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## REVIEW ARTICLE

### CASE STUDY ON HOW ARE THE GAPS BETWEEN THE RINGS OF SATURN ARE FORMED

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#### ABSTRACT

A gas giant with its comprehensive set of continuous and discontinuous rings is a Unique cocktail of interactions between itself, dust and ice, its moons and nearby orbiting satellites and particles. The Gravitational Influence of the moons, notably the largest of them like Titan and Rhea has created Gaps in between the rings. For years this has baffled Astronomers. There has been a speculation that the prograde motion of the planet against the prograde motion of its moons have caused this unique effect. Others speculate that the Density wave theory with its spiral structure theories could provide an explanation for this gap causing influence. This Paper will be a case study on how are the gaps are formed between the rings of Saturn. The paper will explain the various phenomena surrounding the Influences, notably Resonance and orbital collisions and correlate as to why such phenomenon result in gaps being formed. It will also explain about our theory which describes the possibility of retrograde motion of the distant moons and other planetary bodies exerting a Gravitational influence on the Gas Giant Saturn which is in Prograde motion also being a cause for the gaps being formed in the rings, especially in the Cassini Division.

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## INTRODUCTION

Saturn as we know it, is a gas giant and the 6<sup>th</sup> planet from the sun as well as the second largest planet in the solar system. Its radius is nearly ten times that of our planet earth and its mass being 95 times more massive than earth owing to its large size and an extremely larger magnetosphere. The rings of Saturn are the most largest spans of rings for any planet in the solar system stretching out to nearly 450,000 km's in span length. This beautiful sets of rings and ringlets is what makes Saturn more brighter than other gaseous planets, although it still is not visible to the naked eye and cannot be viewed without aided vision (Telescopes). The voyager 1 and 2 missions along with the Cassini satellite missions and recently the new horizons spacecraft mission helped in disproving the speculation that the rings are actually a set of ringlets, and these mission concludes that there are 9 main concentric continuous disc shaped rings around Saturn as well as 3 discontinuous arcs made of ice and dust. As of 2015, 62 moons have been discovered in orbit around Saturn, many of them are less than 10 km in diameter and many of them have been discovered after 1997 (Kirsten Larson, 2007). All these moons in orbits, no matter how small has been discovered to have visible effects on the disc shaped rings. This effect is called as the *Orbital Resonance*. Orbital Resonance is caused due to a recurring gravitational influence exerted by two orbiting bodies on one another.

This influence ejects out smaller particles if they are sharing orbits with giants such as Saturn. The gaps in the rings are a consequence of this influence Titan is Saturn's largest moon and is noticeably larger than mercury which has been identified as one of the major culprits which causes incredible gravitational effects on orbiting planetary bodies and small particles as well. Other notable moons include Rhea, Dione, Hyperion, Prometheus and Tethys. All the moons are significantly reasons for the formation of the gaps between the disc shaped rings.

Numerous gaps and structures are present in the rings Designated from D to the outer F ring. The most densest of all the rings are the A ring and the B ring. As a result the gaps within the two rings are also one of the widest. Huygens Gap and Encke Gap in the Cassini Division are the widest gaps with an average width of 300 kms. These gaps are caused due to the attractive gravitational field of the moons which forces the gap between the division by pushing dust particles and molecules away. An Illustrative Picture is given below as to how the gaps are created because of Orbital Resonance. The Pictures also shows density waves being propagated due to resonance and harmonic oscillations.

### The rings of Saturn and its gaps

#### D ring

The innermost ring of Saturn and the least densest of all the rings with its own set of ringlets. Density waves have been

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observed moving about in a spiral oscillation. This occurrence of waves have been fairly recent and it is due to collisions with other planetary bodies, possibly comets. Collisions have also been an active culprit of gaps being formed. Infact the spiral perturbation of the entire ring structure of Saturn has been due to the possible planetary collisions in the past if the speculations and the assumptions regarding this is proved to be true.

