NGTS FOLLOW-UP OF TESS SINGLE TRANSITS

BEN COOKE

MONOTRANSITS WORKING GROUP LEAD – SAM GILL

NGTS CONSORTIUM

INTRODUCTION

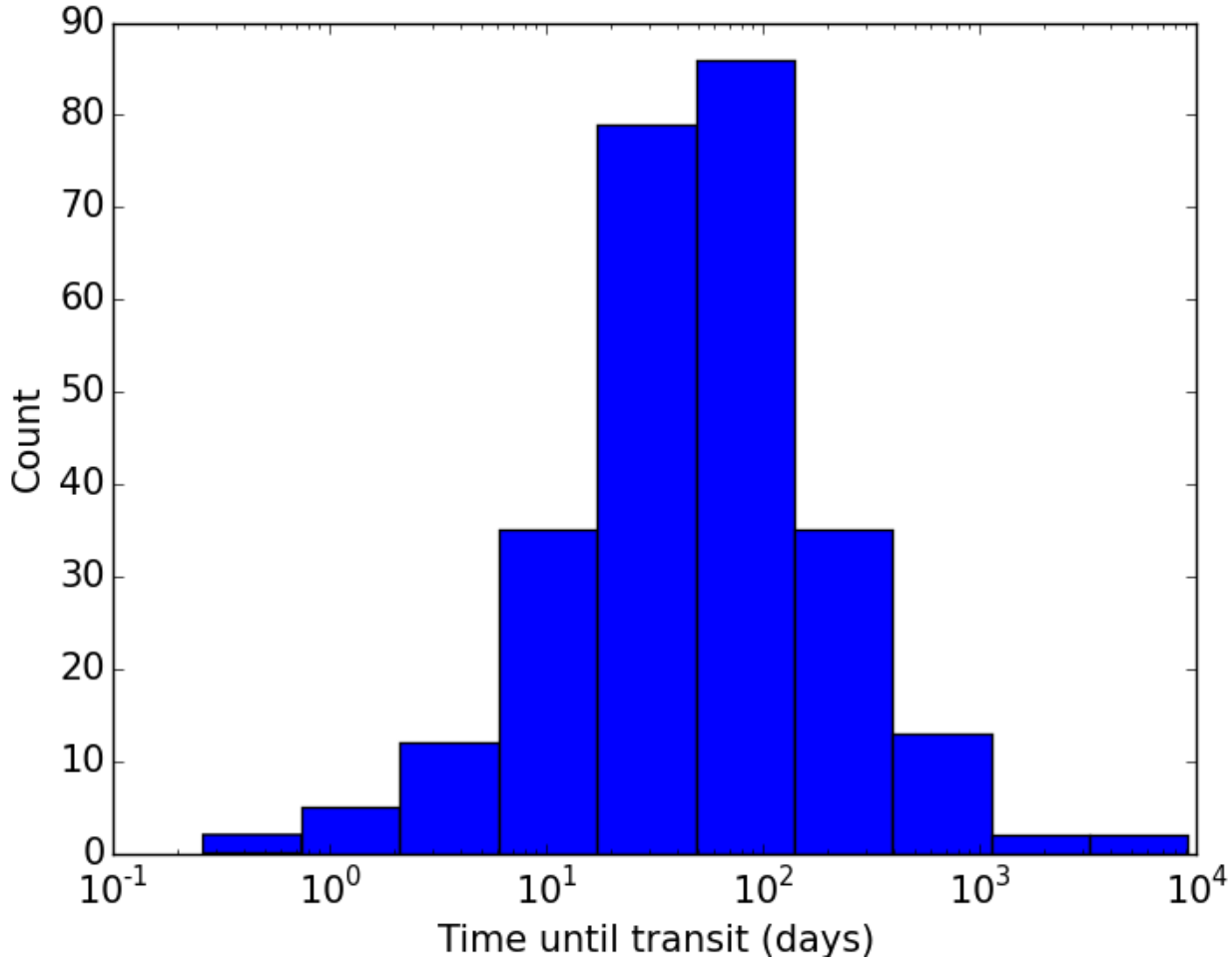
- Motivation
- Candidate identification
- Vetting
- Pre-recovery (WASP)
- Results
- Extended mission

MOTIVATION

- We predict approximately 500 monotransits in TESS (Cooke et al. 2018)
  - Majority will have only 1 sector of data
- Long period systems → Effort for follow-up BUT scientifically interesting

- Photometric follow-up requires lots of time (stare campaign)
- NGTS has 12 fully robotic telescopes
- Can dedicate telescopes to constant surveillance of monotransit candidates

MOTIVATION


90
80
70
60
50
40
30
20
10
0
Count
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
Time until transit (days)

CANDIDATE IDENTIFICATION

- Currently using DIA FFI lightcurves (Oelkers & Stassun 2018)
- Mask out regions of lc (bespoke masks per sector)
- Search lc with transit templates (range of depths/widths)
- Flag transits based on χ^2 value threshold
- lcs with 1 detection per depth/width are monotransit candidates
- Fit flagged transits for more precise parameters

VETTING

- Human eyeballing of candidates
- Check TESS 2min lc if it exists
- Create and compare our own FFI lcs
- Check for blends/neighbours with TIC/Gaia
- Check for asteroids etc.
- Compare transit time with other detections
- Check detections on neighbours

WASP PRE-RECOVERY

- Have access to SuperWASP photometry for majority of southern targets
- Prior to NGTS photometry follow-up we can search WASP database using TESS template
- Detections/non-detections can help constrain possible periods

