Young extrasolar planetary systems:
formation, evolution and star-planet interaction

AUDIZIONI SCHEDE INAF – 19-20 MAGGIO 2021

S. BENATTI (OAPA), A. F. LANZA (OACT) & TEAM EXO-YOUNG + EXO-SPI

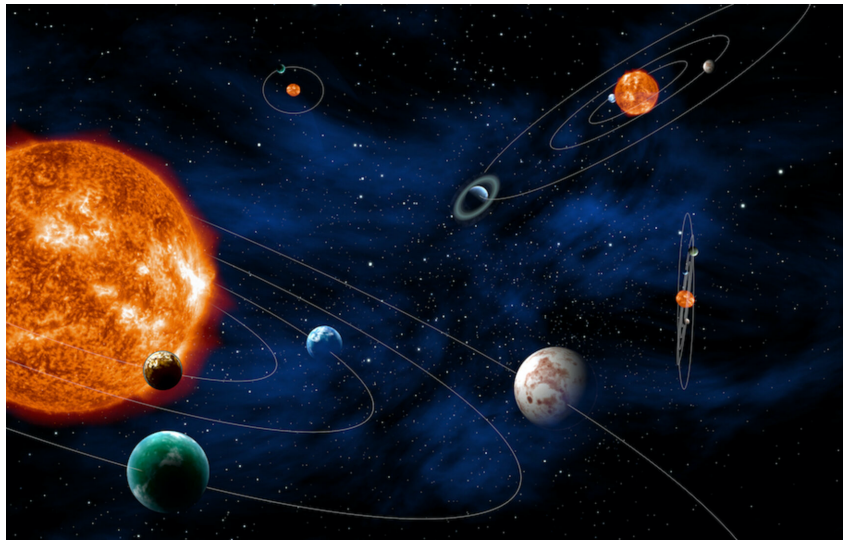
EXO-Young and EXO-SPI

Why do we study **young extrasolar planets**?

- To understand the initial conditions of the planetary systems: planet formation and migration mechanisms
- To validate theoretical models

Where can we find them and how?

- Large separation (imaging)
- Short separation (transits, radial velocity)



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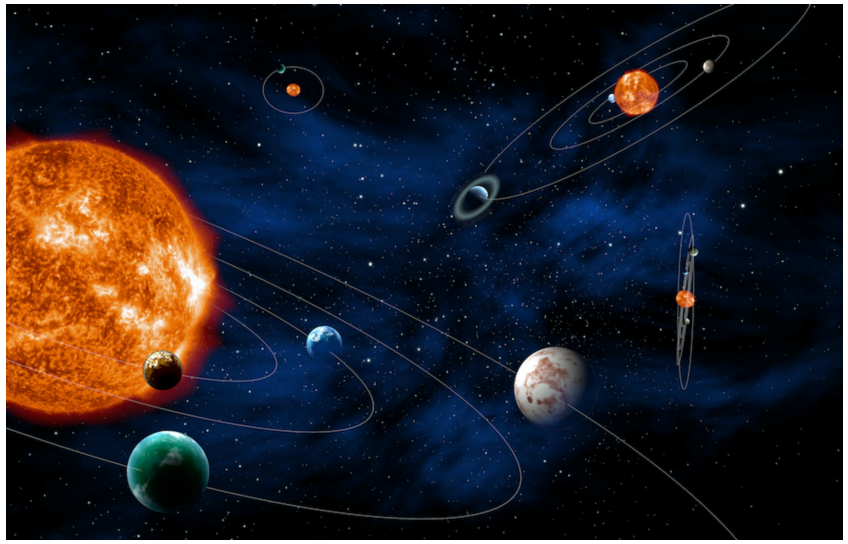
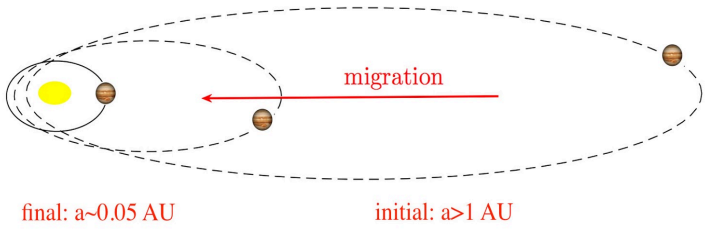




