A POPULATION OF LONG-PERIOD EXOPLANETS FROM K2

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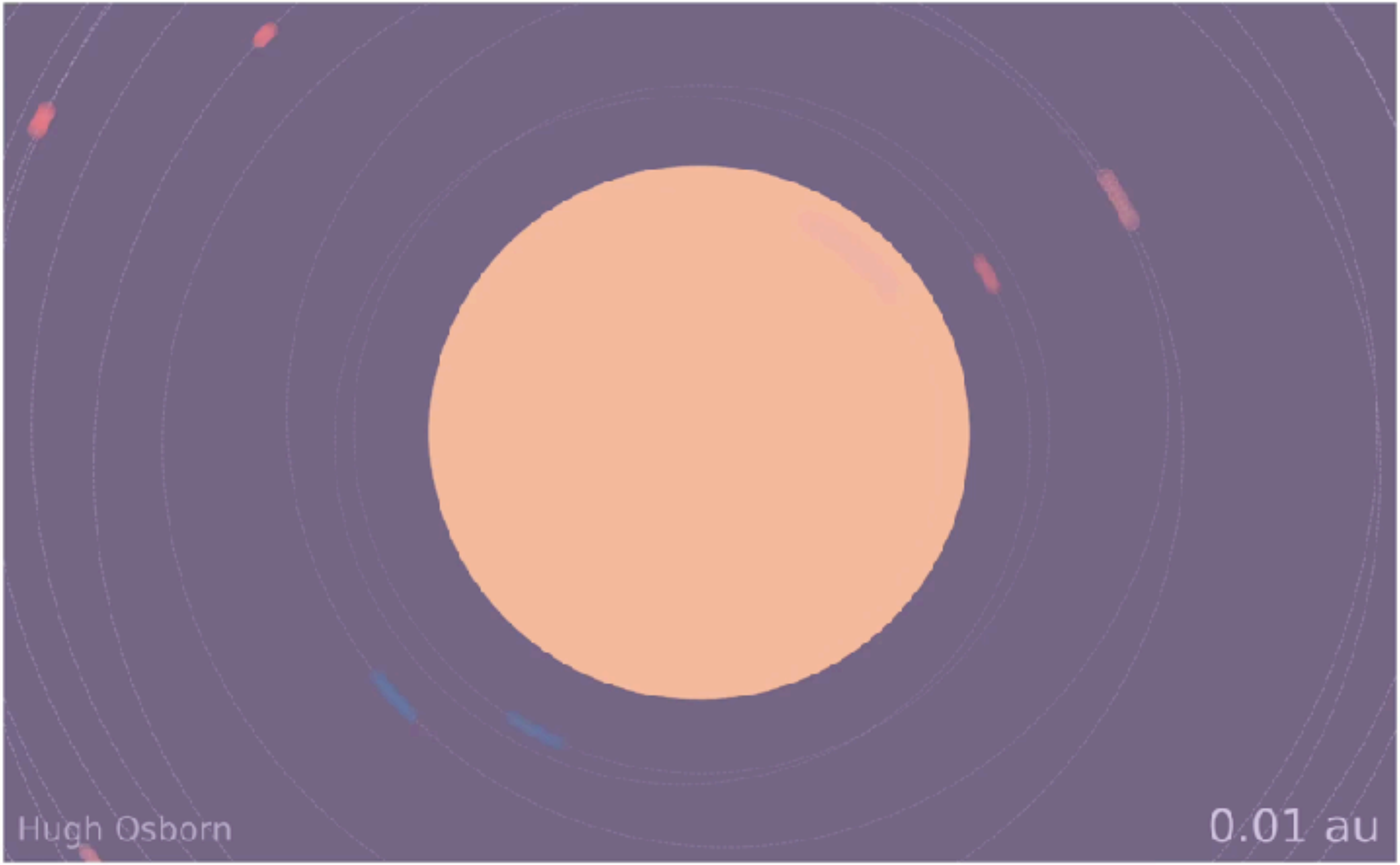
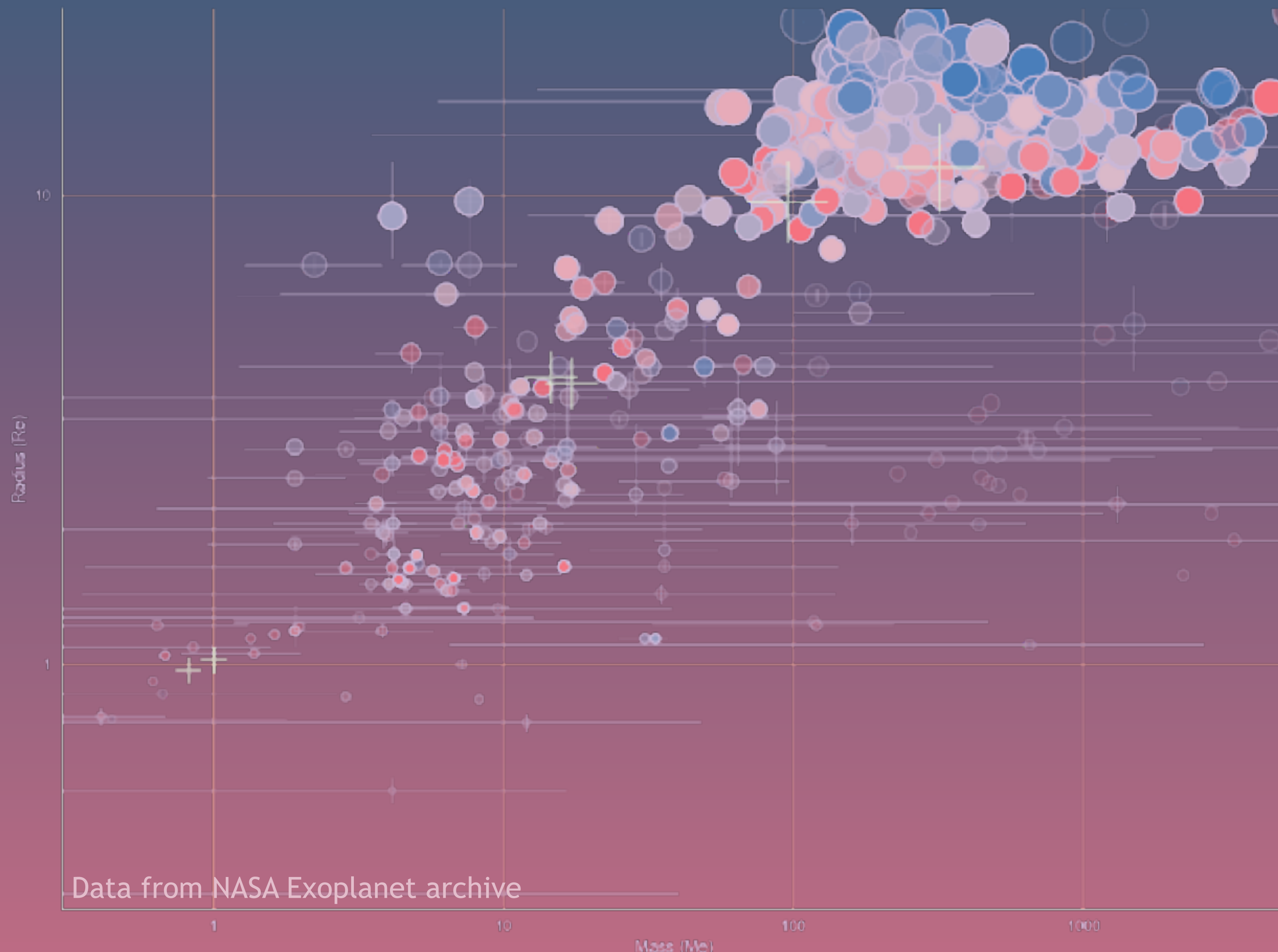
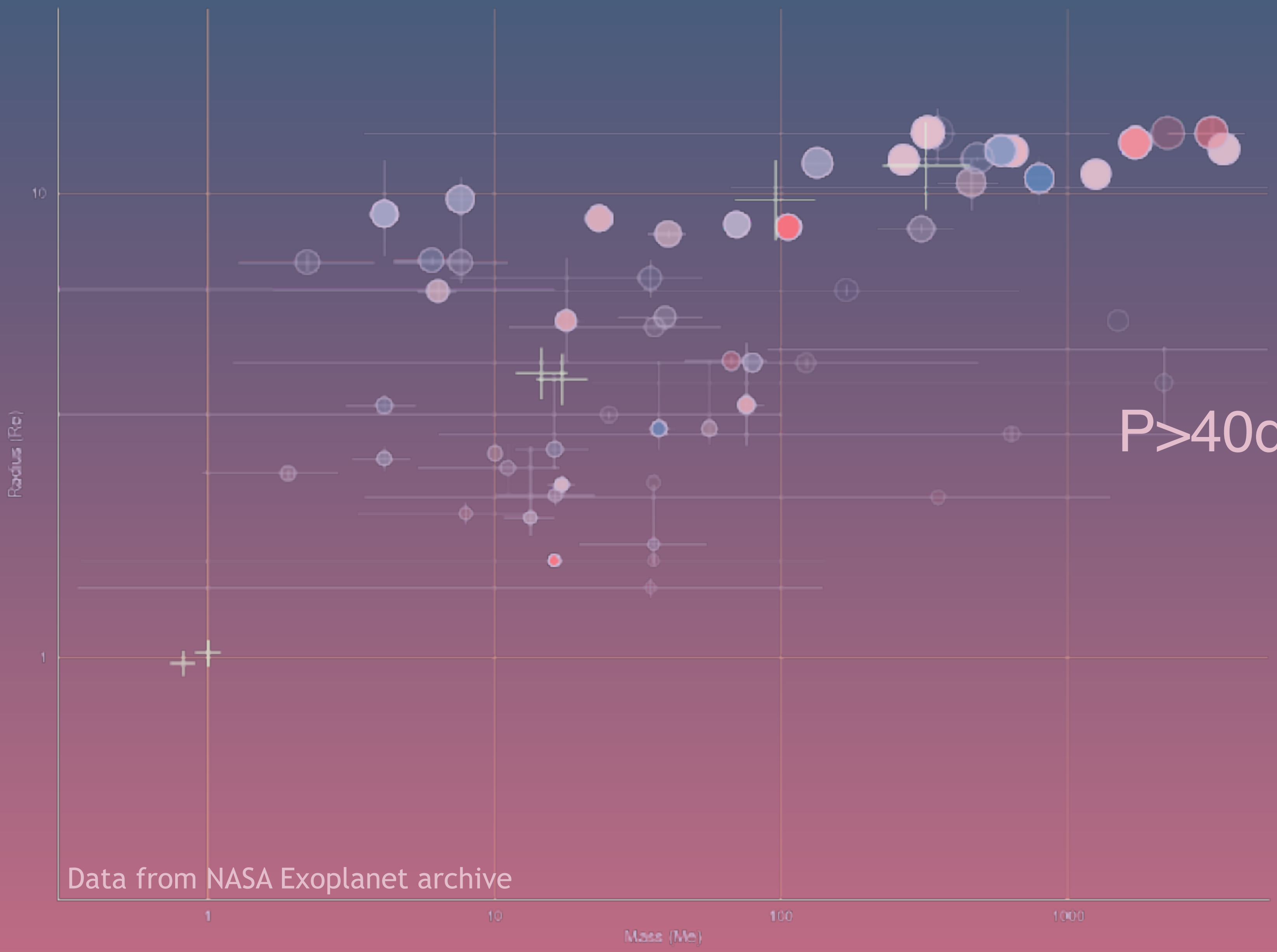
THE STATE OF EXOPLANET DETECTION



