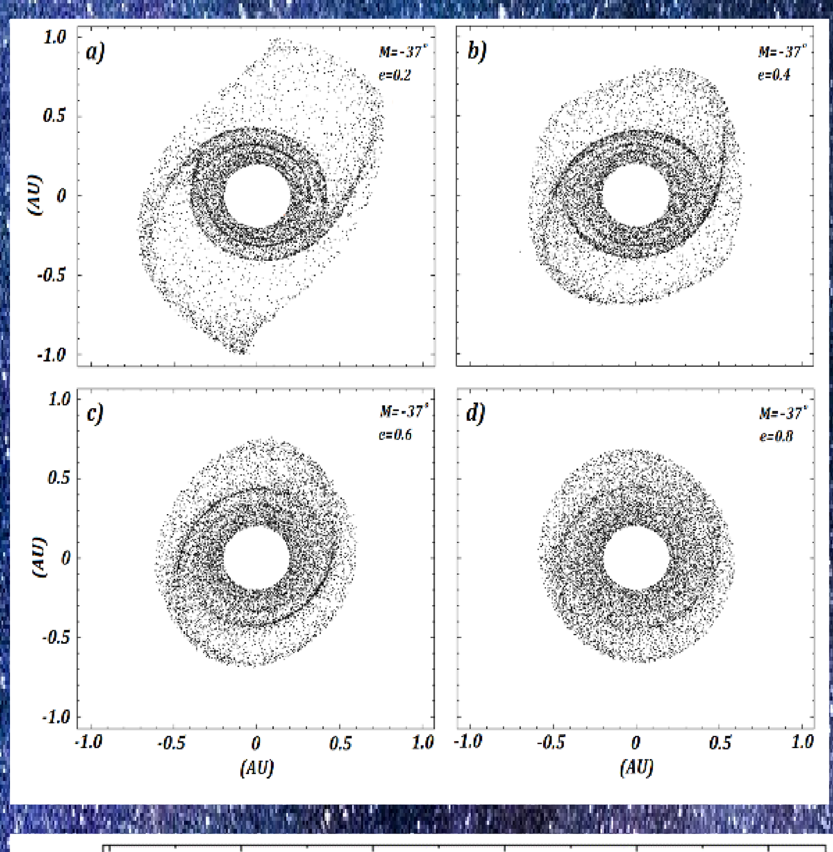
Investigating Gravitational Instabilities Within Planetary Rings During Planet-Planet Scattering Events

