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# DISTURBANCES IN THE DISC FLOW OF SELECTED LMXBs* AND THE VARIATIONS IN THEIR LIGHT CURVES

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***Abstract:*** *Most stars in the Universe have a companion and they are known as binary stars. In the current survey, we focus on the special part binaries, Low-Mass X-ray Binaries (LMXBs)*. Using the mechanisms of hydrodynamics, we studied the behaviour of accretion disc flow after weak disturbances in velocity and density. We obtained that this causes some instability in the disc dynamics and has an effect on the shape of light curves. The observational data of the estimated objects is used to create light curves. We analyzed the variations in their shape, caused by different possible sources.*

## I. Introduction to LMXBs

X-ray astronomy is the branch of astronomy that studies the hot regions of our universe.
In fact, the coronas of the Sun and other stars, with their temperatures of several million degrees, produce x-rays, as do the shock waves associated with supernovae, the surfaces of young neutron stars, the accretion discs and accretion shocks associated with degenerate dwarfs, neutron stars, and black hole candidates in binary systems, the hot gas in clusters of galaxies, and the massive black hole candidates at the cores of galaxies. Our sky is bright with these various X-ray sources.
In current survey we stress our view on the binary stars with accretion discs as X-ray sources (Alpar et al, 1984). Low mass X-ray binaries (LMXBs) are binary systems with a compact object that accretes matter from a low mass optical companion star filling its Roche lobe (van den Heuvel 1975). The LMXBs include semi-detached binaries consisting of either neutron star or black hole primary, and a low mass secondary. Ways of formation and evolution are important and not yet fully understood (Lipunov et al. 2007; Belczynski 2008).
Observationally: the spectra of the LMXB /at maximum light/ are devoid of normal stellar absorption features. The ratio of their X-ray to optical luminosities is much larger than unity. Neutron stars are created in supernovae, and they are generally more massive than the Sun, with maximum masses around 2.5 solar masses the precise mass depends on the physics of the interior, which is highly uncertain.
Some of the Low mass X-ray binaries are soft X-ray transients. They appear suddenly as bright X-ray sources and then disappear smoothly for weeks to months. Neutron stars in low-mass X-ray binaries can be identified when an X-ray burst is observed that lasts around tens of seconds.
Theoretically: the LMXBs are accompanied with accretion discs, which are hydrodynamical flow. Most likely, the reason of these bursts is hidden in the flow fluctuations, such as some unstable phenomena: shock waves, turbulization and pattern formation.
For neutron stars, about half of the gravitational potential energy is released as matter flows through the accretion disk, and the rest is released when the matter falls from the accretion disk into the neutron star's atmosphere.
If the neutron star has a weak magnetic field or there is an absent of such, the accretion disc extends to the neutron star's atmosphere, where the problem becomes very difficult from a theoretical standpoint. The interaction is between supersonic centrifugally - supported fluid and a pressure-supported subsonic atmosphere. In the current survey we study the case of accretion flow without magnetic field.
It is shown in the Figure 1 the image of X-ray binaries in Globular cluster M15, received by Chandra X-Ray satellite.

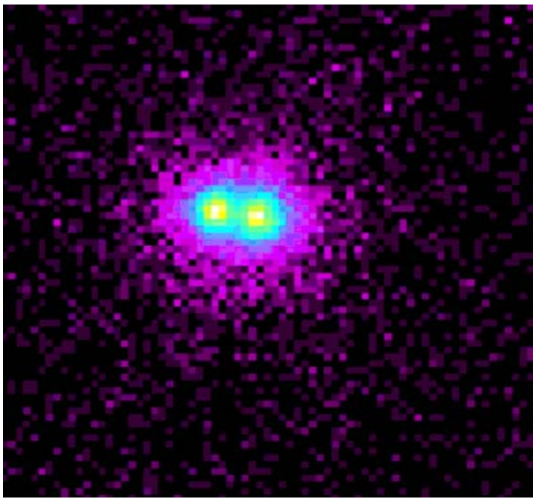

Figure 1. The two X-ray binary systems in Globular cluster M15. This Chandra's image shows two binary systems with neutron stars: one (left) whose neutron star is hidden by accretion disc and one (right) which X-ray burst reveal another neutron star.
**Credit**: NASA/GSFC/N.White, L.Angelini

In the second section we present our theoretical results on the dynamics of the accretion flow, after week consecutive disturbances of velocity, density and pressure. In section III, we turn to the observational data and obtain another evidence of unstable behaviour of disc flow.

