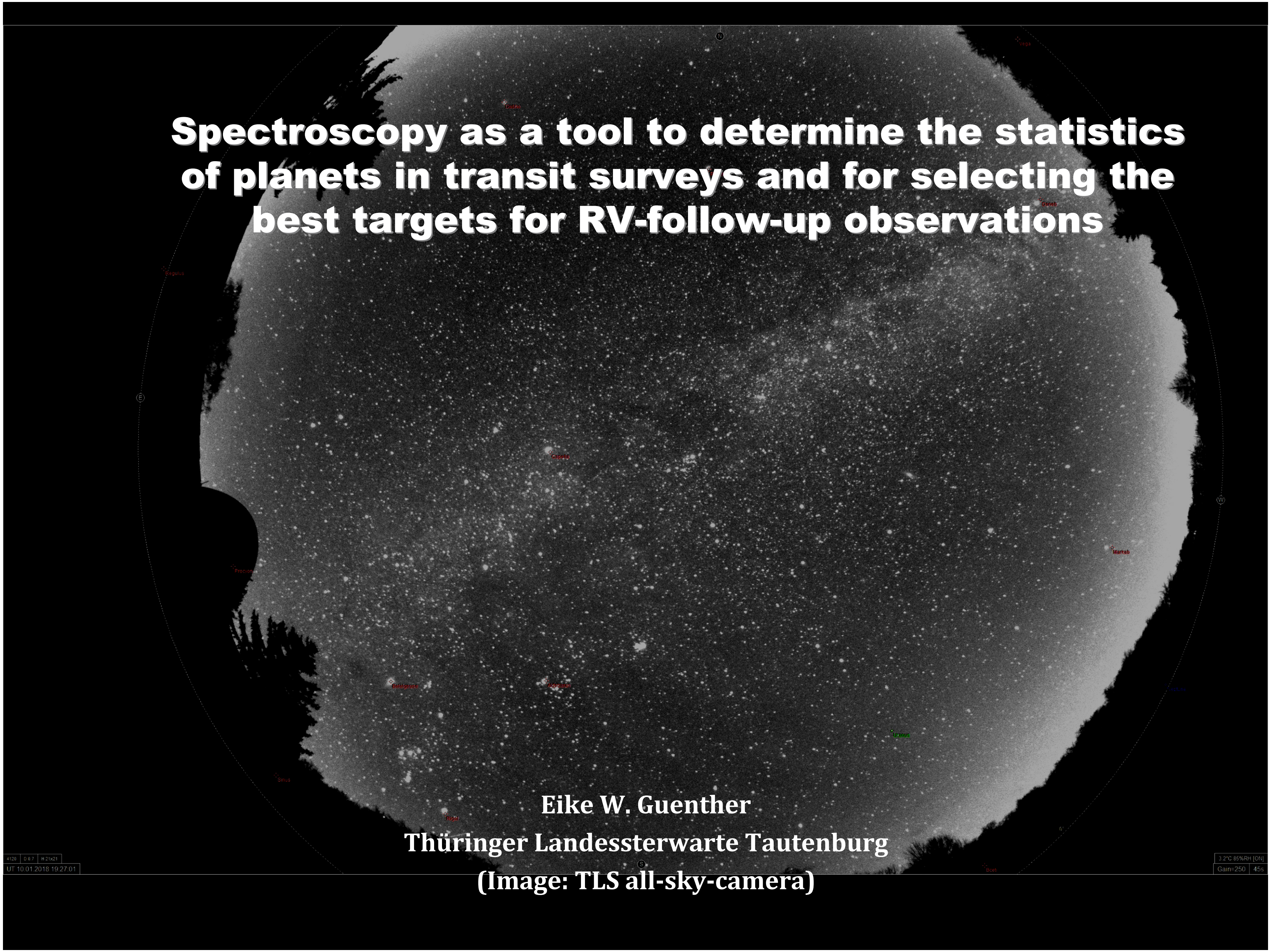
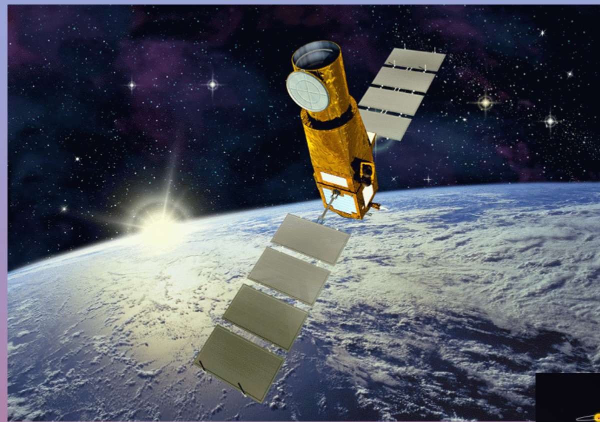
Spectroscopy as a tool to determine the statistics of planets in transit surveys and for selecting the best targets for RV-follow-up observations



Eike W. Guenther
Thüringer Landessterwarte Tautenburg
(Image: TLS all-sky-camera)

Satellite Mission top search for transiting exoplanets are a perfect source of stellar-light curves



CoRoT: Dec 2006-Nov 2012,
400 ppm, R=15 mag star in 6.5 hours,
163000 stars, cadence: 32s,
16 long runs (up to 152 days),
8 short runs 21 days.

Kepler: Mar 2009- May 2013,
20 ppm on V=12 mag star in 6.5 hours,
530506 stars, cadence: 1764s.

