

Exoplanets: The HARPS-N Opportunity (GAPS and GTO)

A. Sozzetti

INAF - Osservatorio Astrofisico di Torino

(For the GAPS and GTO Consortia)

Detection/Characterization

- **Detection (Visible):**

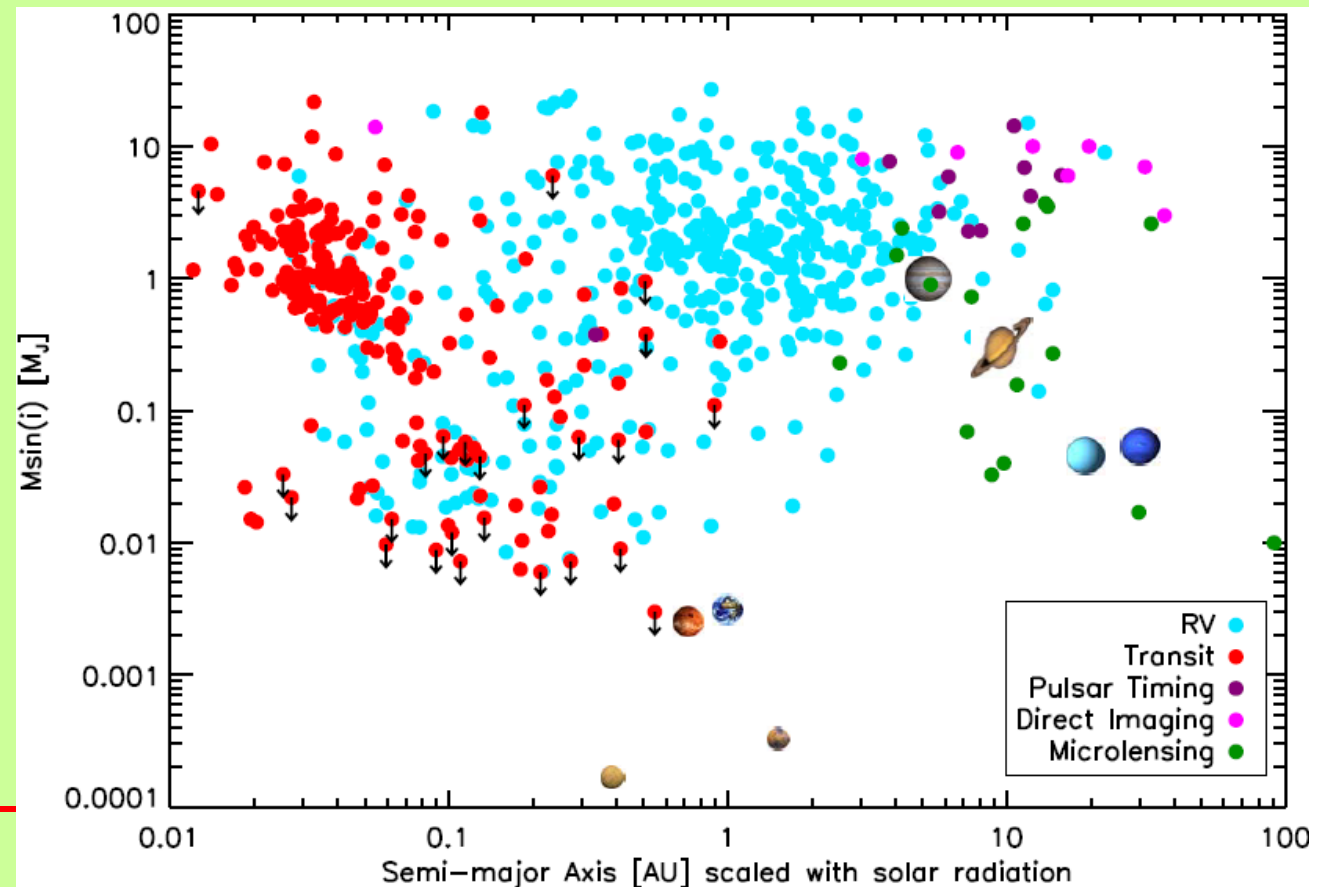
- Doppler spectroscopy (92%)
- Transit photometry (34%)
- Gravitational microlensing (2%)
- Pulsar/pulsation timing (2%)
- imaging (4%)