TARGET SELECTION

- Cuts based on RA/Dec and TESS-band magnitude
- Separate candidates based on R_2 (R_1 from TIC, δ from fit)
  - Planets, EBLMs, EBs
- Choose deepest and widest planet-size signals (easiest to recover, most interesting)
  - Can also target long period EBLMs/EBs of scientific interest
- Prefer targets with fewer TESS sectors of coverage (imply shortest periods)
- Prioritise targets with WASP photometry
- Best candidates are selected for NGTS follow-up

NGTS PHOTOMETRY

- 12 telescopes – can observe multiple candidates simultaneously
- Observe targets continuously while risen
  - Exploring stepping mode (good for wide transits/many candidates)
- Can readily detect signals of ~few mmag with high confidence
- Option to combine multiple telescopes for a single target – can drastically improve S/N for highest priority/most scientifically interesting targets
- Data reduced and examined daily

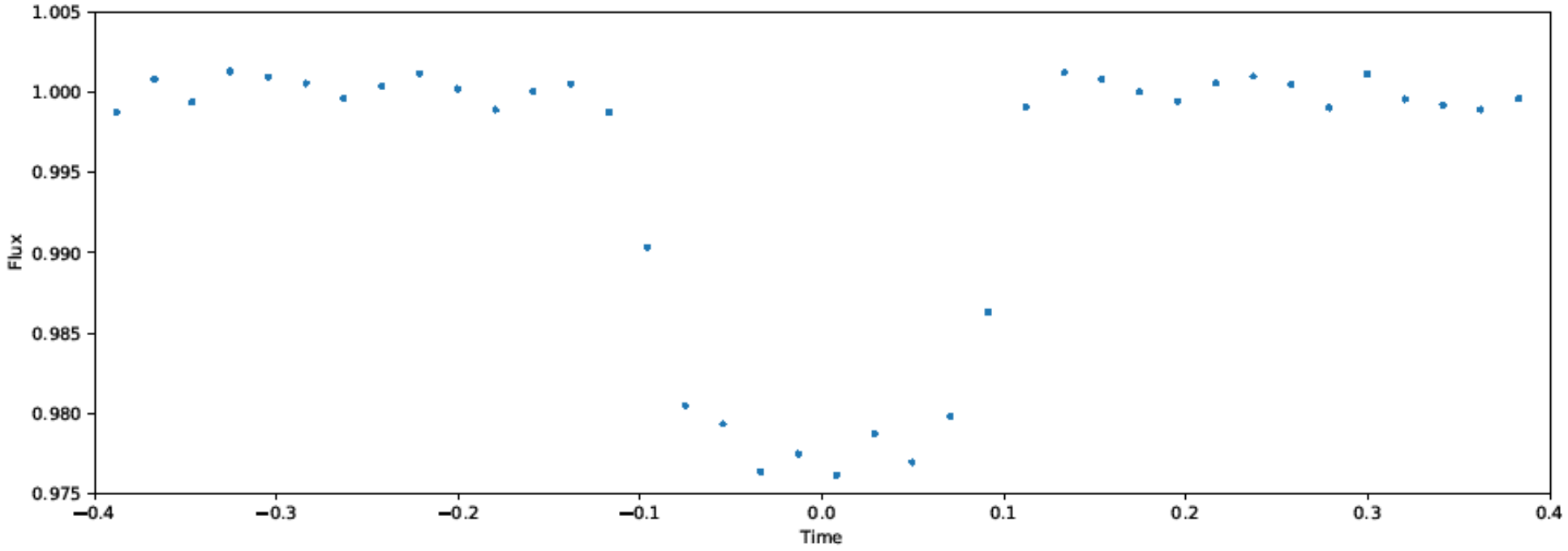
NGTS DATA SEARCH

- Each day search NGTS data with TESS template
- Can combine all TESS, NGTS and WASP data for full search
- Any detection in WASP/NGTS allows a set of periods to be assumed, phasing data can then rule out/confirm predictions

