How RV will... (win)

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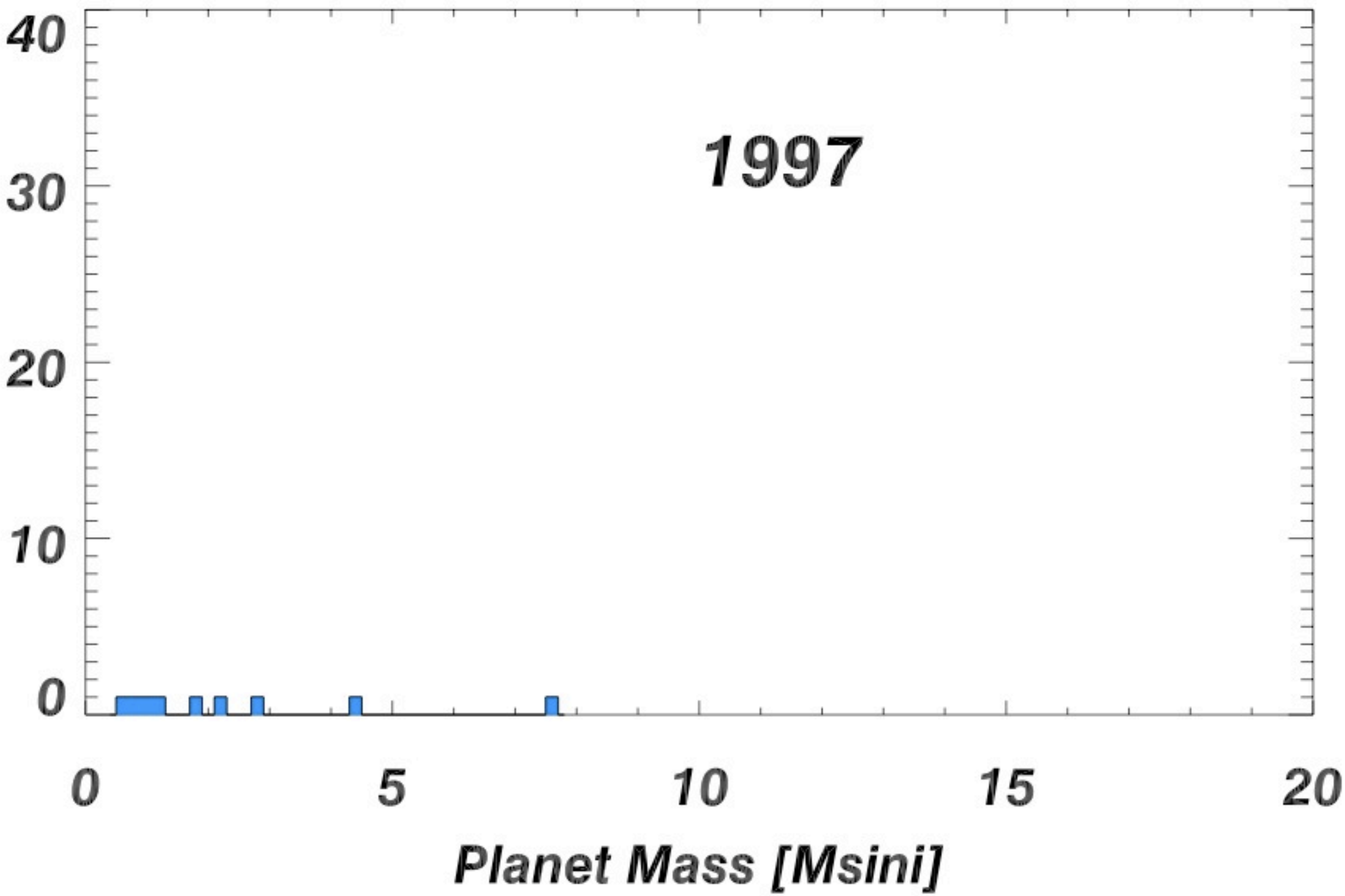
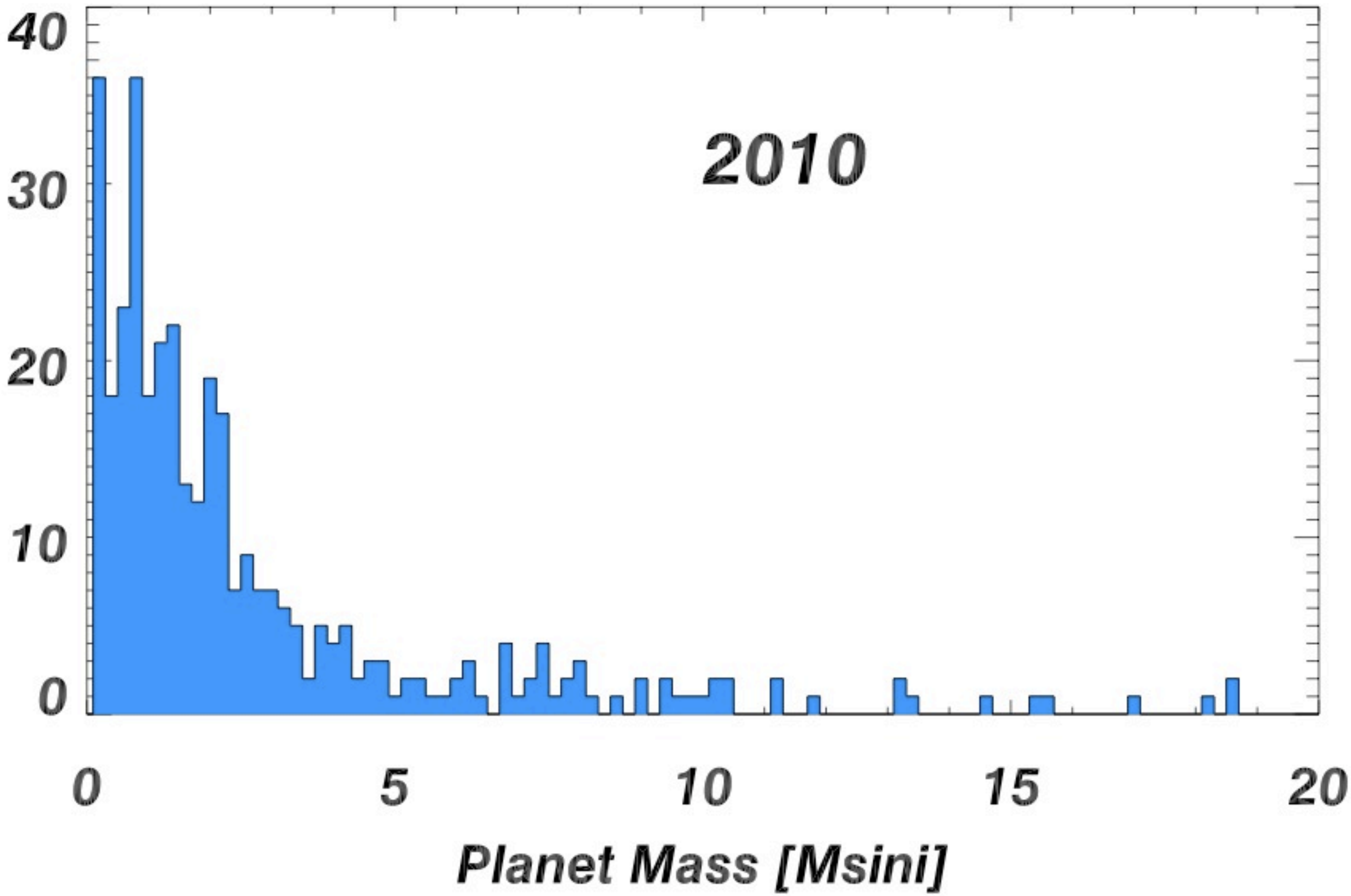
In 2000, we considered the possibility that the RV technique might be productive for a decade until all of the planets detectable with that precision had been found.

That would have been true, but with hard work, the community has managed to push Doppler precision from 3 m/s to 1 m/s, extending the life of the project.

