ASTR 5590 - X-ray Binaries w/Neutron Stars

First discovered in '71 by the UHURU satellite (peace in Swahili ?)

Cen X-3

- 5s pulse period
- 2.1d sinusoidal variation
- massive blue star found to be coincident, w/same 2.1d period
- source disappeared regularly for $\sim \frac{1}{2}$ day : occulted
- Her X-1 similar

Emission much different than radio pulsars → powered not by high rotation & strong B field, but accretion

Pulsations suggest NS, but other evidence?

$$L = 4\pi R^2 \sigma T^4 \sim 10^{30}\,W$$

$$\sigma = 5.67\times10^{-8}\,W\,m^{-2}\,K^{-4}$$

$$R \sim 10\,km \sim 10^4\,m$$

$$T \sim \left(\frac{10^{30}\,W}{4\pi(10^4\,m)^2 \cdot 5.67\times10^{-8}\,W\,m^{-2}\,K^{-4}}\right)^{\frac{1}{4}} K$$

$$\sim 10^7\,K$$

X-rays: assume BB

Wien's law: $\lambda_{max} = \dfrac{0.29\ \mathrm{cm\cdot K}}{T}$

$$E = h\nu_{max} \simeq hc/\lambda_{max}$$

$$= \frac{6.626\times10^{-27}\ \mathrm{erg\cdot s}\cdot 3\times10^{10}\ \mathrm{cm/s}}{1.602\times10^{-9}\ \mathrm{erg/keV}}\ \frac{10^7\ \mathrm{K}}{0.29\ \mathrm{cm\cdot K}}$$

$\cong 4$ keV ✓ consistent w/ obs. emission

Other arguments suggest accretion is the source of power: will discuss this in more detail later

Two types of X-ray binaries

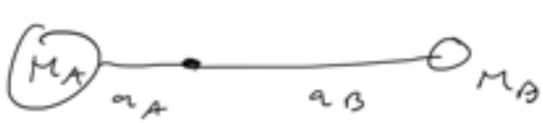
- HMXBs } high or low mass
- LMXBs } donor stars

H: O/B star companions (young)

L: MS stars of lower mass (~few $M_\odot$ to M-star)

Binary Systems : A + B

CoM given by $\dfrac{a_B}{a_A} = \dfrac{M_A}{M_B}$



Doppler shifts : $\frac{\Delta\lambda}{\lambda} = \frac{v_r}{c}$

measured, so can infer

Orbit : $P = \frac{2\pi a_A}{v_A} = \frac{2\pi a_B}{v_B}$

so $\frac{v_A}{v_B} = \frac{a_A}{a_B} = \frac{M_B}{M_A}$

But only measure $v_{r,A} = |v_A| \sin i$

As long as see both stars,

have $\frac{v_A \sin i}{v_B \sin i} = \frac{v_A}{v_B} = \boxed{\frac{M_B}{M_A}}$

From Kepler's 3rd law

$$M_A + M_B = \frac{4\pi^2}{G P^2} (a_A + a_B)^3$$

But, only know $a_A \sin i$ & $a_B \sin i$,

so only get $(M_A + M_B) \sin^3 i$

H: often possible to measure Doppler shifts from both members, which result in M_1/M_2 & $(M_1 + M_2) \sin^3 i$

being measured

★ How can actual masses be disentangled? 

L: often can't ID donor star, so stuck with "single-line spect. binary" case

→ get the mass function

since $P = \frac{2\pi a_A}{v_A} = \frac{2\pi a_B}{v_B}$

$$(M_A + M_B)\sin^3 i = \frac{P}{2\pi G}\left(v_A \sin i + v_B \sin i\right)^3$$

→ if only see A, the x-ray emitting component, can rewrite as

$$= \frac{P}{2\pi G} v_x^3 \sin^3 i \left(1 + \frac{v_o \sin i}{v_x \sin i}\right)^3$$

$\uparrow \frac{M_x}{M_o}$

$$\underbrace{\frac{M_o \cancel{\left(1 + \frac{M_x}{M_o}\right)} \sin^3 i}{\left(1 + \frac{M_x}{M_o}\right)^{\cancel{3}\,2}}}_{\text{unknown}} = \underbrace{\frac{P}{2\pi G}\left(v_x \sin i\right)^3}_{\text{obs.} = f}$$

$$\times \frac{M_o^2}{M_o^2} =$$

$$f(M_x, M_o, i) = \frac{M_o^3 \sin^3 i}{(M_x + M_o)^2}$$

BH binaries tend to be like this, making it harder to estimate their mass (requires more assumptions)

Result (find more recent figure)

- Masses consistent w/ NS expectation, then gap, then larger masses for BH candidates ($\sim 10 M_\odot$)