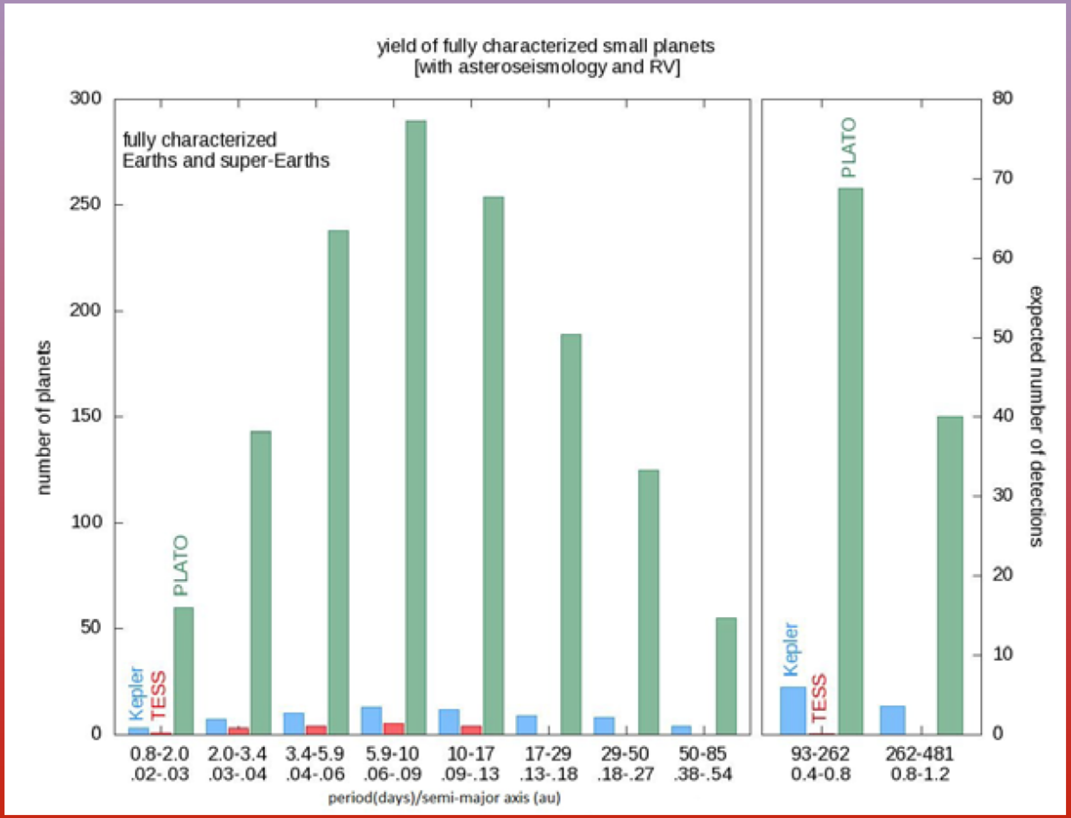
Kepler K2: May 2013 to August 2018
300 ppm, 300000 stars in 12 fields.

TESS: since April 2018,
200 ppm, I=10 mag stars, one hour
500 000 stars, cadence: 120s (selected stars),
1800s full frame.

PLATO: start 2026, 24+2 telescopes
--> more in the next transparencies

Why PLATO?

--> 4000 super-Earth planets around stars with m_v<11 mag.
--> 40-70 super-Earths in the HZ of G-type stars
--> factor 10 better than Kepler for planets with 90 d < P < 500 d periods
--> factor 1000 better than TESS for planets with 90 d < P < 500 d periods



Fraction of stars hosting Earth-like planets in their habitable zones (J. Cabrera)

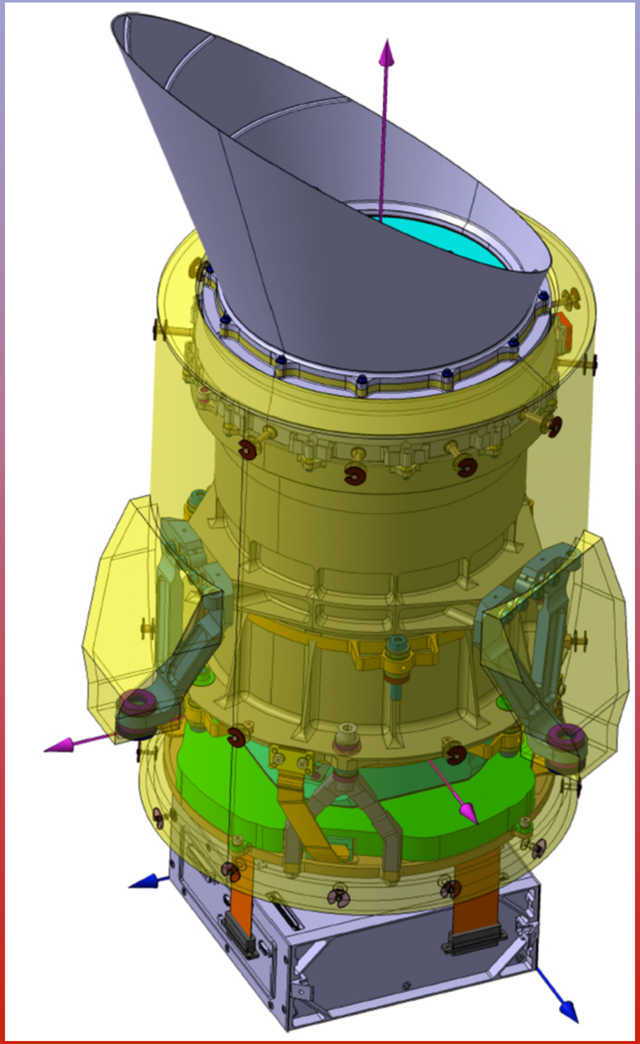
reference	Planet frequency	Host star type
Catanzarite & Shao 2011	1%-3%	Sun-like stars
Traub 2012	20%-58% (34%)	FGK stars
Silurt et al. 2015	5.3%-9.8%	FGK stars
Petgura et al. 2013	7%-15%	GK stars
Batalha et al. 2014	11%-22%	GK star
Foreman-Mackey et al. 2014	0.8%-2.5% (1.7%)	G stars
Traub 2016	90%-110%	G stars
Gaidos 2013	31%-64%	Dwarf stars
Bonfis et al. 2013	28%-95%	M stars
Dressing & Charbonneau 2013	9%-28% (15%)	M stars
Kopparapu 2013	24%-60% (48%)	M stars

The 24+2cameras of PLATO

24 'normal' cameras: cadence of 25 s and stars with $m_V > 8$,
Photometric noise 34 ppm $m_V<11$ mag star in one hour.

2 'fast' cameras: cadence 2.5s stars with m_V ~4 to 8,
Photometric noise 34 ppm $m_V<8$ mag star in one hour.

Total field of about 2250 deg^2
Image scale: 15 arcsec/pixel.



