Prospects in Compact Stars

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Overview

Neutron Stars

- forged in supernova
- 10^6 K; $t_{cooling} \sim 10^6$ yr
- Type-I bursts, LMXBs, HMXBs, pulsars (X-ray/γ-ray)
- isolated neutron stars: pulsars, AXPs/SGRs
- neutron-star binaries

White Dwarfs

- ashes of a sun-like star
- 10^4 K; $t_{cooling} \sim 10^9$ yr
- novae, AM Her, DQ Her, magnetic white dwarfs
- old white dwarfs
- white-dwarf binaries

Neutron Stars …

- The gross properties of neutron stars, their size and mass are determined by a balance between the strong force and general relativity.
- The details of their emission depend on the weak interaction and quantum electrodynamics.
- Neutron stars probe otherwise inaccessible regimes.

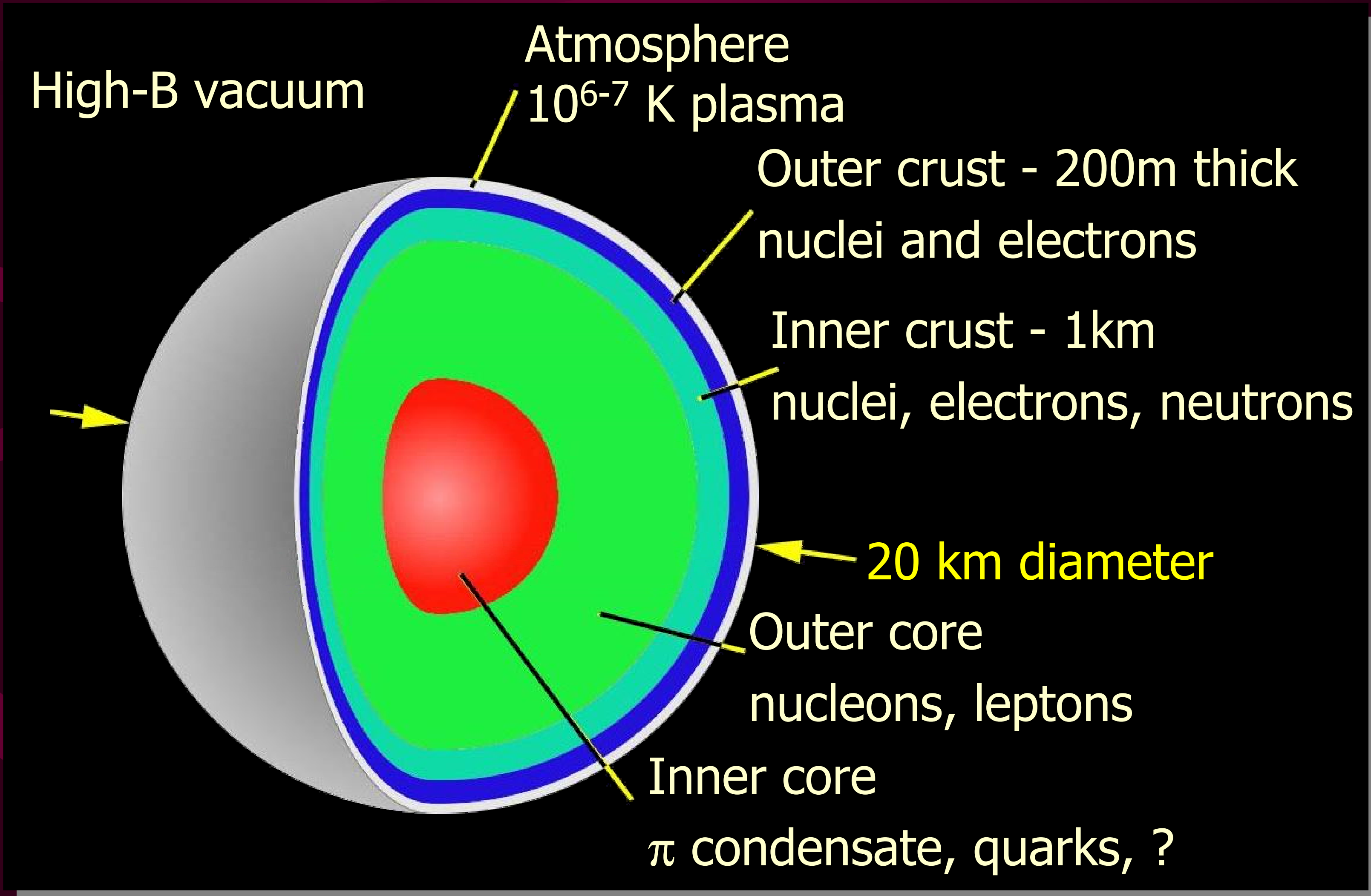
… and Their Environment

- Isolated Pulsars
  - physics of strong magnetized plasmas
  - highly accurate clocks
    - interstellar plasmas
    - gravitational wave background and emission
    - dynamics
- X-ray Binaries
  - physics of accretion in strongly curved spacetime
  - a peek at nuclear burning

