Instrument talk: HARPS

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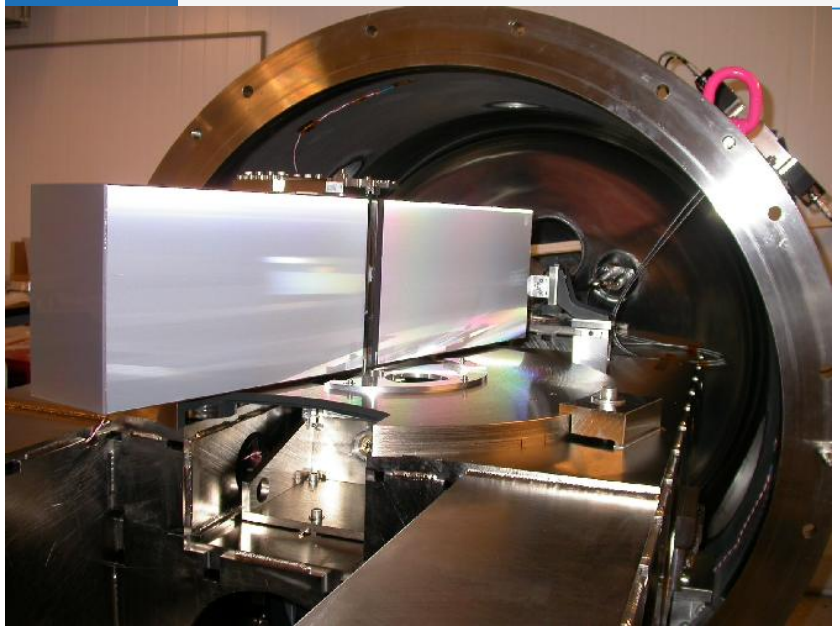
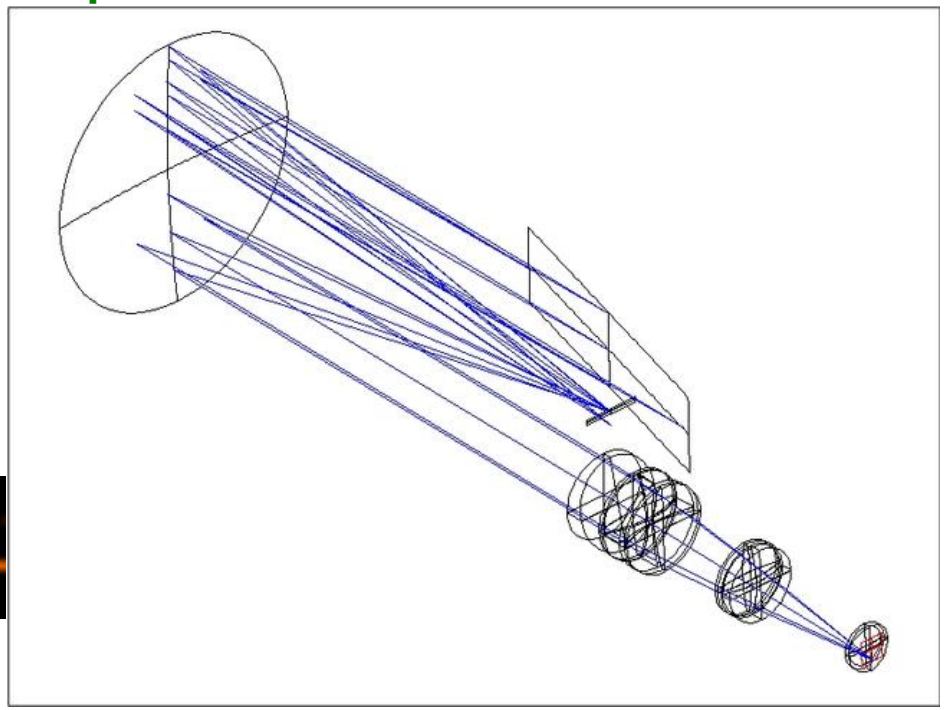
ESO calibration workshop

17-01-2017

HARPS

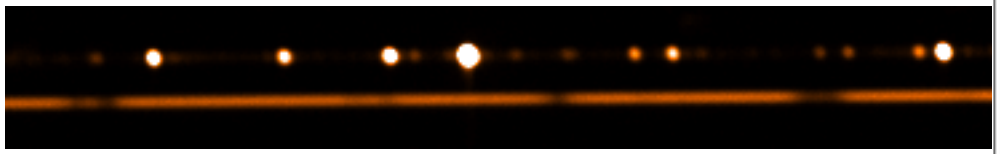


- Fiber fed (1”/1.4”)
- High resolution (R = 115000/80000)
- Temperature stabilized
- In vacuum
- Echelle cross dispersed
- Simultaneous reference
- Fixed spectral format