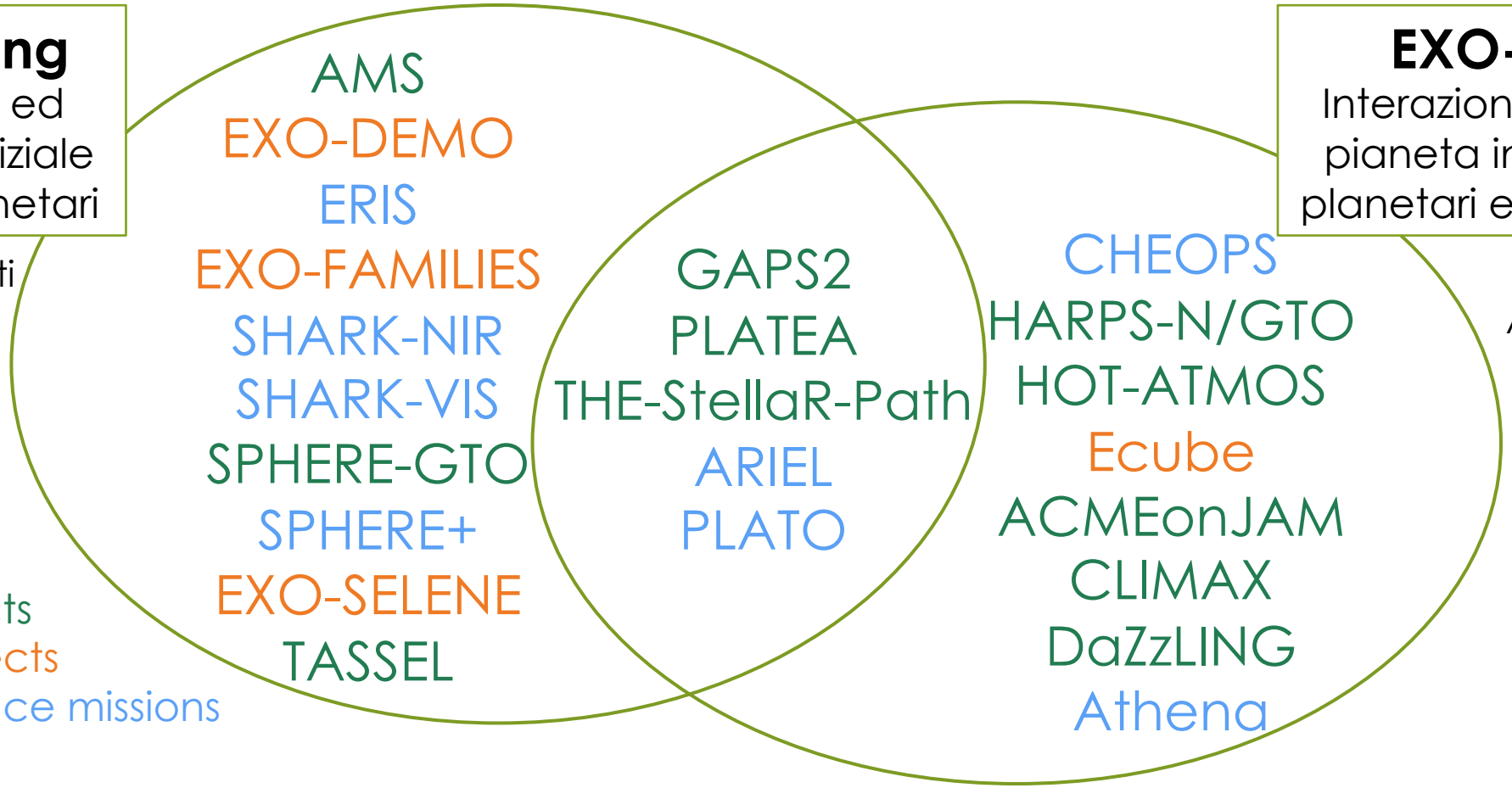
Star-planet interaction

- Mostly operating at close distances ($\lesssim$ 0.2 au) and within 1 Gyr
- Crucial in the orbital circularization in case of high-eccentricity migration (not only for young planets)