Key Observations

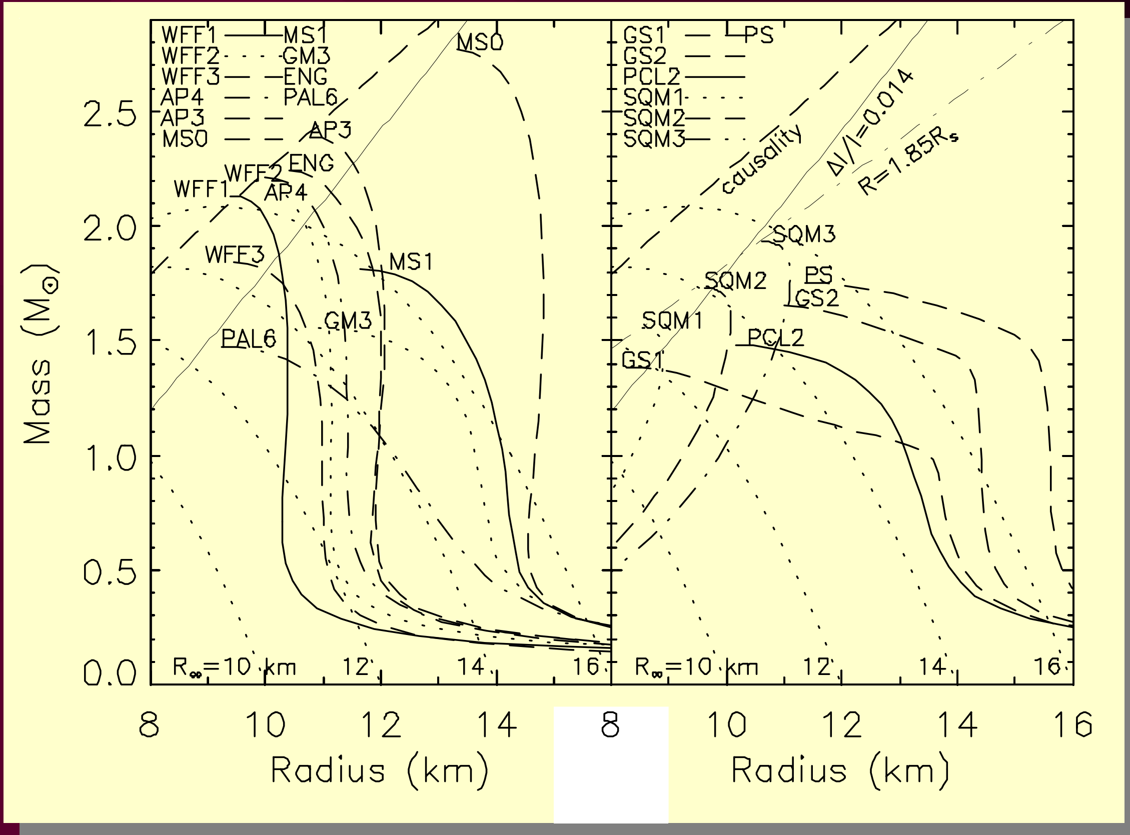
- Imaging
  - discovery of new neutron stars - high spatial resolution
  - gross constraints on emission models
- Spectroscopy
  - interpretation of lines, detailed atmospheric modeling
- Timing
  - periodic oscillations: non-radial oscillations, nuclear instabilities, rotation
  - QPOs
  - noise properties
- Polarimetry
  - accretion/emission geometry
  - propagation effects