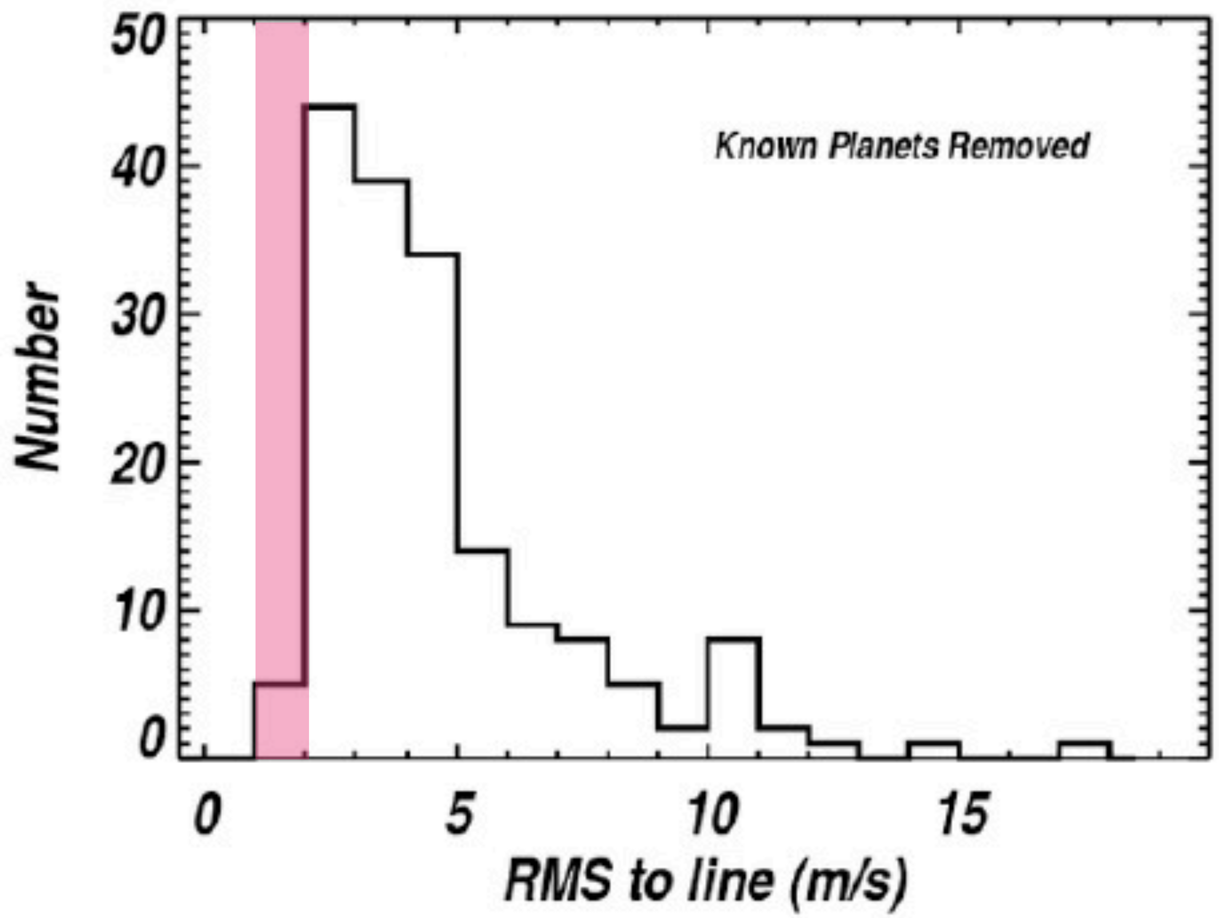
Detection of Exoplanets since 1995



Detection of Exoplanets since 1995



Keck/HIRES



Eta-Earth Survey stars
GKM
Chromospherically quiet
~10-100 observations each

HARPS

M Mayor and S Udry

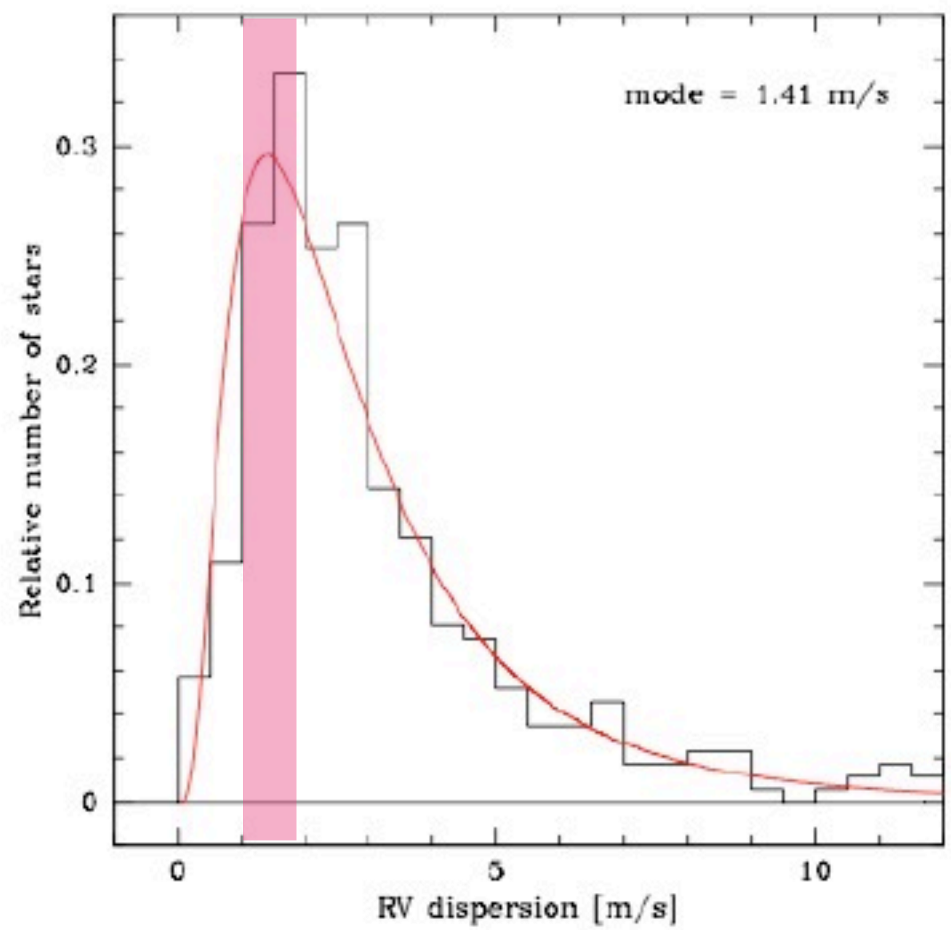
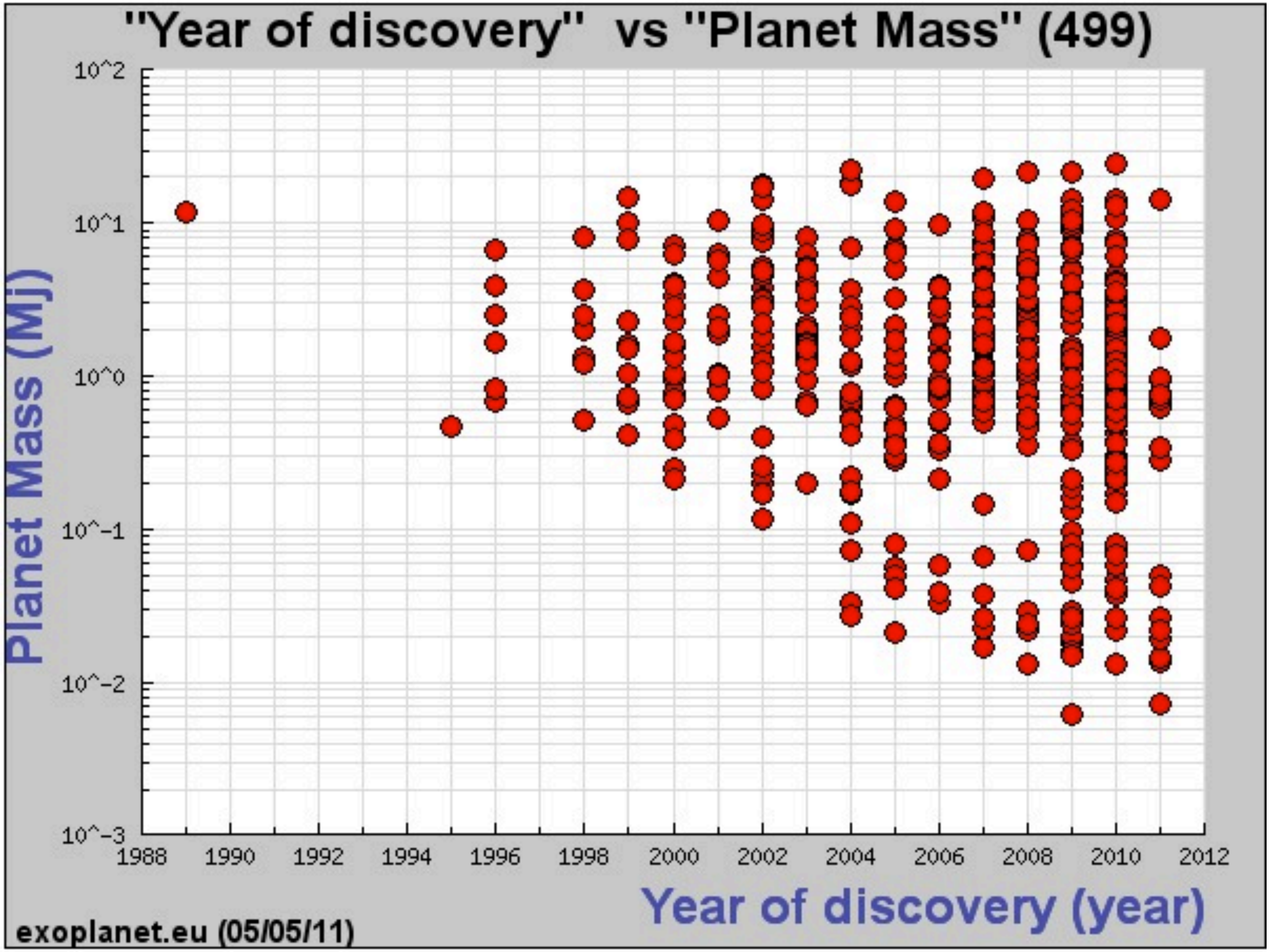


