Planets in Open Clusters

M35 & NGC2158, Asiago

- Stars in OCs share the same **distance**, **age** and **chemical composition, statistically determined**
- OCs span a wide range in terms of **age, metallicity, stellar density**: we can probe the planet frequency as a function of these parameters
- Planet frequency as function of **host stellar mass** in the most reliable way
- Effects of the presence of a **planetary system** on the host **star chemistry**

Planets in Open Clusters and the Habitability Zone

Atmosphere of young planets around young stars	Test atmospheric models on planets at different evolution stages
Characterize the activity of stars as function of their mass and age	Improve planet detection at longer periods and lower masses
Well-known chemical abundances of stars (with and without planets)	Understand the star-planet connection

Planets in Open Clusters seems very helpful! How many of them have been found around MS stars?

6

8 with Kepler validated ones

Planets in Open Clusters

Young OC stars are very active

+

Old OCs are far, MS stars are faint

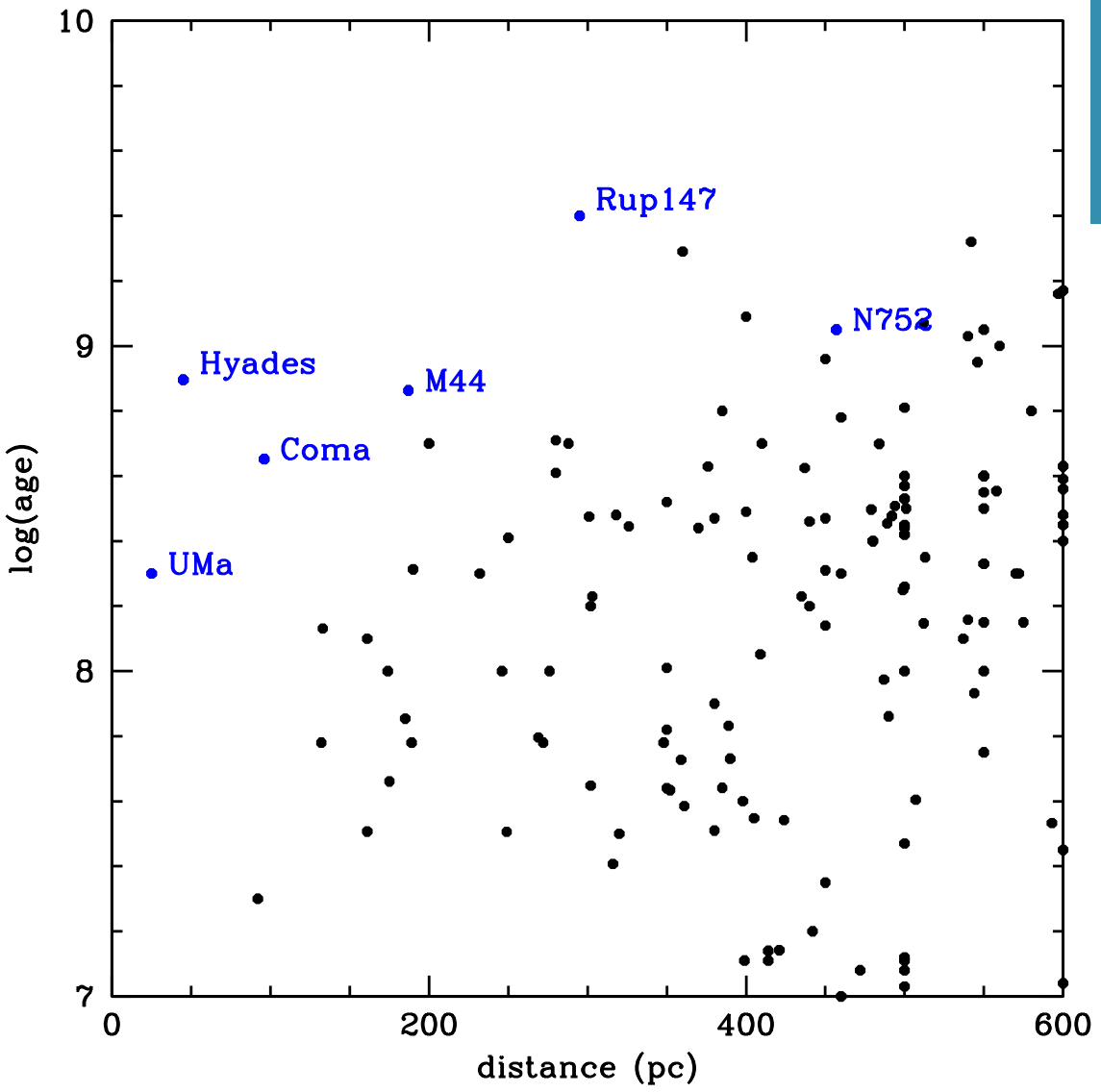
=

Avoided by RV surveys

OC stars very close each other on sky

↓

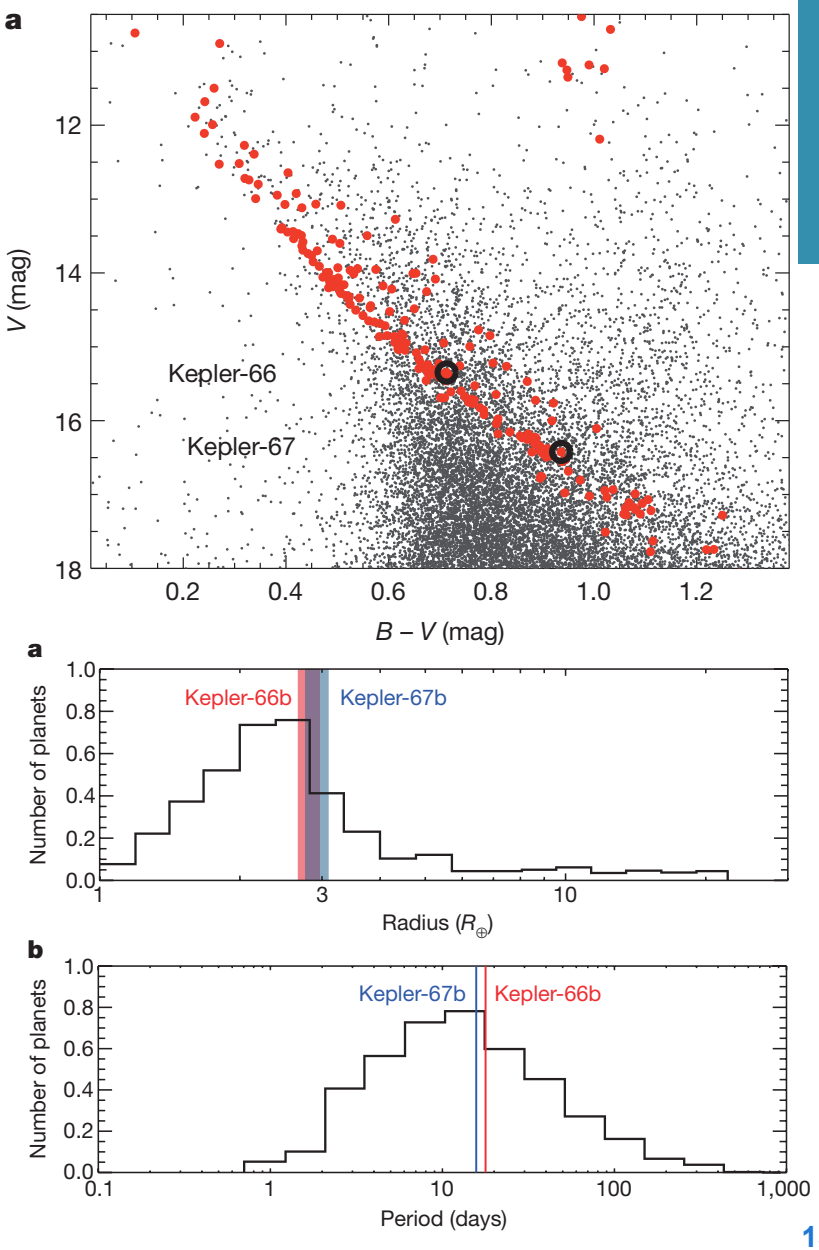
Photometry easier option



Searching for Planets in OCs: **Photometry**

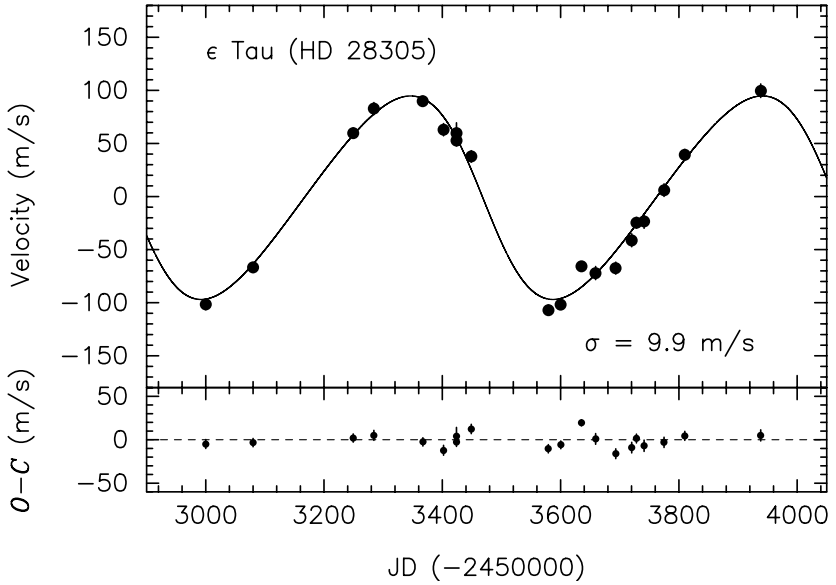
- Photometric searches in M37, NGC188, NGC1245, NGC2158, NGC2362, NGC6791... Without planets. *Are planets less common in clusters?*
- Van Saders & Gaudi 2011: Insufficient sensitivity to small planets, sample sizes barely large enough to find (less common) larger planets. *Null detection still in agreement with field frequency*.
- Meibom et al. 2013: 2 mini-Neptunes, Kepler-66b and Kepler-67b detected in NGC6811 by *Kepler* mission over 377 cluster members. *The same frequency of planets inside and outside open clusters of stars.*