Neutron Star Structure



The Nuclear Equation of State

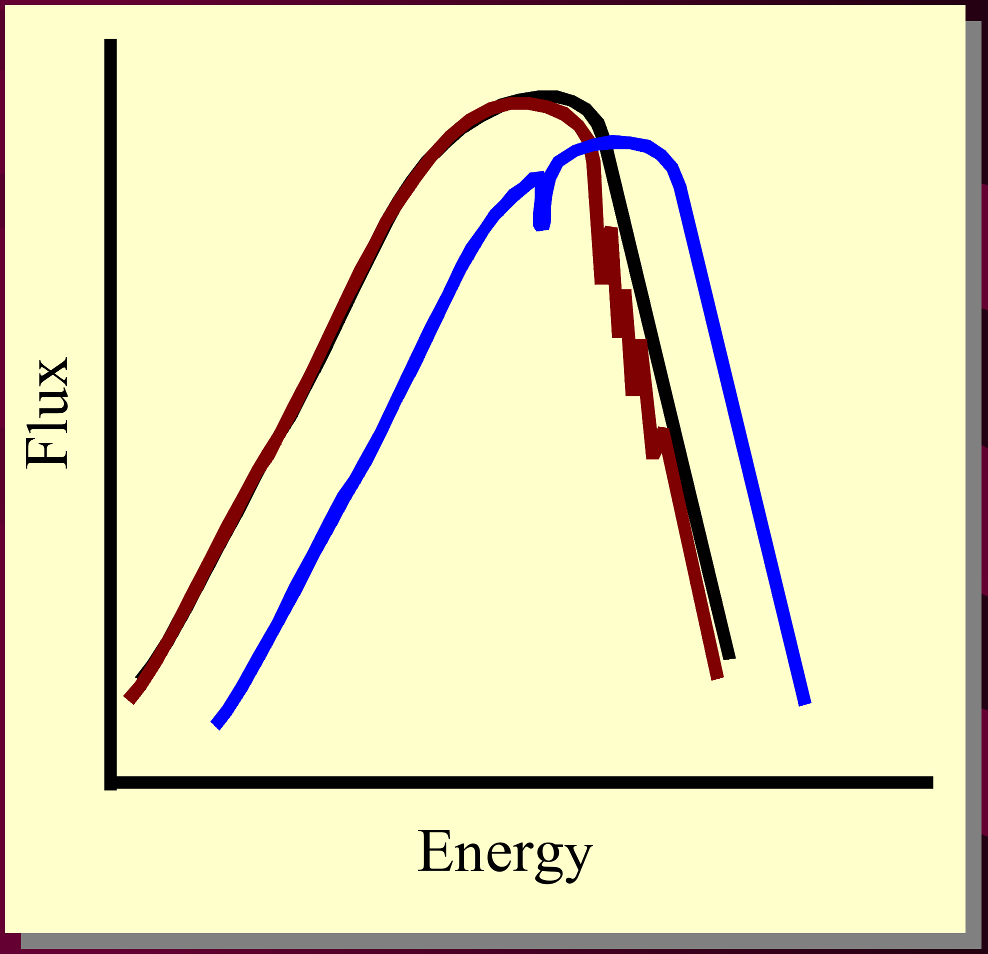
- Softer equations of state result in more compact stars.
  - Relativistic effects
  - Higher surface gravity
- Heat capacity and emissivity depends the composition of the core.



Lattimer & Prakash ‘01

Probing the EOS: Total Flux

- A radius estimate may be off by a order of magnitude, if the wrong atmosphere model is used.
- Look at quiescent LMXBs in globular clusters: isotropic emission, low B-field, known distance, mass estimate.
- Calibration of detectors important across the entire band.
- High signal-to-noise.

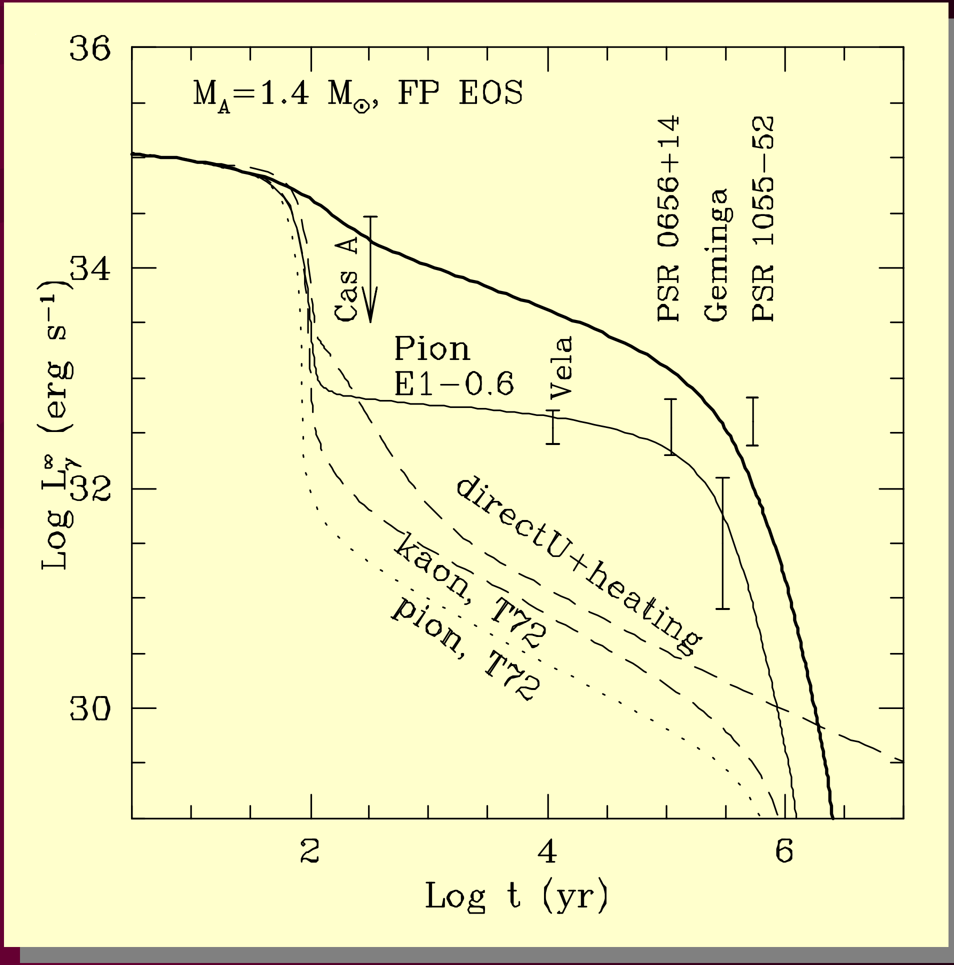


Probing the EOS: Variability

- Since light is bent by the strong gravitational field of a neutron star, we can see around the back.
- The emission from more compact stars varies less as they rotate.
- Variability also depends on the atmosphere and the structure of the magnetic field.

