Selecting targets for the Second Earth Initiative

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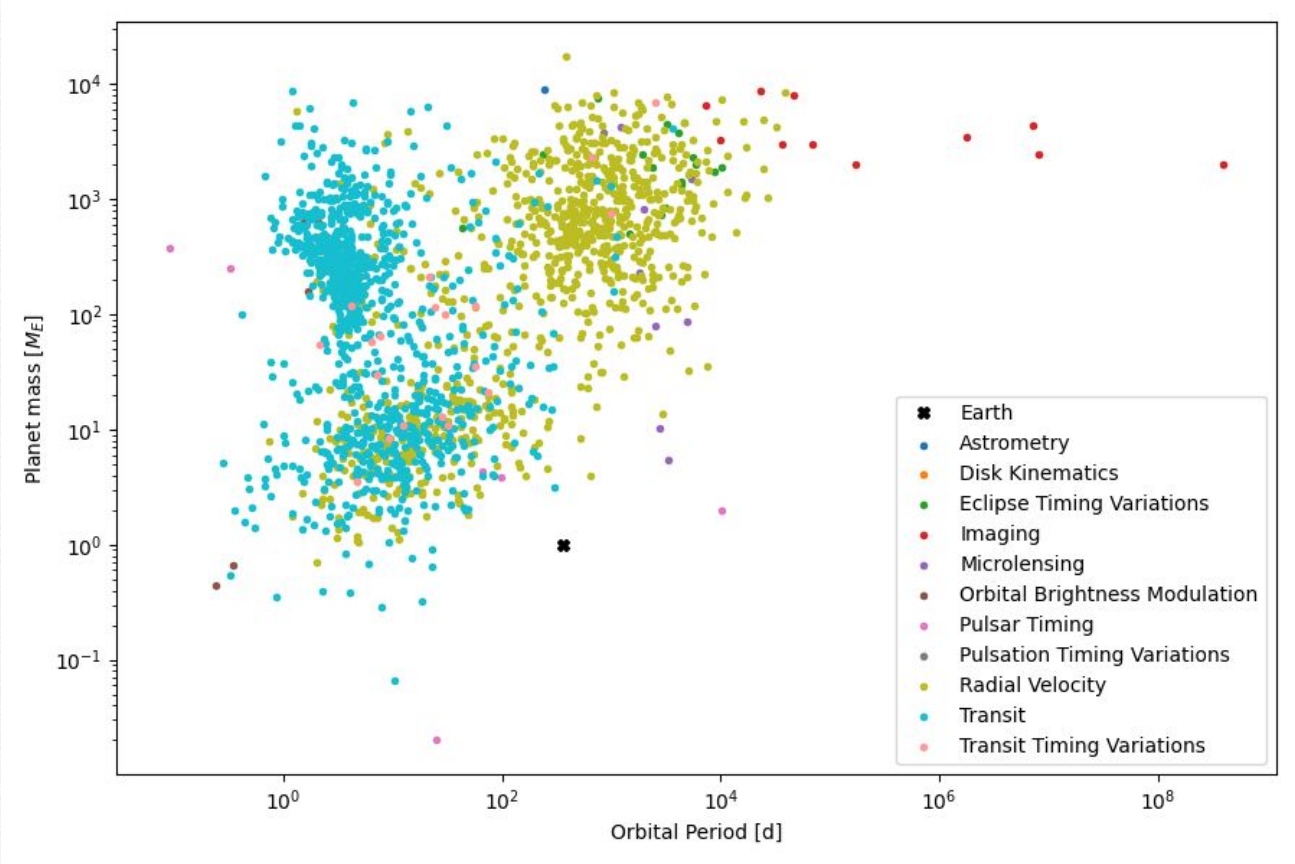
Outline

- Introduction
- Initial selection - Gaia
- ESO archival spectroscopy
- RV precision
- “Final” selection
- Dealing with stellar activity

Introduction

Second Earth?



Ideal targets

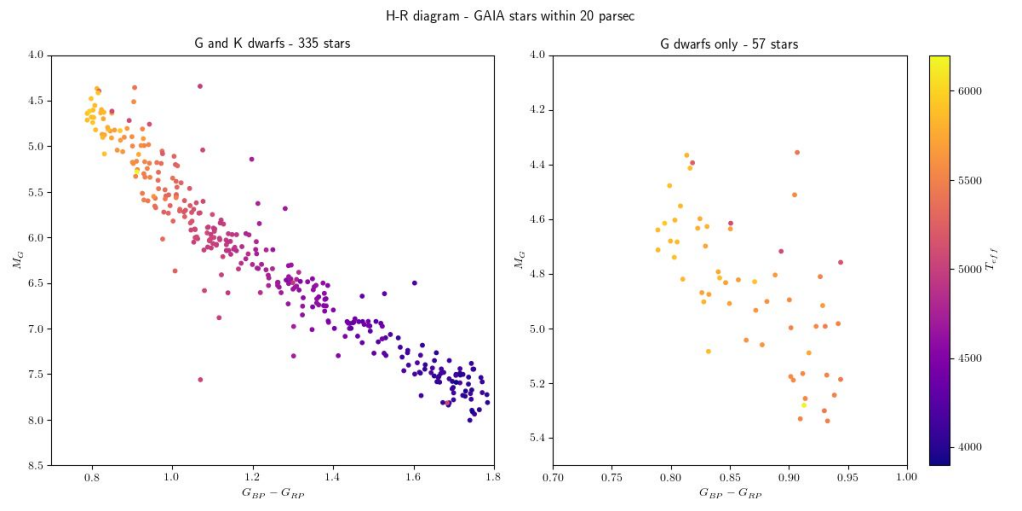
- Bright nearby stars
- G or K spectral type
- Slow rotator
- No strong stellar activity
- No known hot giant planets

