Emission properties of an eccentric disk around HD69830

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Abstract

Spitzer observations of HD 69830 have revealed an excess of emission relative to the stellar photosphere between 8 and 35 microns, but no excess at 70 microns. Subsequent radial velocity observations have also revealed a system of 3 close-in Neptune-mass planets in the same system. We investigate the potential for a long-lived eccentric planetesimal disk to explain these observations. We perform n-body simulations of the system formation to investigate the potential for the formation of eccentric disks and then combine this work with models of their collisional evolution, in order to understand the long-term spectral emission properties of such disks.

Observations

- Radial veocity observations of HD 69830 (Lovis et al. 2006) reveal a system of 3 intermediate mass planets ($M \sin i = 10.2$, 11.8 & $18.1 M_{\oplus}$) orbiting close-in to the central star (Fig 1, semi-major axes of 0.08, 0.19 & 0.63 AU).
- Spitzer observations (Beichman et al. 2005) find a strong SED excess at 8 and $35 \mu m$, but no excess at $70 \mu m$ (Fig 1), indicative of a system containing warm dust ($\sim$ 400K) orbiting close to the central star ($\sim$ 1AU).

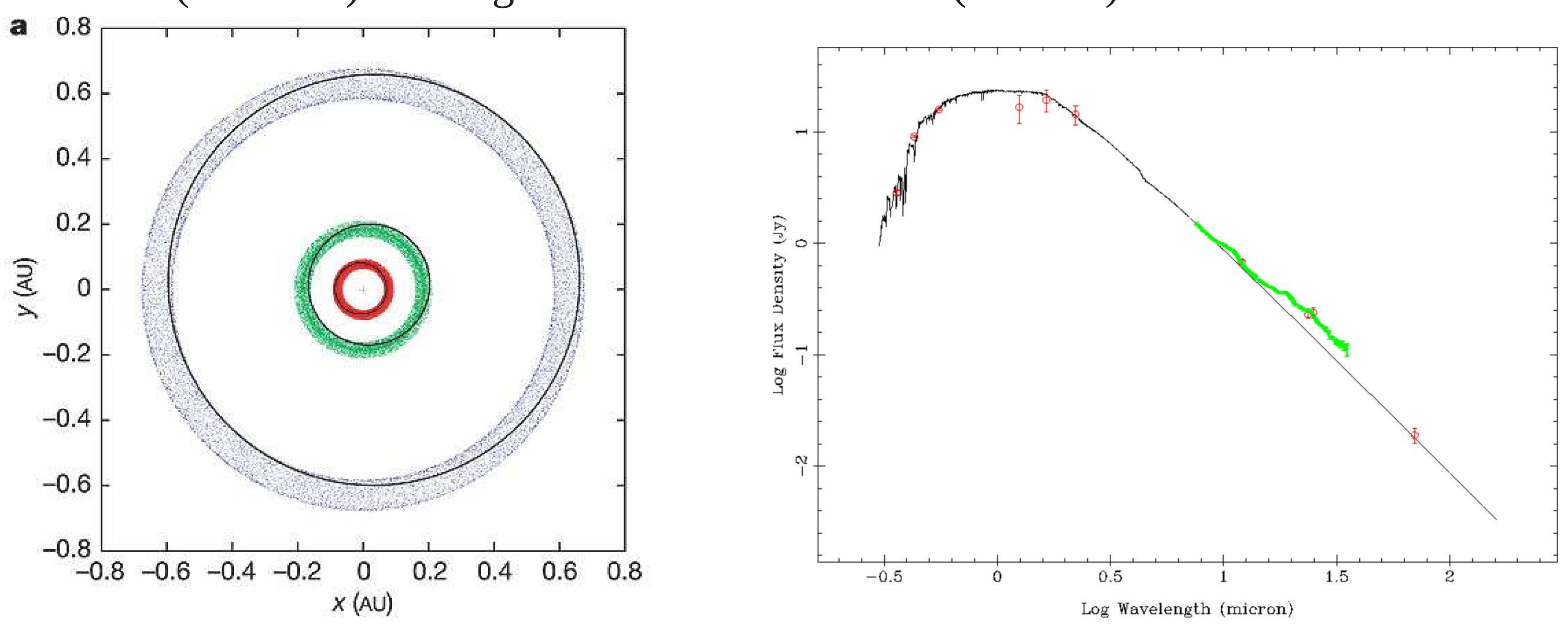

Fig. 1 The HD69830 system: Left - Planetary orbits and their stability (Lovis et al. 2006). Right - Excess emission in the Infrared (Beichman et al. 2005)

Models

Previous work (Beichmann et al. (2005), Lisse et al. (2007), Wyatt et al. (2007)) has suggested that the IR emission could arise in a number of ways: A massive cometary population, the capture of a super-comet into a circular orbit at $\sim 1AU$, steady-state evolution of a planetesimal belt at $\sim 1AU$, a recent collision in a planetesimal belt at $\sim 1AU$, or a LHB-type dynamical instability in an outer belt.