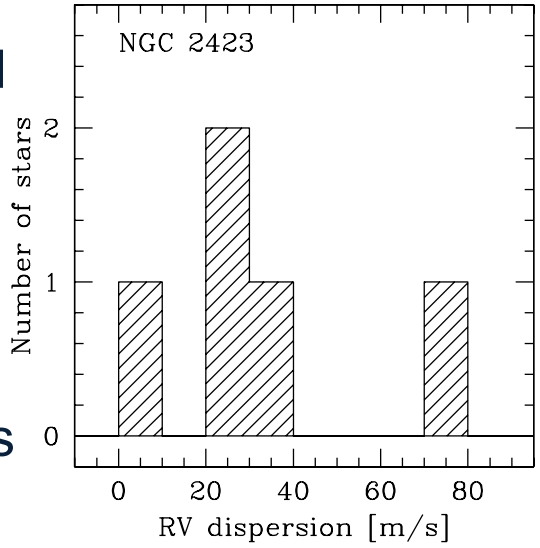
Meibom et al. 2013

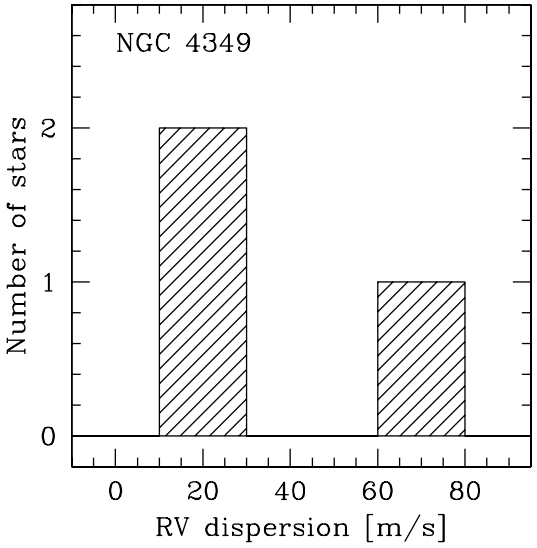


Searching for Planets in OCs:
Radial Velocities of Giant Stars

- ☺ Giant Stars are brighter than Main Sequence counterparts
- Sato et al. 2007: *A planetary companion to the Hyades Giant ε Tauri*, **P=594d M*sini*i=7.6M$_J$**
- Lovis & Mayor 2007: *Planets around evolved intermediate-mass stars.* A **P=714d M*sini*i=10.6M$_J$** in NGC2423 and a **P=678d M*sini*i=19.8M$_J$** in NGC4349
- ☹ Little knowledge of giant star oscillations prevent the discovery of small-mass planets

