göğüş *et al.* 2000)
  - Possible association with G10.0−0.3 challenged by IPN (Hurley *et al.* 1999)

Where is SGR 1806−20?

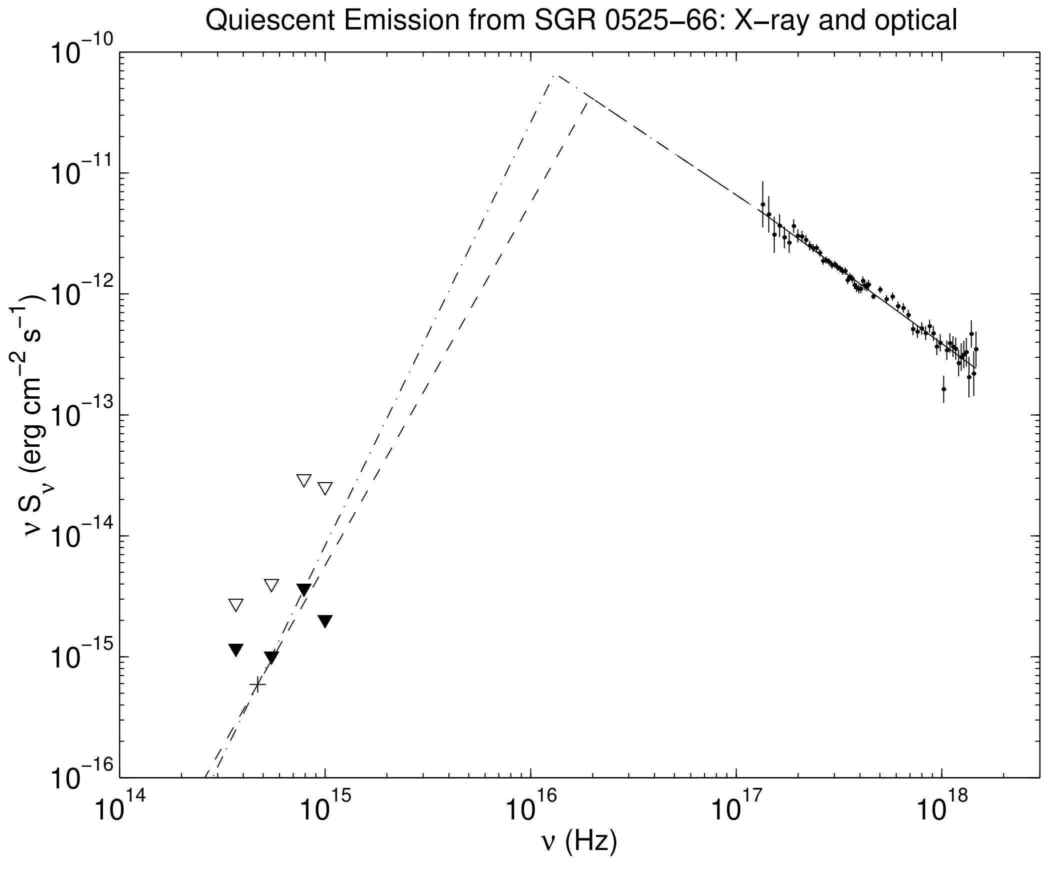
- 15″ from non-thermal radio core!
- Within 2″ of IPN position (Hurley *et al.* 1999)
- ⇒ Not associated with central core, thus SNR association questionable