Figure 2. Histogram of radial-velocity rms for the stars in the high-precision HARPS subprogramme aiming at detecting very low-mass planets. Part of the 'large' rms observed in the tail of the distribution results from stellar activity or from still undetected planetary systems.

Mayor and Udry, 2008,
Phys. Scr. T130, 014010

Plot credit: Andrew Howard

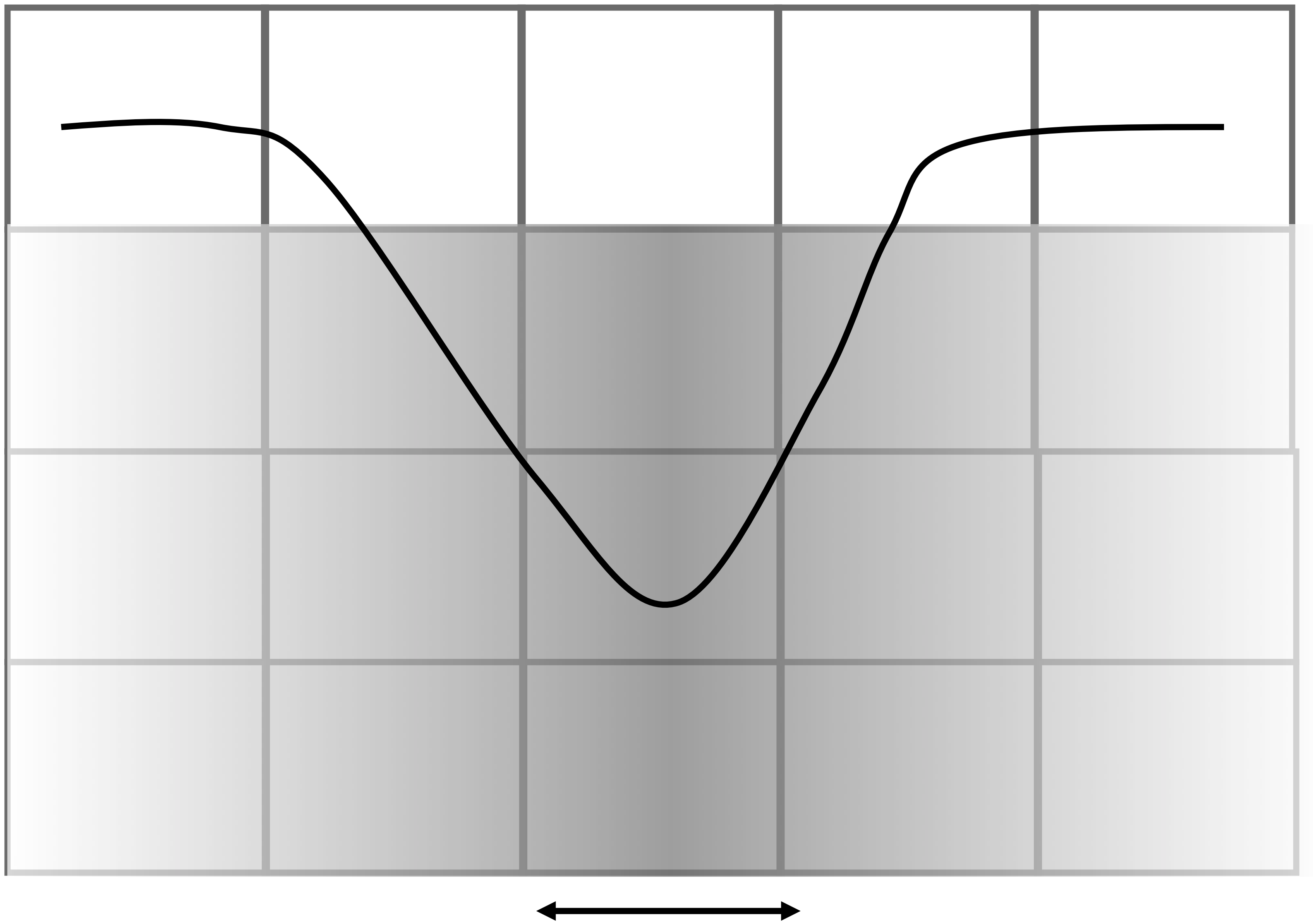


A simple extrapolation to predict the discovery of a large number of Earth-mass planets does not account for the need for higher precision.

Obstacles to higher precision:

