Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *Getting it together.*

Wanna build celestial objects? I mean it sounds easy - you just start with a big cloud of dust and give it a nudge so that it starts to spin and accrete so that you end up with a star with a few wisps of dust left in orbit that then continue to accrete to form planets.

Trouble is - this process doesn't seem to be physically possible when we've tried to replicate it in theoretical models and laboratory tests. I mean, OK - clearly it happens quite readily out there in the universe, but exactly how is the puzzle. There's a problem with the initial small scale accretion steps.

1. *The metre barrier*

Microscopic dust grains seem to stick readily together - through van der Waals forces and electrostatic forces - steadily building up to form millimetre and centimetre sized aggregates. But once they get to this size those sticky forces become less influential - and the objects are still too small to generate a meaningful amount of gravitational attraction. What interactions they do have is more in the nature of bouncing collisions causing pieces to be chipped off those bouncing objects so that they start getting smaller again.

This is an astrophysics problem known as the metre barrier.

To get around the metre barrier, researchers have begun to question the basic assumption that you start with a uniform dust cloud in which spontaneous accretion happens throughout the cloud - meaning that you go from a uniform dust cloud to a uniform collection of very small rocks.

2. *Dust clouds aren't actually uniform*

Firstly it's unlikely that any dust cloud will be particularly uniform. A dust cloud, at least in the modern universe, will have all sorts of trace elements mixed in - delivered by past supernovae, as well as planetary nebulae from red giants.

This diversity of content may disrupts the uniformity of accretion events - and may be why the early universe was populated by whopping, hypergiant stars - while these days stars form across a wide variety of sizes - and for the most part they are smaller.

So, a degree of instability can be expected in small-scale dust aggregation - where the diversity of atomic weight between different elements may make some dust specks more successful at aggregation and accretion than others. Also, turbulence in a dust cloud may create whirlpools and eddies that will favour the local aggregation of small particles into larger particles. Current theory is that a nearby supernova or perhaps a nearby pass of a migrating star is the trigger event that turns a relatively stable dust cloud into a stellar nursery.

3. *Over long time periods, unlikely things do eventually happen.*

There is also a certain stochastic inevitability about anything that has the faintest chance of happening - eventually happening. Over several million years, within a huge dust cloud that might be several hundred astronomical units in diameter, a huge variety of interactions becomes possible. And even with a 99.99% likelihood that no object can ever aggregate to a size bigger than a metre, it's still entirely likely that this is going to happen somewhere, sometime, in that vast area of dust.

It's possible to model some rare collision events that do result in the building up of mass by sub-metre sized objects. For example – while a two body collision may just result in a deflecting bounce – three or four bodies colliding from different directions could result in two or three of them being jammed together with just one of the objects flung away - carrying most of the kinetic energy of the collision with it.

And some bouncing collisions may help compactify an object - making it denser, even if not increasing its mass. This will help with later accretion stages, since more gravitational potential is generated by a small dense body – than a small diffuse body.

4. *Once you're past the metre barrier, everything snowballs.*

Now, once an aggregated object achieves a certain mass it will become less engaged in turbulent flow and more likely to adopt a defined Keplerian orbit around a centre of mass. So, the object will begin to move through, rather than move with, the dust. Under these circumstances, it will behave like a snowball rolling down a snow-covered hill, collecting a covering of dust as it ploughs through the dust cloud - increasing its diameter as it goes.

Modelling with this snowball process can build up objects with a radius between 100 and 1000 kilometres, at which point further growth is almost guaranteed through the gravitational attraction that the large objects are able to generate – regardless of some fairly vigorous collisions such objects may subsequently endure.

There's still another theoretical problem here – since the resistance of the dust should slow the snowballs' velocity – so even though they grow in mass they also undergo orbital decay – which means these growing snowballs may just spiral slowly inwards and crash into their star. But OK – perhaps most of them do – and it's just a couple now and again that get flung back outwards by interaction with other snowballs – just enough to keep their orbit high, despite the continued braking effect of the dust.

5. *Bringing it all together.*

So, given that the formation of any large objects by accretion, is unlikely – and even when they do most of them will just fall into the star - it's perhaps not so hard to see why 99.9% of the mass of our solar system is in the Sun – and our planets are a very scant remainder what was once a thick and dusty protoplanetary disk.

It's also likely that the evolution of a planetary system from a protoplanetary disk by the snowball process could take quite a long time. It's estimated that it may take from 1-10 million years to go from a thick dense dust cloud to a collection 100 to 1000 kilometre radius-sized objects, which then undergo further evolution through collisions until a stable system of planets is resolved.

The period between when the dust cloud that became our solar system began to flatten and spin around a central point of mass, until that mass was heavy and dense enough to form a main sequence star, is estimated to be at least 50 million years – and then there might have been another 50 million years, while the protoplanetary disk evolved into orbiting planets and belts – with most of the planets, except the ones nearest the Sun, managing to hang onto their own little accretion disks to form moons and rings.

6. *The mandatory punchline.*

So, you know? I reckon this theory has more than a snowball's chance in hell of being right.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website where we just bounce ideas around until something accretes. No ads, no profit, just good science. Bye.