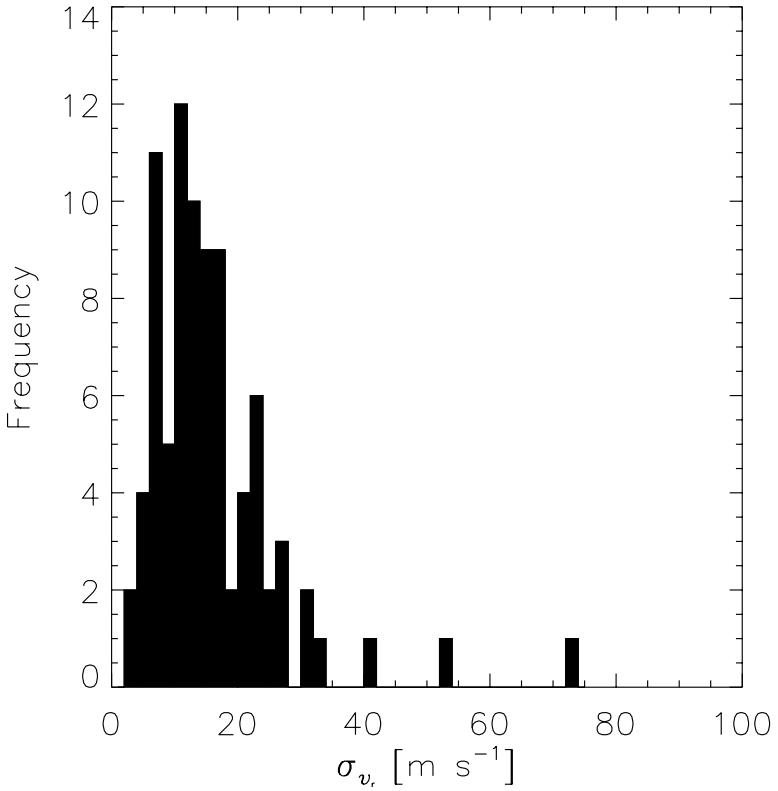






Searching for Planets in OCs:
Radial Velocities of MS Stars

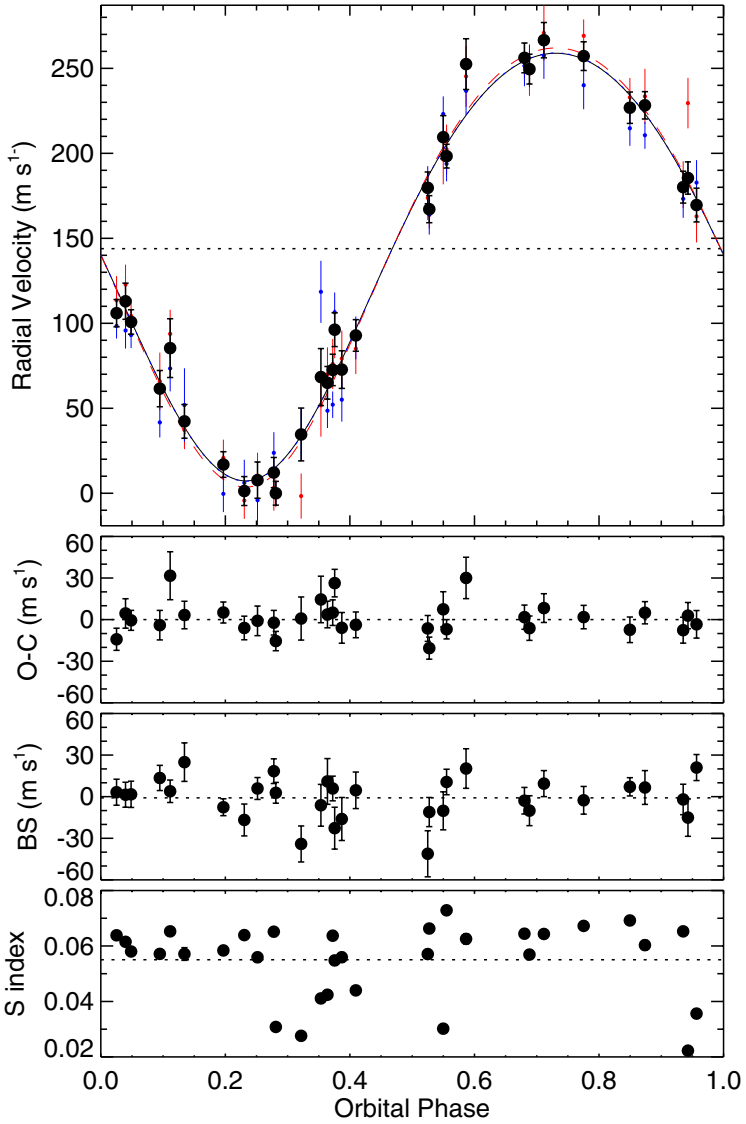
- Chocran et al. 2002, *Searching for planets in the Hyades. I. The Keck Radial Velocity survey*
- 94 F5V to M2V stars, magnitude range V=7.5-11. No planet found
- The survey was affected by the little knowledge of stellar activity of young stars (*RV jitter*)
  - Sparse sampling
  - No simultaneous photometric observations
  - Only CaII H&K emission lines as activity indicator. I_2 gas cell contaminates the spectra



- A small number of stars were then observed more intensively, spectroscopically and photometrically, and…….

Searching for Planets in OCs:
Hot-Jupiters around OC stars

- Quinn et al. 2012: *Two "b"s in the Beehive: the discovery of the first Hot Jupiters in an Open Cluster*
  - **P=4.43d M*sini*=0.54M_J**
  - **P=2.14d M*sini*=1.84M_J**
- Quinn et al. 2014: *HD 285507b: an eccentric Hot Jupiter in the Hyades Open Cluster*
  - **P=6.09d M*sini*=0.54M_J e=0.09**
- Observational strategy focused on the detection of short-period, massive planets.