1. Instrumental stability
2. Analysis errors, SNR
4. Astrophysical noise

Instrumental stability



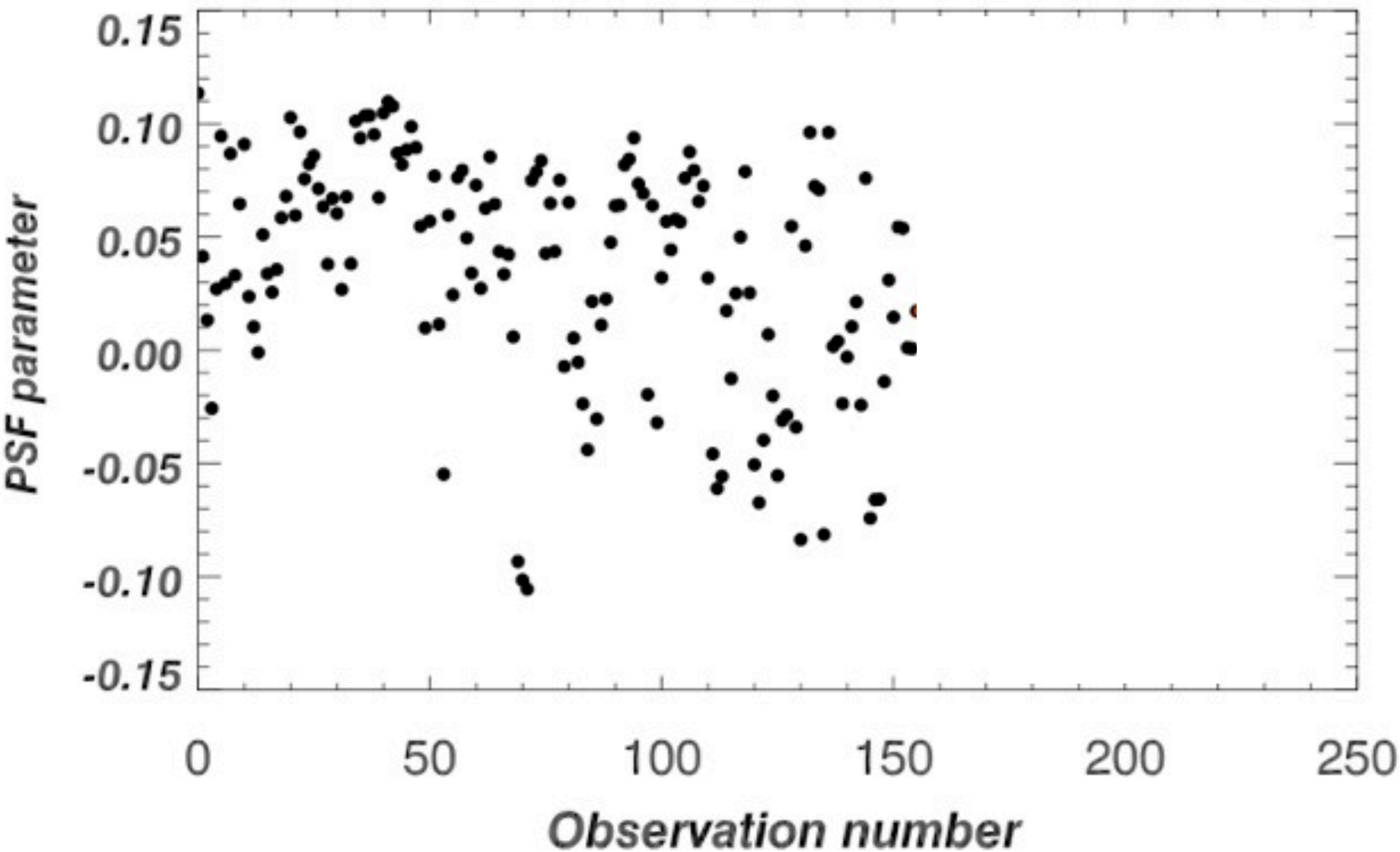
One pixel: Physical dimension of ~15 μ

1 m s^{-1} precision = 1/2000th (~100 Si atoms in a crystal lattice)

10 cm s^{-1} precision = 1/20000th (~10 Si atoms in a crystal)

Requirement: extreme stability (optics, pressure, temperature)