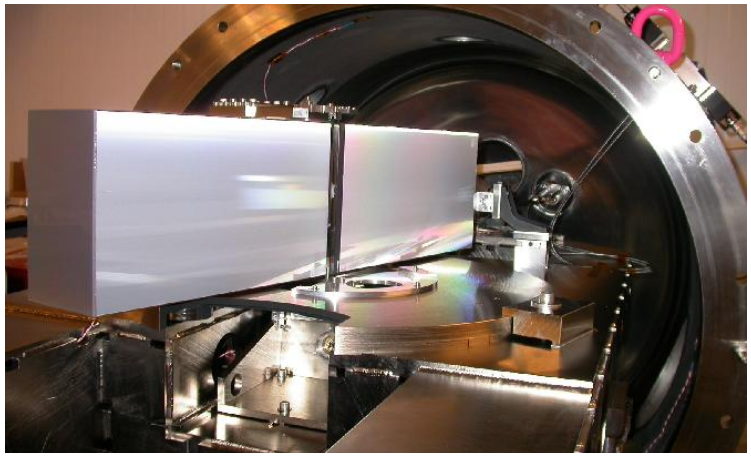
- Pressure stability: <10^{-3}mbar
- Temperature stability: <1mK RMS in one day

ThAr reference spectrum



Stellar spectrum

Instrument modes



All modes are equipped with
an online pipeline installed in La Silla

- HAM (High precision)
  - 1” fiber on sky, R~115000
  - “Double scrambler” for improved RV precision
  - Second fiber used for simultaneous reference
- EGGS (High efficiency, since 2005)
  - 1.4” fiber on sky, R~80000
  - No “double scrambler” for improved throughput
  - Second fiber used for sky subtraction (not fully supported by pipeline)
- HARPSPOL (Polarimetry, since 2011)
  - Linear and circular polarimetry
  - Second fiber used for the “extraordinary” polarimetric component

Pipeline

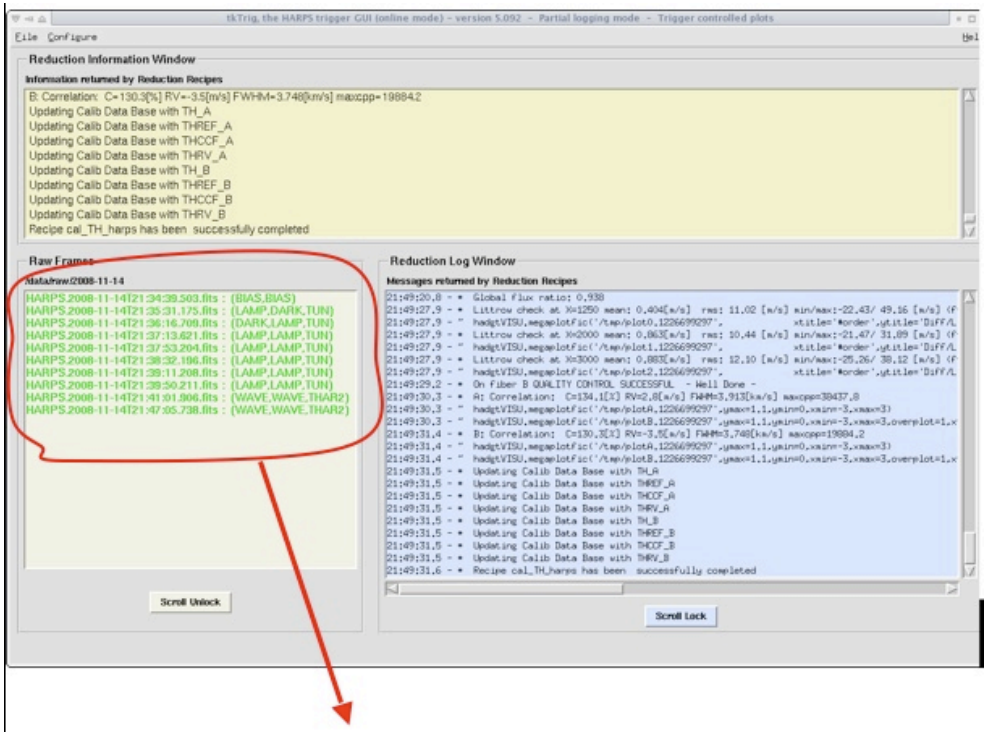
Equipped with an online & offline pipeline running in La Silla on all inst. modes.

Since 2003 delivers science ready data products to the users.
Since 2007 science ready data products are available from the archive.

The pipeline is also used for Quality Control by the instrument scientist.

Various pipeline upgrades,
The online archive is updated with the data from the latest running pipeline.

A new release (3.8) is now under test.



All files are green, all the calibrations passed quality control, we are happy !

HARPS calibration plan day time

- RV standard calib. (HAM mode, every day; 20 minutes)
  - Bias (health check)
  - Flat field (SNR ~700)
  - Fiber cross-contamination
  - Wavelength calibration (ThAr1 – ThAr2)
  - Drift calibration (ThAr1 – FP)
- EGGS calibrations (when needed / calib. Nights; 20 minutes)
- Polarimetric calib. (when needed; ~ 1-2 hours)
- High SNR observations (large number of flat fields)

