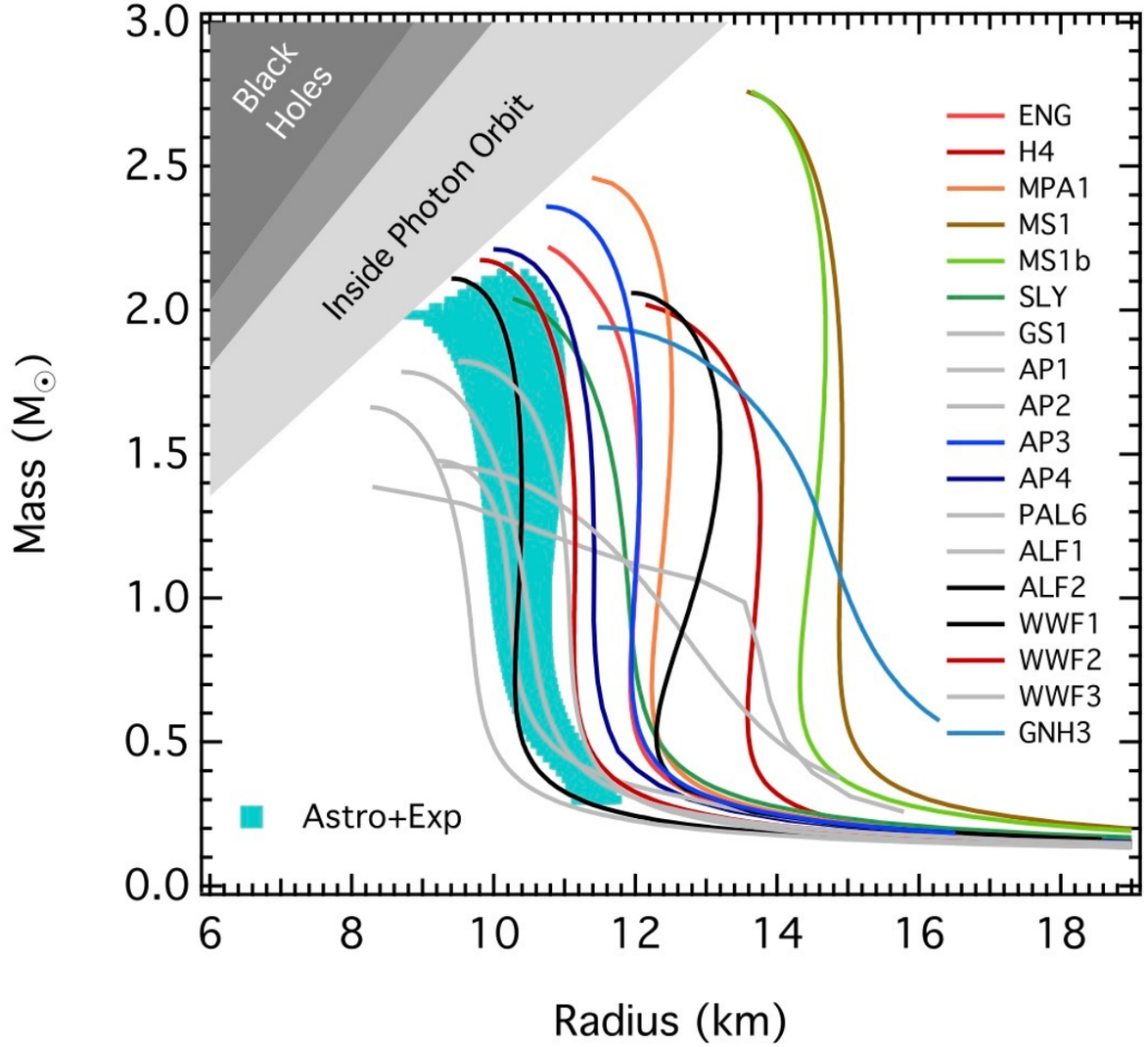
Neutron Star Science with the X-ray Surveyor

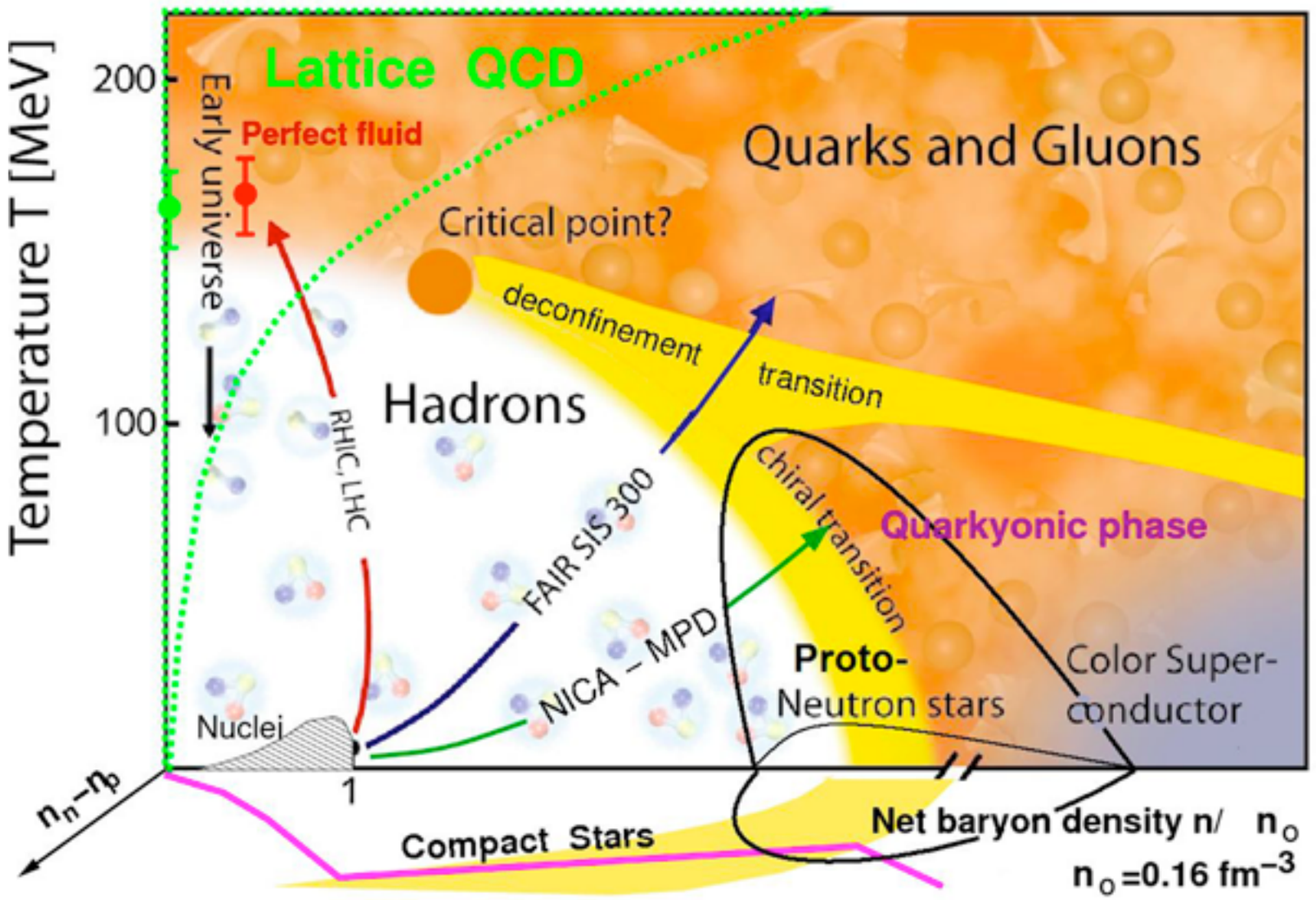
Feryal Ozel



Open Questions Neutron Star Astrophysics

- The Nature of Dense Matter
- The Evolution and Effects of Magnetic Fields
- Observations of Neutron Star Mergers

Open Questions in QCD and Dense Matter



- Expect quark degrees of freedom at ~3 ρ_{ns}
- But the interactions of quark matter?
- Strangeness? (e.g., hyperons?)

Why is Dense Matter of interest to Astrophysics?