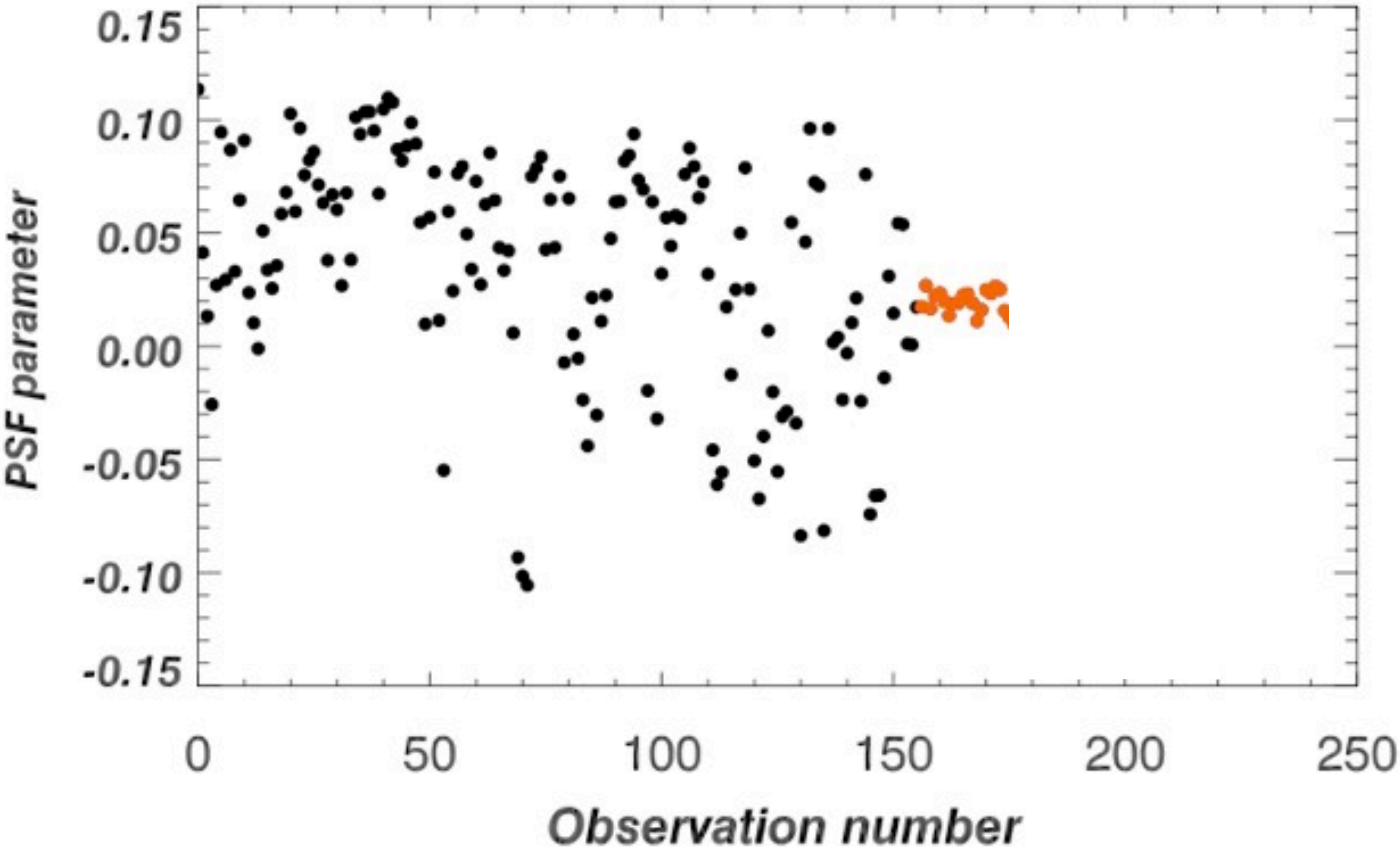
Instrumental stability



Illumination of spectrograph optics
must be unchanging

Spronck & Fischer 2010

Instrumental stability



Illumination of spectrograph optics
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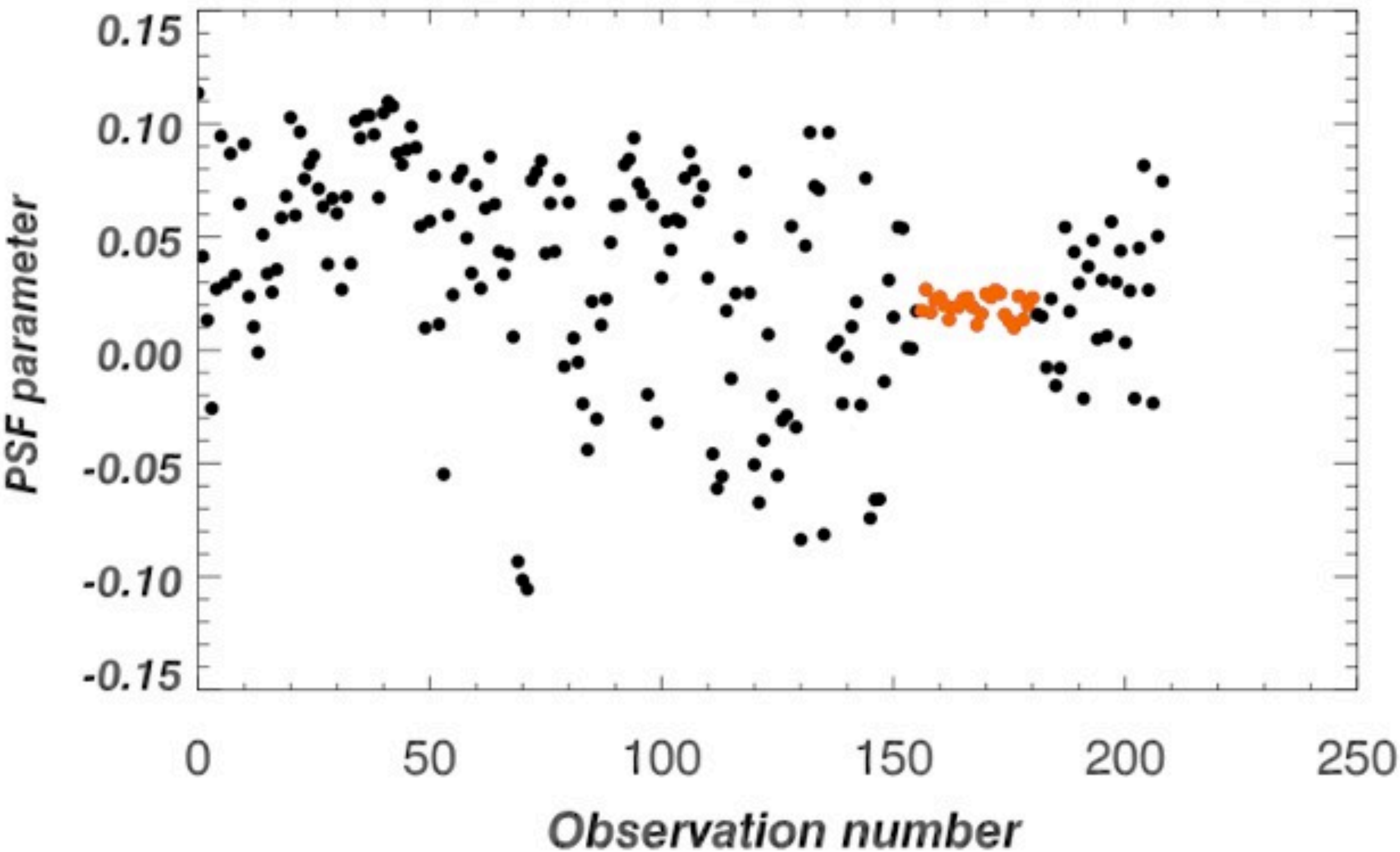
Spronck & Fischer 2010