### II. Basic theoretical features of the considering problem

As it is known the accretion disc is a hydrodynamical flow. In this reason we apply in a section down the equations of hydrodynamics that describe the dynamic of the flow. We receive these equations, as we take in account of the presence of neutron stars in a binary system.
To study these features for the astrophysical flows, such as accretion in binary star, we choose to explore by the equations of Navier-Stokes, because of the fullness of their form and the possibility of suitable transformations. When the neutron stars are the pair of the binaries, we consider viscous, rotating fluid and we couldn't neglect the gravitational potential and the centrifugal force. In that case, the Navier – Stokes equation takes the form:

(1) $$\frac{\partial v}{\partial t} + v.\nabla v = -\frac{1}{\rho}\nabla P - \Omega \times (\Omega \times r) - \nabla\Phi + \nu\nabla^2 v$$

Where the basic denotations are: $\rho$ - is the mass density of the flow; we consider $\rho \neq const$ so that the radial entropy gradient exists; $v$ - is the velocity of the flow; $P$ - is the pressure; $\nu$ - is the kinematic viscousity; $\Omega$ - is the angular velocity; $\Omega \times (\Omega \times r)$ - is the centrifugal force of the rotating accretion flow; $\nabla\Phi$ - express the gravitational potential.
The energy balance equation for a viscous non-ideal fluid is:

(2) $$\frac{\partial}{\partial t}\left[\rho\left(\frac{1}{2}v^2 + \varepsilon + \Phi\right)\right] + \nabla.\left[\rho v\left(\frac{1}{2}v^2 + h + \Phi\right) - 2\eta\sigma.v\right] = 0\,;$$

where: $\frac{\partial}{\partial t}\left[\rho\left(\frac{1}{2}v^2 + \varepsilon + \Phi\right)\right]$ - is the total energy density, where the first term denotes the kinetic energy, the second is the internal energy and the third express the potential of the gravitational field.
$\left[\rho v\left(\frac{1}{2}v^2 + h + \Phi\right)\right]$ - is the total energy flux, where $h = \varepsilon + P/\rho$ is the enthalpy.
$\eta$ is the shear viscosity of the flow;

$\sigma$ is the rate of shear;

Following the assertion that the flow becomes instable when some of the parameters: velocity, density or pressure are disturbed, we make the necessary transformations of the above equations, including the quantities:

(3) $V = v + u\,;\rho_0 = \rho + \rho^{'}\,;\ p = P + p^{'}\,;$

Where $V,\rho_0,p$ are the total quantities of velocity, density and pressure; $v,\rho,P$ are the time averaged values; $u,\rho^{'},p^{'}$ are the perturbations in time. We choose for the perturbations to be in an exponent form and for the velocity it is: $u = \mathbf{exp}(if_c t + im\varphi)$, where $f_c$ is the complex frequency of perturbation; $m$ is the mode number, over $\varphi$ direction.
In Figure 2 below it is shown the velocity excesses and the density fluctuations distribution over r.

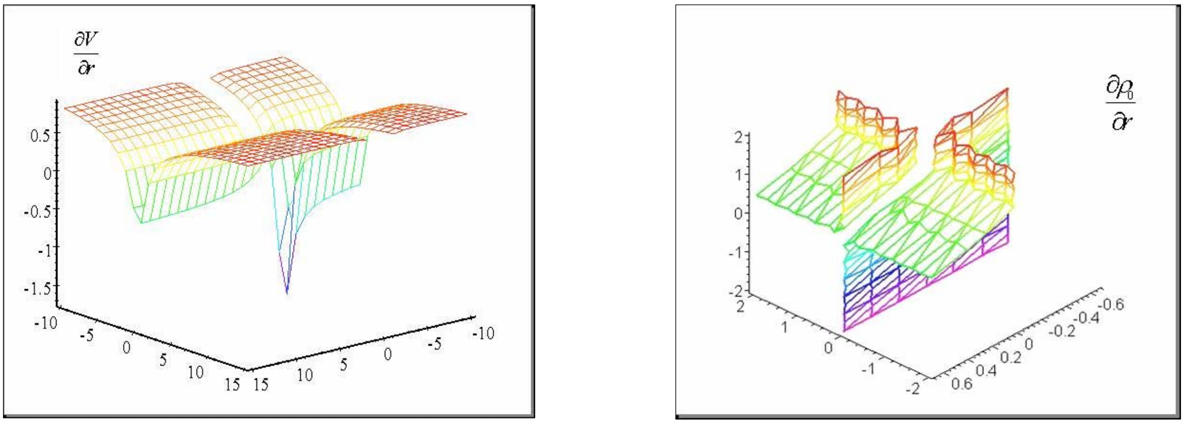


Figure 2. The images show the variations and exceeding of fluctuations of density (fig.2b) and velocity (fig.2a). These two graphics are received applying analytical examinations of the perturbed quantities and using appropriate mathematics software to parameterize the value.

