# Accretion

In his article about extrasolar planets, Spencer (2017, p. 274-275) notes and quotes that particles up to about 1 mm may accrete (join together) by electrostatic charge and Van der Waals forces, which are stronger than gravity at such short ranges. He also notes that numerical models of accretion for large bodies, asteroids to planets, start with a size of about 1 km. Within the six orders of magnitude of sizes in between, particle collisions are likely to lead to breakup. The variations of nebular hypotheses for planetary formation propose a mixture of gasses and solid particles in a orbiting disk circling a host star and coalescing into larger bodies. But the hypotheses cannot account for the inability of accretion for sizes between 1 mm and 1 km to fuse into asteroids and larger bodies.

While the formation of a planetary system cannot be experimentally accomplished, particle interactions within the size range of 1 mm to 1 km are readily documentable. They show that gravitational forces are too weak to hold assemblages of solid particles together and fuse them into rocks, especially during collisions. Ordinary people around the world are daily observing some of the particle collisions within this size range. This might be included in what is now called citizen science.

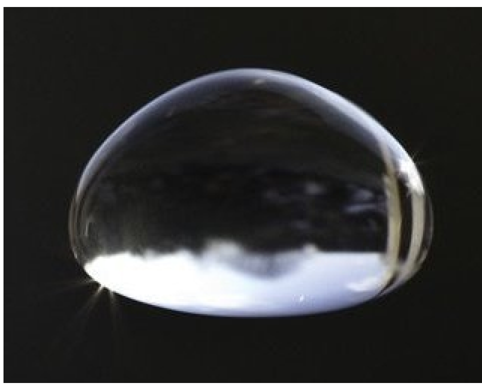

Figure 1. Water drop in free fall.

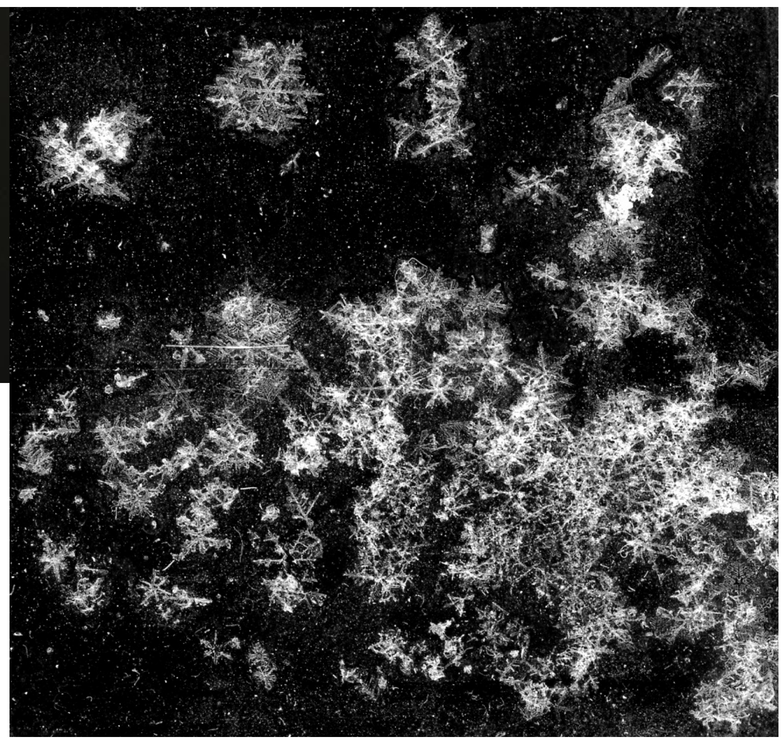

Figure 2. This huge snow aggregate of dendrites of less than 3 cm size spread out to 4 cm on impact during preservation about 50 years ago.

One might notice that raindrops do not exceed about 1 cm in size (Figure 1). In cold climates, snow aggregates usually do not exceed about 3 cm in size (Figure 2). Falling through the air, the very large precipitation particles tend to fragment. The largest snow aggregates are held together mostly by interlocking dendritic branches and some possible deposition of condensing water vapor and/or freezing of water droplets. Hailstones exceed these sizes, but their growth comes from the freezing of supercooled water onto their surfaces.

Though not relevant to solid particles in space, bulk liquid water larger than 1 cm moving in calm air fragments into small droplets. In the 1960s Duncan C. Blanchard dropped buckets of water down the elevator shaft of a tall unfinished skyscraper office building in Albany, New York (personal communication). The bulk water broke up into water droplets no larger than 1 cm, as measured near the bottom of the shaft.