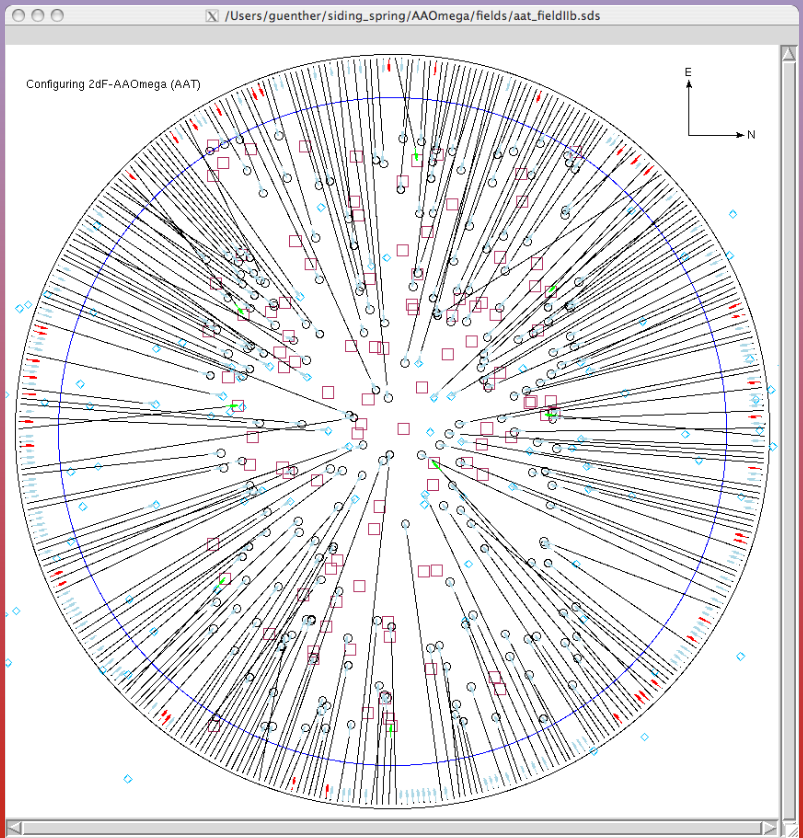
The satellite surveys provide us with perfect photometric data, particularly PLATO, but we need to

1.) **Characterize the sample**: Take spectra of all stars, or at least as many as possible.

2.) **Identify best candidates:** Identify stars with Earth-like planets in the habitable zone were the determination of the masses is possible.

1.) Characterizing the sample:

We have done that already for the CoRoT mission using AAOmega@AAT (work by D. Sebastian)



Blue: 360-570 nm; R=1300

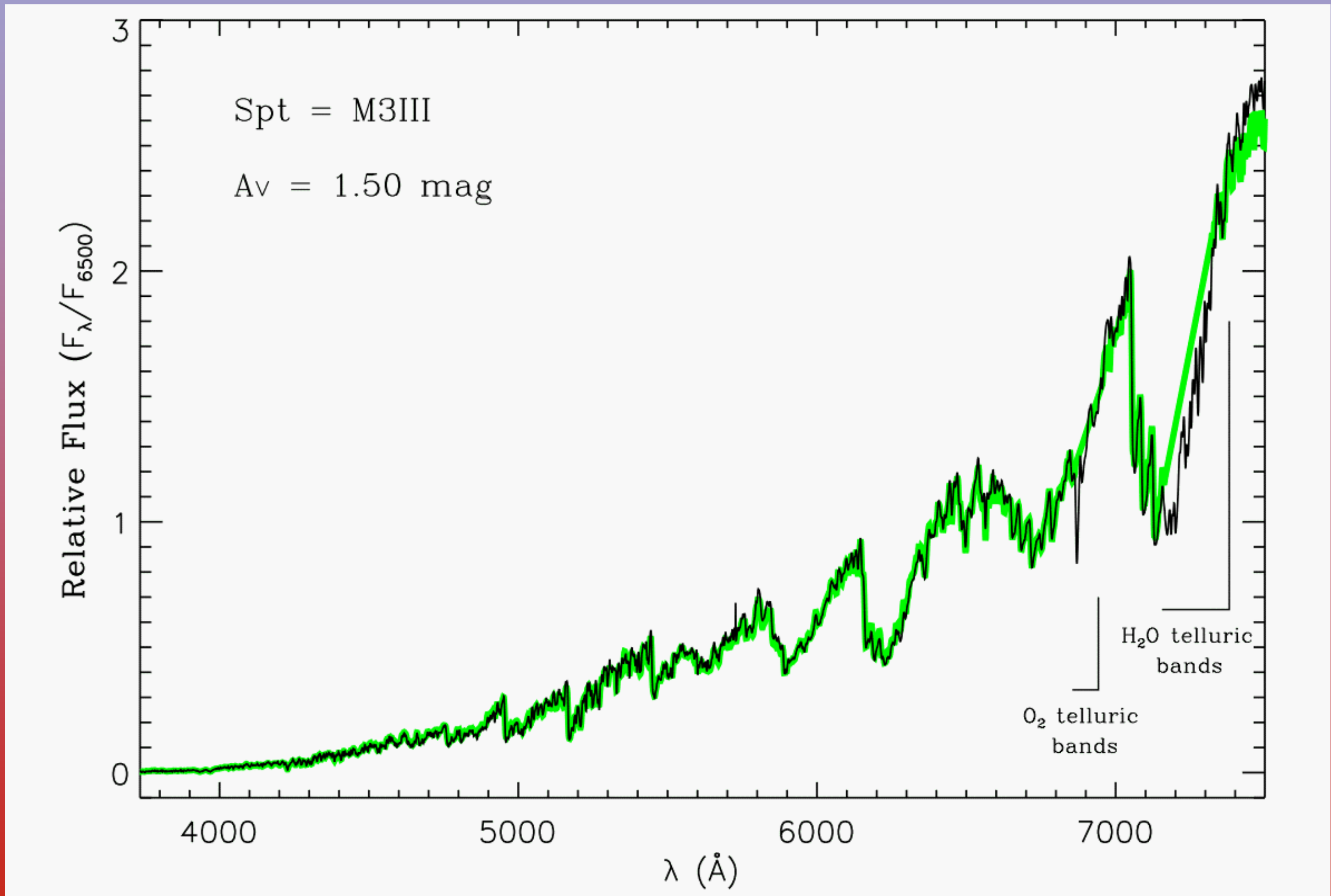
Red: 570-890 nm; R=1300

How do we determine the Spectral- types from the low-resolution spectra for thousands stars?

