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An alternative explanation of the 'spokes' observed in Saturn's rings

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ABSTRACT: In the 1970's amateur astronomer Stephen J. O'Meara first observed that the planet Saturn sometimes show spokes flaring out like those on a bicycle wheel. This phenomenon was confirmed by the Voyager Spacecraft flybys in the early 1980s. The 'spokes' as they are now known as, are not governed by gravitational interactions with the planet, moons, or ring material. The later Cassini probe confirmed that the 'spokes' are likely under the influence of the gas giant's global magnetic field. Here we show the 'spokes' that appear in Saturn's rings consist of grains of silicates coated in pyrolytic carbon through the process of Chemical Vapour Deposition (CVD). Pyrolytic carbon is a highly diamagnetic substance and can levitate above a sufficiently strong magnetic field. The 'spokes' also consist of ice particles that are diamagnetic as well. The photoelectric effect can be used to explain why the silicates coated in pyrolytic carbon return to the main ring structure when exposed to sunlight of a specific frequency. The pyrolytic carbon grains become paramagnetic when some of the unhybridised $2p_z$ orbitals lose their unpaired delocalised electrons, thus collapsing the π bond molecular orbital structure. The pyrolytic carbon grains are now attracted towards the magnetic field emanating above and below the main ring structure. It is suggested that the 'spokes' in Saturn's B ring are always present and that no plasma triggering event is required to increase plasma density. The 'spokes', however, are only visible when a favourable viewing angle is allowed, and their visibility is also dependent on the angle of the sunlight hitting Saturn's rings.

1. INTRODUCTION

Observed first by amateur astronomer Stephen J. O'Meara[1] in the 1970s and then subsequently observed by the Voyager Spacecraft flybys[1] in the early 1980s, it was realised that the 'spokes' flare out like spokes on a bicycle wheel.

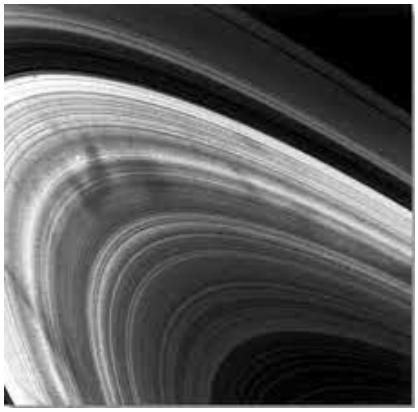

Figure 1: Voyager's image of the spokes (Image credit: JPL NASA)

The observed behaviour of the 'spokes' indicates that they are not governed by gravitational interactions with the planets, moons, or ring material. In 2005 the Cassini probe[2] confirmed that the 'spokes' are likely under the influence of the gas giant's global magnetic field.

Various models have been proposed by (Morfill, 2003)[3] to explain the appearance of the 'spokes' observed in Saturn's rings. The most widely accepted model purports that meteorite bombardment of the rings produces a transient cloud of dense plasma that charges the dust, causing the dust to levitate above and below the plane of the rings. It is theorised that the 'spokes' are created by resonate interactions between the oscillations within the rings and the rotating magnetosphere.

Another model (Jones, 2006)[4] suggests that the 'spokes' may be produced by lightning-induced electron beams striking the rings, at locations magnetically connected to thunderstorms. The researchers suggest that Saturn's ionospheric density controls the location of the 'spokes' formation. Electron beam propagation to the rings may produce the observed X-ray emissions and supply

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particles to Saturn radiation belts, thus modifying the rings' composition over time.

Scientists (Goertz, 1984)[5] suggest that the 'spokes' in Saturn's rings are formed by electrostatically charged dust particles that are suspended in Saturn's magnetic field. As such these particles rotate in sync with the planet rather than its ring particles which display Keplerian motion about Saturn. At times, due to the angle of incoming sunlight, these electrostatically charged dust particles lose their electrostatic charge and fall back into the main ring structure hence the 'spokes' disappear at times. The 'spokes' have been observed by the Cassini spacecraft to be able to form on a time scale of minutes and fade away in a few hours.

2. HYPOTHESIS

The small percentage of carbon that constitutes Saturn's B ring is diamagnetic pyrolytic carbon. During the formation of Saturn's protoplanetary disk, it is hypothesised, that pyrolytic carbon would have been deposited via Chemical Vapour Deposition (CVD) of hydrocarbon gases such as methane, onto fine grains of silicates which acted as a substrate. These fine grains of silicates coated in pyrolytic carbon can levitate above or below a strong magnetic field due to pyrolytic carbon being highly diamagnetic. It is also suggested that Saturn's B ring has a sufficiently strong magnetic field emanating orthogonally above and below its plane to levitate these pyrolytic carbon grains.

