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Hopes and challenges in modern planet formation

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With the discovery of over 5000 extrasolar planets to date, the formation and evolution of planets and planetary systems are one of the most rapidly developing fields of astrophysics.

In the standard 'bottom-up' scenario, planets form from planetesimals — km or larger-sized bodies. Planetesimals form from small, mm-cm size pebbles, which themselves form from micro-sized dust grains, which are immersed in gaseous protoplanetary disks around young stars. The formation of planetesimals is arguably the most important step in planet formation theory, but it is the least understood.

In particular, pebbles are too large for growth through collisional sticking but are too small for their mutual gravitational attraction to be effective. The leading theory to grow from pebbles to planetesimals rely on a leap-growth mechanism called the streaming instability. This instability is powered by the mutual friction between dust and gas in rotating flows and can generate high-density clumps of pebbles that eventually undergo collective gravitational collapse directly into planetesimals. How the streaming instability operates under realistic disk conditions has therefore become a critical issue to address.

In this talk, I describe several obstacles, but also new possibilities, on the road from dust to planets from recent theoretical modeling of planetesimal formation in modern models of protoplanetary disks. These include the effect of turbulence, disk structure, and magnetic fields.

I will also describe how planets, even after their formation, continue to interact with their nascent protoplanetary disk to produce complex morphology — a fact that can be reverse-engineered to detect young exoplanets.