Accretion delay in High Mass X-Ray Binaries (and subsequent investigations)

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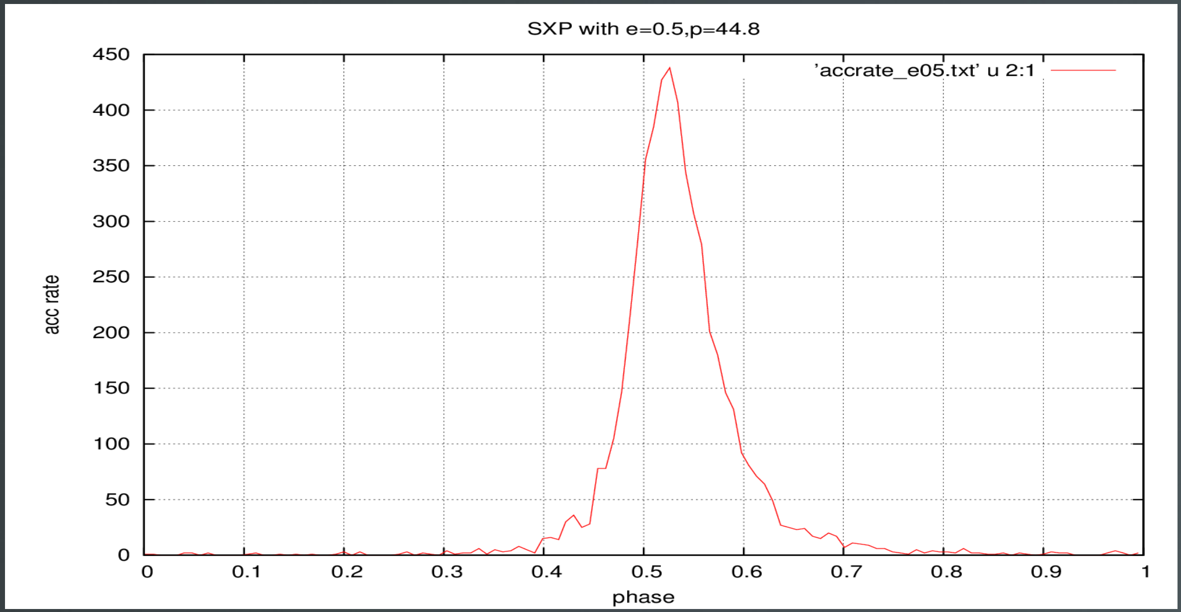
- Smoothed Particle Hydrodynamics model of the circumstellar disc in HMXRB's
- Code developed by Benz(1990), Bate (1996) and Okazaki (2000)
- The model produces a data log from which the analysis is carried out.
- Binary files... from which the visualisations were taken using SPLASH (Price D. 2007)

First Run: varying orbital period

- A set of simulations were run with varying orbital periods of 24.3 days, 36.0d, 44.8d, 55.5d, 65.0d, 75.1d, and 83.5d
- Mass Be Star 18 solar masses
- Mass of Neutron Star 1.4 solar masses
- Eccentricity 0.5
- Coplanar model