In the above theoretically considerations, we showed some instability features in accretion disc flow, according to the above requirements of the neutron stars. In the next section we will consider how these processes have an effect on the light curves of the X-ray binaries with neutron stars as a primary.

### III. Effects on the light curves shape

The shape of the luminosity of LMXBs may provide important information about their long term evolution. Postnov & Kuranov (2005) noted that the observed shape of the LMXBs luminosity function depends on the distribution of the masses of optical donor star. They assume that the X-ray luminosity of the compact object is directly proportional to the mass transfer rate in the binary system.
Measurement of the variation of the X-ray luminosity of an object provides a wealth of information about the dynamics and physical processes in a system. The spin of an object will often appear as a periodic fluctuation in the object's X-ray luminosity. The eclipse of an object by an orbiting companion will appear as a periodic dip in the X-ray luminosity. Instabilities or fluctuations in the flow of material through an accretion disk can appear as random or quasi-periodic fluctuations in the X-ray luminosity, which provides information on the physics of fluid flown onto an accreting source. The last relation is most important for the considerations of the current paper problem and we make a conformation of this fact here.
How this look on the light curves shape, which we create for the selected binaries figures (3, 4, 5). The luminosity of these three binaries has different behaviour. It is essential for our suggestions the magnitude variations of 4 an over. However the magnitude variations in LMXBs are not so high, but changes sharply. These springs, as well, points to the running of unstable processes, usually in a boundary of accretion disc flow.

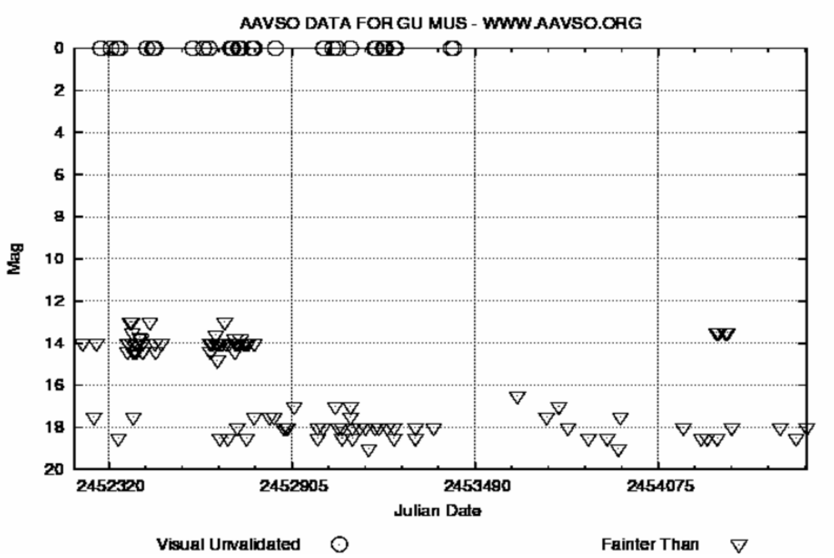


Figure 3. Light curve of LMXB GU Mus /Musca/. This is an ellipsoidal rotating variable, close binary with ellipsoidal components. This binary behaves as intense variable X-ray source. The image is created on the observational data of AAVSO /www.aavso.org/.

There is not enough and rich observational data of LMXBs, because of their specificity. The optical radiation from an X-ray source arises from a different set of processes, and often from different parts of a system than X-rays, so the ability to make these observations provides much more information about the physical conditions at the X-ray source. The coherent kHz oscillations discovering during X-ray bursts from LMXBs strongly suggest (Strohmayer 1996) for the existence of neutron stars in such binaries.

We selected the below LMXBs from the General Catalogue of Variable Stars (Kholopov et al 1987) and Catalogue of CV, LMXBs and related objects (Ritter and Kolb 2003). They are observed, as follows, by the observers of AAVSO.

