Spectral analysis of bursting source MXB 1728-34

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Wilga 2012
Why these objects are interesting

Spectral analysis allow us to determine mass and radius of neutron star

so

allows for constrain of the EOS and physics of the super dense matter

provide new information for model of neutron star birth as well as for the model of binary stars evolution
Values of the neutron star mass show strong concentration around $M = 1.4 \, M_{\odot}$, at least for pulsars.

Is it truth for other types of objects?

Theoretically mass of the neutron star can be in the range $0.1 - 3.0 \, M_{\odot}$
Basic features of X-ray bursters

Discovered 35 years ago by Grindlay et al. (1976) and by Belian et al. (1976).

These sources are neutron stars in interacting binaries.

Companion star has low/very low mass.

Weak magnetic field of the neutron star.

During decay of the burst spectrum becomes softer — type I of the burst.

X-ray bursts are recurrent events but not strictly periodic.

Time intervals between bursts are typically in the range \(\sim 10^4-10^5\) s.

Energy released per burst is \(\sim 10^{39}\) ergs.

The source of the X-ray burst is the thermonuclear flash.
Example of the burst spectrum
Properties of MXB 1728-34

Discovered as X-ray source in 1976 during Uhuru sky monitoring.

Identified as X-ray burst source in 1976 (Lewin et al.; Hoffman et al.).

Source type atoll.

Time between X-ray bursts is typically 4–8 hr.

Spin frequency of the neutron star is 364 Hz.

Optical counterpart was not observed.

Estimated distance is 4.2–5.1 kpc.

This source does not show superbursts.
Assumptions of our method

We analyzed spectra integrated over 0.25 sec at the end of bursts. We assume that at this time atmosphere is static with constant temperature.

We negligible presence of accretion disk and accretion flow. Only the neutron star atmosphere is source of photons.

+ specific assumptions of model atmospheres
Assumptions of the model atmosphere

Plane-parallel geometry.
Hydrostatic and radiative equilibrium
Non-rotating neutron star.
Magnetic field does not modify opacity coefficients.
We do not include relativistic corrections in model atmosphere.
We include f-f, b-f, b-b processes and Compton scattering.
Photons are scattered on relativistic electrons with thermal velocity distribution.
We allow for large relative energy and momentum exchange between photon and electron during a single scattering.
We reject well-known Kompaneets approximation!
Our results

1, 2 and 3-σ confidence ranges (gray contours), based on spectra during the bursts.

Light gray rectangle – Shaposhnikov et al. (2003),
dark gray rectangle – Kaminker et al. (1989),
dashed line – Fujimoto & Gottwald (1989).
Summary

Our method allows us for the determination of a neutron star parameters, which are independent on the distance.

We determined radius of the neutron star, and not just the radius of emitting area!

The best fit we obtained for models with He/H=0.11 Fe/H=10\(^{-3}\). For these models 1-σ confidence level gives:

\[
M = 0.103-1.516 \ M_{\odot} \quad R = 1.948-9.779 \ \text{km}
\]

These parameters are in agreement with EOS of strange quark matter.

In the very near future, models with other chemical compositions will be fitted.
Post Scriptum

January 5th 2012, after 16 years, Rossi X-Ray Timing Explorer finished its mission, because of money.