HARPS calibration plan
Night time

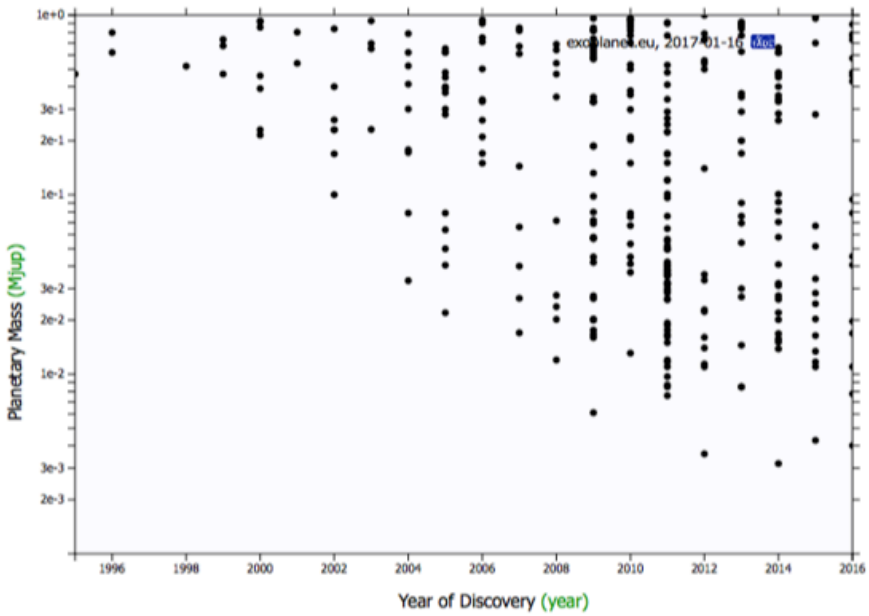
- Reference for drift measurement: simultaneous
- Spectro-photometric stds. (only programs requiring it <5%)
  - Observed also on “calibration nights”
- Parasitic light measurement (Na saturated stars), on calibration nights

