We simulate the evolution of the circumstellar and circumbinary disks in a system configured to appear similar to that observed for the GG Tau A binary. We find that mass transfer onto the circumstellar disks is episodic with maximal transfer rates which change from orbit to orbit, but which occur following each apojove passage. Accretion rates onto the stars themselves does not display such periodicities, so the disk masses vary somewhat over the binary orbit. Averaged over time, mass transfer into and out of the disks equilibrates at a disk mass of about one Jupiter mass, for both the primary and secondary. The transfer rate of material through the disks is rapid enough to effectively replace the entire disk in less than 10,000 yr. We discuss the implications of our results on planet formation in this and similar systems.

**Physical Model and Numerical Method**

- We use the **Smoothed Particle Hydrodynamics** (SPH) code VINE (Wetzstein et al., 2009, Nelson et al., 2009) to simulate the evolution of the GG Tau A system in 6.5 kyr using a total of ~1.8 million particles. Approximately ~17000 and ~4000 are allocated to the primary and secondary disks respectively, the rest to the circumbinary. We also run a low resolution run, with ~425 thousand particles, is also shown in figures 2 and 3.
- We include from the disks, using the prescription originally described in Nelson et al. 2000, in which a vertical structure model is used to define a “photosphere” temperature at each location in each disk, which is then used to define a blackbody cooling rate there.
- We implement a similar model to define temperature from the two stars, from light impinging on the disk photosphere at each location.
- Gravitational forces from both stars and the gas of the disk material are included.
- Masses from the circumbinary disks onto the stars is permitted. The mass and momentum of any particle traveling closer than 0.3 AU from either star is added to that star’s value and the SPH particle is removed from the simulation.

**Introduction**

The GG Tau A system is one of the best studied binary proto-stellar systems (see e.g. Beust & Dutrey 2005, Guilloteau et al. 1999, and their references). The binary components are characterized by a projected separation of ~35 AU, and are surrounded by a torus, sharply bounded at intermediate radial dimensions of ~180 AU and ~260 AU and inclined relative to the line of sight by 37°. In addition, a lower density disk extends outwards to ~800 AU. This system forms one component of a hierarchical quadruple system with projected separation of ~1500 AU. The quality and variety of observations of GG Tau A make it an excellent laboratory for testing theoretical models of binary formation and evolution, and in this work we attempt to simulate a system based on its configuration. Our focus will be to address the following questions:

- What is the actual semi-major axis and eccentricity of the stars? Models of Beust & Dutrey, fitting observed proper motions, suggest orbit parameters of a=32 AU and e=0.3, but with slightly larger error bars, a range extending from a=25 to 70 AU, and e=0 to 0.6 is possible. As Beust & Dutrey discuss, a semi-major axis of ~62 AU is also expected based on resonance analysis and the observed inner edge of the torus.
- Can we reproduce the sharp inner/outer boundaries, as well as the asymmetries observed in the torus, in the context of the stirring generated by the binary motion?
- What are the features of the circumstellar disks? Can planet formation occur there?

**Analysis, Discussion and Ongoing Work**

- The circum-binary torus develops persistent, but dynamically changing internal structure, with non-circular structure.
- To what extent will the boundary propagate inwards when a smaller orbit is assumed for the binary?  The inner torus “edge”, such that an edge can be defined at all, falls at radii inward of the 180 AU radius derived from observations. Over timescales of several binary orbits (not shown here), the torus extends inwards both more and less than in the images above, as the torus itself evolves.
- To what extent will the inner edge propagate inwards when a smaller orbit is assumed for the binary?  The inner torus “edge”, such that an edge can be defined at all, falls at radii inward of the 180 AU radius derived from observations. Over timescales of several binary orbits (not shown here), the torus extends inwards both more and less than in the images above, as the torus itself evolves.
- To what extent do such asymmetries affect determination of the system’s inclination, derived from de-projecting the torus into an assumed circular shape?  Remnant spiral structures generated over multiple binary orbits overlap each other as they propagate outward. At some locations sharp boundaries exist between one region and the next. At others, a much shallower gradient exists.
- How well do such structures reproduce the sharp torus/disk boundary observed/fit by Guilloteau et al.?  Remnant spiral structures generated over multiple binary orbits overlap each other as they propagate outward. At some locations sharp boundaries exist between one region and the next. At others, a much shallower gradient exists.
- Mass falls episodically onto both circumstellar disks preferentially onto the secondary disk, such that its mass grows to ~2x that of the primary.
- Disk morphologies extend to ~15 AU and to masses of ~1M⊙, and include episodic internal spiral structure.
- Accretion through both disks at rates high enough to replace all material in them within a few thousand years.

**Bibliography**

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