Supersonic snowballs in hell: How comets explode, fizzle out, or survive a flight through the Sun's atmosphere

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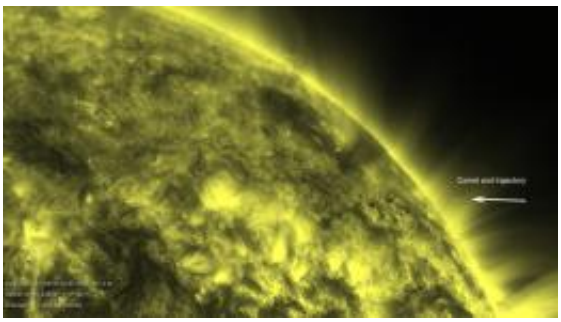

(PhysOrg.com) -- Since the 1980s astronomers have seen thousands of comets falling towards the Sun, most of them too small to survive a close approach, let alone to re-emerge. Until recently no such objects had been seen very close to the Sun as the glare of sunlight made them impossible to observe. Now a team of scientists led by Professor Emeritus John Brown, Astronomer Royal for Scotland and former Regius Professor of Astronomy at Glasgow University, have worked out which comets make it through this fiery journey, which fizzle out high up and which explode just above the surface. Prof. Brown will present this new work in a paper at the National Astronomy Meeting in Manchester on Friday 30 March.

Comets are giant dusty snowballs believed to date from the epoch of the formation of the Sun and planets, so carry important information about the early history and composition of the Solar system. The comets we see spend most of their time very far from the Sun, orbiting in the so called Oort Cloud, before being disrupted into orbits that carry them towards our nearest star over tens of thousands of years.

When comets reach the inner Solar System, their dusty ices melt and vaporise to form huge tails blown back by the solar wind and by sunlight. The largest, like the famous Comet Hale Bopp seen in the late 1990s, have nuclei tens of kilometres across and masses of 10 million million tonnes. Objects this large only lose a tiny fraction of their material on each passage around the Sun, so are able to survive thousands of journeys through the Solar System. In contrast, the smallest objects may only be 10 metres across with a mass of 1000 tonnes. If these small comets make a close approach to the Sun, they are vaporised by sunlight and by the friction of the atmospheric gas.

In the culmination of work carried out over the last few years, Professor Brown and his colleagues are now able to predict how comets lose their mass and are destroyed in the solar atmosphere, their behaviour depending on whether or not their orbital path reaches into the 'lower atmosphere' 7000 km (roughly 1% of the solar radius) from the top of the brightest visible solar layer, the photosphere. The team worked out the different ways comets give up their mass, momentum and energy to the Sun's atmosphere according to their height. Above 7000 km the cometary nuclei are slowly vaporised by sunlight and the gases streaming off into the coma and tail lose energy and momentum by atmospheric drag. In the low solar atmosphere material is stripped away not by sunlight but by the drag of the solar gas surrounding the comet and by exploding under the 'ram pressure' force of the atmosphere as the comet runs into denser layers.

The group found that sunskimmer comets (those with their closest approach more than 7000 km from the Sun) are destroyed in a slow 'fizzle' lasting hundreds to thousands of seconds, depending on their mass. During their demise they should emit weak but detectable extreme ultraviolet (XUV) radiation. In contrast, the 'sunplungers' that approach the Sun more closely will be destroyed in a few seconds as they crash into the dense layers of the lower solar atmosphere. The resulting explosions produce effects similar to those of solar flares, such as sunquakes on the Sun's surface. Finally, if the most massive comets were to collide with the Sun they would produce dramatic explosions just above the photosphere itself.

In July and December last year the NASA Solar Dynamics Observatory (SDO) satellite made the first direct observations of comets making close approaches to the Sun. The first comet, C / 2011 N3 (SOHO) was completely destroyed after passing 100,000 km above the photosphere whilst the second and larger comet, C / 2011 W3 (Lovejoy) survived a close approach to a similar distance (140,000 km) although it lost a significant fraction of its mass in the process. Both events were in line with the predictions of Prof. Brown and his collaborators. They emphasise that, contrary to some news releases, the death or attrition of such comets has nothing to do with the high temperature (two million degrees Celsius) of the outer solar atmosphere since, though hot, it is so tenuous that it contains little heat.

Prof. Brown comments: "In modelling how icy comets behave in this extreme environment, we really are starting to understand what happens to these 'supersonic snowballs in hell' when they make a close approach to the Sun.

"The two sun skimmers seen last year have already given us a new insight into the Sun's atmosphere and it's only a matter of time before we see the flare from a sun plunger – with a low enough orbit to reach the

lower atmosphere of the Sun. When that happens we will be able to analyse the light from the resulting 'cometary flare' and find out even more about the composition of the interiors of comets."

Provided by Royal Astronomical Society

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