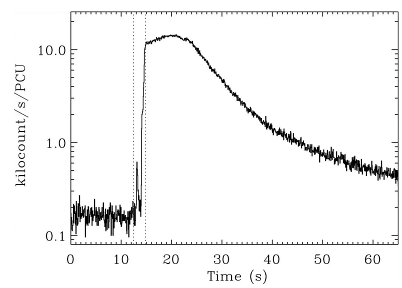
Weak Hydrogen Flash as the Precursor of X-ray Bursts?

In an X-ray binary star system, a neutron star accretes hydrogen-rich gas from a sun-like companion star. When the mass transfer is fast, the accreted gas is heavily compressed and heated to high temperature so that the hydrogen burning is limited by beta-decay processes, i.e., the conversion of a proton to a neutron. These weak nuclear reactions slowly and stably fuse hydrogen to helium. Hence, a helium layer is formed under the hydrogen burning layer. If the mass transfer speed is maintained, enough helium fuel will be piled up and can trigger an explosion known as normal *X-ray Burst*. However, when the mass transfer is somehow slowed down, to the point where hydrogen burning is governed by the proton capture process, then hydrogen can burns explosively. The heat from the explosive hydrogen burning transports both up to the surface and down to the helium layer. If the helium layer is sufficiently heated, it can ignite and trigger a violent explosion. Since the helium layer is usually ~ 10 times more massive than the hydrogen layer, it takes ~ 10 times longer for the heat from helium burning to transport to the surface. From the observational point of view, the X-ray burst is composed of a weak burst first (due to hydrogen explosive burning) and then a strong burst (due to helium explosive burning). Such kind of burst was discovered by Bhattacharyya and Strohmayer (2007), who found that, when the accretion rate drops to around 0.01 Eddington rate, an unusual burst with a weaker precursor occurs (shown in the bottom-right figure).

To test this argument, a multi-zone model with varying mass accretion rate is needed. We are using a 1-D Lagrangian hydrodynamical scheme (the KEPLER code) to simulate the burst and to understand the mechanism of the unusual burst with a precusor.

An X-ray binary star system. Matter flows from a sun-like star (in the background in this image) to the surface of a neutron star (the white spot in center of the disk) through a disk orbiting the neutron star. Image credit: Space Telescope Science Institute



X-ray burst shows a precursor event. This burst was detected on 2002 October 19 by *RXTE* PCA from the accreting millisecond pulsar SAX J1808.4-3658. Image credit: Bhattacharyya & Strohmayer (2007).

Researchers:

Peng, F.[1]
Brown, E.F.[2]
Heger, A.[3]

[1] Caltech, [2] MSU, [3] LANL

This work has been supported by the **J**oint **I**nstitute for **N**uclear **A**strophysics under NSF-PFC Grant PHY-02-16783. FP is supported by the Sherman Fairchild Postdoctoral Fellowship at Caltech. EFB is supported by the NSF under grant AST-0507456. AH is supported under the auspices of the National Nuclear Security Administration of the U.S. Department of Energy at Los Alamos National Laboratory under Contract No. DE-AC52-06NA25396.

References:

Bhattacharyya, S. and Strohmayer, T.E., An Unusual Precursor Burst with Oscillations from SAX J1808.4-3658, 2007, ApJ, 656, 414