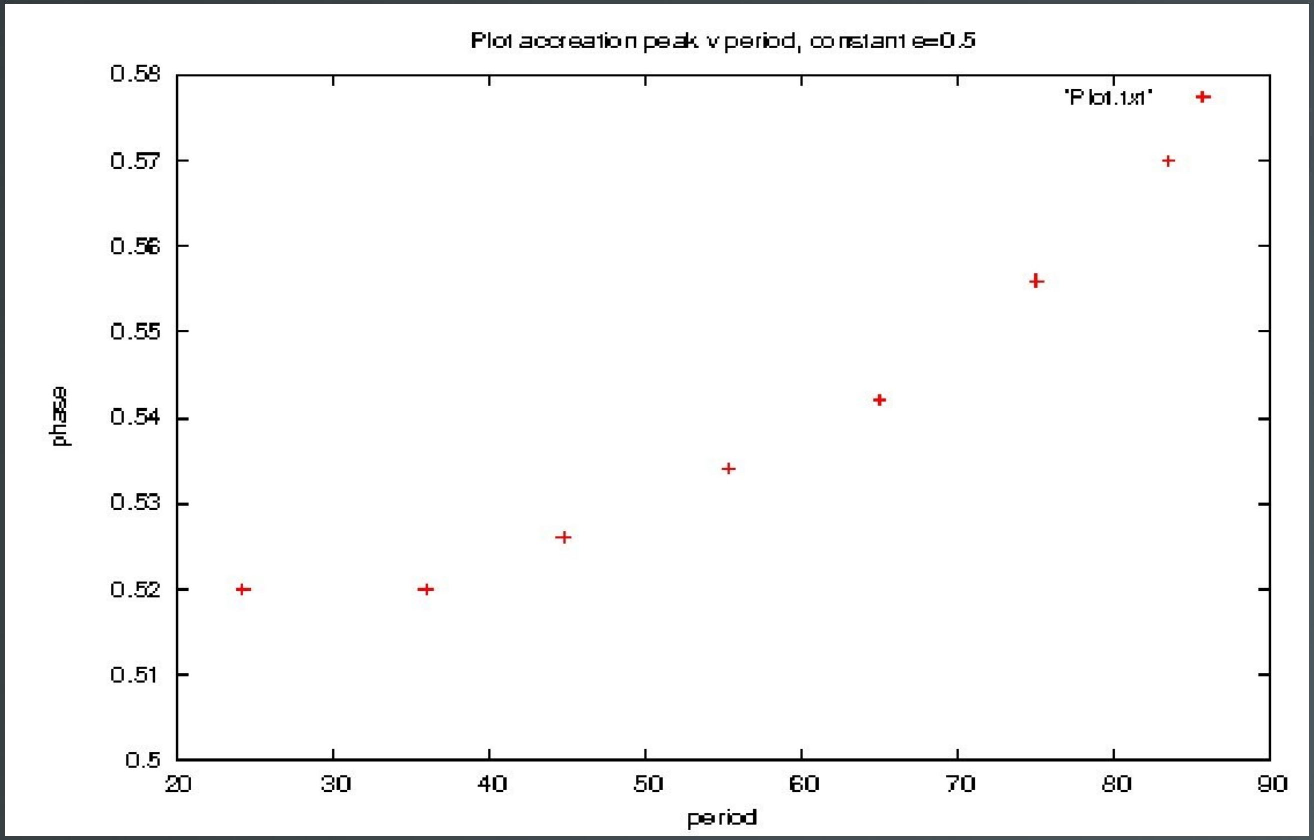
Result 1

- There is a delay for the peak of accretion rate after periastron. Periastron is at 0.5
- Although not obvious there is a measure of exponential decay



Result 2

- The delay depends on the orbital period
- Periastron is at 0.5