Cooling: Young Neutron Stars

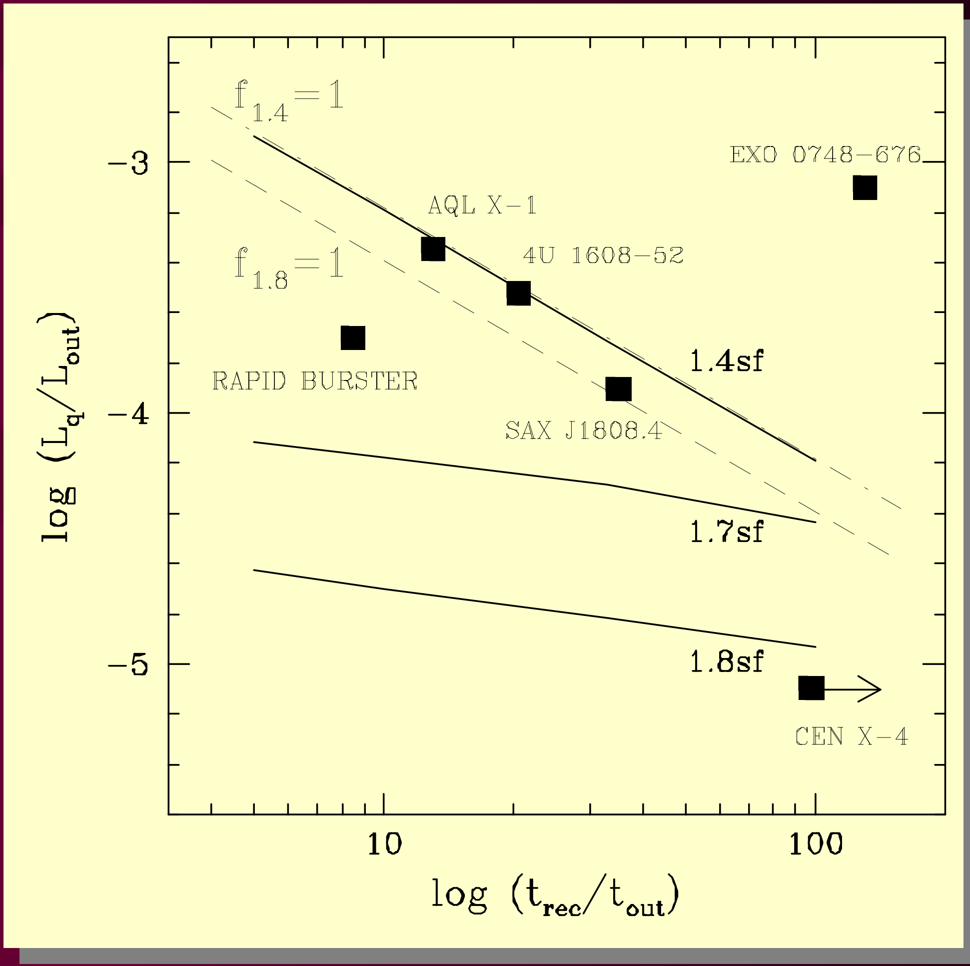
- If pions or quarks are present in the cores of young neutron stars, they cool much faster.
- How long it takes the surface to "find out" that the core is cooling quickly depends on the EOS.
  - 100 yr for soft EOS
  - 1000 yr for hard EOS