Initial selection - Gaia

Initial selection from Gaia

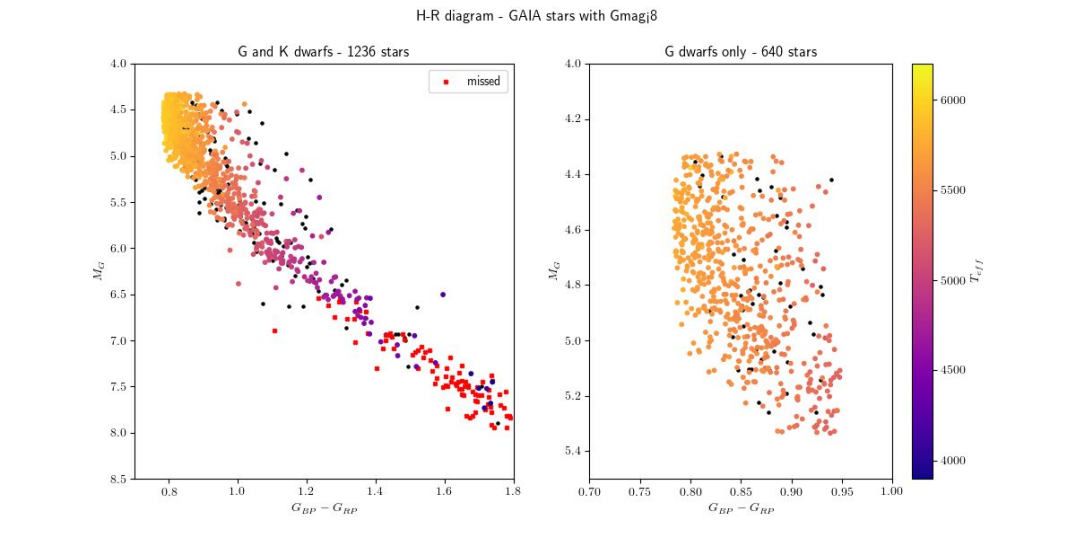
- Distance-limited sample - 20 parsec cut
- Observable from La Silla
- Colour-magnitude cuts to get G & K stars:

	M_G	G_{BP} - G_{RP}
G & K stars	4.325 - 8.03	0.784 - 1.79
G stars	4.325 - 5.34	0.84 - 0.950



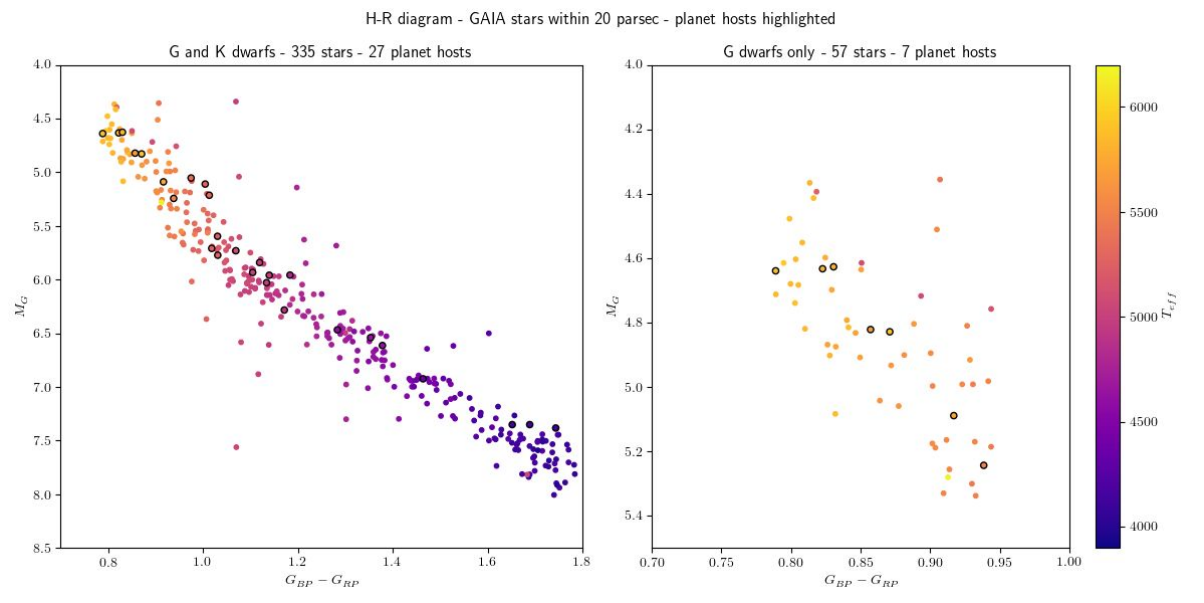
Initial selection from Gaia

- What about a magnitude-limited sample?
  - Lose many K dwarfs
  - Add MANY G dwarfs!



