HARPS3

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Terra Hunting Experiment Consortium:

PI: D. Queloz

UNIVERSITY OF CAMBRIDGE

UNIVERSITY OF EXETER

OBSERVATOIRE DE GENÈVE FONDÉ EN 1772

QUEEN'S UNIVERSITY BELFAST

PRINCETON UNIVERSITY

INSTITUTO DE ASTROFISICA DE CANARIAS · IAC

UPPSALA UNIVERSITET

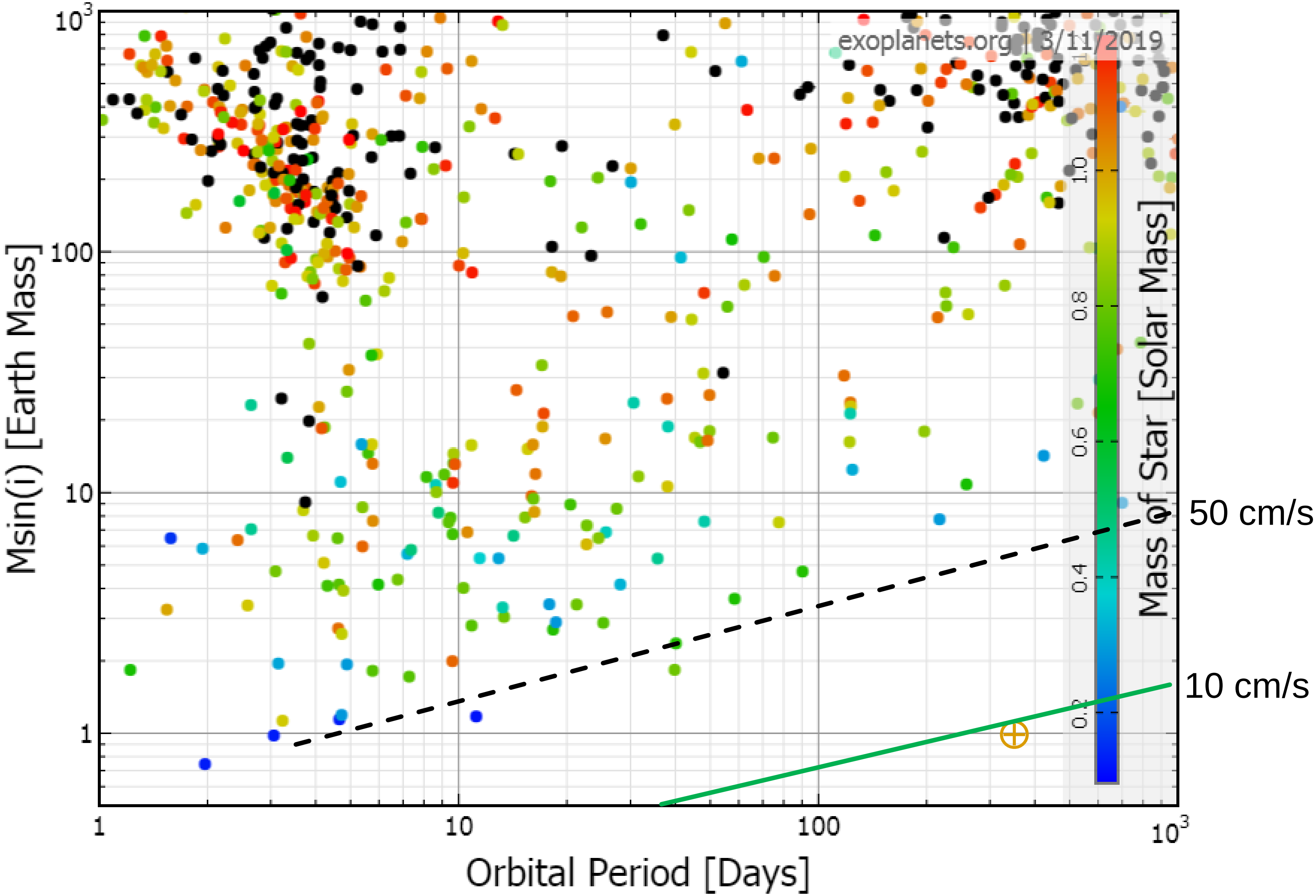
NOVA

UNIVERSITY OF OXFORD

FLATIRON INSTITUTE

www.terrahunting.org

WHY ARE WE BUILDING HARPS3?