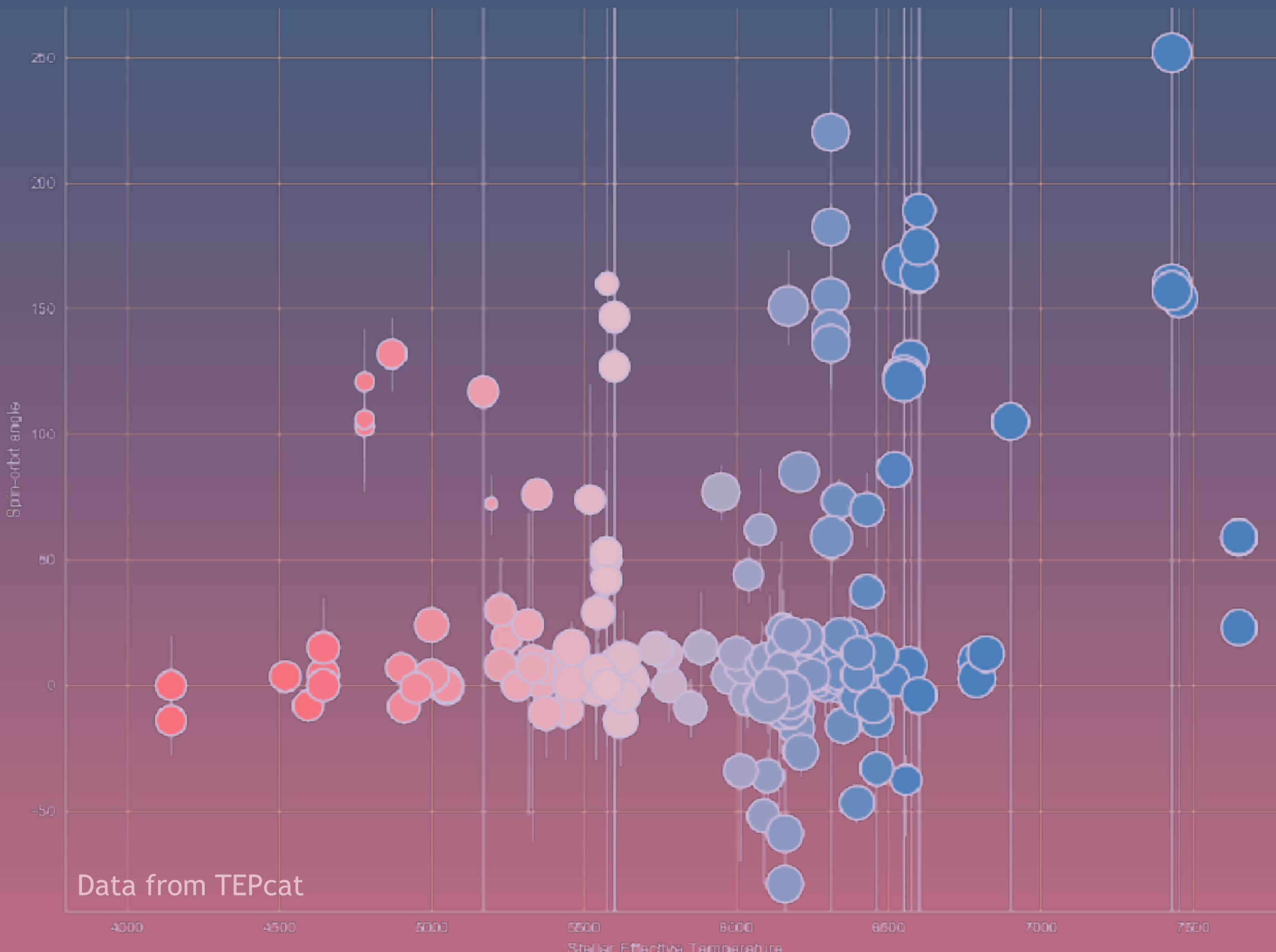
THE STATE OF EXOPLANET CHARACTERISATION



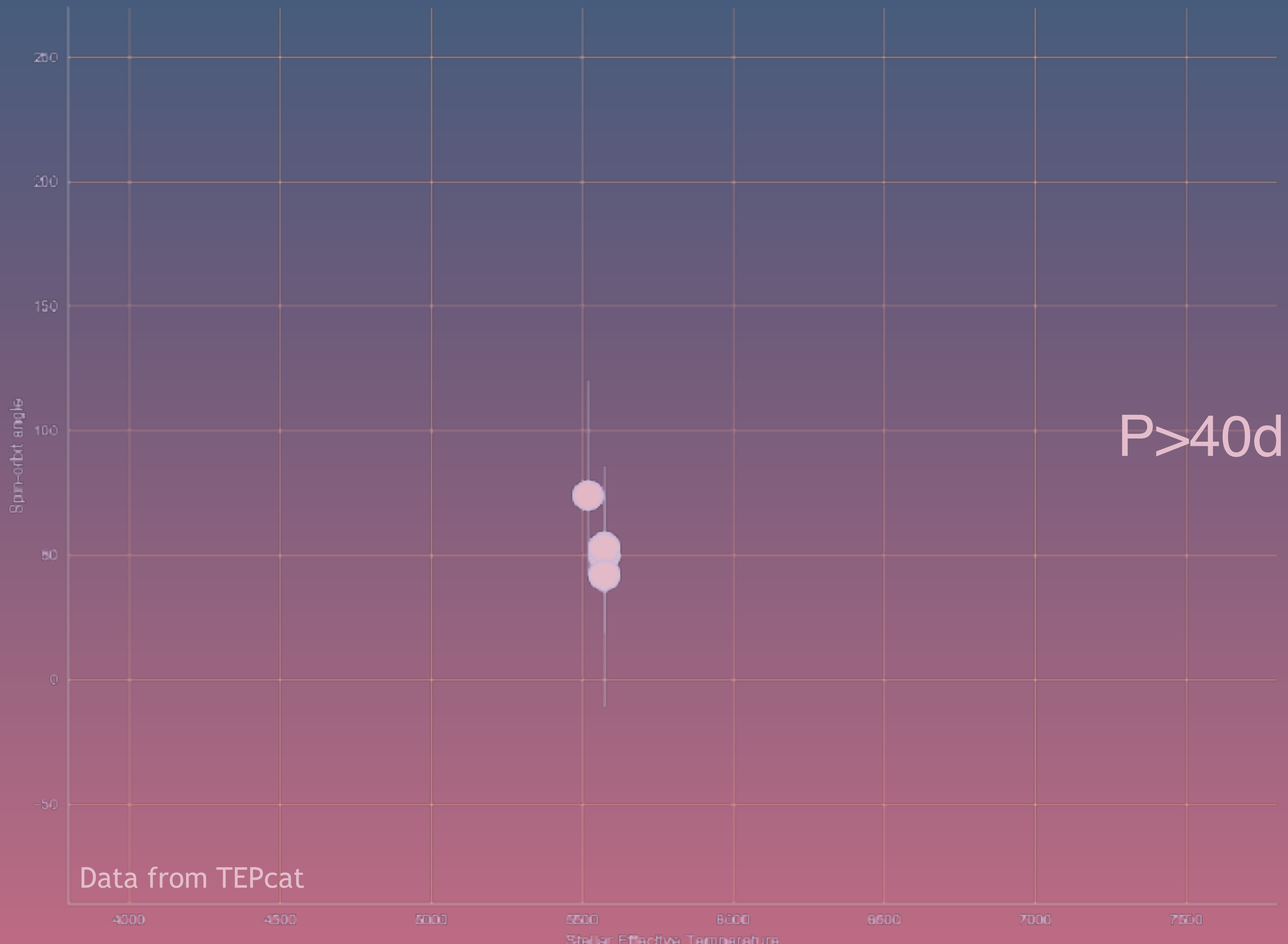
THE STATE OF EXOPLANET CHARACTERISATION



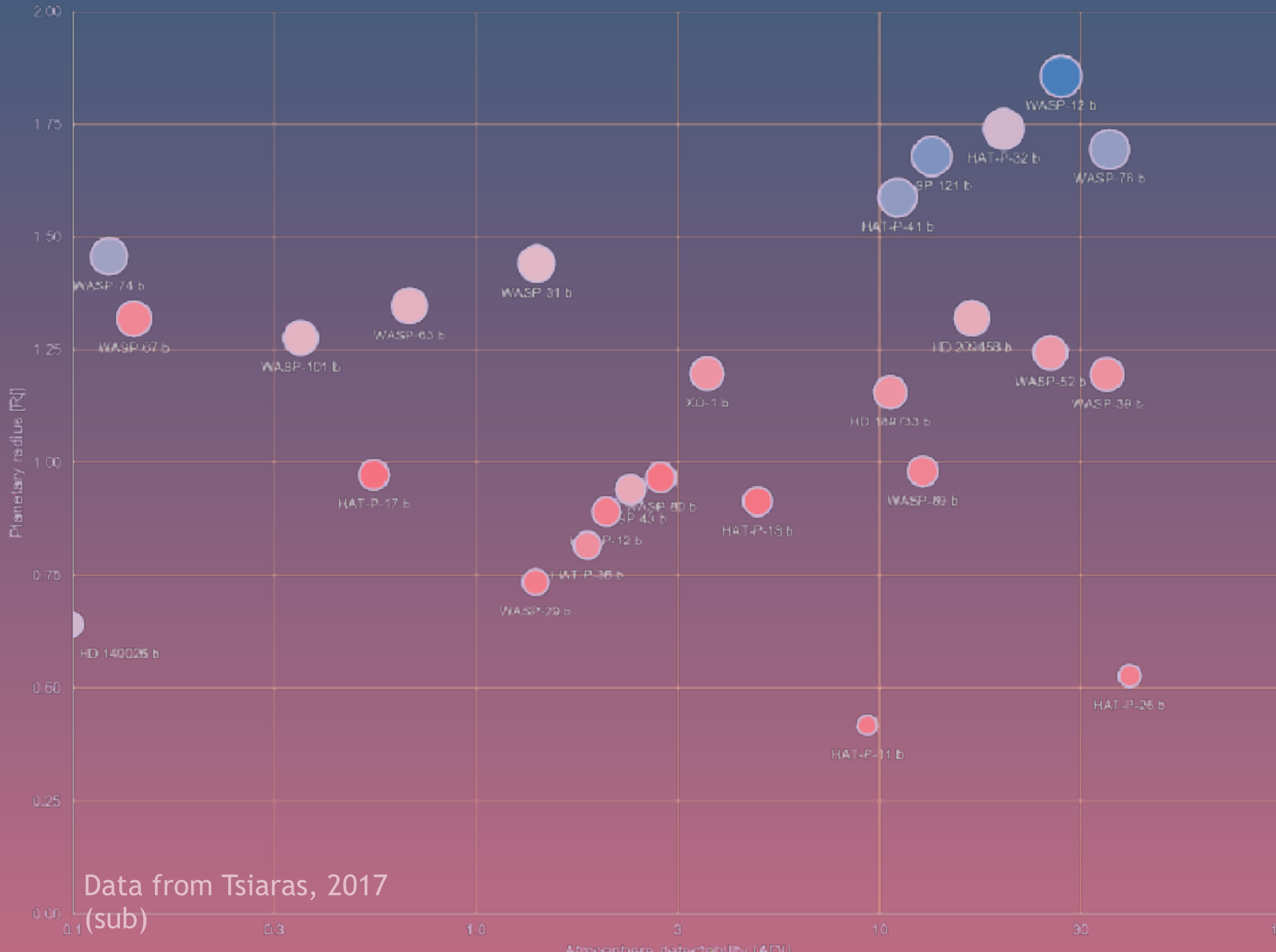
THE STATE OF EXOPLANET CHARACTERISATION



THE STATE OF EXOPLANET CHARACTERISATION

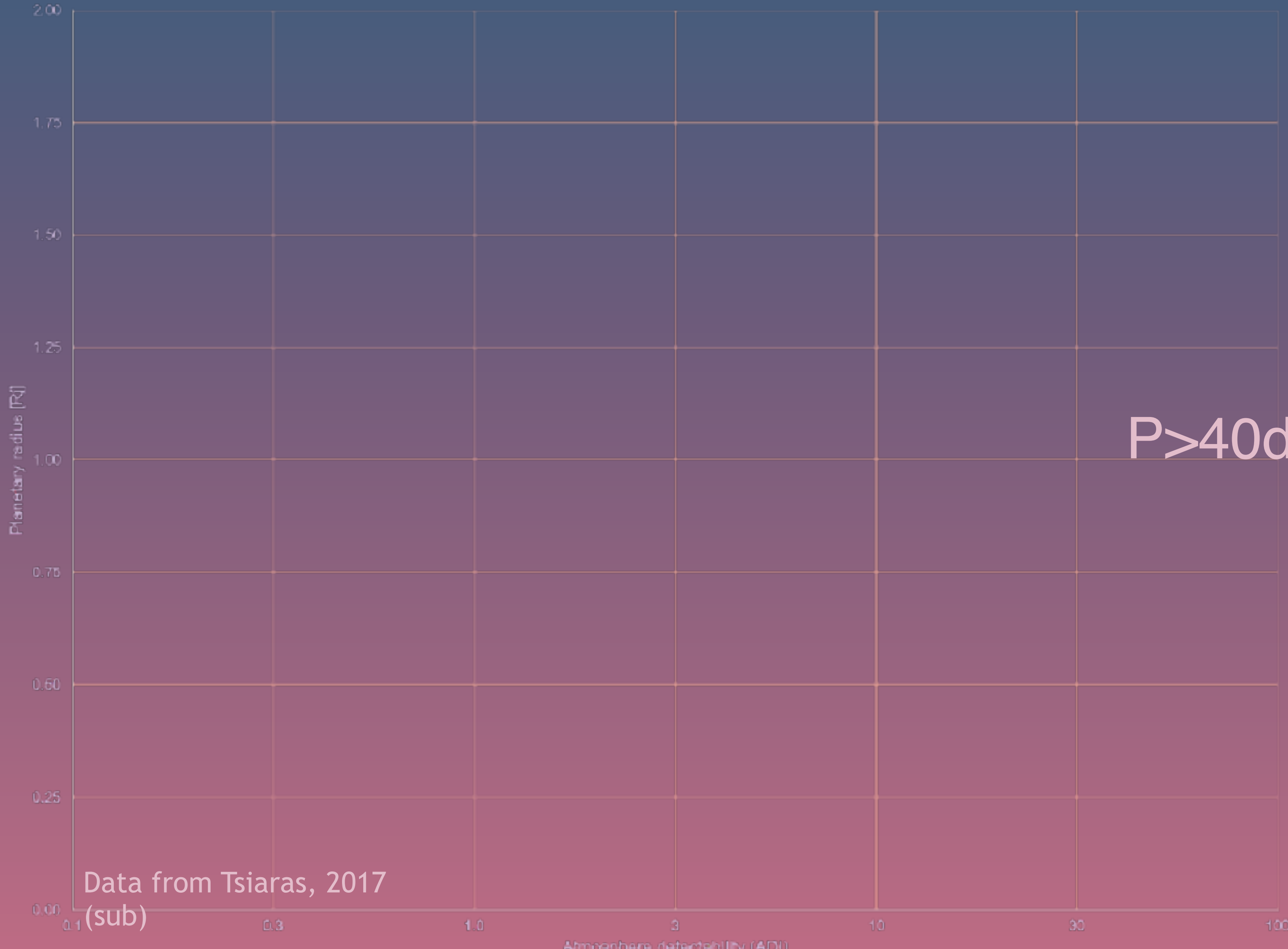


THE STATE OF EXOPLANET CHARACTERISATION

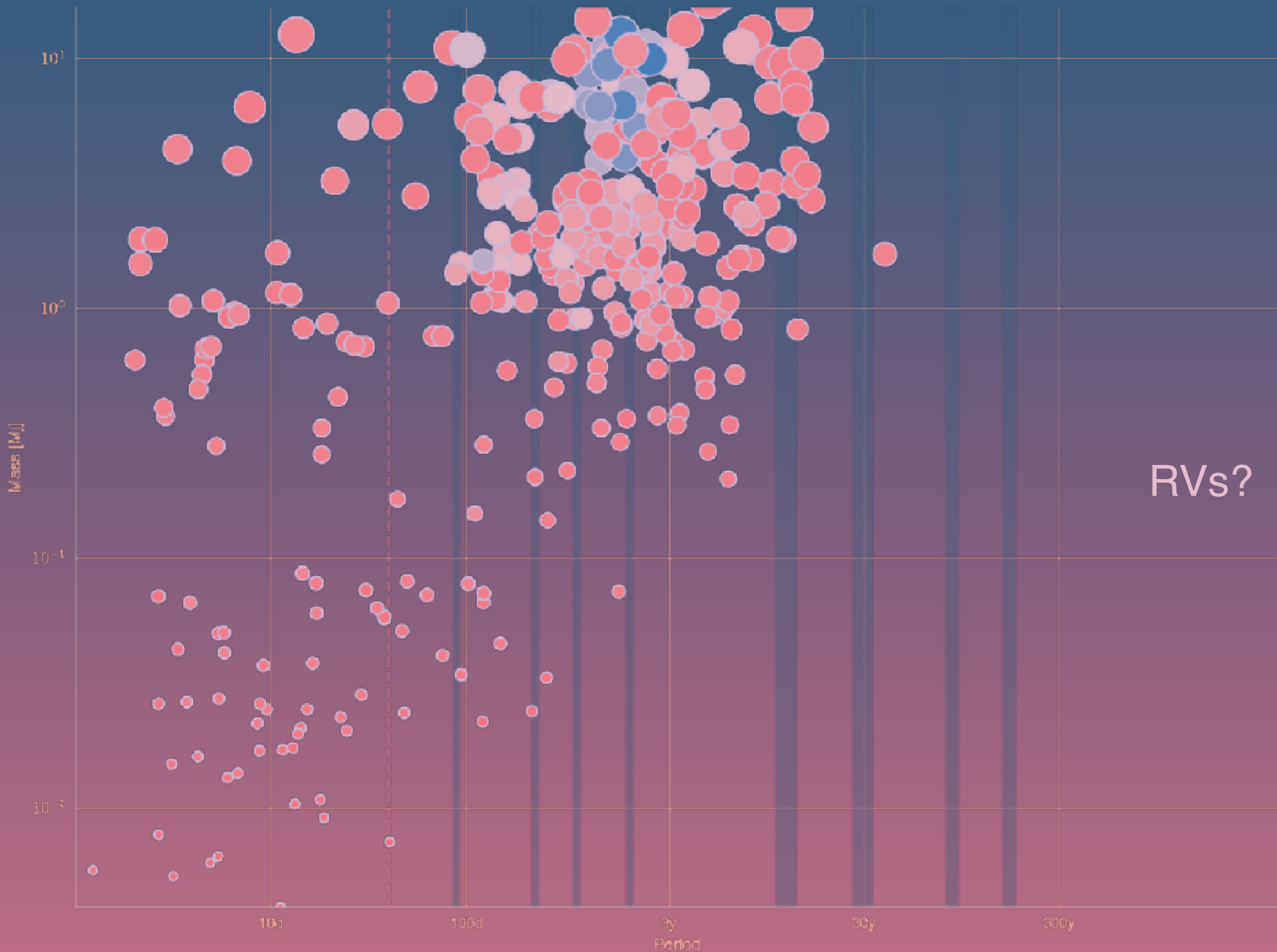


Data from Tsiaras, 2017 (sub)

