The Global Architecture of Planetary Systems (GAPS) project

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The project

- Collaboration among about 80 scientists in 10 italian institutes + external collaborators
- Original initiative at OAPD
- UNIPD also key member (Piotto / Marzari)
- Long-term multi-purpose observing program at TNG using HARPS-N since 2012 and now GIARPS
- GAPS1 (2013-2017): focus on the architecture of planetary systems (RV technique)
- GAPS2 (2018-2022): Focus on the origin of planetary systems through RV studies of young stars and atmospheric characterization
- Approved as long-term program at TNG
- Relevance of outreach component

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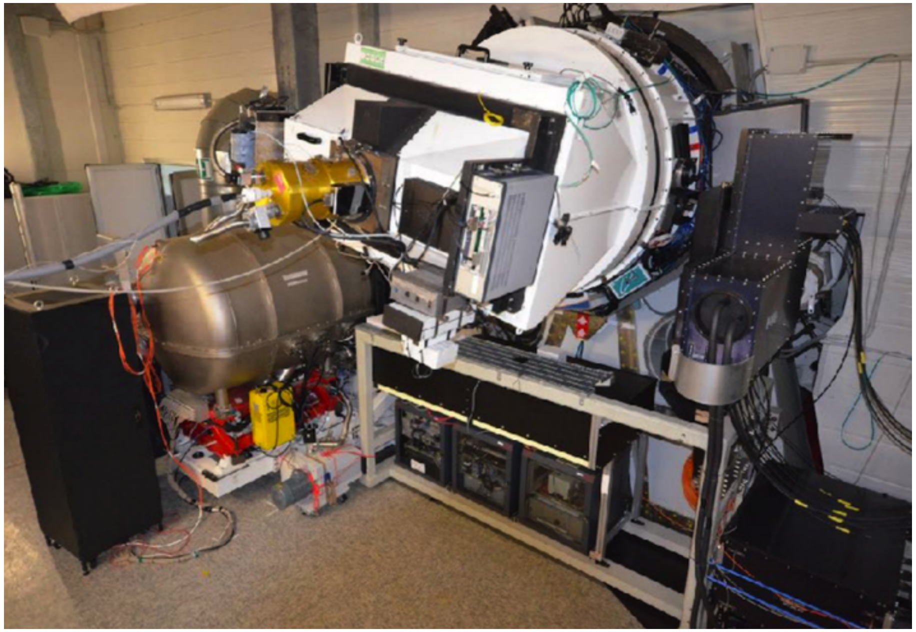
HARPS-N + GIANO-B = GIARPS

- Simultaneous use of HARPS-N (0.38-0.69 μm; R~115,000) and GIANO (0.95-2.45 μm R~50,000) through a dichroic, at the Nasmith-B platform of the TNG; GIANO moved from Nasmith-A and upgraded (now slit-based)
- High-resolution VIS-NIR spectra, high-precision radial velocity
- Management: Italian Exoplanetary community through the *Premiale WOW*, with a particular effort by the GAPS team (funds, manpower, observing time)



GAPS1: Planet detection highlights

- 1st **binary** with both stars **hosting planets** (Desidera+2014)
- 1st **planetary system** around an **OC** member (Praesepe, Malavolta+2016)
- **Super Earth systems** around M dwarf (Affer+2016)
- Giant planet around giant star with **VIS-NIR spectroscopy** (Gonzalez-Alvarez+2017)
- 2 **planets** around **metal poor** stars (Barbato+2018)
- A system with a **hot super-Earth**, one **temperate Neptune** and a **cold Jupiter** mass companion (Benatti+ in prep)
- About 30 refereed papers up to now

A new beginning: GAPS-2.0

- GAPS-2 is a 5-yr long-term program at TNG building up to the experience gained within the previous GAPS collaboration. Same instrument (GIARPS), same collaboration, more focused science case
- **GAPS-2 has been approved starting from AOT37 (34 nights/semester); observing time will be granted on a year-by-year basis (annual report);**
- GAPS-1 (2012-2017) was oriented toward the «*exploration of the diversity of the architectures of planetary system*». We have found an astonishing diversity in the architectures of planetary systems as well as in exoplanet orbital and physical parameters.
- GAPS-2 (2017-2022) is focused on the next step: «*What are the origins of this diversity?*»