exoplanets.org | 3/11/2019
Msin(i) [Earth Mass]
Orbital Period [Days]
Mass of Star [Solar Mass]
50 cm/s
10 cm/s
1
10
100
10^3
0.2
0.4
0.6
0.8
1.0

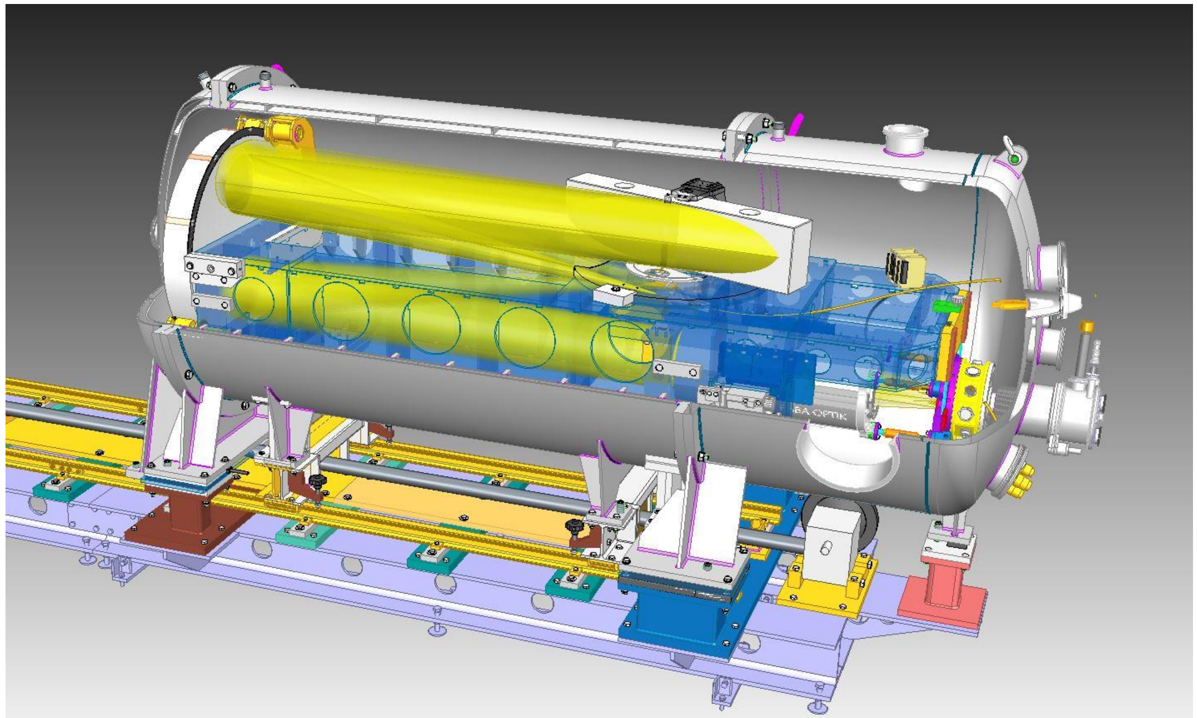
TERRA HUNTING EXPERIMENT

- 10 year programme to find the RV signal of an "Earth-twin"
  - (and also be filling in the long-period planets discovery space as a byproduct)
- Sample of bright solar-like stars (Vmag < 8.5)
- Optimised, intensive observing strategy – robotic scheduling and operations
  - Targets observed *every night*
  - + Spectro-polarimetric measurements (cadence TBD)
  - Allows better tracking of stellar activity signals
  - Repeated over many years → capture many repeats of planetary Doppler signal
  - …. 1000+ measurements per star

BRIEF OVERVIEW OF HARPS3

- Close-copy of HARPS/HARPS-N
  - Demonstrated RV accuracy ~ 50 cm/s
- Stable, fibre-fed, high resolution spectrograph
  - R = 115,000
  - λ range 380 – 690 nm

ROBOTIC!