3. JUSTIFICATION OF HYPOTHESIS

In the laboratory it has been demonstrated that diamagnetic pyrolytic carbon levitates above a sufficiently strong magnetic field, see (Fig.2).

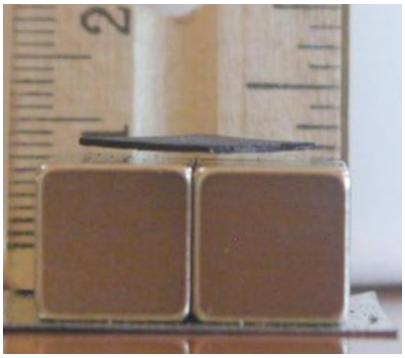

Figure 2: Levitating pyrolytic carbon (Image credit: scitoys.com)

Pyrolytic carbon is a man-made substance, but it is predicted that Saturn's rings consist of a small percentage of pyrolytic carbon. This type of carbon is formed in a vacuum at high temperatures of above 1400K, this process is known as flash vacuum pyrolysis. The dark 'spokes' which are observed in Saturn's B ring consist of levitating particles that transition periodically from motion in synchronisation with the rotation of Saturn's magnetic field to normal Keplerian motion within the main ring. The dark 'spokes' are only observed in Saturn's B ring which corresponds to the 1500K region in the protoplanetary disk formation (Fig.4).

4. RESEARCH

Hydrocarbons such as methane can be converted to pyrolytic carbon at temperatures above 1400K as indicated in equation (1) below. Research (Spilker, 2019)[6] also indicates that the Cassini mission found an abundance of various hydrocarbons in the 'rain' produced by Saturn's rings (Fig. 3) which represents the composition of 'ring rain' produced by Saturn's rings. It should be noted that silicates were also detected in the 'ring rain' which (Fig.3) neglects to show.

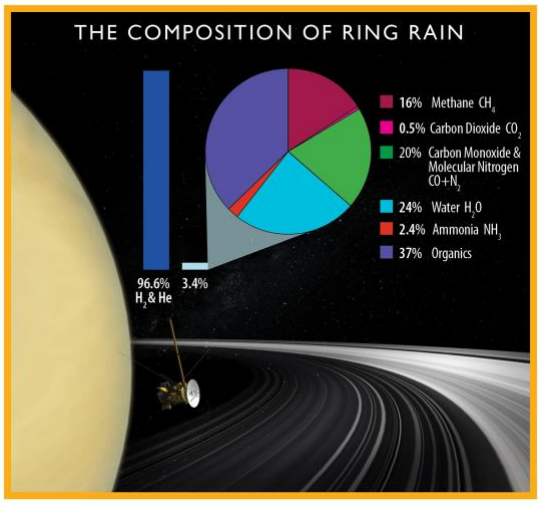

Figure 3: Composition of ring rain (Image credit: NASA/JPL/SwRI)

$$CH_{4(g)} + 1400K \rightarrow C_{(s)} + 2H_{2(g)} \quad (1)$$

Research (Henning et al. 2013)[7] suggests that during Saturn's formation, the innermost parts of its

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protoplanetary disk would have reached these temperatures. The protoplanetary diagram below (Fig.4), the 1500K region would correspond to Saturn's B ring, which is why the dark 'spokes' are only observed in this ring. The temperature beyond the 1500K region would be too cold, so no dark 'spoke' formation would be observed beyond Saturn's B ring.

Saturn's ring system closely resembles the disc of dust and debris from which Earth and the other planets in the solar system originated approximately 4.55 billion years ago. This protoplanetary disc formed as result of gravitational collapse of a spherical cloud composed of extremely cold gas and dust. As the rotating cloud contracted, it transformed into a flat disc shape, exhibiting the swirling motion around the newly formed sun. "Once the sun had blown away the gas, the disc of orbiting rubble would have resembled the disc of Saturn's ring system" says Professor Carl Murray[8].