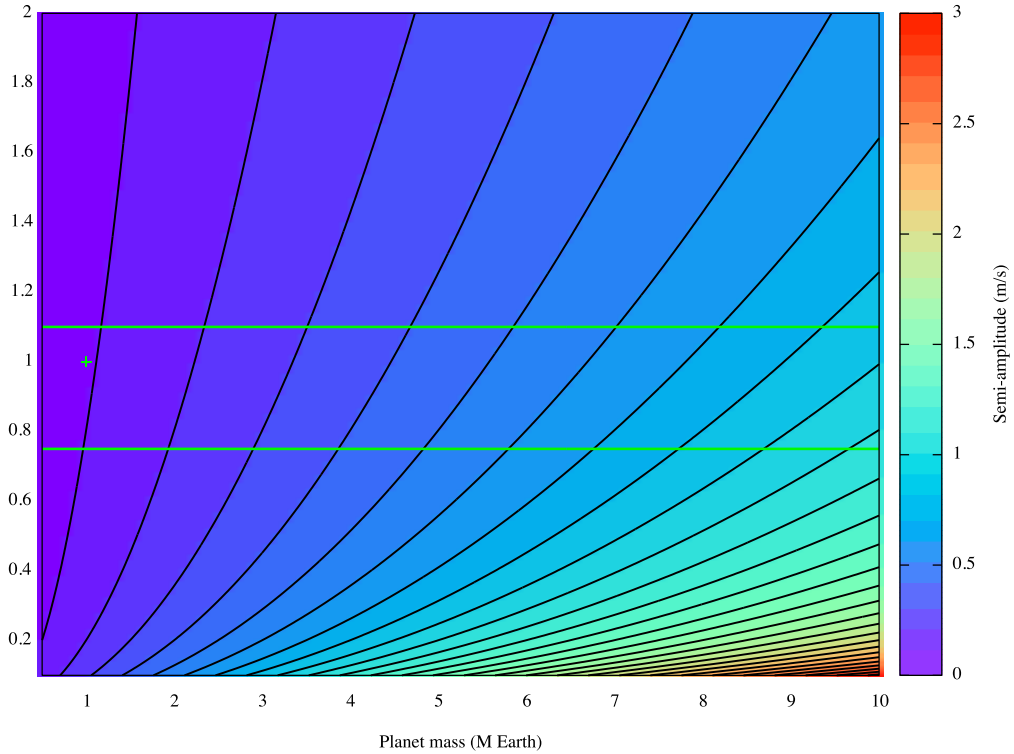
HARPS

HARPS = High Accuracy Radial velocity Planet Search

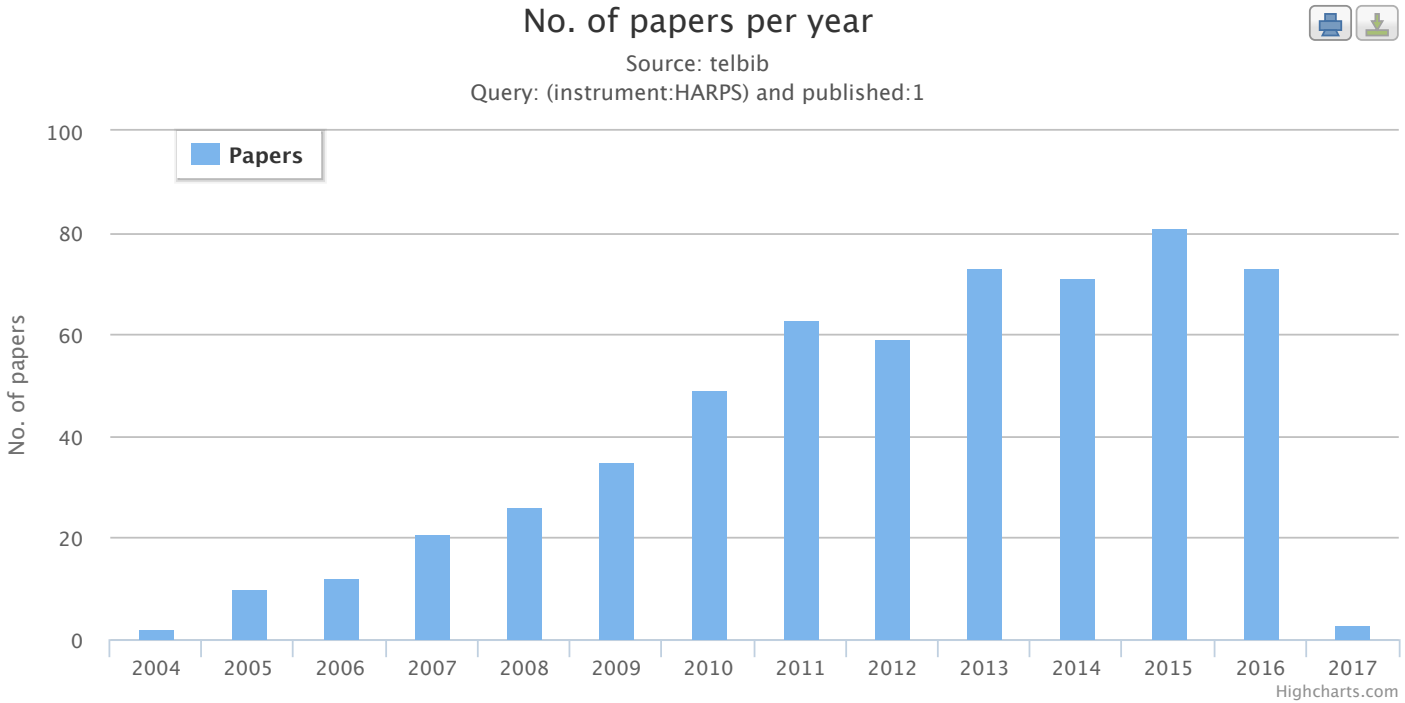
Goal RV precision: 1m/s

Commissioned: 2003





Demonstrated RV precision: 0.6m/s



~ ¾ related to exo-planets

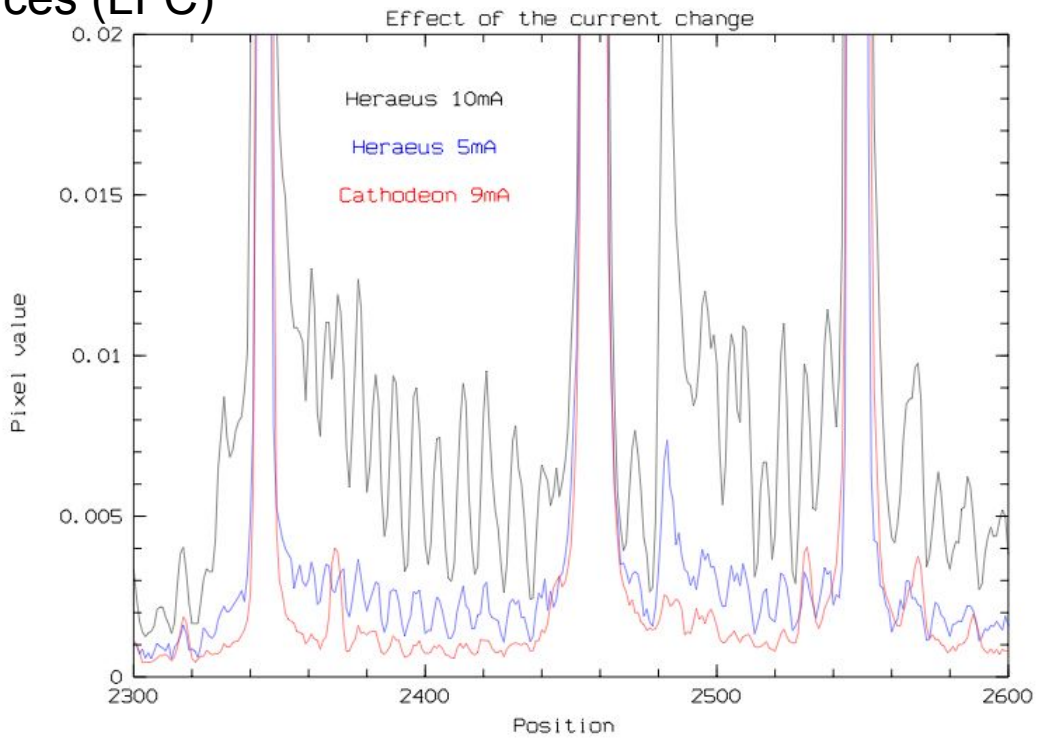
Increasing the RV precision

- ☆ High purity ThAr hollow cathod lamps
- ☆ Fabry Perot
- ☆ Guiding
- ☆ Octogonal fibers
- ☆ Laser Frequency Comb

HARPS ThAr lamps

In 2006 new EU regulations impacted the way ThAr hollow cathode lamps are produced. The new lamps do not have the purity level needed to reach high RV precision / accuracy. Contaminants in some cases bury Th lines.