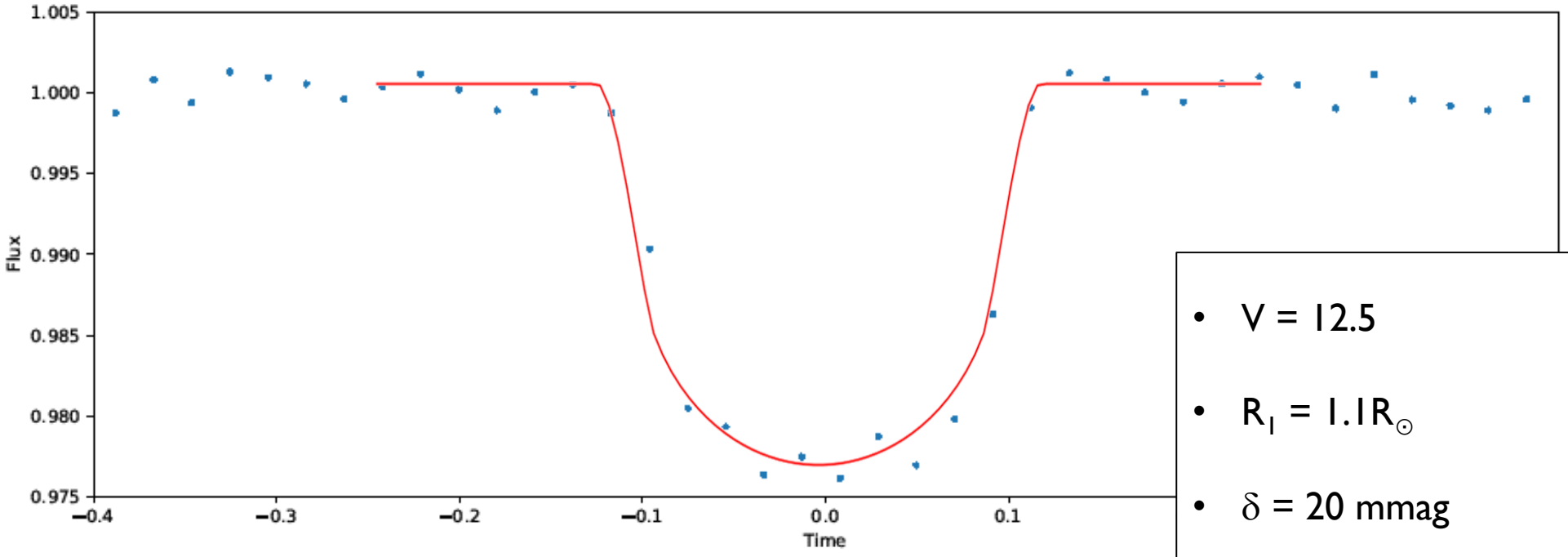
RESULTS

- Currently have many hundred of candidates from sectors 1-5
  - Try and select candidates early to observe them as soon as they begin to rise
- Continuous process of vetting, selecting and updating potential candidates
  - Try not to update too regularly – need long baselines to catch transits
- Have successfully recovered 5 TESS monotransit candidates in NGTS

I - TESS

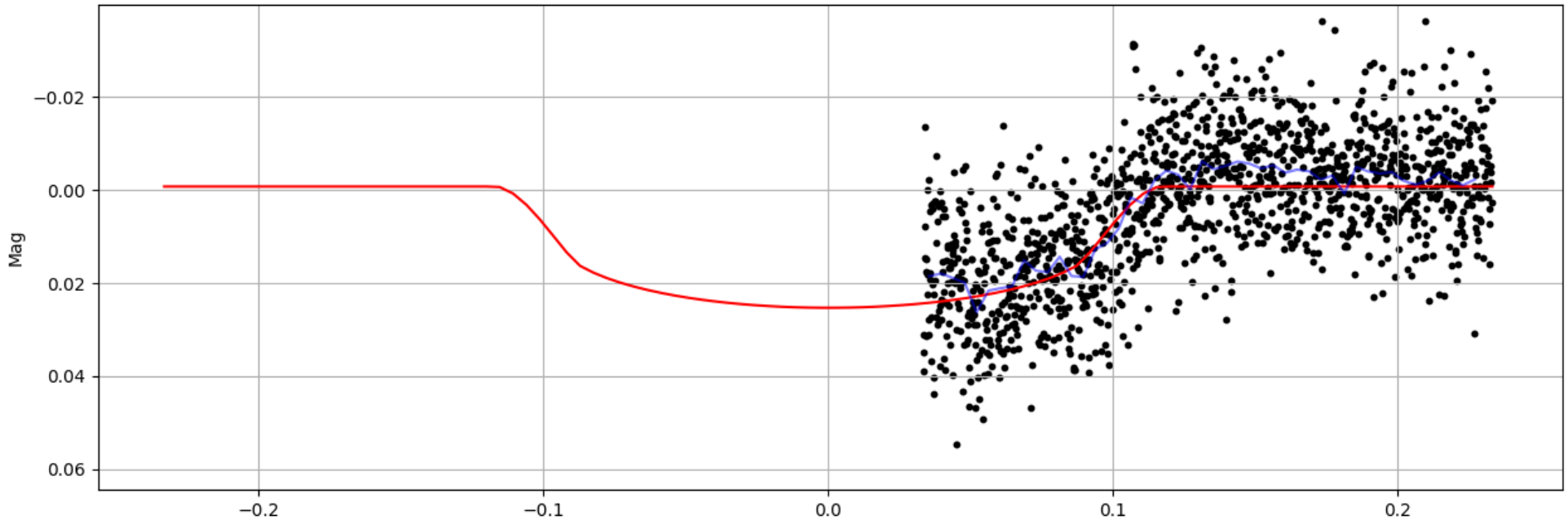

1.005
1.000
0.995
0.990
0.985
0.980
0.975
Flux
−0.4
−0.3
−0.2
−0.1
0.0
0.1
0.2
0.3
0.4
Time