- Supernova Mechanism
- Neutron Star/Black Hole Division
- Coalescing Neutron Stars:
  - Gamma-ray Bursts
  - Gravitational Waves

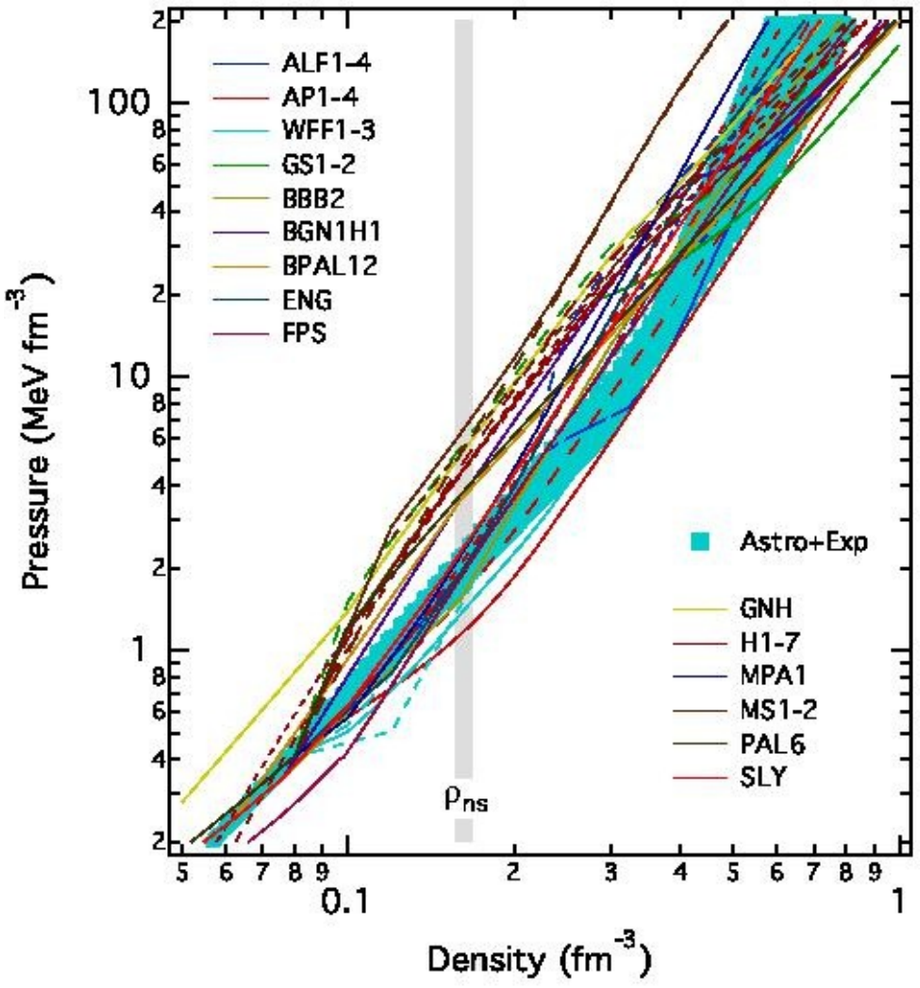
Movie credit: Luciano Rezzolla

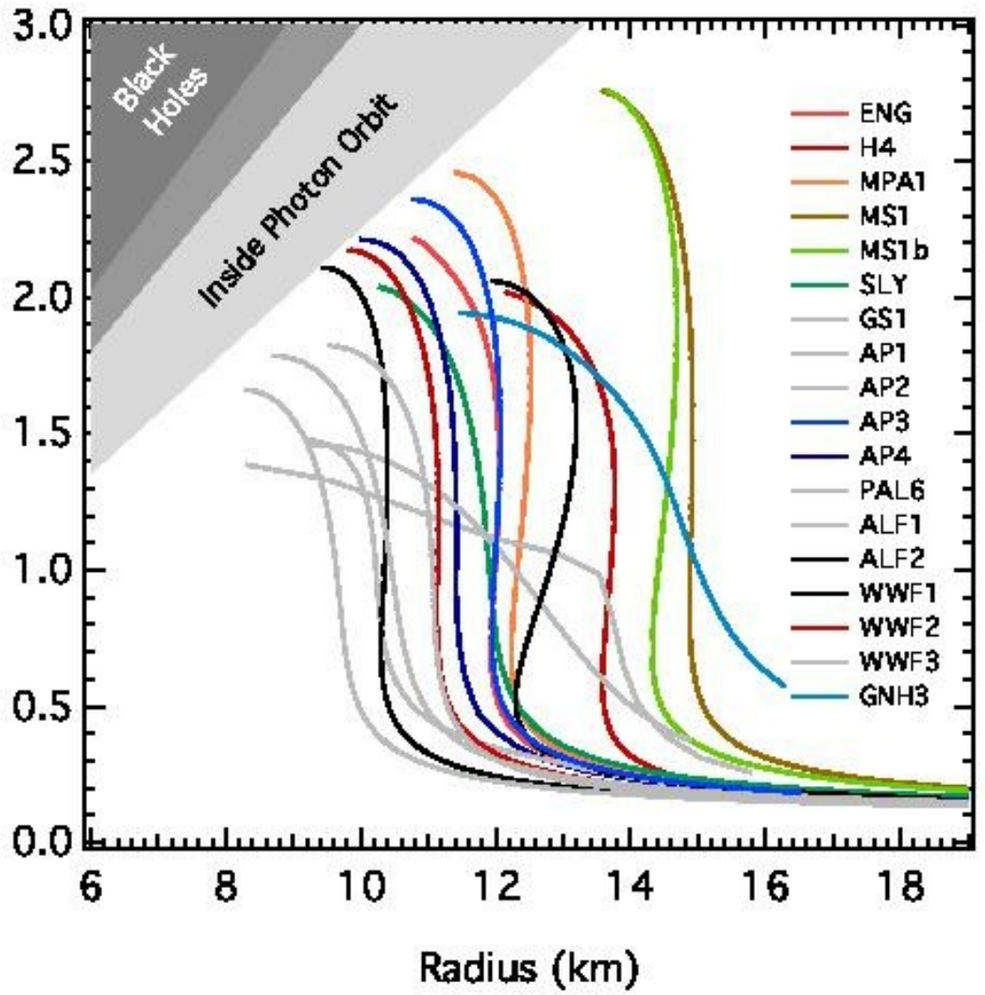
Using Neutron Stars for QCD

- Neutron star mass-radius relation maps faithfully to EoS
- Measure radii and control systematics
- Make measurements using new methods

What do the Radii Data Tell Us?

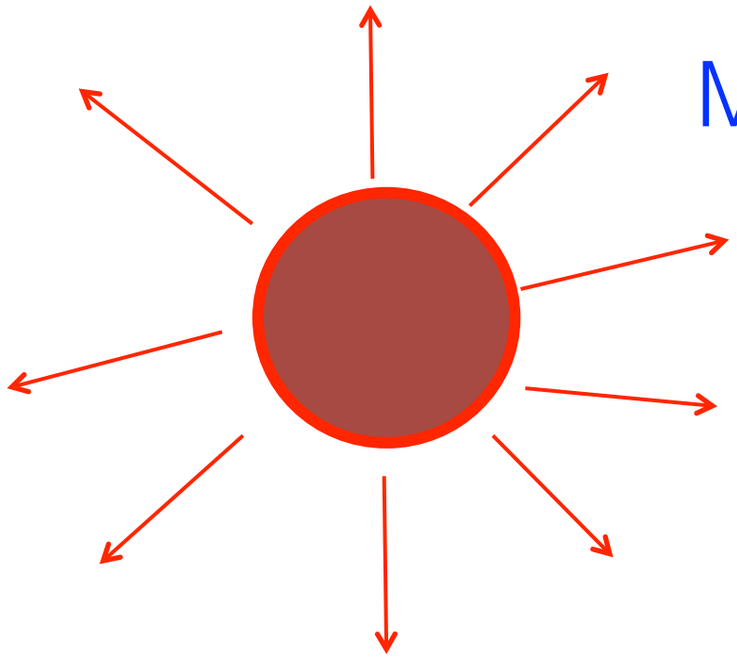
Neutron Star (M,R) relation maps faithfully to the EoS P(ρ)