- **Characterization (Visible/IR):**

- Transit timing
- Transmission spectroscopy
- Rossiter-McLaughlin effect
- Reflected light
- Infrared emission

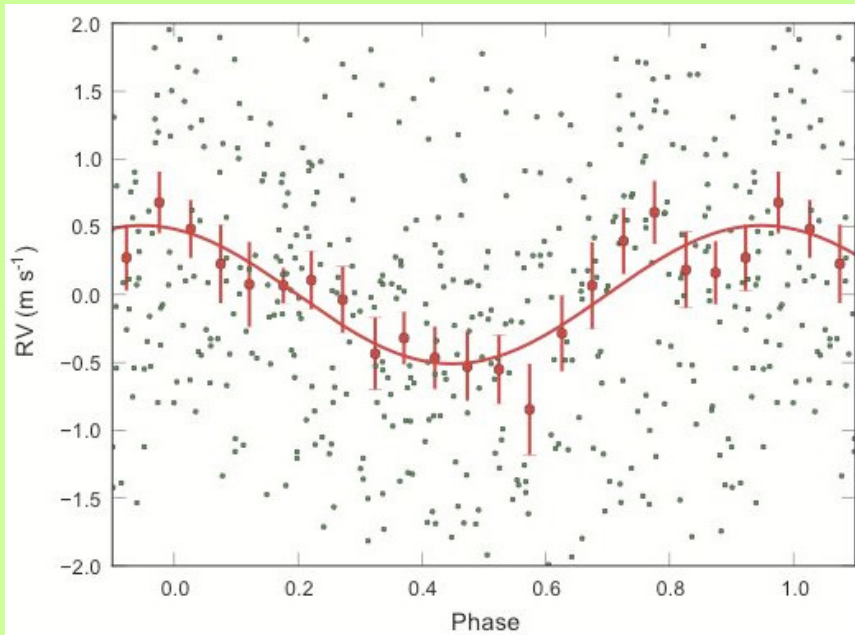
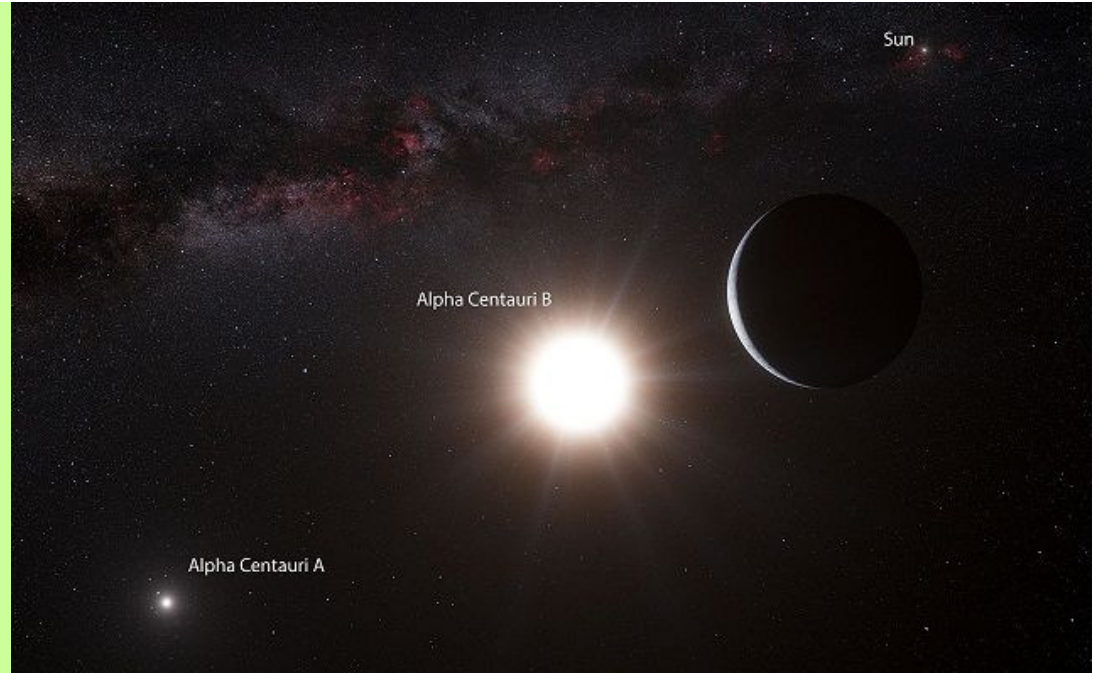
864 Exoplanets known today, in 679 systems