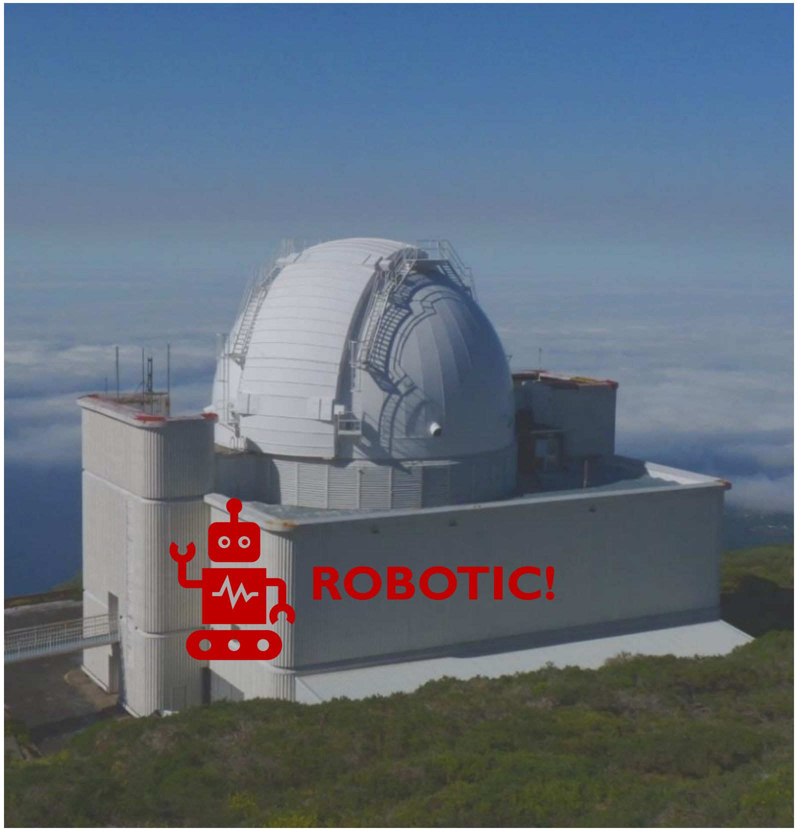


HARPS-N. Picture courtesy of Observatoire de l'Université de Genève

HARPS3 for a Roboticized Isaac Newton Telescope, *Samantha J. Thompson, Didier Queloz, Isabelle Baraffe, Martyn Brake, Andrey Dolgopolov, Martin Fisher, Michel Fleury, Joost Geelhoed and 20 co-authors*, **Proc. SPIE vol. 9908 (2016).**

WHERE WILL IT BE INSTALLED?

- The 2.5m Isaac Newton Telescope (INT) in La Palma, Canary Islands
  - Equatorial mounting
  - Fibre at Cassegrain focus (1.4” on-sky)
  - Photon noise of 40cm/s for 8th mag G-dwarf, av. seeing, 20min exp.
  - Dedicated Coudé rooms
    - Shorter fibre, improved blue efficiency
  - Refurb to enable robotic operations
  - Nightly access for 10 years (~50% time per night on average)



INT current info: http://www.ing.iac.es/Astronomy/telescopes/int/

FEATURES OF HARPS3

- Full-Stokes, dual-beam polarimeter (integrated in the design of the Cass fibre adapter)
- Octagonal fibres + double scrambler + guiding accuracy of 0.05" RMS (goal) over an exposure
- Echelle grating substrate: Zerodur Class 0 SPECIAL, CTE = 0 ± 0.010 · 10^{-6}/K
- Calibration Unit – 8 switchable light sources
- Detector Unit:
  - e2V chip: CCD231-84-0-G57
  - A new design continuous-flow cryostat
  - Enhanced CCD calibration
- Nightly access for THE → improved time sampled RV data series
- Robotic operation