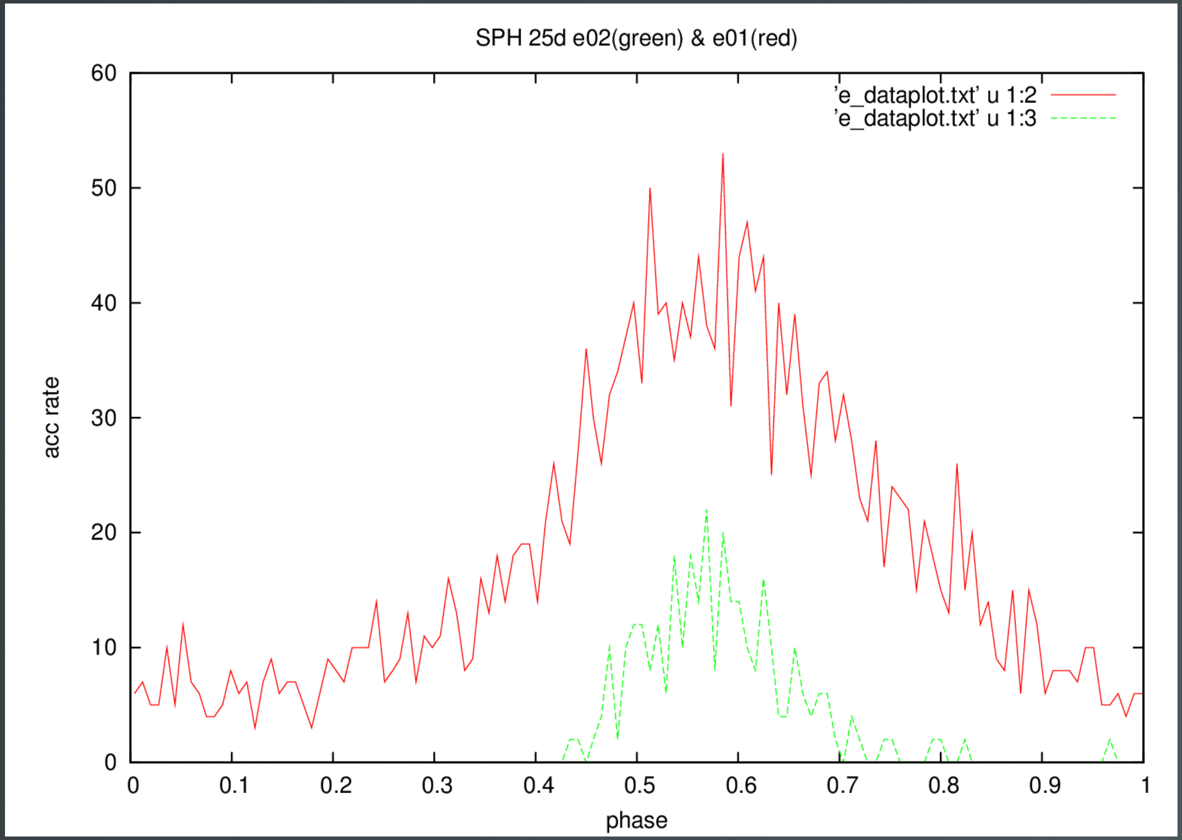


Second run: varying eccentricity

- Nine simulations were run with eccentricity varying from 0.1 through to 0.9 in steps of 0.1
- 18 Solar Masses for Be Star
- 1.4 Solar masses for Neutron Star
- Period of 25 days
- Coplanar model