129 in multiple-planet systems



High-Precision RVs

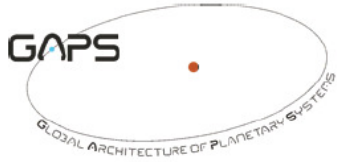
- 1-m/s precision measurements
- Fundamental for transiting candidates confirmation (mass determination)
- Long-term surveys (e.g. HARPS) critical for uncovering planet properties, frequencies, and correlations with the hosts' characteristics
- The discovery of planets with Earth's mass (not radius) already made!



α Cen Bb

Lessons from HARPS-S

- State-of-the-art precision (2x better than the second-best contender), unique facility in the South
- Single-handedly producing the present sample of planets with masses not much different from Earth's
- It required taking over the 3.6m ESO telescope

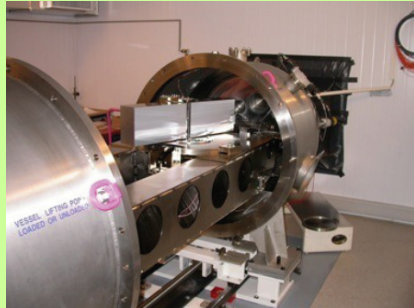


HARPS-N@TNG

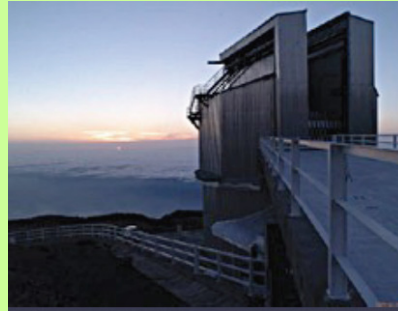


- HARPS-N beats (right now) other optical Northern spectrographs
- It can reproduce the successes obtained by HARPS-S in exoplanets science (and stellar astrophysics), and it's easily accessible to the Italian community
- It does require a very large investment in observing time -> strategic thinking and decisions
- It must be proven to be a successful undertaking