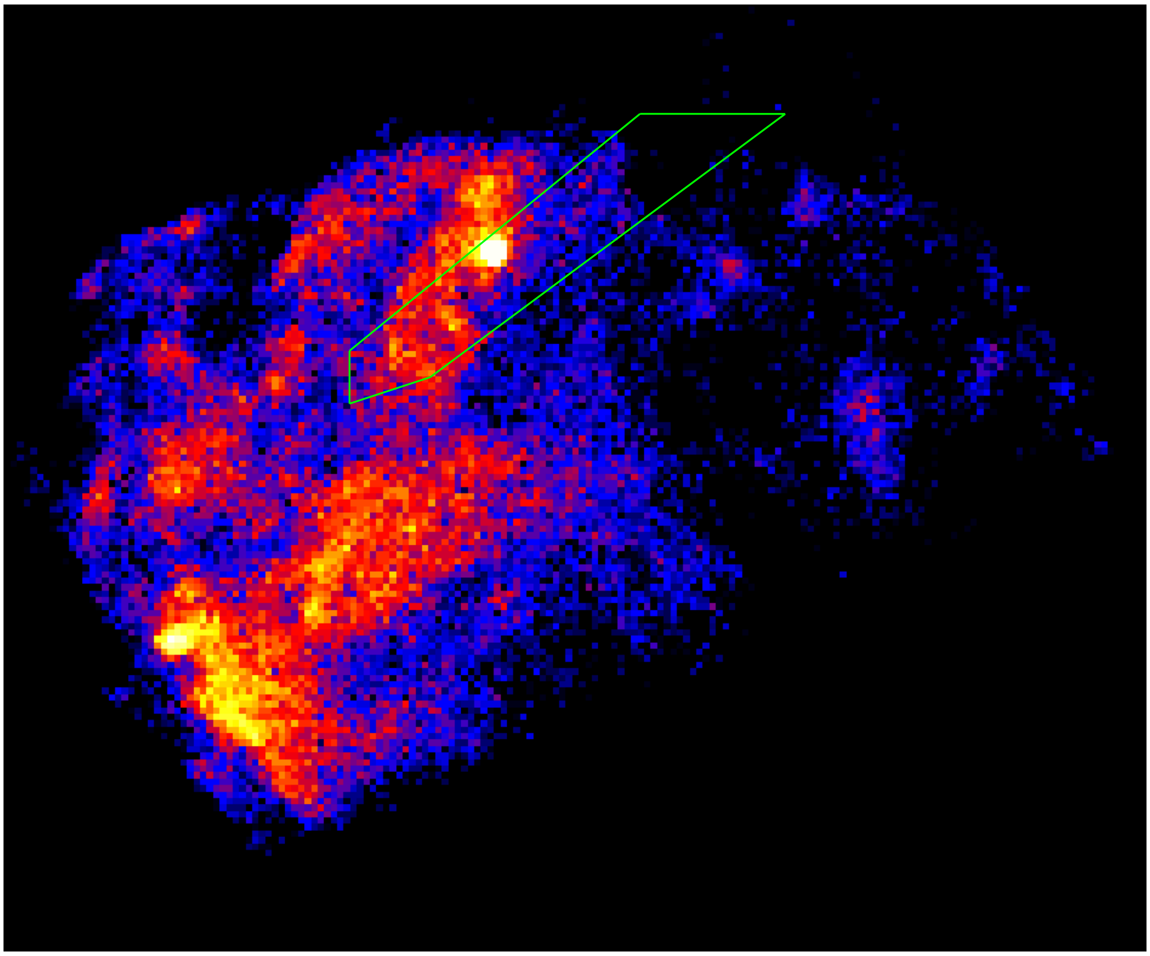
From Hurley (1999), with approximate CXO position

Where is SGR 0525−66?

- In N49
- No optical counterpart found with HST
- $\Rightarrow$ Severely limits possible disk



CXO spectrum and HST upper limits for SGR 0525−66. Filled triangles are data, open triangles are corrected for absorption. Lines are $S_\nu \propto \nu^2$ or $\nu^{2.5}$ and cross is expected flux, inspired by Hulleman *et al.* (2000).



CXO ACIS image of N49 / SGR 0525−66, with approximate error box.
The SGR is the point source towards the upper left.

How Large Are They?