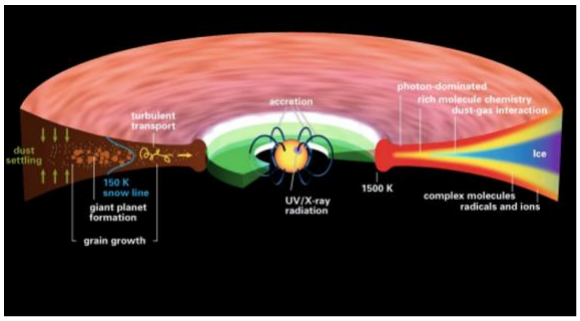

Figure 4: Protoplanetary disk formation (Image credit: astrochymist.org)

The 'spokes' also consist of ice particles which are diamagnetic as well. The photoelectric effect can be used to explain why the silicates coated in pyrolytic carbon return to the main ring structure when exposed to sunlight of a specific frequency.

The pyrolytic carbon grains become paramagnetic when some of the unhybridised $2p_z$ orbitals lose their unpaired delocalised electrons, thus collapsing the π bond molecular orbital structure. The pyrolytic carbon grains are now attracted to the magnetic field emanating above and below the main ring structure.

The dark 'spokes' in Saturn's B ring become visible due to the backscattering of light (Fig.5). This proposed mechanism suggests that Saturn's B ring produces a magnetic field that emanates orthogonally above and below its ring plane.

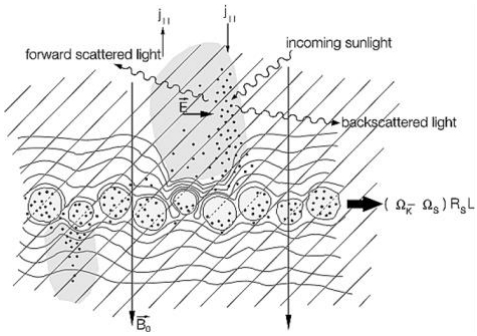

Figure 5: Forward and backscattering of light (Horanyi et al. 2004)

The bright 'spokes' in (Fig.6) are visible on the unilluminated side of Saturn's rings when the sun's illumination of the rings is at a maximum (directly below or above the ring plane). The bright 'spokes' can be explained due to the forward scattering of light (Fig.5) caused by the grains of pyrolytic carbon which levitate above the plane of Saturn's rings.

The bright 'spokes' which appear on the illuminated side of Saturn's rings may be due to the sunlight reflecting off the small, levitated ice particles. These small ice particles are also diamagnetic but unlike the silicates covered in pyrolytic carbon, they remain unaffected by natural sunlight as they are not magnetically susceptible to natural sunlight i.e., the photoelectric effect will not occur. The small ice particles remain levitated above Saturn's main rings, until the intensity of the sunlight causes them to sublimate and thus disappear.

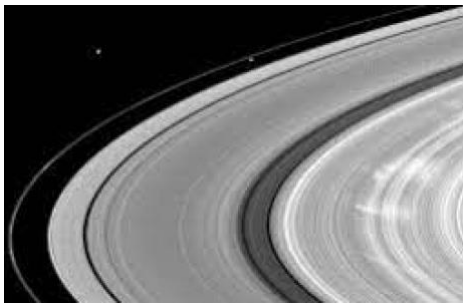

Figure 6: Bright spokes in Saturn's B ring observed by Cassini (Image Credit: Smithsonian National Air and Space Museum)

As such, Saturn's rings can be considered an electromagnetic phenomenon, as also suggested by Professor Vladimir Tchernyi and Sergey Kapranov[9]. They elucidate the entire story of Saturn's particle's magnetism based on a classical electrodynamic solution of the problem of the particle's motion in the

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gravitational and magnetic field of Saturn. They provide solutions for diamagnetic & superconducting particles in Saturn's rings.

The ring's magnetic fields enable the fine grains of silicates covered in pyrolytic carbon to levitate above and below the main ice-ring structures due to their highly diamagnetic nature, thus producing the observed dark and bright 'spoke' structures that rotate in synchronization with the rotation of Saturn's magnetic field.

The electromagnetic nature of Saturn's rings may be explained by either Saturn's complex magnetic field or by the interaction of Saturn's magnetic field with the solar wind which may charge the rings.

It is suggested that the 'spokes' in Saturn's B ring are always present and no plasma triggering event is required to increase plasma density. The 'spokes', however, are only visible when a favourable viewing angle is allowed, and their visibility is also dependent on the angle of the sunlight hitting Saturn's rings.

It is also predicted that the recent samples taken from the carbonaceous asteroids Bennu and Ryugu will contain large quantities of pyrolytic 'diamagnetic' carbon.

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