An Overview on the EXO-Young & EXO-SPI: Schede madri – schede figlie

EXO-Young
Formazione ed evoluzione iniziale di sistemi planetari

Coord.: S. Benatti



EXO-SPI
Interazione stella-pianeta in sistemi planetari extrasolari

Coord.:
A. F. Lanza

Ongoing projects
Submitted projects
Instruments/Space missions

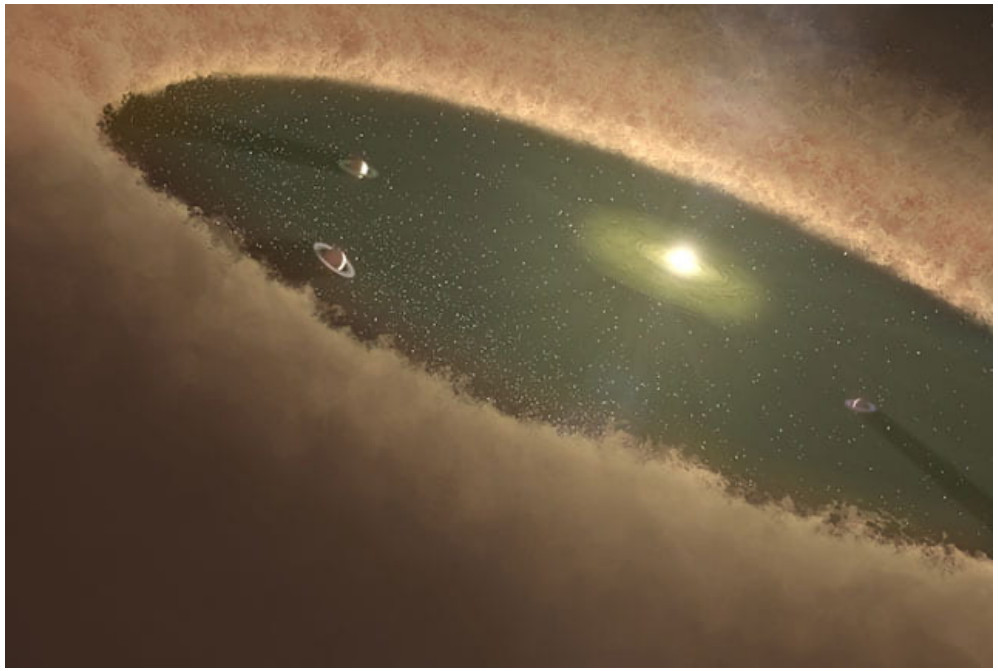
EXO-Young & EXO-SPI: our Team

- 11 INAF Institutes
- TNG – FGG
- Collaborators in 15 national and international institutions including 7 Italian Universities
- About 100 researchers
- FTE INAF TI (2021-23)= 26.5
- FTE INAF TD (2021-23)= 17

Science: key questions

What is the **origin** of the planetary system **diversity**?

- What are the properties of the young exoplanet population at **large separation**?
- What are the properties of the young **close-in** exoplanet population?
- Young close-in planets: what is the role of the atmospheric **evaporation** induced by the high-energy irradiation and the S-P **tidal** heating?
- How do the planets **form** and **evolve**?