Initial selection from Gaia

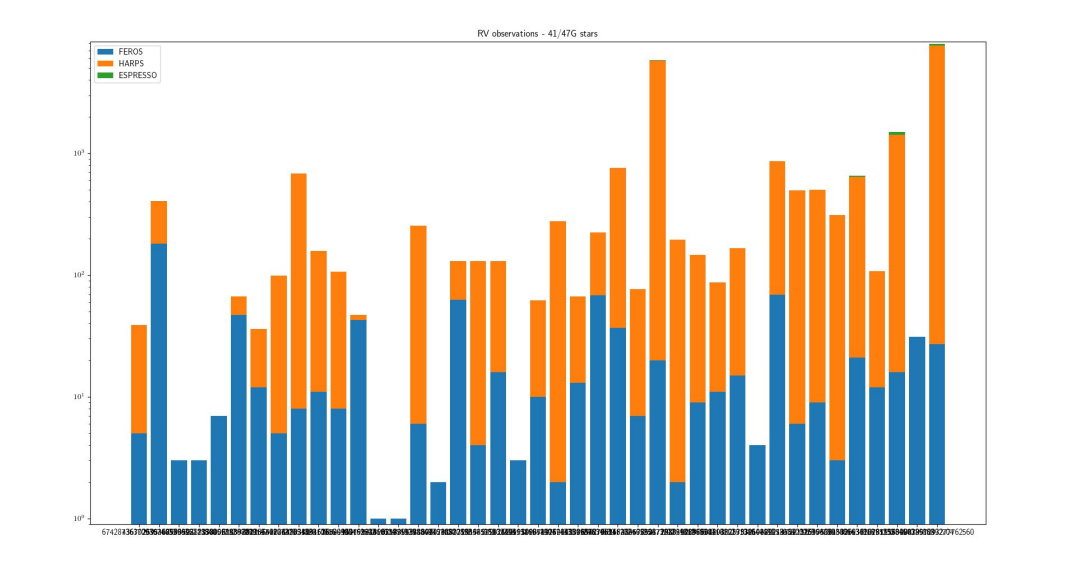
- Cross-match with exoplanet archive for known planets
    - Cross-matching can fail for Gaia DR3 IDs! Gaia DR2 IDs seem robust



ESO spectroscopy

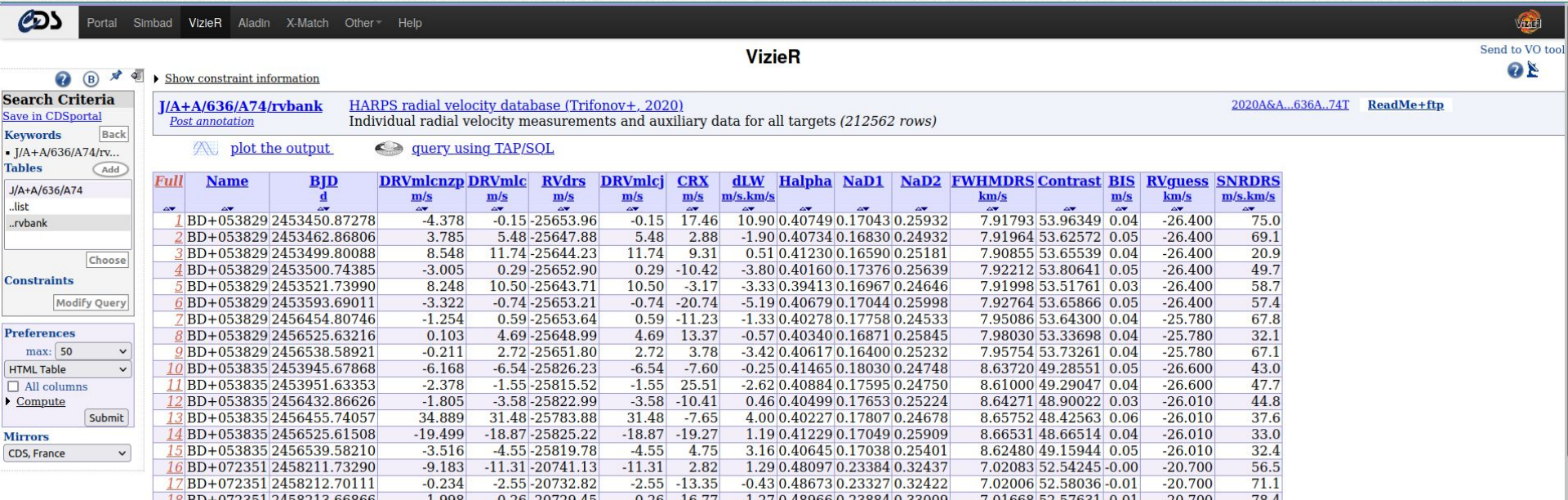
ESO spectroscopy archives

	G & K stars observed (of 335)	G stars observed (of 47)
FEROS	192	41
HARPS	154	32
ESPRESSO	15	4