Origin diagnostics

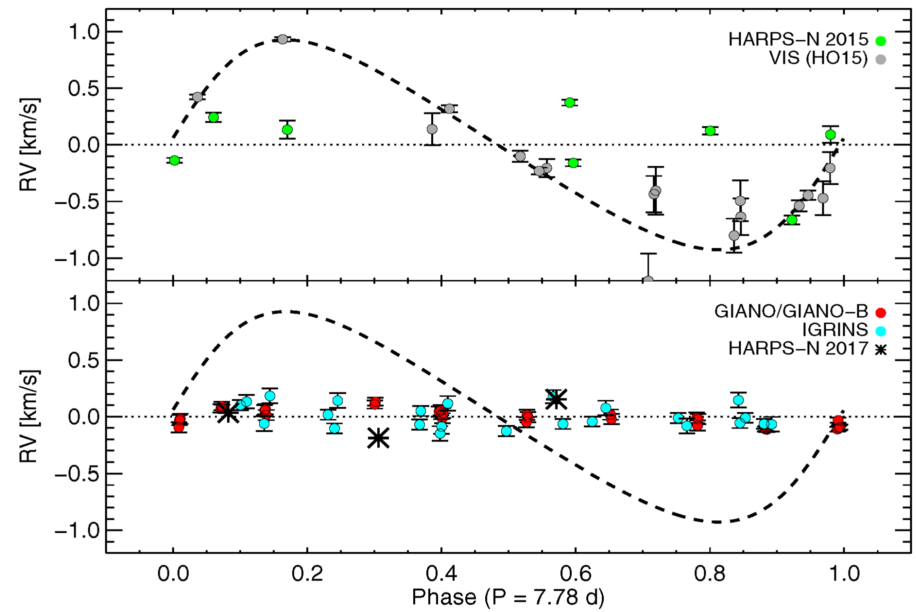
GAPS

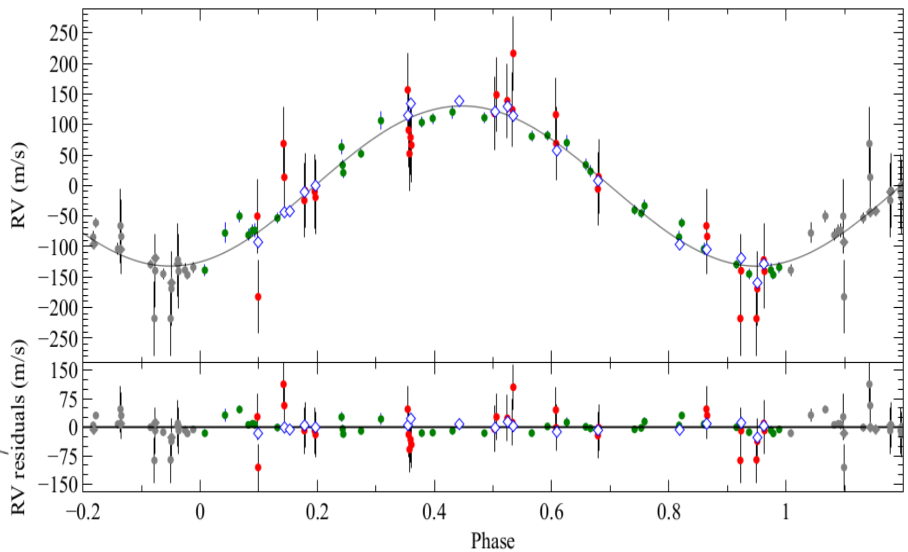
- Frequency and orbital properties of planets as a function of age
- Differences expected for plausible migration mechanisms (Migration within disk very quick; outcome of planet-planet scattering at any epoch; initially high eccentricity orbits; Kozai migration only at later epochs)
- Planet radius and density of Neptune-mass planets as a function of age to probe evaporation processes