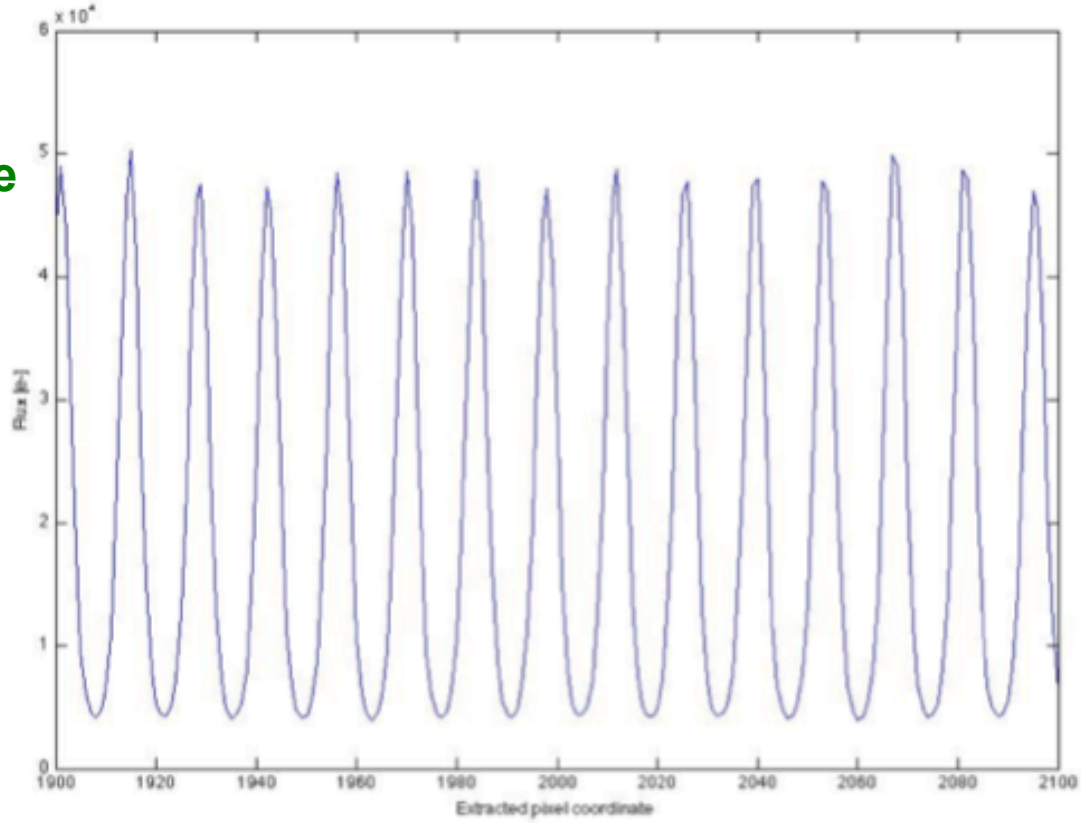
⇒ Limit strictly the use of ThAr lamps
⇒ Use FP for drift measurments
⇒ Search for alternative calibration sources (LFC)



Fabry Perot for drift measurement

- Stabilized etanol illuminated by a LDLS
- Well distributed, uniform spectrum across the detector
- Better than 3cm/s photon noise on a single frame
- Less than 10cm/s drift per night
- Lines positions “unknown” => not good for wavelength calibration

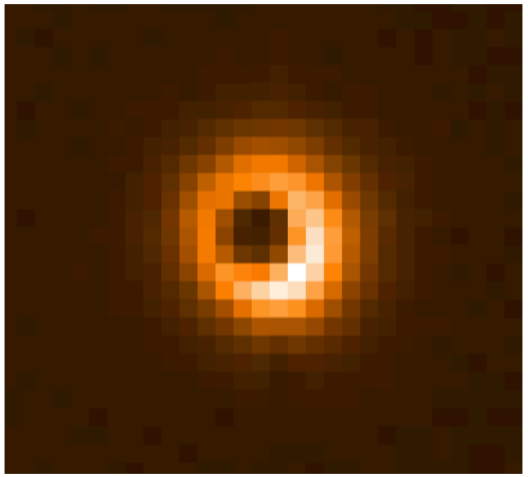
⇒ **Good for simultaneous reference to measure overnight drifts to better then 10cm/s.**