Science: results & perspectives

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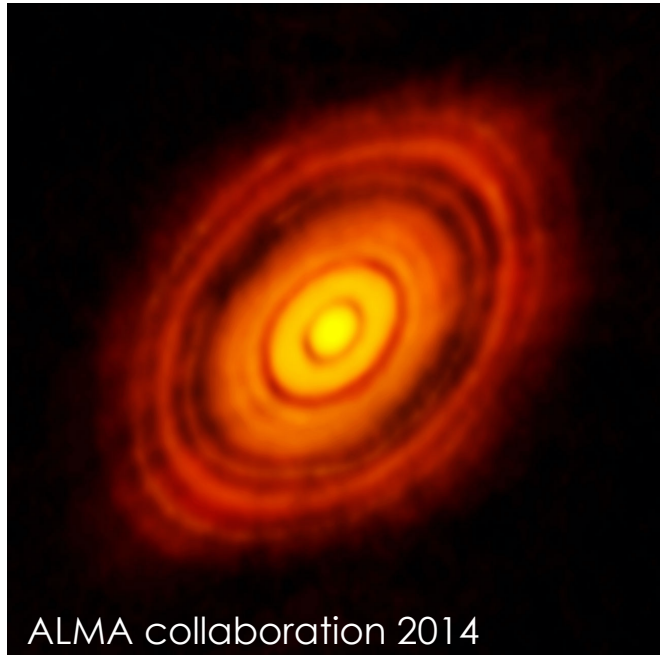
Planets form at large separation from the central star (tens to hundreds of au)



At this stage, planets experience contraction, they are hot and bright: they can be observed!

Science: results & perspectives

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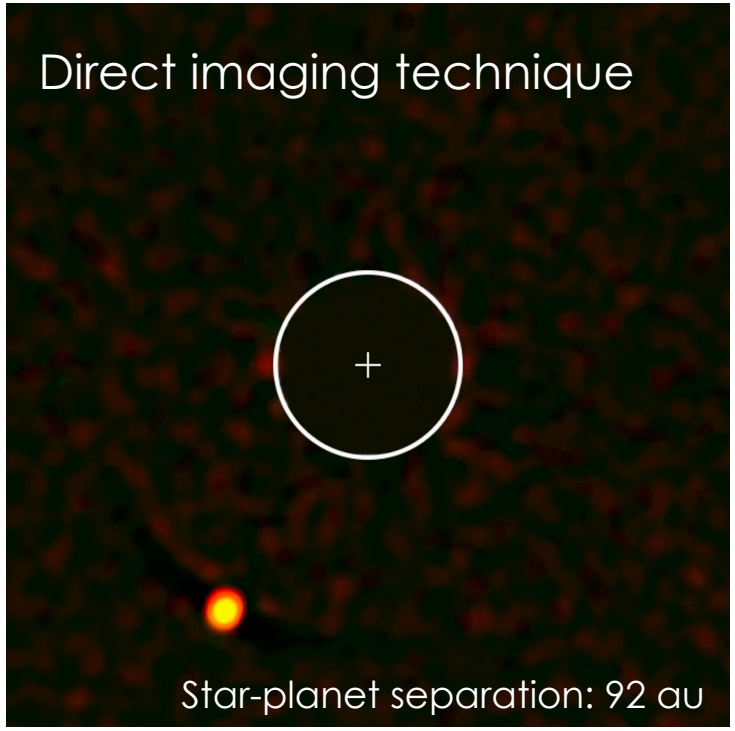

Chauvin, Desidera et al. 2017: HIP 65426 b, the first planet from the SHINE survey with SPHERE@VLT