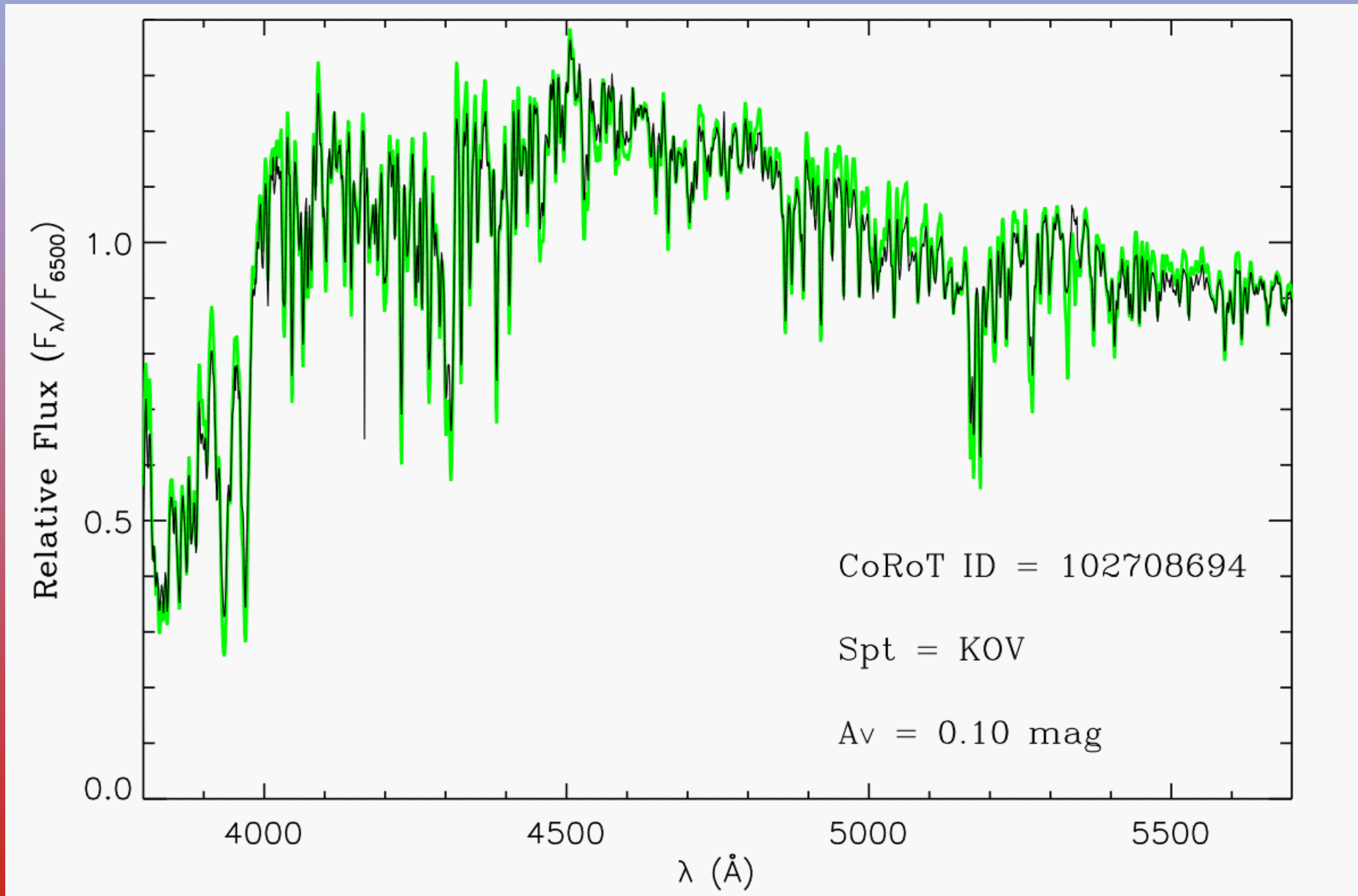
We fit each observed spectrum with a suitable grid of templates, taking the amount of extinction into account.

An example

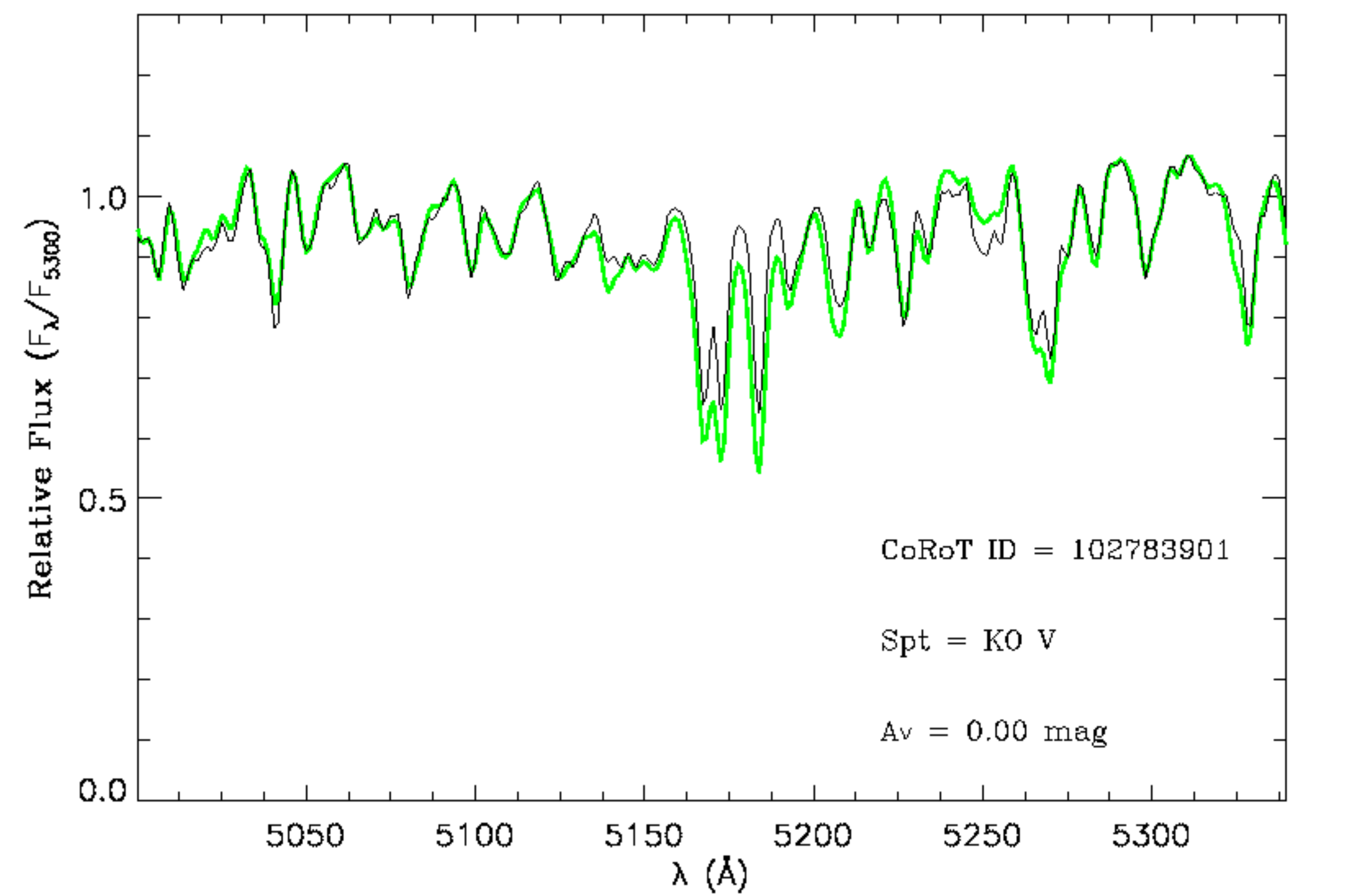
(observations: black, template: green)