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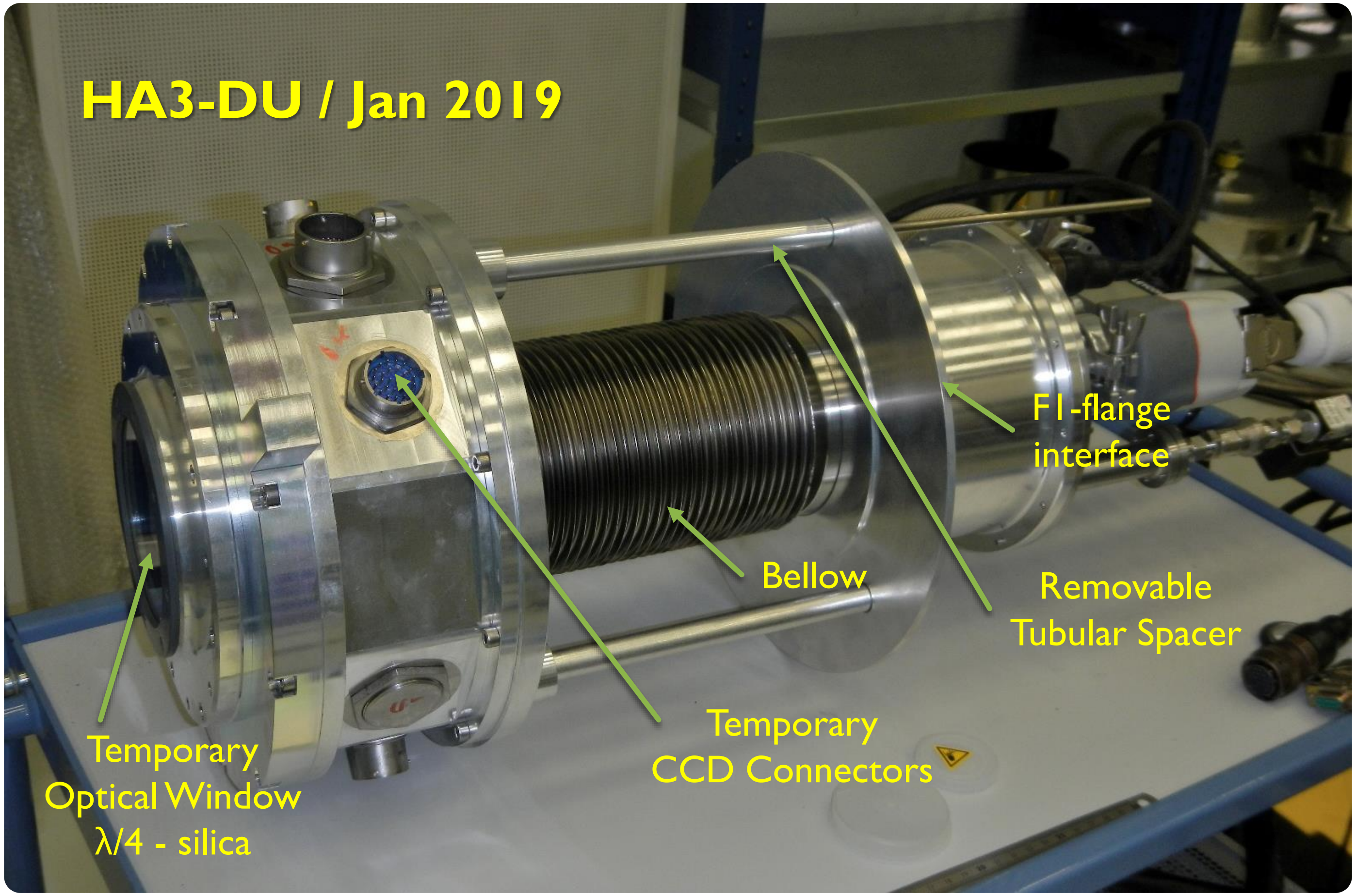

- ~1 mK rms stability … verification tests this summer
- Vacuum pressure inside detector unit ~2x10^{-6} mbar

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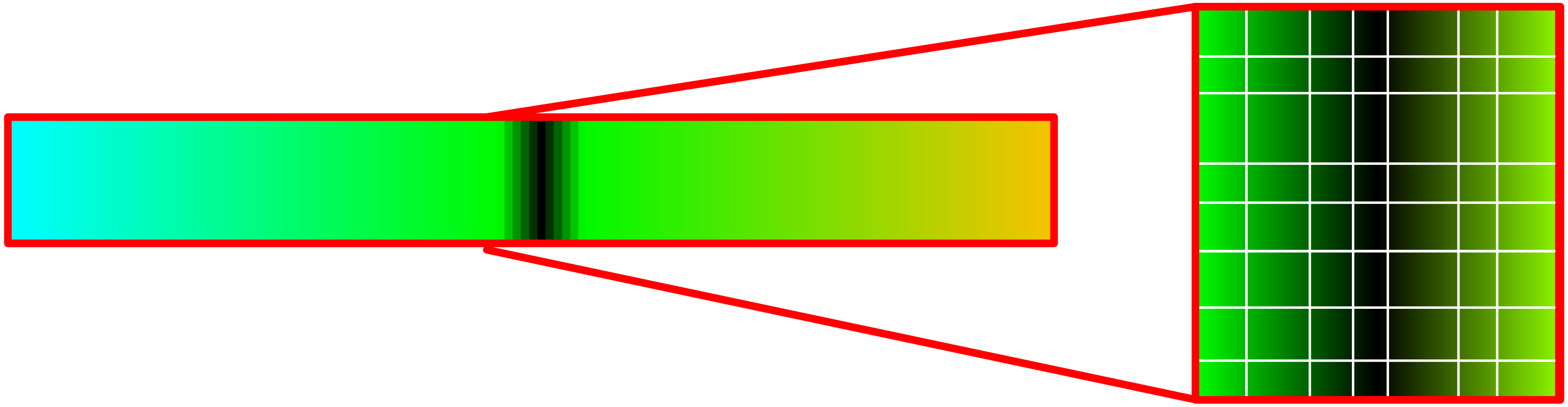
CCD CHARACTERISATION