1 - TESS

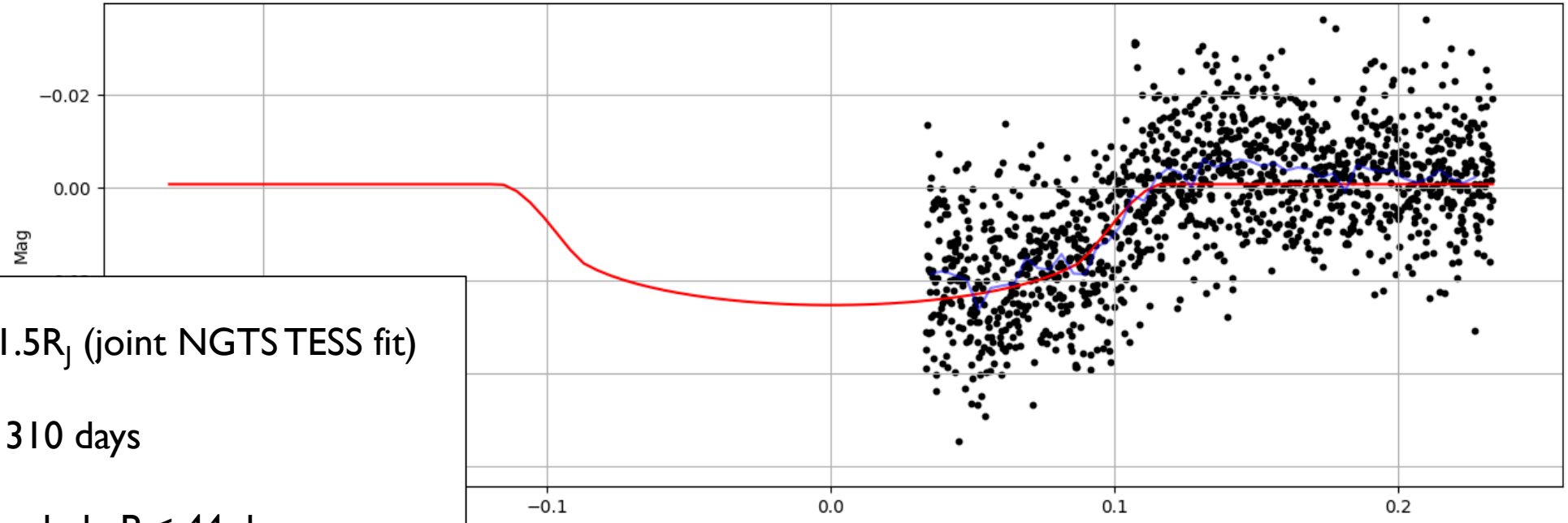


- V = 12.5
- $R_1 = 1.1 R_\odot$
- δ = 20 mmag
- 2 TESS sectors

1 - NGTS

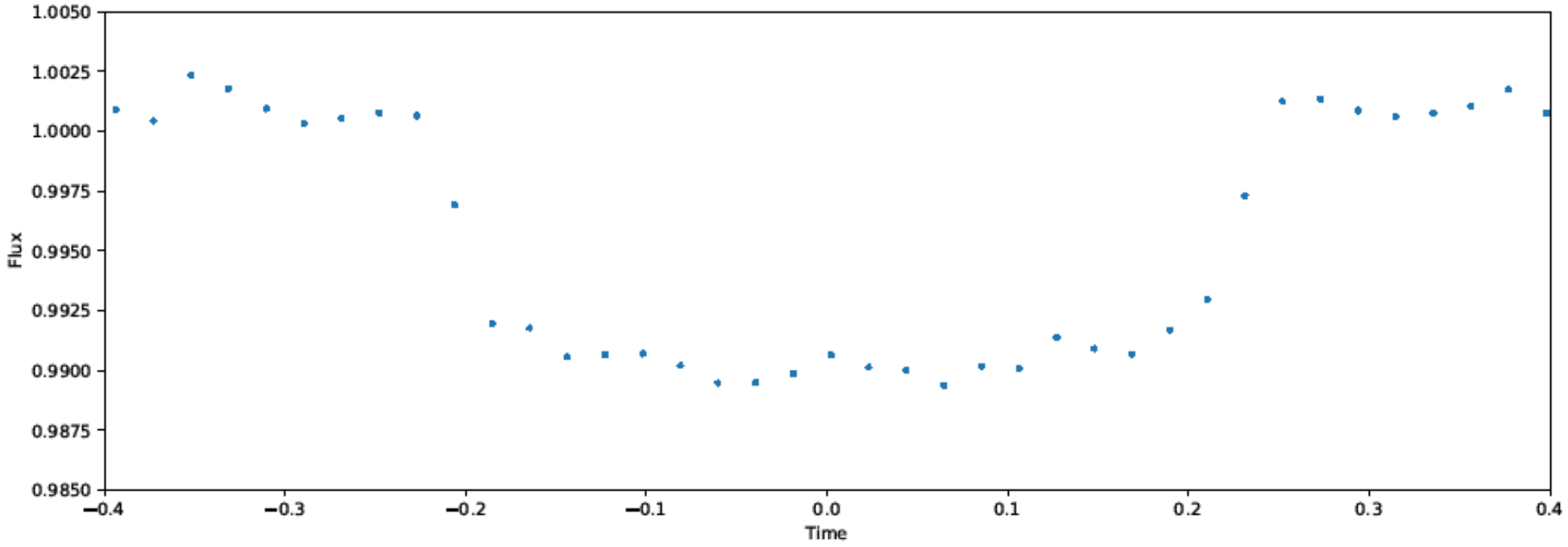


1 - NGTS

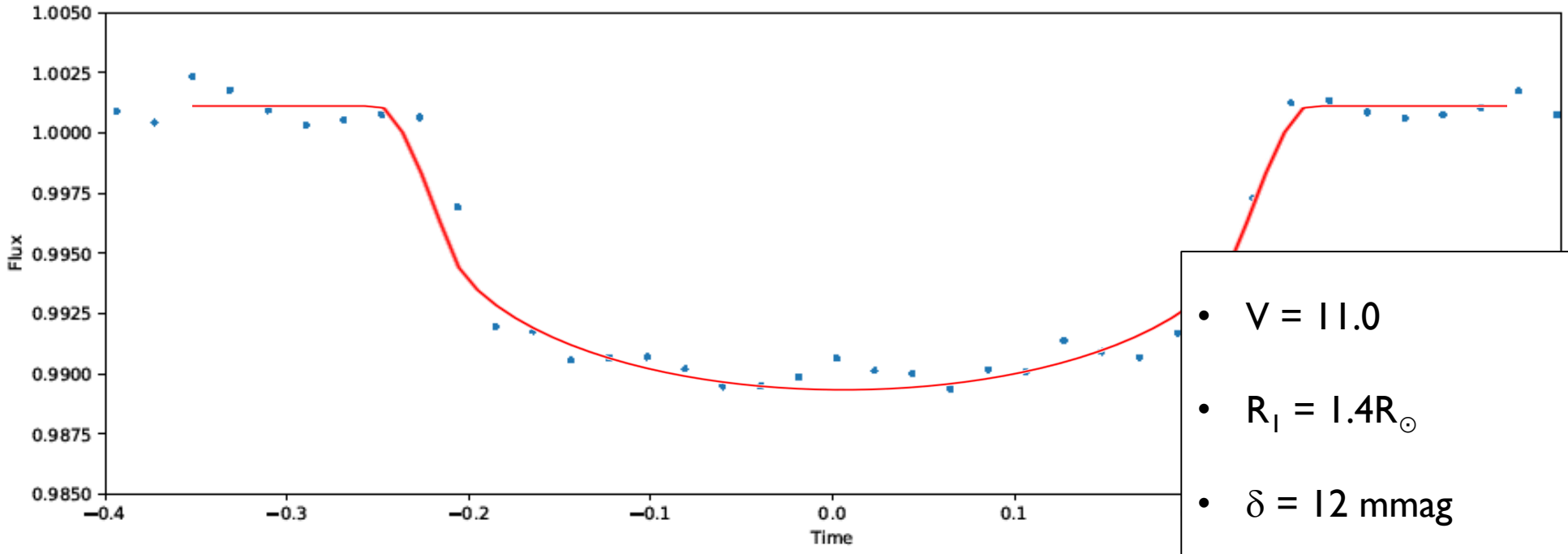


- R_2 = 1.5R_J (joint NGTS TESS fit)
