Exploring the Neutron Star
Where We See the Densest Matter in Our Universe

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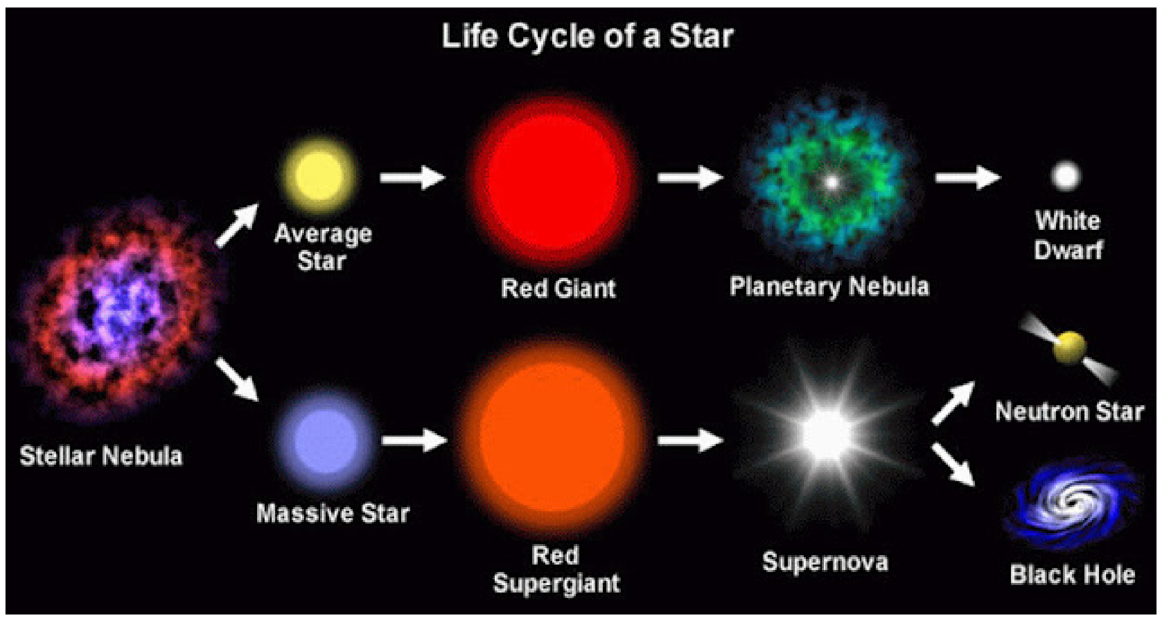


Motivation - How matters interact in extremely dense environments?

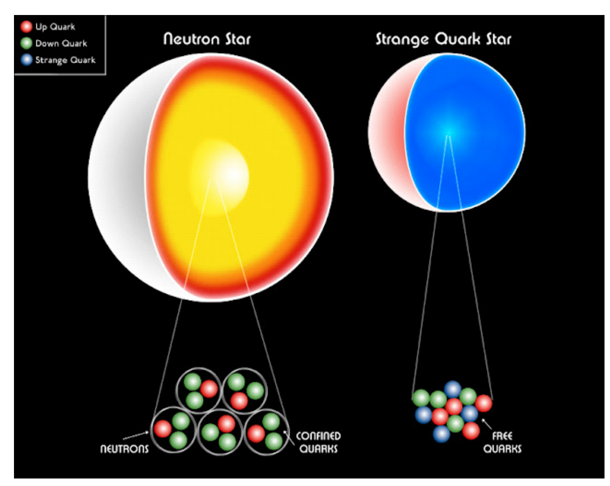
Radius ~ 10 - 20 km (size of Manhattan)
Mass ~ 1.4 - 2.0 solar mass
Spin frequency ~ 300 - 600 Hz
Core density ~ 5 - 10 * nuclear density

