High Mass X-ray Binaries and Studying 1A0535+262 Source

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Introduction

An Interacting binary star is a star system where matter falls from one star (the donor star) towards the other star (the accretor). If the accretor is a compact star, an accretion disk may form in proper conditions.

X-ray binary systems (XRBs), are binary stars where matter in the accretion disc star is hot enough to emit most of its light in x-ray radiation.

High mass x-ray binaries (HMXBs) are subclass of XRBs systems where the donor star usually an O or B star, a blue supergiant, is a massive star. One of the most famous HMXB source is Cygnus X-1, which was the first identified black hole candidate.

In the case of the accretor is a neutron star (NS), matter within the disk in the magnetosphere of the NS will be magnetically funneled into the it's poles, which makes the NS pulsating, so HMXB systems can also be X-ray pulsars.

HMXBs are very important for Understanding the evolution of stars and binary systems, studying compact objects, stellar winds, and material exchange between binary stars. They also serve other physical and astrophysical fields such as accretion physics and plays an important role in relativity.

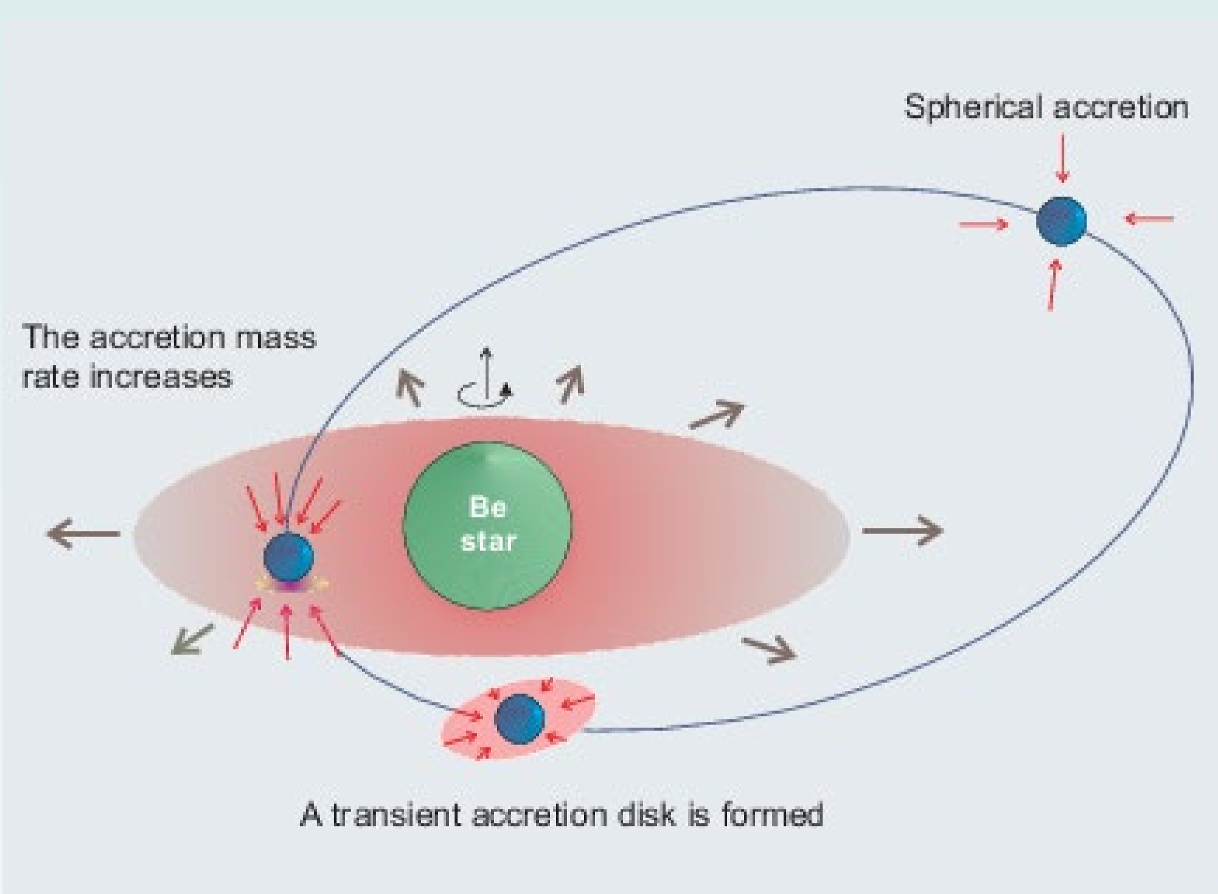
Classification

HMXBs can be classified into 2 classes; if the companion star is an OB supergiant the system is called supergiant x-ray binary system (SGXB), while if it is a Be star, the system is called Be x-ray binary system (BeXB).

SGXBs are the standard HMXB systems, they have short orbital periods (less than 10 days), and small orbital eccentricity (less than 0.1), such as Cyg X-1. In SGXB.
SGXBs have a constant x-ray radiation with luminosity ranging between 10^{34} and 10^{37} erg/s, but this radiation increases after the Roche lobe overflow, and the luminosity can exceed 10^{38} erg/s.

The orbital parameters of BeXBs oppose that of SGXBs, they have long orbital periods varying from dozens of days to several years, and high eccentricity comparing to SGXBs.