HARPS radial velocities

- Corrected HARPS-RVBANK (Trifonov et al. 2020):
  - RVs recomputed with SERVAL pipeline
  - Pre/post HARPS upgrade separation
  - Systematic errors corrected
  - Activity indicators provided



Portal Simbad VizieR Aladin X-Match Other Help

VizieR

Send to VO tool

Show constraint information

Search Criteria

Save in CDSportal

Keywords Back

▪ J/A+A/636/A74/rv...

Tables Add

J/A+A/636/A74

..list

..rvbank

Choose

Constraints

Modify Query

Preferences

max: 50

HTML Table

All columns

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J/A+A/636/A74/rvbank — HARPS radial velocity database (Trifonov+, 2020) — 2020A&A...636A..74T — ReadMe+ftp

Post annotation

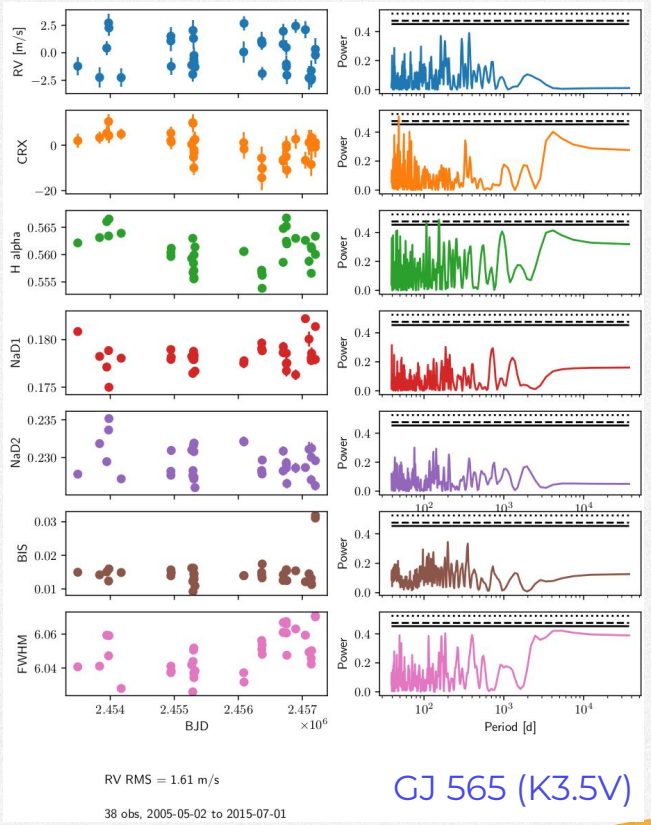
Individual radial velocity measurements and auxiliary data for all targets *(212562 rows)*