- ΔT = 310 days
- Can exclude P < 44 days
- Have CORALIE RV points

2 - TESS

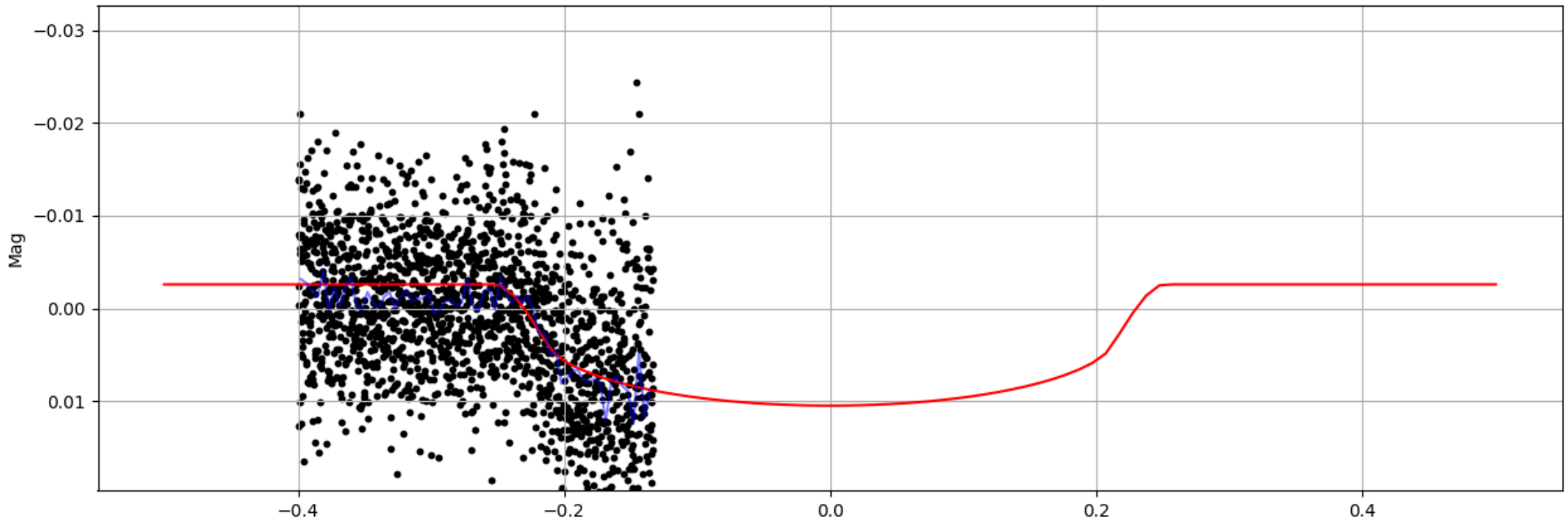

1.0050
1.0025
1.0000
0.9975
0.9950
0.9925
0.9900
0.9875
0.9850
Flux
−0.4
−0.3
−0.2
−0.1
0.0
0.1
0.2
0.3
0.4
Time