Available since October 1st 2011
Pipeline assisted

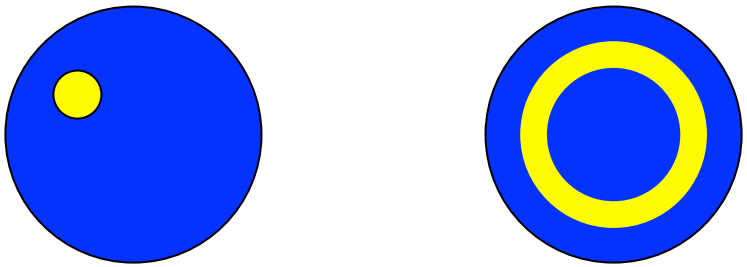
Guiding I

"Bad" guiding, 0.5" de-centering, ~3 m/s contribution to RV

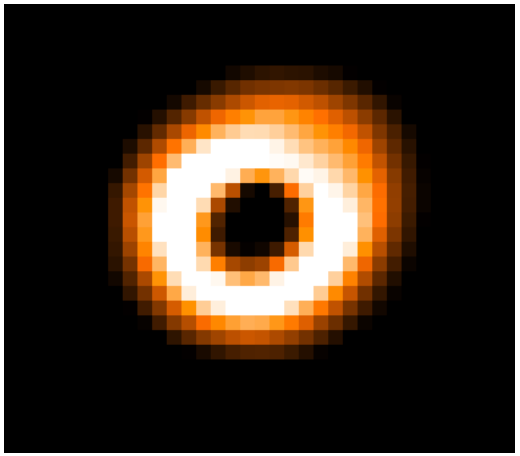


Bad centering

Fiber entrance Fiber exit

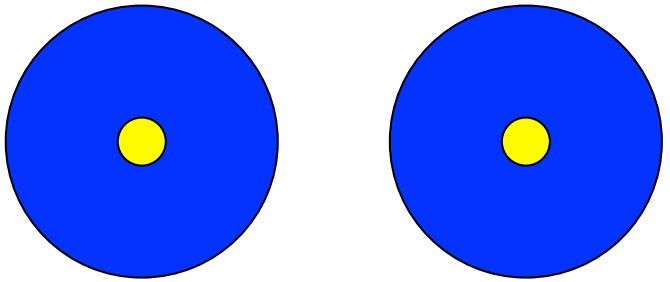


"Good" guiding, 0.1" RMS, ~30 cm/s contribution to RV

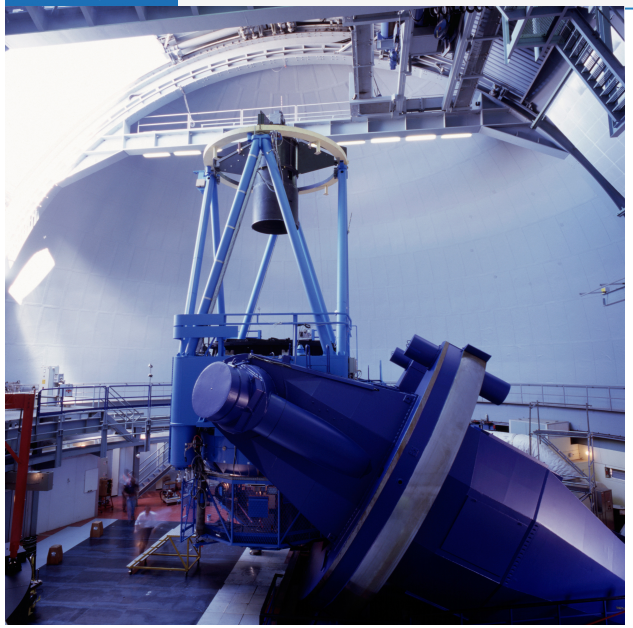


Good centering

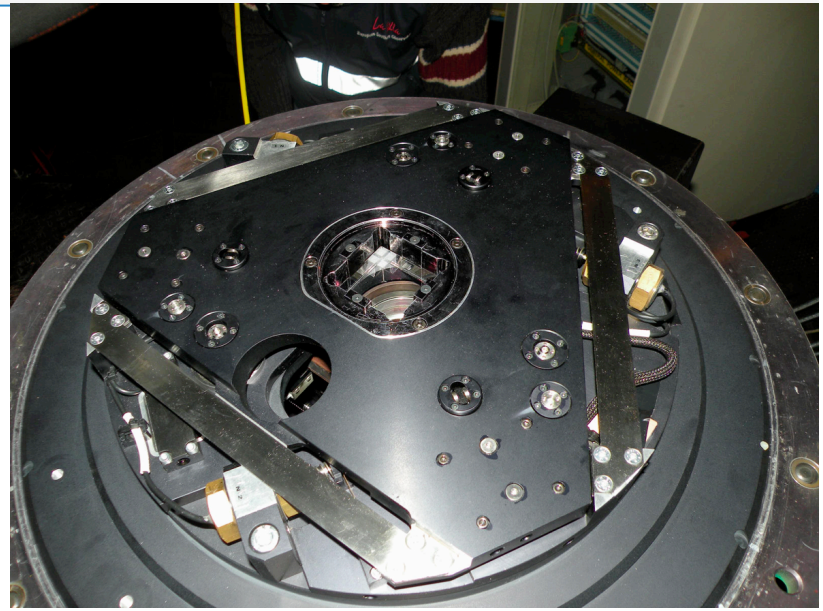
Fiber entrance Fiber exit



Guiding II



200 tons telescope



2 kg tip-tilt table

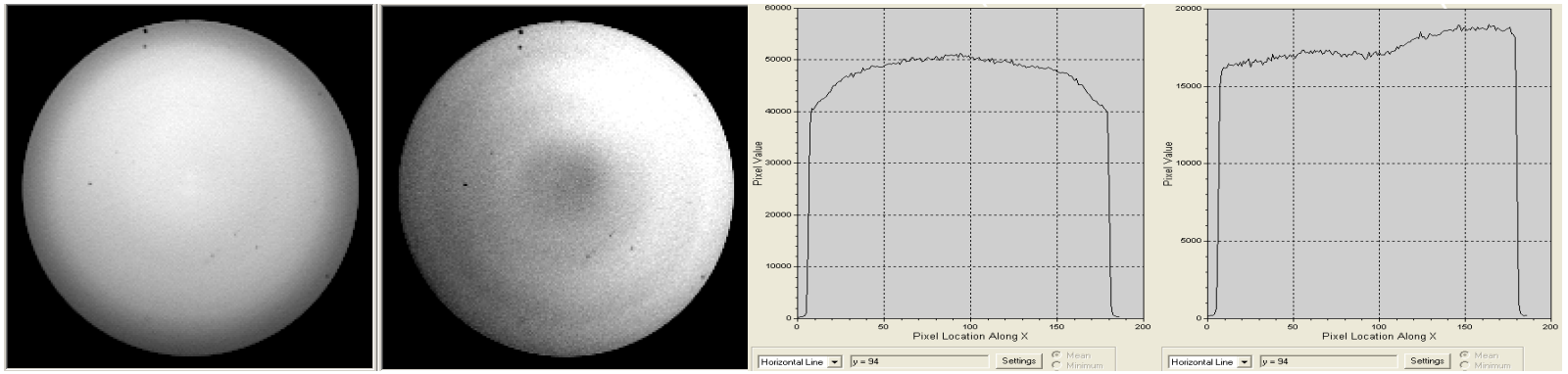
- Increase: guiding accuracy, speed
- Correct for “slow” (up to 10 Hz) perturbations
- RMS ~ 0.05”