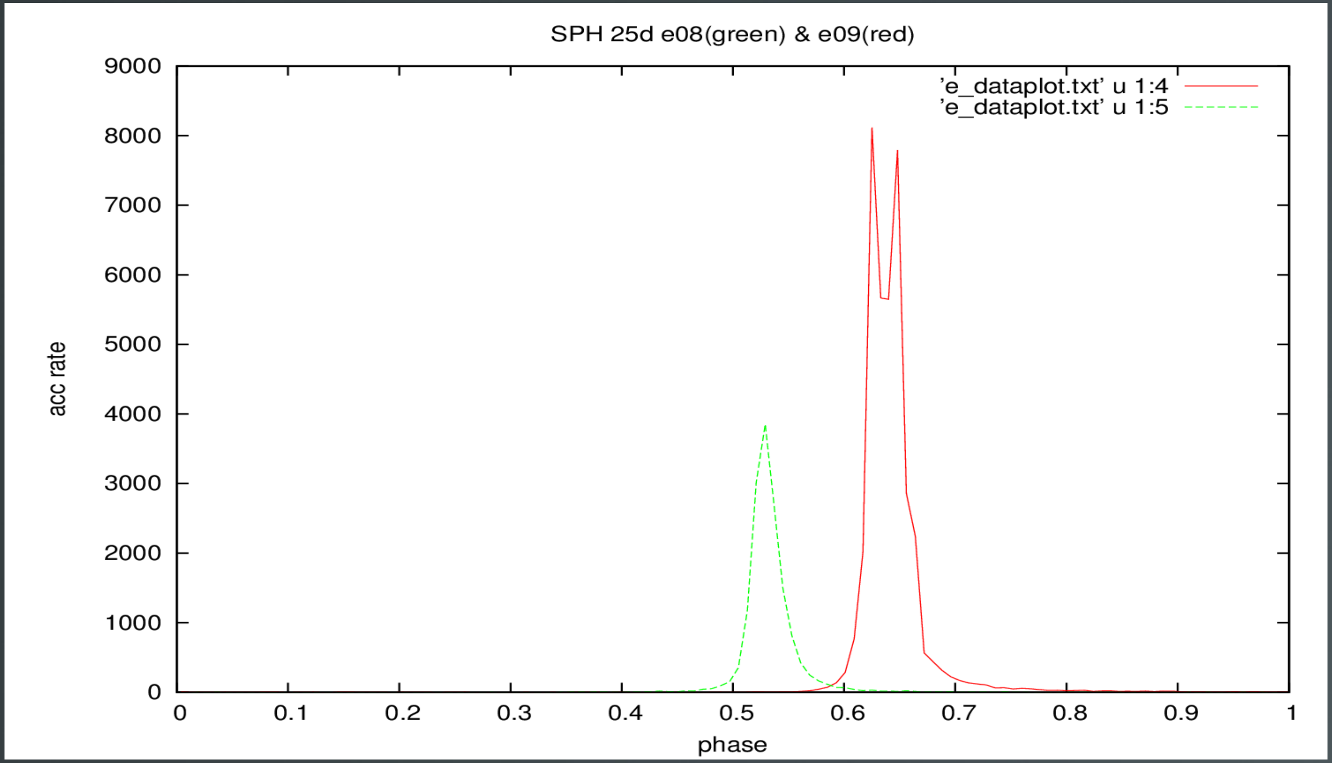
Result 3

For an eccentricity of 0.1 the NS was accreting continuously



Result 4

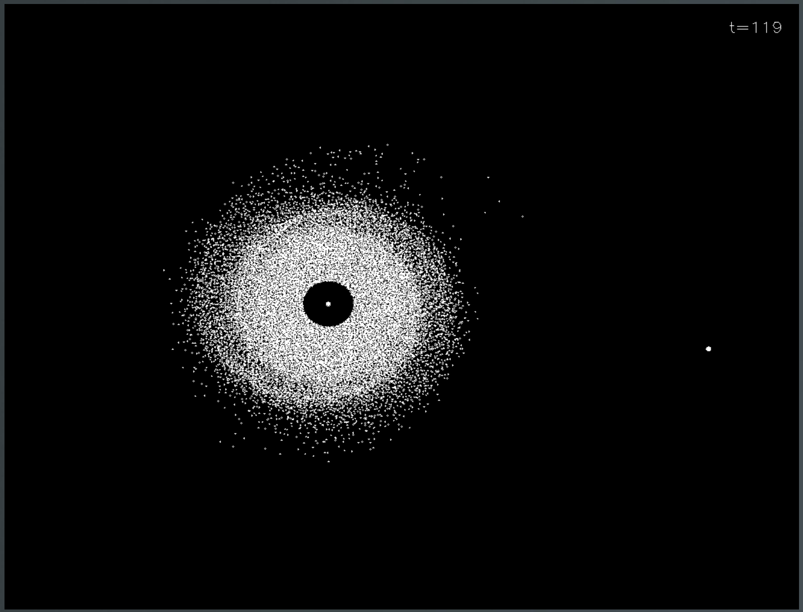
- For eccentricity 0.9 there is double accretion peak
- The peak is after 0.6 of the phase

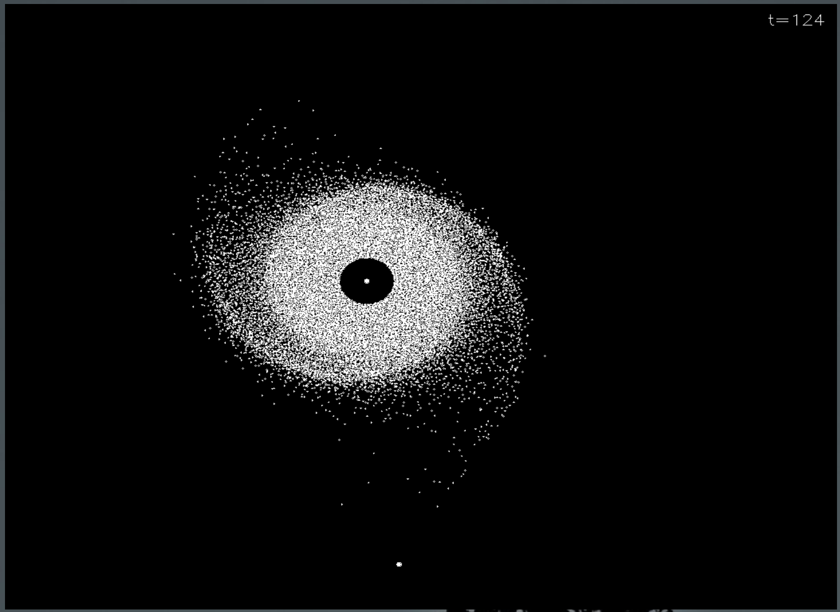


- So what is causing the double peak?
- We set about investigating this.

Eccentricity 0.2

- On the left visualisation with the Neutron Star at apastron (0.0)
- On the right phase is 0.75. The disc is large.

