HARPS-N @ TNG, two years harvesting data: Performances and results

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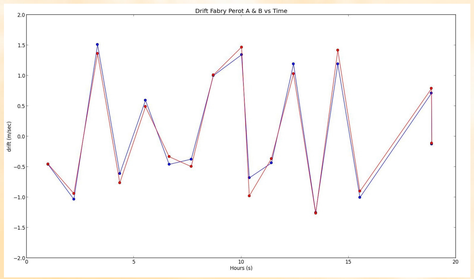
ABSTRACT

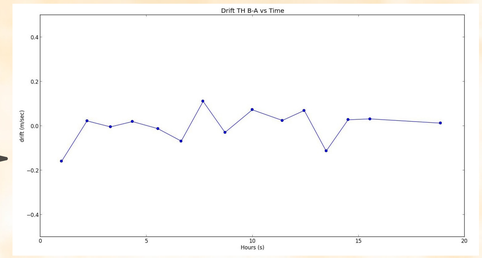
The planet hunter HARPS-N, in operation at the Telescopio Nazionale Galileo (TNG) from April 2012 is a high resolution spectrograph designed to achieve a very high radial velocity precision measurement thanks to an ultra stable environment and in a temperature-controlled vacuum. The main part of the observing time was devoted to Kepler field and achieved a very important result with the discovery of a terrestrial exoplanet. After two year of operation, we are able to show the performances and the results of the instrument.

HARPS stability



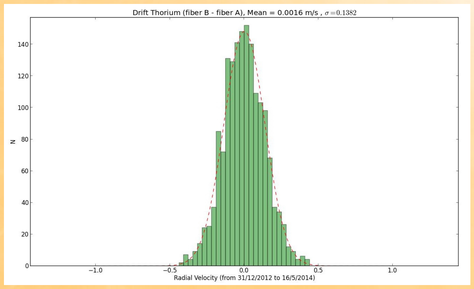
1-Series of radial-velocity measurements on thorium calibration. The red and blue point represents the instrumentally induced velocity change during 18 consecutive hours on the fiber A and fiber B (RVa and RVb)

B-A

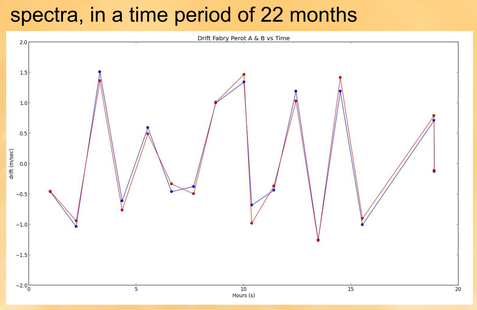


2-Plot of the difference between the RV drift measured by the A and B fiber of the series in figure 1

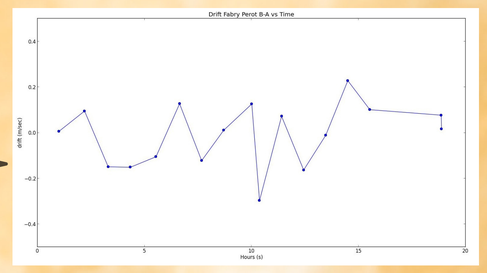
The drift-corrected radial velocity distribution calculated with more than 1600 thorium calibration spectra shows a standard deviation of 0.138 m/sec.
The difference between the calculated distribution and the internal error predicted is due to a combination of the long term drift of 10 cm/sec/day, due to a opto-mechanic effects and measured with the laser-comb (see laser-comb section) and a thorium lamps effect due to the different emission of the thorium A and thorium B lamps.
The comparison between the experimental measurements along 22 months and the internal error is very satisfactory and demonstrates that the statistical noise is as expected taking into account the effects mentioned above.



