The GAPS search and characterization of planetary systems with HARPS-N at TNG

A. S. Bonomo[1], S. Desidera[2], A. Sozzetti[1], M. Damasso[1], S. Benatti[2], K. Biazzo[3], R. Claudi[2], E. Covino[4], M. Esposito[5], D. Gandolfi[6], R. Gratton[2], A. F. Lanza[3], L. Malavolta[2,7], G. Micela[8], V. Nascimbeni[2,7], I. Pagano[3], G. Piotto[7], and the GAPS Team

1: INAF-Osservatorio Astrofisico di Torino; 2: INAF-Osservatorio Astronomico di Padova; 3: INAF-Osservatorio Astrofisico di Catania; 4: INAF-Osservatorio Astronomico di Capodimonte; 5: Instituto de Astrofisica de Canarias; 6: Landessternwarte Konigstuhl, ZAH, Universitat Heidelberg; 7: Dipartimento di Fisica e Astronomia Galileo Galilei, Università di Padova; 8: INAF-Osservatorio Astronomico di Palermo;

email: bonomo@oato.inaf.it

The high-accuracy and high-precision HARPS-N spectrograph has been installed during Spring 2012 at the 3.6-m Telescopio Nazionale Galileo at La Palma island and is likely the most performing instrument to search for extrasolar planets via the Doppler method in the northern hemisphere. The GAPS Consortium has been awarded 80 nights per year of observing time to:

- search for additional planets around relatively bright stars which are known to host giant planets in wide and close-in orbits;
- search for planets across a wide range of masses and orbital separations around nearby stars with different properties, such as mass and metallicity, and/or in different environments (single stars, multiple stellar systems, members of open clusters);
- characterize the degree of (mis)alignment of transiting systems;
- study tidal and magnetic star-planet interactions;
- characterize host stars through asteroseismic analyses of high-cadence radial-velocity (RV) measurements.

The main goal of this intensive RV campaign is the understanding of the architecture, formation, and evolution of planetary systems.

First results

No giant planets around the metal-poor star HIP11952 ([Fe/H=-1.9]) (Desidera, Sozzetti, Bonomo et al. 2013)

Our HARPS-N data excluded the presence of the two giant planets with orbital periods of ~7 and ~290 days around HIP11952 which had been announced by Setiawan et al. (2012). This disclaimer is important because, according to the scenario of planet formation through core accretion, giant planets can not form in an extremely metal-poor ([Fe/H=-1.9]) environment (e.g., Johnson & Li, 2012).

XO-2: the first case of a binary system whose both components host a planetary system

XO-2N

- It hosts the transiting hot Jupiter XO-2N b (M_p=0.57 M_J, R_p= 0.98 R_J, P=2.61 d) which was discovered by Burke et al. (2007).
- A prograde orbit and long-term trend were unveiled by Narita et al. (2011).
- 30 new HARPS-N RVs allowed us to i) better constrain the orbital obliquity, indicating spin-orbit alignment of the system, and ii) see the curvature of the long-term trend (see Fig. 2), which provides further constrains on the long-period companion XO-2N c: P ≥ 14 yr, K ≥ 15 m/s, M ≥ 1.3 M_J (Damasso et al., in prep.).

XO-2S

- 64 HARPS-N RV measurements (Fig. 3) revealed a planetary system composed by a Saturn-mass planet (XO-2S b: M_p sini=0.26 ± 0.01 M_J) and another companion slightly more massive than Jupiter (XO-2S c: M_p sini=1.37 ± 0.05 M_J). The two planets are moderately eccentric and have orbital periods of 18.2 and 120.8 days, respectively (Desidera, Bonomo, Claudi et al., 2014).
- A long-term trend of 0.053 ± 0.001 m/s/d due to an additional companion of yet unknown nature was also detected (see Fig. 3).