If the two stars are close to each other, while the compact star (NS) orbiting the Be star, at some point it intersects with the circumstellar disk formed by solar winds produced by the Be star and accretes matter with low rotational speed and high density, at this point the intensity of the X-ray radiation increases dramatically, producing an outburst that last for weeks to months.



Formation and evolution

There are many formation processes of HMXBs, the most important process when the two stars of the binary system are so close to each other, they will start to exchange matter, in this case the binary system is called a close binary system.

Now let's take an example of a HMXB to explain the evolution of these systems. First, we have two main-sequence stars S1 and S2 with a mass of M1 = 14.4 $M_\odot$ and M2 = 8.0 $M_\odot$, respectively, and the initial orbital period is 100.0 days. The evolution includes the following processes:

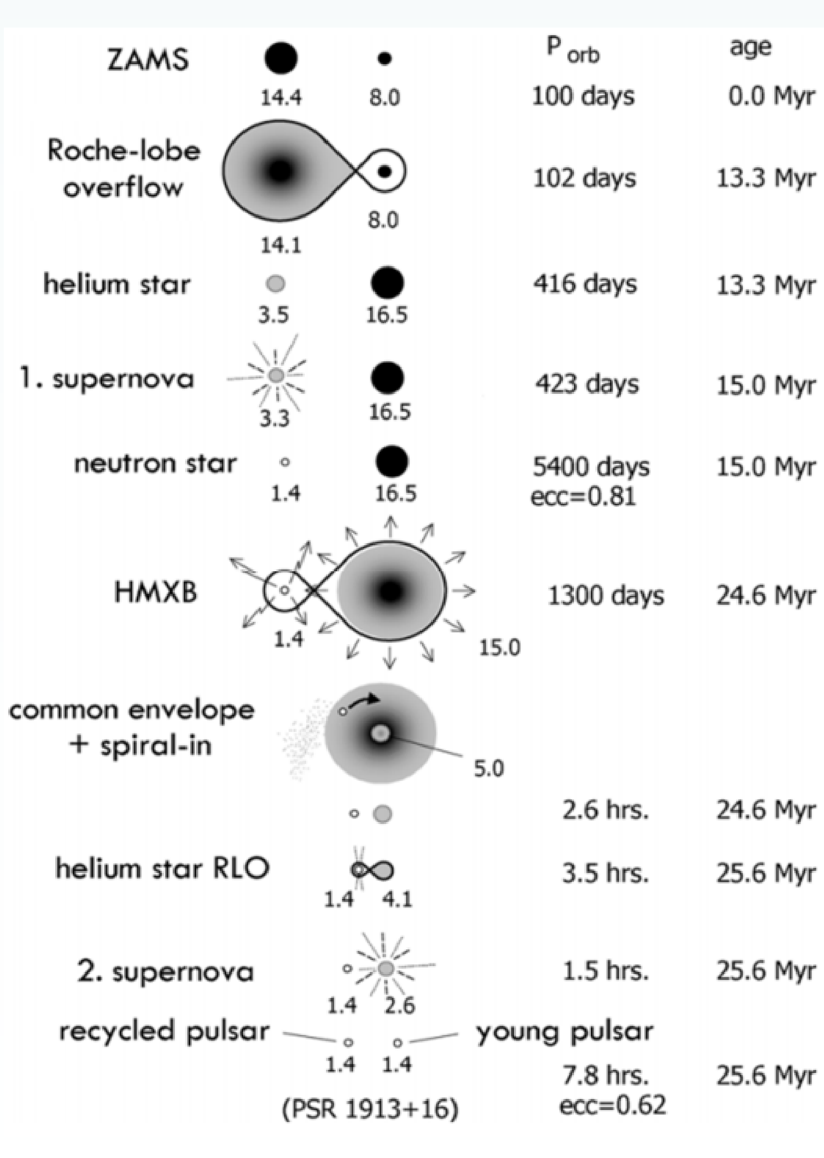
1.The stage of zero-age main sequence (ZAMS):
In the first stage we have 2 main-sequence stars, and the time is zero.