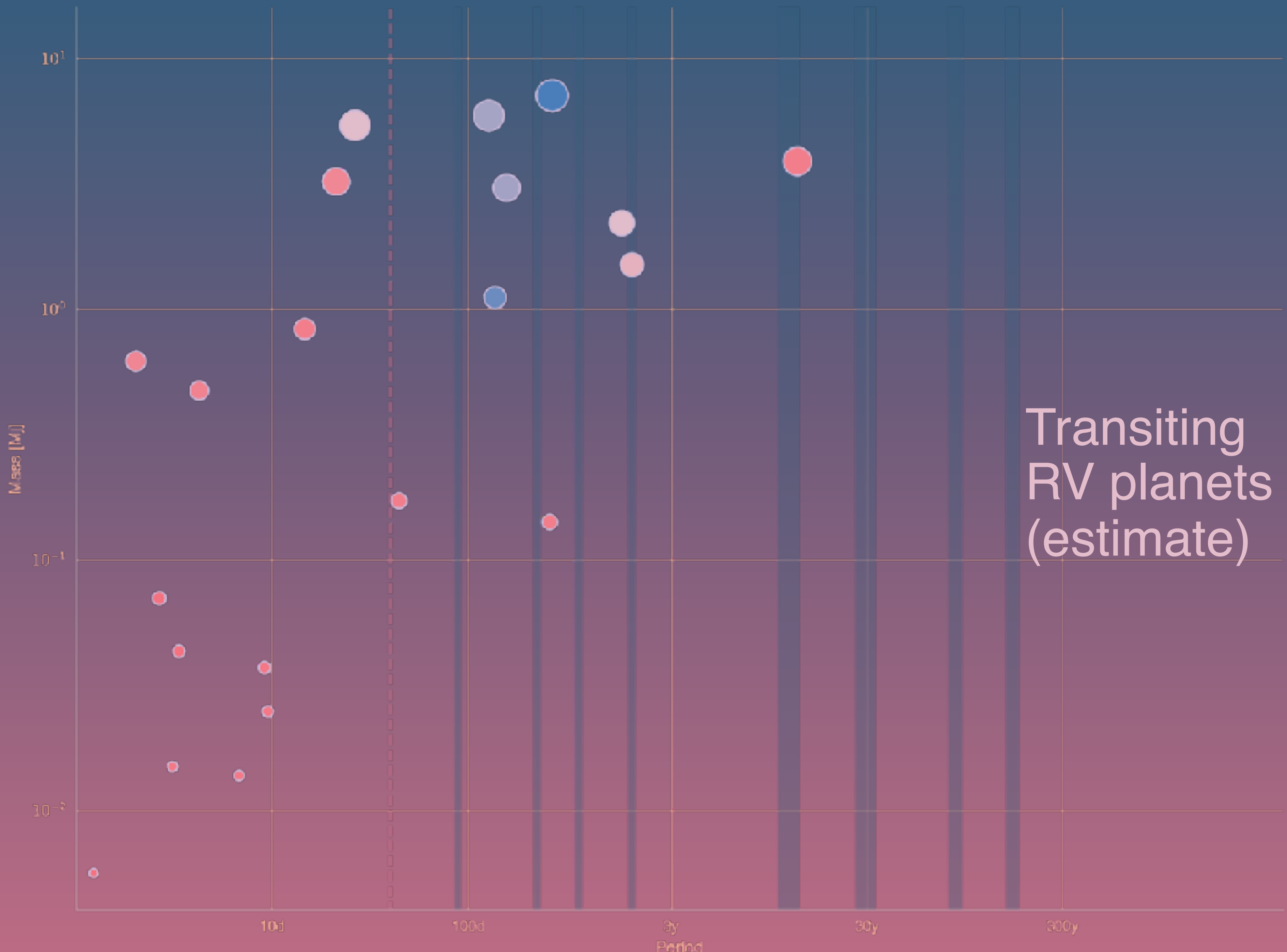
THE STATE OF EXOPLANET CHARACTERISATION



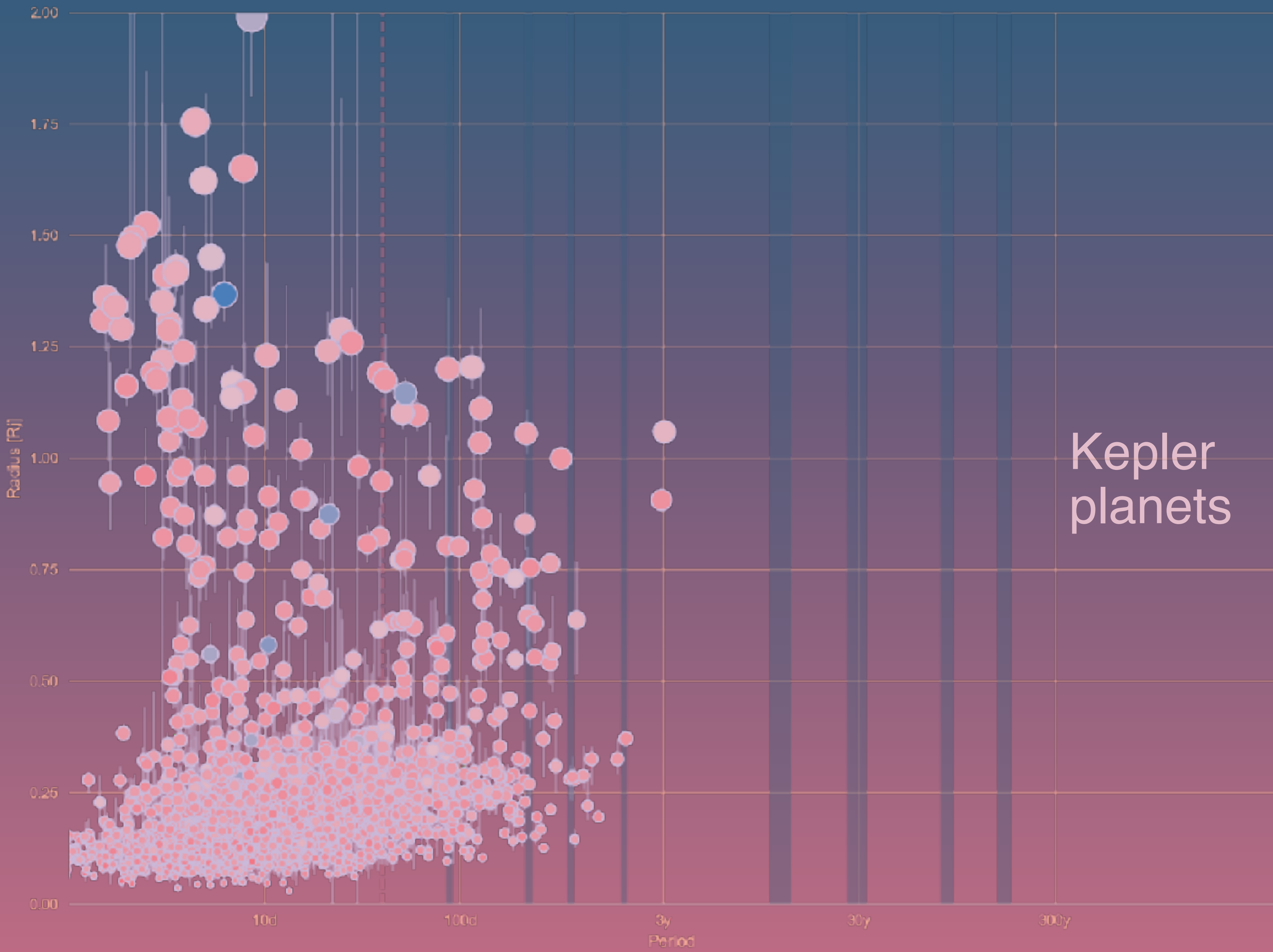
SO HOW DO WE REACH LONGER PERIODS?



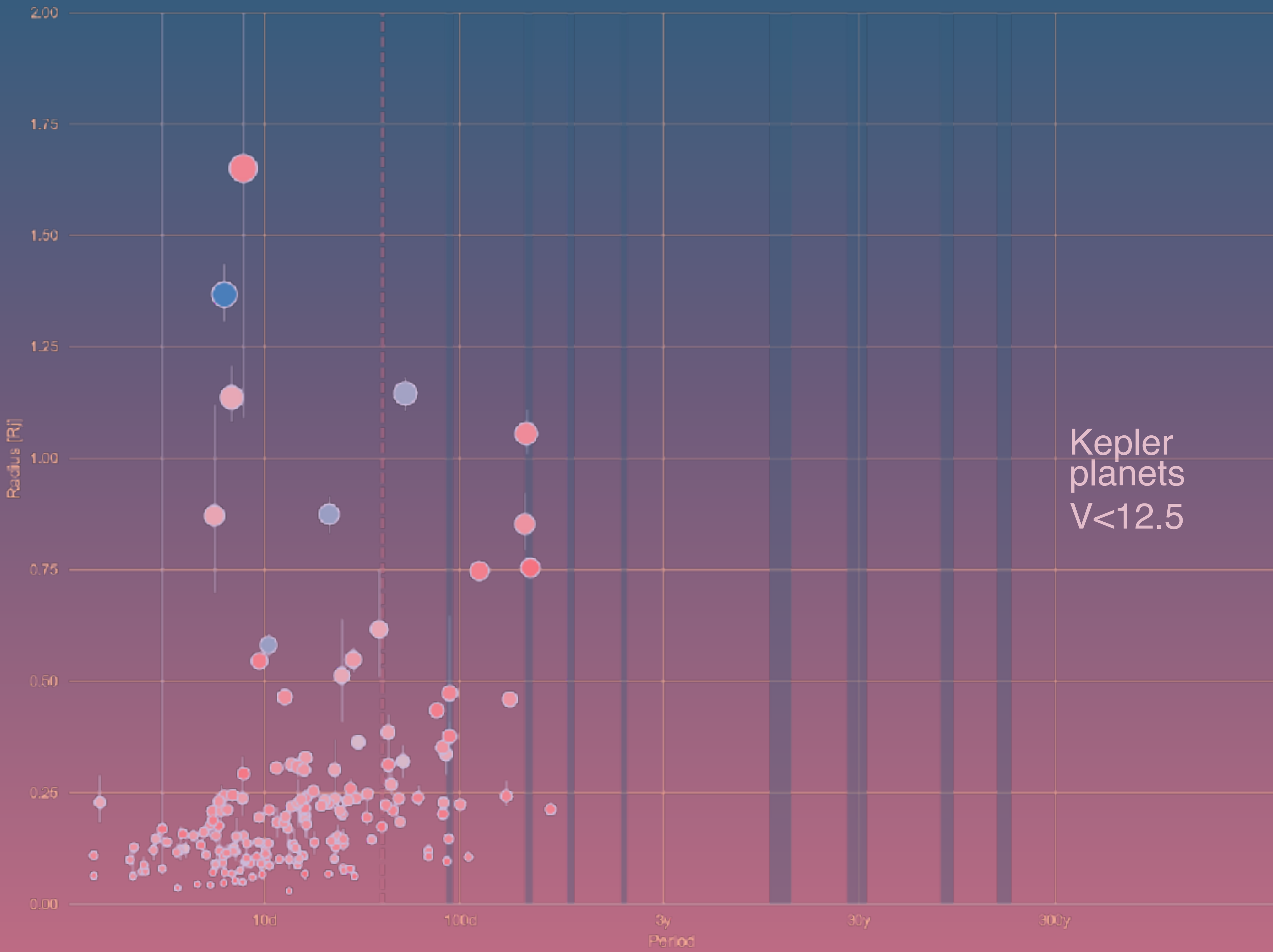
RVs?



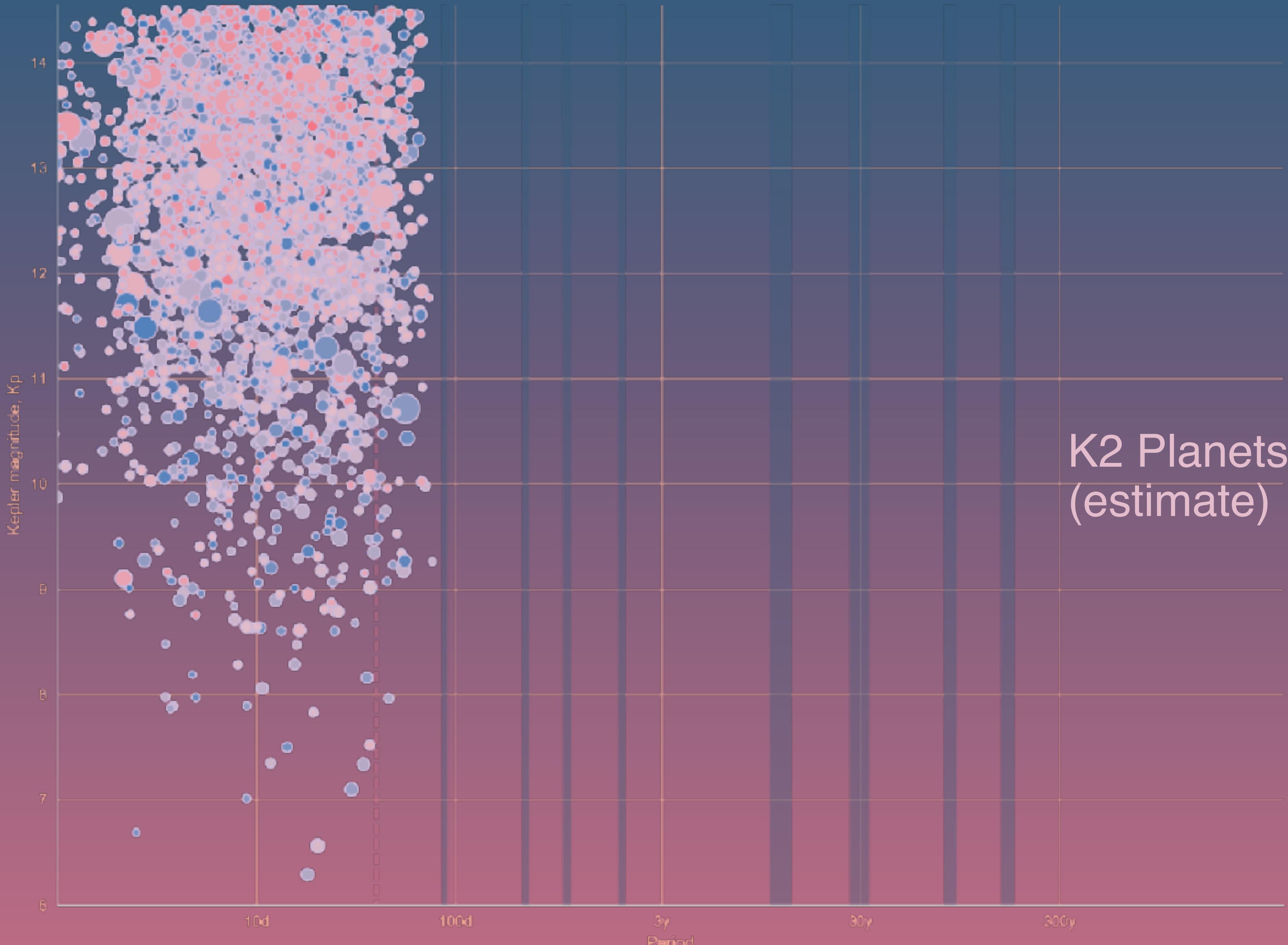
Transiting
RV planets
(estimate)