Lattimer & Prakash 2001; Ozel & Psaltis 2009

Measurement of Radii



Method: Broadband Spectroscopy

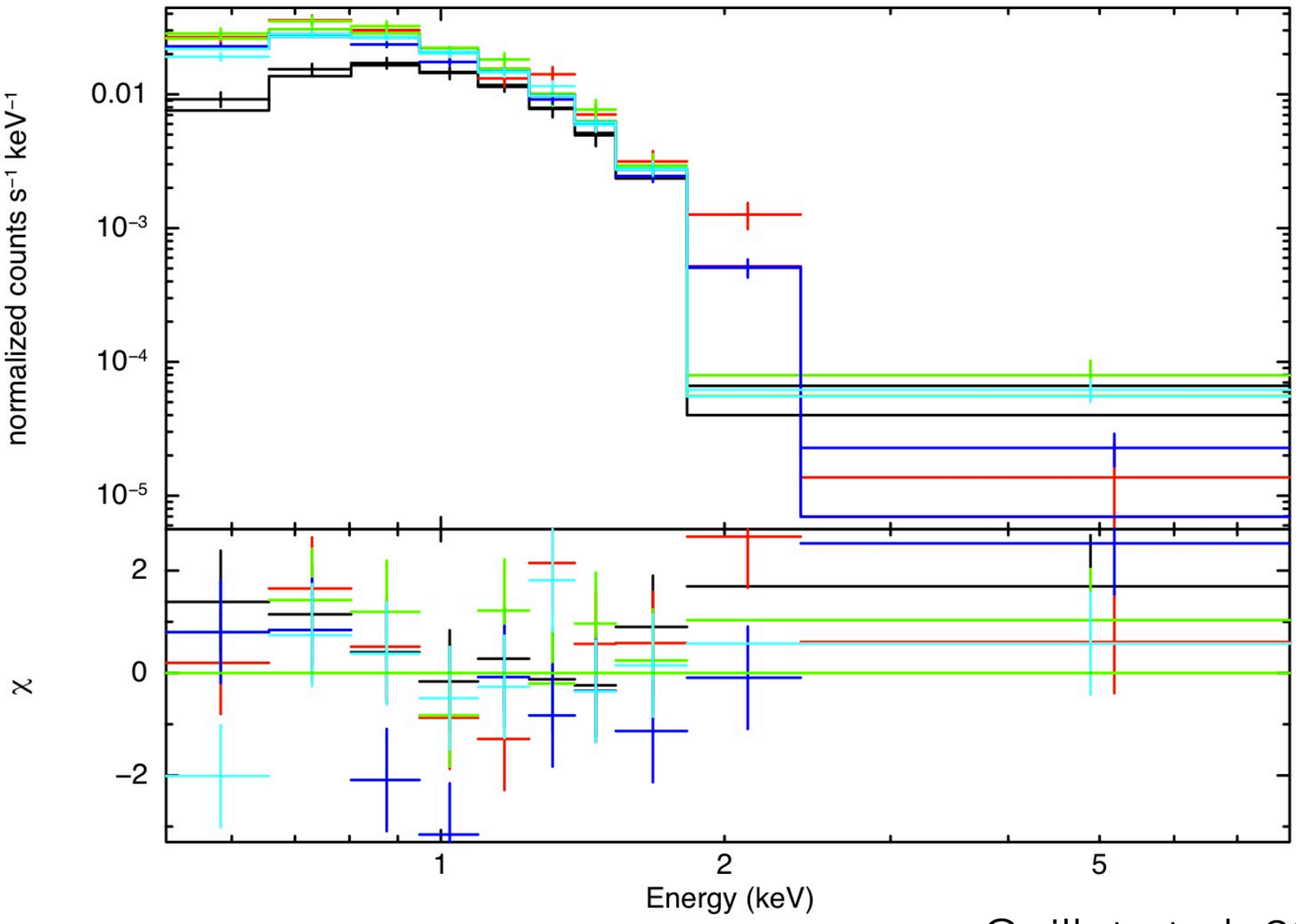
$$R^2 = \frac{F\ D^2}{\sigma\ T^4}\left(1 - \frac{2GM}{Rc^2}\right)^{-1}$$

TARGETS

- Little/no accretion disk emission
- Little/no magnetospheric emission
- Low magnetic field

The Radius Measurement from qLMXBs

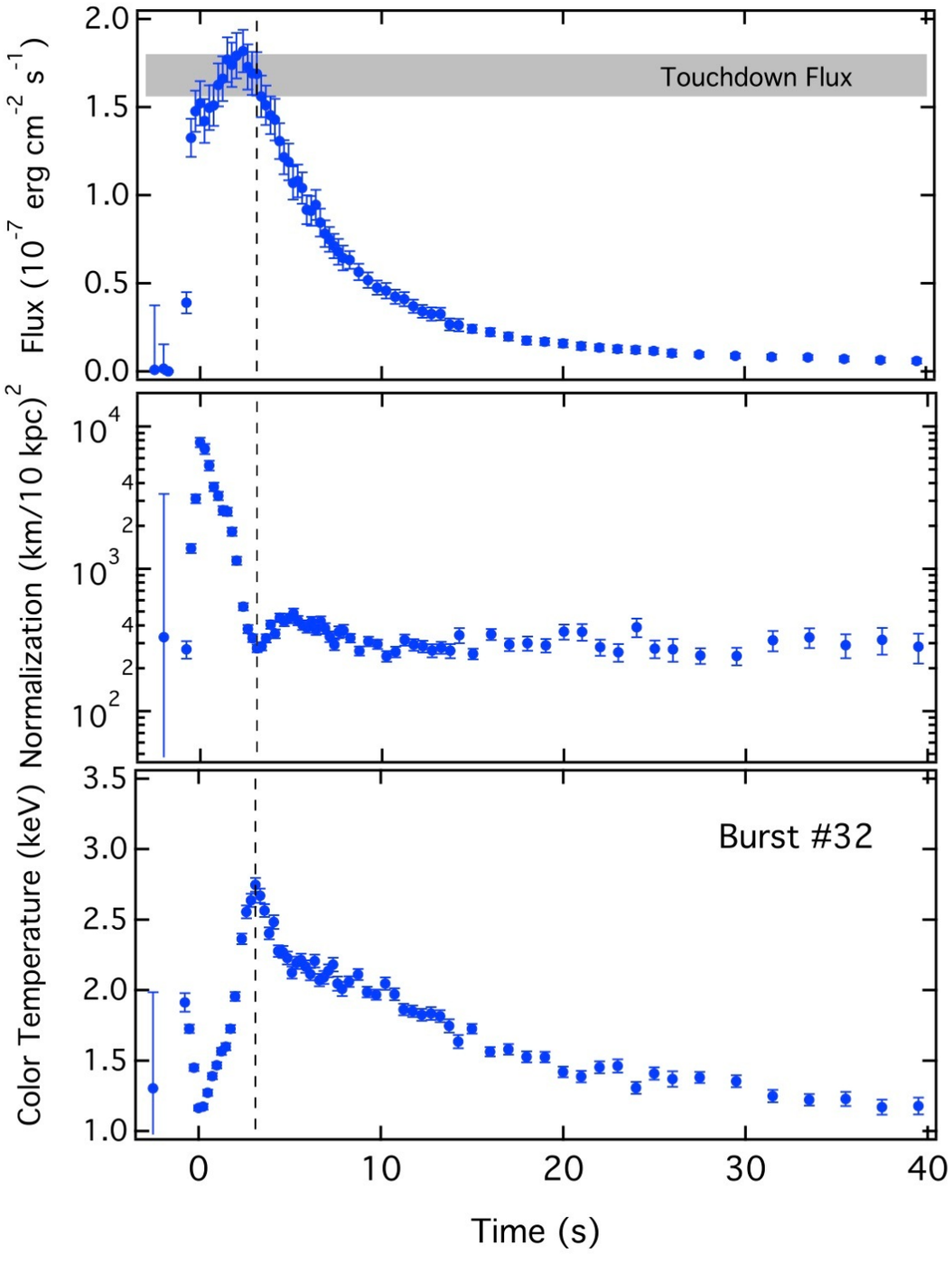
Chandra observations of U24 in NGC 6397
at five different quiescent epochs