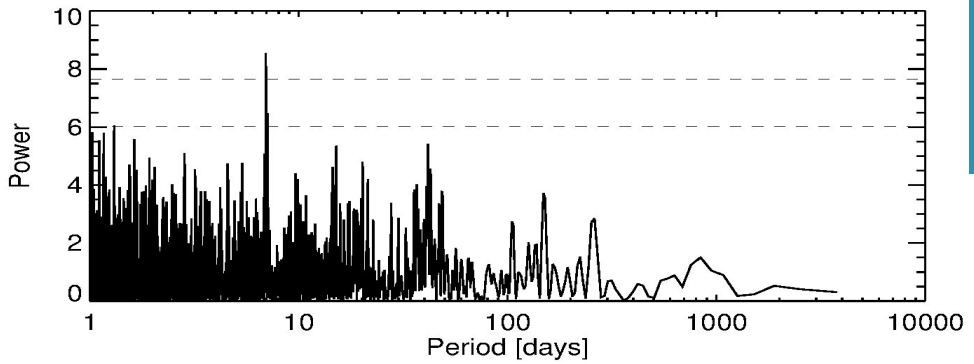


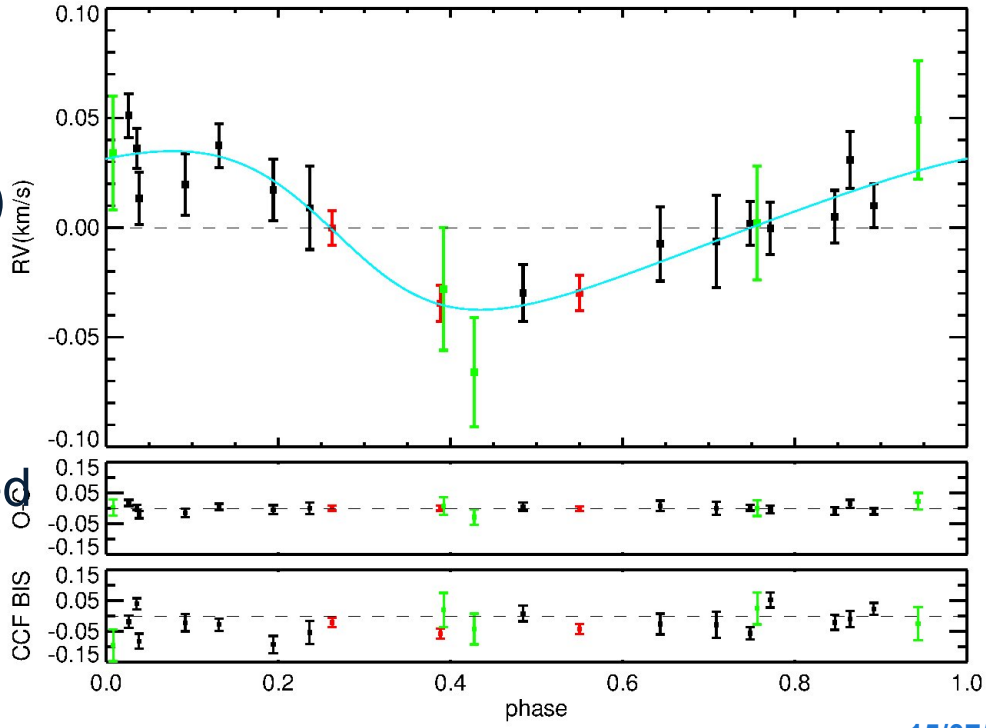
Searching for Planets in OCs:
Hot-Jupiters around OC stars

- Brucalassi et al. 2014: *Three planetary companions around M67 stars*
  - **P=6.96d M*sini*i=0.34M_J, e=0.24**
  - **P=5.12d M*sini*i=0.40M_J, e=0.39**
  - **P=121d M*sini*i=1.54M_J e=0.35** (around a giant star)

- M67 is old (~4 Gyr), activity has been neglected

- Observational strategy focused on giant planets. HARPS in lower-resolution setting.



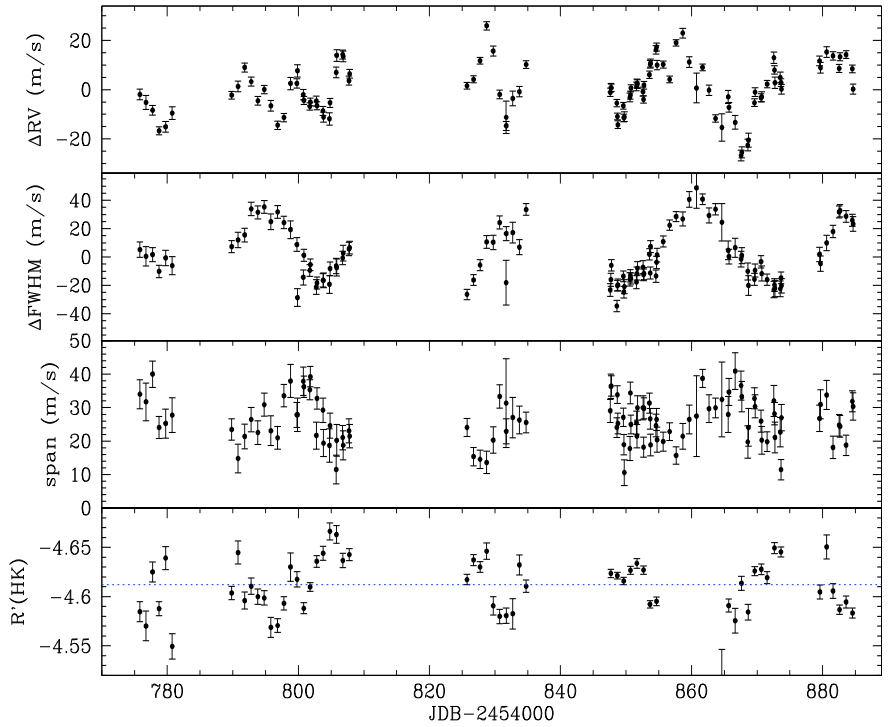


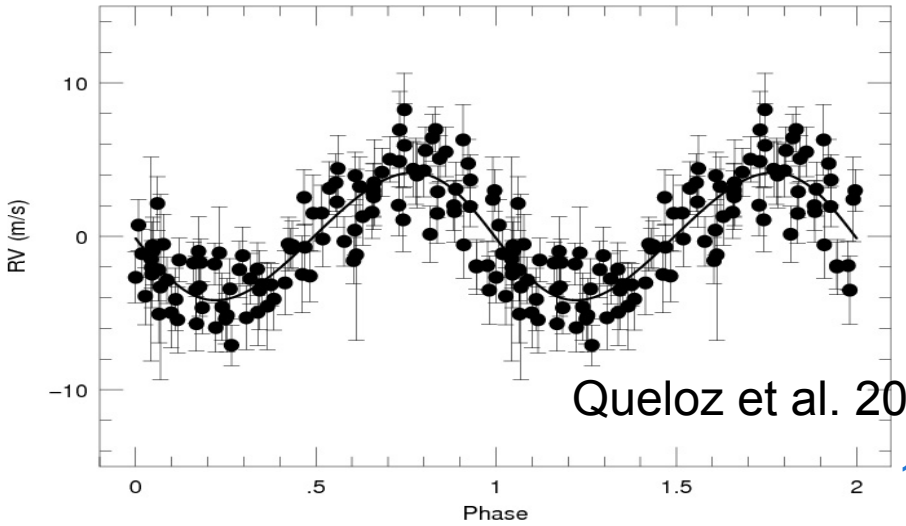
OCs, RVs and stellar activity

- Activity is a noise, you don't need precise RVs….