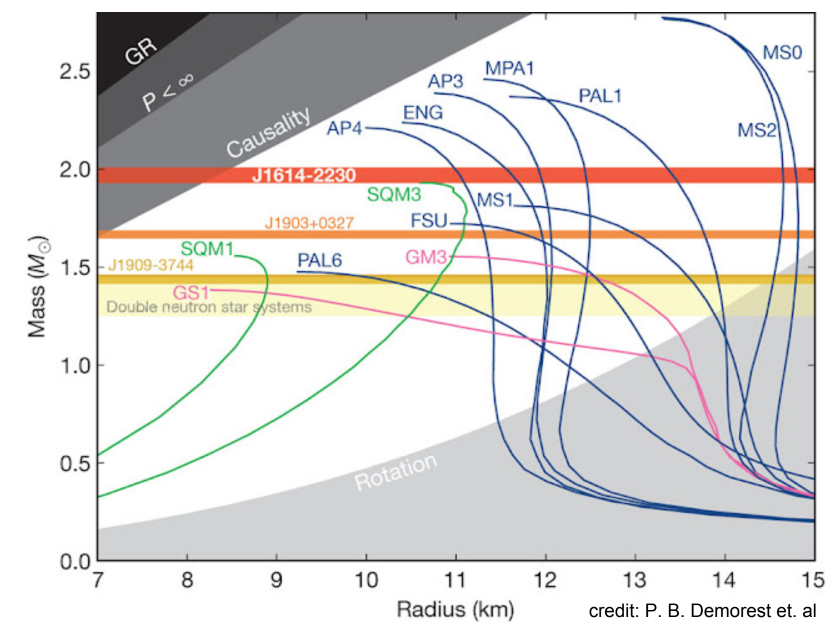
Currently, we do not yet understand how matters interact at such high densities and low (comparatively) temperatures, and no terrestrial experiments seem possible. So the study of neutron stars can give us insights to fundamental nuclear physics.

Key to constrain the theory - Measuring the mass, radius and spin of neutron star

Mass, radius and spin frequency of the same neutron star are to be measured in order to constrain equation of state (EOS) models that are available in the literature.

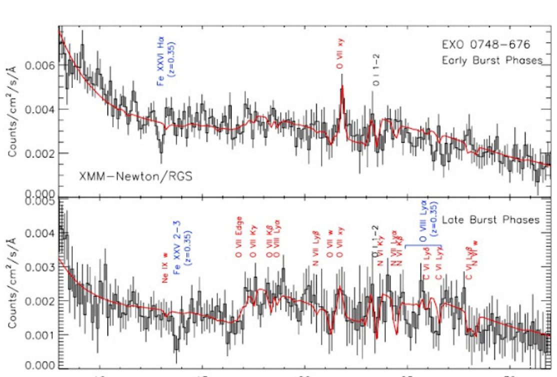
While we have ways to measure the spin and mass of the neutron star, the radius measurement is the hardest, it's no better than measuring the size of an atom in California from New York!