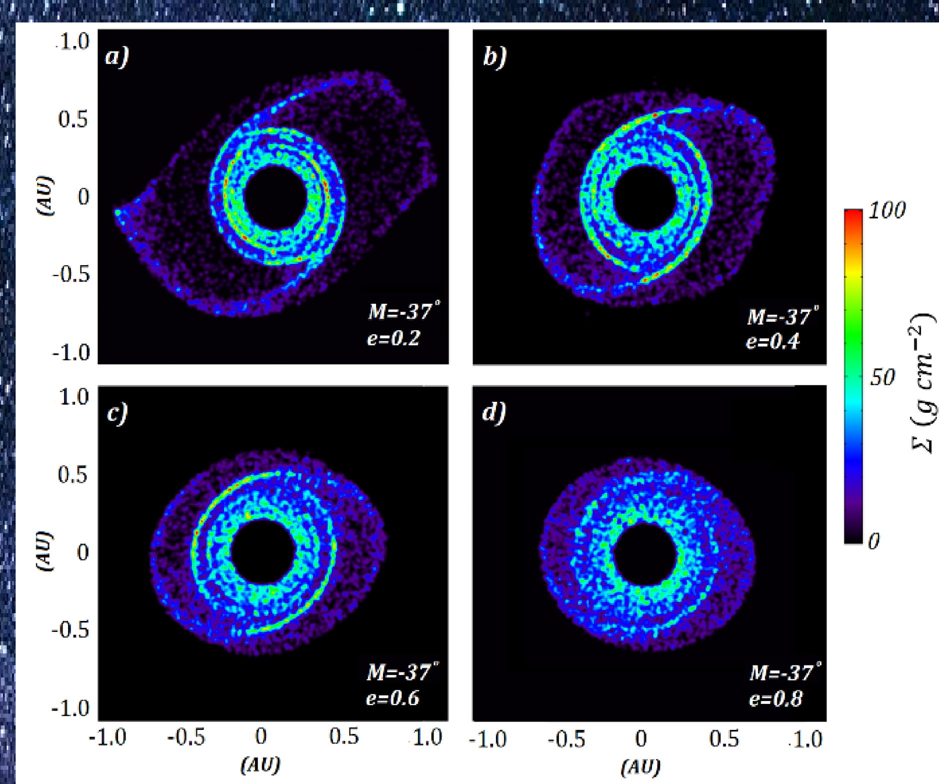
Introduction

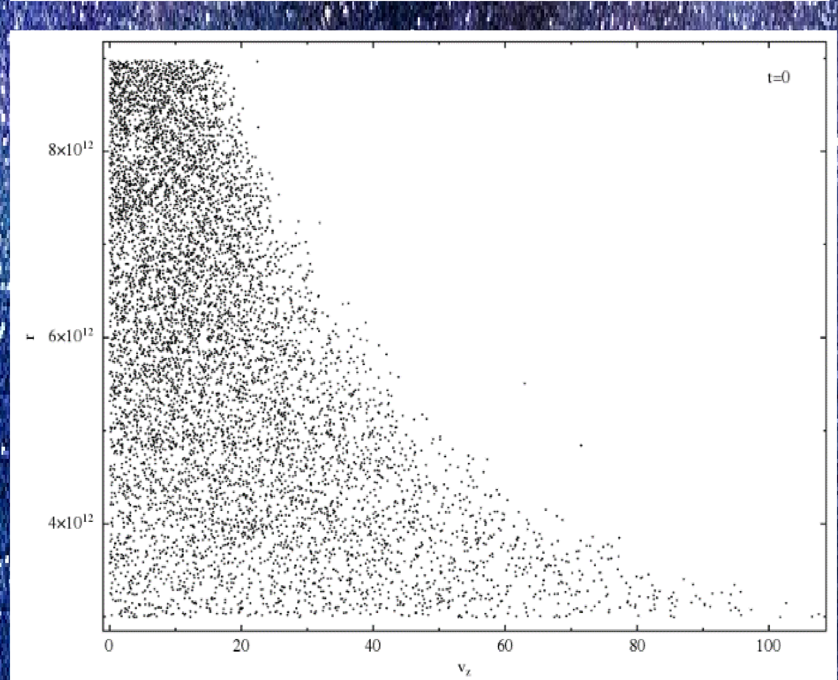
Exoplanet J1407b was used as the main source of information during the investigation. The planet is between 10 and 40 times larger than the size of Jupiter with planetary rings that are estimated to be around 200 times the size of Saturn's rings. A unique part of this system is the eccentricity of the planets orbit in relation to its star which is between 0.2 and 0.6, in comparison the Earth's eccentricity is 0.0167. The investigation looked at using the data acquired on J1047b to simulate the planetary rings as the planet orbit its nearby star. The gravitation instabilities were investigated using the Toomre parameter to approximate the stability of the rings at different points along its orbital period.

Aims

The aim of this project was to understand how eccentric orbits can affect a planets ring system and to understand if moons can form in a planetary ring.