plot the output — query using TAP/SQL

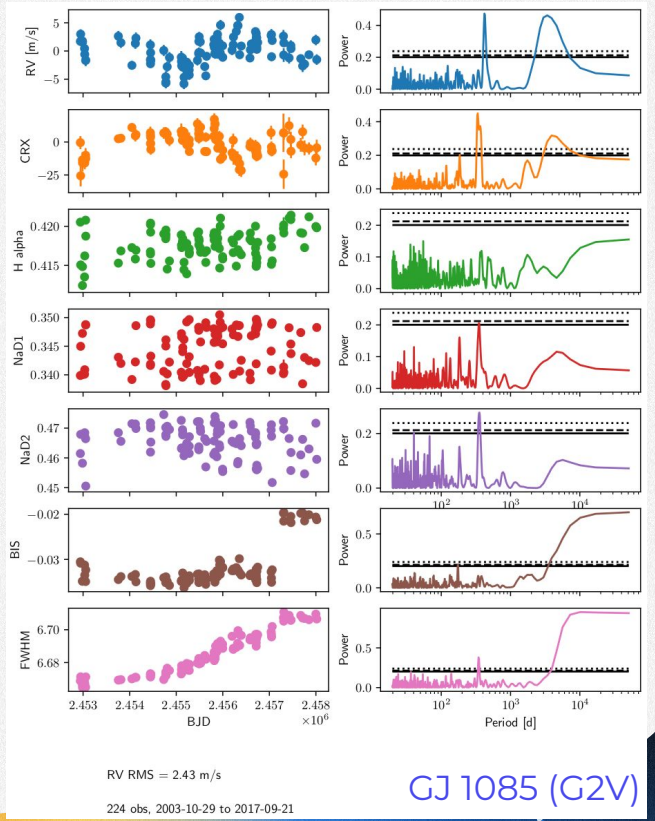
Full	Name	BJD d	DRVmlcnzp m/s	DRVmlc m/s	RVdrs m/s	DRVmlcj m/s	CRX m/s	dLW m/s.km/s	Halpha	NaD1	NaD2	FWHMDRS km/s	Contrast	BIS m/s	RVguess km/s	SNRDRS m/s.km/s
1	BD+053829	2453450.87278	-4.378	-0.15	-25653.96	-0.15	17.46	10.90	0.40749	0.17043	0.25932	7.91793	53.96349	0.04	-26.400	75.0
2	BD+053829	2453462.86806	3.785	5.48	-25647.88	5.48	2.88	-1.90	0.40734	0.16830	0.24932	7.91964	53.62572	0.05	-26.400	69.1
3	BD+053829	2453499.80088	8.548	11.74	-25644.23	11.74	9.31	0.51	0.41230	0.16590	0.25181	7.90855	53.65539	0.04	-26.400	20.9
4	BD+053829	2453500.74385	-3.005	0.29	-25652.90	0.29	-10.42	-3.80	0.40160	0.17376	0.25639	7.92212	53.80641	0.05	-26.400	49.7
5	BD+053829	2453521.73990	8.248	10.50	-25643.71	10.50	-3.17	-3.33	0.39413	0.16967	0.24646	7.91998	53.51761	0.03	-26.400	58.7
6	BD+053829	2453593.69011	-3.322	-0.74	-25653.21	-0.74	-20.74	-5.19	0.40679	0.17044	0.25998	7.92764	53.65866	0.05	-26.400	57.4
7	BD+053829	2456454.80746	-1.254	0.59	-25653.64	0.59	-11.23	-1.33	0.40278	0.17758	0.24533	7.95086	53.64300	0.04	-25.780	67.8
8	BD+053829	2456525.63216	0.103	4.69	-25648.99	4.69	13.37	-0.57	0.40340	0.16871	0.25845	7.98030	53.33698	0.04	-25.780	32.1
9	BD+053829	2456538.58921	-0.211	2.72	-25651.80	2.72	3.78	-3.42	0.40617	0.16400	0.25232	7.95754	53.73261	0.04	-25.780	67.1
10	BD+053835	2453945.67868	-6.168	-6.54	-25826.23	-6.54	-7.60	-0.25	0.41465	0.18030	0.24748	8.63720	49.28551	0.05	-26.600	43.0
11	BD+053835	2453951.63353	-2.378	-1.55	-25815.52	-1.55	25.51	-2.62	0.40884	0.17595	0.24750	8.61000	49.29047	0.04	-26.600	47.7
12	BD+053835	2456432.86626	-1.805	-3.58	-25822.99	-3.58	-10.41	0.46	0.40499	0.17653	0.25224	8.64271	48.90022	0.03	-26.010	44.8
13	BD+053835	2456455.74057	34.889	31.48	-25783.88	31.48	-7.65	4.00	0.40227	0.17807	0.24678	8.65752	48.42563	0.06	-26.010	37.6
14	BD+053835	2456525.61508	-19.499	-18.87	-25825.22	-18.87	-19.27	1.19	0.41229	0.17049	0.25909	8.66531	48.66514	0.04	-26.010	33.0
15	BD+053835	2456539.58210	-3.516	-4.55	-25819.78	-4.55	4.75	3.16	0.40645	0.17038	0.25401	8.62480	49.15944	0.05	-26.010	32.4
16	BD+072351	2458211.73290	-9.183	-11.31	-20741.13	-11.31	2.82	1.29	0.48097	0.23384	0.32437	7.02083	52.54245	-0.00	-20.700	56.5
17	BD+072351	2458212.70111	-0.234	-2.55	-20732.82	-2.55	-13.35	-0.43	0.48673	0.23327	0.32422	7.02006	52.58036	-0.01	-20.700	71.1
18	BD+072351	2458213.66866	1.998	0.26	-20729.45	0.26	16.77	1.27	0.48966	0.23884	0.33009	7.01668	52.57631	-0.01	-20.700	78.4