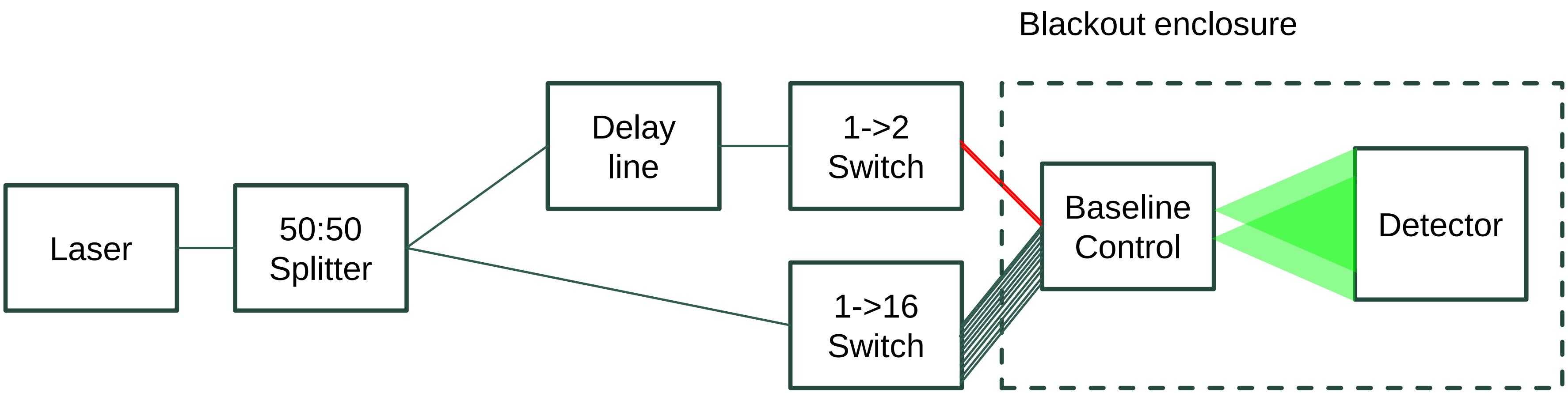
Motivation:

- Assuming a perfect CCD geometry introduces error to wavelength solution
- FWHM of spectral line ~ 3 px, 0.1 m/s ≈ 1/1000 px
- ➢ Map the effective pixel positions to this accuracy or better (goal 1e-4 px)