- Study of planetary atmospheres
- Chemical composition tracing the original location of the planets C/O and O/H ratios)

Confirmations and retractions

Hot Jupiter around the very active K star BD+201790 (age 100 Myr) ruled out using GIARPS commissioning data (Carleo et al. 2018)

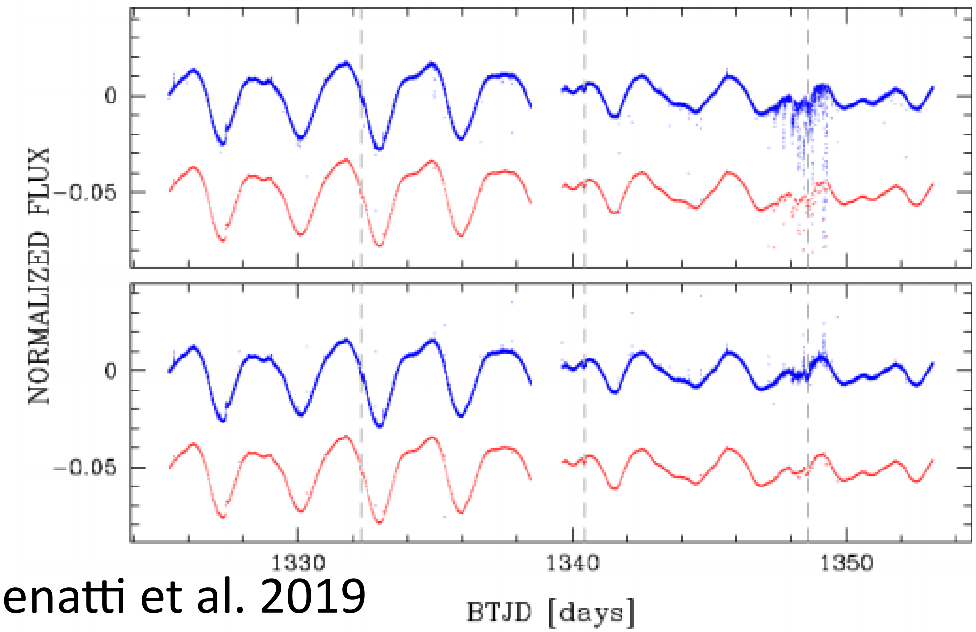


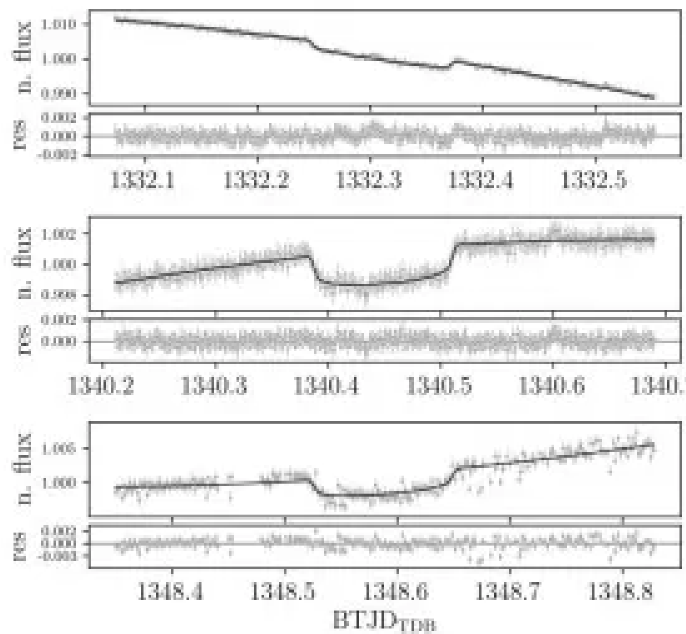


Hot Jupiter around the Hyades star HD 285507 confirmed with GIARPS: same RV amplitude in optical and NIR (Carleo et al. 2019)