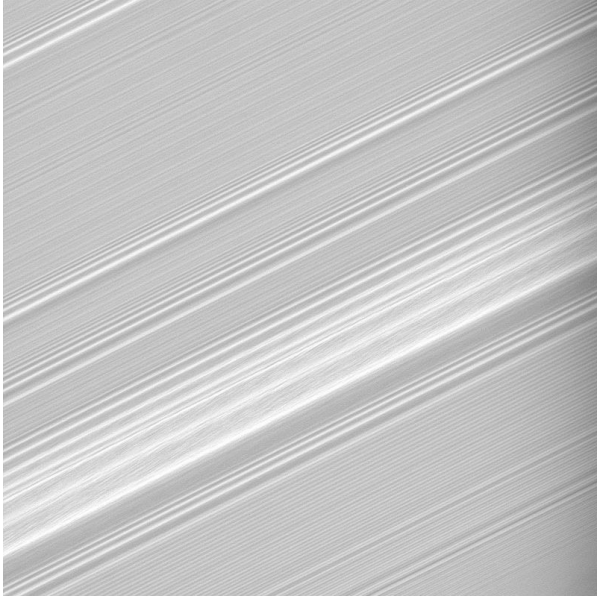


Fig. 1. Google Images (Rings Of Saturn)

### C ring

The second ring of the gas giant extending from 74500km to 92000km located inward of the B ring is composed of darker particles and is also less denser than its B and A counterparts. The C ring is also home to gaps which is caused due to orbital resonance of the moons especially Titan, which is in close proximity to the C ring. There is also a ringlet named as the *Titan ringlet* caused due to its orbital influence. This proves that moons are major culprits for causing the gaps. The Titan ringlet is encompassed by the *Colombo gap*, A gap with a width of 160 km's in the inner side of the C ring. In the outer side of the C ring there is another ringlet named the *Maxwell gap* with a width of nearly 300 km. However this unique gap encompasses no moons within its horizon.

### B ring

The most massive, densest (Robert and Vanderbei) and largest of the entire ring system of Saturn is the B ring which extends from 92000 km to 117500 km range. It is also the most brightest of the ring system featuring an extreme luminous intensity. Because of a dense and saturated set of particles present in a radial format, No gaps have been observed in the B ring so far, except for the *Hyugens Gapon* its outer edge side. Instead because of gravitational influences and forces, the rings are structured in a radial fashion as described above called as *Spokes*. Controlled by the magnetic pull of Saturn. Gravitational Anomalies might be the reason for the formation of spokes although in this stage there is widespread speculation.

### A ring

The outermost of all the large rings. Its boundaries start from the *Cassini Division* to the edge of the smaller F ring. There are huge gaps in the A ring caused due to orbital resonance influences exerted by the moons Atlas, Janus, Pan and epimetheus. The largest of the Gaps is called as *Encke Gap* which has a width of 325 km's and has the small moon Pan orbiting within its confines. These moons cause disturbances and vibrations in particle flow and thus their influences cause such huge gaps.