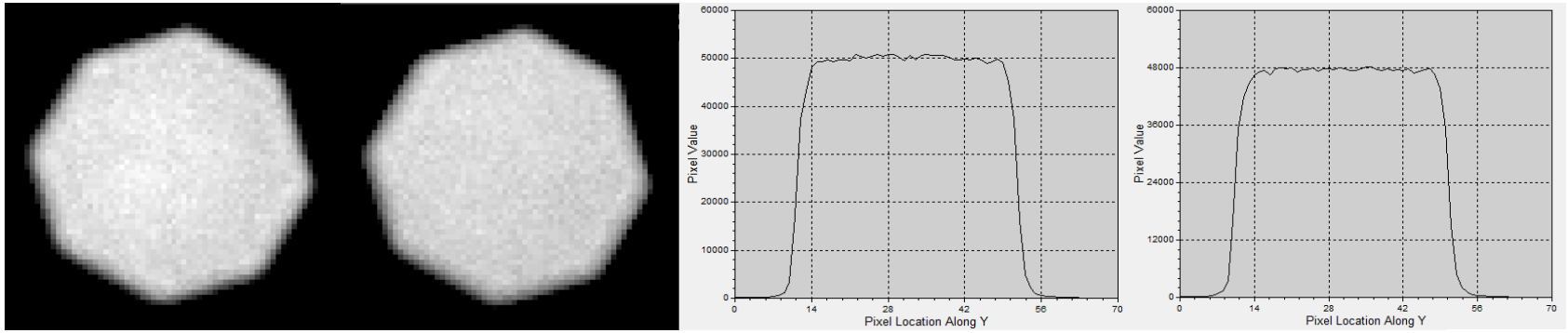
HD20794	e. m. mean	e. m. max	e. m. RMS	SNR	RV	RV Noise
TTT	293k | 28k	402k | 39k	52k | 7k	161 | 8	- | 54cm/s	51cm/s | -
AG	272k | 37k	397k | 47k	56k | 10k	154 | 11	- | 76cm/s	53cm/s | -

Octogonal fibers I

Excellent scrambling !

Near field:

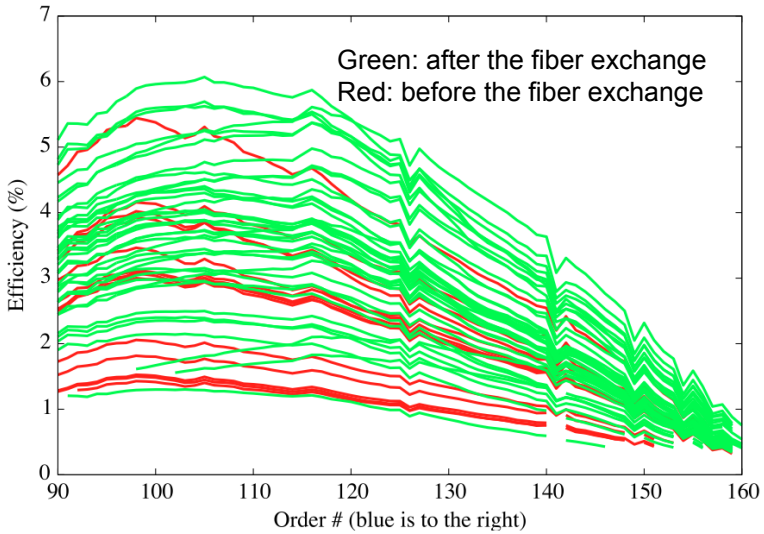


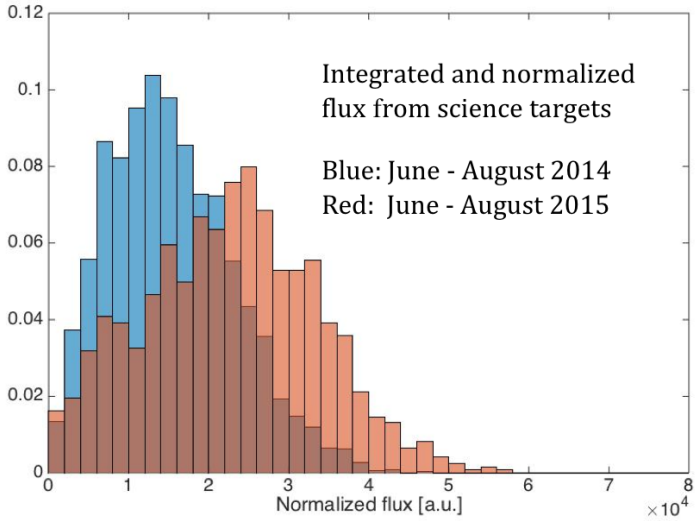


From G. Avila

Octogonal fibers II: installation on HARPS

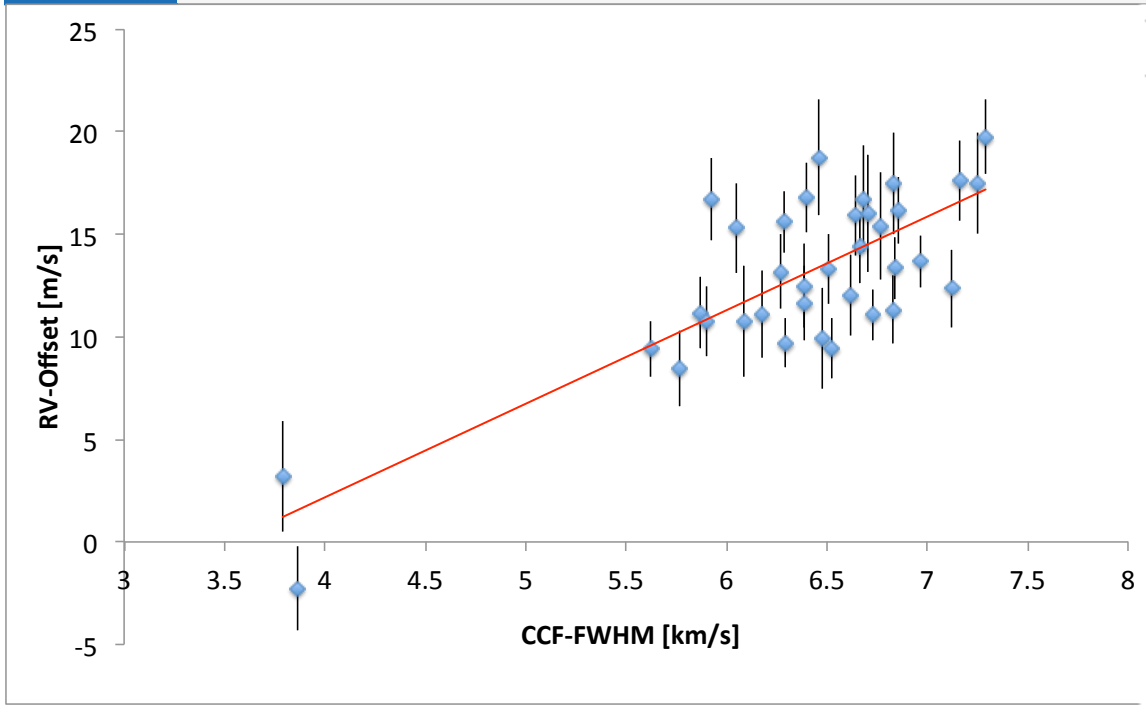
- **RV became insensistive to de-centering of the star in the fiber**
- **RV became insensistive to slight de-focussing of the telescope**
- Increased throughput by 30% - 40%





G. Lo Curto et al., ESO Messenger, 2015, 162, 9C

RV offset pre / post fiber exchange



Star name	Spectral type	RV-Offset [m/s]	Dispersion [m/s]	CCF-FWHM [km/s]
Gl701	M2.0V	3.219	2.713	3.790
Gl588	M2.5V	-2.281	2.042	3.866
HD104006	K0.5V	9.413	1.358	5.622
HD154577	K2.5V	8.444	1.821	5.767
HD144628	K1V	11.182	1.762	5.873
HD109200	K1V	10.776	1.714	5.903
HD26965A	K0.5V	16.732	2.017	5.927
HD55	K4.5V	15.297	2.178	6.049
HD142709	K5V	10.778	2.727	6.087
HD131653	G5	11.088	2.123	6.181
HD123265	G8	13.186	1.838	6.270
HD10700	G8.5V	15.619	1.509	6.287
HD165920	K1IV	9.696	1.201	6.293
HD147518	G4V	12.494	2.041	6.387
HD134088	G0V	11.637	1.802	6.388
HD20794	G8V	16.807	1.702	6.401
HD23249	K1III-IV	18.740	2.817	6.460
HD207869	G6V	9.934	2.459	6.477
HD199288	G2V	13.309	1.732	6.509
HD78747	G5V	9.423	1.462	6.528
HD124292	G8V	12.020	1.955	6.618
HD199604	G2V	15.916	1.946	6.643
HD210752	G0	14.371	1.745	6.665
HD38858	G2V	16.736	2.571	6.682
HD196892	F6V	16.023	2.855	6.704
HD97343	G8.5V	11.057	1.252	6.729
HD206998	G0	15.422	2.623	6.768
HD213628	G8V	11.337	1.655	6.829
HD177565	G6V	17.491	2.489	6.833
HD161612	G8V	13.361	1.531	6.839
HD210918	G2V	16.145	1.622	6.858
HD183658	G0	13.667	1.251	6.969
HD190248	G8IV	12.358	1.895	7.121
HD65907A	F9.5V	17.632	1.965	7.162
HD3823	G0V	17.488	2.449	7.252
HD1581	F9.5V	19.753	1.838	7.291

The fiber exchange of June 1st 2015 generated a RV offset dependent on the star.
Users with data sets spanning in time before and after the upgrade are advised to fit the offset from their data.

G. Lo Curto et al., ESO Messenger, 2015, 162, 9C

Laser Frequency Comb

- As many as possible, non-blended, equally spaced lines (line spacing tuned to the resolution of the spectrograph)
- Smooth intensity distribution across the spectrum
- Unresolved lines
- Extreme stability and accuracy (better than $2*10^{-11}$)