Picture credit: R. Hall

Schematic of CCD measurement



532nm Diode
40mW

380-700nm

Fiber
Stretcher

Chose
any pair

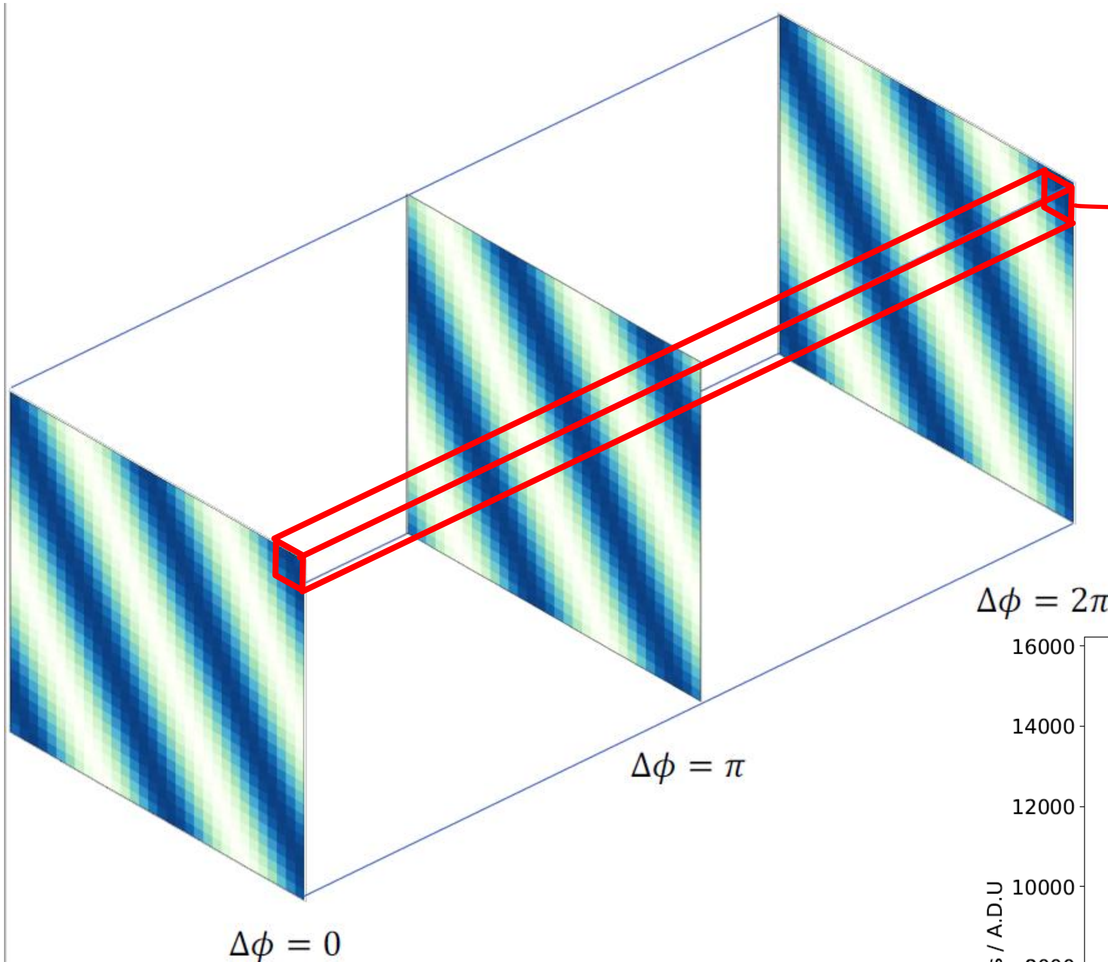
Machined block
with precise
grooves for fibers

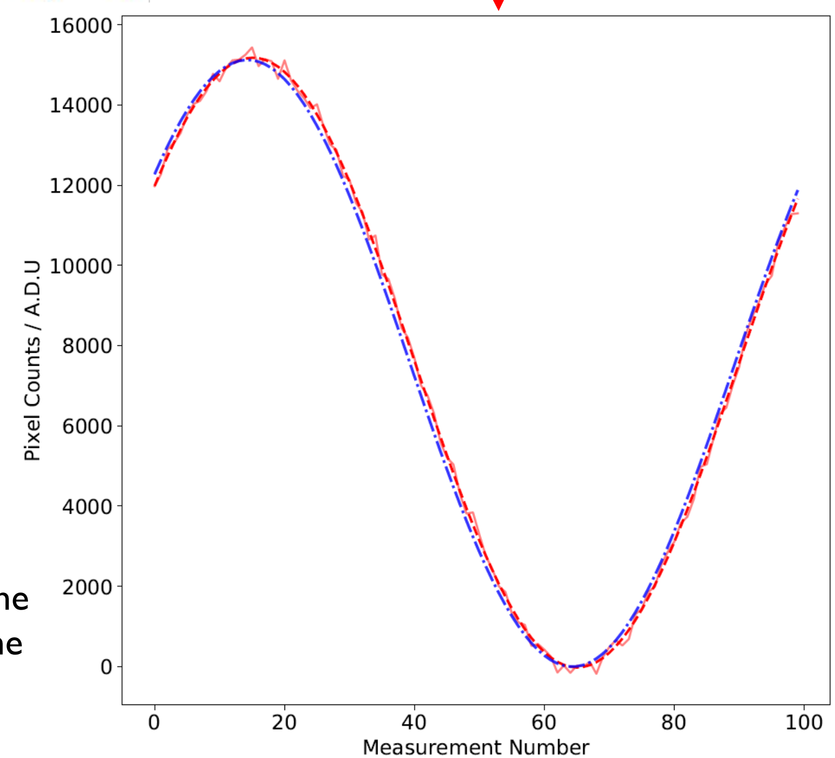
2K detector,
room temp

Measuring the effective pixel positions for the HARPS3 CCD, *Richard Hall et al.*, **SPIE 2016, new paper in prep – 2019**

Method based on previous works by Shaklan+ 1995, Crouzier+ 2012

Slide credit: R. Hall





A schematic of the phase-swept data-cube. A column of the data from a single pixel yields a sine-wave which contains pixel displacement information.