Figure 3. Texas National Guard UH-60 Blackhawk drops water over hot spots.

Confirmation experiments of bulk water in 60 m of freefall were reported by Blanchard and Spencer (1970), giving maximum sizes of 9 mm and indications that drops larger than about 5 mm were unstable. Water released from large buckets under a helicopter during forest fire suppression likewise fragments into a similar spray of raindrop sizes (Figure 3). Surface tension forces, which are much stronger than gravity, cannot hold together bulk water falling through the air.

On 7 December 1968 lake-effect clouds from Lake Erie were heavily seeded with AgI in an attempt to produce ice crystal sizes much smaller than normal, with the hope that they would fall more slowly and drift farther inland beyond the coastal transportation corridor (Holroyd and Jiusto, 1971). Snow crystals averaging only 200 micrometers in size were indeed produced, as sampled and analyzed by Holroyd.

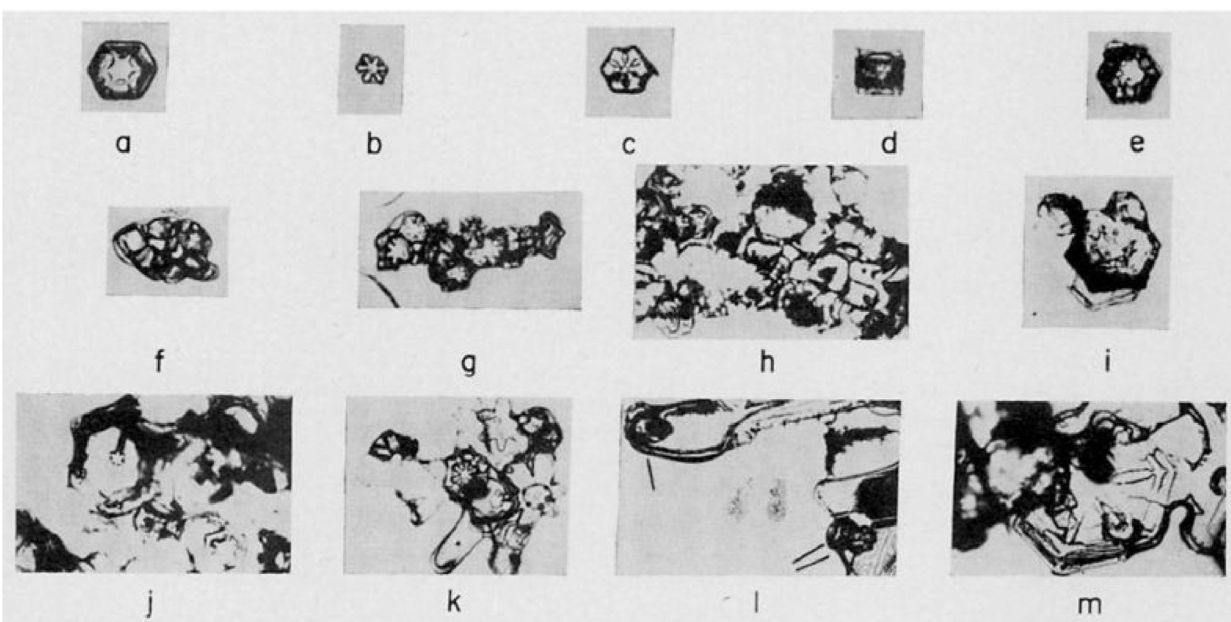

FIG. 2. Photographs of snow crystals falling from 1315 to 1411 EST on 7 December 1968 while the seeded cloud was overhead. Scale for all photographs: 1 cm = 300 $\mu$.

Figure 4. Copy of Figure 2 from Holroyd and Jiusto (1971) of single and aggregated tiny ice crystals.

The small crystals (Figure 4) were thick hexagonal plates and solid columns, unlike the natural dendritic crystals falling from those clouds. However, they aggregated into snowflakes of sizes similar to the natural snowflakes and with similar falling speeds. The small crystals with no branches to interlock were likely held together by water vapor deposition rather than riming (freezing of supercooled cloud droplets), though electrostatic forces may also have been involved. This is similar to the observation in Spencer (2017) that particles smaller than 1 mm can accrete from non-gravitational forces.

Figure 5a. Gobi Desert sand dune surface.