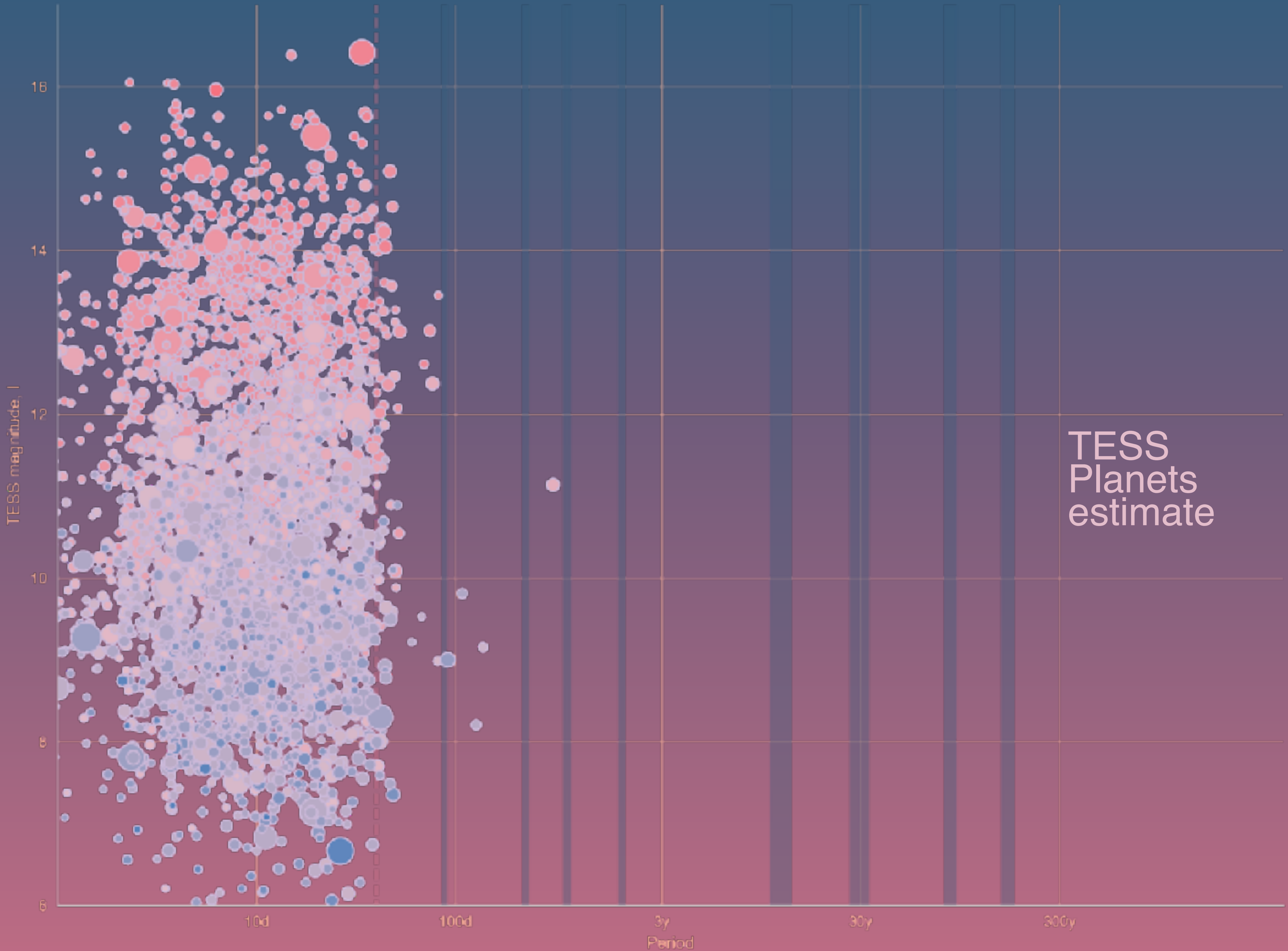
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Radius [Rj]
10d
100d
3y
30y
300y
Period
Kepler
planets



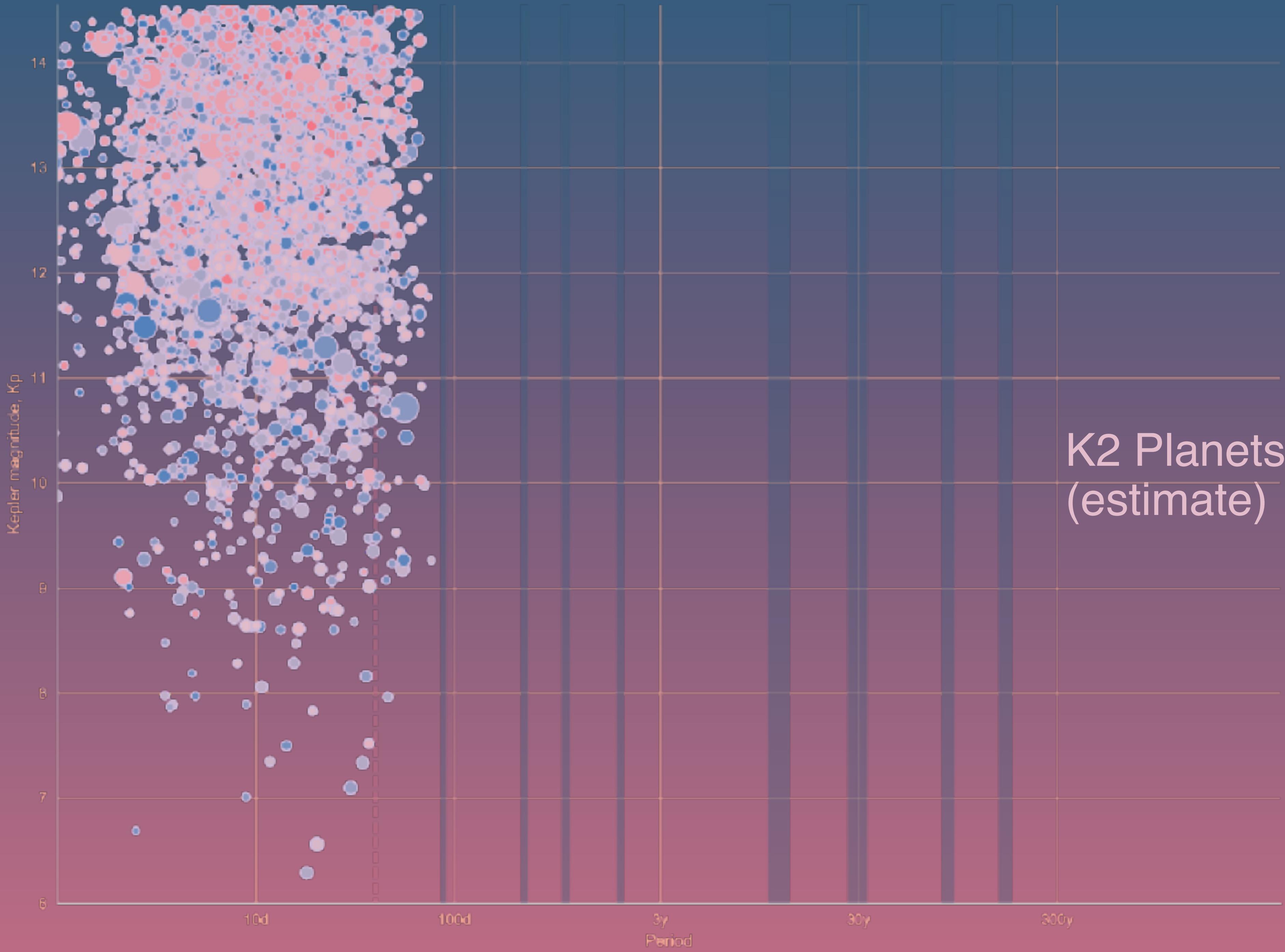
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Radius [RJ]
10d
100d
3y
30y
300y
Period
Kepler planets
V<12.5



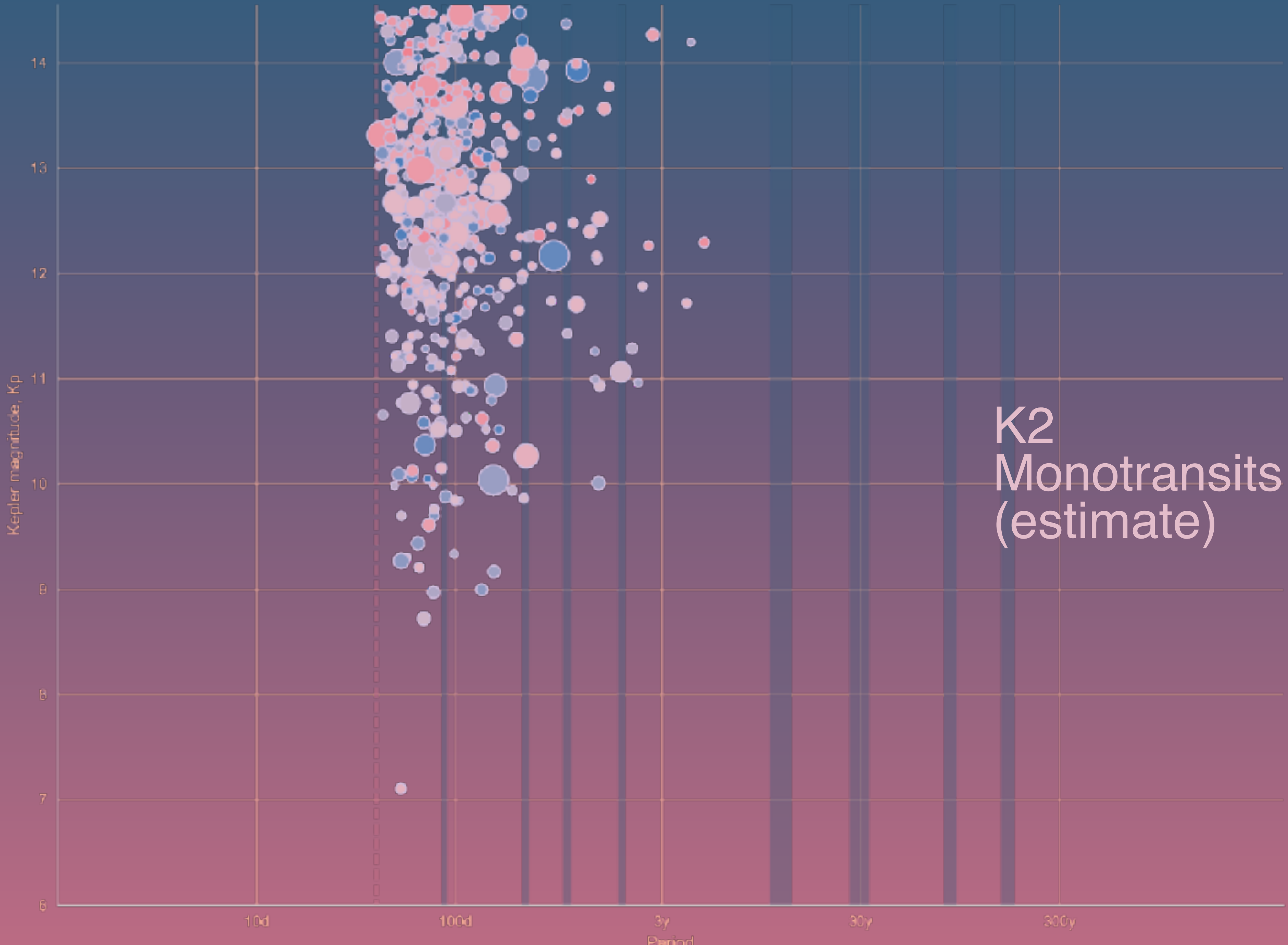
K2 Planets
(estimate)