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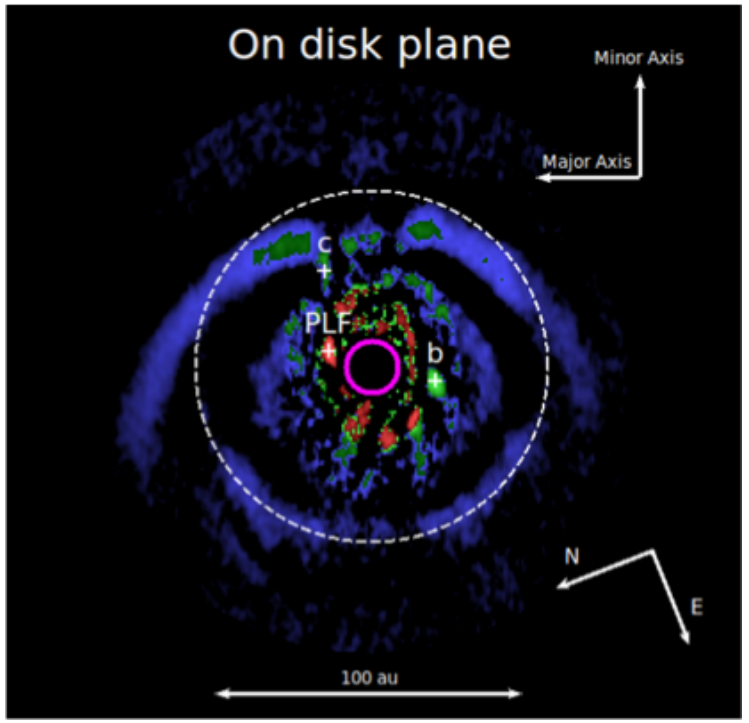

Mesa et al. 2019: the system of PDS70 revealed through the dust of the disk shows one additional structure, still not constrained

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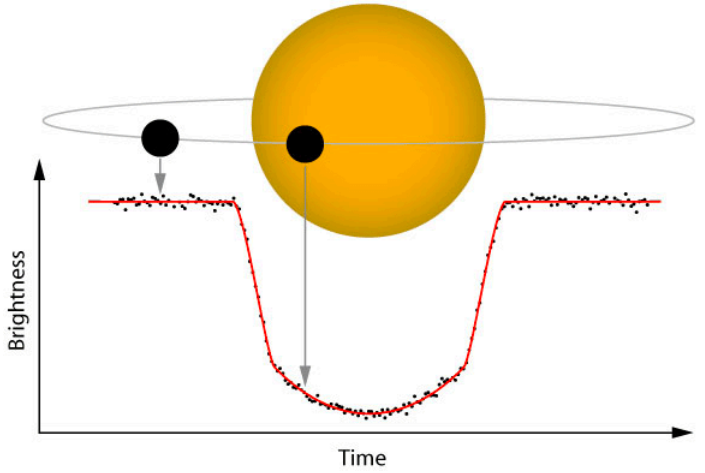
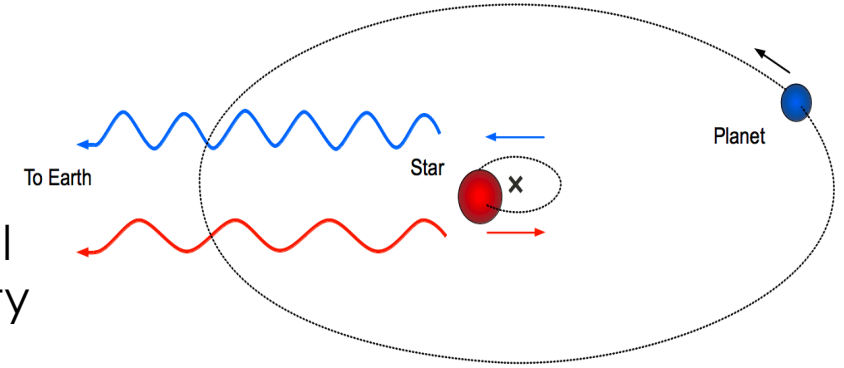