In many parts of our world are large deserts, many with dunes of loosely accumulating and moving sand. The particles in Figure 5 (a and b) from the Gobi Desert of Inner Mongolia, China, are less than 1 mm in size and easily dispersed by wind. They will never turn into rock without the addition of a binding agent - silica, carbonate, iron or similar. Sand in space will not gravitationally accrete into solid rock.


Figure 5b. Gobi Desert sand, The smallest division of the metric ruler is 1 mm.

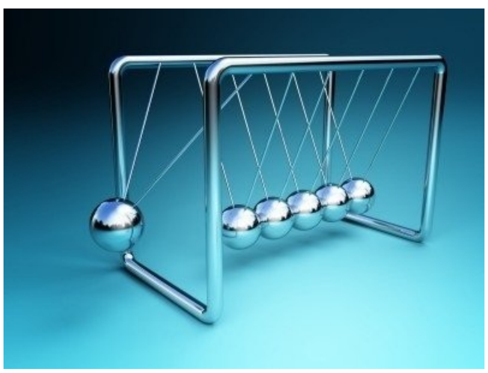

Figure 6. Collision balls apparatus

There is a collision balls apparatus commonly used in physics demonstrations for conservation of energy and momentum. Ball sizes are typically in the centimeter size range, suspended on strings. Most are touching. When the moving end ball strikes the series of touching balls, the first ball stops and the ball at the far end is ejected to beyond until it swings back. The same physics should apply to loosely accreted particles in space. The impact of an incoming particle is likely to eject at least one similar particle, though the impact could shatter the entire particle assemblage instead.

Increasing the size to a few centimeters, a billiards table arrangement (Figure 7) usually starts with 15 touching balls. When struck by the incoming ball, the assemblage shatters. The gravitational attraction between the balls is insignificant. The frictional force between the balls and the table surface is much greater in comparison.

Figure 7. Billiards balls about to scatter.

Figure 8. The incoming ball scatters the bowling pins.

Increasing the size to tens of centimeters, bowling likewise shows that the incoming “particle” (bowling ball) shatters the orderly arrangement of the pins (Figure 8). The objects do not fuse together into fewer and larger objects.

The next size increment comes from two examples of two meter-sized objects actually colliding in space. They did not fuse into a single object.

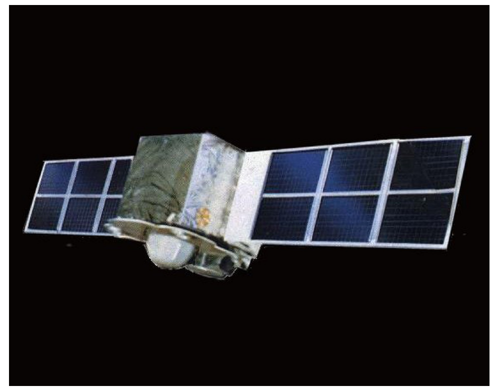

Figure 9. The Chinese Fengyun FY-1C weather satellite.

On January 11, 2007, China conducted an anti-satellite missile test. An old Chinese weather satellite (Figure 9 - the FY-1C polar orbit satellite of the Fengyun series) with a mass of 750 kg - was intentionally destroyed by a kinetic kill vehicle traveling with a speed of 8 km/s in the opposite direction.

This event was then the largest recorded creation of space debris in history with more than 2,000 pieces of trackable size (golf ball size and larger) officially cataloged in the immediate aftermath, and an estimated 150,000 debris particles. As of October 2016, a total of 3,438 pieces of debris had been detected, with 571 decayed and 2,867 still in orbit nine years after the incident. So the impact of two large objects did not fuse them together. Instead many thousands of smaller pieces of space junk were created, creating hazards for other satellites.

Two years later, on February 10, 2009 over Siberia, the inactive Russian Cosmos 2251 communication satellite accidentally collided with the American Iridium 33 satellite that was providing mobile phone service. Cosmos 2251 was a cylinder about 2 meters in diameter and two meters high with a mass of 900 kg. Iridium 33 was about 4 by 1.8 meters in size with a mass of 700 kg. They impacted at nearly right angles at a relative speed of 11.65 km/s. Analyses by Aerospace indicated about 200,000 1-cm untrackable debris objects and more than 3273 10-cm or larger objects that are trackable (Figure 10). Over time they are burning up upon re-entry into the atmosphere, but some hazardous debris will last for decades. Again, the two multimeter-sized objects did not fuse together into a single object but shattered into hundreds of thousands of smaller objects.