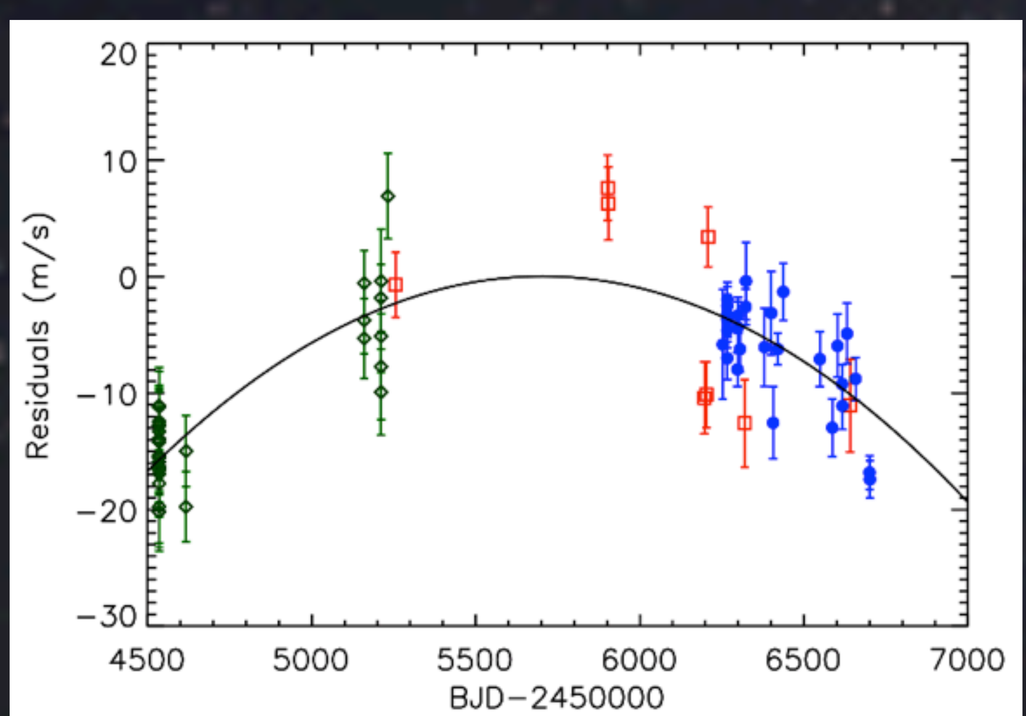

Fig. 2. Residuals of SUBARU (green diamonds), HIRES (red squares), and HARPS-N (blue circles) RVs of XO-2N after subtracting the Keplerian orbit of XO-2N b. A quadratic trend due to an additional companion is clearly visible.

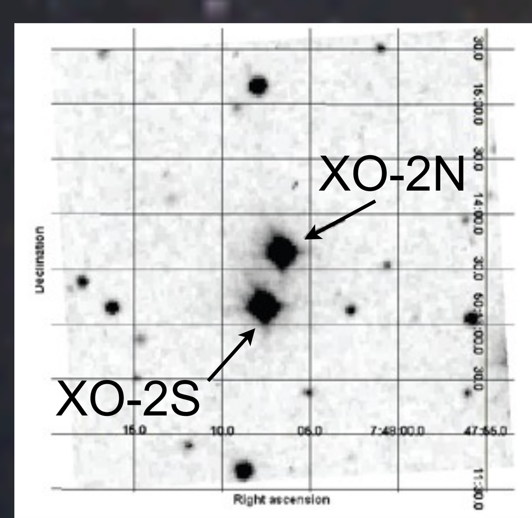

Fig.1: Finding chart showing the XO-2 binary system.