WRONG

- Corot-7 (M=4.8 $M_{\oplus}$): *RV jitter* has a structure that can be removed
- Now: must understand activity to find habitable planets
- Agreement on the importance of **rotational period** of the star and simultaneous **photometric observations**

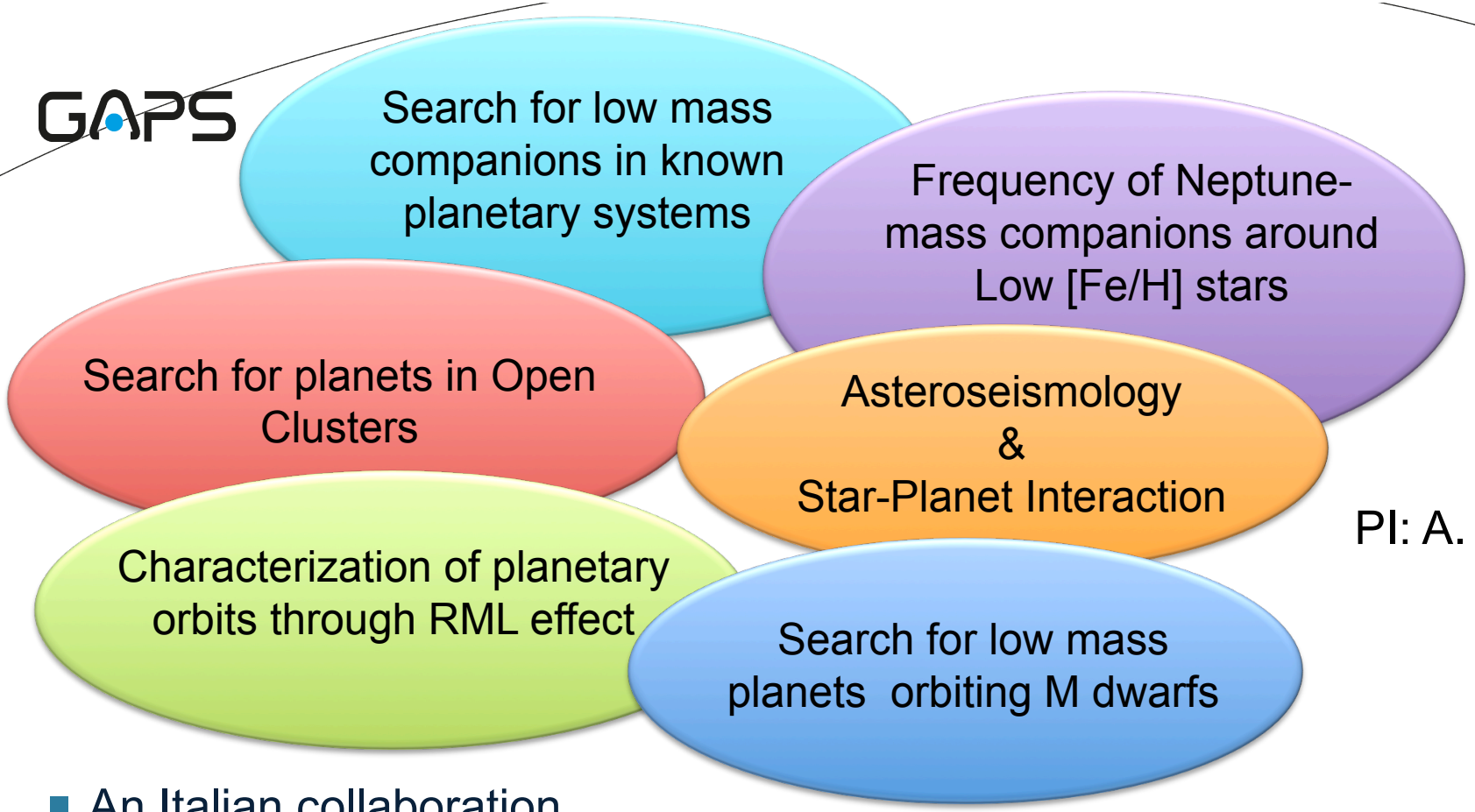




Queloz et al. 2009

Global Architecture of Planetary Systems