Transit



Radial velocity

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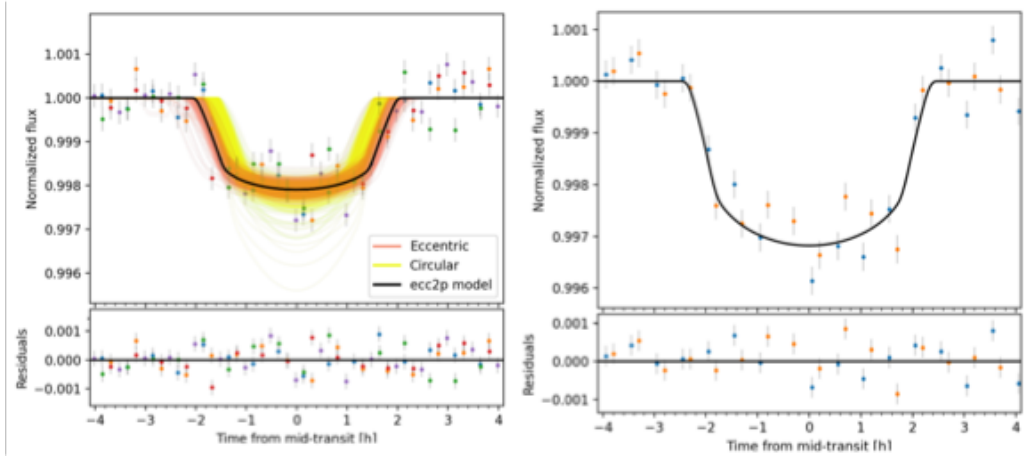
Planets at young ages seem to have relatively small radii, in contrast with the previous claims



Carleo et al. 2021: two Neptune size planets around the 50 Myr old K2 star TOI-942

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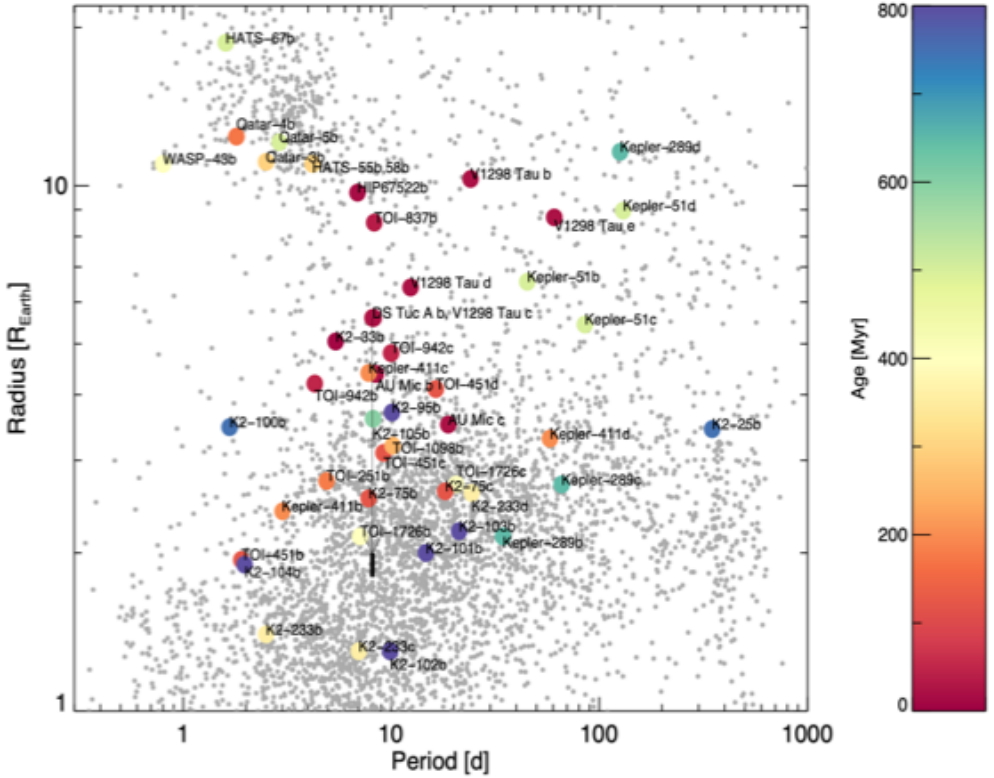

Benatti et al. 2021: DS Tuc A b (40 Myr) and the first ensemble view of young close-in planets