Saturn rings (Figure 11) have been observed for centuries, and more recently in fine detail by the Cassini satellite mission. Analyses continue, so it is not known now much the small ring particles are accreting or fragmenting. Nor has the speed of these processes been determined, but it appears to be slow. What seems likely is that the particles in the rings of Saturn are not accreting into large moons or asteroids.

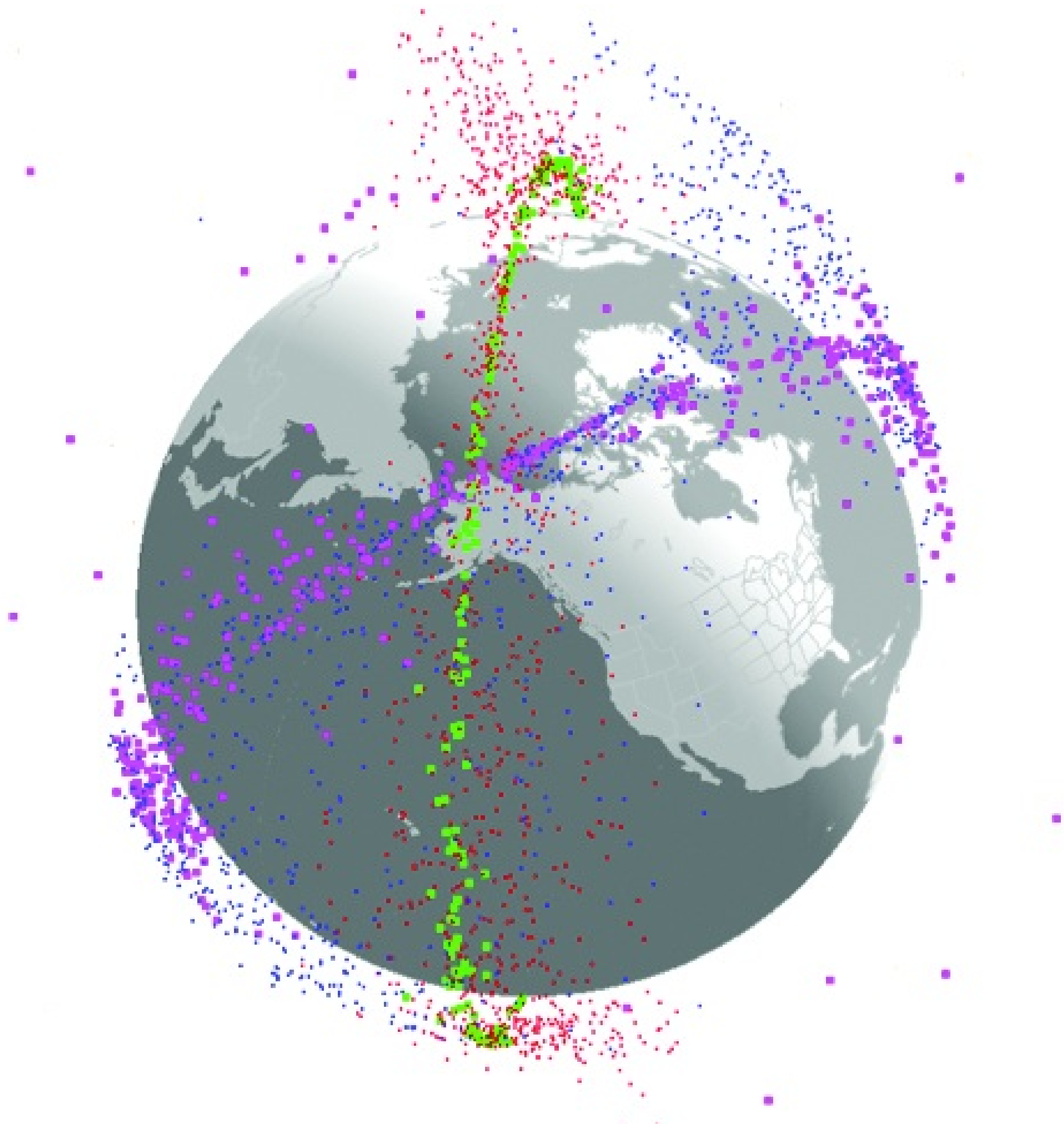

Figure 10. Caption from Aerospace: “This image compares the cataloged debris from Iridium 33 (green) and Cosmos 2251 (purple) for sizes approximately 10 centimeters or larger. Overlaid in red and blue are Aerospace models of the 1 centimeter and larger debris that is untrackable.”