The phase difference between the dashed lines is due to the component of the pixel displacement in the direction of the wavevector.

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SAMPLING STRATEGIES

On the Feasibility of Intense Radial Velocity Surveys for Earth-twin Discoveries, *RD Hall, SJ Thompson, W Handley, D Queloz,* **Monthly Notices of the Royal Astronomical Society 479 (3), 2968-2987 (2018).**

Simulated data series:

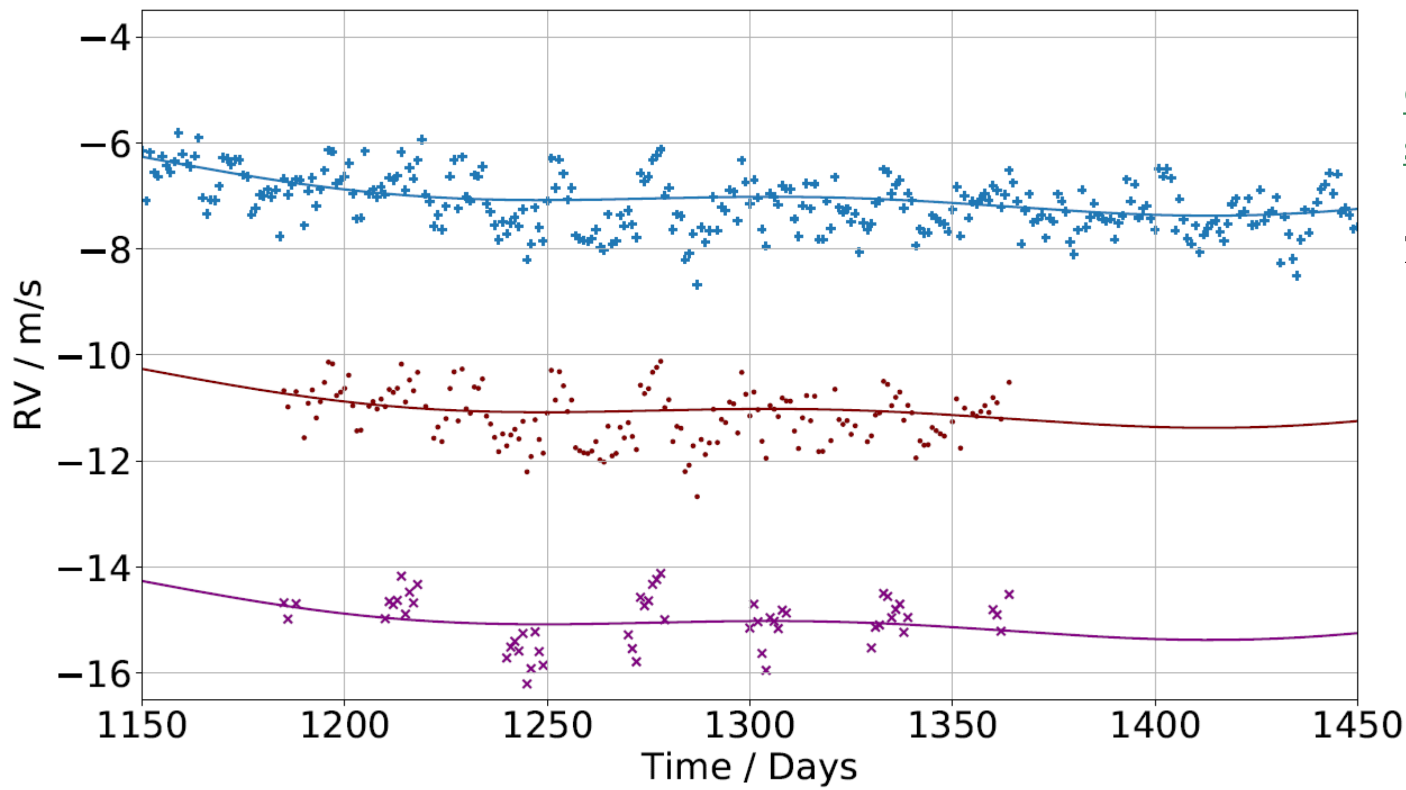
- Used SOAP 2.0 for stellar "noise" signal (Dumusque et al. ApJ, Vol. 796, 2 (2014))
- Assumed a low activity G8 star (0.8 $M_{\odot}$)
- Included photon noise at the 1σ = 30 cm/s level

Simulated observing schedules for THE:

- 180 day obs window in 1 year
- 20% bad weather outages (summer weather pattern)
- Total duration: 5 years and 10 years