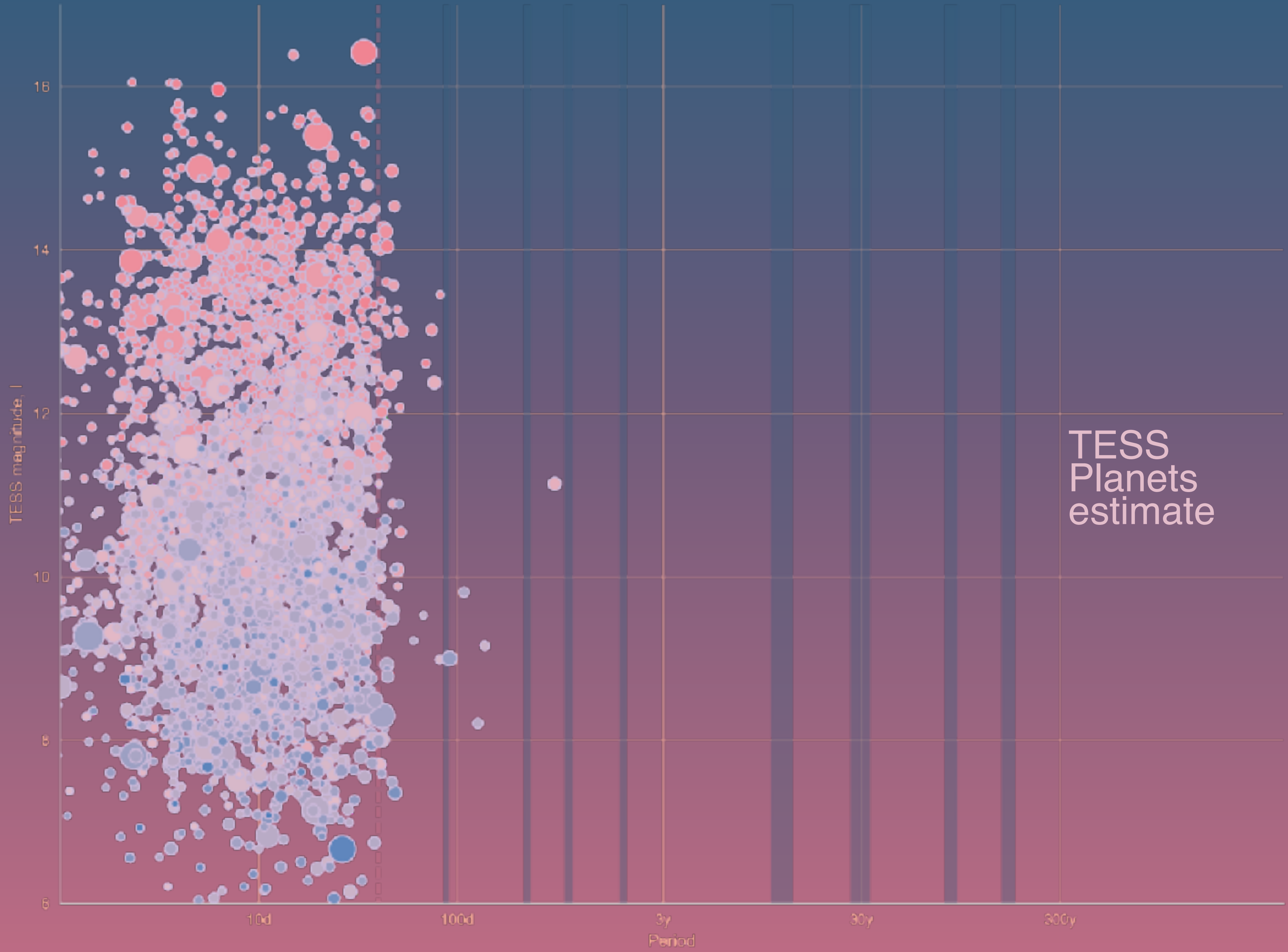


TESS
Planets
estimate

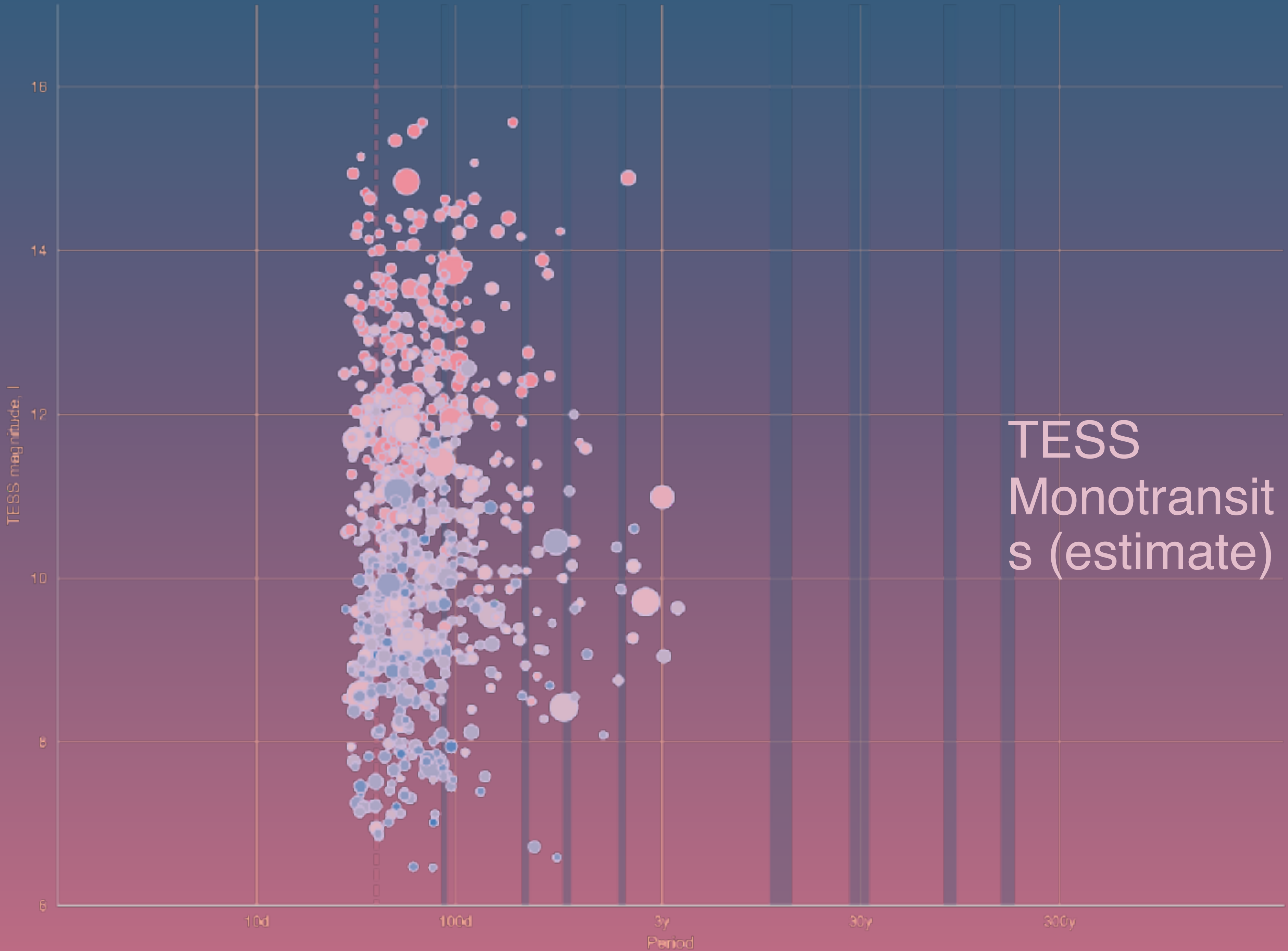


K2 Planets
(estimate)


K2
Monotransits
(estimate)
Kepler magnitude, Kp
14
13
12
11
10
9
8
7
6
10d
100d
3y
30y
300y
Period



TESS
Planets
estimate



TESS Monotransits (estimate)

FINDING SINGLE TRANSITS

From Kepler:

- Papers by Wang (2015), Uehara (2016) & Foreman-Mackey (2016) found 67 planet candidates.
- 2.7±0.9 planets with 0.1-1R_J and $2<P<25$ yrs.

From K2:

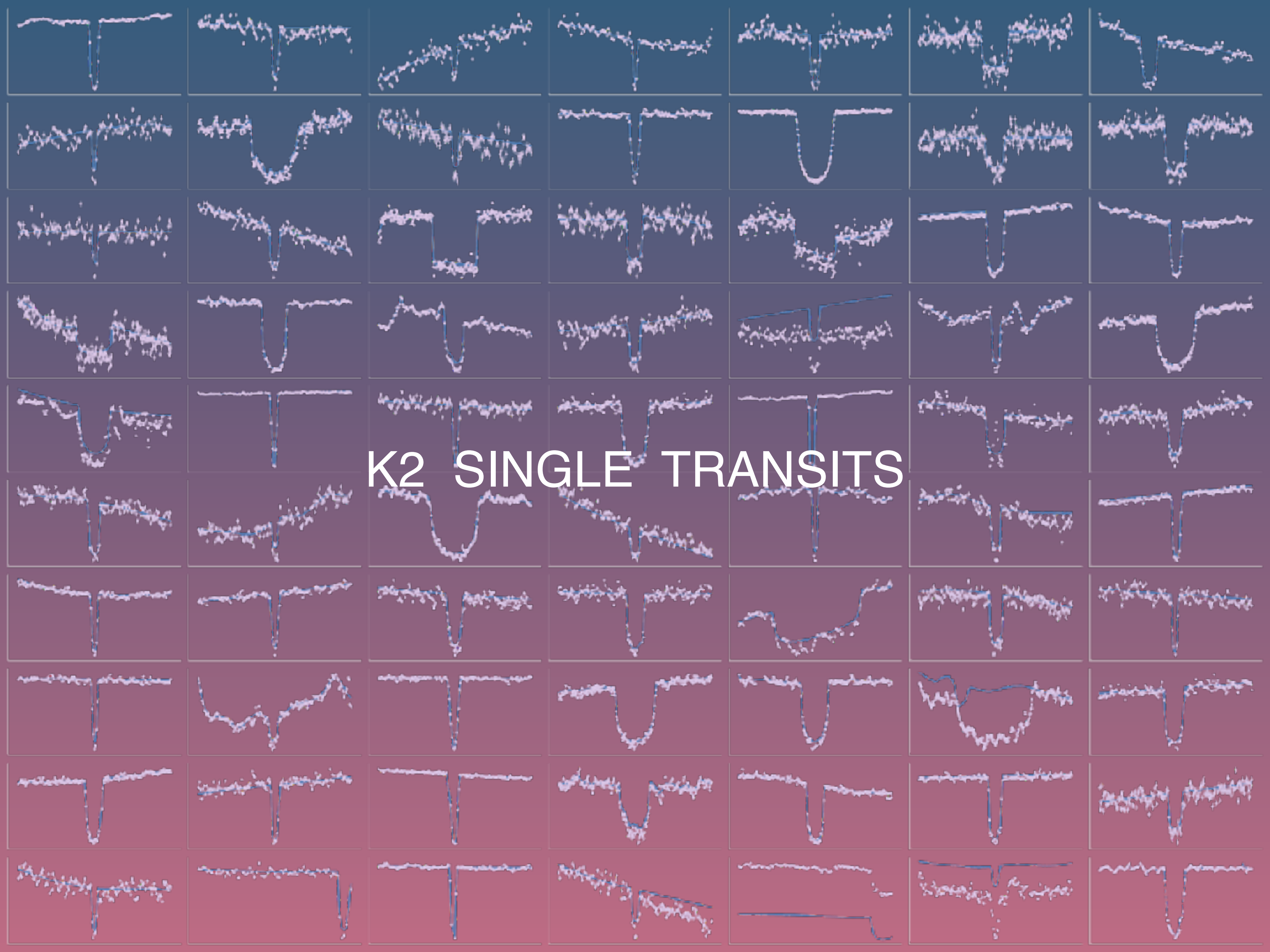
- K2-2b; 9d period. Vanderburg (2013)
- HR 41378 d, e & f; Vanderburg (2016)

From the ground:

- LHS 1140b, Dittmann (2017)

FINDING SINGLE TRANSITS

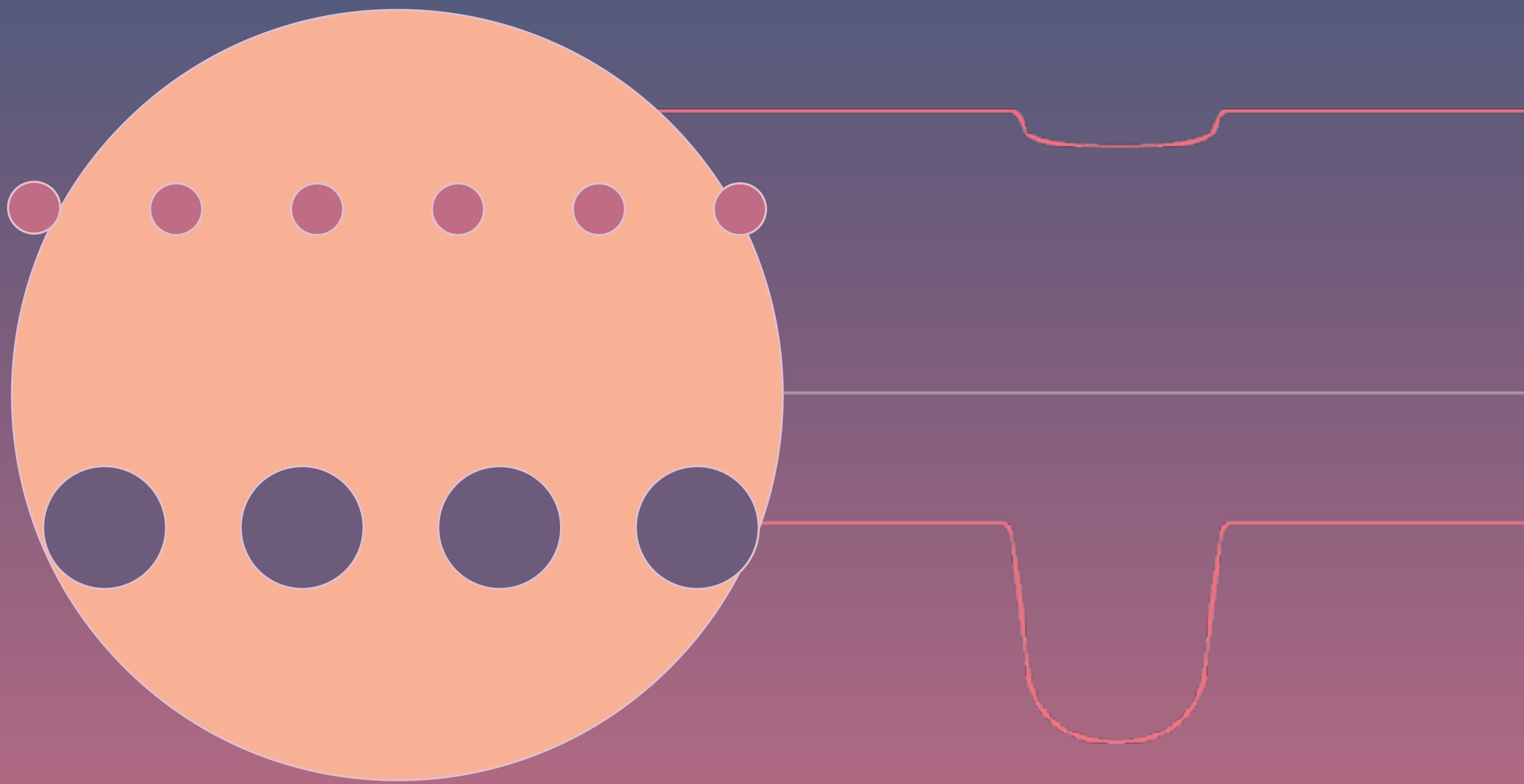
- Often detected in “normal” phase-folded transit searches
- Manual “Eyeballing” (eg Planet Hunters)
- Single transit-specific search (preliminary):
  - Finds all dips in the lightcurve
  - Fit transit model and noise model to dips
  - Use random forest trained on injections to classify dip