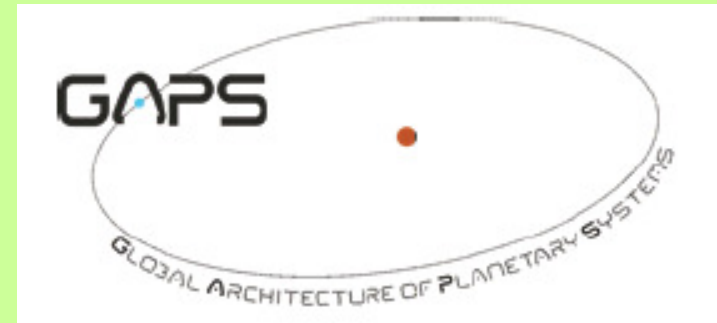
The HARPS-N Opportunity



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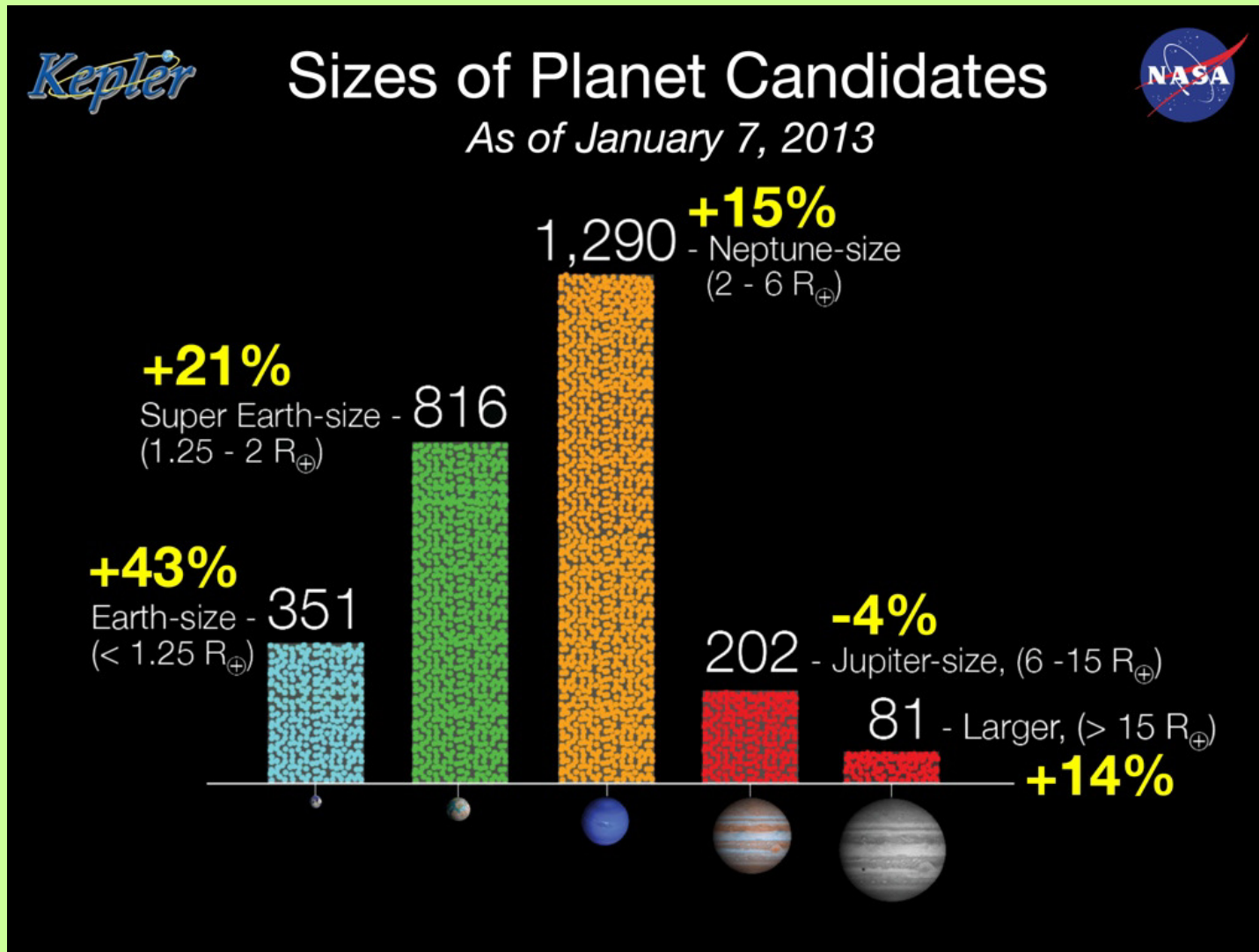


- **GAPS: A long-term programme for the comprehensive characterization of the architectural properties of planetary systems as a function of the hosts' characteristics**
- **GTO: 1) determine densities of terrestrial planets identified by Kepler, 2) search for rocky planets around nearby solar-type dwarfs**

