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ESTIMATING THE AGE OF HD95086b BY ALMA

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ABSTRACT

HD95086 is a young (~17Myr) system that harbours both an extended bright dusty debris disk and a 5M_{Jup} giant planet orbits at ~62AU with an unknown eccentricity (Rameau et al. 2013). The dust grains are found to be located in two distinct belts and in-between a dust depleted region (presumably a chaotic zone) formed with a size of ~80AU (Moor et al., 2013; Su et al., 2015). We modelled the gravitational perturbation of the planet on the debris disk by means of N-body integrations. An eccentric planet excites the formation of spiral pattern in the dust distribution due to its gravitational perturbation. The emerging structure evolves such that the spiral pattern is winding outwards with time (Wyatt 2005). The evolution of this spiral pattern is found to be nearly independent of the planetary eccentricity for models that assumes fixed chaotic zone width having similar size inner dust hole. Based on synthetic sub-millimetre images, we conclude that it is possible to estimate the age of planet by inferring the age of secular perturbation with ALMA observations.

SECULAR PERTURBATIONS

Giant planets form a chaotic zone around its orbit. As a result, the bodies originally orbit in the chaotic zone are scattered out and form a dust depleted hole in the disk. Based on the overlapping and the width of high order resonant orbits, the size of this chaotic zone can bee calculated (Wisdom, 1980 for low and Mustill & Wyatt, 2009, for significant planetary eccentricities). The inner edge of the outer dust belt of HD95086 is at ~80AU. Assuming that this hole is formed by the discovered planet, the radius of the chaotic zone has to be ~80AU for arbitrary planetary eccentricity. Thus, a model set can be defined in which the size of chaotic zone is fixed for different planetary eccentricities (Fig. 1).

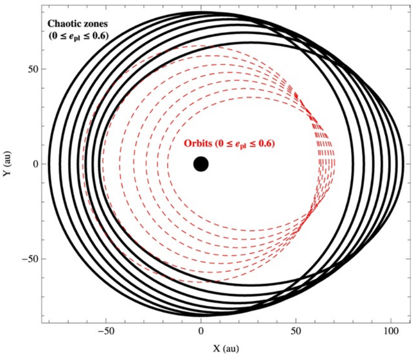

Fig. 1: Chaotic zones of a giant planet on different e_{pl}.

It is known that a giant planet perturbs the orbits' of bodies in its disk. Based on the theory of secular perturbations, Wyatt (2005) has shown that a time-evolving, one armed spiral structure develops for non circular planetary orbits. The time-scale of secular perturbation at a given radius (r) depends on the planetary semi-major axis and eccentricity ($t_{sec} \sim r^2(e_{pl}a_{pl})^{1/5}$). However, in the model set assumming fixed chaotic zone width, the eccentricity dependence is suppressed (Fig. 2). Such models have a peculiar feature: the time-evolution of spiral pattern only weakly depends on the planetary eccentricity. Therefore it is worth investigating the evolution of spiral patterns assuming different planetary eccentricities.

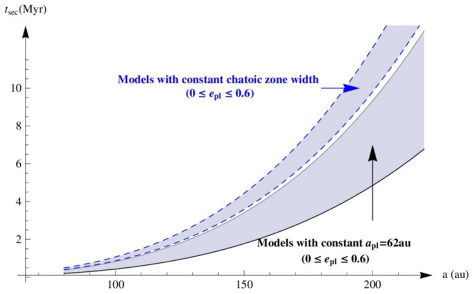

Fig. 2: Time-scale of secular perturbations with different e_{pl}.

N-BODY SIMULATIONS

We modelled the 20Myr secular perturbation of a 5M_{Jup} planet on its debris disk consisting of dust particles initially on circular orbits at 1-270AU. We concern the sub-millimetre brightness distribution of the system, tracing the distribution of large grains (>100μm) for which the radiation pressure can be neglected. The planetary semi-major axis is set such that its chaotic zone width of 80AU is fixed for $0.1 \leq e_{pl} \leq 0.6$. We used our own fully GPU-based N-body code HIPERION which utilises 4-8th order Hermite schemes (Regaly et al. in prep). Based on the particle distribution given by N-body simulations (2^{18} particles), we calculated the thermal emission of the optically thin dust at 1.3mm with DUSTMAP (C. Stark). In our model the dust consisted of "astronomical" silicate grains. The applied stellar and disk parameters (L_*=7L_{sun}, M_*=1.7M_{Sun}, d=90pc, i=25°, PA=115°) corresponds to that of HD95086. Figs. 3 and 4 show the dust distribution (left panels) and the thermal emission at 1.3mm convolved with 0.3"x0.3" beam size (right panels) for 1.25 and 5Myr of secular perturbation for e_{pl}=0.2 and 0.6, respectively.