Umeda et al. '01

Cooling: Soft X-Ray Transients

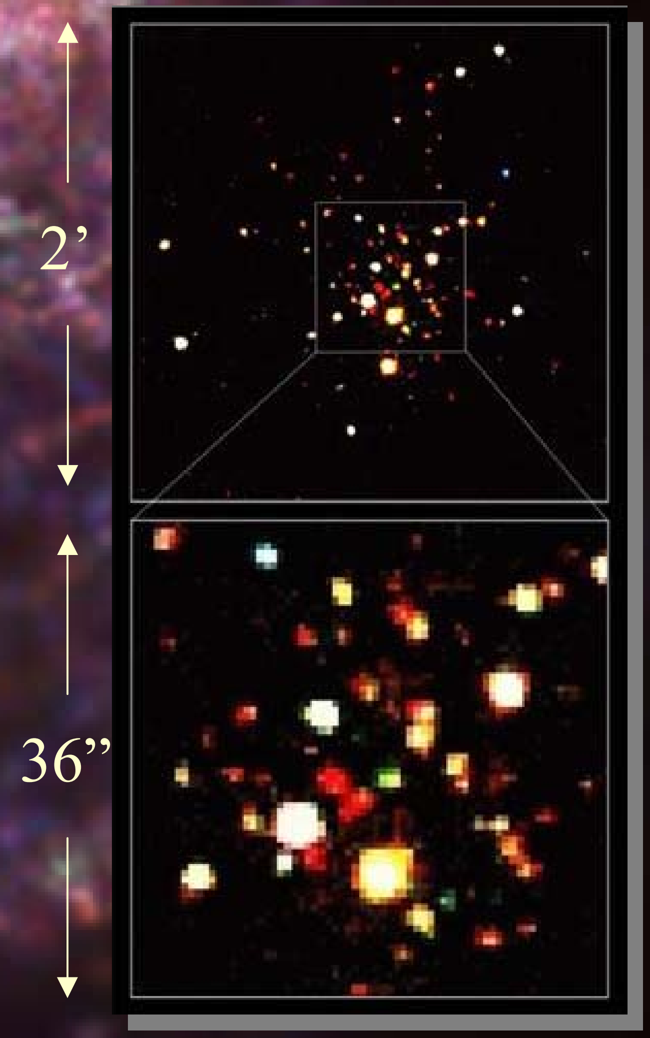
- If their quiescent emission is not due to accretion, then the EOS is unlikely to allow π or quarks.
- In quiescence the emission is from an unmagnetized H atmosphere (well understood).



Possenti et al. '01

High Spatial Resolution

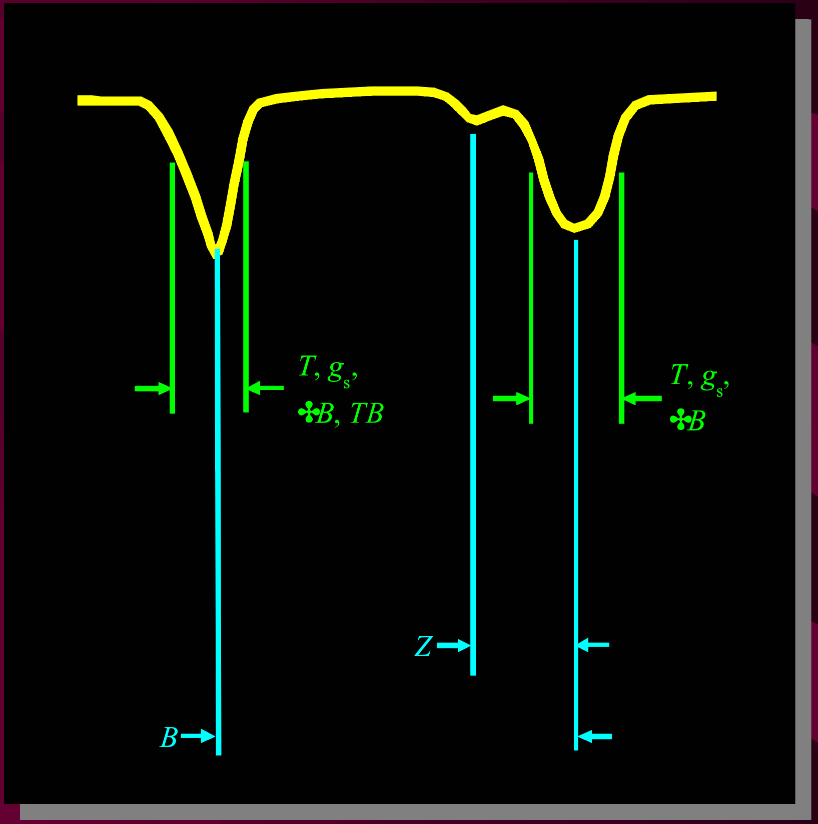
- High spatial resolution of Chandra has significantly broadened the sample of accreting neutron stars.
- The emission of young neutron stars is often dominated by the emission of the surrounding SNR.