DS Tuc b: a very young transiting planet

- G6 star member of Tuc-Hor association; age 40 Myr
- Observed by TESS: light curve dominated by rotational modulations but three transits hidden in the light curve
- Validated as planets thanks to the availability of HARPS and NaCo archive data (Benatti et al. 2019)
- P=8.1 days, R=0.5 Rjup, mass determination on-going, highly inflated structure expected
- **TESS follow-up of young candidates to be performed in GAPS2.**





Benatti et al. 2019

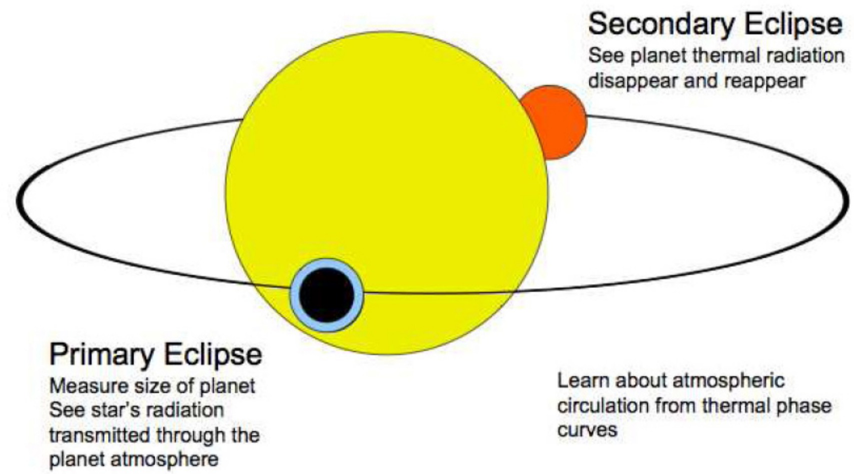
How to detect exoplanetary atmospheres

Spectroscopy of combined light (star+planet) is a powerful tool to probe atomic and molecular species in exoplanetary atmospheres

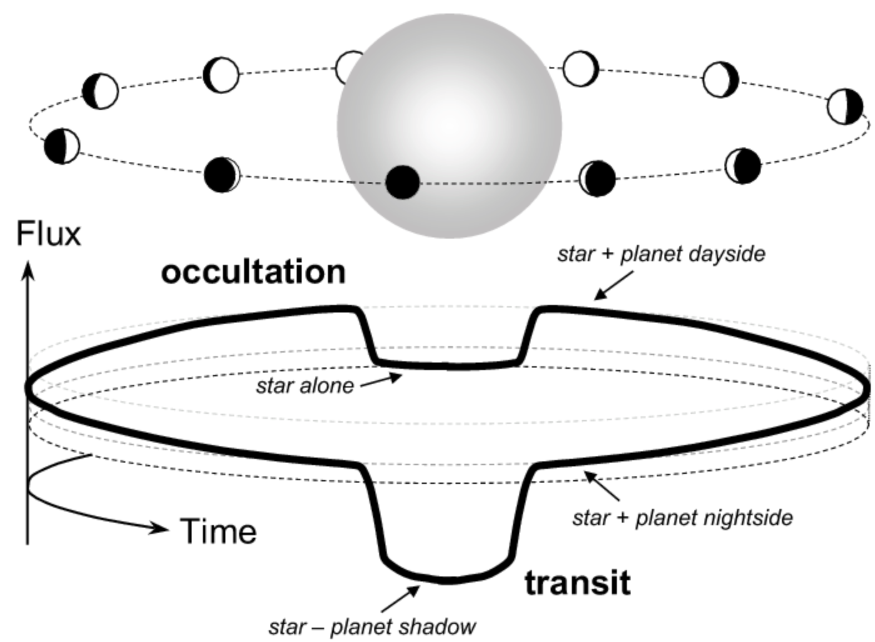
Transmission spectroscopy (TS) during transits is able to probe the terminator region up to several scale heights

Emission spectroscopy (ES) probes the day-side hemisphere of the planet and is more sensitive to the lowest layers. ES does not always require a transiting geometry!