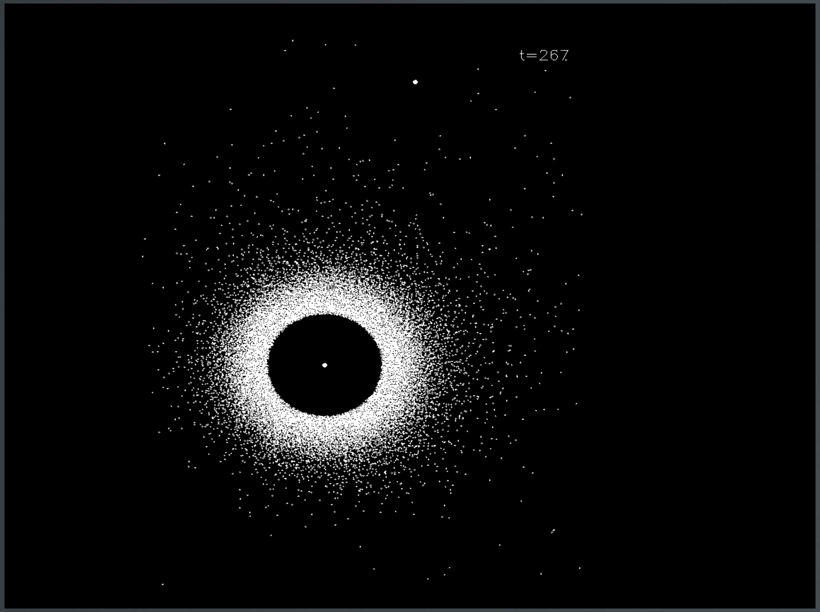


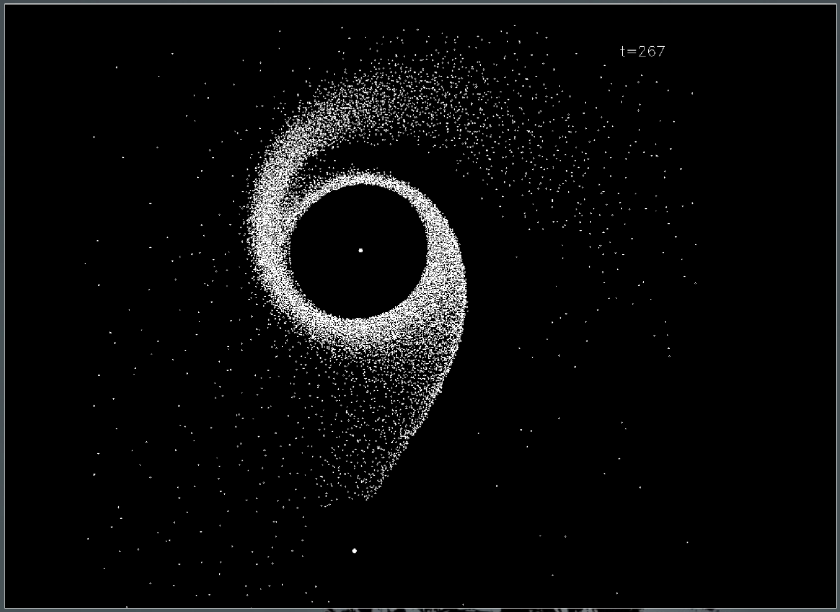


- Spiral arms are formed when perturbed by the passage of the NS through periastron.
- The NS accretes from the leading arm
- A trailing arm is formed (Boyle & Walker 1986)
- The passage of the NS is around the edge of the disc, it does not cut across

Eccentricity 0.8

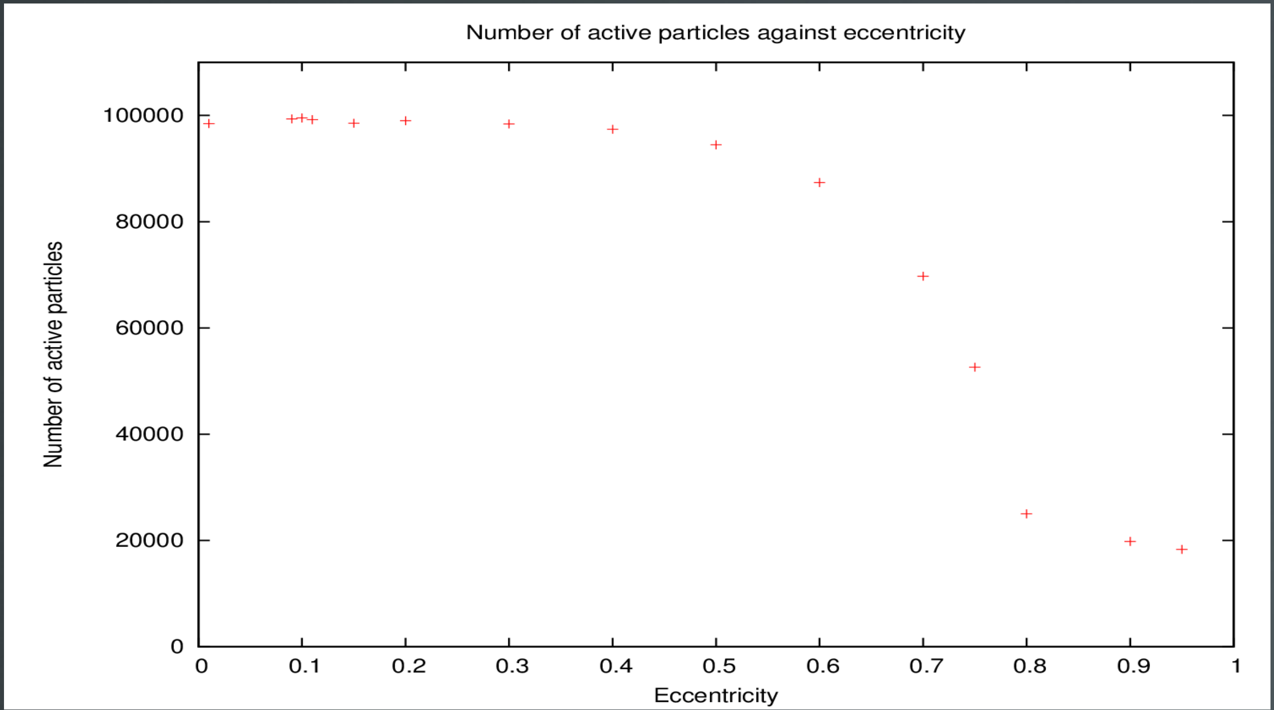
- On the left the neutron star is at phase 0.2
- On the right at 0.75, the NS accretes from the leading arm, again. Note: scale is larger than for e = 0.2