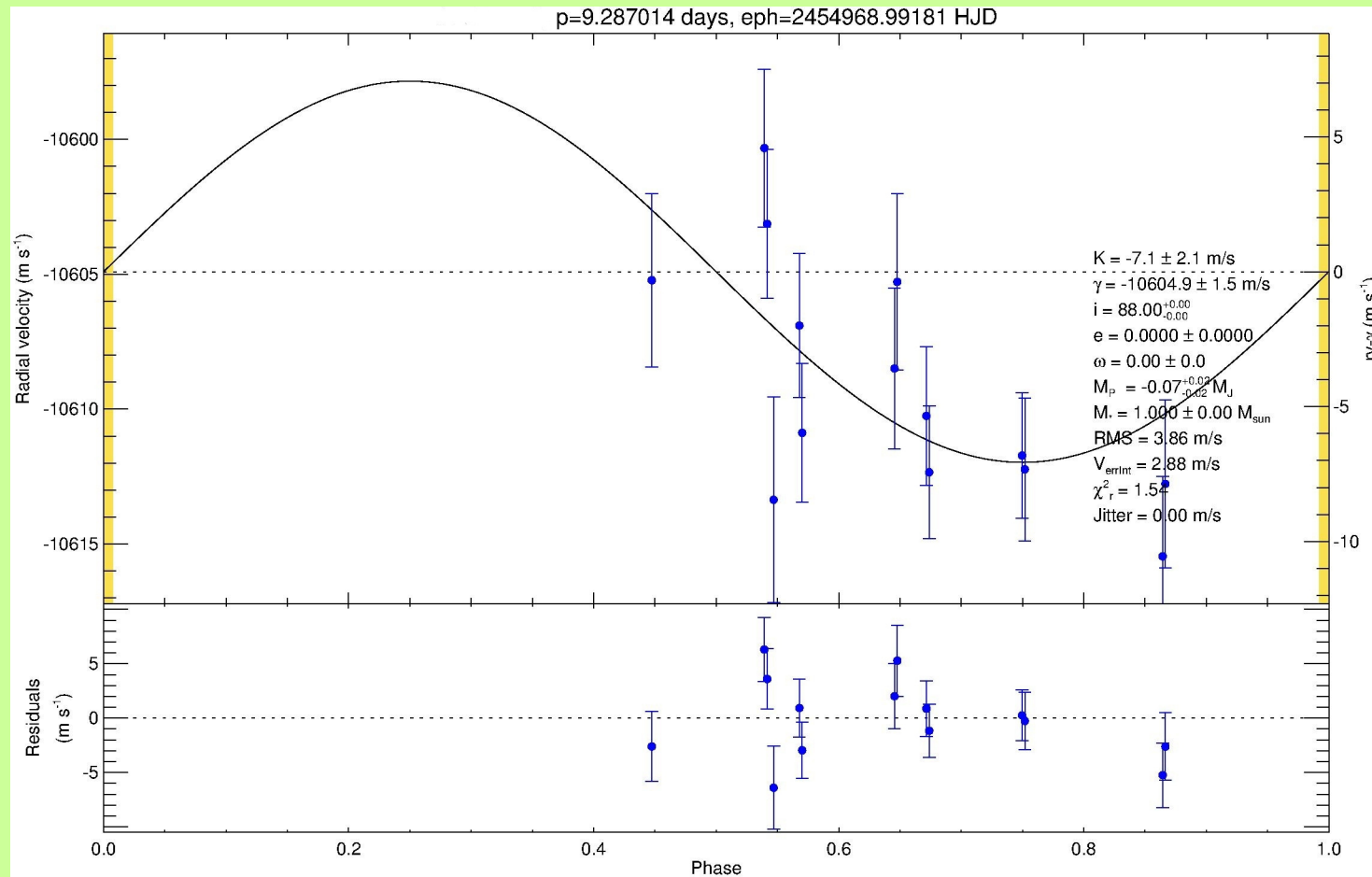
Transiting Planets: A Treasure Trove

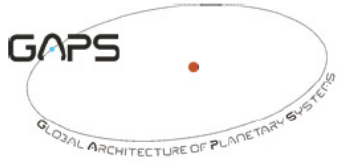
- Learn about the history of planet migration through Rossiter-McLaughlin effect measurements
- Learn about the architecture of multiple systems
- Learn about the physical structure and composition of exoplanets
- Learn about the structure, chemistry, and dynamics of atmospheres

Kepler: a 10^{-5} mag Precision Machine!