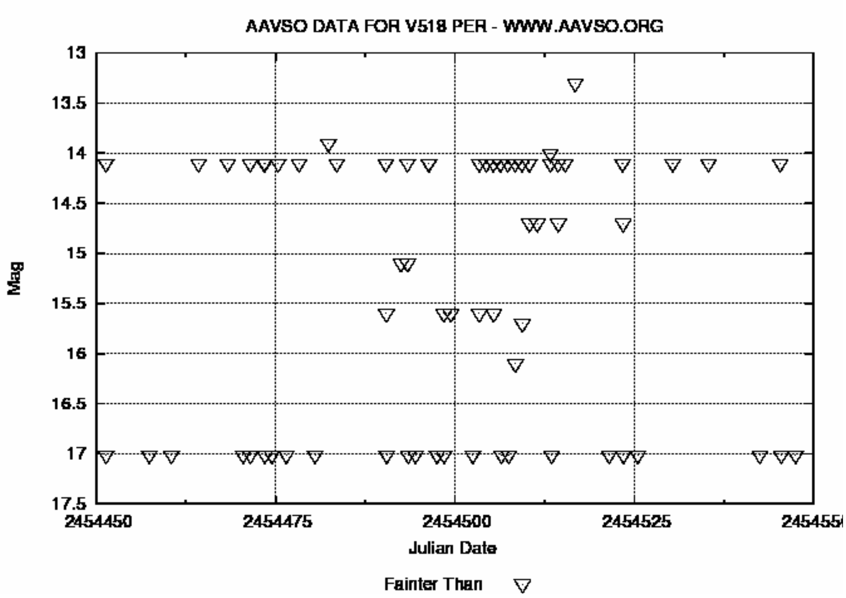


Figure 4. The light curve of LMXB V518 Per /Perseus/ (RK catalogue of X-ray stars). This is an ellipsoidal rotating variable. It is seen the sharp drop of luminosity in a short period. The image is created on the observational data of AAVSO /www.aavso.org/.

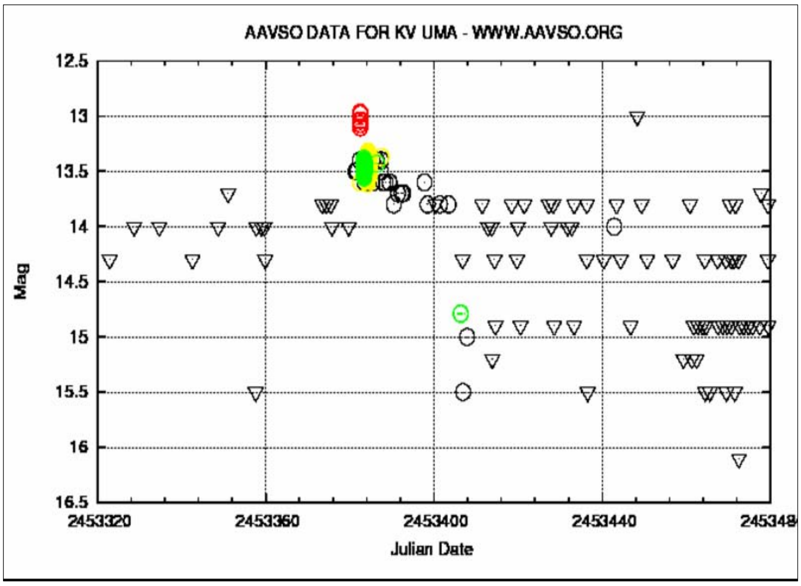


Figure 5. The light curve of KV UMa /Ursa Major/. This is intense variable X-ray source binary systems. This nova-like transient system, occasionally rapidly increases in brightness, probably caused by some kind of instable behavior in the mass transitions between two objects. The image is created on the observational data of AAVSO /www.aavso.org/.

**Final remarks of the results**

Gravitational potential of neutron stars provide the most effective mechanism of releasing energy from matter. The viscosity in accretion discs slowly converts gravitational energy into thermal.
We may assert that the variations of the shapes of the presented lightcurves give us information about the conditions inside the accretion flow and to conclude for the existence of some kind of unstable processes. We used the well known common assertion of instability and after including the perturbation quantities in the hydrodynamical equations, the possibility of turbulization of the flow is grown. Observationally these disturbances in stability state of the disc flow are expressed as pulsations, bursts, rapidly rotation, quasi-periodic oscillations and etc. In this way, the theoretical predictions of the second section above are in corroboration with observational evidences.

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