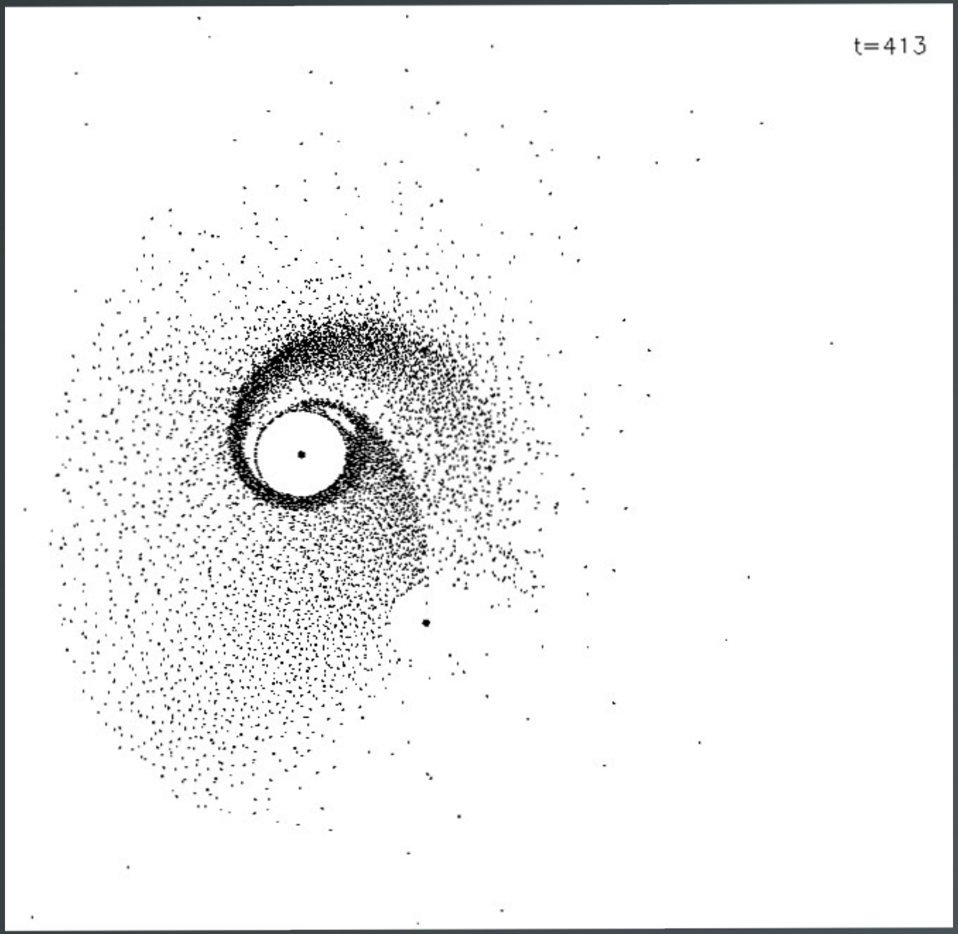


Result 5

- The disc size varies with eccentricity
- Additional runs were carried out at 0.09, 0.11, 0.15, 0.75 and 0.95



Eccentricity = 0.9



- Arms brought up closer together
- Phase = 0.8
- The NS is accreting from the SECOND arm.

Physics of Spiral Density Waves

- Spiral density waves in the disc are caused by the passage of the NS through periastron
- The velocity of the NS is larger at periastron for higher eccentricity systems (Kepler's 3rd Law)
- Also when comparing the velocities at the edge of each disc, smaller radii discs will have greater velocities at their outer edge
- Result: The neutron star is accreting from both arms as the disc mass is smaller and there is an increase in angular momentum transfer