Grindlay et al. ‘01

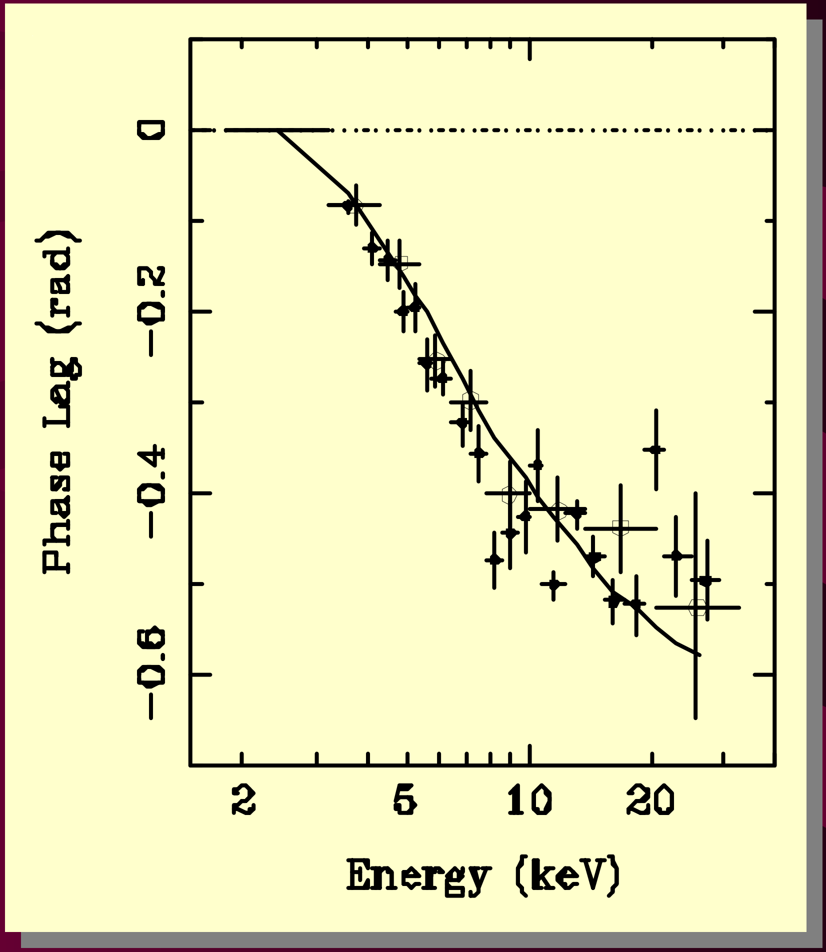
Probing the EOS: Spectroscopy

- Spectral lines from neutron-star surfaces: gravitational redshift and acceleration
- For light-elements wavelengths depend on the strength of the magnetic field.
- We haven’t seen any lines yet.



Timing: Phase Profile

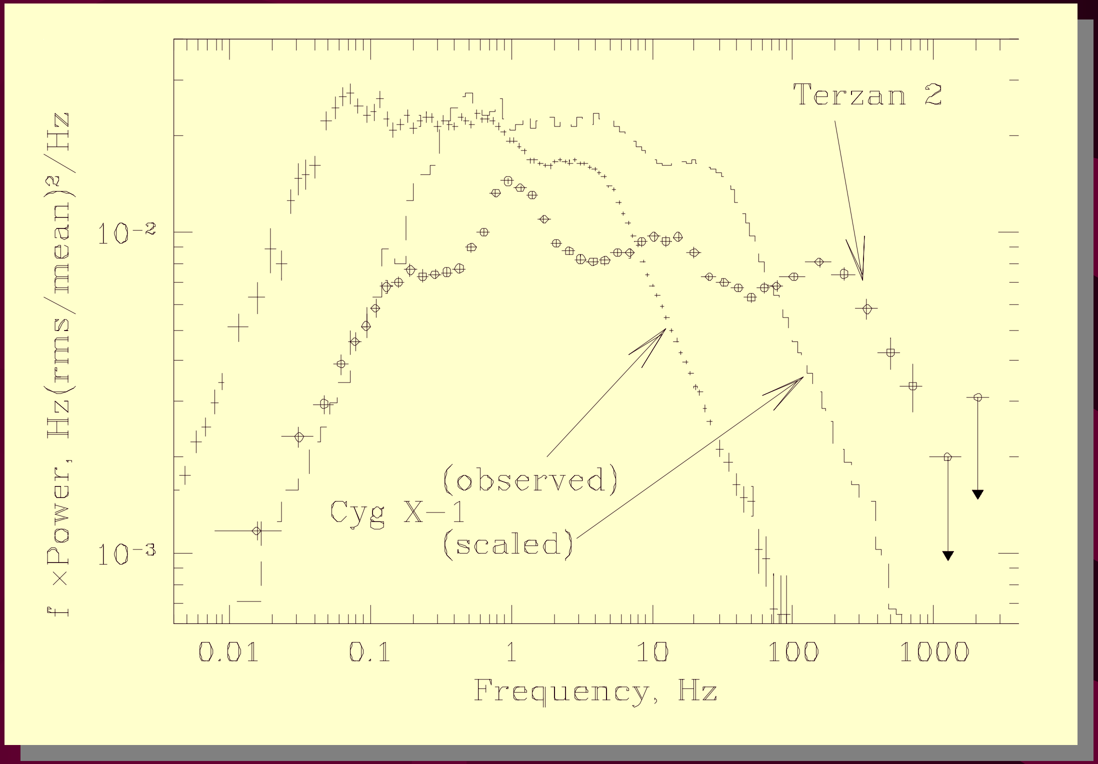
- SAX J1808.4 spins fast enough that Doppler boosting has a significant effect on the pulsed profile.
- Can constrain the radius independent of the distance to the source!