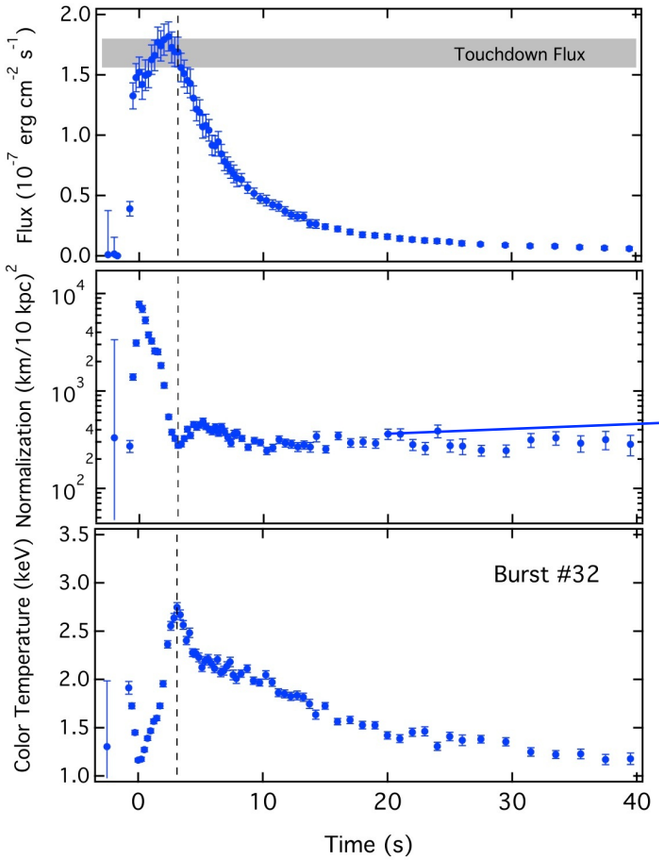
Guillot et al. 2011

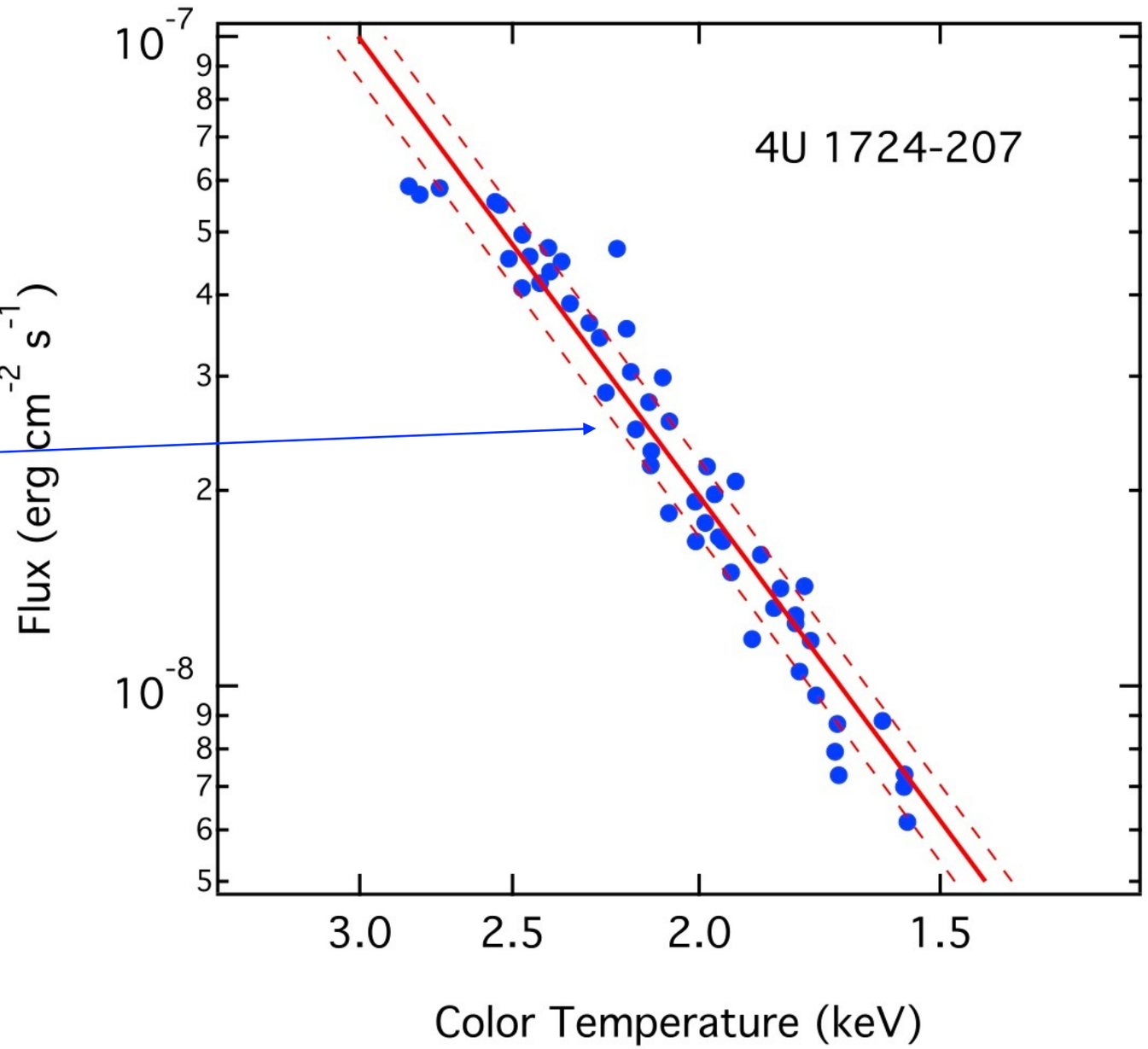
Chandra's angular resolution has been essential for globular clusters

Radius Measurement using Thermonuclear Bursts

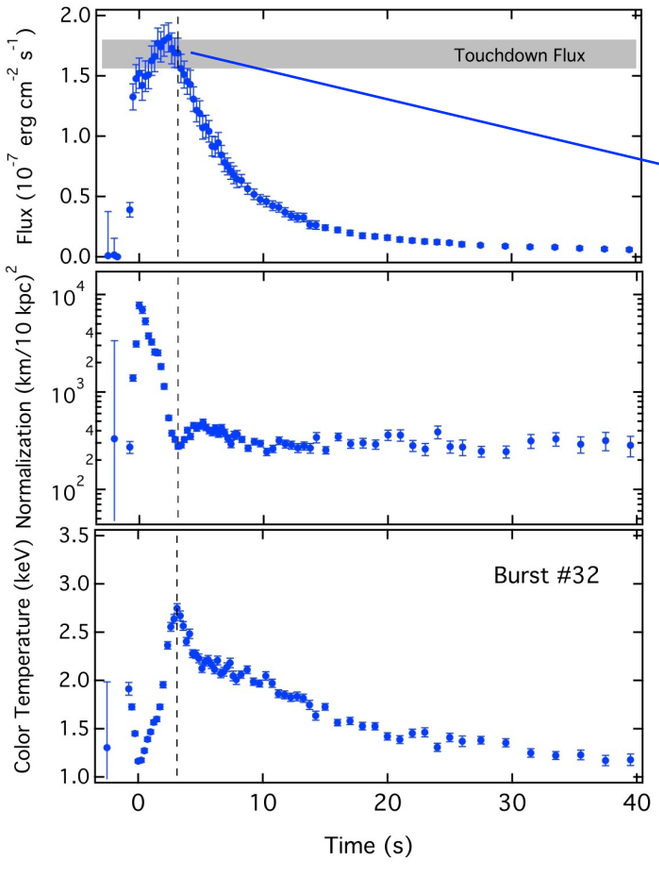


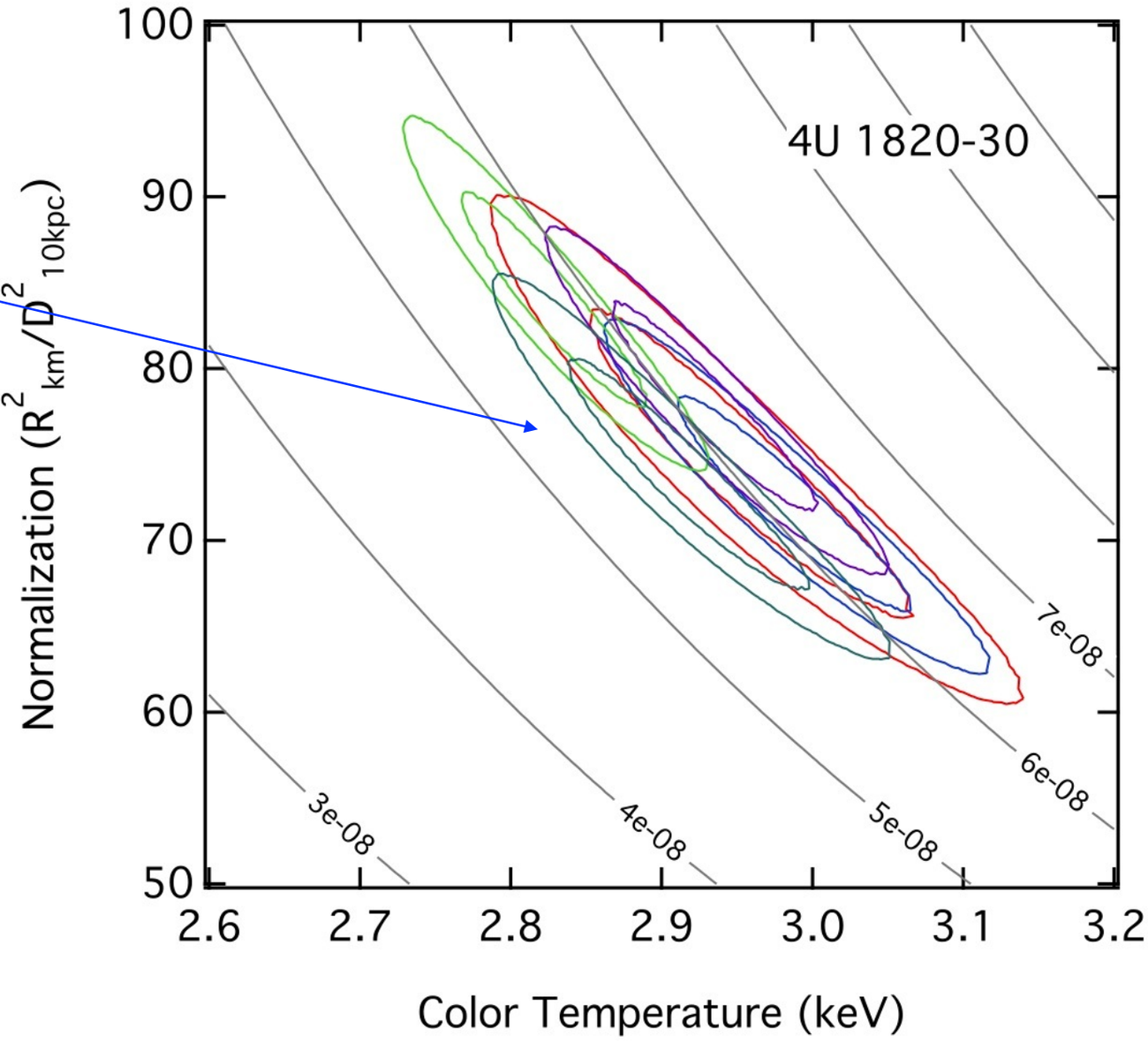
Radius Measurement using Thermonuclear Bursts