2 - TESS

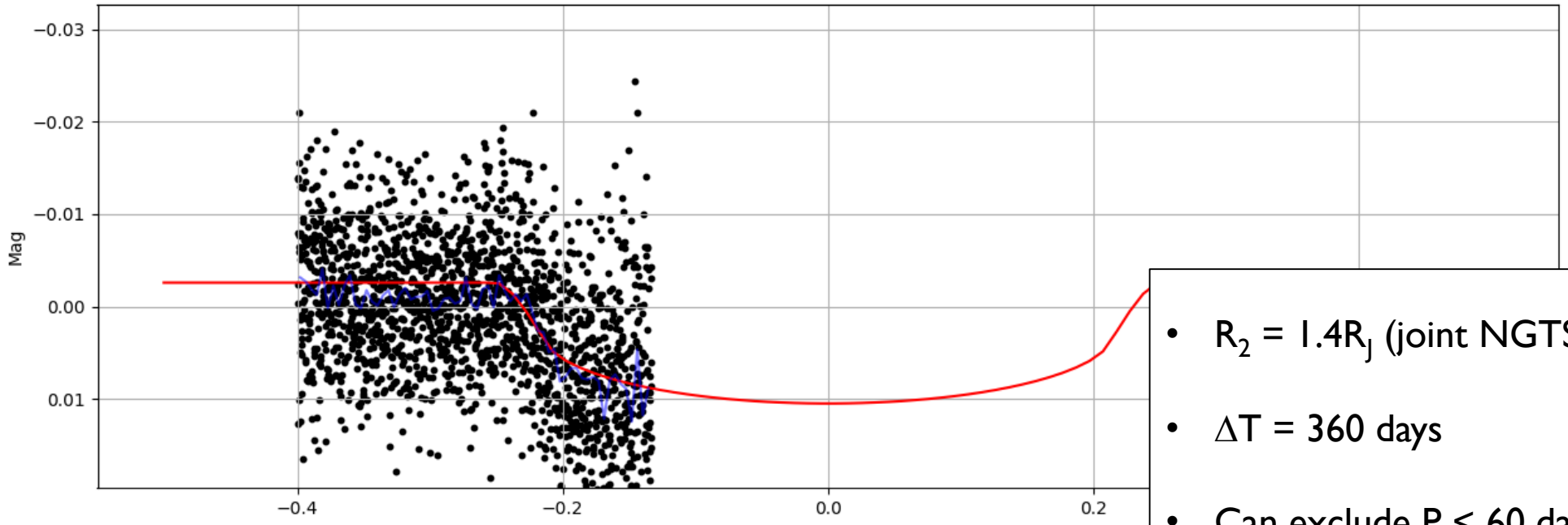


- V = 11.0
- $R_1 = 1.4R_\odot$
- δ = 12 mmag
- 1 TESS sector

2 - NGTS

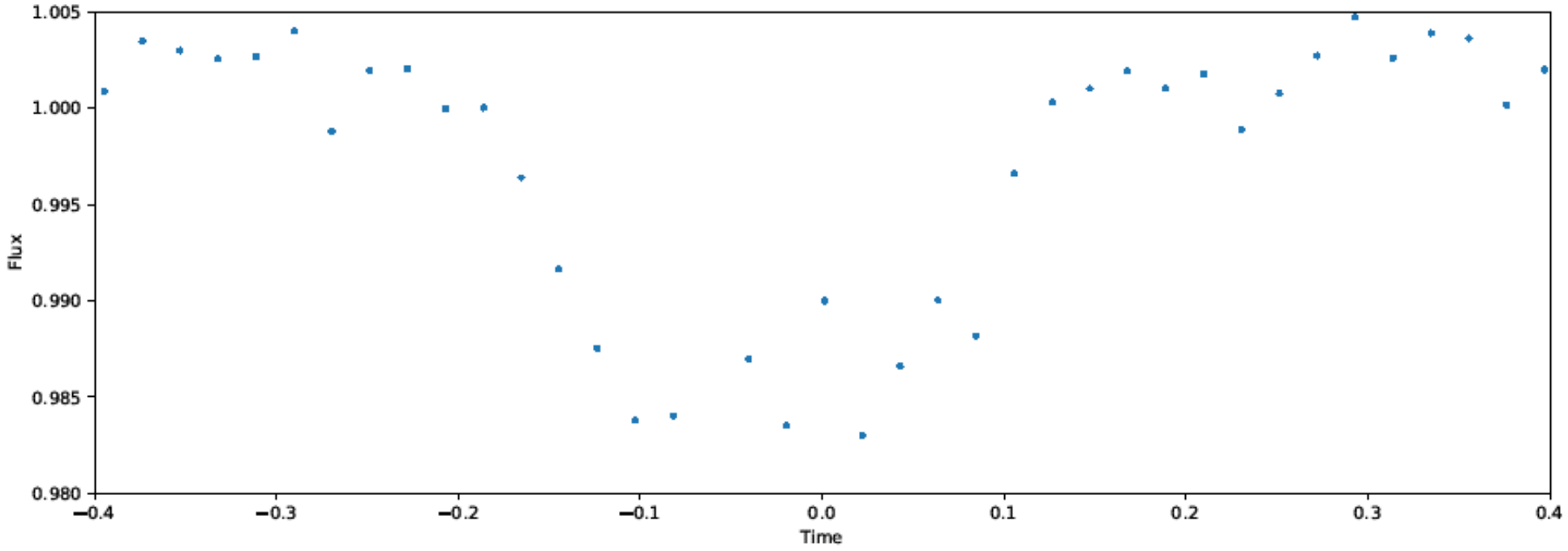


2 - NGTS

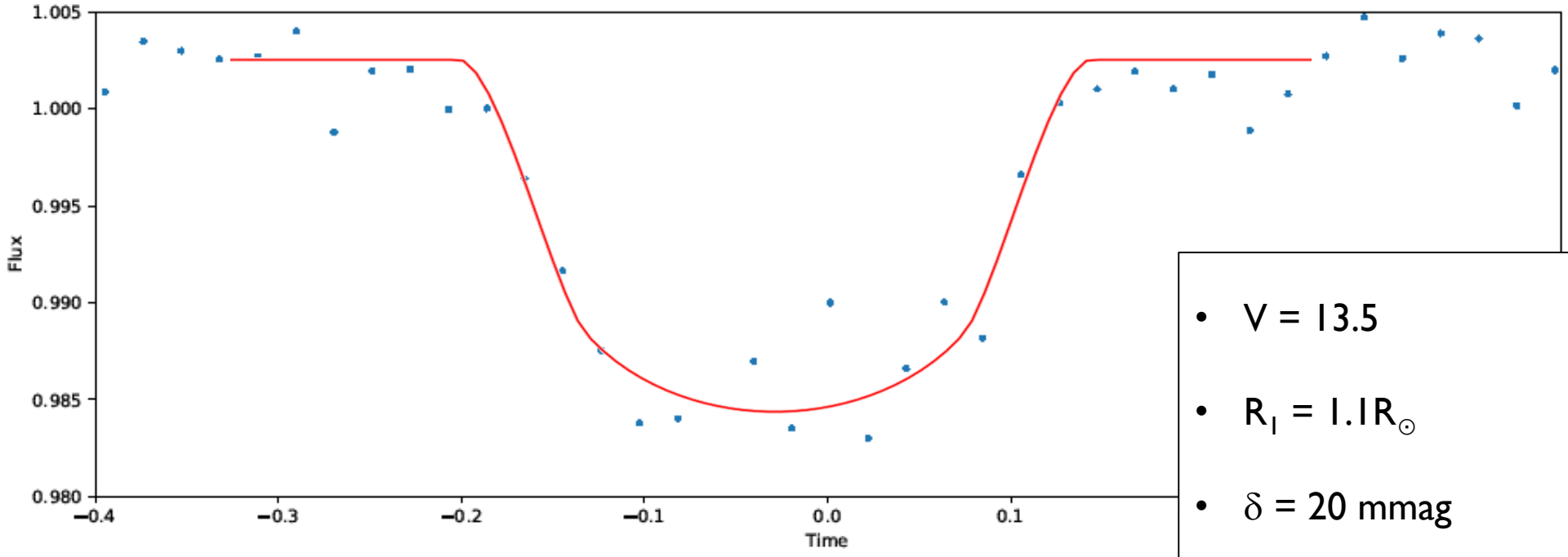