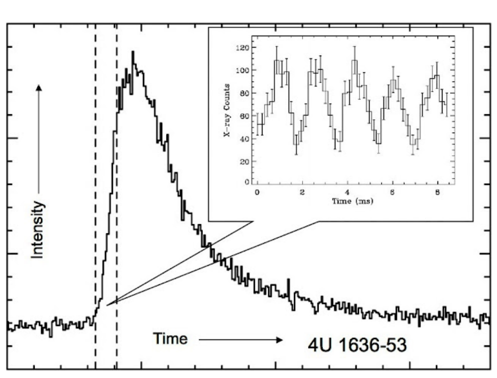


credit: P. B. Demorest et. al

X-ray Bursts - A probe to the intrinsic properties of neutron stars



Cottam, Paerels, & Mendez 2002



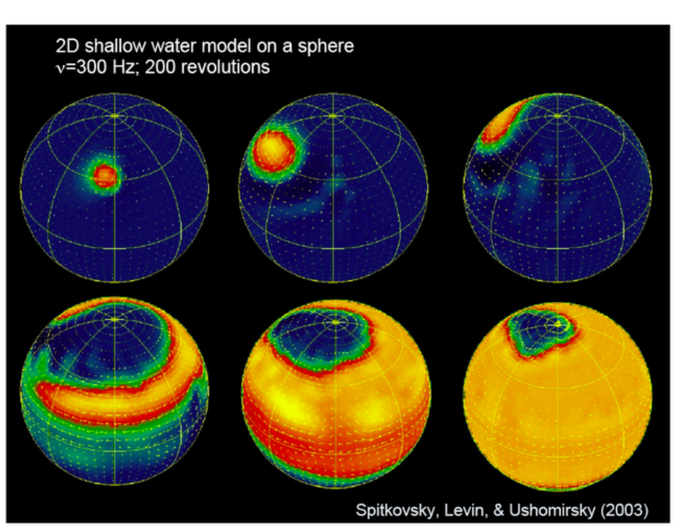
credit: T. Strohmayer

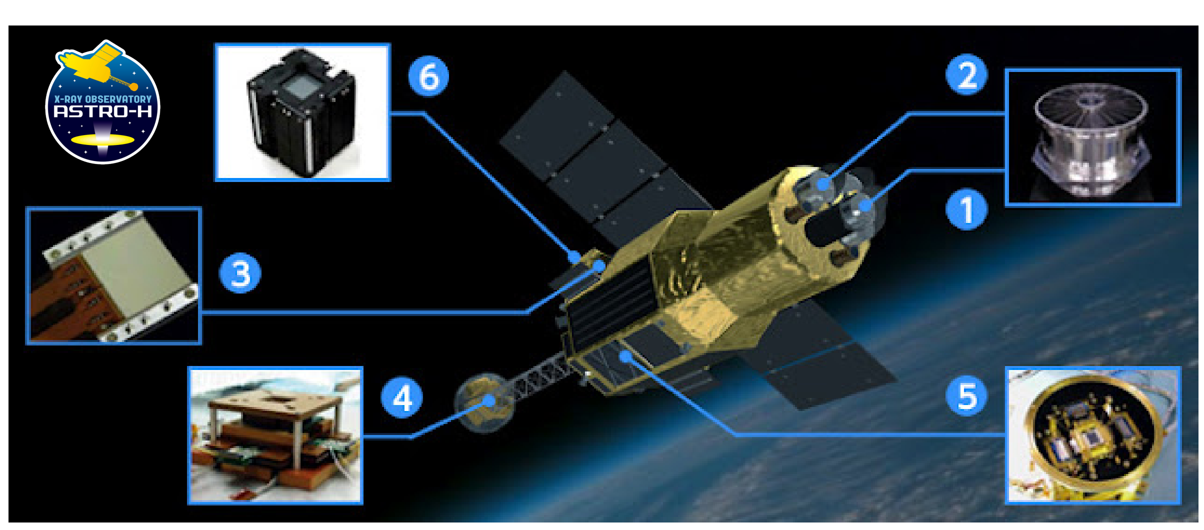
Instead of direct measurement, we can study neutron star surface phenomenons that are linked to its intrinsic properties.

X-ray bursts are unstable nuclear burning of accreted matter on the neutron star surface. They are observed in Low Mass X-ray Binaries (LMXB), Where a neutron star has a companion of < 1 solar mass. They show timing and spectral features that can be used to constrain the mass, radius and spin frequency of the same neutron star.

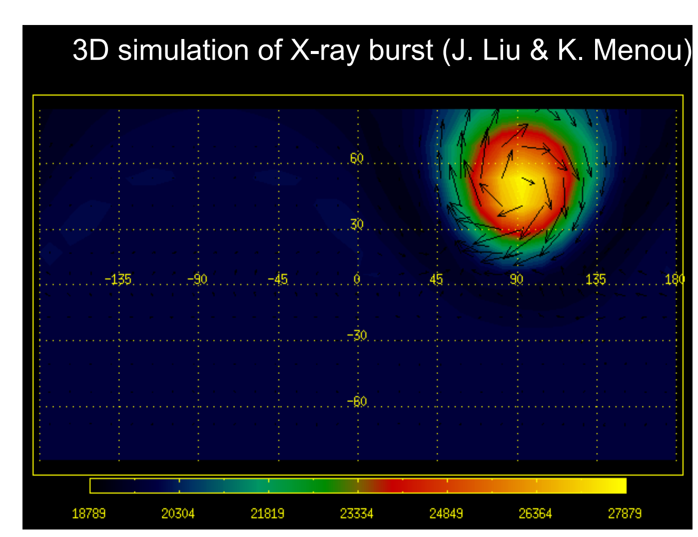
Source	Freq.
4U 1608-522	620
SAX J1750-2900	600
MXB 1743-29	589
4U 1636-536	581
MXB 1659-298	567
Aql X-1	549
KS 1731-260	524
SAX J1748.9-2901	410
SAX J1808.4-3658	401
4U 1728-34	363
4U 1702-429	329
4U 1916-053	270

Summer mission - Matching the theory with observations





1.Soft X-ray Telescope 2.Hard X-ray Telescope 3.Soft X-ray Imager 4.Hard X-ray Imager 5.Soft X-ray Spectrometer 6.Soft Gamma-ray Detector



Previous works

An early 1D model by Cumming & Bildsten (1999) successfully explained the magnitude and sign of observed change in the burst oscillation using hydrostatic expansion and conservation of angular momentum, but failed to account for the asymmetry of these burst oscillations.

A 2D model by Spitkovsky et. al. (2002) has explained the very short rising time, the large frequency drift of burst, and the high degree of coherence of burst oscillations during the cooling tail. However, this model remains incomplete due to the discount of the vertical mixing and heat diffusion, which can be crucial for burning front propagation.

This work

Understanding the coupling among vertical layers requires developing a 3D model, which is the focus of this work. Previously, we have done 3D simulations of X-ray burst with combinations of various neutron star parameters.(spin, mass, radius, pressure, hotspot shape & location, etc.)

To do in the summer & beyound:
1. Screen and analyze observation data (RXTE, Suzaku, & Ginga space telescope);
2. Compare the simulation results with observation data;
3. Study the capability to detect absorption lines with ASTRO-H, JAXA's next X-ray space mission to be launched in 2013.