GAPS

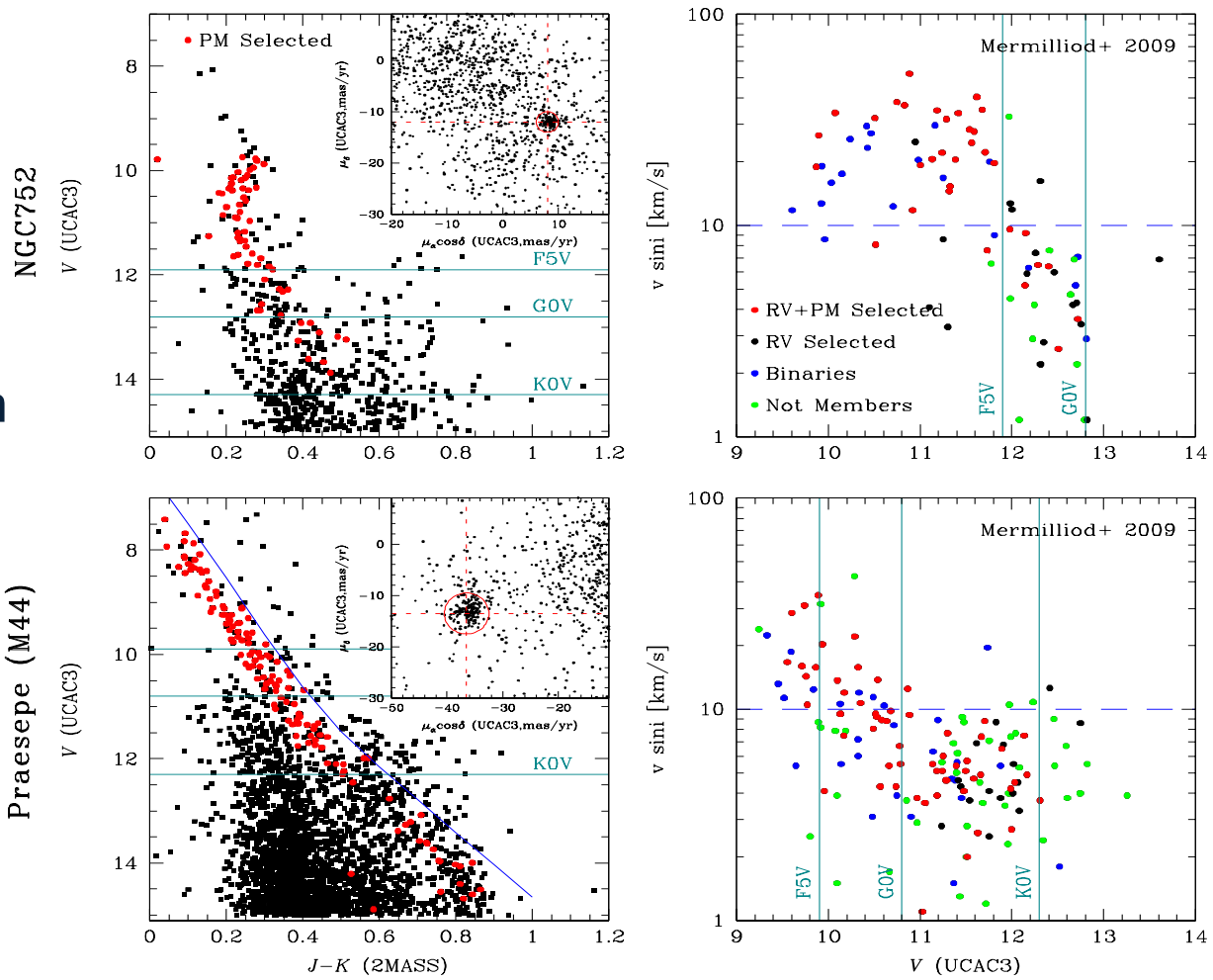


PI: A. Sozzetti

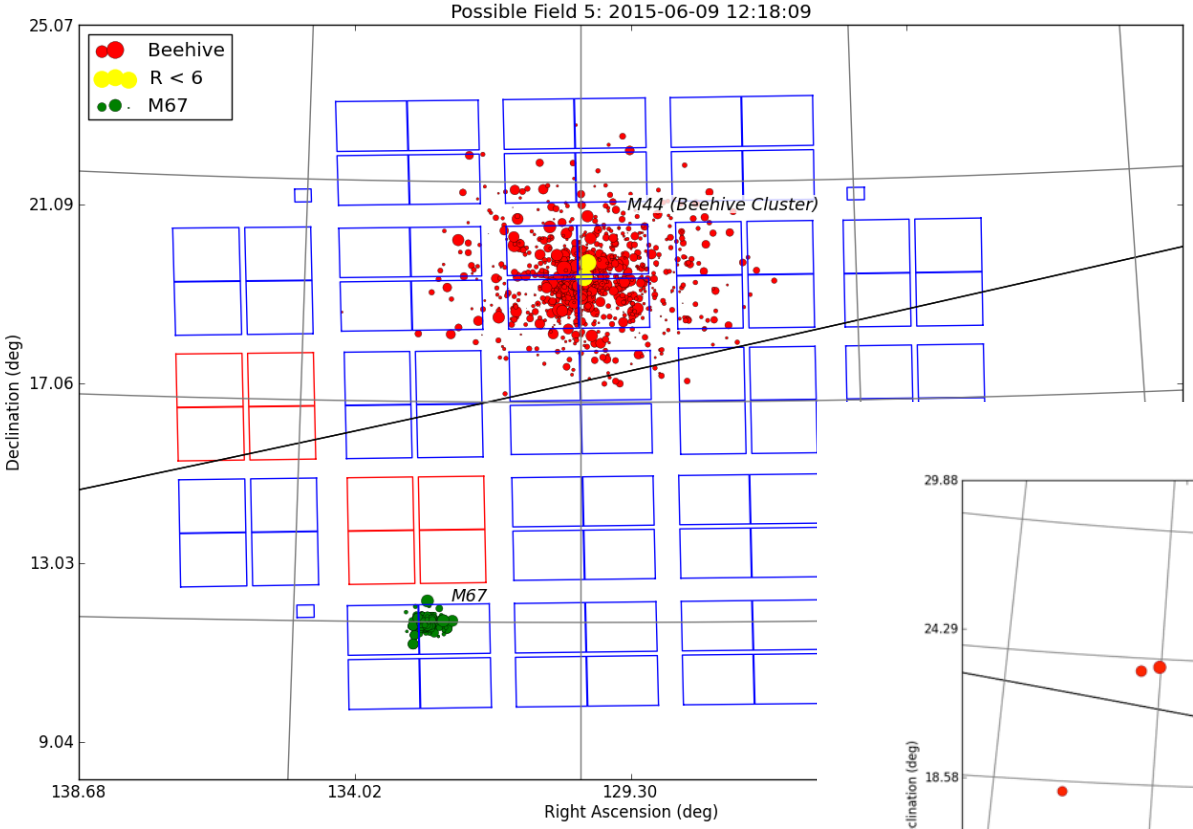
- An Italian collaboration to make the best use of HARPS-N@TNG
- 6 sub-programs to disentangle activity signals from planetary ones, understand the formation of planetary system and detect low-mass (**habitable**?) planets