Ford '00

Timing: Noise

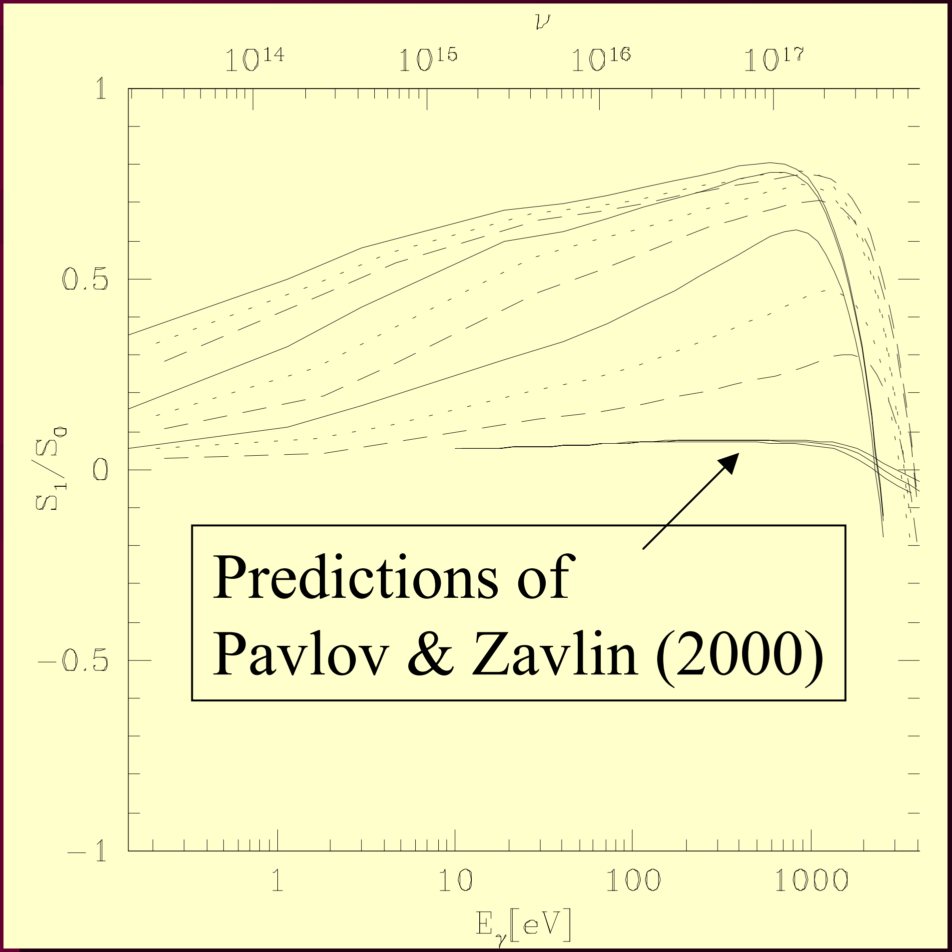
- Accreting neutron stars exhibit more noise at high frequencies than black holes.
- Possibly probes the physics of the boundary layer.



Revnivtsev & Sunyaev '00

Broadband Polarimetry: QED

- It dramatically affects the extent of polarization.
- Observations of polarized light in the optical would most sensitively probe the NS.
- X-ray data would probe QED.



Heyl, Shaviv & Lloyd ‘01

Neutron Stars: Close

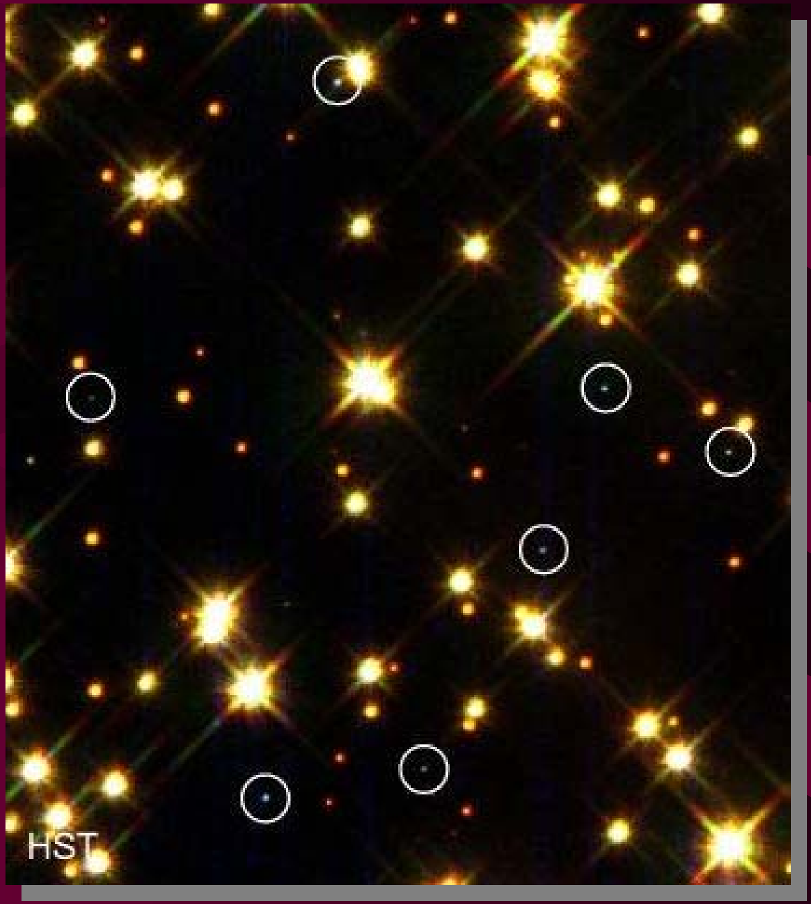
- Constellation X will provide a unique window into the interior of neutron stars and supernovae.
- Probes of strong-field QED require polarization measurements but are otherwise straightforward.
- EXIST will be able to discover neutron stars along highly absorbed lines of sight, survey for transcients (SGRs, LMXBs), probe the properties of accretion disk coronae and constrain the magnetic field strengths of strongly magnetized neutron stars.
- ARISE will resolve the termination shocks in pulsar wind nebulae.