K2 SINGLE TRANSITS

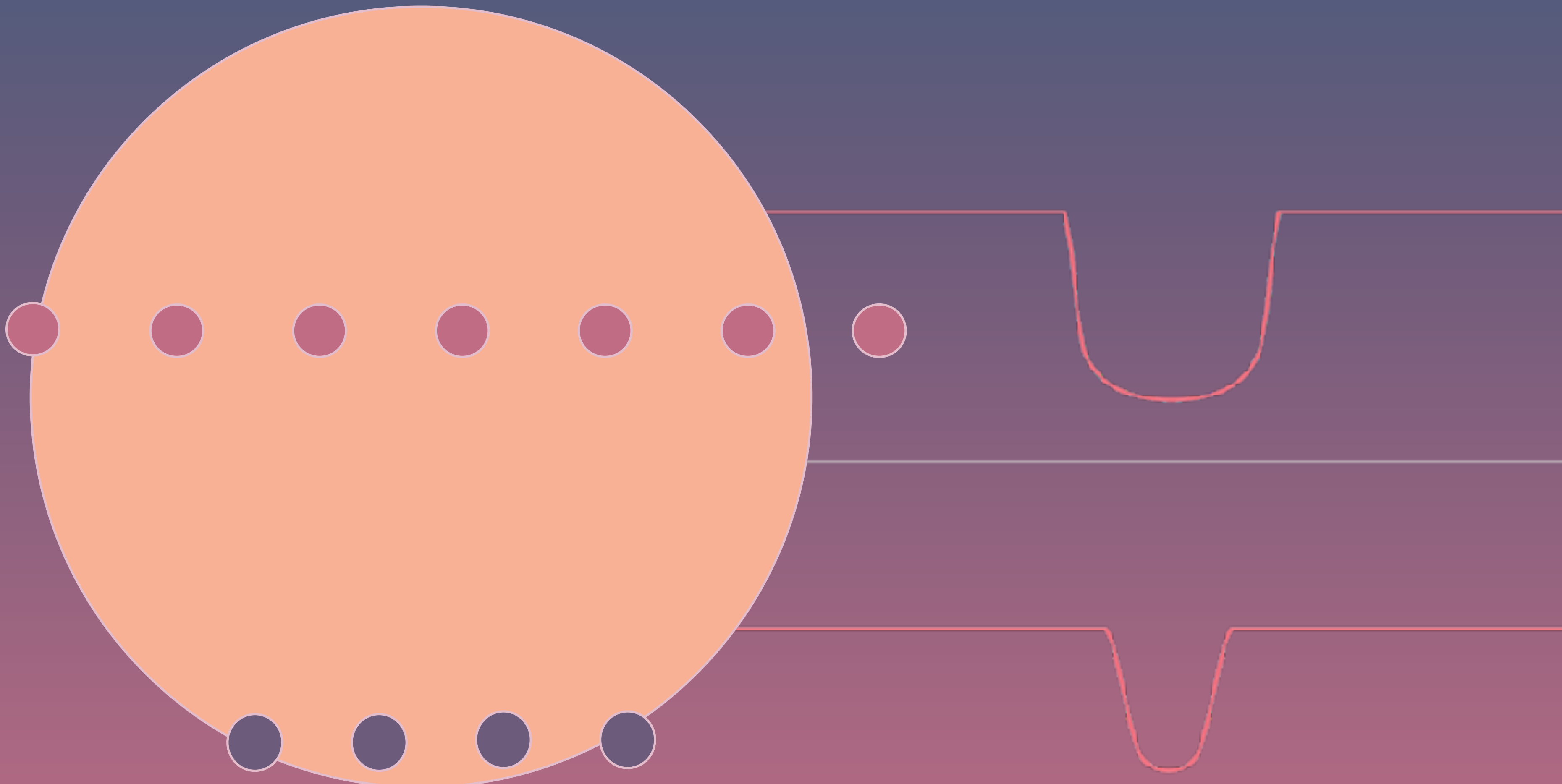
K2 SINGLE TRANSITS

- ~150 Candidates
- 80 EBs (depth>2%)
  - 30 include secondary eclipse
- 70 Planet candidates validated using:
  - Centroid shift
  - Check raw postage stamp images (k2flix)
  - Depth difference in different detrending methods
  - 52 have 67%+ of planet radii posterior $<1.5R_{Jup}$

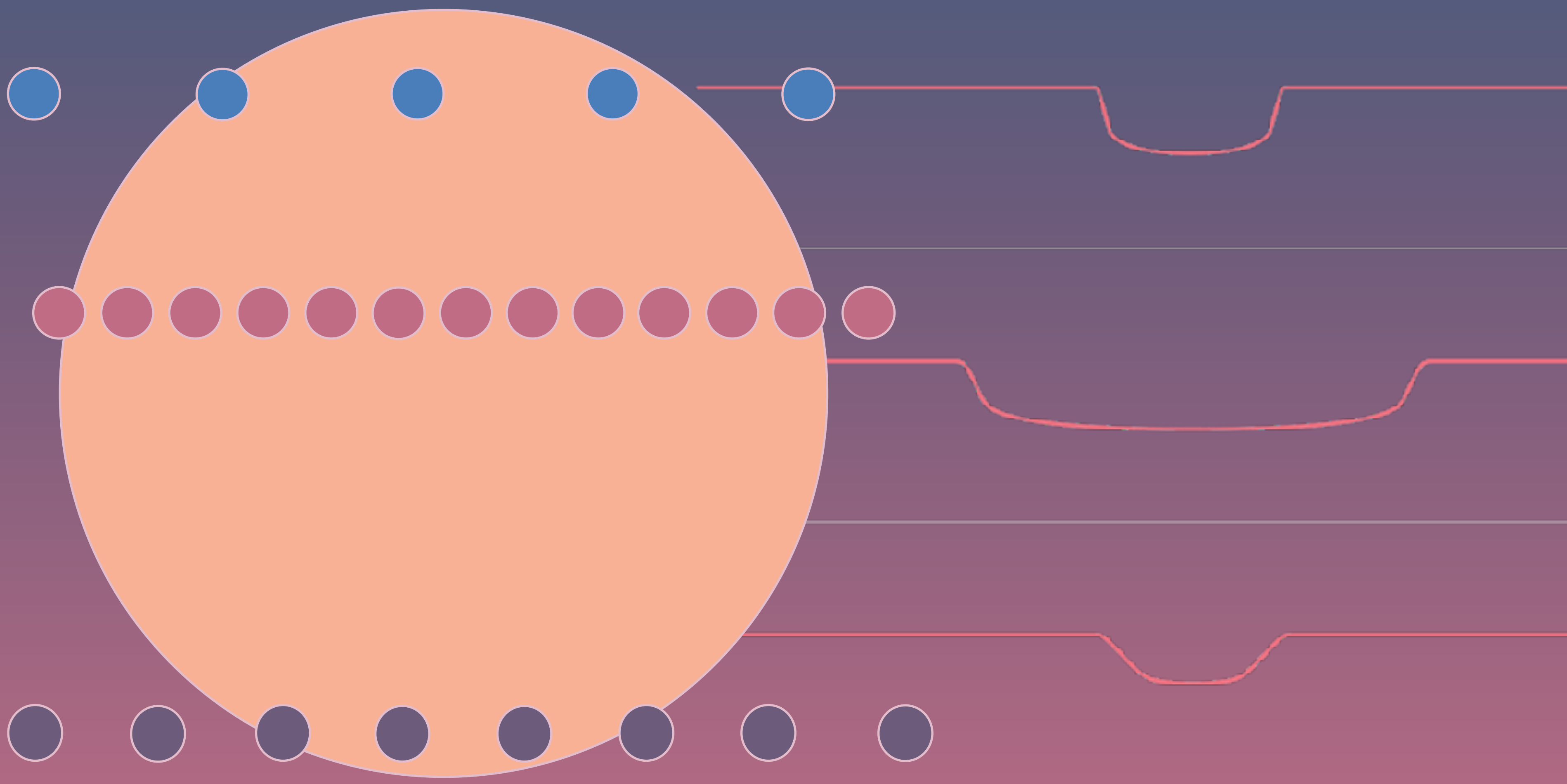
CHARACTERISING PLANETS FROM SINGLE TRANSITS



CHARACTERISING PLANETS FROM SINGLE TRANSITS



CHARACTERISING PLANETS FROM SINGLE TRANSITS



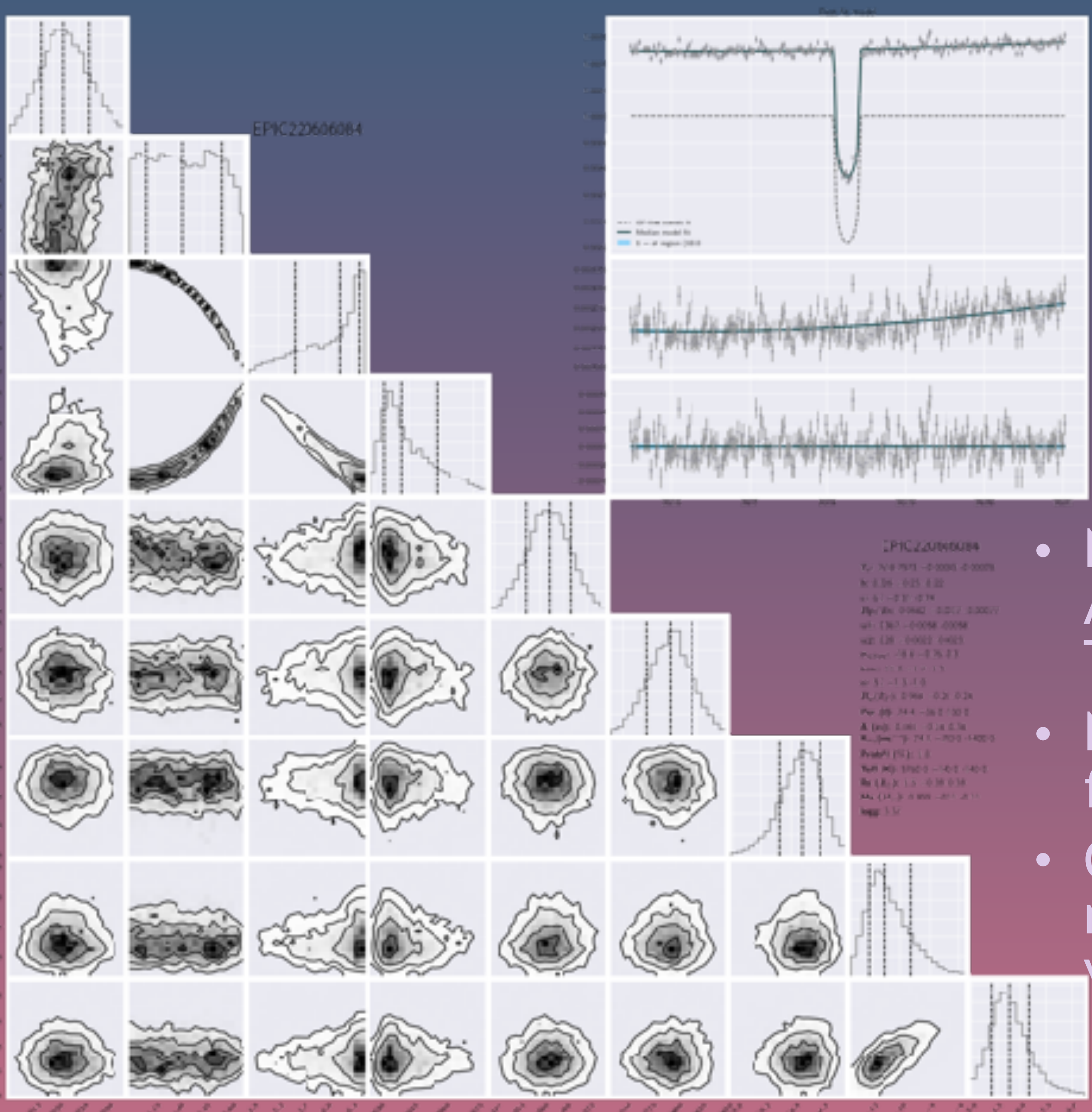
CHARACTERISING PLANETS FROM SINGLE TRANSITS

Assumptions:

- Limb Darkening set with Stellar T_{eff} and log g
- Circular orbit
- No dilution/blending
- Model-dependent stellar radius from stellar evolution models (where log g is available) or main sequence fit.

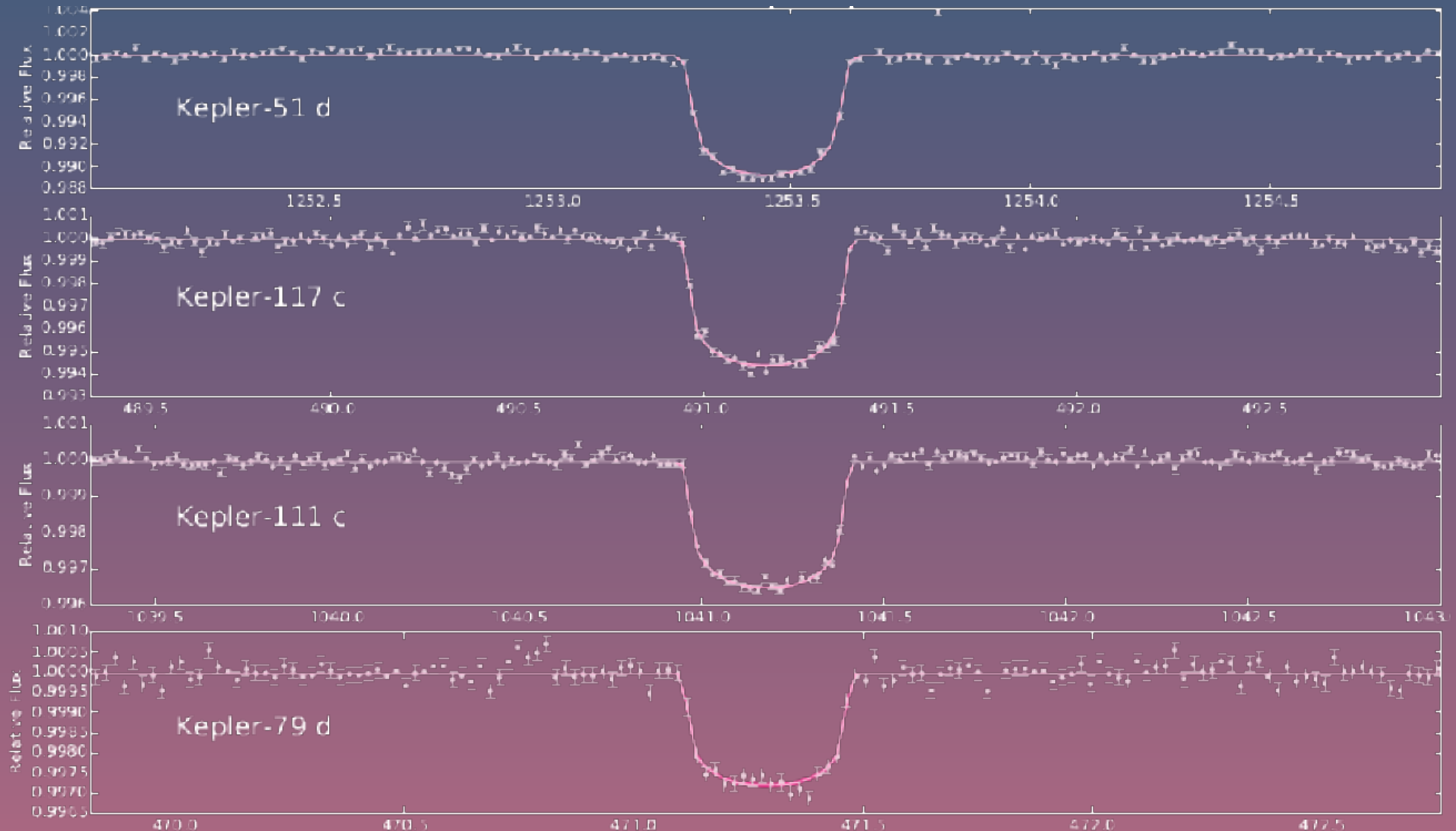
Stellar information from spectra (~30 objects) or EPIC (Huber, 2014)