Wyatt et al. (2007) demonstrated that the collisional processing of a circular belt at $\sim 1AU$ would have removed most of the belt's mass in a time much shorter than the age of the system, hence making this an unattractive option for explaining the emission. However, we wished to investigated whether an *eccentric* disk could survive for a longer period, and moreover, whether such an eccentric disk would naturally arise as a byproduct of the planet formation process in HD69830.

Simulations of Planet Migration & Planetesimal Scattering

We use the semi-analytic migration models of Alibert et al. (2006) as the basis for a detailed n-body simulation of planet formation and migration in HD69830, employing the MERCURY code of Chambers 1999. We investigate the scattering of planetesimals (test-particles) due to the forced migration of the planets, examining the accretion rates, the effects of gas damping and the self-excitation of the planetary eccentricities.

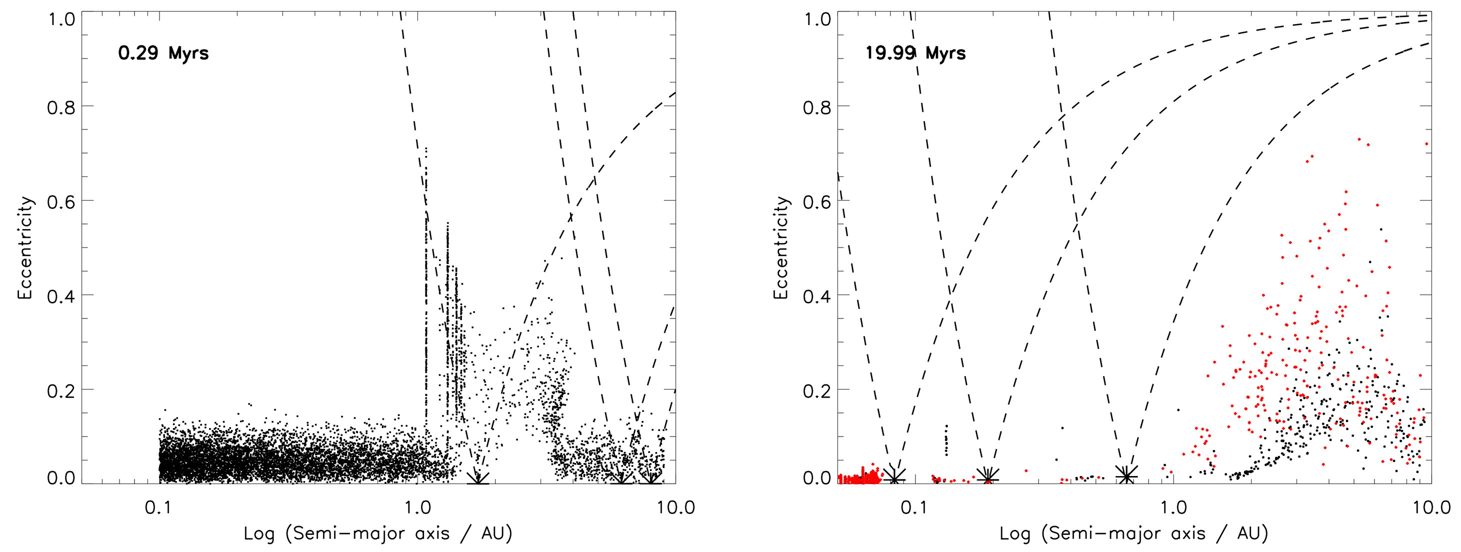

Fig. 2: Eccentricity-v-Semi-major axis plots. Left - The system 0.29 Myr after the commencement of migration. Populations of shepherded planetesimals are clearly visible, trapped in MMRs as they are forcibly migrated ahead of the planets. Right - At 20 Myr, planet migration and growth has finished and the gas disk has dissipated, we find that there is a massive, eccentric, size-sorted scattered disc present in the system, BLACK - 100km planetesimals; RED - 1,000km

We find (Example results, Fig 2) that

- The models of Alibert et al. 2006 *cannot* self consistently explain the observed eccentricities and masses of the planets around HD 69830. Our n-body models suggest that the relative rates of accretion would be very different from those assumed in their semi-analytic formulation.
- However, we find that gas damping of planetesimals does *not* act as an insurmountable obstacle to the existence of an excited disk in the system: In all of the simulations we performed, a massive, extended and excited disk remained in the system exterior to the planets
- Gas damping works to size sort the planetesimals, resulting in the largest planetesimals (which are likely to contain a very large proportion of the mass) having the most eccentric orbits.