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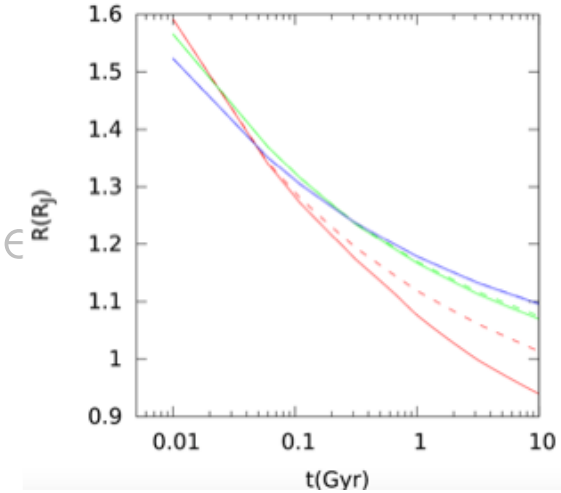
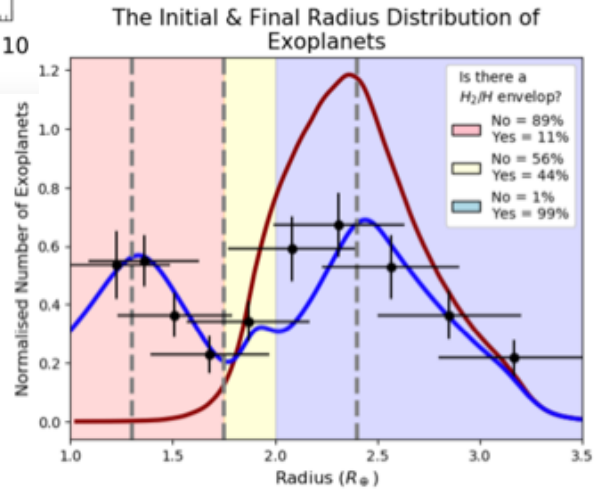


Locci et al 2019:
Radius evolution with time as induced by the irradiation of the young stellar host

Modirrousta-Galian et al. 2020:
Photoevaporation is consistent with the bimodal radius distribution of exoplanets



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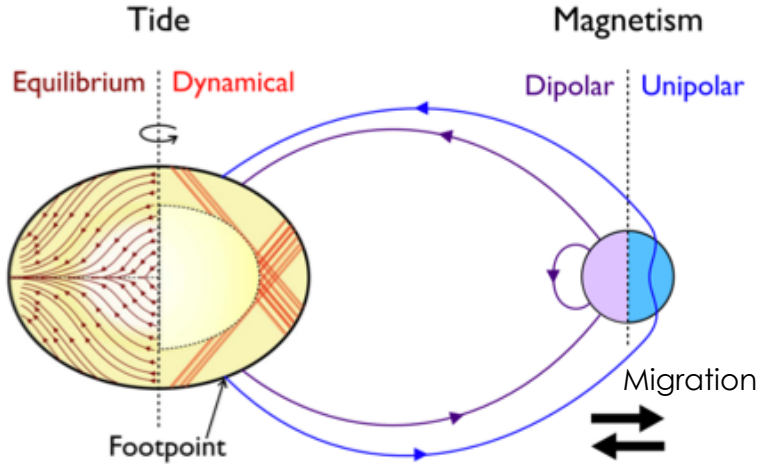
Tidal and magnetic interaction



(Strugarek+2017)

Lanza 2009: energy budget estimation of the SPI

Bonomo et al. 2017: statistical study on the hot Jupiter migration and tidal interaction

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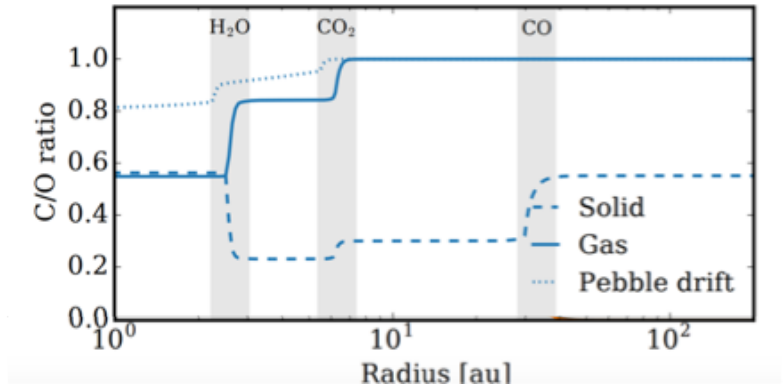
The C/O ratio in the chemical abundances of planetary atmospheres tells the formation and migration history of a planet