...another example...

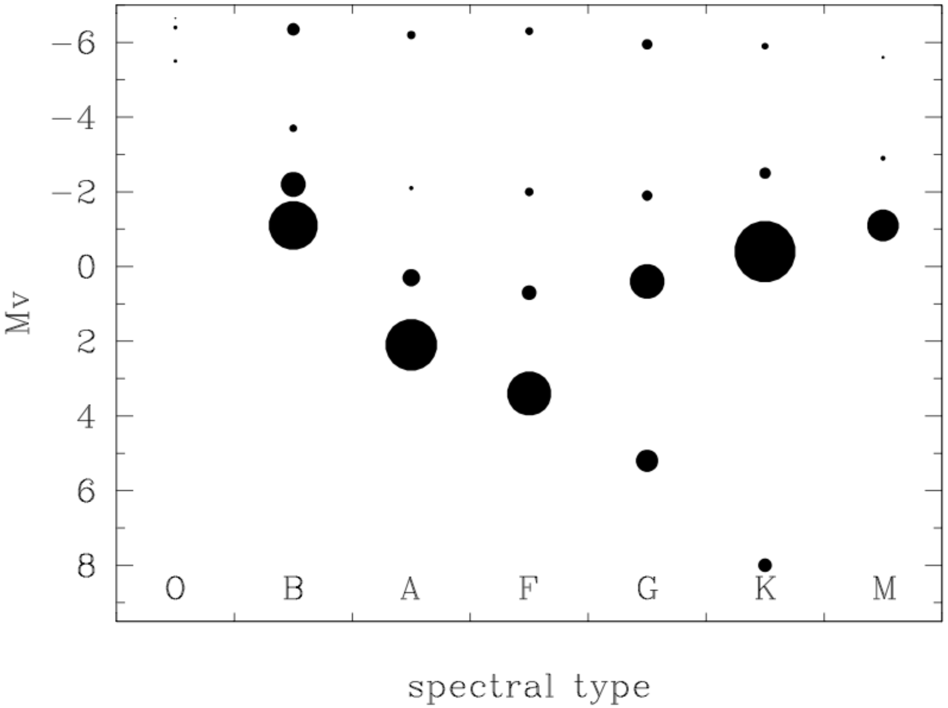


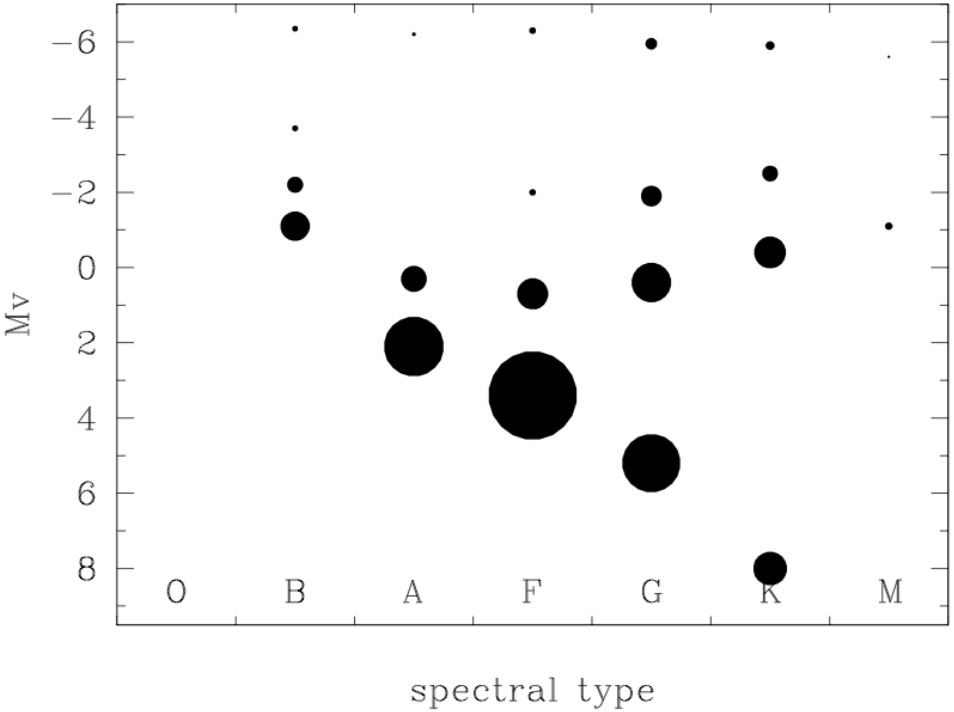
...we can determine the luminosity classes using the Magnesium lines (giant does not fit).