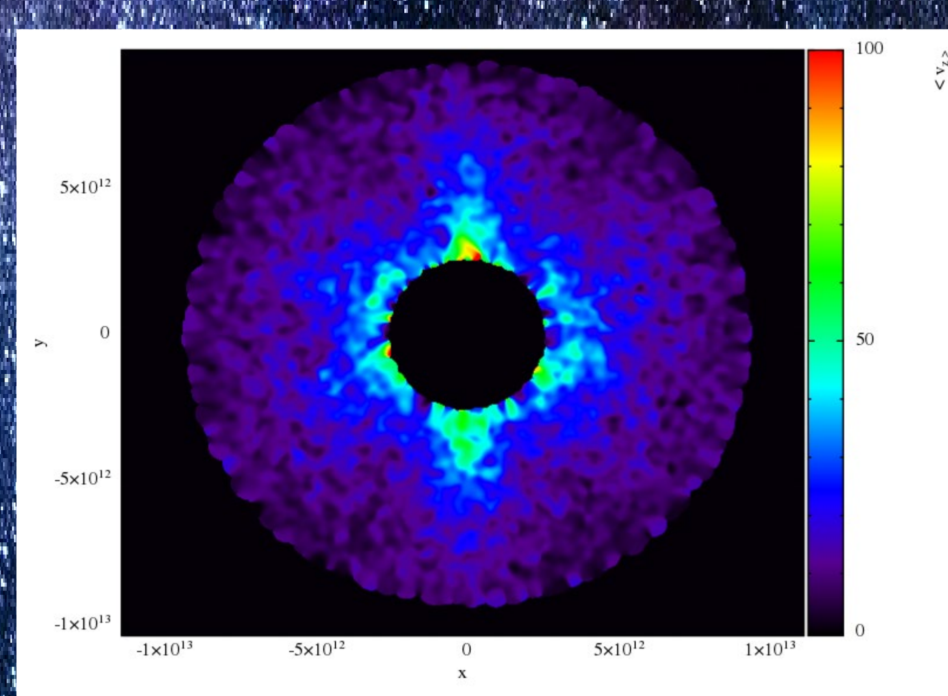


Figure 1 (Top Left): Visualisation of the J1407b ring system used in calculations at different eccentricities. Figure 2 (Top Right): Density distribution of the J1407b ring system. Figure 3 (Bottom left): Radial Toomre values. Figure 4 (Bottom right): Render of the Toomre values of the ring system.

Conclusions

This investigation showed that during highly eccentric orbits planetary rings are torn apart by tidal forces and that the stability of ring particles decreases as the exoplanet approaches the star. The investigation also showed how the particles stability is distributed around the planet, with particles closer to the planet being less stable and particles on the out edge more stable. This can be explained by the Roche limit of the exoplanet which can be visualised through figure 4. Research done also provides evidence for where a potential moon system could be as during the exoplanets orbit the outer parts of the ring system are destroyed by the highly eccentric orbit and the inner parts are naturally more unstable, therefore providing a 'goldilocks' zone for a potential moon.

Methodology

For the investigation programs were created in Splash and IDL (Interactive data language) to analyse data files from simulations performed previously. To investigate the gravitational instabilities in the planetary rings calculations were performed on the data files to find the radial velocity dispersion and the Toomre parameter at different stages of the planets orbit.

Critical radial velocity dispersions were calculated using a stable Toomre parameter of 1, these were then compared to our calculated velocities to yield a result for the Toomre parameter for each of the 10,000 particles in the system. Splash was then used to represent and graph the data for the Toomre parameters calculated for each particle along with positional data also calculated.

Particles were considered to be 'stable' if there Toomre values were less than 10. The Toomre parameter was calculated from

$$Q = \frac{V_r \Omega}{\Pi G \Sigma}$$

Results

The investigation showed that as the planet approached the pericentre of its orbit the rings were broken apart with many particles exhibiting very high Toomre values. This is in comparison to the Toomre parameters and positional data taken from earlier snapshots before nearing the star.

Figure 3 and 4 shows how the Toomre parameter is spread out in the ring system with the outer parts being more stable than the inner ring parts of the ring system. With radial velocity dispersion around 90 m/s and around 5000 particles in the system considered to be stable. Later snapshots taken as the planet approached the star revealed a significant decrease in the number of stable particles.

Overall the results showed that in early snapshots the outer parts of the ring system were a lot more stable than the inner parts, to a certain extent. There was a radius at which the particles became a lot more stable. This is thought to be around the same distance as the Roche Limit which explains why particles within it exhibit significantly higher Toomre values.

References

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