Radius Measurement using Thermonuclear Bursts

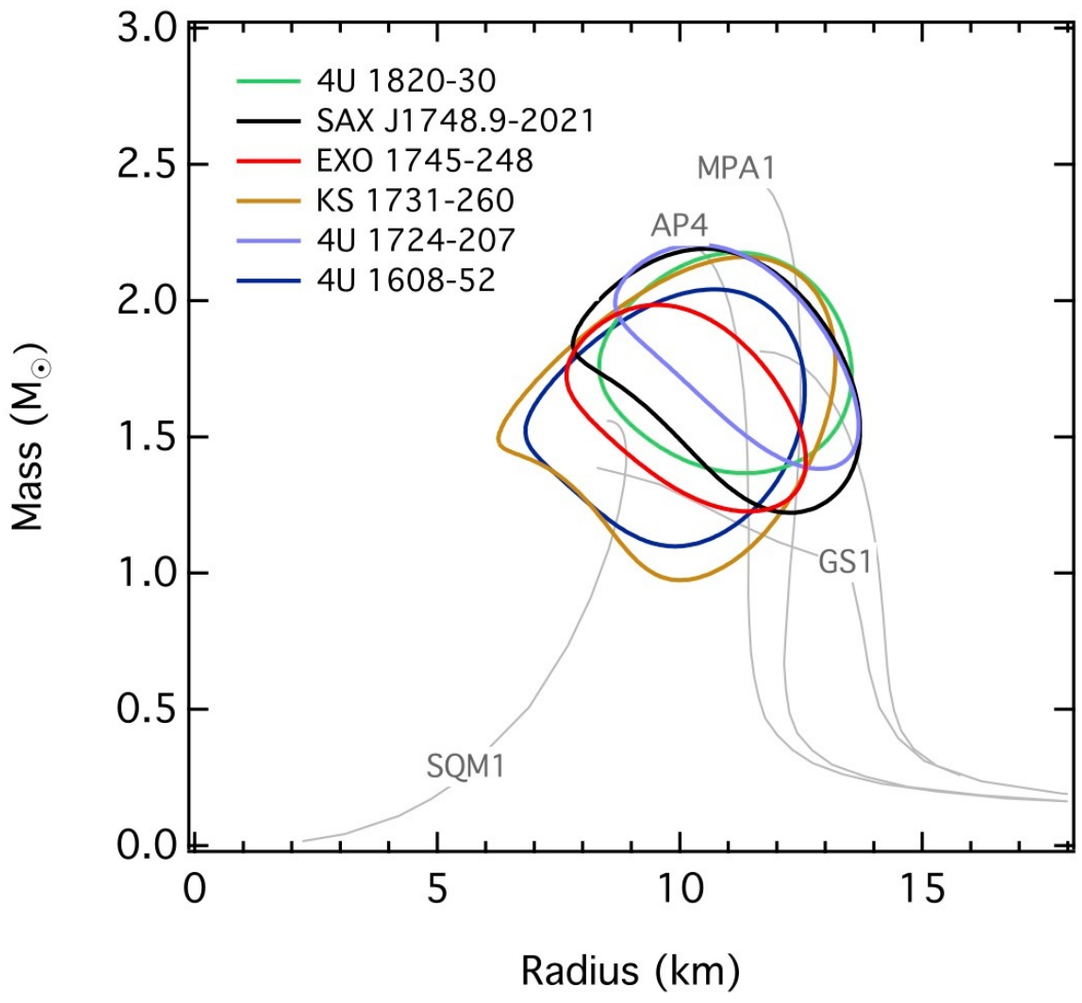




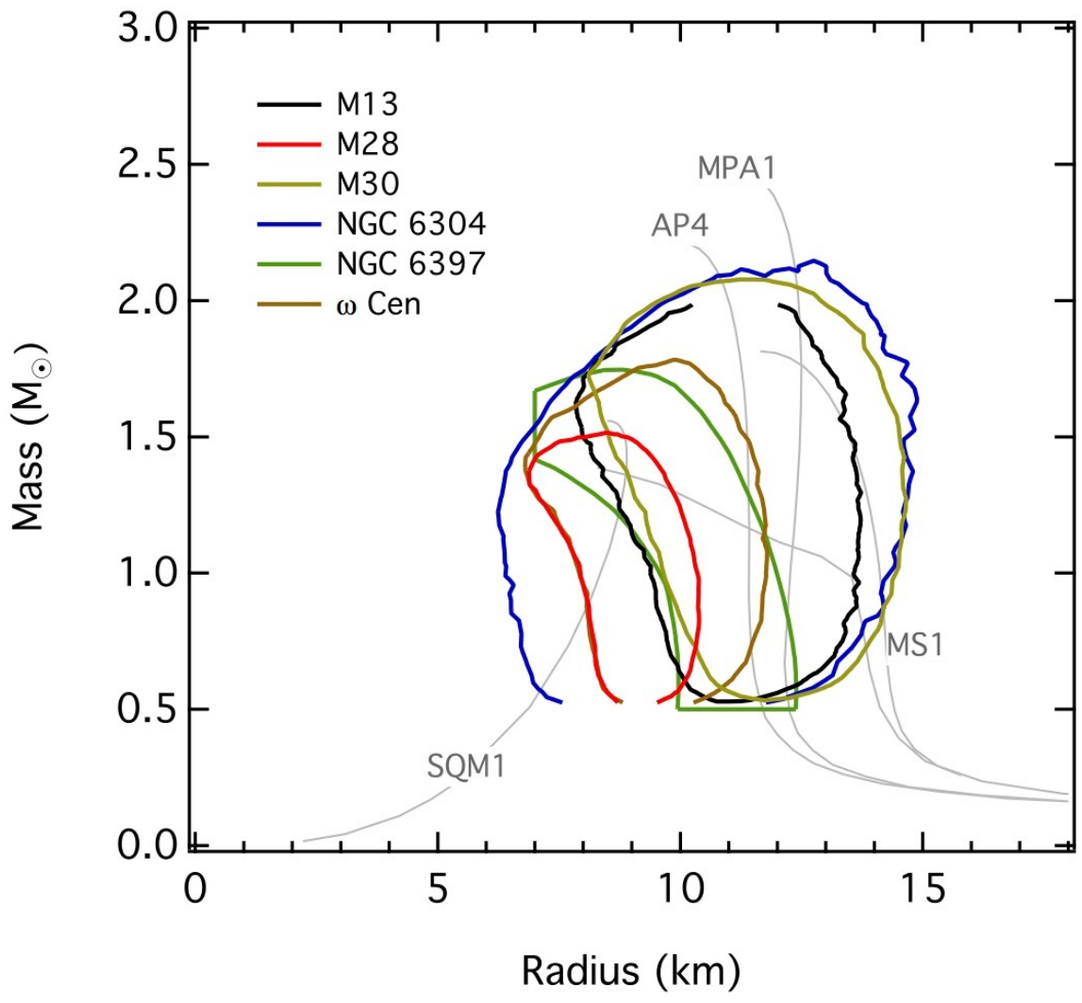
$$L_{\rm Edd} = \frac{4\,\pi\,G\,c\,M}{\sigma_T\,(1+X)}\left(1-\frac{2\,G\,M}{R\,c^2}\right)^{1/2}$$