3-drift-corrected radial velocity distribution (RVb -RVa) calculated with more than 1600 thorium calibration spectra, in a time period of 22 months



B-A

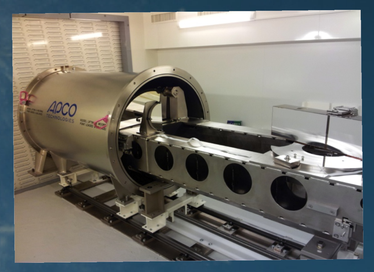


4-Series of radial-velocity measurements on fabry-Perot. The red and blue point represents the instrumentally induced velocity change during 18 consecutive hours on the fiber A and fiber B (RVa and RVb)

5-Plot of the difference between the RV drift measured by the A and B fiber of the series in figure 4

General characteristics

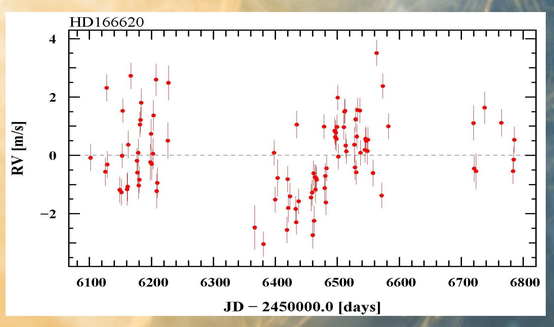
Spectrograph type	Fiber fed, cross-dispersed echelle spectrograph
Spectral resolution	R = 115'000
Fiber field	FOV = 1"
Wavelength range	383 nm - 690 nm
Total efficiency	e = 8 % @ 550 nm (incl. telescope and atmosphere @ 0.8" seeing)
Sampling	s = 3.3 px per FWHM
Calibration	ThAr + Simultaneous reference (fed by 2 fibers)
CCD	Back-illuminated 4k4 E2V CCD231 (graded coating)
Pixel size	15 µm
Environment	Vacuum operation - 0.001 K temperature stability
Global short-term precision	0.3 m/s
Global long-term precision	better than 0.6 m/s
Observational efficiency	SNR = 50 per extracted pixel on a Mv=8, TExp = 60 sec
wavelength accuracy	60 m/s (2x10E-7) on a single line



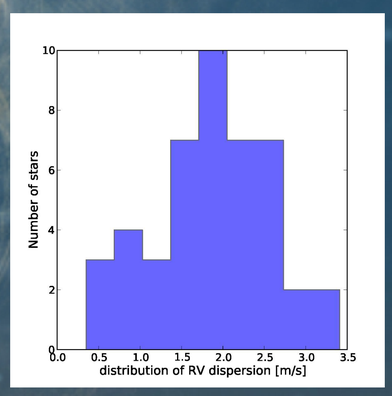
HARPSN vacuum vessel

HARPS-N is a fiber-fed, cross-dispersed echelle spectrograph, based on the design of its predecessor working at ESO 3.6 m. This successful spectrograph already has proven its capability to achieve a precision better than 1 meter per second and revealed several super-earth planets in the habitable zone,

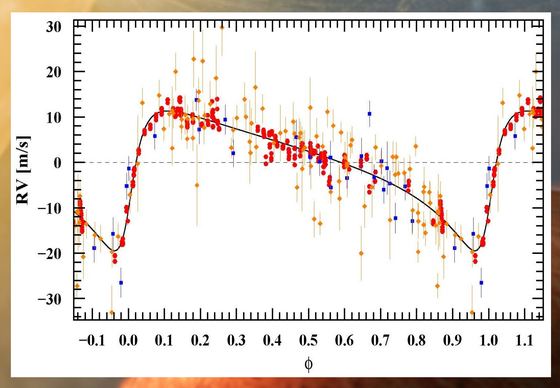
Radial velocity precision



Series of radial velocity measurements on the quiet, non-rotating star HD166620, observed for 21 months, from June 2012 to March 2014 in the GTO long term program



Distribution of RV dispersion on a RPS GTO sample; most of the RPS star have a magnitude between 5 and 8 and the distribution of RV is centered on 2 m/sec



RV Dispersion		
HARPSN (TNG)	1.82 m/s	points
Hamilton (Lick)	5.86 m/s	Orange points
HIRES (Keck)	4.54 m/s	Blue points

The RV of the planetary system HD 3651, which hosts a giant planet, was measured with different instruments:
HARPS-N(red), Hamilton(orange),Hires(blue).