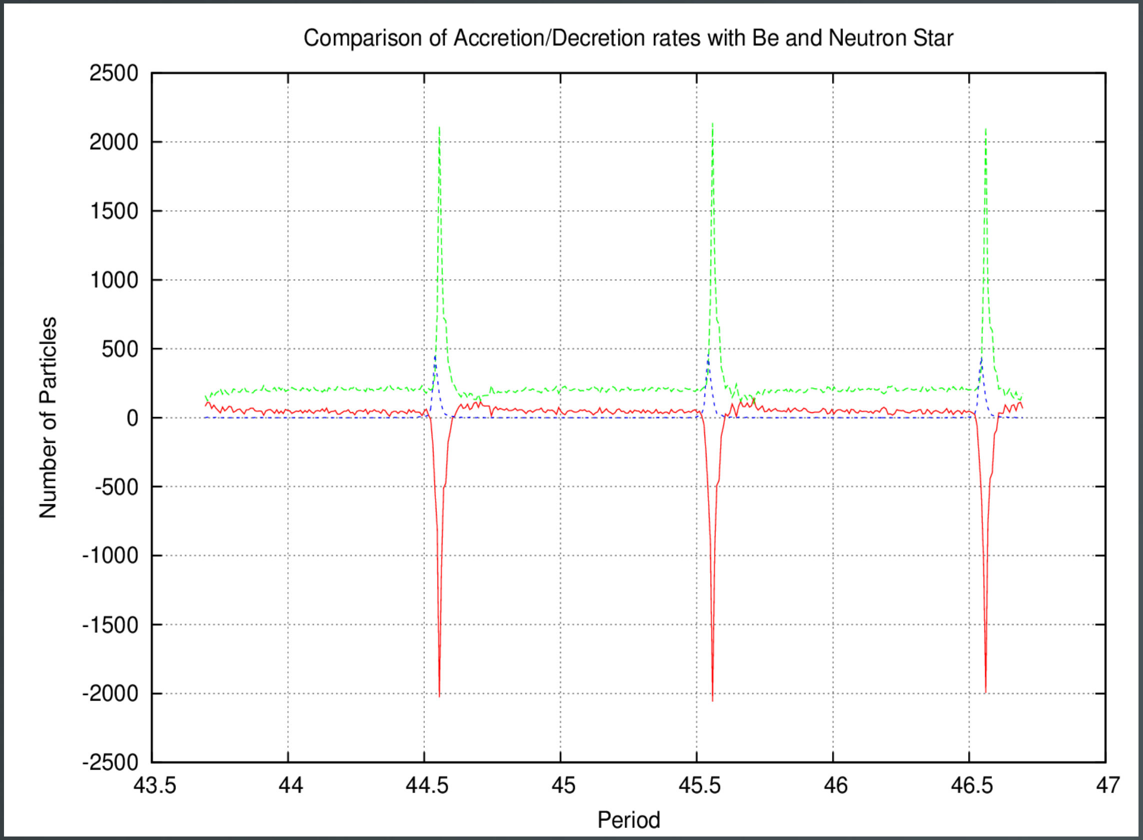
- Within the disc the matter and the density waves are separate.
- Within the disc is a region where they both rotate at the same speed, the co-rotation radius
- Outside the co-rotation radius the spiral density wave travels faster
- Within the co-rotation radius the matter travels faster
- There is a positive amount of angular momentum and energy outside the co-rotation radius

- Inside the co-rotation radius there is a negative amount of angular momentum and energy
- Would this not mean that there would be a flow of material from the circumstellar disc back onto the Be star? We investigated mass loss from the disc.

- Spiral Density Waves Lin & Shu 1964
- Gas Dynamics (Frank H. Shu) Chapter 12 Change of sign across co-rotation

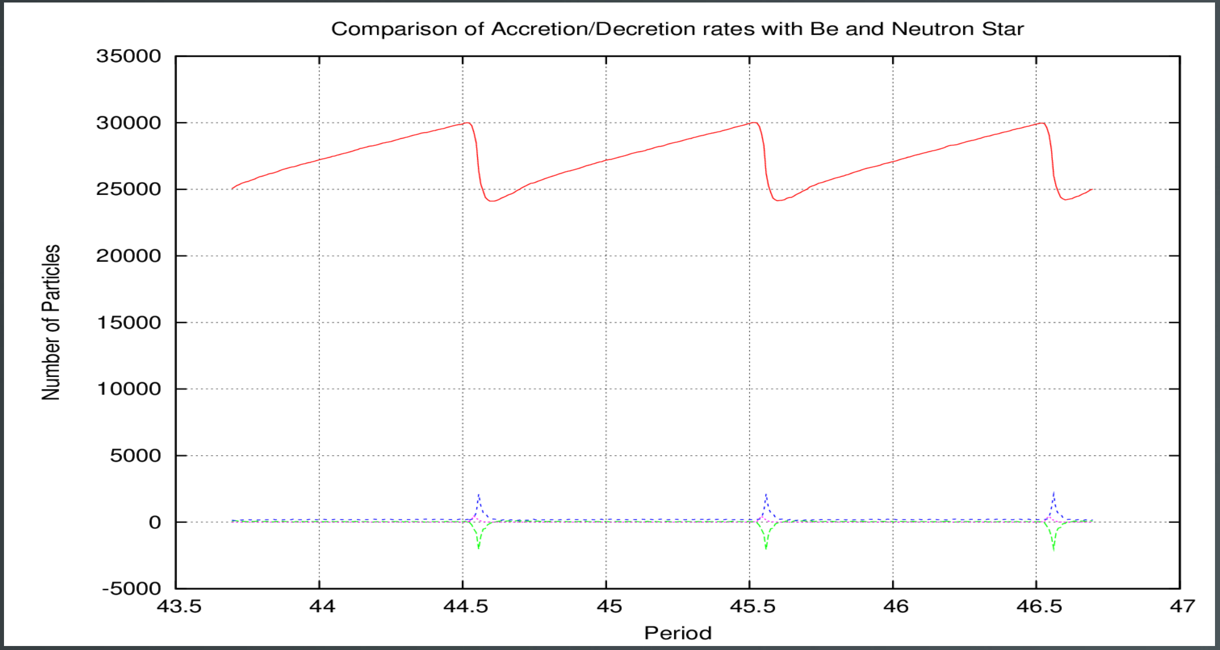
Mass Loss from Disc, Be Star takes material BACK from the disc.