Searching for Low-Mass Planets in OCs:
The OC Survey with HARPS & HARPS-N

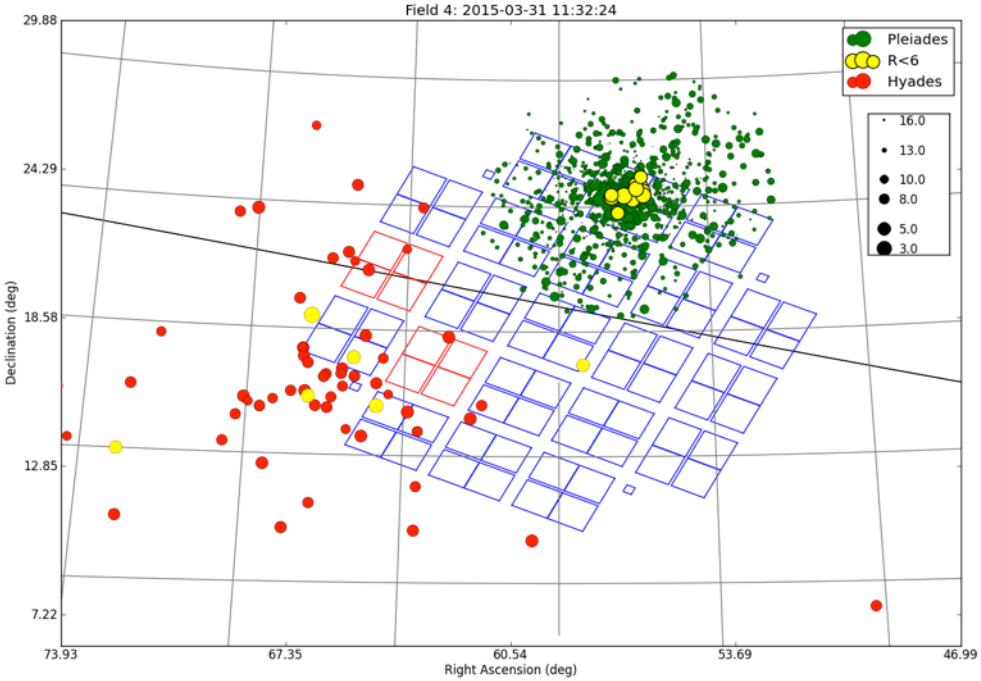
- Currently surveying three Open Clusters
- **M44** (600 My), **NGC752** (1.5 Gy) with HARPS-N, 5 nights/semester with GAPS
- **Ruprecht 147** (3 Gy) with HARPS, 26 nights in 3 years (PI: Minniti)
- **Hyades** to start soon
- Great deal on target membership and activity analysis



Searching for Planets in OCs:
K2 observations



- Many OCs included in K2 fields on specific request of community!



Planets in OCs are becoming hot-topic

Conclusions

- Photometry does not find a different frequency of planets in Open Clusters respect to the field
- Earlier RV surveys did not take activity into account properly
- Later RV surveys focused on giant stars, or just to find Hot Jupiter
- We now have the hardware (HARPS-N@TNG, HARPS@3.6m, high-precision photometry) and the tools (Activity indexes…) to discover low-mass planets in OCs
- Not only planet discoveries: star-planet chemical connection, dynamics of stellar encounters…

SEVENTH FRAMEWORK PROGRAMME

Measuring ETA_EARTH: Characterization of Terrestrial Planetary Systems with Kepler, HARPS-N, and Gaia - P.I: Dr. Sozzetti – Research funded by the EU 7th Framework Programme (FP7/2007-2013) under grant agreement n° 313014.