TS and ES are highly **complementary** as they probe different chemical/physical environments and are subject to different biases and limitations. Other complementarities arise from the different spectral range investigated (e.g., IR vs. VIS)



Adapted from Seager



Winn+ 2011

Preliminary results of GAPS/AT

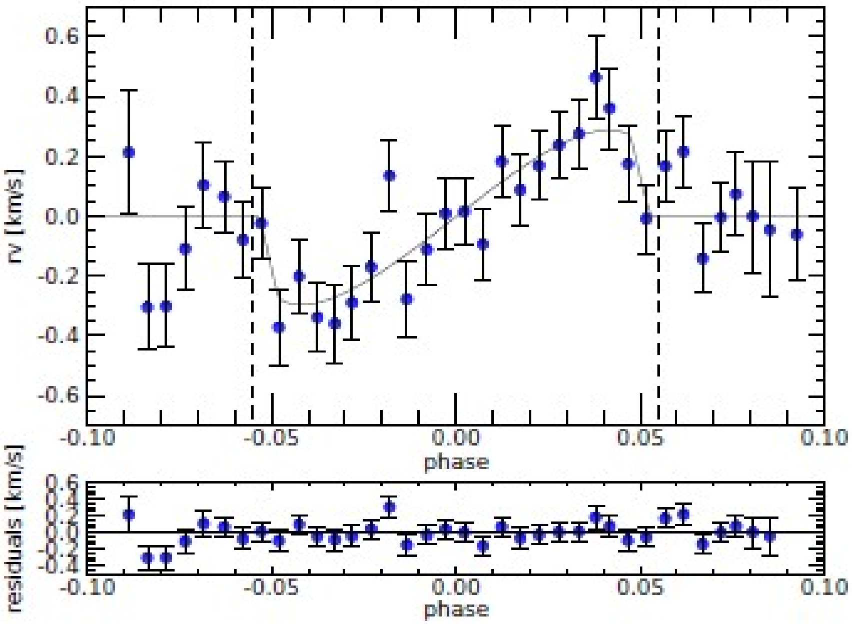


Fig. 5. Atmospheric RML effect of KELT-9b. Vertical dashed lines show the ingress and egress of transit.

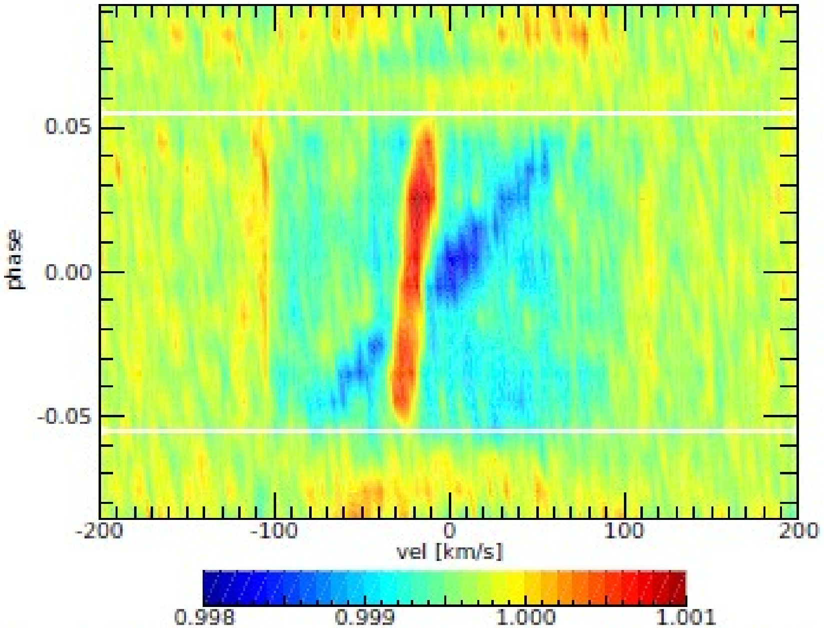


Fig. 6. Mean line profile tomography of the four KELT-9 transits observed, centered in the stellar restframe. Horizontal white lines show the ingress and egress of transit. The doppler shadow of the planet (in red) and the planetary atmosphere track (in blue) are both evident. The light-blue depression during the transit is caused by the photometric decrease of flux.

Borsa et al. 2019