- $R_2 = 1.4R_J$ (joint NGTS TESS fit)
- $\Delta T = 360$ days
- Can exclude $P < 60$ days
- Have CORALIE RV points

3 - TESS

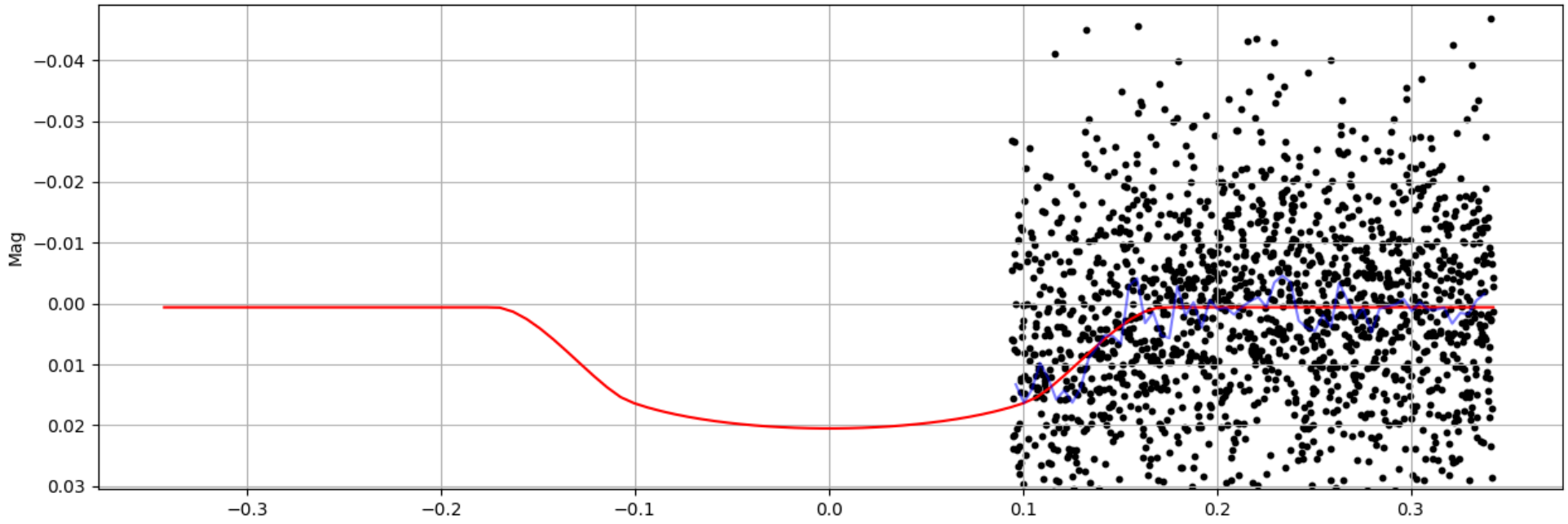

1.005
1.000
0.995
0.990
0.985
0.980
Flux
−0.4
−0.3
−0.2
−0.1
0.0
0.1
0.2
0.3
0.4
Time

