

# Planetary Systems Dynamics Eccentric patterns in debris disks & Planetary migration in binary systems

V. Faramaz<sup>1</sup>, H. Beust<sup>1</sup>, J.-C. Augereau<sup>1</sup>, A. Bonsor<sup>1</sup>, P. Thébault<sup>2</sup>,  
Y. Wu<sup>3</sup>, J. P. Marshall<sup>4</sup>, C. del Burgo<sup>5</sup>, S. Ertel<sup>1</sup>, C. Eiroa<sup>4</sup>,  
B. Montesinos<sup>6</sup>, A. Mora<sup>7</sup>, and the DUNES team

<sup>1</sup>UJF-Grenoble 1 / CNRS-INSU, Institut de Planétologie et d'Astrophysique  
de Grenoble (IPAG) UMR 5274, Grenoble, F-38041, France

<sup>2</sup>LESIA, Observatoire de Paris, 92195 Meudon France

<sup>3</sup>Dpt. of Astronomy and Astrophysics, University of Toronto, ON M5S 3H4, Canada

<sup>4</sup>Dpt. Física Teòrica, Facultad de Ciencias, Universidad Autónoma  
de Madrid, Cantoblanco, 28049 Madrid, Spain

<sup>5</sup>Instituto Nacional de Astrofísica, Óptica y Electrónica,  
Luis Enrique Erro 1, Sta. Ma. Tonantzintla, Puebla, Mexico

<sup>6</sup>Dpt. de Astrofísica, Centro de Astrobiología (INTA-CSIC), ESAC Campus,  
P.O.Box 78, E-28691 Villanueva de la Cañada, Madrid, Spain

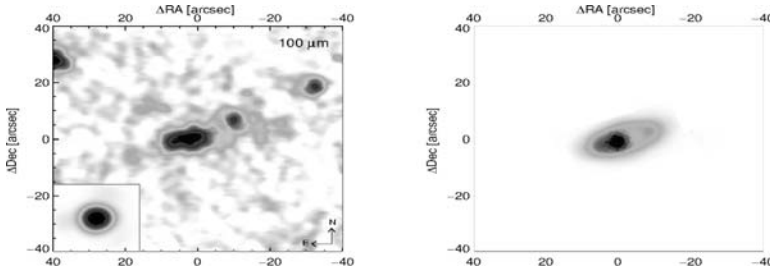
<sup>7</sup>Aurora Technology B.V., ESA-ESAC Gaia SOC. P.O. Box 78,  
E28691 Villanueva de la Cañada, Madrid, Spain

**Abstract.** We present some highlights of two ongoing investigations that deal with the dynamics of planetary systems. Firstly, until recently, observed eccentric patterns in debris disks were found in young systems. However recent observations of Gyr-old eccentric debris disks leads to question the survival timescale of this type of asymmetry. One such disk was recently observed in the far-IR by the *Herschel Space Observatory* around  $\zeta^2$  Reticuli. Secondly, as a binary companion orbits a circumprimary disk, it creates regions where planet formation is strongly handicapped. However, some planets were detected in this zone in tight binary systems ( $\gamma$  Cep, HD 196885). We aim to determine whether a binary companion can affect migration such that planets are brought in these regions and focus in particular on the planetesimal-driven migration mechanism.

**Keywords.** Circumstellar matter – Methods: N-body Simulations – Celestial mechanics – Stars:  $\zeta^2$  Reticuli, planetary systems

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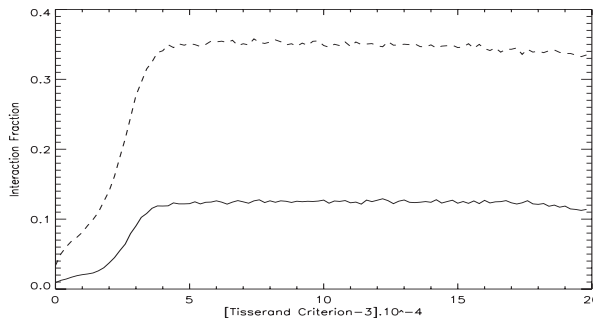
*Can eccentric debris disks be long-lived?* Recent *Herschel* far-IR observations of the debris disk surrounding the 2-3 Gyr old star  $\zeta^2$  Reticuli, obtained as part of the DUNES key program (see Eiroa *et al.*, 2013), reveal an asymmetric double-lobed circumstellar feature (Fig. 1, left panel), interpreted as a ring like structure seen almost edge-on with an elliptical shape and minimum eccentricity of 0.3, extending from 70 to 120 AU (Eiroa *et al.*, 2010). So far, eccentric patterns in debris disks were observed in young systems (HR 4796: 10 Myr ; Fomalhaut: 440 Myr), and attributed to the dynamical shaping of the disk by massive companion on an eccentric orbit (see e.g. Wyatt, 1999). We discuss here the origin of this eccentric pattern in the  $\zeta^2$  Reticuli system, and the ability to maintain the disk asymmetry over Gyrs. Through a modeling method combining analytical predictions, numerical N-body treatment (Levison & Duncan, 1994) and radiative transfer, we can put constraints on the orbital parameters of hypothetical perturbers that could induce a disk structure compatible with observational constraints. The synthetic images support the hypothesis that the observed double-lobe feature is the signature of an eccentric ring (see Fig. 1, right panel), and our synthetic model supports the presence



**Figure 1.** *Left:* Herschel/PACS Observations of  $\zeta^2$  Reticuli at 100 microns. *Right:* Synthetic image at 100 microns.

of a planetary mass companion orbiting at several tens of AU from its host star, and on a significantly eccentric orbit (Faramaz *et al.* 2013, in prep.).

*Planetary migration in binary systems* Planetesimal-driven migration mechanism leads a planet to exchange angular momentum with planetesimals during close encounters. Angular momentum passes from outer to inner material and components experience a mutual gravitational attraction. In a system with a single planet, timescales favour interactions with inner material, and thus inward migration (see Fig. 1 of Kirsh *et al.* 2009). Our goal is to investigate this process in binary systems: preliminary results show that in the presence of a binary companion, the direction of migration could be reversed: interactions with outer material seems favoured, which would move planets out rather than in (see Fig. 2). This may provide an explanation for the presence of planets in regions of binary systems where models fail to explain in situ formation (see the review by Thébault P., 2011).



**Figure 2.** Probability for a planetesimal to suffer a close encounter as a function of its Tisserand parameter, and thus as a function of its distance to a planet of mass  $4.5M_{\oplus}$  at 10 AU on a circular orbit in the presence of a  $1M_{\odot}$  binary companion on a circular orbit at 100 AU, within  $3R_{\text{Hill}}$ , and for inner (solid line) and outer (dashed line) material.

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