Dynamical modeling of the Herschel-resolved Disk of ζ^2 Reticuli

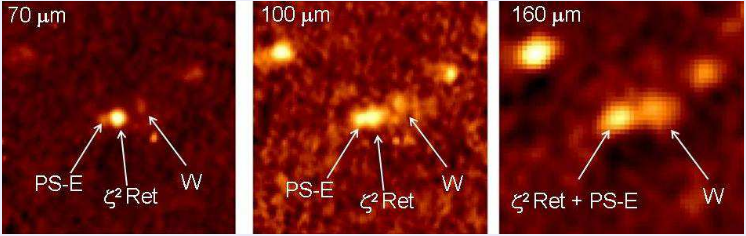
Virginie Faramaz, IPAG-FOST team, PhD Student

Heidelberg-Grenoble Meeting

October 2012 8-9th

Resolved Herschel/PACS images & Interpretation

Herschel Observations [Eiroa et al.(2010)]



The star

- G star in a binary
- Distance 12 pc
- Age 2-3 Gyr

The disk

- Probability for a background object 10^{-3}
- Asymmetric double-lobed feature
- Disk most probably observed edge-on
- Ring 70-120 AU & Eccentricity ≥ 0.3

Question

Can such asymmetries survive the Gyr timescales ?

Eccentric companions : footprints on debris disks

The pericenter glow phenomenon (Wyatt)

Recipe for an Eccentric Ring

- Force the eccentricities of planetesimals $e_f \simeq \frac{5}{4} \frac{\alpha e_p}{1 - e_p^2}$
- Tend to make their orbits apsidally aligned
- Wait for the spirals appearing due to differential precession

  timescales to be wounded $t_{glow} = \frac{2\pi}{(d\varpi/dt)_{100\,AU}}$

Can only be produced by an eccentric companion (planetary or stellar) coplanar or almost to the disk.

The Binary Companion ζ^1 Ret ?

- Projected distance from ζ^2 Ret : 3713 AU
- Pair is physical (proper common motion) [Shaya & Olling (2011)]

A yet undetected planet ?

- HARPS Survey $v_{Doppler} < 2$ m/s [Mayor et al. (2003)]
- No hint for a planet with $a \leq 5 - 10$ AU

The Binary Companion ζ^1 Reticuli

Assumptions and Analytical Predictions

Data and Assumptions

Projected distance 3713 AU

Assumed present-day location of ζ^1 Reticuli at apoastron

Analytical Predictions

Using the expression for the forced eccentricity on a planetesimal located at $\sim$ 100 AU gives

$$e_{binary} \geq 0.815$$

This involves : $a_{binary} \sim 2046$ AU

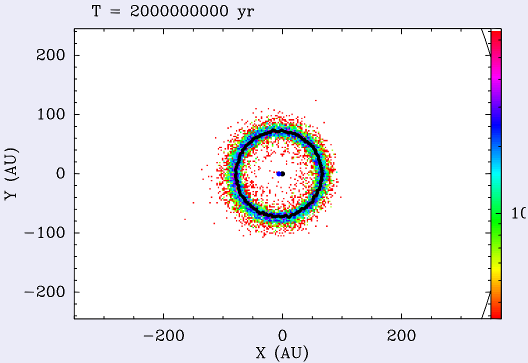
Although highly eccentric, not unlikely (Duquennoy & Mayor 1991)

Let's put this orbit to test numerically, using a N-body symplectic code.

The Binary Companion ζ^1 Reticuli

Numerical Study

Numerically ($e_{binary} = 0.815$, $a_{binary} = 2046$ AU, coplanar)



Conclusion

ζ^1 Reticuli highly probably not responsible for the disk eccentric structure.

Planetary perturbers

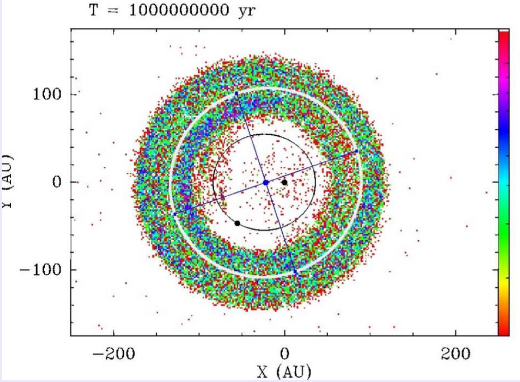
An Inner Perturber

Constraints & Parametric exploration

Disk inner edge due to a perturber's chaotic zone (resonance overlap).