Eccentric Disk Emission Properties

We consider an extension to the work of Wyatt et al. (2007) and model the expected collisional lifetime of an eccentric planetesimal population. We find that for a fixed-pericentre population, extending the eccentricity from 0 to 0.9 increases the collisional timescale and hence the remaining mass by a factor of 30 (Fig 3), meaning that at 2Gyr there may be sufficient mass remaining to explain the observed emission. Given that our n-body simulations predict the existence of such an eccentric population, we wish to understand its expected emission profile.

The emission properties of black bodies on such eccentric orbits results in there being far too much emission at long wavelengths to be consistent with observations. We therefore investigate grey-body emission models for these bodies

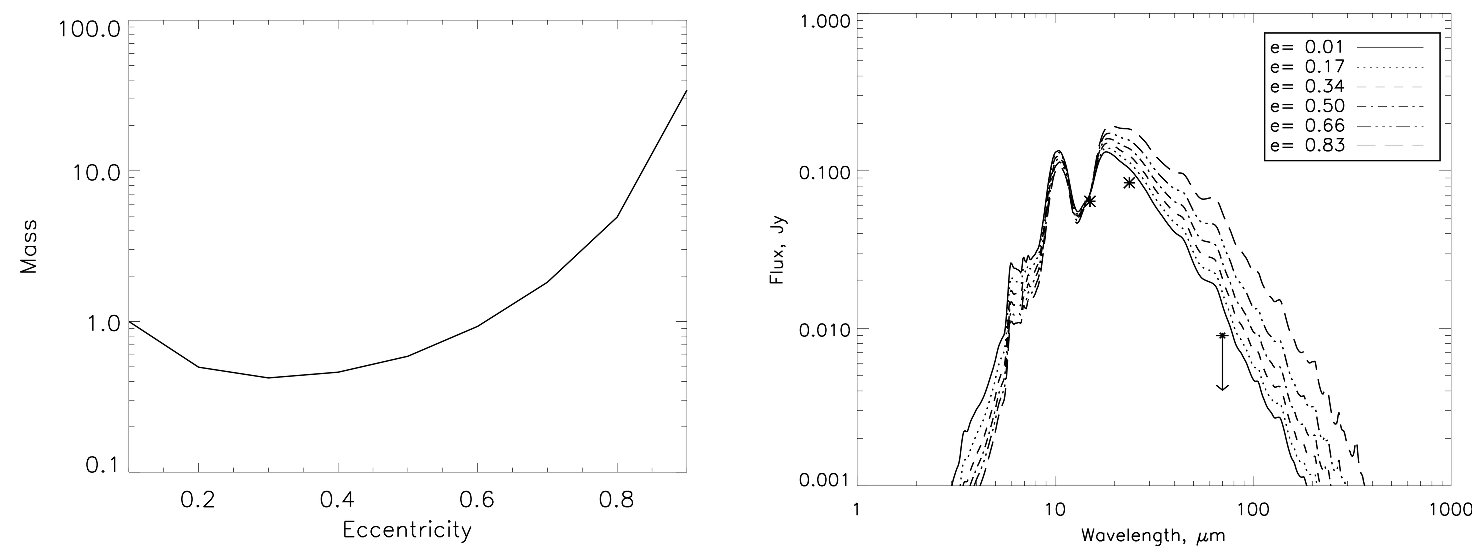

Fig. 3, Left - Remaining mass (arbitrary units) compared to the (circular) model of Wyatt et al. (2007), showing the increase in remaining mass at late times for eccentric disks with $q = 1AU$. Right - Grey-Body emission profiles for asteroidal composition. With $q = 1AU$ the emission at long wavelengths is too high.

The grey body emission *does* lower the long wavelength emission (Fig 3), but not, in current models, by an amount sufficient to fit with the observational limits.

Conclusions

- An extended, eccentric, massive, size-sorted disk is very likely to have existed in the HD69830 system at the end of the planet formation period.
- For a given pericentre, more eccentric disks allow more mass to survive in a planetesimals disk at late times, and hence sufficient mass may remain to explain the observed IR emission.
- Results of SED modelling suggest that our current models of grey-body emission on eccentric orbits *cannot* explain the observed emission in HD 69830.
- Further work will be required to understand whether refinements to the size distribution, compositional models or the inclusion of a more sophisticated sublimation model would significantly lower the long-wavelength emission and thus satisfy spectral constraints

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