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Enceladus : What's Up with That Place ?

Special points of interest:

- Enceladus news
- Einstein Rings
- Nuclear Physics on Mars
- Superfluous questions

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Saturn's satellite Enceladus has been an object of fascination since its discovery. Early observers noted its extreme brightness in telescopes and spectra, and observations from the Voyager spacecraft in the 1980's confirmed its high albedo (reflectance). Its reflectance is the same as that of freshly fallen snow.
Voyager had found indications that Enceladus was venting gases and contributing particles to Saturn E ring when it flew by in the 1980's (Smith et al, 1982).

Now the Cassini spacecraft has made very close flybys that have given even more information about this unusual body. Fissures in the surface show very warm temperatures and plumes of water and carbon dioxide were observed that reach hundred of kilometers above the surface.

Enceladus is so small that it does not have a "collisional" atmosphere. That is, the vapor pressure is so low, the molecules rarely collide with each other and escape easily to space. The fact that an atmosphere was detected by Cassini implies a continual replenishment of gases from the surface fissures.

Recent interesting results reported by Cassini are:

A . Temperatures of 145 K in the region of the fissures near the south pole (Spencer et al, 2006). Since the equilibrium temperature of the satellite in the absence of any other heat source is around 80K, this high temperature is remarkable; the source of the heating is thought to be from tidal effects; radiogenic heating from isotopes is insufficient to cause such high temperatures. The north pole which has been sitting in darkness since 1995 is very cold by comparison, 32 K.

B. The atmospheric plume rising hundreds of kilometers above the surface was large enough to cause a deflection of ions in Saturn's magnetic field (ions had to travel around the plume.) The plume redistributes water from the interior to the atmosphere and coats the surface with fresh, crystalline ice and snow (Kivelson et al. 2006)

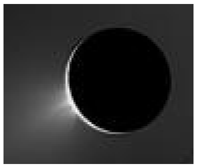
C. The geologic activity yields some of the most interesting terrain in the Saturn system: "folded ice mountains", "fractured canyons" and smoothed craters that look like ice cream (Kargel 2006)

Kargel, Science, 311,1389 (2006)

Kivelson et al, Science, 311, 1391 (2006)

Smith et al., Science, 215, 504 (1982)

Spencer et al , Science, 311, 1401(2006)



Enceladus Active world: Plumes, tectonics and freshly fallen snow

Top: Enceladus, (Voyager 2)
Middle: Faults and craters
Bottom: Plumes from polar regions, (Cassini)
– All photos courtesy NASA —

Weird Physics: Einstein Rings

T. Dockweiler

Astronomical objects have the ability to act as "lenses". This means they can focus and distort light coming from objects behind them as seen by an observer. The greater their mass, the greater their intensifying gravitational field. This was predicted by Soldner in 1804 in response to Laplace's invisible bodies hypothesis, and by Einstein in 1911 (with a hand drawing of bent light by a star in a letter to Hale in 1913). This was before his publication on the General Theory of Relativity (1916) in which gravitational fields fields "warp" space-time and thereby bend light as well.

This effect was spectacularly confirmed during a total solar eclipse on May 29, 1919 with the displacement of light from the star Kappa 2 Tauri. If the alignment is somewhat off, and the more intense the gravitational field, then arcs of light can be formed around the edge of the gravitational lens. Multiple images or gravitational mirages can occur as well. If the alignment is perfect and square on with the observer, a ring will be produced around the edge of the gravitational lens of the foreground object or group of objects. This ring is known as a Chwolson Ring or **Einstein Ring**, a special class of gravitational lenses. They can also be known as "cosmic rings".

The phenomenon of a ring was first postulated by Chwolson in 1924. Einstein provided greater thought and detail in a paper in 1936.

There are three classes of gravitational lensing. "Microlensing" involves no apparent shape distortion but the amount of light changes over time for a background object. This method was used for determining the first microlensed extra-solar planet OGLE-2005-BLG-071, announced in 2004. Small deflections or distortions of a few percent of background objects which are detected by analyzing large numbers of objects are known as "weak lensing". Large deflections produce visible distortions which can cause multiple images, arcs, and rings are known as "strong lensing".

The first gravitational lens was discovered accidentally in 1979 at Kitt Peak National Observatory in a quasar designated Q0957+561, which became known as the "Twin Quasar" (actually one quasar with a reflected image).

The object Abell 2218 (a cluster of galaxies) was used to detect the most distant galaxy known (announced February, 2004). The first Chwolson/Einstein Ring discovered was announced in 1988, the extended radio source MG1131+0456. Eight new Chwolson/Einstein Rings were announced at the end of 2005, having been discovered through the SLACS subproject of the Sloan Digital Sky Survey which is produced with a 2.5 meter (98.4 Inch) telescope at Apache Point Observatory in New Mexico.