HARPS-N GTO: Sample Result

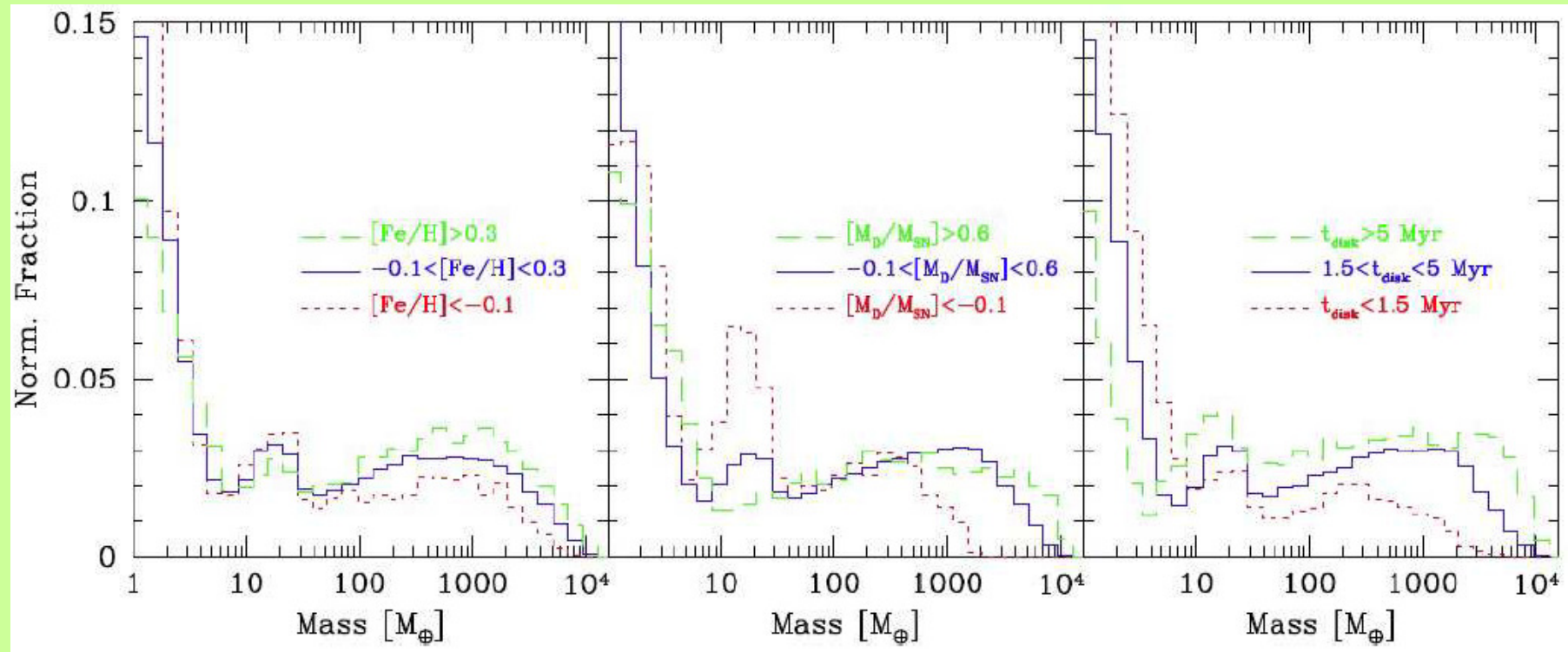




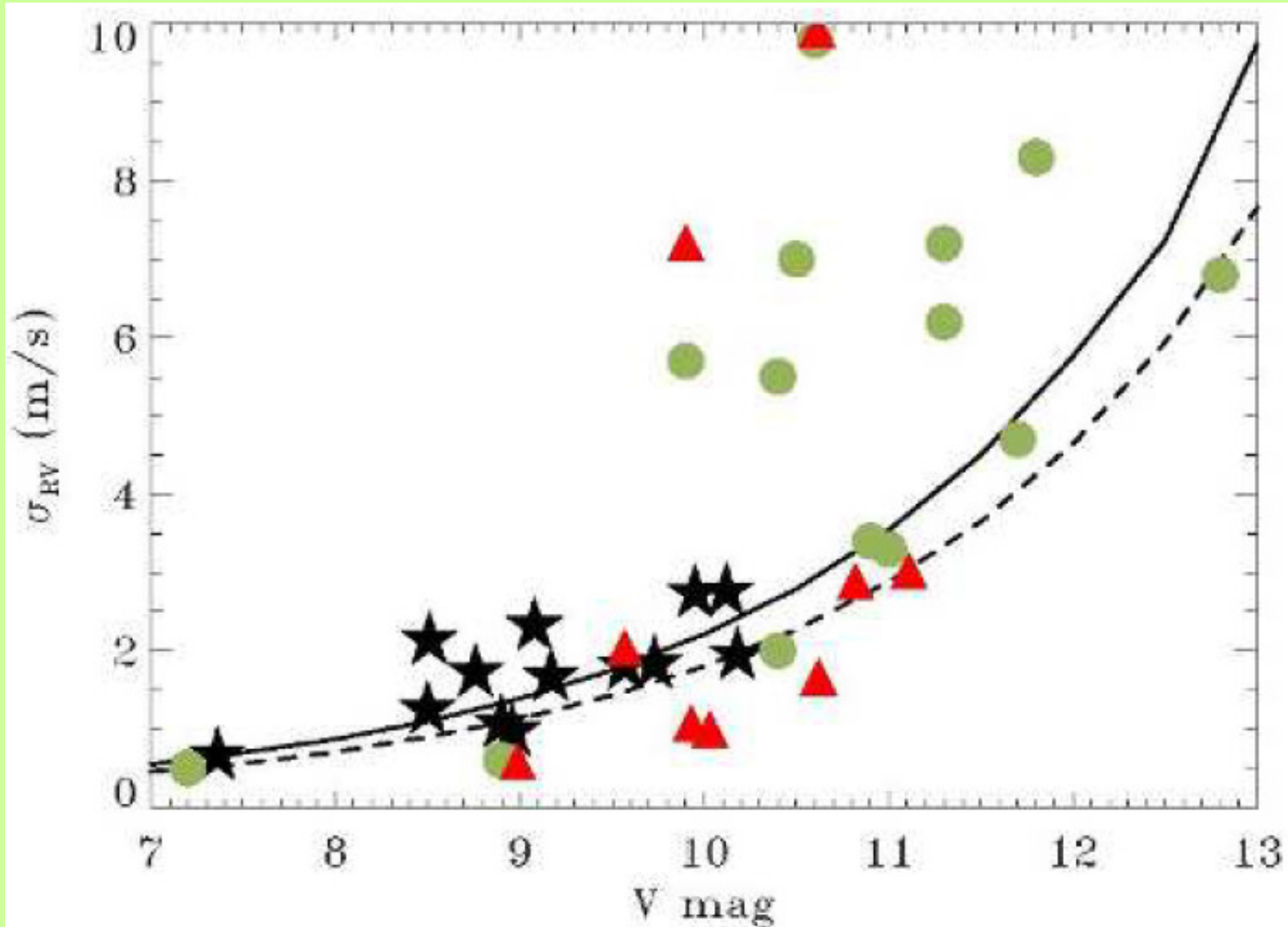
GAPS Science

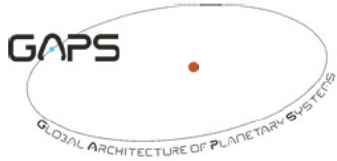
- Determine the occurrence rates of low-mass systems as a function of stellar properties (mass, metallicity)
- Measure the occurrence rate of giant planets in dense stellar environments
- Unveil the orbital architecture of multi-planet systems across orders of magnitude in mass and orbital separation
- Discriminate between scenarios for orbital evolution of planetary systems
- Characterize the degree of different types of star-planet interactions

Example: Planets Around Metal-Poor Stars



Sample Result

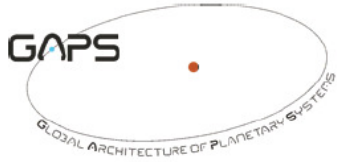




GAPS: Synergies with...



- **Precision NIR RVs (GIANO)**
- **Ultra-high precision RVs (ESPRESSO)**
- **Ongoing ground-based transit surveys (APACHE)**
- **Upcoming space-borne observatories devoted to transiting planets science (CHEOPS, TESS, PLATO)**
- **High-precision astrometry (Gaia)**



The Gaia – HARPS-N Synergy (1)



The combination of RVs of ALL bright ($V < 13$), nearby ($d < 200$ pc) stars observed with HARPS-N and Gaia astrometry will allow to:

- a) characterize planetary systems across orders of magnitude in mass and orbital separation
- b) improve studies of the dynamical evolution of multiple systems with giant planets

HARPS-N will cherry-pick on Gaia astrometric giant planet detections to:

- a) look for low-mass and/or short-period companions missed by Gaia
- b) improve the characterization of long-period orbits

The Gaia – HARPS-N Synergy (2)

- * **ALL parallaxes of HARPS-N GTO program stars in the Kepler field released formally around mid-2016**
 - * **For a typical target with $V < 15$ at < 0.5 kpc, expect $\sigma(n)/n < 2-3\%$**
 - * **Re-calibrate absolute luminosities**
 - * **Derive trigonometric gravities to ~ 0.05 dex**
 - * **Re-determine the stellar radii to $< 5\%$ -> re-assess the planets' structural properties**
- > A global statistical analysis of planetary properties and frequencies (including η_{\oplus}) in the Kepler field as a function of stellar properties (mass, metallicity)**

Forward Look

- **A strategic choice has been made**
- **A community is responding in a coordinate fashion**
- **Evolutions in the use of 2-4m class telescopes are ongoing**
- **Must identify venues for optimal balance amongst and satisfaction of all communities**