Right: HRD that CoRoT observed in IRa01, LRa01, LRa02

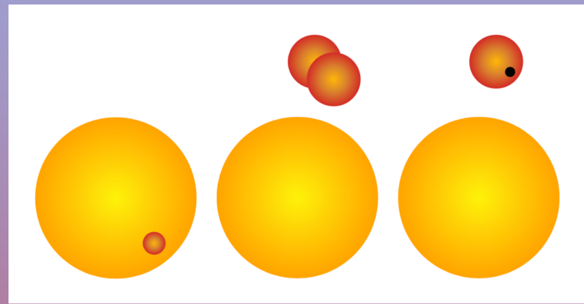
Left: HRD of the bright stars (V>6.5 mag, left)





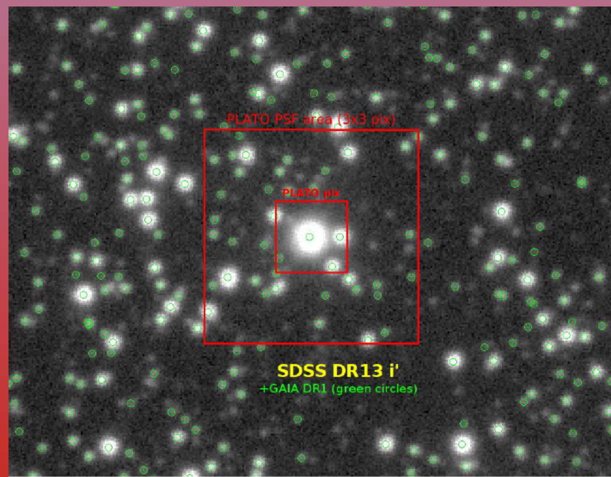
2.) Strategy to identify best candidates for Earth-like planets in the habitable zone were we can determine the mass

a.) Remove false-positives.



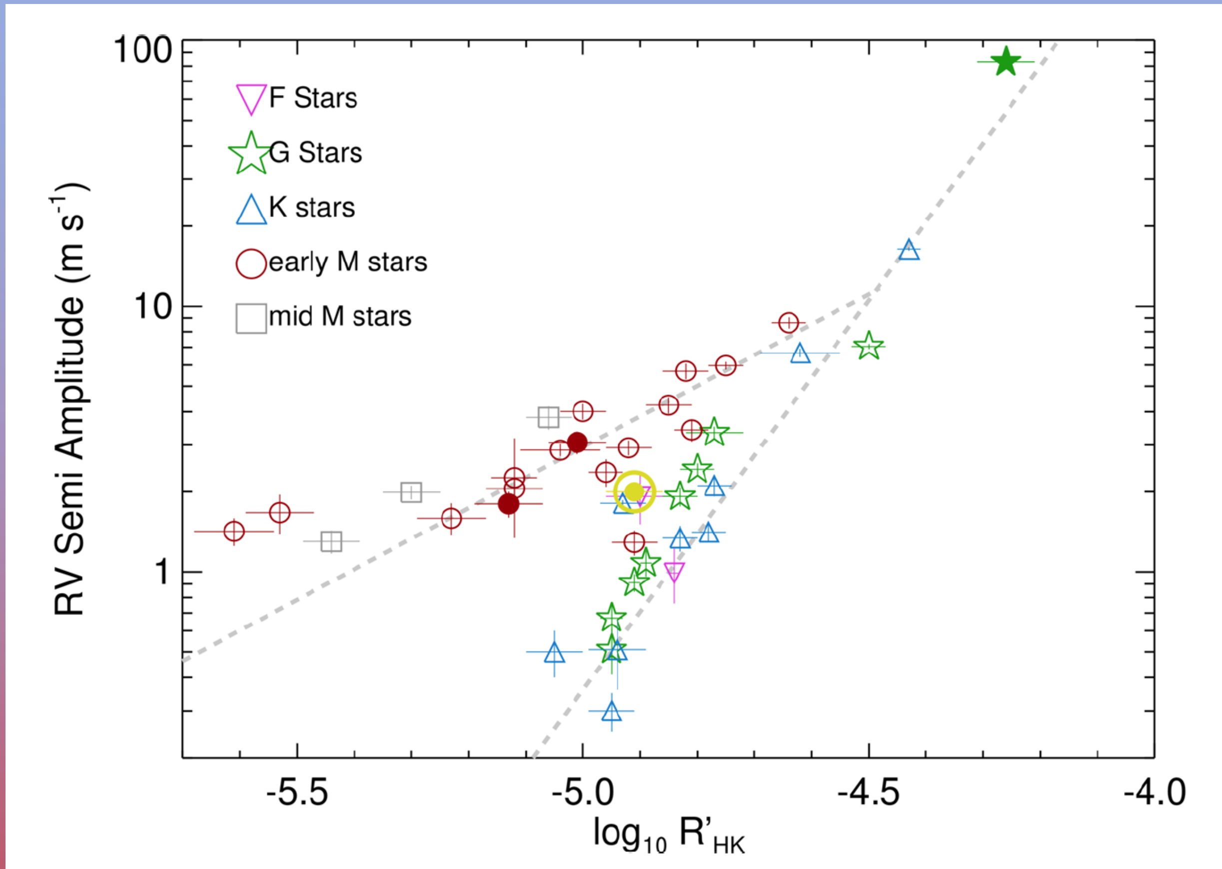
b.) Estimate RV-signal of planet based on R_{planet}/R_{star} and P_{orbit} as derived from PLATO-data, combined with $R_{star,}$ M_{sta}as derived from GAIA-data and HR-spectra.

c.) Estimate the RV-jitter of star using CaII HK-index and vsini as derived from the HR-spectra (vsini can also be estimated from rotation period as derived using PLATO photometry).



d.) Calculate how many spectra are needed to detect planet with HARPS, or ESPRESSO taking the activity jitter and the measurement error in to account.

--> Select targets to be observed with 2m-class telescopes, HARPS, ESPRESSO.



Sun:

. RV rms (in m/s) for specific components.