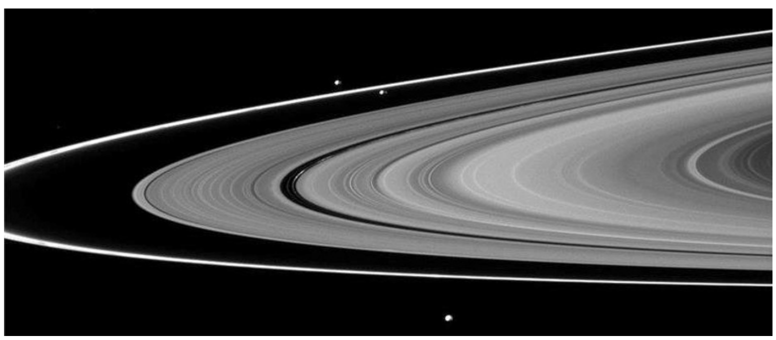

Figure 11. Saturn’s rings and some small moons.

Near the largest end of the size range, comet cores are typically a few kilometers in size. Of course, there is no nebular dust ring around the sun at present by which comets might accrete more particles. The solar wind is eroding comets, producing their bright tails of dust and sand particles and the fainter tail of ions (Figure 12).

When passing close to Jupiter or the Sun the strong gravitational gradients fragment comets into large pieces. Figure 1 of Davis (2017) (Figure 13) shows the 21 fragments of Comet Shoemaker-Levy 9 between its prior fragmentation by Jupiter and its collision with Jupiter.

So space dust and sand can never gather together in a gaseous environment to form meteorites, asteroids and planets as proposed by the nebular hypothesis. Gravity is too weak and other forces are too strong in the particle size range of about 1 mm to 1 km.

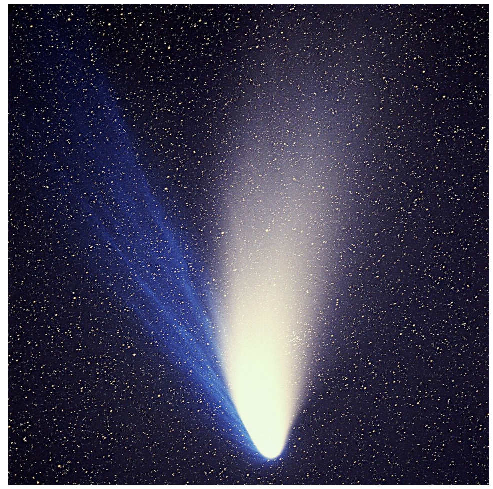
Figure 12. Comet Hale-Bopp with bright dust tail and blue ion tail.

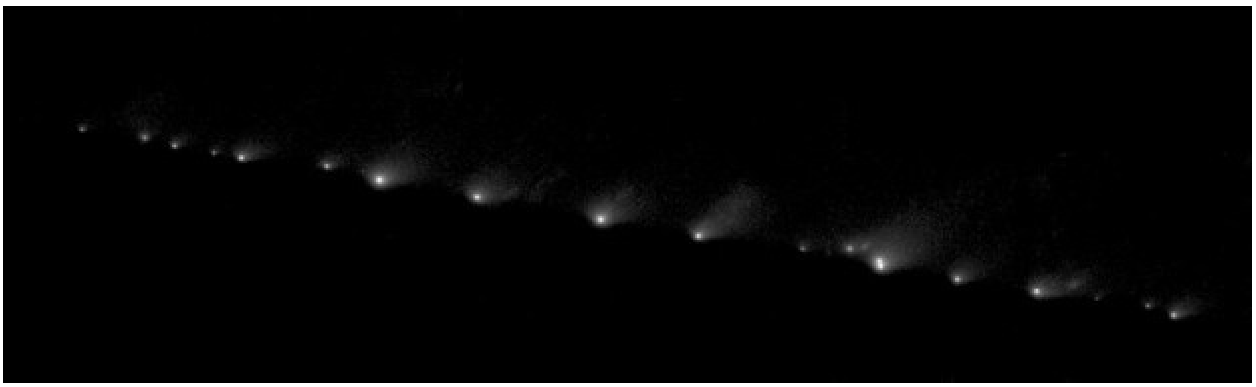
Figure 13. Comet Shoemaker-Levy 9 after fragmentation by a close encounter with Jupiter.

# References


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