- Blue: Accretion rate onto NS. Green: Mass rate gain by Be star. Red: Mass loss rate from disc



Comparison Timing

- Red Curve top is absolute number of particles in the Circumstellar disc. This shows how the disc suddenly reduces in size



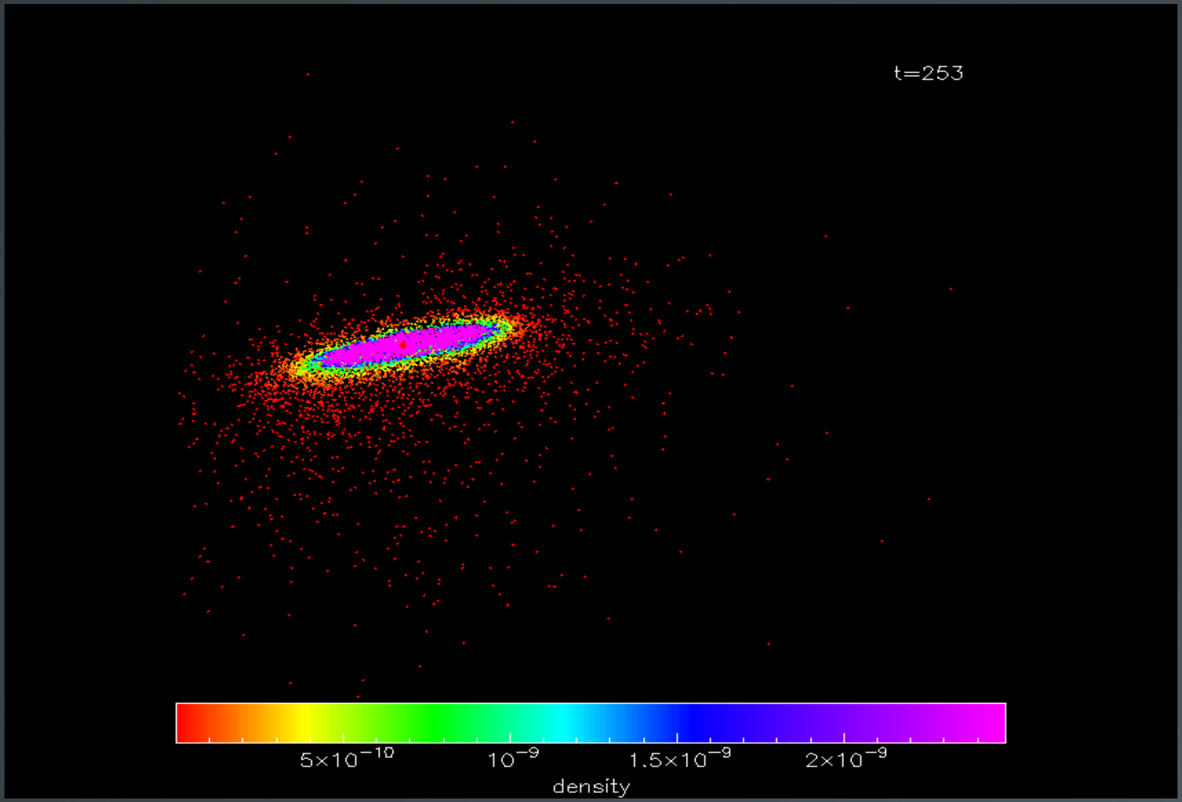
Result 6

- The NS accretes from the outer edge of the disc
- For high eccentricity models there is a mass loss BACK onto the Be star that commences just after accretion by the NS
- It takes a finite time for the feedback mechanism to pass to the inside of the disc

- To investigate this further a proposal has been put to SALT to make optical high resolution observations in order to detect change in the structure and size of the disc.

Coming up next

Same again with the NS inclined to the disc



Summary Coplanar Model

- There is an accretion peak occurring after periastron
- The delay depends upon period
- For a model with e= 0.1 the NS accretes continuously
- For a model of e = 0.9 there is a double accretion peak
- Eccentricity of the model dictates the size of the disc.

Summary contd

- The NS accretes from both leading and trailing arms in a high eccentricity coplanar model producing a double peak profile
- There is a co-rotation radius within the Be disc for the material and spiral density wave.
- The circumstellar disc loses mass back onto the Be star when the NS is accreting from the disc.