HARPS RVs

- Periodograms of RVs and activity indicators
- RV RMS
- Median-per-night RVs



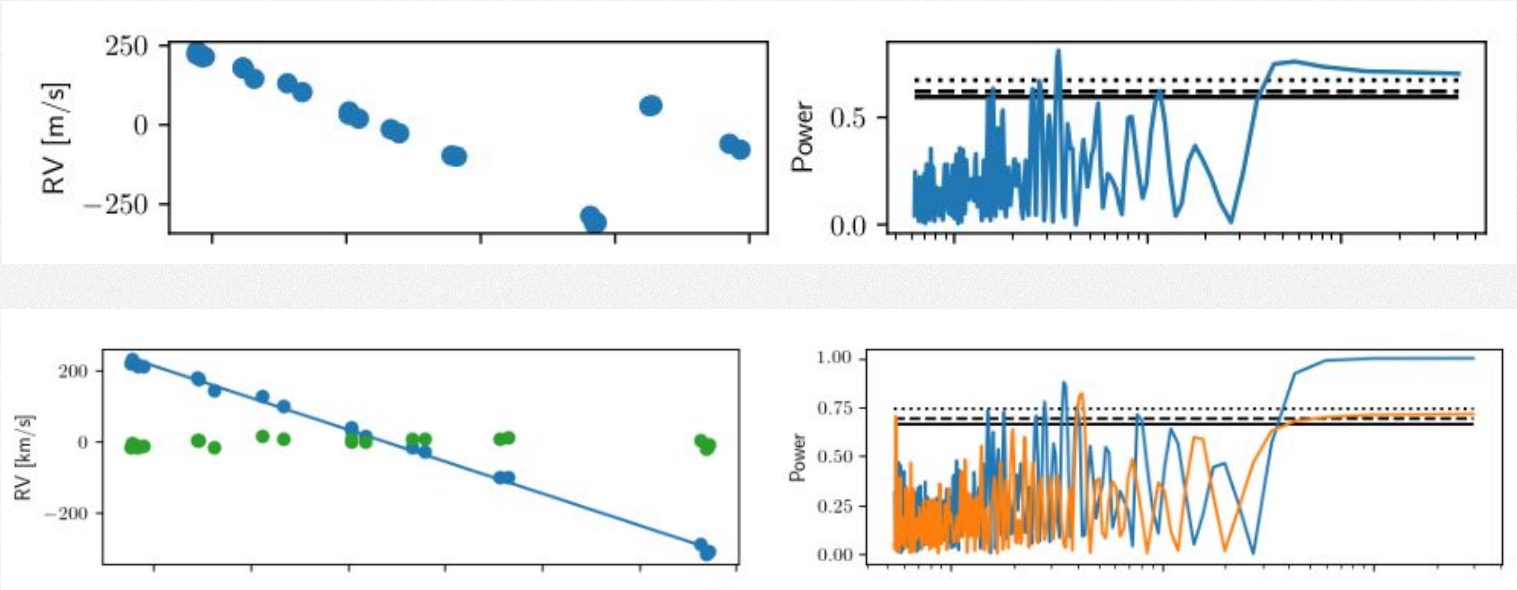
GJ 565 (K3.5V)



GJ 1085 (G2V)

Target vetting with HARPS

- Linear trends, RV offsets



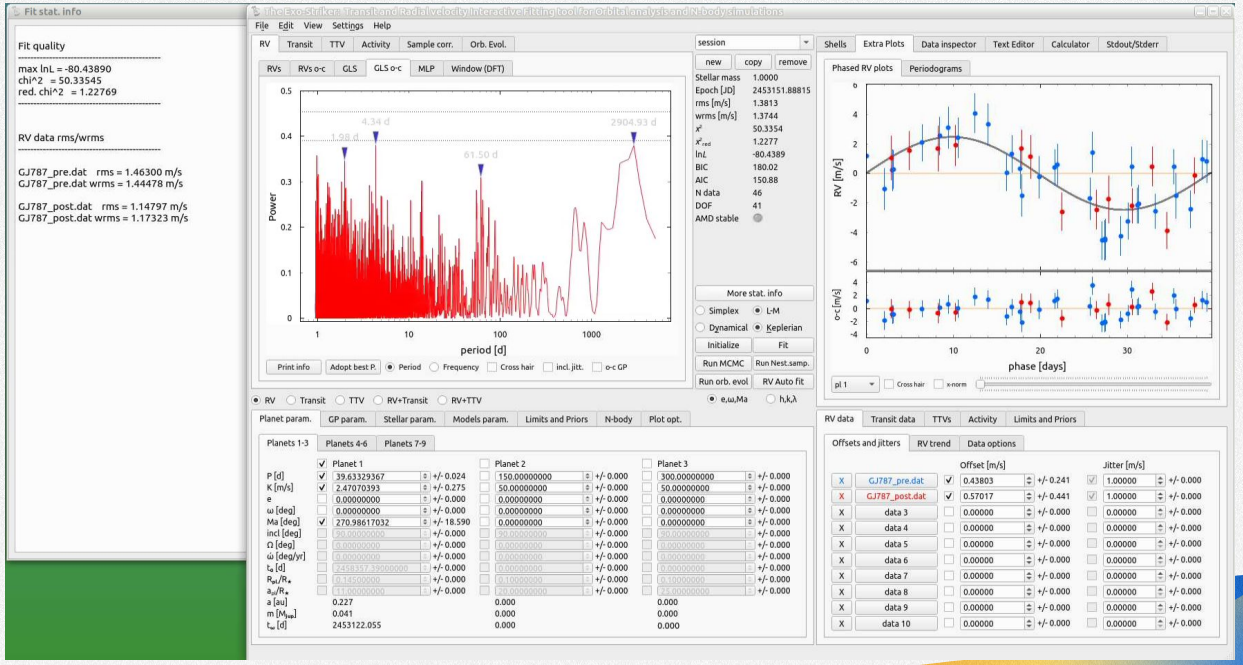
Target selection

Future work

- Better database!
  - Linked webpage, rather than spreadsheet?
  - Link to Simbad? Scrape all info from Simbad?
  - More Gaia information?
- Literature search on all targets

Target vetting with HARPS

- Strong RV signals fitted out using exostriker
  - Unpublished planets?