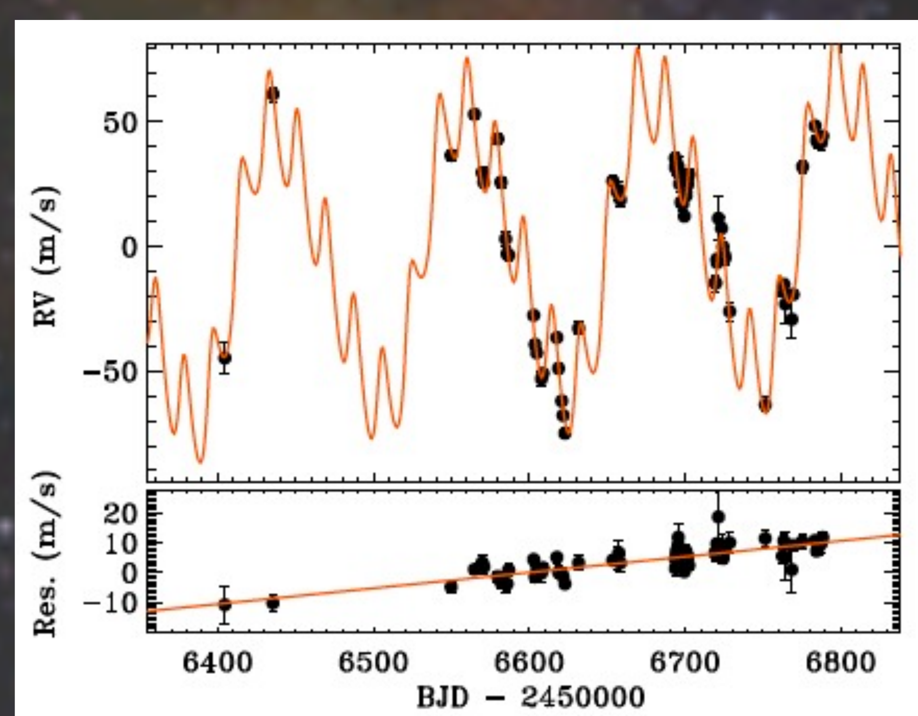

Fig. 3. Upper panel: relative HARPS-N RVs of XO-2S. The overplotted line is the best-fit Keplerian solution for two planets and a linear trend. Lower panel: residuals after removing the contribution of the two planets XO-2Sb and XO-2Sc. The overplotted line is the best-fit linear trend. From Desidera et al. (2014).

XO-2 represents a unique laboratory to understand planet formation and evolution processes. Indeed, the two stars are nearly identical, have the same age (7 ± 2 Gyr), and their protoplanetary disks were likely very similar. However, their planetary systems are rather different.

Understanding the evolution of Jupiter-class planets and star-planet tidal interactions

This is one of the main goals of the GAPS Consortium that is conducted in two ways:

- by measuring the sky-projected obliquities of transiting planets via the Rossiter-McLaughlin effect; these have been measured for Qatar-1b (Covino et al., 2013) and HAT-P-18b (Esposito et al., 2014), which turned out to be aligned (λ=-8.4 ± 7.1 deg) in a prograde orbit and misaligned in a retrograde orbit (λ=132 ± 15 deg), respectively.
- by taking additional high-precision RVs of bright stars (V ≤ 12.5) hosting transiting planets over a few years to i) improve (in a few cases to a larger extent) the measure of their eccentricity, and ii) search for additional long-period companions. Both these informations are important to study the tidal evolution of hot Jupiters (Pont et al., 2011; Husnoo et al., 2012) and to put constraints on the presence of additional companions which might have caused spin-orbit misalignments (see, e.g., Knutson et al. 2014). We are currently analysing with Bayesian Differential Evolution Markov Chain Monte Carlo tools the HARPS-N RVs obtained in the last two years for about 30 known transiting systems (Bonomo et al., in prep.).

Stay tuned, this is only the beginning: new results on the discovery and characterization of planetary systems will soon come!

Acknowledgments: The GAPS project in Italy acknowledges support from INAF through the "Progetti Premiali" funding scheme of the Italian Ministry of Education, University, and Research.