CHARACTERISING PLANETS FROM SINGLE TRANSITS

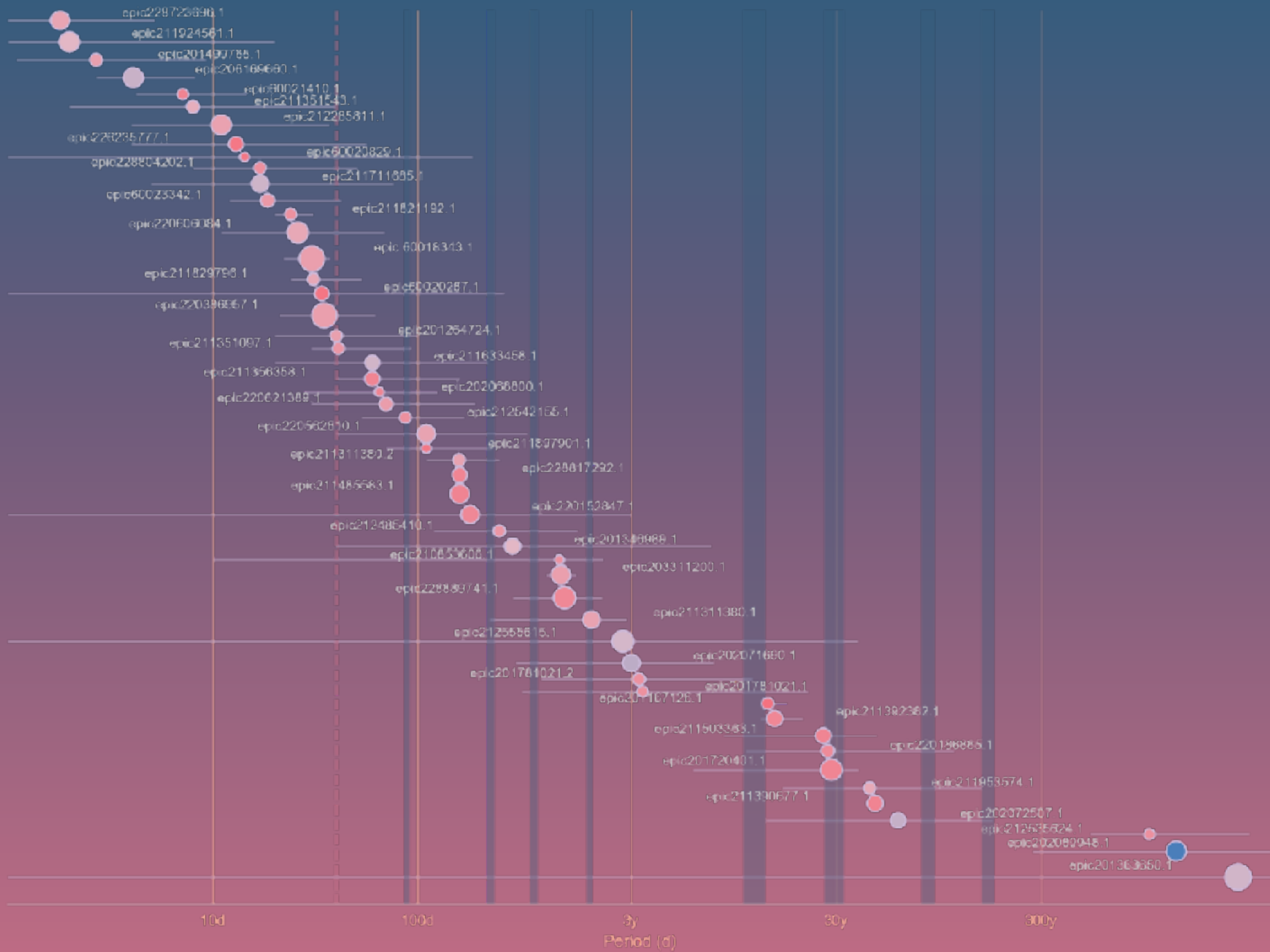


- Namaste: An MCMC Analysis of Single Transiting Exoplanets
- Namaste MCMC model for EPIC 220606084
- Gaussian Processes to model stellar variability

CHARACTERISING PLANETS FROM SINGLE TRANSITS



Namaste runs on known Kepler planets - estimates periods within uncertainties (<20%)



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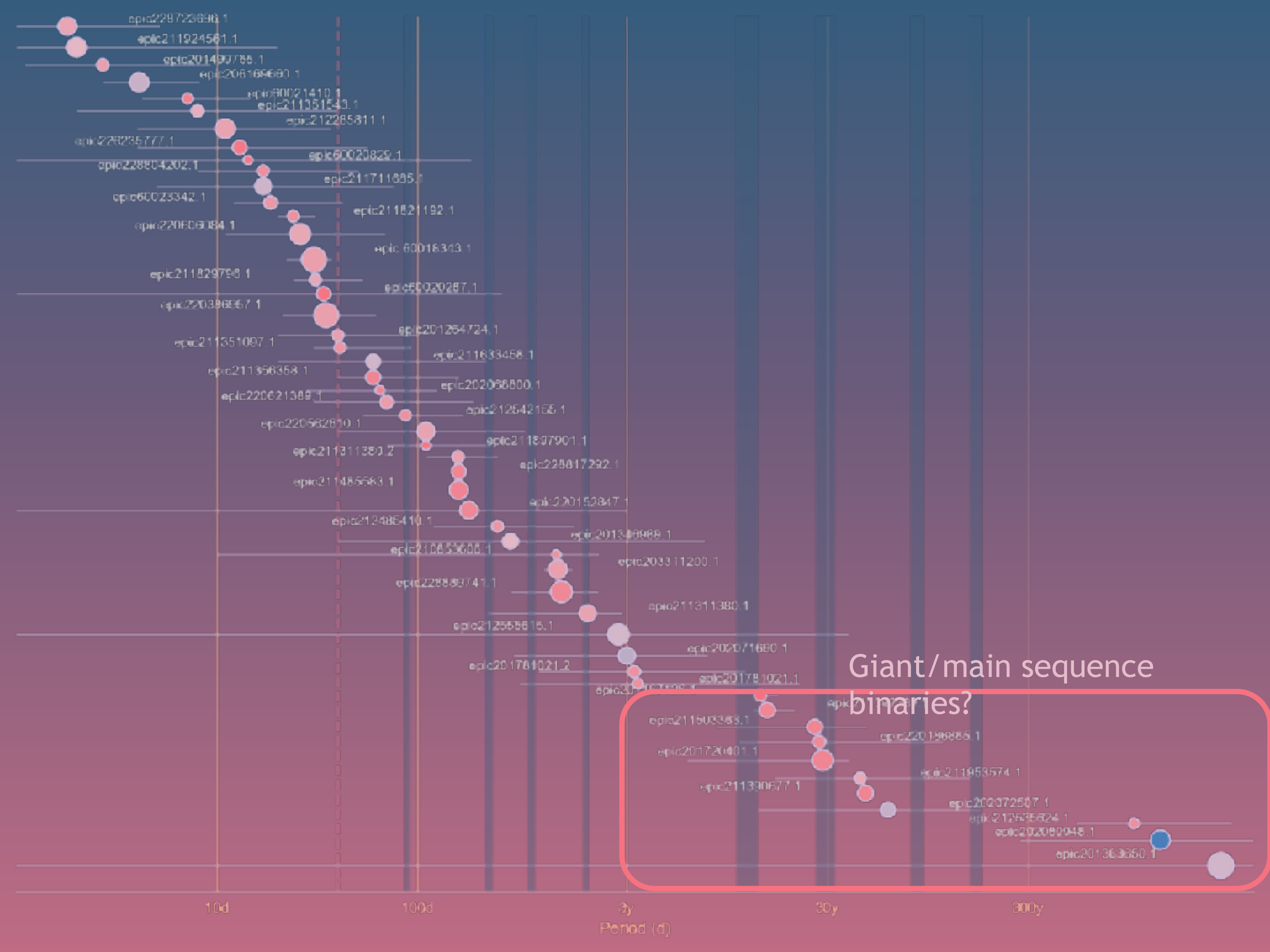
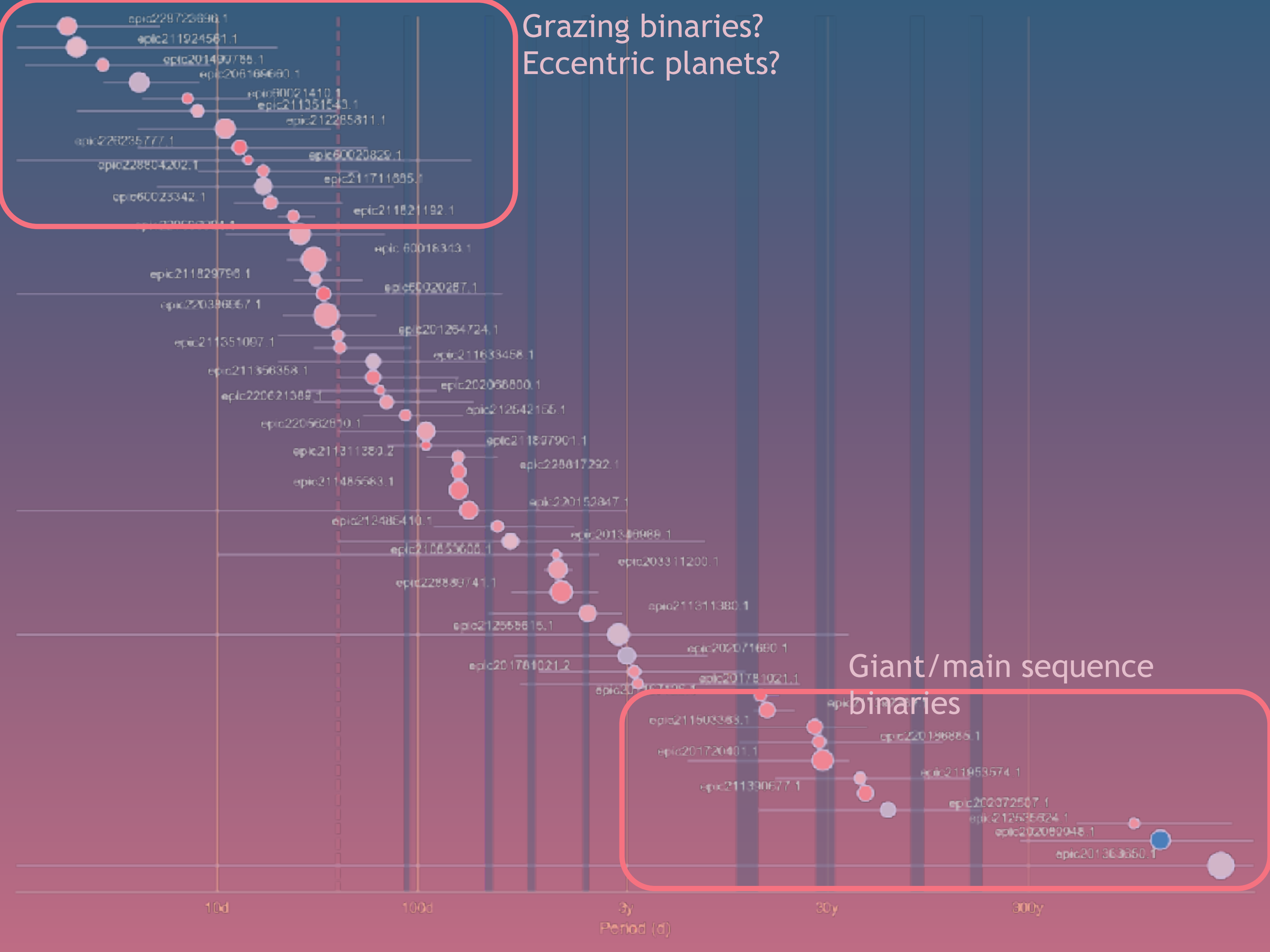
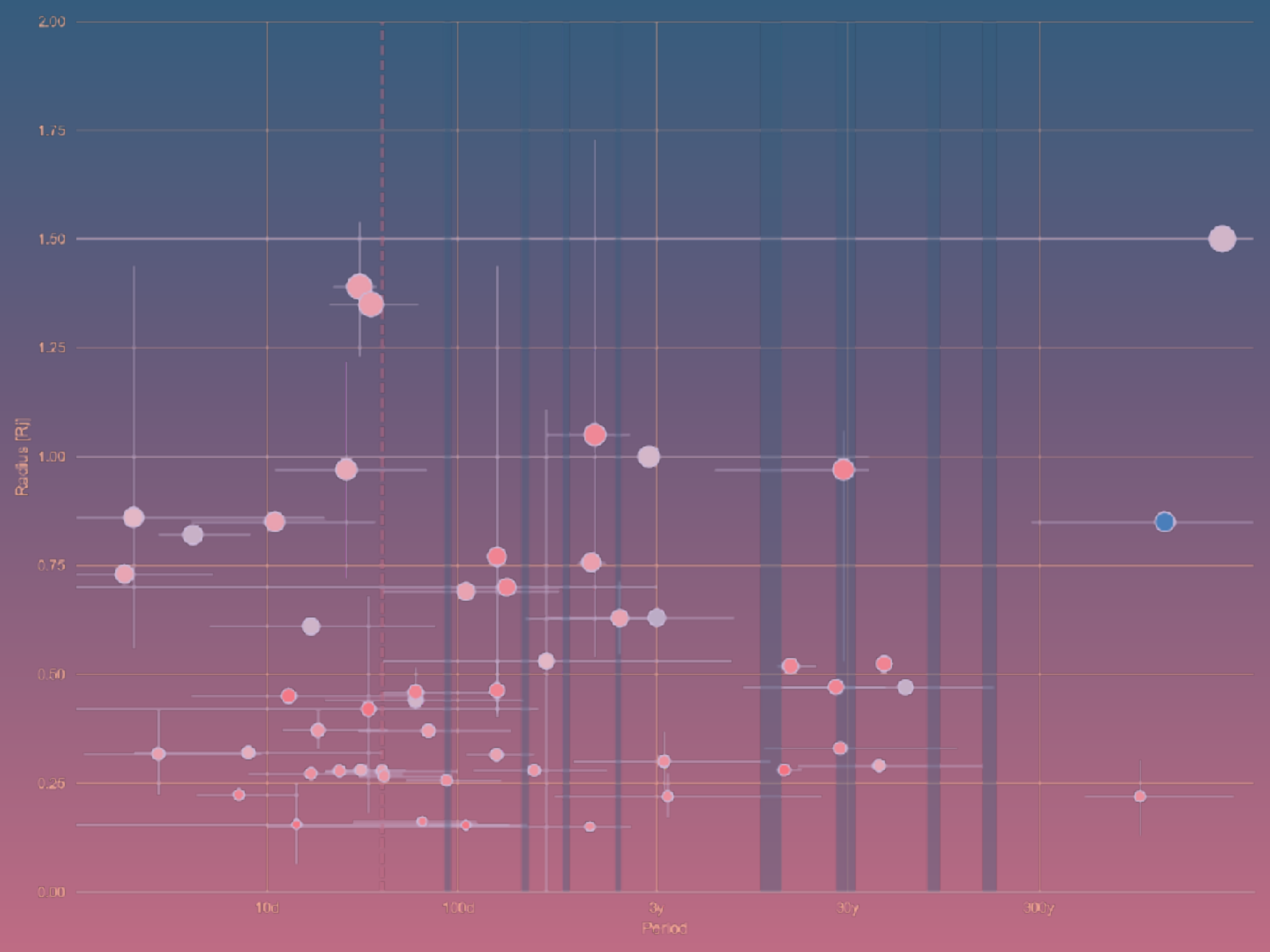
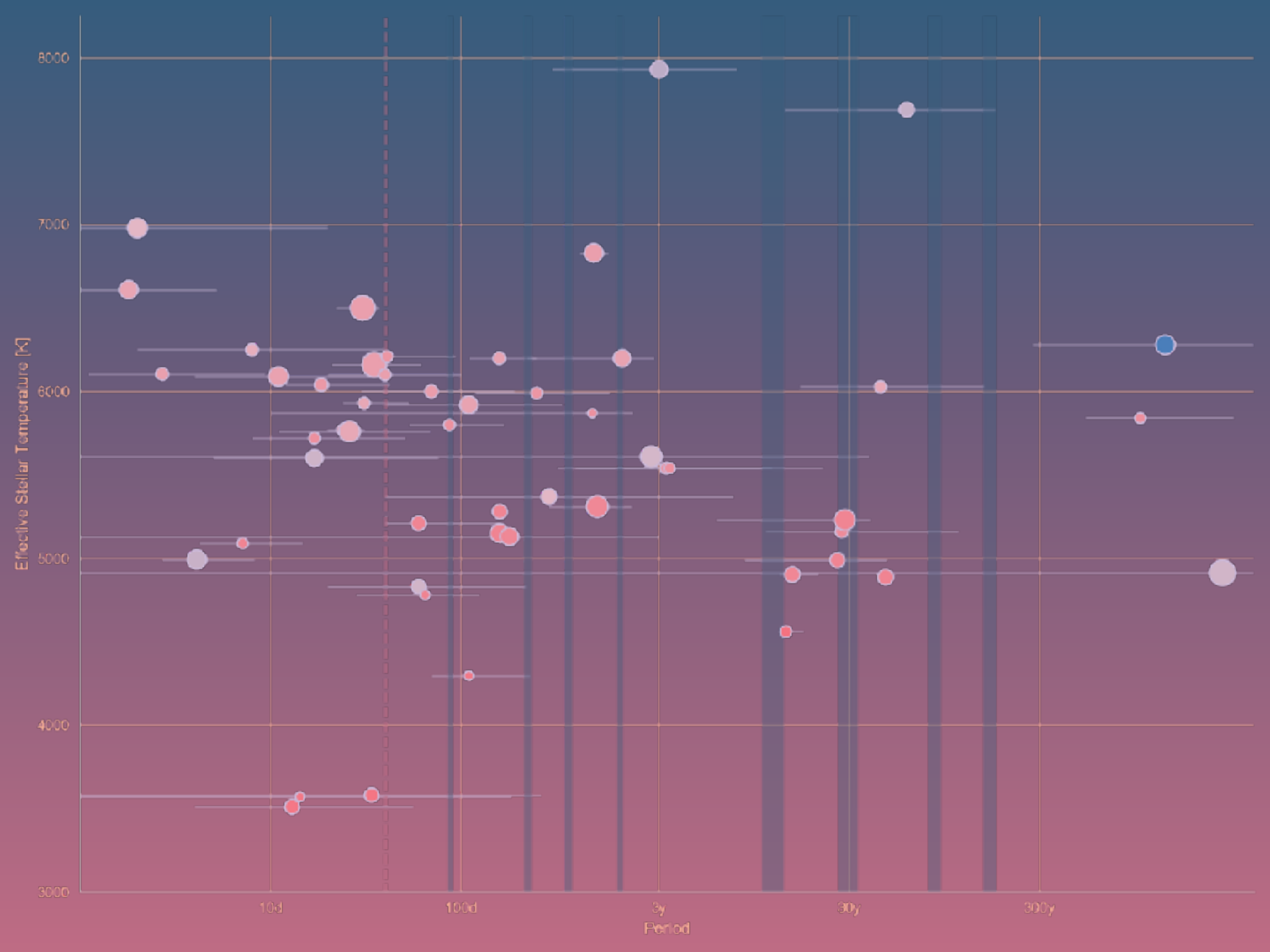
epic212285811.1
epic211821192.1
epic211829798.1
epic220396867.1
epic201264724.1
epic211351097.1
epic211633458.1
epic211356358.1
epic202066800.1
epic220621389.1
epic212542155.1
epic211311380.2
epic211485583.1
epic212485410.1
epic203311200.1
epic211311380.1
epic212555615.1
epic202071680.1
epic201781021.2
epic201781021.1
epic211392387.1
epic201720401.1
epic211953574.1
epic211390677.1
epic202072507.1
epic202089948.1
epic201363350.1
10d
100d
3y
30y
300y
Period (d)