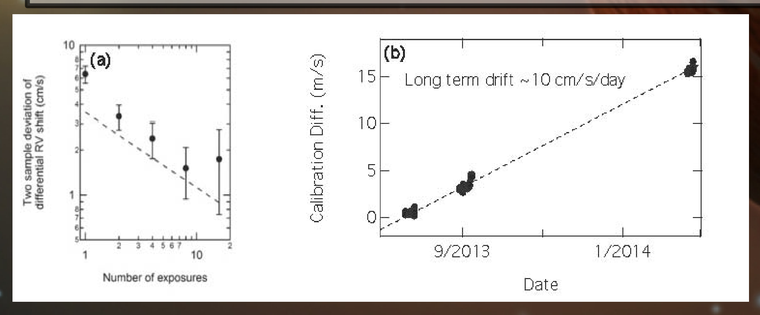
The values of the dispersions for this tree instruments are shown in this figure and resumed in the table.

The astro-comb wavelength calibrator

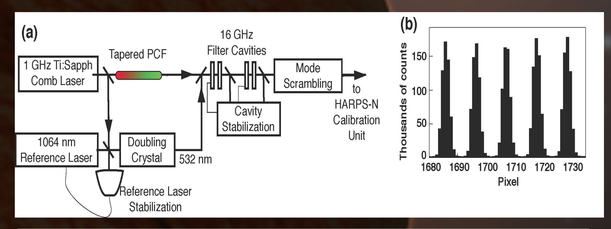
The astro-comb is a high precision wavelength calibrator, operating at the TNG, for use with HARPSN since January of 2013.

The astro-comb calibrates in the green-orange spectral range from 5000-6200 Å.
In a series of measurements, the astro-comb has been used to:

- calibrate the HARPS-N spectrograph,
- determine the instrument line profile in the spectral range over which calibration light is available,
- characterize the performance of the HARPS-N spectrograph, and
- monitor the differential drift between the calibration of the science and calibration fibers.



(a) Short-term sensitivity of astro-comb in measuring HARPS-N spectrograph as represented by the two sample deviation of the difference between the calibrations of the two HARPS-N fibers when both are illuminated by astro-comb light, with one sigma error bars. Differences between exposures are derived from cross-correlations with the sum of all exposures. Dashed line is the expected photon shot noise limit.
(b) Long-term stability of HARPS-N spectrograph when using simultaneous calibration. Shown is the difference in calibration between the science and calibration fibers as measured with the astro-comb.



Schematic of key components of astro-comb optics and a small section of the astro-comb spectrum in one order.

The Data Reduction Software

The Data reduction Software (DRS), developed at the same time of the instrument, was modified along the operation period. Some procedure was fined and other was added in order to improve the precision and in order to provide more features to the astronomer.

- **CTE correction**
- **Color correction**
- **Background/crosstalk reduction**
- **RHK calculation**

Recent HARPS-N Science Highlights

1.The GAPS Programme with HARPS-N at TNG. The retrograde orbit of HAT-P-18b (Esposito, M. et al., 2014, A&A, 564, 13)
2. An Earth-sized planet with an Earth-like density (Pepe, F. et al., 2013, Nature, 503,377)
3. The GAPS programme with HARPS-N at TNG. No giant planets around the metal-poor star HIP 11952 (Desidera, S. et al., 2013, A&A, 554, 29)
4. The GAPS programme with HARPS-N at TNG. Observations of the Rossiter-McLaughlin effect and characterisation of the transiting system Qatar-1 (Covino, E. et al., 2013, A&A, 554, 28)
5. KOI-200 b and KOI-889 b: Two transiting exoplanets detected and characterized with Kepler, SOPHIE, and HARPS-N (Hébrard, G. et al., 2013, A&A, 554, 114)

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