Neutron Star Radius Results

Six Burst Sources

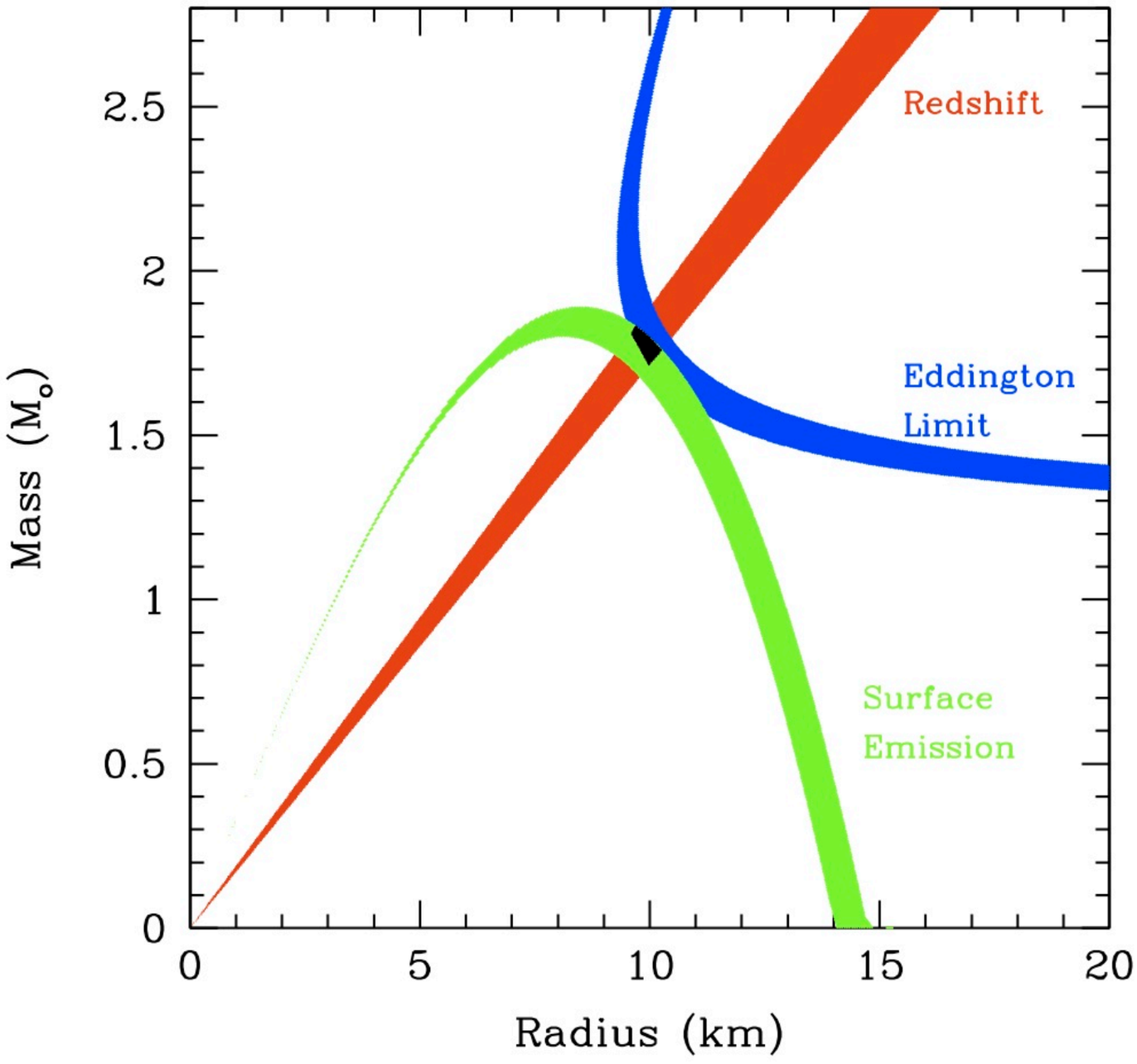


Six+one qLMXBs



Ozel et al. 2015

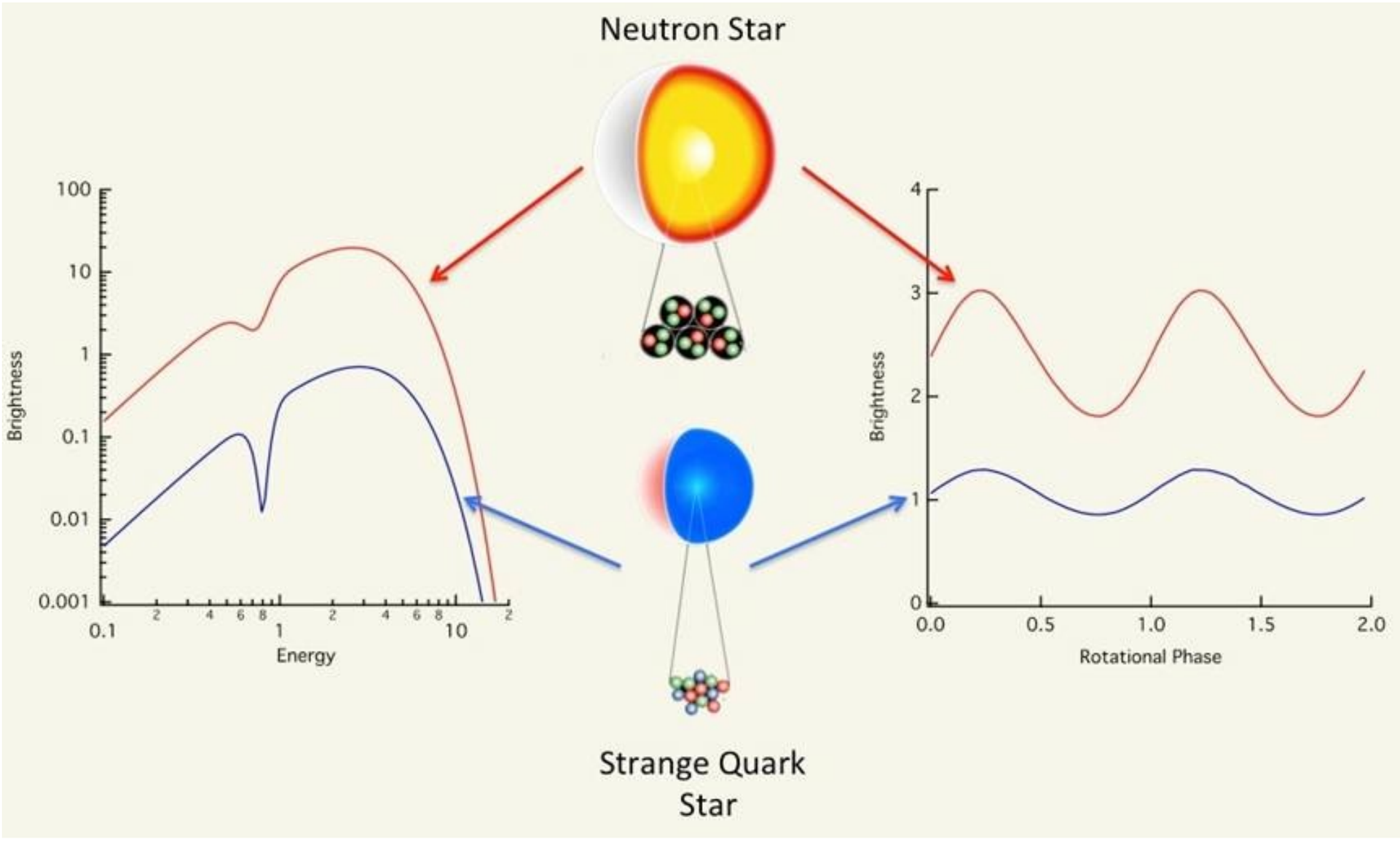
Measurement of Radii



Expected Lines from NS Surfaces

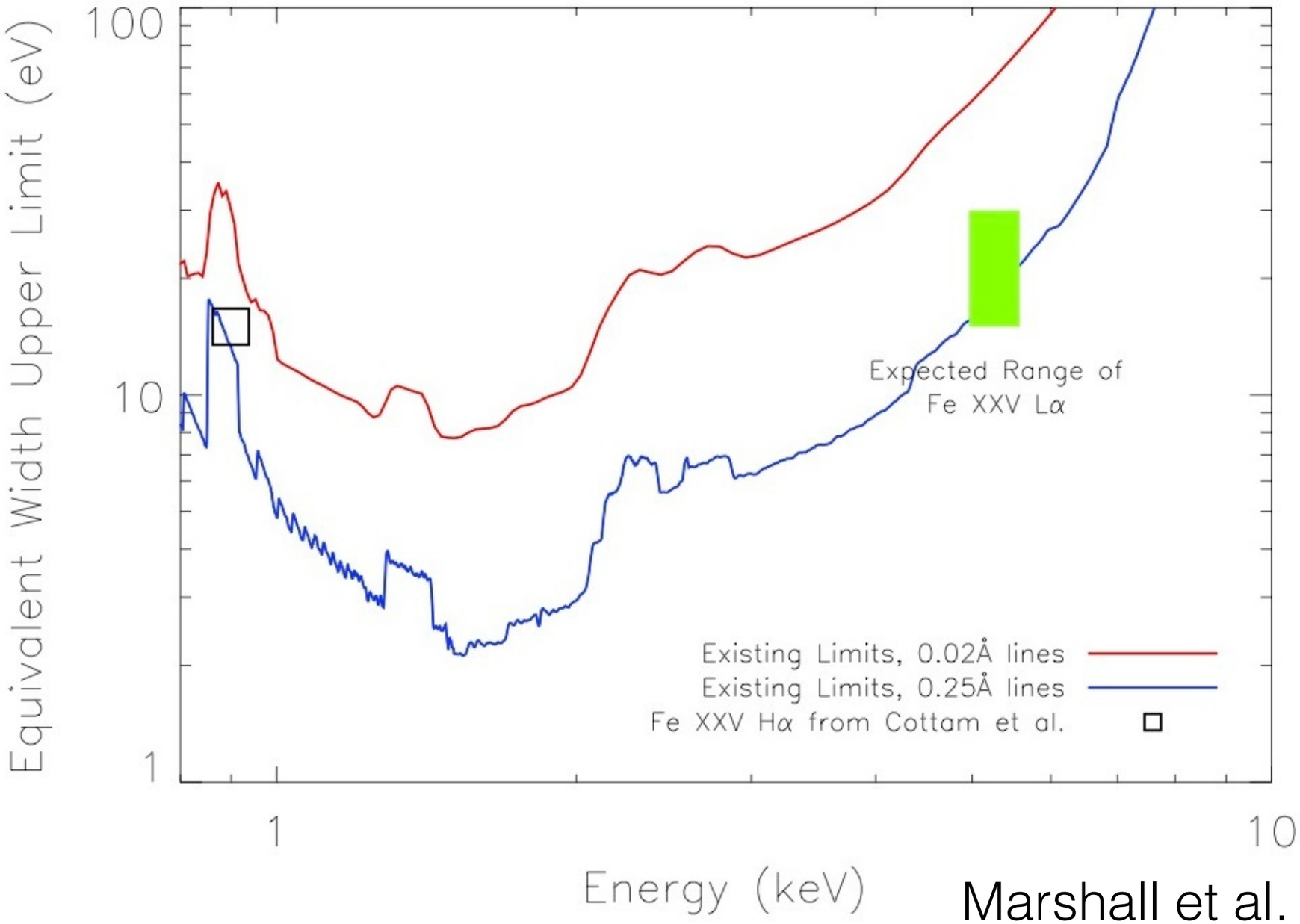
- Observing line features are difficult but doable