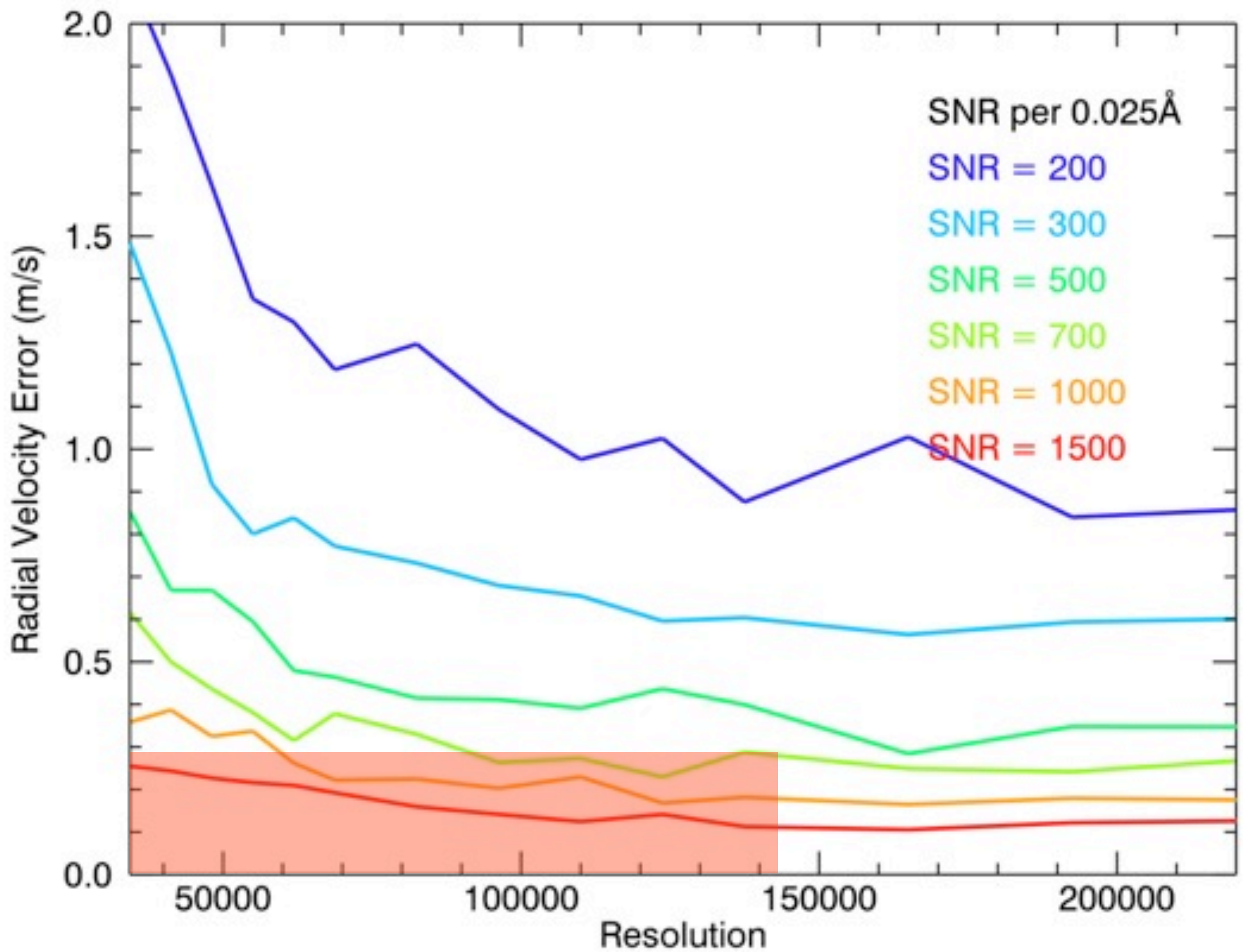
Instrumental stability



Illumination of spectrograph optics
must be unchanging

Spronck & Fischer 2010

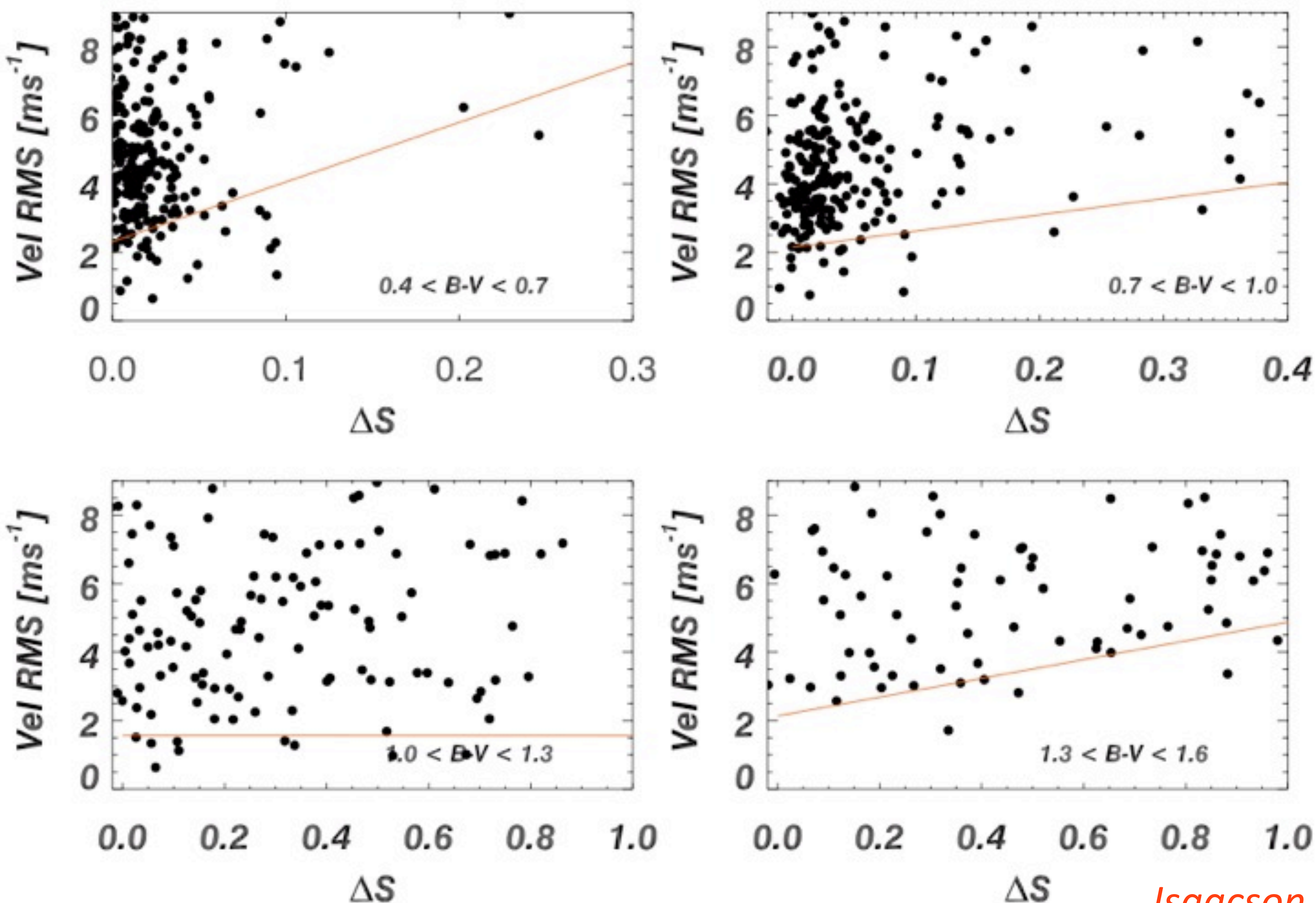
Analysis Errors and SNR



Plot credit: Jack Moriarty

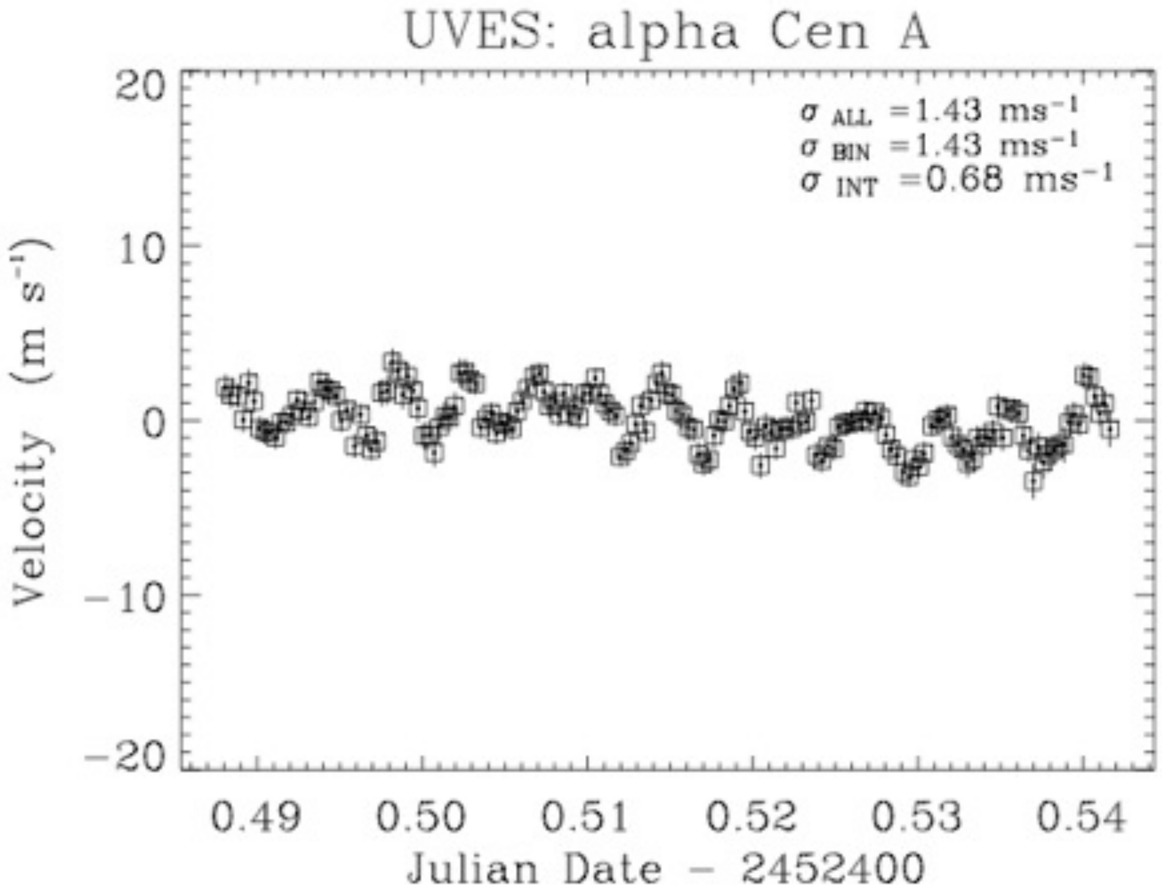
- Additional errors (e.g., PSF model) decrease precision
- Simulation code is an important component for understanding robustness of Doppler code.