Target vetting with archival RVs

Future work:

- HARPS-RVBANK:
  - doesn’t contain all targets
  - isn’t updated
  - Use HARPS-DRS RVs? Update RVBANK?
- What about targets not observed with HARPS?
  - FEROS archival RVs? No official pipeline, the data needs to be reduced

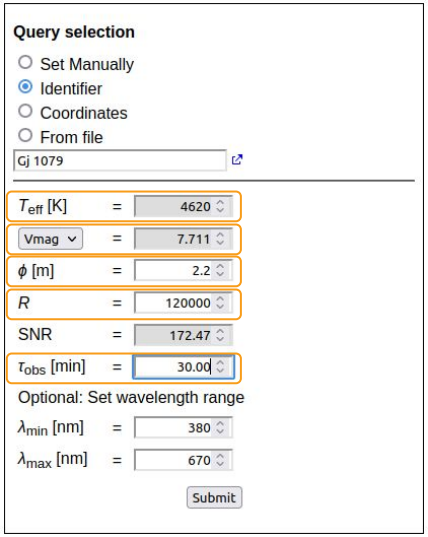
RV precision

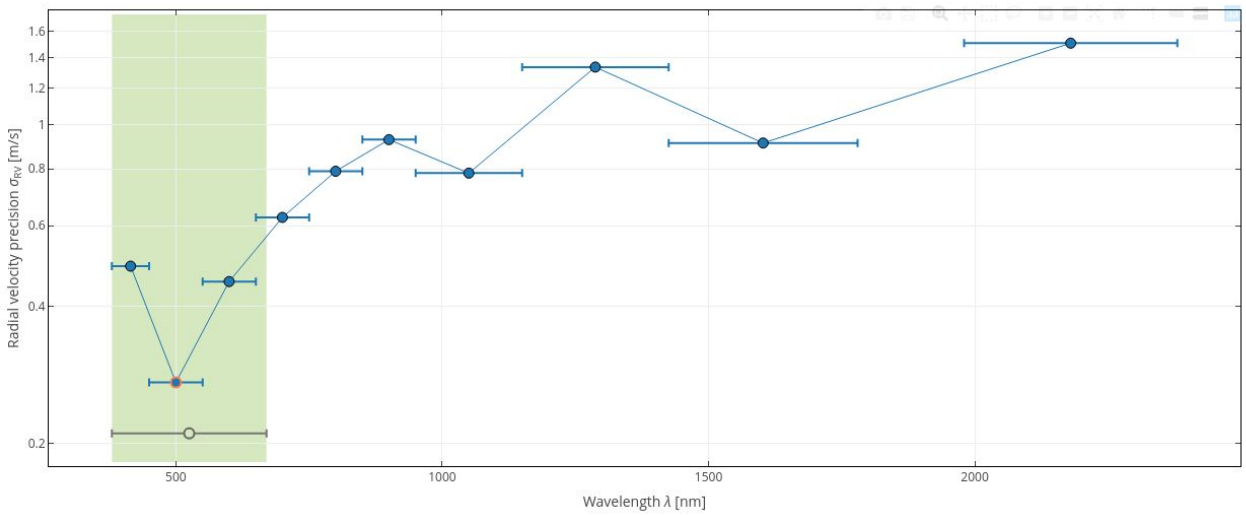
RV precision

- Earth-twin RV signal: ~ 0.1 m/s
- RV precision attainable can be estimated:
- Reiners & Zechmeister, 2020
    - RV precision
    - HZ Minimum planet mass limit

RV precision

- http://www.astro.physik.uni-goettingen.de/research/rvprecision/ (Reiners & Zechmeister, 2020)





λ_{min} [nm]	λ_{max} [nm]	RV precision [m/s]
380	450	0.49
450	550	0.27
550	650	0.45
650	750	0.63
750	850	0.79
850	950	0.93
950	1150	0.78
1150	1425	1.34
1425	1780	0.91
1980	2380	1.51
380	670	0.21

Final (?) selection

Target selection

- Low RMS
- Low Vsini
- No signals in RV or activity periodograms
- Known planets cross-checked with Exoplanet Archive
  - No known hot/warm giants (but hot giants useful for QC!)
- Good RV precision