- Settling time very short: look in the right places
- Account for line broadening effects
- Have sensitivity and energy resolution

Expected Lines from NS Surfaces



Line redshifts and widths are a function of the NS compactness

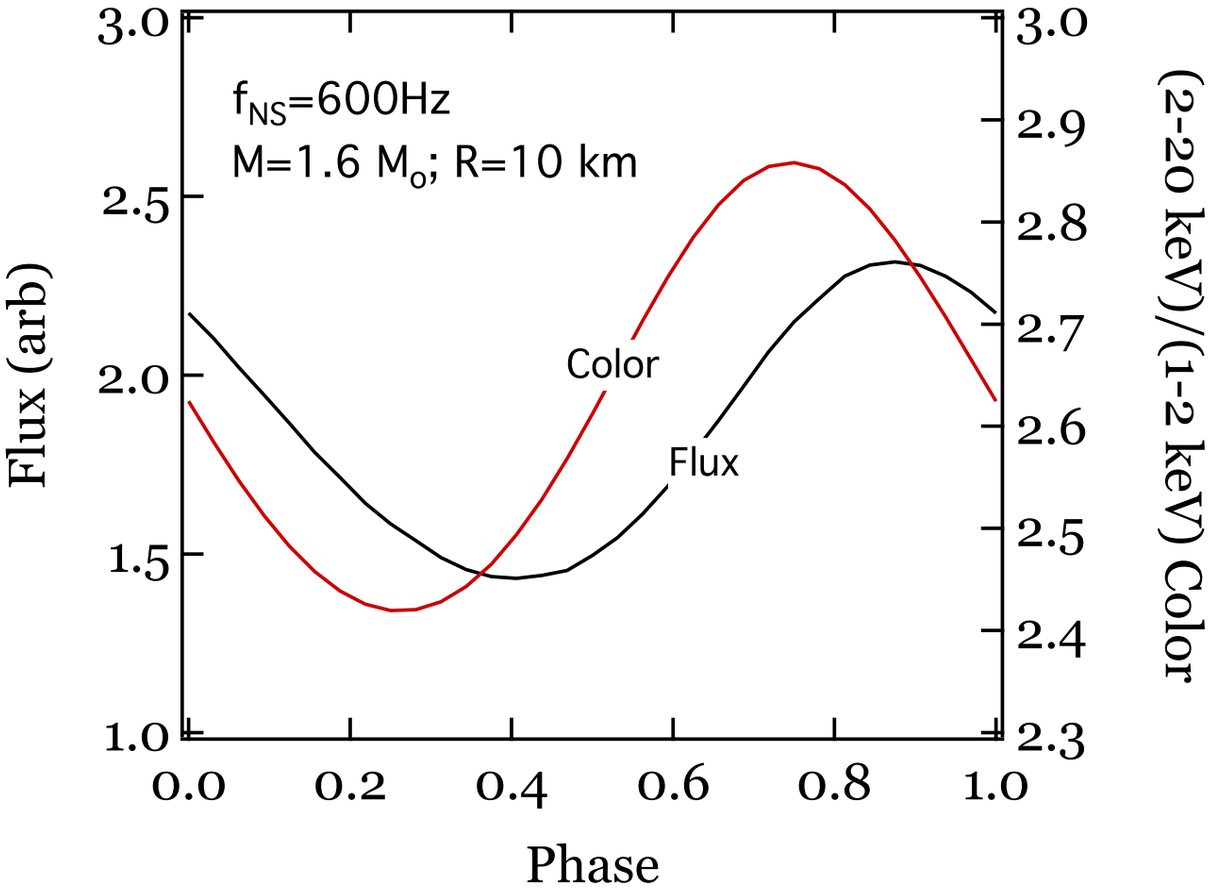
Searches so far have failed



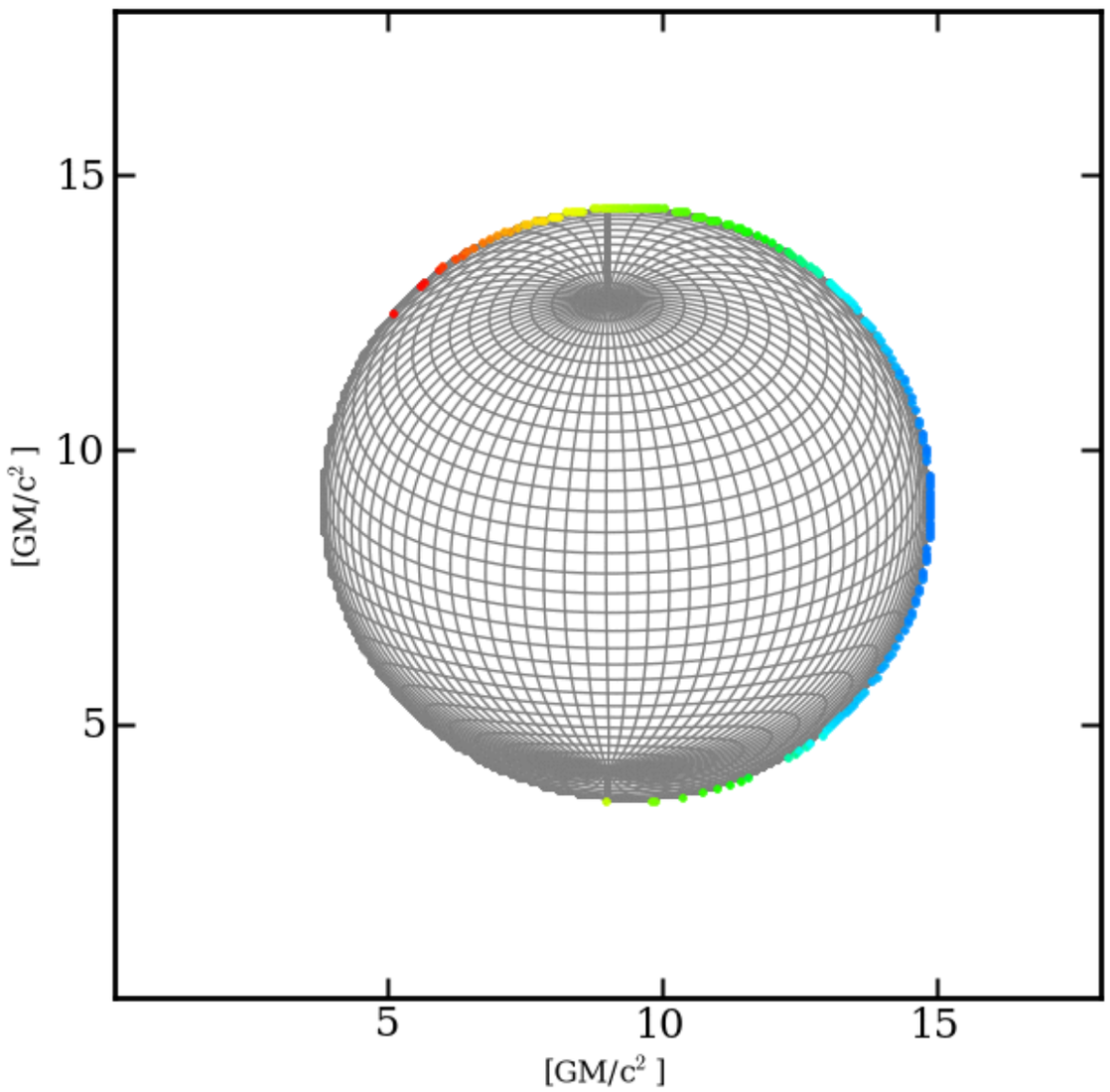
Marshall et al.