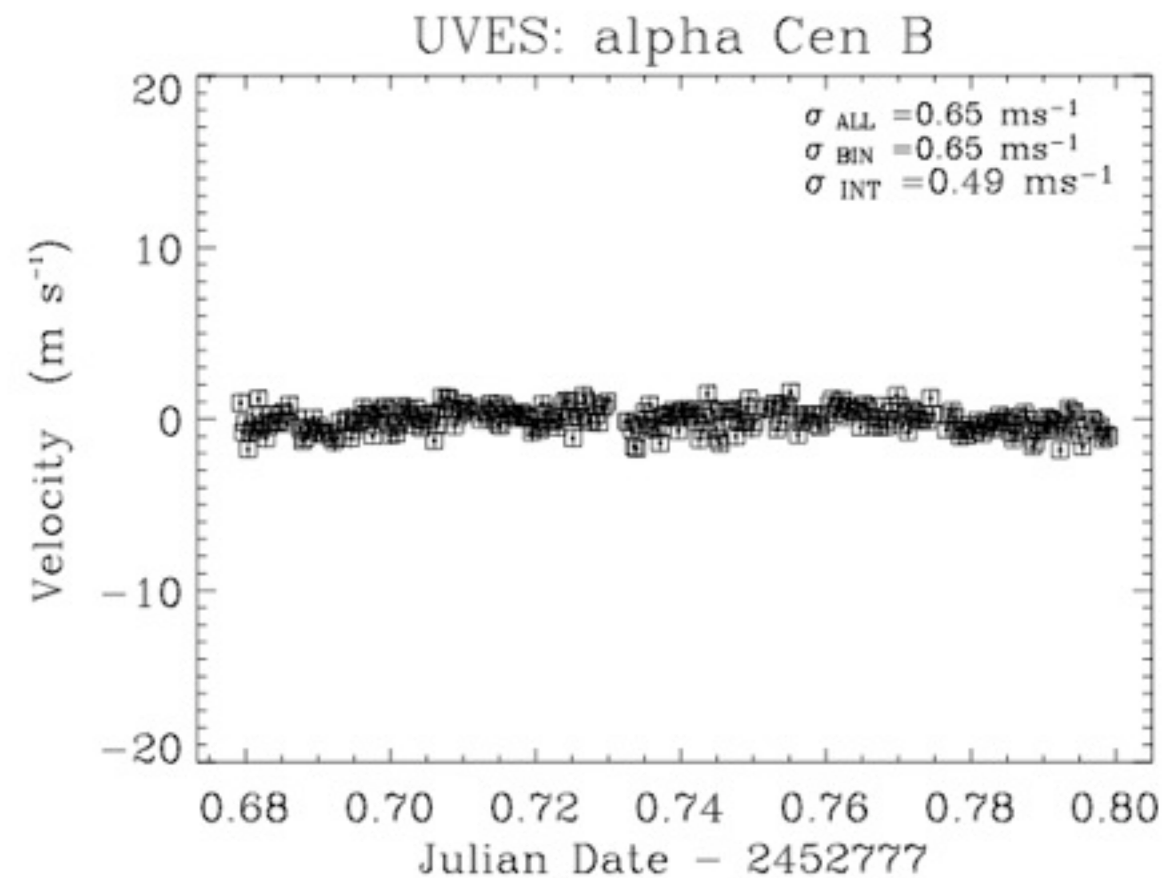
Astrophysical noise



Isaacson & Fischer 2010

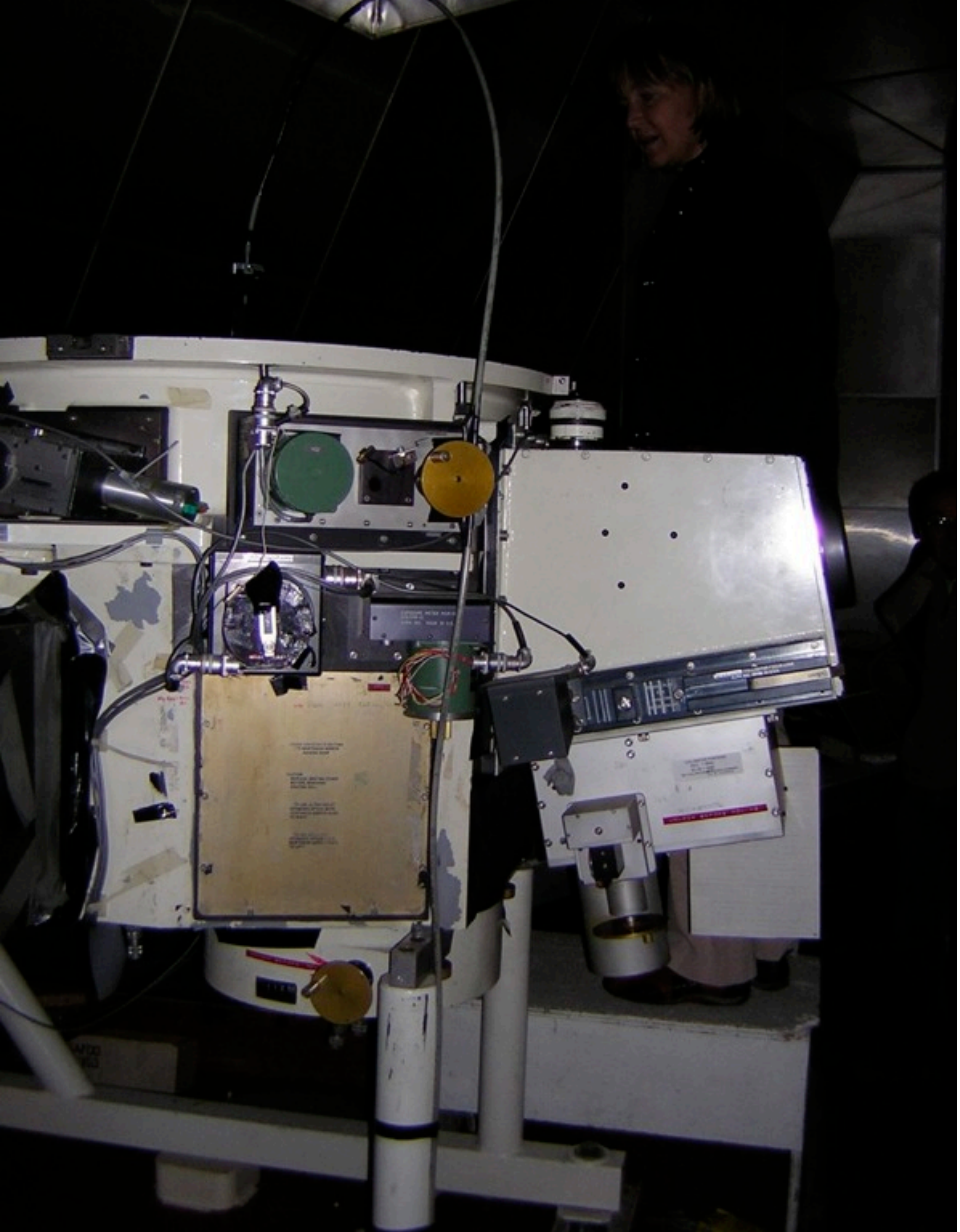
The minimum RMS sets a "floor" in activity (intrinsic to star?) and includes instrumental and analysis errors. Low activity stars have less jitter.





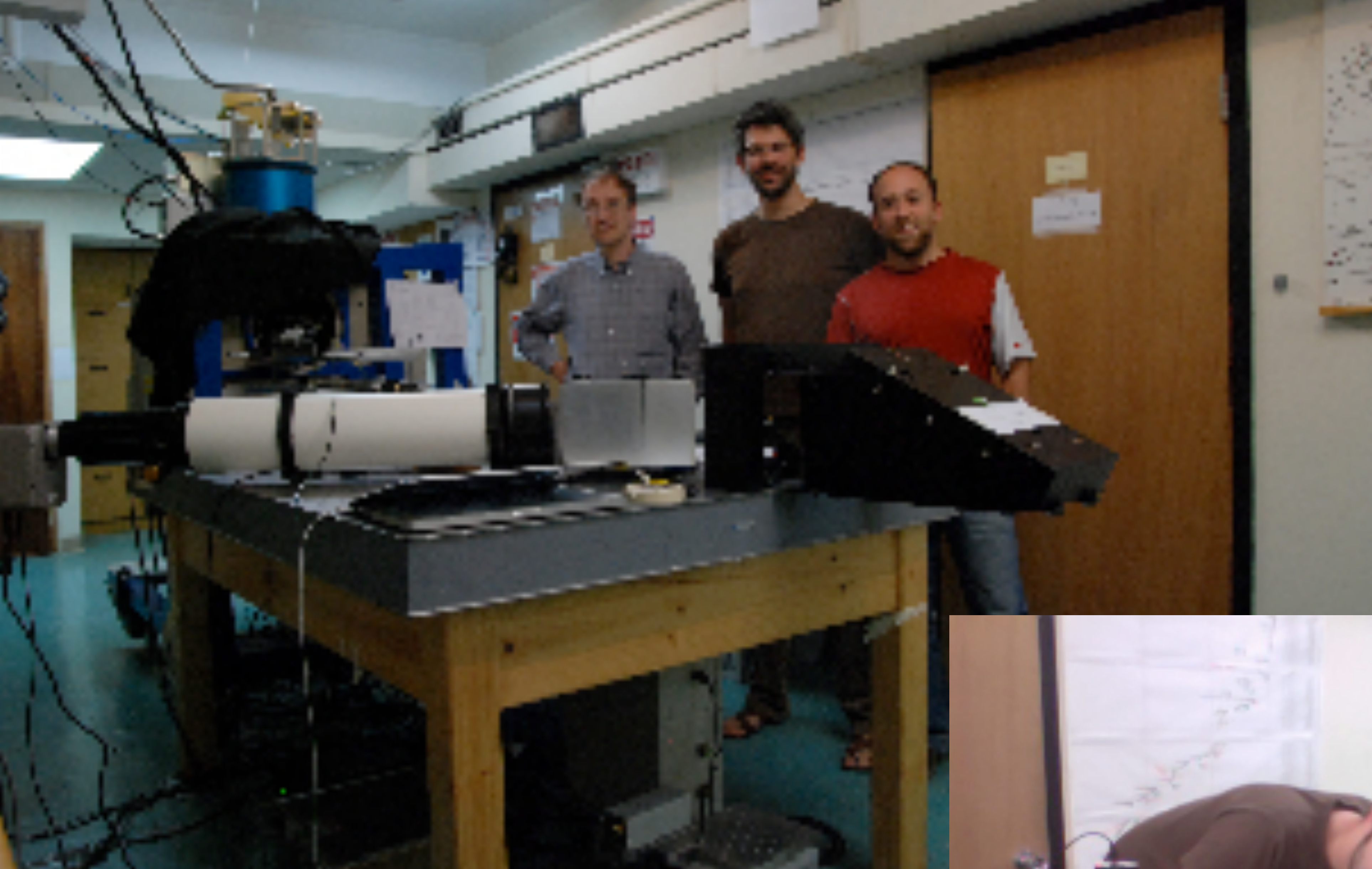
We can can beat down non-white high frequency noise, like p-mode oscillations.

The Europeans are aiming for instrumental precision of 10 cm s^{-1} (Espresso @ VLT) and 1cm s^{-1} (CODEX @ GSMT).