	Gaia name	other name	HARPS obs	Nights observed	RV RMS (unbinr	number known p	Vmag	Vsini	Reiners RV precision	Reiners HZ Me limit	Simbad sp type	start obs	end obs	obs span	notes	suitable
2	3052753116376	GJ1094	7	7	0.67	0	8.351	2.854	0.16	1.86	K4V	2003-12-14	2006-11-15	2.92	Only 7 obs over	1
3	2904830113367	GJ1079	79	79	1.23	0	7.711	1.873	0.3	2.22	K2/3V	2003-10-31	2018-05-02	14.50	No signal in RVs	1
4	6229442835525	GJ565	38	38	1.61	0	7.805	1.180	0.3	2.16	K3.5V	2005-05-02	2015-07-01	10.16	Low RV scatter,	1
5	2452378776434	HD10700	11346	561	1.62	4	3.500	0.518	0.05	0.4	G8V	2003-10-27	2017-11-29	14.09	4 known planets	1
6	2436812303124	GJ9824	35	34	1.64	0	7.796	1.929	0.32	2.37	K2V	2003-10-29	2015-12-15	12.13	Hint of RV signa	1
7	6854626246593	GJ796	61	37	1.78	0	6.370	0.735	0.19	1.61	G7.5IV-V	2003-11-05	2015-10-16	11.95	No peaks in RV,	1
8	5630532113072	GJ1126	69	67	1.88	0	8.319	2.292	0.15	1.71	K3.5V	2003-12-11	2016-05-24	12.45	No data on exop	1
9	6427244702486	GJ776	659	259	3.32	2	6.070	0.841	0.19	1.76	G2V	2003-10-25	2017-08-03	13.77	Two known plan	1
10	4634528720388	GJ3021	30	3	30.99	1	6.578	5.065	0.21	1.8	G8V	2004-10-11	2004-10-19	0.02	One known plan	4
11	4079684229322	GJ722	73	22	1.46	0	5.860	4.000	0.16	1.42	G6V	2004-09-13	2007-09-07	2.98	Some signals ar	1
12	4847957293277	HD20794	576	73	1.46	4	4.270	0.564	0.07	0.61	G6V	2015-08-21	2016-02-16	0.49	4 planets (Pepe	2
13	3480332916165	GJ446	108	65	1.50	0	6.480	1.382	0.21	1.8	G6V	2004-02-03	2016-06-30	12.41	Nothing in RVs,	2
14	3195919528988	HD26965	616	101	1.81	1	4.430	0.369	0.07	0.59	K0V	2003-10-27	2016-03-27	12.42	Triple star syster	2
15	6471497502884	GJ798	79	62	1.86	0	8.820		0.2	1.95	K7V	2004-09-23	2013-08-21	8.91	Nothing in RVs,	2
16	2322574488107	GJ18.0	6	6	2.22	0	7.916	2.357	0.33	2.28	K3V	2003-10-30	2009-09-02	5.84	No data on exop	2
17	6669657123437	GJ787	46	46	2.23	0	8.708	2.734	0.19	2.09	K5.5V	2004-05-26	2015-10-16	11.39	Strong RV peak	2
18	5994771148252	GJ604	52	51	2.24	0	8.055	2.700	0.14	1.57	K4V	2004-07-20	2016-04-26	11.77	Low-significance	2
19	5378886891122	GJ435	6	6	2.32	0	7.762	3.640	0.12	1.35	K4.5Vk:	2004-01-11	2007-03-12	3.16	Only 6 points ov	2
20	4364527594192	GJ653	70	70	2.61	0	7.709	2.500	0.12	1.29	K4/5V	2004-09-14	2016-09-30	12.04	Some RV peaks	3
21	5902750168276	HD136352	685	249	2.76	3	5.650	1.546	0.15	1.4	G3/5V	2004-05-27	2017-08-04	13.19	3 known planets	2
22	4270446404294	GJ715	51	47	3.05	0	8.004	1.212	0.14	1.71	K4V	2005-07-26	2015-09-13	10.13	RV RMS 3.16 m	2
23	4737533237421	HD21209A	65	64	3.46	0	8.590	2.326	0.17	1.93	K3.5V	2003-10-29	2016-09-30	12.92	No data on exop	2

Stellar activity

Impact of stellar activity

- Earth-twin RV signal: ~10 cm/s
- Instrumental noise floors: ~ 30 cm/s (ESPRESSO)
- Stellar-activity induced RV signals: often ~1 m/s or higher!
- Sun as a star?
    - Sun is uniquely well characterized
    - But is it representative of all G and K stars?

ESPRESSO activity proposal

- Four bright stars:
  - G2 to G9
  - expected photon noise limits of ≤ 15 cm/s
  - low variability in HARPS RVs and activity indicators
  - no hot/warm giant planets
- Observe ~every night for a month, covering a rotation period
- Study the impact of stellar activity on radial velocities at the sub-m/s level
  - activity indicators
  - line-by-line RVs
  - explore recently proposed techniques

Thank you!
Questions?