2.Roche-lobe overflow (RLOF):
In the second stage the more massive star (S1), evolve faster and fill up the RLOF, so mass transfers from S1 to S2.

3.A binary system including an ammoniacal star:
At the end of matter transformation and a new binary system composed of a helium star and a star whose mass is 16.5 $M_\odot$ is formed.

4.The stage of supernova outburst:
After 1.7 Myr, the ammoniacal star dies by a supernova explosion, forming a NS of mass 1.4 $M_\odot$.

5.The stage of HMXB:
After 24.6-Myr-long evolution, NS starts to accrete matter from the companion. Currently, the system turns into SGXB or BeXB.



6.The stage of the evolution of common envelope (CE):
Because of the transportation process, NS is covered by the envelope of the massive companion, Part of common envelope is stripped away from the binary system leaving a close binary system formed by a helium star and a neutron star.

7.Second supernova explosion:
After that, a second RLOF occurs between NS and the helium star, then the last one dies by a supernova explosion forming another neutron star.

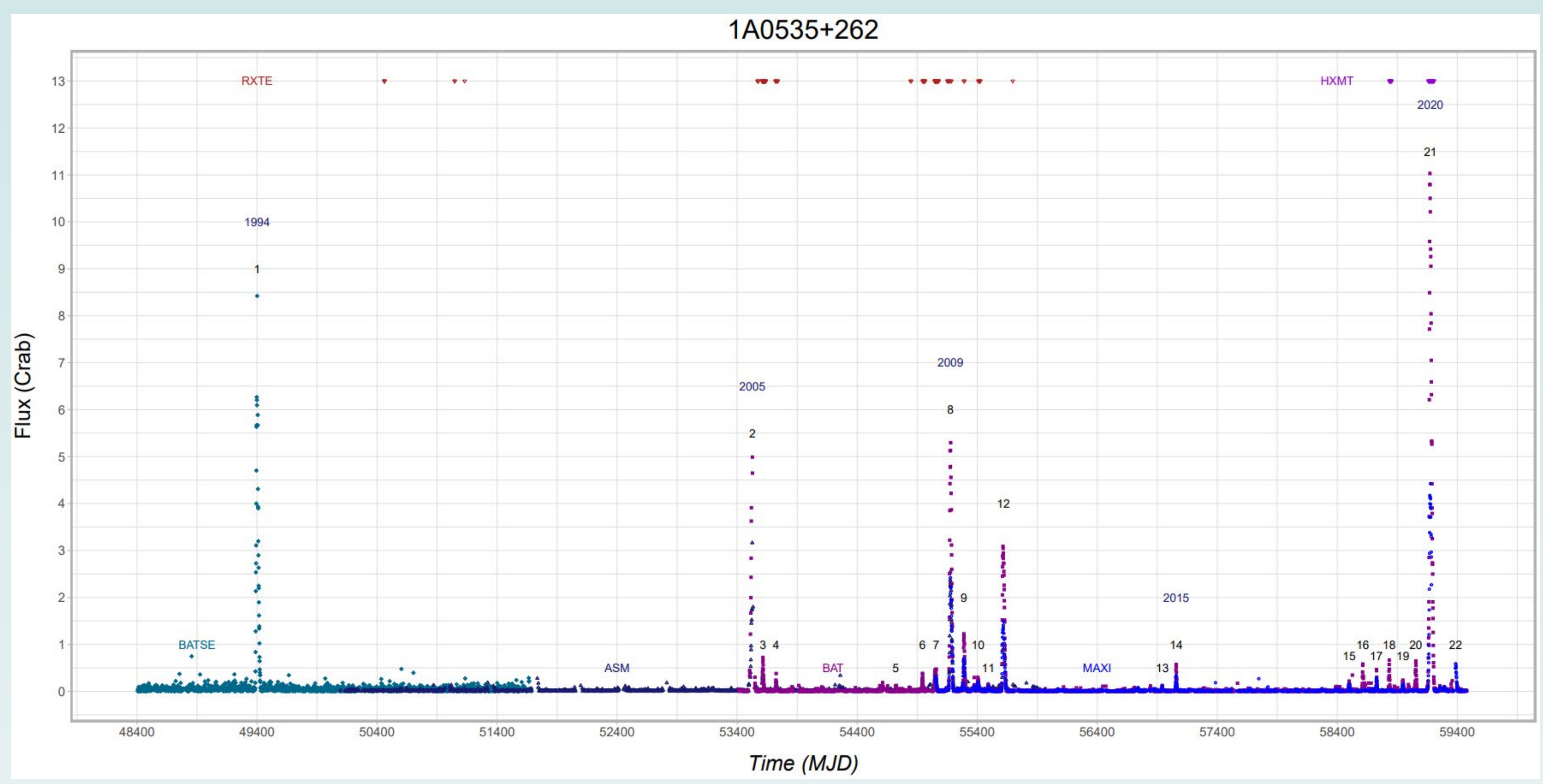
8.Merging of compact stars:
The remaining two neutron stars are merged emitting observable gravitational waves.

In this example the two main-sequence stars became neutron stars, but this is not the only case, massive stars can also be black holes, so we have three results: NS + NS, BH + BH, or BH + NS.