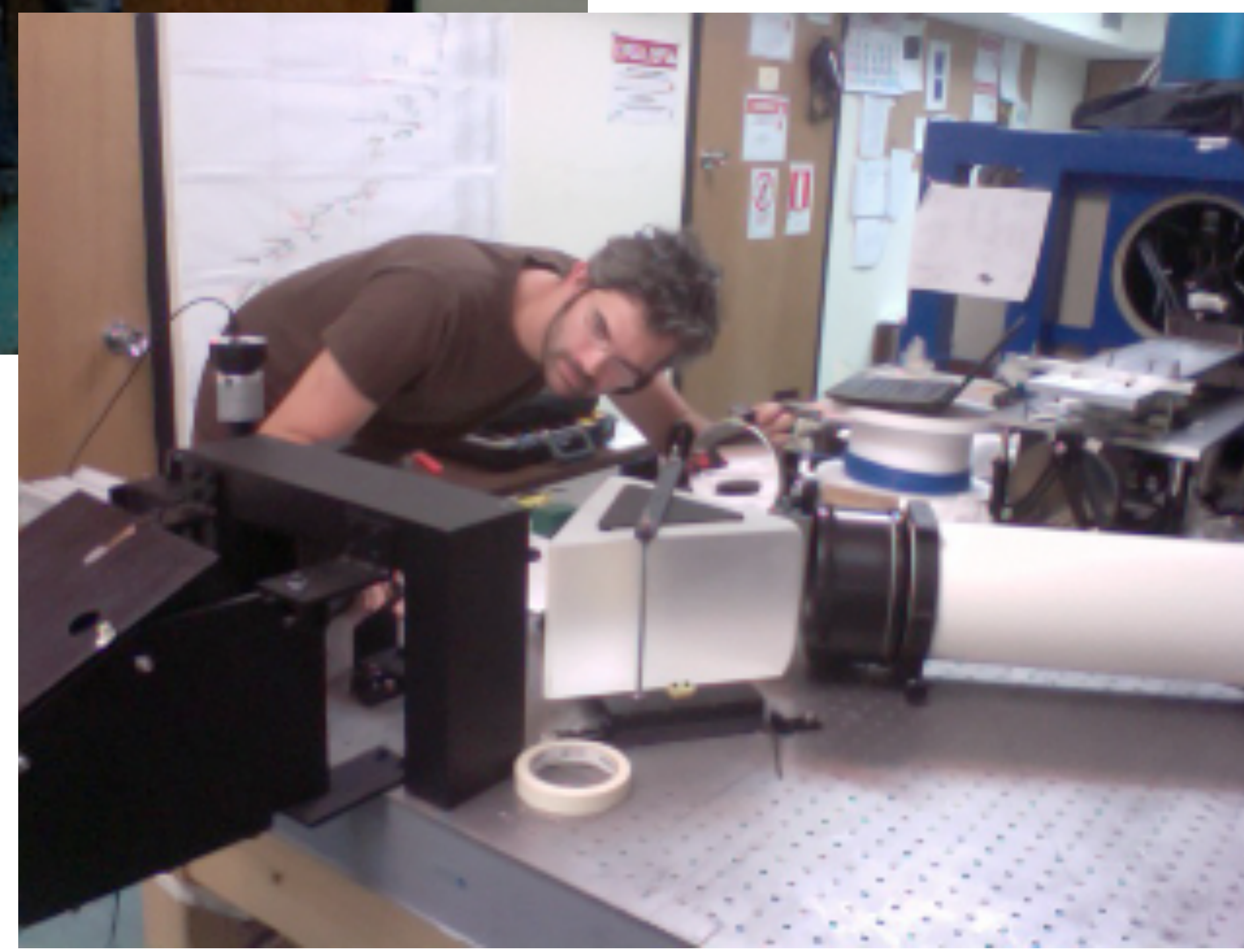


Started a project in 2008 to better understand the floor in Doppler precision: search for low mass planets around alpha Centauri A and B.

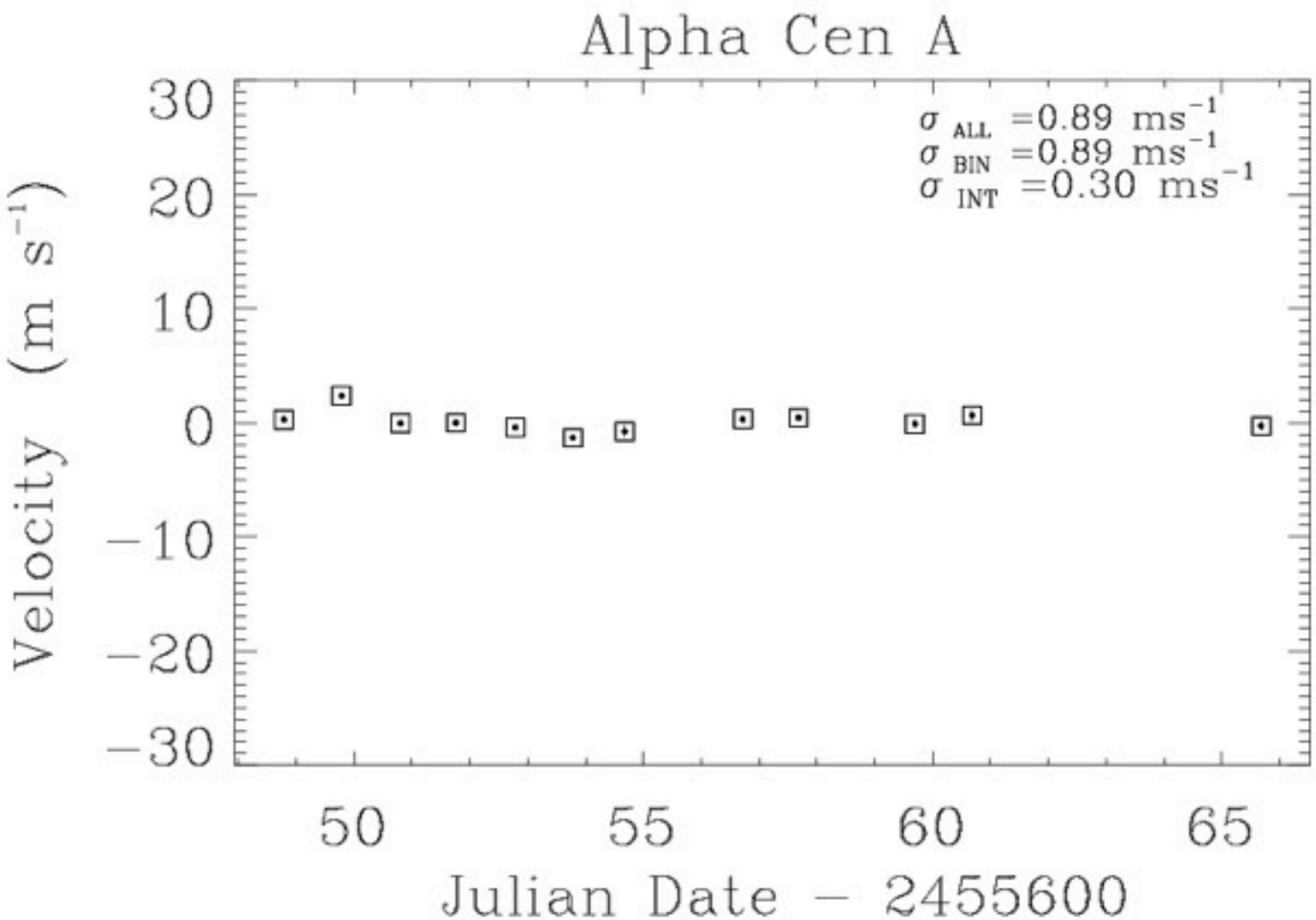
(instrumental stability issues)



NSF MRI funding to replace the CTIO Echelle with CHIRON (R: 90,000 - 120,000)



Tokovinin, Schwab, Spronck, Fischer 2010



First 2 weeks of data after commissioning in April 2011.

Yale Doppler Diagnostic Facility.

- Bench-mounted R=80,000 spectrograph to test impact of design choices on RV precision (then move to CHIRON at CTIO).
- Extensive testing of fiber coupling and scrambling.
- Looking for outstanding postdocs who want to work on innovative designs to break through to higher precision.

Summary:
Cost
Technical Readiness
Ground-based vs Space-based