Analysis:

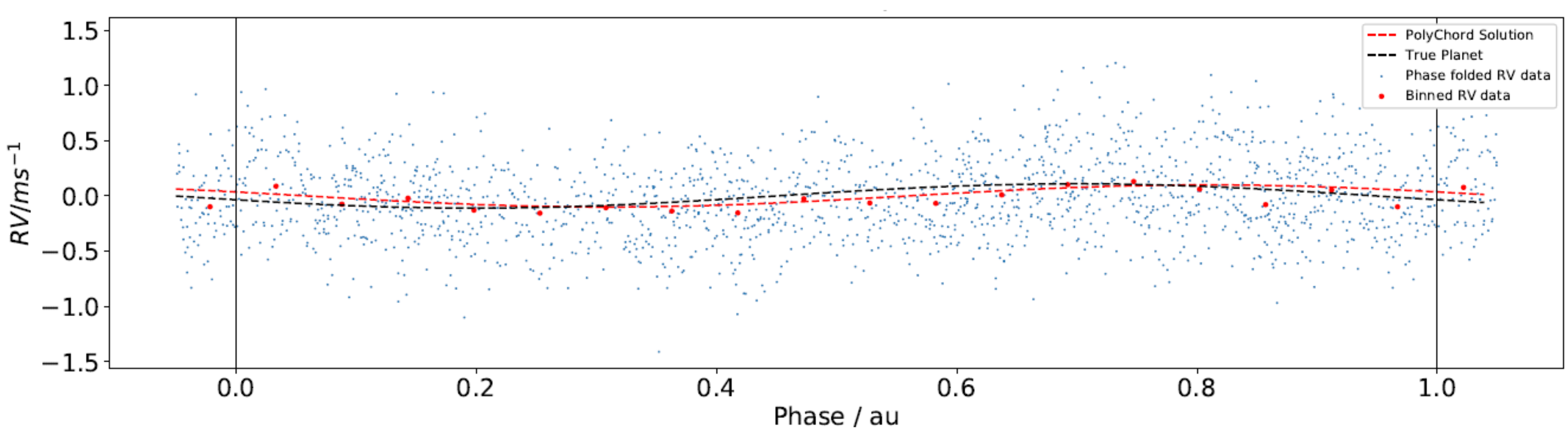
- Assumed a stellar noise "correction factor" of 4 (original stellar noise ~ 1.5 m/s)
- Used a Bayesian nested sampling approach: PolyChord – Handley et al. MNRAS, Vol. 453, 4 (2015)



Compares 3 sampling schedules:

1. "Space"
2. HARPS3 THE schedule (every available night)
3. "Classic TAC"

THE schedule compares favourably with Space schedule



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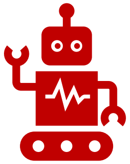
ROBOTIC OPERATION



- Design in all functionality needed for a fully robotic operation
- Dispatch scheduler (automated, optimised observations)
  - Science and calibration data collection

Quality control tools:

- Extensive engineering database (recording time series data from all the environment sensors, system faults/alerts etc…)
- Alerts can be generated from:
  - DRS-processed data and Engineering data
  - Any monitored variables (and combinations)
  - Event triggered
- FITS files will be assembled from a raw detector frame and ancillary data/metadata provided by the robotic control system:
  - Usual science metadata
  - Engineering metadata to include exp meter time series and acquisition and integrated guide images

CURRENT STATUS

- **2019**
  - HARPS3 is now fully funded – full steam ahead!
  - Final design reviews for Cass fibre adapter unit, telescope upgrade plans, software systems
  - Delivery of Grade0 CCD
  - Assembly and testing of new continuous flow cryostat
  - Delivery of Echelle grating
- **2020**
  - Refurbishment of INT's large Coudé room
  - INT roboticization works begin
- **2021**
  - Assembly, integration and testing in labs (all sub-systems)
  - HARPS3 1st light on INT

SUMMARY

- HARPS3 will be commissioned on the Isaac Newton Telescope during 2021
- HARPS3 + POL on the INT will offer a unique capability
  - Robotic mode of operation + automated scheduler ➔ **facilitates optimum sampling strategies**
  - **Every night** has time dedicated to THE **and open-time programmes**
- Terra Hunting Experiment
  - Sampling - regular **and** long time-series RV data (up to 1500 points over 10 years) to help disambiguate stellar activity and planetary Doppler signals
  - Geared to find Earth-mass planets in the unexplored low-mass/long-period region of 100-300 days