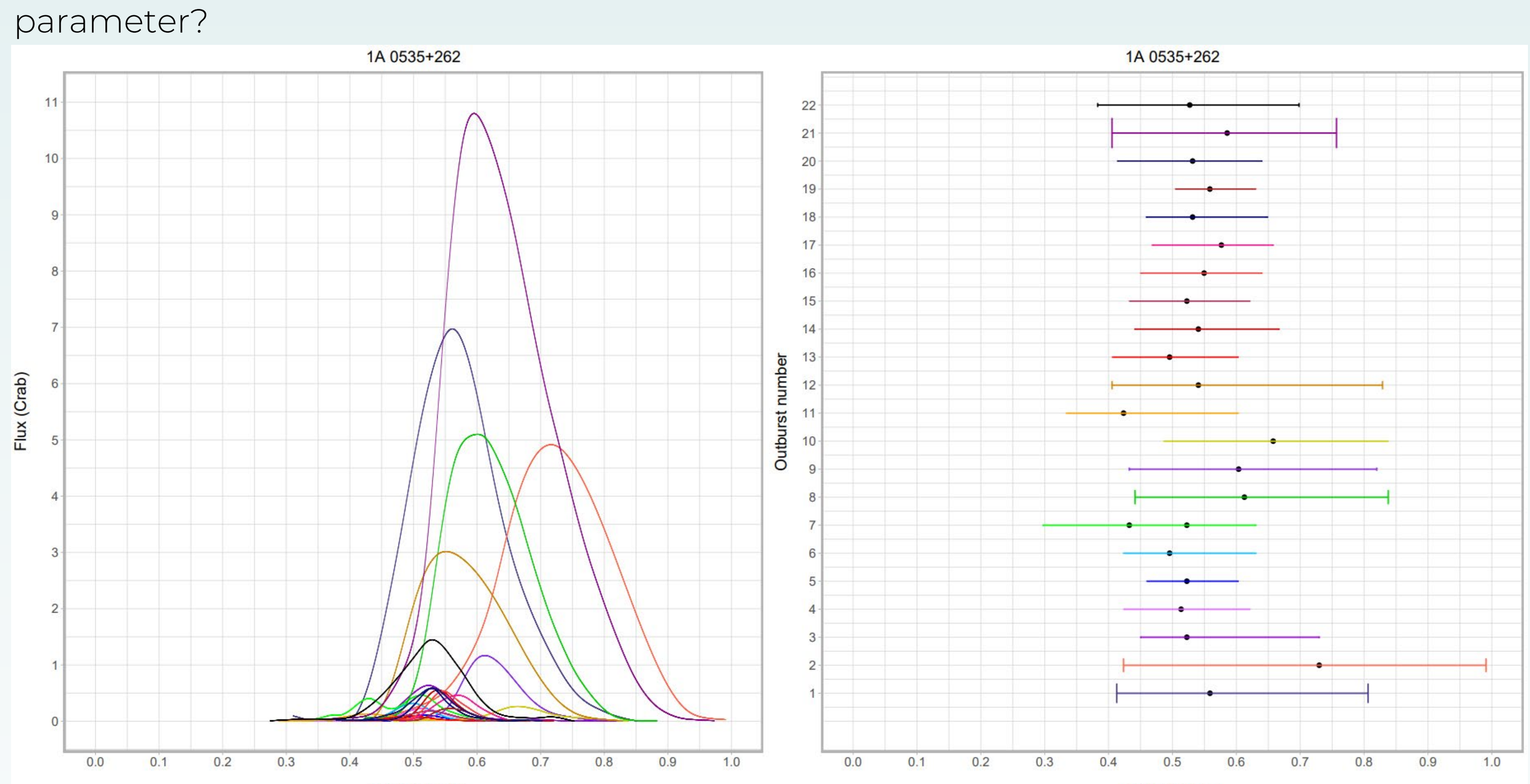
1A0535+262 high mass x-ray binary

In order to understand HMSXBs more and more, we must study many HMXB sources. One of the most important HMXB sources is 1A0535+262 which is a BeXB.

First let's plot the light curve of this source for flux as the function of time in MJD. As we can see in the figure below, the source shows peaks at some times, these peaks are outbursts produced by the source.
The source produced 22 outbursts along 28 years (from 1994 until now).



Now what if we convert time into orbital phase and plot all outbursts with respect to this parameter?



The figure shows outbursts with respect to orbital phase. The right part is clearer to see each outburst, it's start, end time and total duration independently.
The length and width of the bars correspond to duration and flux, respectively.

By analyzing this graph, we notice that outburst production doesn't happen anywhere, it is around a specific phase orbit which is equal to 0.55, an this is a very important result.

Conclusion

In this review, we explained the definition, classification, and evolution of high mass x-ray binaries, and we get a very important result about outburst production time by studying a member of HMXB population. So, by collecting, observing, and analyzing more samples of X-ray binaries with high mass companion, our understanding of these objects will be further advanced.

References

Confirming NGC 6231 as the parent cluster of the runaway high-mass X-ray binary HD 153919/4U 1700-37 with Gaia DR2.

Luminosity dependence of the cyclotron line energy in 1A 0535+262 observed by Insight-HXMT during 2020 giant outburst.

High-Mass X-ray binary: Classification, Formation, and Evolution.