The First Stages of Planet Formation

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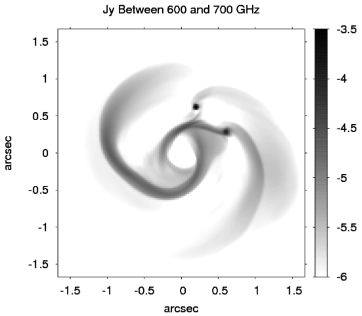
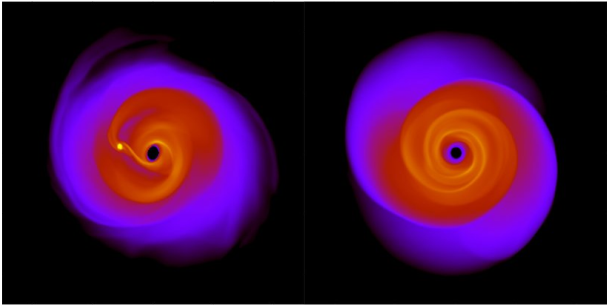


Image: Observable morphology of a simulated gravitationally unstable disk with newly-formed fragments. The image assumes that the disk is 150 pc away, giving a radial extent of about 150 AU.

Summary

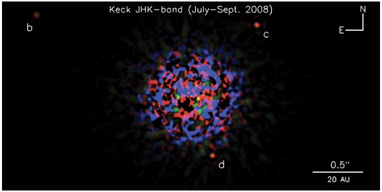
The projects supported by this Sagan Fellowship will focus on early disk evolution – the period that starts and sets the stage for planet formation. Models for this phase of disk evolution are crucial to our understanding of the diversity of planetary systems and of the robustness of planet formation. For this research, supercomputer simulations will be used to study when and where large solids begin to form, to investigate the formation mechanisms of gas giants, and to explore heating events in protoplanetary disks that can process dust and alter disk chemistry.

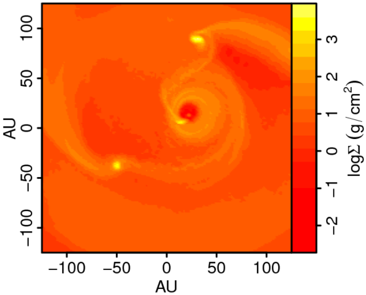
Exploring When and Where Planet Formation Begins



Left: During its formation, the protoplanetary disk became gravitationally unstable and fragmented into a dense clump. Clumps that survive may become gas giant planets, while clumps that do not survive can become factories for processing dust very early in a disk's lifetime. *Right:* The disk became gravitationally unstable during its formation and produced prominent spiral structure, but did not produce fragments. Even the spiral waves in this young disk may be sites for the start of planet formation. The disks shown here are about 300 AU in radius. The innermost portion of the disk has been removed for computational considerations (From Boley 2009).

Exploring Formation Mechanisms of Gas Giant Planets

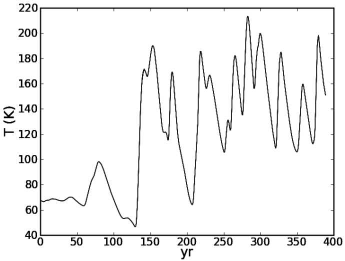




Systems like HR8799 may be best explained through the fragmentation of spiral arms in the outer regions of disks.

Left: Direct image of HR8799, a planetary system with three gas giants on wide orbits (image credit: Marois et al. 2008, Sci., 322). *Right:* Surface density plot of a gravitationally unstable disk with newly-formed fragments. The disk becomes unstable during its formation (from Boley et al. 2010).

Exploring Consequences of Spiral Waves for Disk Chemistry



Spiral waves, clumps, and clump disruption can cause strong, local variations in disk thermodynamics. Dust, ice, and gas will be exposed to abrupt changes in temperature and pressure as they pass through asymmetric disk structure, e.g., shocks along spiral arms. These pressure and temperature variations could give rise to rich disk chemistry with observational signatures.