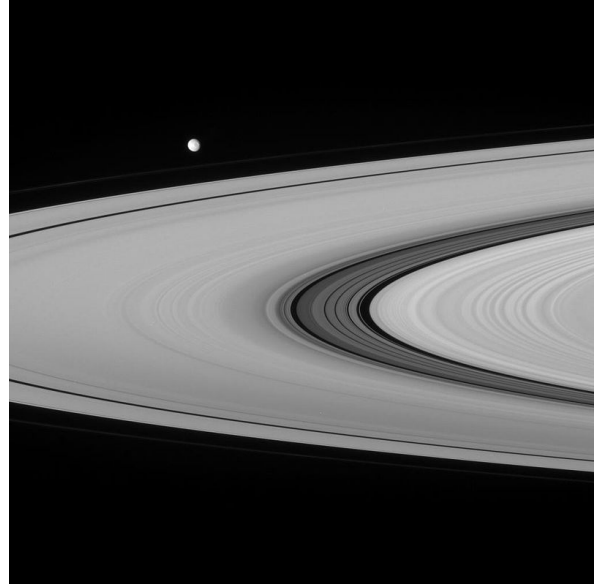


Fig. 2. Cassini Division – Google Images

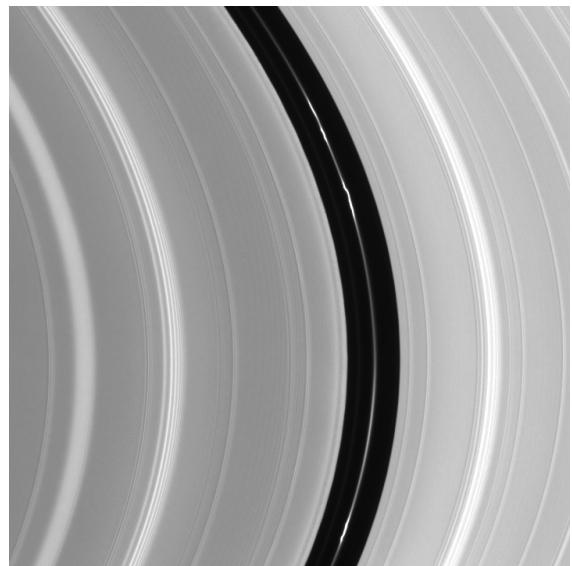


Fig. 3. The Black orbit shows the orbit of the moon Pan which is present inside a ringlet – Google Images

### Cassini Division

A 5000 km Division which separates the B and A ring. The division is characterized by a lot of gaps due to the presence of strong orbital resonance and also unusually low in density. As a result it exhibits particles similar in composition to the innermost ring particles. Because of its low density it is very bright in appearance (Linda Spilker).

## Observations and inference

From the Above context and Explanations, it is observed that moons and orbital collision are the major causes which created the various gaps. In the Cessini Division alone there are about 12 Distinct Gaps because of the proximity of moons and the presence of ringlets. Also There is widespread speculation that Comet collisions and their debris have been causes for the gaps. Also Gravitational Anomalies are also suspected to be the cause. However till Date there has been no clear answer for this uncertainty.

We have proposed a theory that Retrograde motion of certain asteroids, comets and small moons of Saturn and their Gravitational influence against the Prograde or direct motion of the Gas planet Saturn could be the cause of Gaps being formed. Since an inclination of  $90^\circ$  to  $180^\circ$  is retrograde orbit and a completely opposite orbit to this is prograde motion, there will be a increased gravitational influence between two planetary bodies going in two different directions, hence this causes the particles to be forced away from the horizon creating huge gaps. The inclination and axial tilts of planetary bodies should also be taken into account when measuring forces and distances. The inclination of Saturn to the sun is  $5.51^\circ$ , while its Axial tilt is  $26.73^\circ$ . Hence by calculating the inclination angle and the axial tilt of the moons, asteroids or comets which moves in retrograde fashion, we will be able to then proceed with distance and collision calculations which can accurately explain us about the location of the gaps and the reason why it was formed.

Inclination is given by

$i = \arccos(h_z / |h|)$  where h is orbital momentum and i is inclination of the planetary body

The Axial tilt for Saturn is given by

$$\varepsilon = 26.7308.30'' - 53.745''T - 0.0108''T^2 + 0.0217''T^3 - 0.640''*10^{-6} T^4$$

And thus by calculating the Axial Tilt of the Distant moons, We can finally figure out the origin of the gaps.

## Conclusion

The Hypothesis of Gravitational Influences on two planetary bodies have been suspected to exist since the formation of the solar system. Orbital resonances have also been observed in other planets and the influences between Jupiter and its moons can be compared to that of Saturn. However there is still inadequate data and not enough proof pertaining to the history of the ring system or the gaps formed or the interaction with its moons. Hence with the advent of more theoretical and experimental results and proposals, a more comprehensive understanding of the ring system can be established.

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