$e = 0.2 - 0.4 - 0.6$ $\quad\quad$ $m = 0.1 - 0.5 - 1M_{Jup}$

Example : $m = 0.5M_{Jup}$ and $e = 0.4$

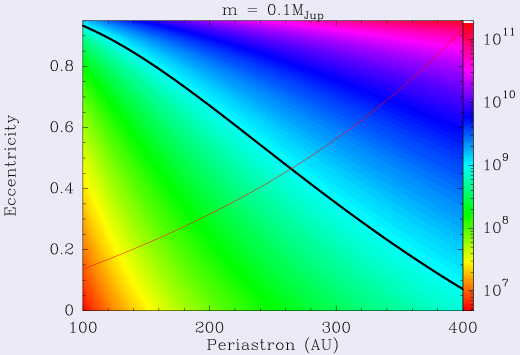


Planetary perturbers
An Outer Perturber

Parametric Exploration

3 parameters explored : eccentricity, mass, periastron

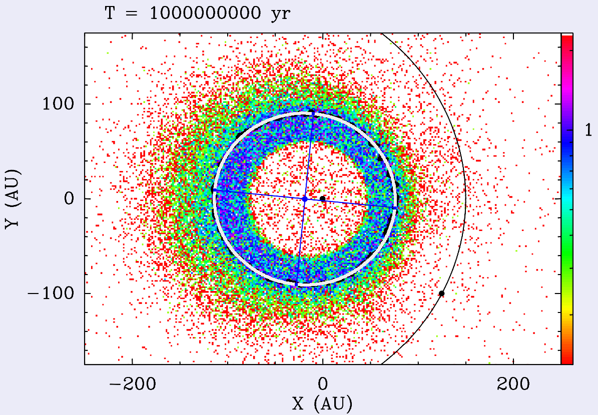
$$e = 0.2 - 0.4 - 0.6 \qquad m = 0.1 - 1 - 2M_{Jup}$$
$$q = 150 - 200 - 250AU$$



Planetary perturbers

An Outer Perturber

Example : $m = 1 M_{Jup}$, $q = 150$ AU and $e = 0.4$

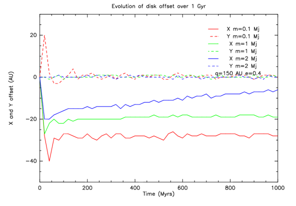


Conclusions & Prospects

Conclusions

Gyr Surviving Asymmetry

In each case, inner or outer perturber, the asymmetry can be maintained on Gyr timescales.



Inner Perturber

- Lower mass limit seems to be $0.1 M_{\mathrm{Jup}}$
- Best candidates have $\mathrm{m} = 0.5 - 1\mathrm{M}_{\mathrm{Jup}}$ with $\mathrm{e} = 0.4$

Outer Perturber

- Upper mass limit seems to be $2 M_{\mathrm{Jup}}$.
- For periastrons in the range 150-250 AU, masses are between $0.1 - 1 M_{\mathrm{Jup}}$ and $e \gtrsim 0.3$.

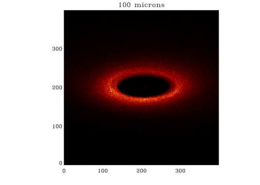
Conclusions & Prospects

Prospects

Create Synthetic Images

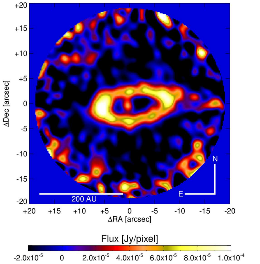
- Dust distribution & Radiation pressure
- Dust emissivity with GraTer (see e.g. Lebreton et al. 2012)
- Instrument effect
- Compare with Herschel/PACS images

Preliminary Result



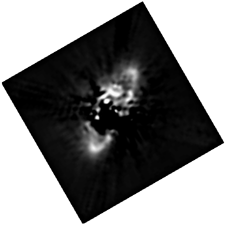
New Observations

ALMA Cycle 1 Proposal submitted

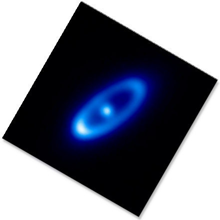


Synthetic image

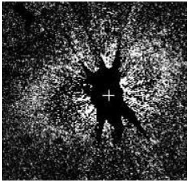
Thank you for your attention !



HR 4796, Schneider et al. 1999, NICMOS, **10 Myr**



Fomalhaut, Acke et al. 2012, Herschel far-IR imagery, **450 Myrs**



HD 202268, Krist et al. 2012, HST/STIS coronography, **2 Gyr**

And thanks to the Ciment people !

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