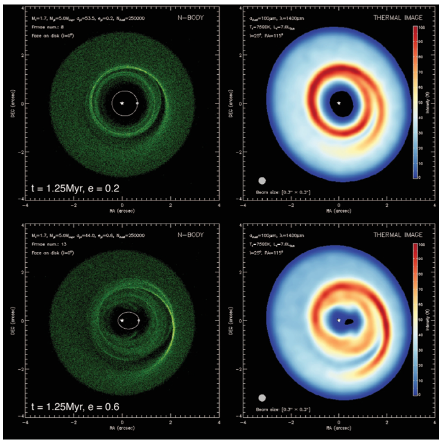

Fig. 3: Secular perturbations at 1.25Myr for e_{pl} = 0.1 and 0.6.

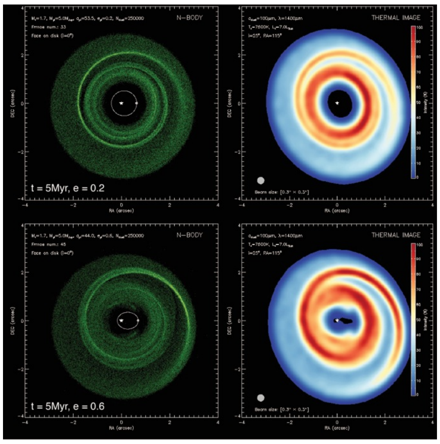

Fig. 4: Secular perturbations at 5Myr for e_{pl} = 0.1 and 0.6.

In agreement with Wyatt (2005), we observed the excitation of spiral patterns in the distribution of dusty material. The spiral patterns evolves with time and its rate of evolution is found to be independent of the planetary eccentricity. Moreover, the higher the eccentricity the stronger the contrast in spiral pattern has been observed in thermal images.

OBSERVABILITY BY ALMA

We calculated synthetic ALMA images for the presented models by ALMA Observation Support Tool. The observing setup were: ALMA Cycle 3 C36-4n configuration, 230.16 GHz central frequency, 7.5 GHz bandwidth, 3h exposure time, 1.262mm precipitable water vapour column. The restored beam size is 0.5"x0.4". Fig. 5 shows the deconvolved images using CLEAN algorithm for models presented in Figs. 3 and 4.

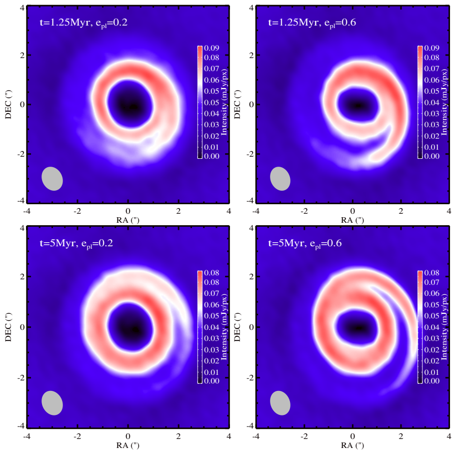

Fig. 5: Synthetic ALMA observation at 1.3mm with 3h exposure.

We found that the spiral patterns and its evolution can be reconstructed as long as e_{pl}>0.1. For low eccentricities the contrast in spiral pattern is to low to be detected with the above ALMA configuration.

CONCLUSION

Due to the secular perturbation of the planet observable spiral patterns form even for modest planetary eccentricity (e_{pl}>0.1). Knowing the size of the inner dust depleted region and the planetary mass a model set can be constructed in which the evolution of spiral patterns are independent of the planetary eccentricity. Therefore the longevity of secular perturbation can be inferred by comparing the observed and simulated spiral patterns. As the fully fledged giant planet itself should be present at the beginning of secular perturbation, an upper limit for its final phase of formation can be inferred by determining the difference of systemic age and the longevity of perturbation. Based on our results, the birth time of HD95086b indeed can be estimated by high-resolution ALMA observations.

REFERENCES

Moór, A. et al. 2013, ApJ 775; **Mustill**, A. J. & **Wyatt**, M. C. 2009, MNRAS 419; **Rameau**, J. 2013, ApJL 779; **Su**, K. Y. L. et al. 2015, ApJ 799; **Wisdom**, J., 1980, ApJ 85; **Wyatt.**, M. C. 2005, A&A, 440; A. J.

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