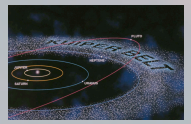
Debris disk: a first view of extrasolar planetary systems

Jérémy Lebreton, Jean-Charles Augereau et al., *Université de Grenoble / Laboratoire d'AstrOphysique de Grenoble*

Context

• **Debris Disks** are a type of circumstellar disks, revealed by their infrared emission in ~20% of the MS stars.

• Extrasolar analogues to the Solar System **Edgeworth-Kuiper Belt**, they are the remnant of planet formation.



The Edgeworth-Kuiper Belt (EKB)

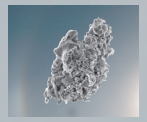
• A ~17 AU-wide disk of rocky and icy material extending beyond the orbit of Neptune (30 AU).
• From ~µm dust grains to >1000 km plutinos
• >70,000 EKB objects over 100 km
• Expected IR-excess $L_{dust}/L^* \sim 10^{-7}$

• These dusty disks differ from protoplanetary disks as they need to be continuously replenished through **collisions in a population of larger bodies.**

→ Asteroids, comets and planetesimals

The 500-meter asteroid Itokawa

Collisional cascade



~10 µm dust grain

Key questions

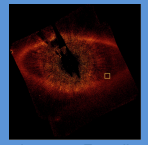
• We want a complete view of planetary systems and their history.
• Presence of exo-EKBs vs. presence of planets
• Elucidate the evolutionary link between gas-rich protoplanetary disks and gas-poor debris disks
• Investigate water abundances in the planet-forming regions of disks

Disks and planets

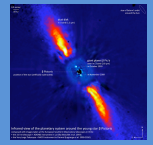
• The presence of a companion imprints its signature on a debris disk

→ Clumps, rings, belts, eccentric distributions, spiral patterns, ...

Detailed modeling of these disks can reveal the position and mass of hidden planets.



The offset between Fomalhaut and its disk is caused by a <3M_J planet. (Kalas et al. 2008, *Science* **322**)



The planet in the disk of β Pictoris explains its ring-like structure and inner warp. (Lagrange et al. 2010, Science **329**, Absil et al. 2010, submitted to A&A)

• *How can asteroid belts affect habitability?*

• ***The Late Heavy Bombardment**: In the young history (700 Myr) of the Solar System, the migration of giant planets pertubed the Kuiper Belt, bringing numerous planetesimals to hyperbolic orbits and resulting in a cataclysmic event on the primordial Earth.*

• *This event: (1) likely cleared a large fraction of the asteroids and comets of the Solar System **reducing the frequency of cataclysmic events** in its later history, (2) might have brought **large quantities of water onto the Earth surface.***

Earth-like planets with a comparable impact rate to the Earth may be uncommon!

Herschel observations and modeling of planetary systems around nearby stars

• Planetary systems as seen by Herschel

→ An ESA sub-mm Space Observatory with important participation from NASA

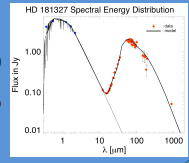
***GASPS**: GAS in Protoplanetary Systems (400h)*

Study of the transition gas-rich protoplanetary through gas-poor debris disks. PACS observations of fine structures lines ([CII], [OI],H_2O) for circumstellar disks down to ~10^{-5} M_{sun}.

HD 181327 *(Lebreton et al., in prep.)*

•A young F5.5V star, member of the β Pictoris moving group (~12 Myr), located at 50.6 pc, with a far-IR excess $L_{IR}/L_* = 2.10^{-3}$.
•HST imaging of that debris disk revealed a 36 AU-wide ringlike disk centered at 86 AU.

→The disk is cold (<88 K) and massive (0.2 $M_\oplus$)
→The grains are porous aggregates (P ~ 65%) and contain a large fraction of ice (70%).
→They are small (amin~1µm) and close to collisional equilibrium.
→Non-detection of the [OI] and [CII] lines

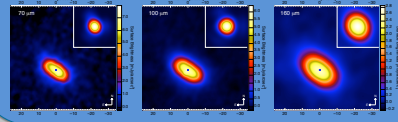


***DUNES**: DUst around NEarby Stars (140h)*

PACS and SPIRE photometric observations of cold disks around nearby stars. Characterization of faint « exo-Kuiper Belts » ($L_{dust}/L_* \sim$ a few times 10^{-7})

q^1 Eri *(Augereau et al., in prep.)*

•A ~2 Gyr-old solar-type star (F8V), located at 17 pc. $L_{IR}/L_* = 3.8.10^{-4}$.
*•The disk is **resolved in both scattered and thermal light**, revealing a ~40 AU wide belt peaking at ~85 AU.*
→ « The first real Edgeworth-Kuiper Belt analogue ever observed »
•The initial disk mass inferred from a collisional approach is unrealistically high → Recent perturbation? Delayed stirring by a yet undiscovered planet?



Herschel/PACS images of the q1 Eri disk at 70, 100 and 160 µm