(Madhusudhan 2019)

Giacobbe et al. 2021: measurement of the C/O ratio for the mature planet HD209458b
Turrini et al. 2021: better constraints by using other elemental ratios (C/N, N/O, S/N)

INAF Leadership

- EXO-SPI: 2005 to date
- EXO-Young: 2014 to date

Acknowledged experience of INAF researchers:

- **SPI MODELLING and OBSERVATIONS:** physics of magnetic fields, stellar activity, X-ray and EUV emission, tidal effects (Lanza 2009, Sanz-Forcada+2011, Maggio+2015, Pillitteri+2015, Bonomo+2017, Locci+2019, Lodato+2019, Modirrousta-Galian+2020)
- **TECHNOLOGY**: in particular with adaptive optics systems, like SPHERE, SHARK-NIR, SHARK-VIS, ERIS (Claudi+2008, Farinato+2014, Mattioli+2018, Davies,Esposito+2018, Marafatto+2020) and the GIANO/GIARPS project (Claudi+2017)
- **Young Planets OBSERVATIONS**: GTO/large programs dedicated to young planets at large and close separation, advance in GP modeling (Fedele+2018, Mesa+2019, Desidera+2021, Nardiello 2020, Damasso+2020, Carleo+2021, Benatti+2021)

Future planning

- **Currently**, several projects are ongoing or have just started (→ 2023/2024):
  - Observations (e.g. GAPS2, HARPS-N GTO, SPHERE GTO, TASSEL, HOT-ATMOS) Modelling/Computation (e.g. AMS, CLIMAX) or both (e.g. THE-StellaR-Path, PLATEA)
- **Future** projects are proposed, more in the forthcoming years:
  - EXO-DEMO, EXO-FAMILIES, EXO-SELENE, Ecube
- Several **instruments** are producing data or are close to their integration phase. **Space missions** are flying or adopted by ESA (>2026). **Multiband** approach:
  - Ground-based: SPHERE, HARPS-N, GIANO-B, GIARPS, SHARK-VIS&NIR, ERIS,…
  - Space-based: CHEOPS, XMM-Newton, PLATO, ARIEL, ATHENA,…

Funds

- PRIN INAF PLATEA: almost completely dedicated to EXO-Young & EXO-SPI
- PRIN INAF Genesis-SKA (SPHERE)
- ASI-INAF 2018.16.HH.0 (THE StellaR Path and TASSEL): partially dedicated to EXO-Young & EXO-SPI
- ASI-INAF 2018.22.HH.0 (ARIEL): limited to the science team activities on EXO-Young
- PLATO: limited to the science team activities on EXO-Young
- AMS (Mainstream): partially dedicated to EXO-Young
- Premiale WOW: implementation of the GIARPS observing mode at TNG
- Premiale FRONTIERA, T-Rex: limited on this topic (e.g. SPHERE)
- Marie-Curie (SPHERE)
- SHARK-NIR + VIS: limited to the science team activities on EXO-Young

Critical points

Scientific issues

- Stellar activity treatment preventing a robust estimate of the planetary mass: implication on the planet atmospheric characterization and evolution → effort in data analysis is ongoing
- Planet candidate validation with imaging + planets embedded in their protoplanetary disc → this should be mitigated with the availability of SHARKs + LMIRcam @LBT
- Limited expertise in Italy on planetary structure and planet evolutionary tracks → need of new professional figures
- Promote the joining of modeling and observations communities

Program issues: this is a new, attractive, rapidly growing and demanding field

- High competition with teams having institutionally granted access to different observing facilities enabling quick planet candidate validation
- Difficult planning because of the long and discontinuous procedure of national calls, projects evaluation and funding distribution
- We are/must be present in the main international projects: it is crucial to strengthen the resources to capitalize our effort performed up to now

Thank you for your attention