Just over a dozen Chwolson/Einstein Rings with diameters up to an arc second are now known, most discovered in the radio range. Very few are optical, i.e. visible light.

On June 30, 2005 a team using the Very Large Telescope of the European Southern Observatory announced the discovery of the farthest known Chwolson/Einstein Ring [FOR J0332-3557 in the constellation Fornax] found yet with the intervening lens at 8 million light years from Earth, and further announced that it was the most complete ring found at that time, with imaging showing almost ¾ of a circle.

View of Einstein Ring: Foreground object distorts the image of the object behind it. Its gravity bends the light so it appears as a ring.

- -All photos courtesy NASA-

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Nuclear Physics on Mars: MSL and Near-Surface Water

M. Busch

Almost all current Mars missions have the mission strategy "follow the water". This usually means looking for evidence of past liquid water because the current Martian surface is very dry. However, neutron and gamma-ray observations from orbit show that there is roughly 10% by mass water within a meter of the surface, based on the inferred hydrogen abundance (Feldman, et al. 2004, Mitrofanov, et al. 2004).

This water could be liquid in the pore spaces between grains, chemically bound, or as ice deposits. If the former, liquid could be present at some tens of centimeters depth on the planet. The Spirit rover has seen salt deposits that may have been formed by groundwater. To determine what this water is, we need detailed information on the concentration as a function of depth in the soil. Ice deposits have the greatest density of water, pore-space groundwater the least.

The orbital observations use the cosmic ray-induced neutron flux from the surface. Neutrons produced by cosmic ray showers are reduced in energy and thermalized by scattering off of hydrogen. The degree of modulation depends on the amount of hydrogen present, which is expected to be almost entirely in the form of water. The cosmic ray flux is constant, so passive measurements are not sensitive to the vertical structure of water, but only to the total concentration in the uppermost meter or so of soil (the penetration depth of the neutrons).

The Mars Science Laboratory, NASA's next rover mission, will carry an active neutron source (see MSL website). A constant flux gives no depth information, but a pulse does, because neutrons that penetrate deeper take longer to return to the surface and be measured. The MSL neutron source is based on fusing deuterium and tritium to helium and neutrons, in 30 microsecond bursts up to ten times per second (Mitrofanov, et al. 2005). The neutrons fly out in all directions, roughly half of them scatter around a few cubic meters of soil, and within tens of milliseconds the radiation has dissipated, with a few hundred neutrons recorded by the counters.

This is the first instance of fusion done on another planet. The source works by accelerating deuterium up to several hundred keV, then smashing it into tritium. The deuterium and tritium fuse, producing helium and neutrons.

Although this is fusion, it is not on any scale approaching profitability for energy generation, except that it gives a pulsed source of uniform-energy neutrons (the machine produces 1E14 neutrons over its lifetime, but takes several kilowatt hours to do so). Incidently, fusion for energy generally avoids the deuterium-tritium reaction, because neutrons are very hard to confine.

This technique is sensitive to water contents of a tenth of a percent, in layers tens of centimeters thick, if a hundred pulses are summed. A more accurate method might be to dig a hole. But the rover needs to drive, and digging a hole a meter deep is time consuming. If the water-content does not vary on meter scales horizontally, the neutron source can be pulsed as the rover moves across the surface and water can be mapped for the entire mission with little time and energy expended.

Beautiful horizon:
Viking orbiter view of Mars

And so MSL will carry a desktop fusion reactor as well a fission-based thermoisotopic generator and a laser. Stay tuned for mankind's first advanced nuclear fusion experiments done on another planet !

References:

Feldman, et al., 2004; JGR, Vol. 109, E09006.

Mitrofanov, et al., 2004; Solar System Research, Vol. 38, No. 4, pp. 253-265

Mitrofanov, et al., 2005; 36th LPSC; abstract 1635

MSL mission website, http://marsprogram.jpl.nasa.gov/msl/index.html

-All photos courtesy NASA-

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Superfluous Questions:

1. What was the first satellite in the Uranian system found to have carbon dioxide on its surface in 2003 ?

a) Umbriel b) Ariel c) Oberon d) Titania

2. Who discovered Triton ?

a) William Herschel b) Galileo Galilei b) William Lassell d) Edward Barnard

3. What year were the Uranian rings first detected ?

a) 1955 b) 1962 c) 1977 d) 1982

Who first reported methane in Titan's atmosphere ?

a) William Pickering b) John Brashear c) Gerard Kuiper d) Christiaan Huygens

a) What is the highest temperature recently reported on the surface of Enceladus by the CIRS instrument on Cassini ?

a) 132 K b) 122 K c) 145 K d) 180 K

—-> ANSWERS in next months issue of the Science Newsletter ! <——-