	Spots	Plages	sp+pl	Conv.	Total
All	0.34	0.31	0.33	2.38	2.40
Low	0.09	0.10	0.08	0.44	0.44
High	0.48	0.44	0.42	1.39	1.42

$\log_{10}(K)=2.93*\log_{10}(R'_{HK})+14.23$ for GK-stars

Suarez Mascare˜no et al. 2017

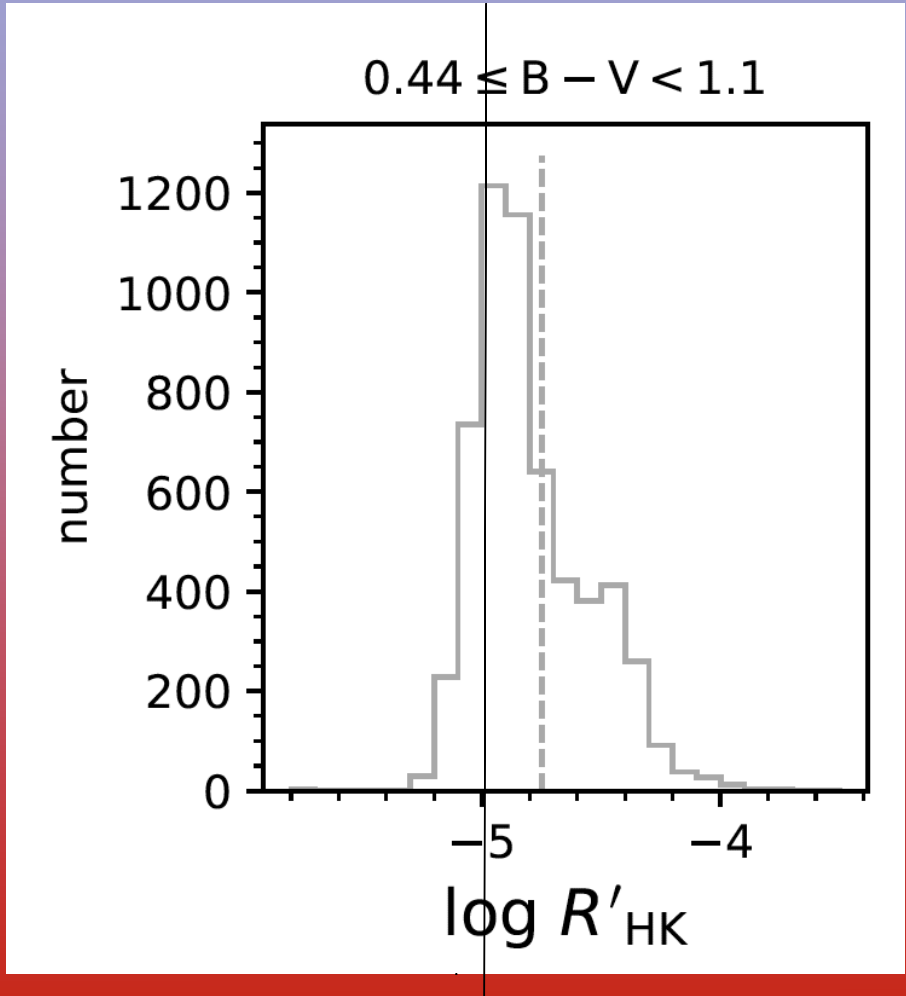
Limiting factor: Activity level of G/K-stars

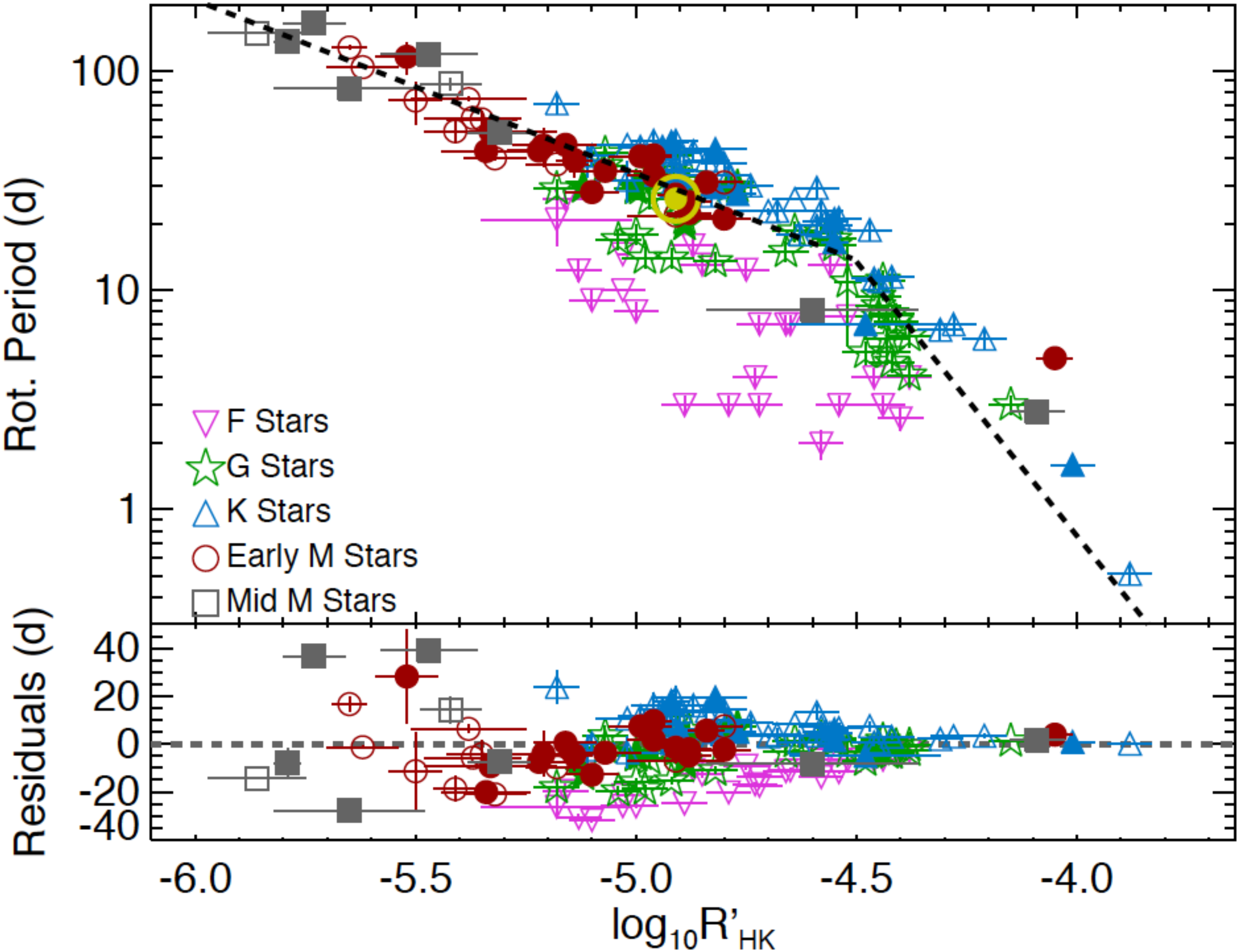
--> 40% of the G-stars have R'_{HK}<-4.9. These stars are inactive enough to limit the stellar jitter to 1 m/s.