Giant/main sequence binaries?
10d
100d
3y
30y
300y
Period (d)

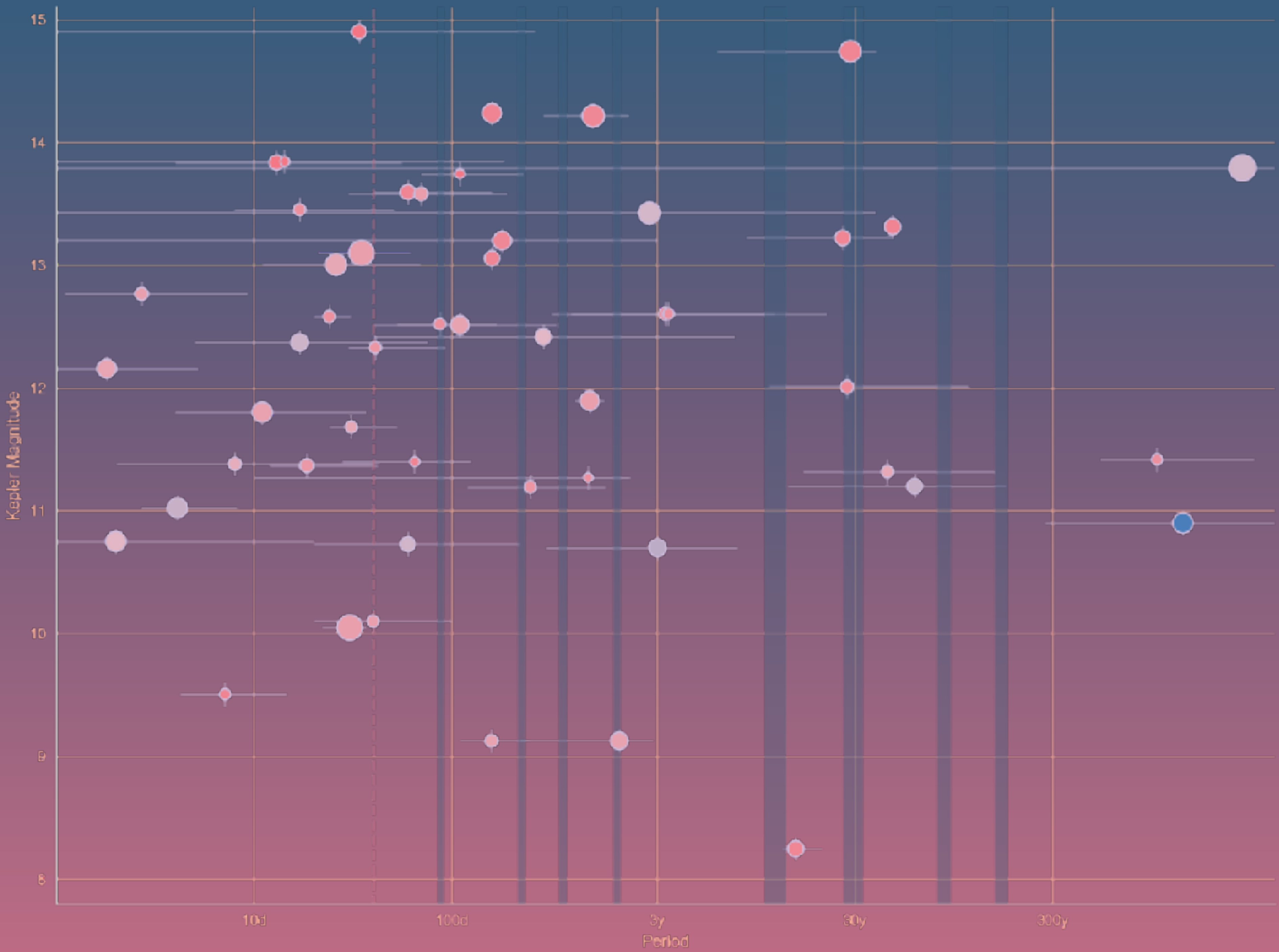


Grazing binaries?
Eccentric planets?
Giant/main sequence binaries
10d
100d
3y
30y
300y
Period (d)


2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Radius [RJ]
10d
100d
3y
30y
300y
Period



Effective Stellar Temperature [K]
8000
7000
6000
5000
4000
3000
10d
100d
3y
30y
300y
Period



15
14
13
12
11
10
9
8
Kepler Magnitude
10d
100d
3y
30y
300y
Period

FROM CANDIDATES TO PLANETS

VALIDATION

- Difficult to statistically validate without orbital period.

CONFIRMATION

1. Radial Velocities
2. Use future photometry to find another transit (e.g. TESS)
3. Gaia astrometry for largest planets.

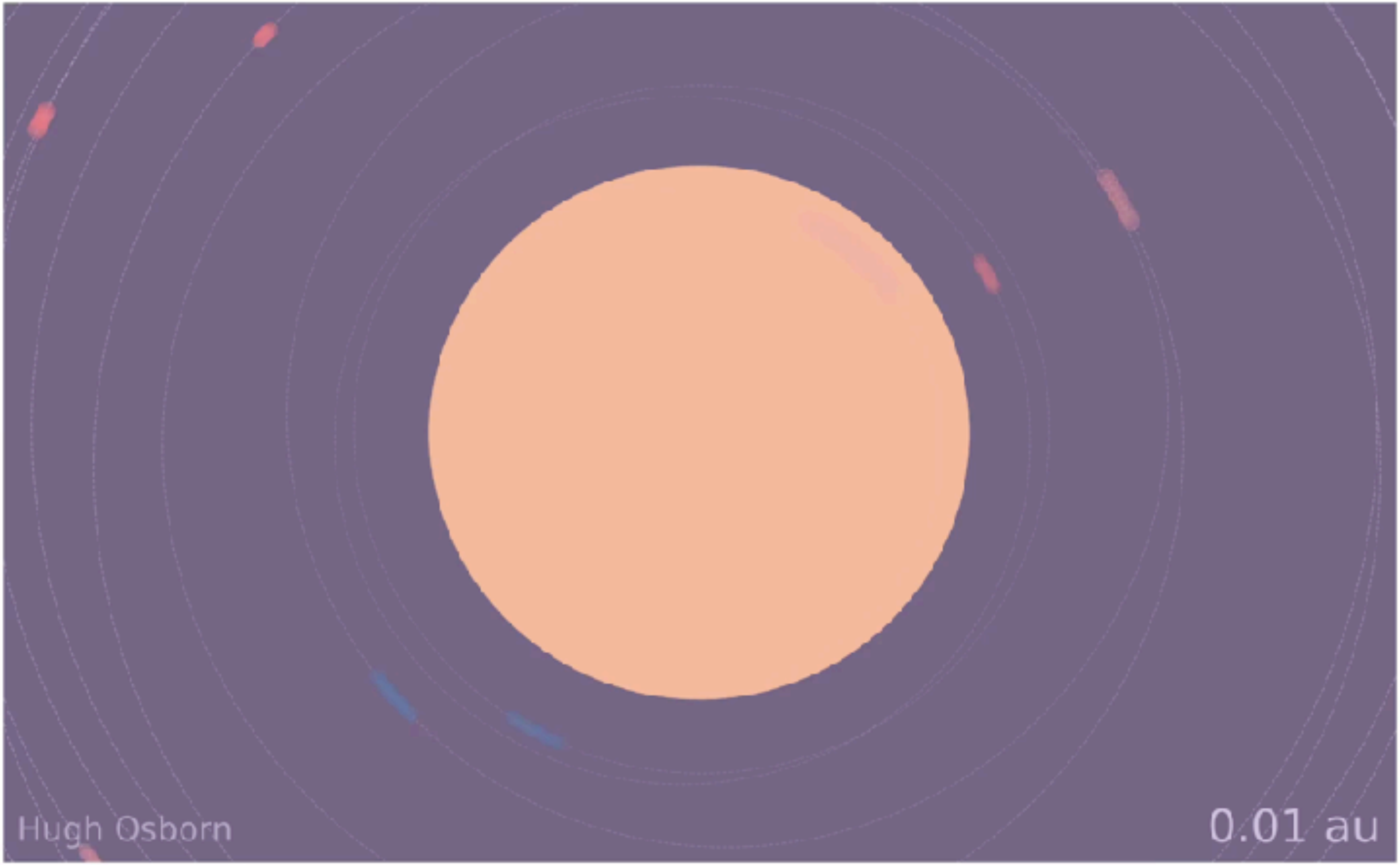
SOME FOLLOW-UP RESULTS

- HR 41378 system,
  - 3 single transits
  - Planet ‘e’ is a Jupiter-radius planet
  - Upper limit on mass
- EPIC 203311200.1
  - Coralie RVs
  - Best-fit orbit = P~220d, M~6M_J.

CONCLUSION

- Single transits can start filling in the long period gap in transiting planet parameter
- 50 strong candidates from single transits in K2 with orbits from 50d to ~years.
- RVs required for confirmation
- TESS is likely to find hundreds more
- Those orbiting bright stars can be characterised: radii, masses, spin-orbit alignment, etc

ANY QUESTIONS ?



EXTRA

Ground-based transit surveys:

WASP

- Performed injection/recovery tests on 136 000 WASP lightcurves (2 years of WASP-N stare data)
- Expect ~1.2 single transiting planets per year

NGTS

- 126 000 lightcurves.
- Recovery of ~4.1 single transiting planets per year