→ Need Collecting Area

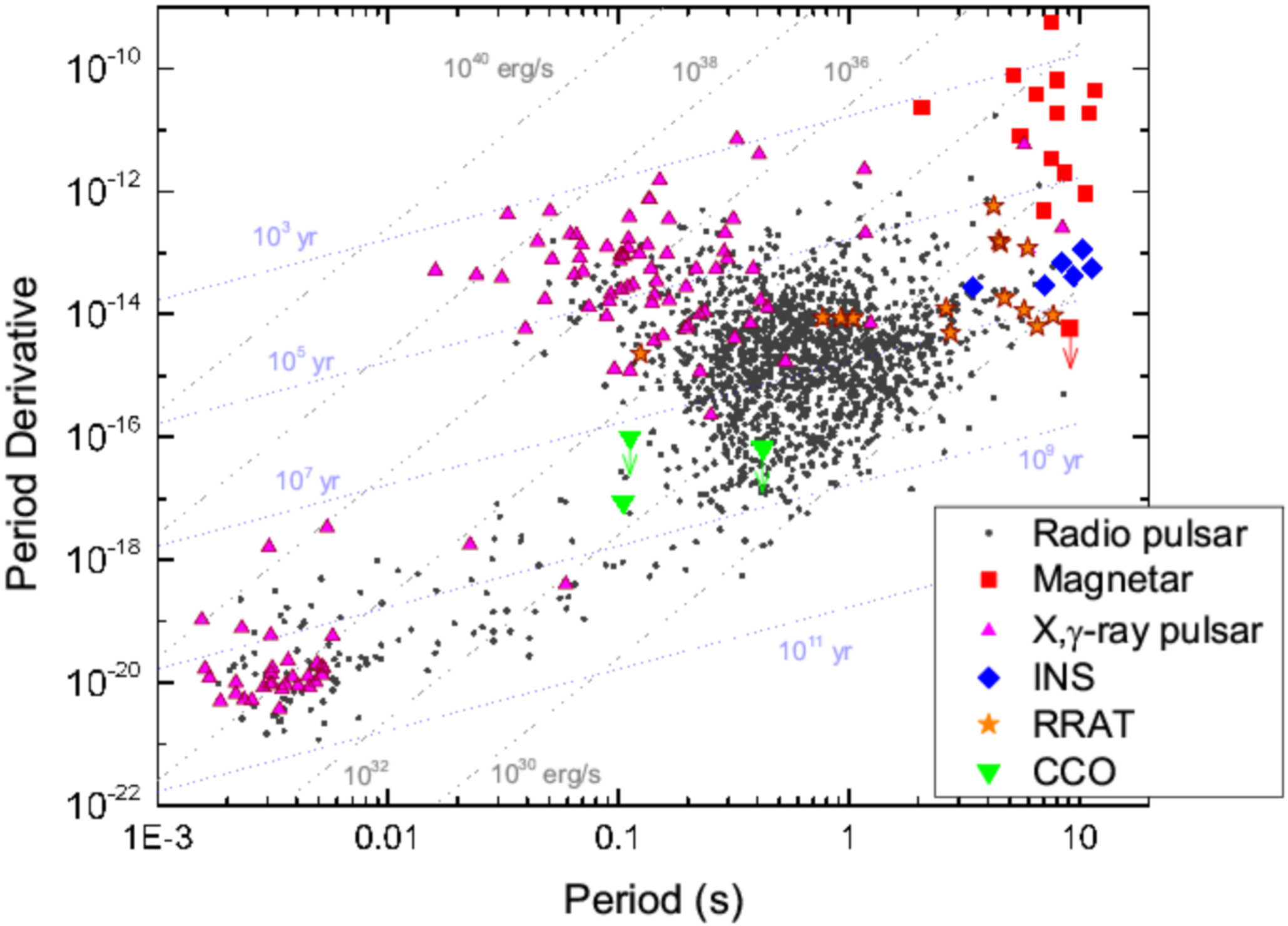
Radius Measurements from Pulse Profiles



NICER

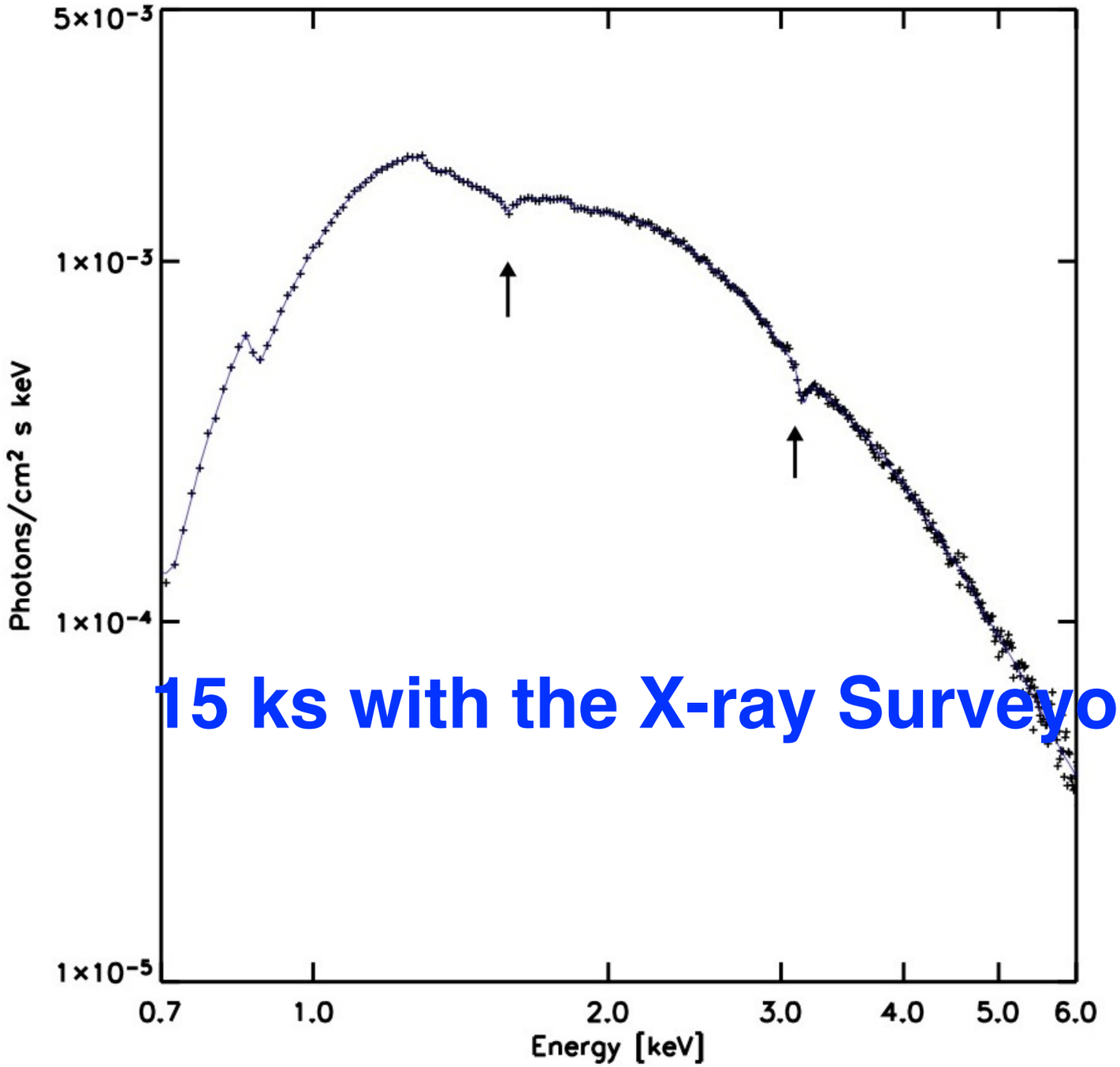


Mysteries of Magnetic Fields



Spectral Features: p cyclotron line

Simulated 750 ks X-ray spectrum of 1E 1048.1-5937 with Chandra



15 ks with the X-ray Surveyor

The Need for an X-ray Surveyor

- Neutron star science questions interest a broad physics/astrophysics community
- Large collecting area is key for progress
- As is energy resolution for lines, spectral distortions
- Angular resolution for crowded fields
- Time resolution allows bright burst spectroscopy