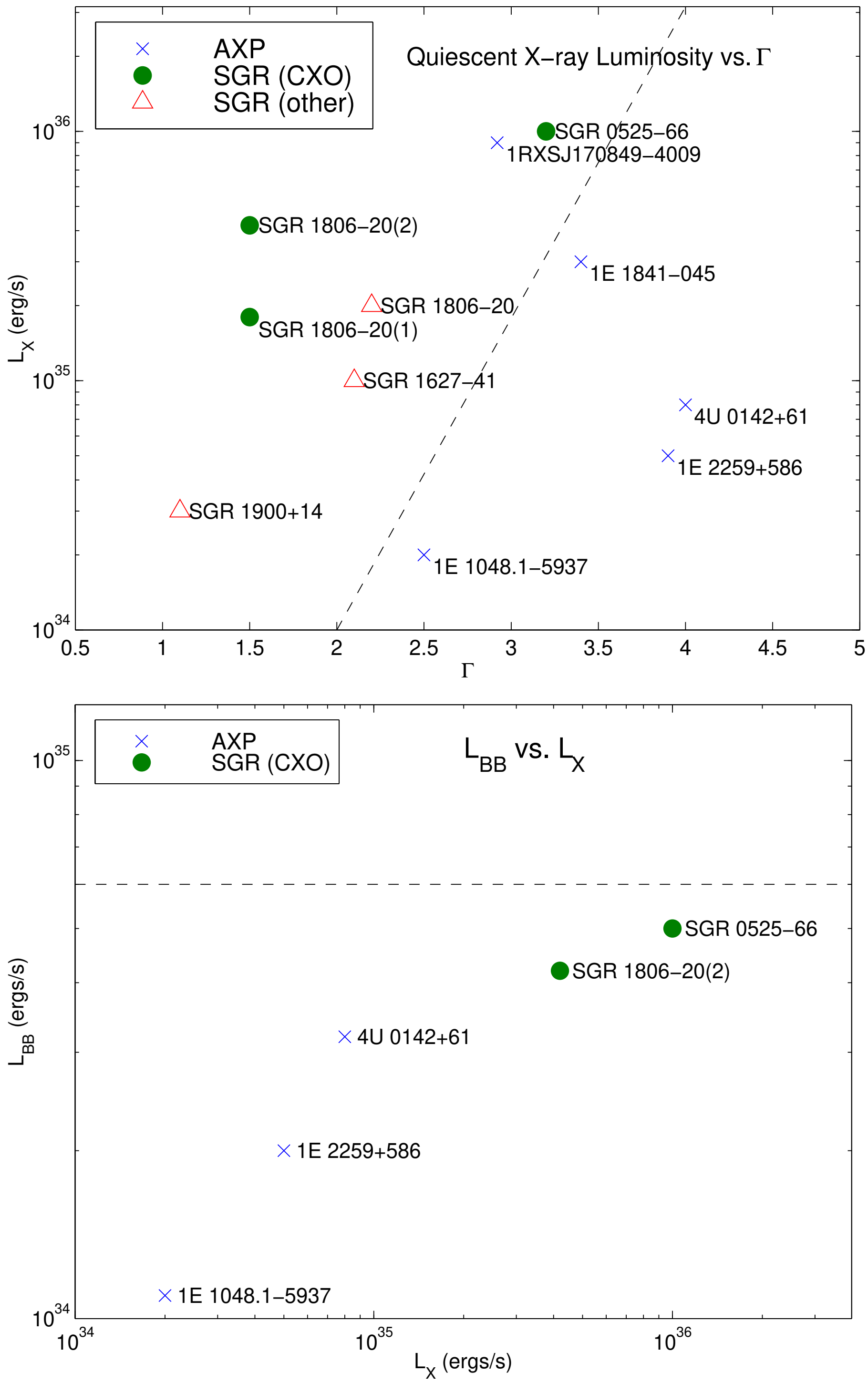
- Both unresolved with CXO ($\theta < 0\farcs33$)
- $\Rightarrow$ No residual synchrotron nebulae

How Fast Are They Spinning?

- Not ideal task for CXO-ACIS
- Even so, detect
  - 7.4924(4) s (SGR 1806−20), consistent with new spindown (Woods 2000, ITP)
  - 4.0218(2) s (SGR 0525−66), marginally detected
    Presumed to be harmonic of 8.0436(4) s (will be confirmed with future observations)

What Do Their Spectra Look Like?

- Tried Blackbody (BB), Powerlaw (PL), and combined (PL+BB)
- SGR 0525−66:
  - Prefer PL or PL+BB fits; not BB alone
  - PL fit: $\Gamma = 3.24 \pm 0.06$
  - PL+BB fit: $\Gamma = 3.2 \pm 0.2$, $kT = 0.5$ keV, BB is $\approx 5\%$ of 0.5–10 keV flux
  - BB portion of combined fit poorly constrained due to absorption and dropping ACIS sensitivity
- SGR 1806−20:
  - Prefer PL, PL+BB; not BB alone
  - Different observations have different count rates, maybe fluxes and spectra
  - $\Rightarrow$ Has to do with burst?
  - $\Gamma = 1.5$–1.9, $kT = 0.65$ keV
  - BB is $\approx 10\%$ of 2–10 keV flux
  - Again, soft BB component not well constrained due to high absorption and dropping ACIS sensitivity



Luminosity and spectral data for AXPs and SGRs. Lines are arbitrary. Non-CXO data from Hurley (1999); Mereghetti (1999).

Conclusions:

- νF_ν may peak in UV, like AXPs (Hulleman *et al.* 2000)
  - PL dominates spectrum / luminosity
  - Constrains energetics even more severely
  - $\Rightarrow B \gtrsim 10^{15}$ G?
- If observed only now, SGR 0525$-$66 looks like AXP (or even RQNS), only brighter
  - $\Rightarrow$ SGR 0525$-$66 is transition object
- Are SNR associations real?
  - SGR 1900+14 and SGR 1806$-$20 now dubious
  - N49 / SGR 0525$-$66 may be coincidence (don't see interaction), but N_H's are same for SNR and SGR
- PL from tangled B-field / BB from surface?
  - Γ describes B-field
  - BB flux can saturate with high B due to ν cooling
  - Bursts change spectrum?