--> 20% of the G-stars have R'_{HK}<-5.0.

Stars with R'_{HK}<-5.0 are inactive enough to achieve 0.5 m/s by taking 100 RVs.

This allows the detection of a 4 M_{Earth} planet in HZ of G-star, or 2 M_{Earth} of K-star.





Rot. Period (d)
100
10
1
F Stars
G Stars
K Stars
Early M Stars
Mid M Stars
Residuals (d)
40
20
0
-20
-40
-6.0
-5.5
-5.0
-4.5
-4.0
$\log_{10}R'_{HK}$

PLATOspec @ ESO 1.5m telescope

Project:

- **TLS Tautenburg,**
- **Astronomical Institute AS CR, Ondrejov,**
- **Universidad Catolica de Chile**

Instrument:

- **Wavelength range: 360-680nm**
- **UV optimized**
- **Resolution: 70000 (4.2 km/s)**
- **Sampling: >2 pix**
- **Fibre-fed Echelle-spectrograph**
- **Iodine-cell**
- **CCD: 2kx2k CCD**

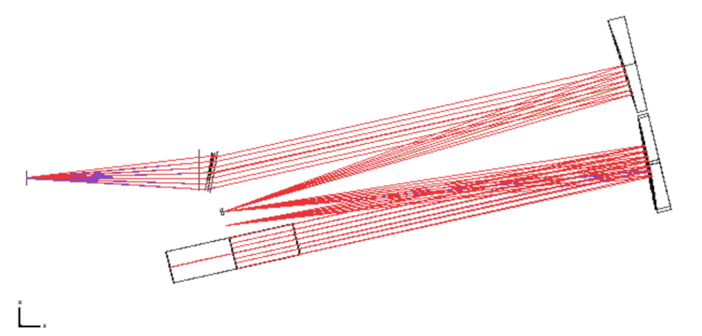
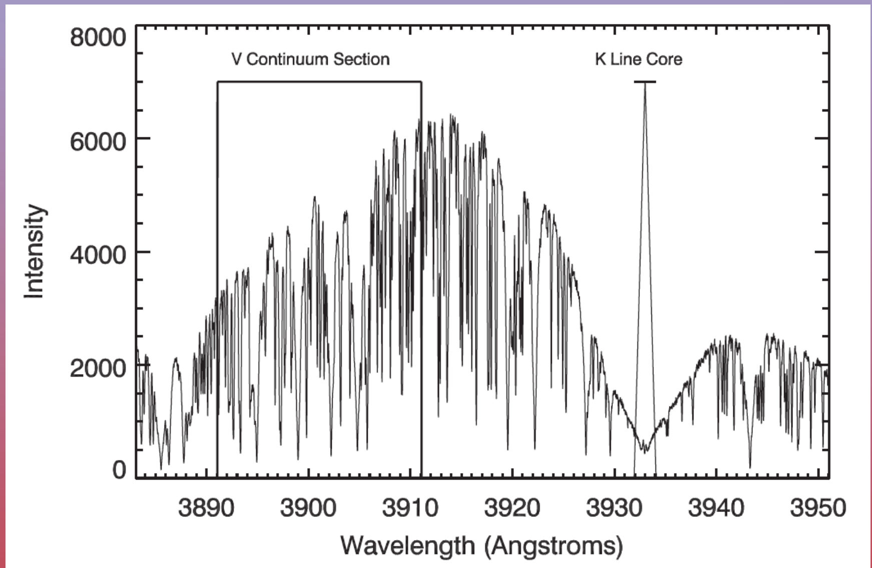
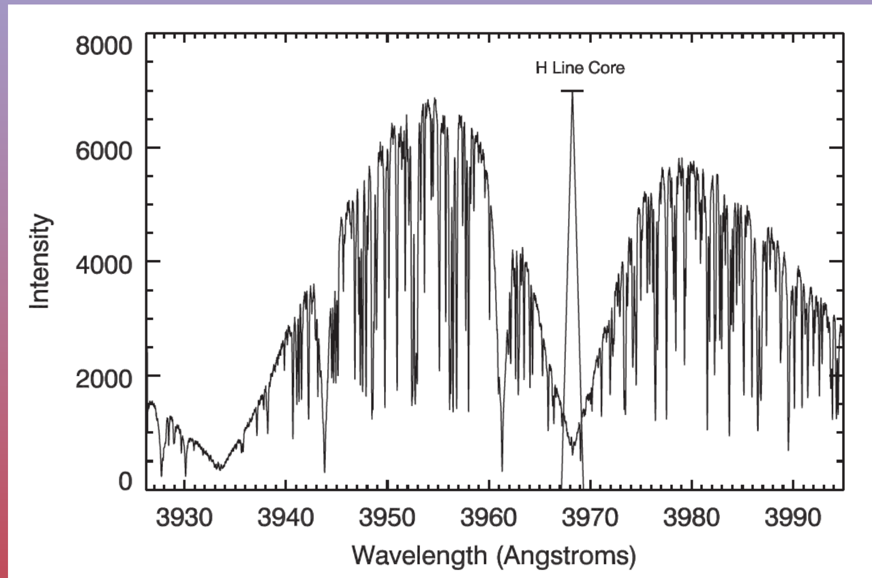


Fig. 2 Spectrograph optical lay out in white pupil configuration with two collimating mirrors both of 1280 mm focal length

S/N>20 better 30 in the CaII H,K lines needed

CaIIK: 3933.666 AA, CaIIH: 3968.468 AA





Width of line core: 0.2 nm --> 150 km/s --> 70 pixel with PLATOspec

Summary:

The satellite survey provide us with perfect photometric data, particularly PLATO but we need

1.) multi-object spectroscopy to characterize the sample.

2.) HR-spectroscopy with UV optimized spectrograph to identify inactive stars were the detection of Earth-like planets in the habitable zone is possible with ESPRESSO.