White Dwarfs: Overview

- White dwarfs result when stars up to 8 M_X exhaust their fuel.
- Typically, their emission is less energetic and their evolution is slower than neutron stars.
- Nearby white dwarfs born soon after the birth of the Galaxy are still visible.

Think globally, act locally...

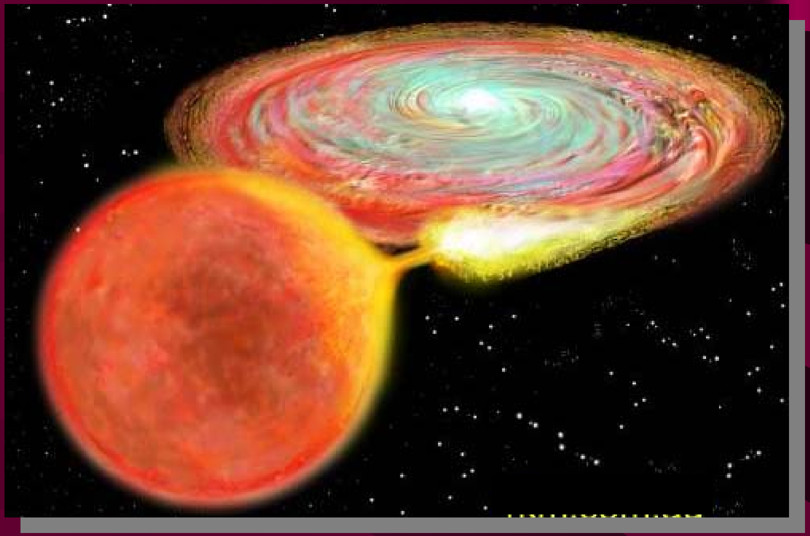
- Deep optical/UV searches uncover faint white dwarfs.
- These white dwarfs provide archeological evidence of the star formation rate over the history of the Galaxy.

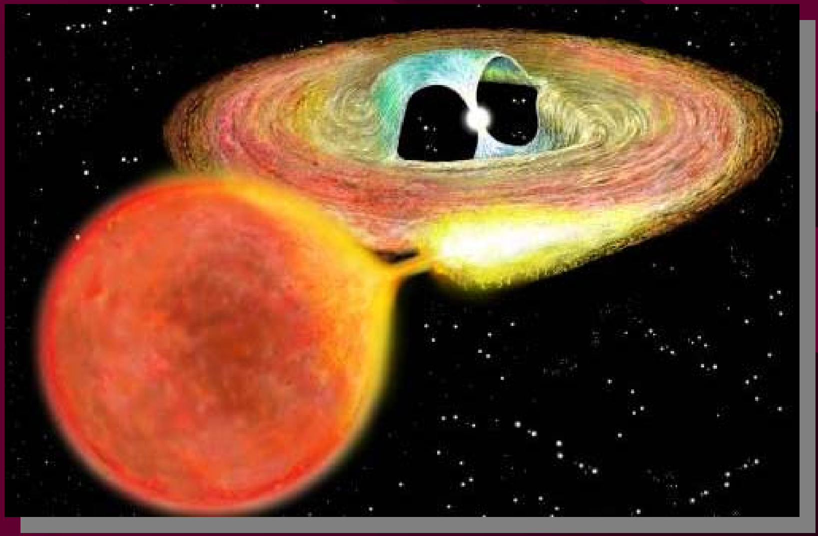


H. Richer '97

Probing Accretion Processes

- Accreting white dwarfs tend to be bright and change on moderate timescales.
- Build an empirical "Newtonian" understanding of accretion for comparison with black-hole and neutron-star systems.
- What about magnetic white dwarfs?





White Dwarfs: Close

- Many of the outlined observational endeavors for neutron stars will reap significant gains in the study of white dwarfs as well.
- EXIST, Constellation-X and Chandra will discover and characterize many accreting dwarfs.
- LISA will detect gravitational radiation from many WD binaries and maybe some isolated ones.
- The continuation of space-based optical/UV astronomy fosters the discovery of faint WDs.