3 - TESS

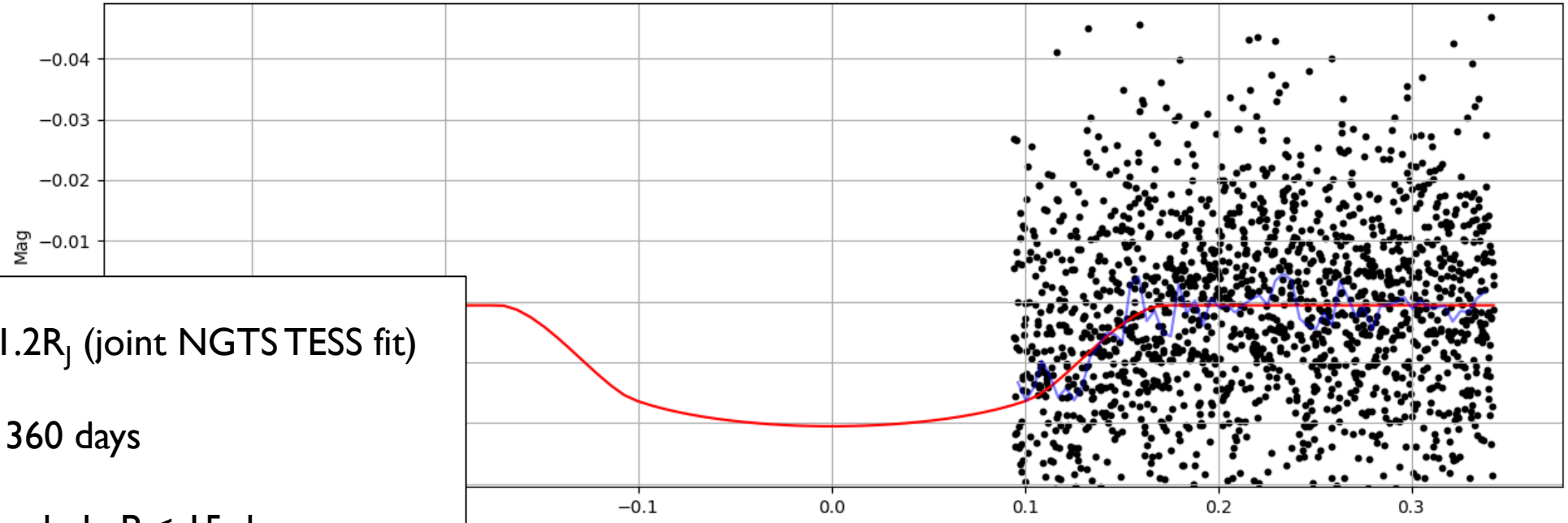


- V = 13.5
- $R_1 = 1.1 R_\odot$
- δ = 20 mmag
- 1 TESS sector

3 - NGTS

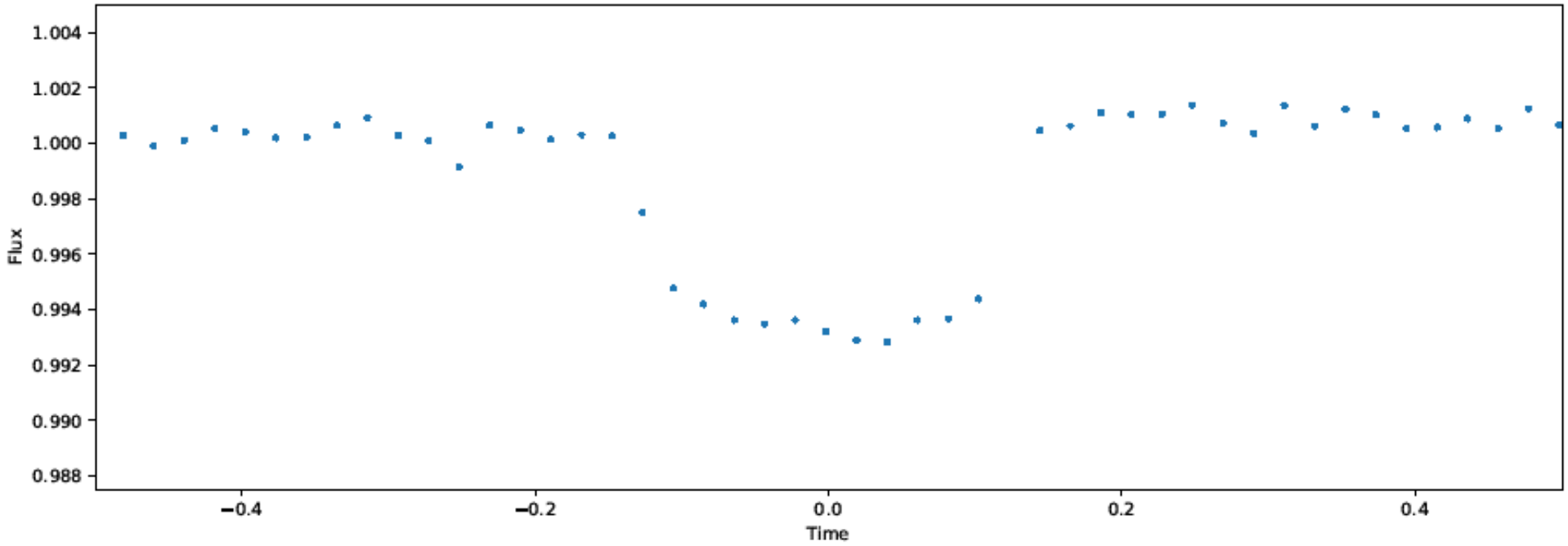


3 - NGTS

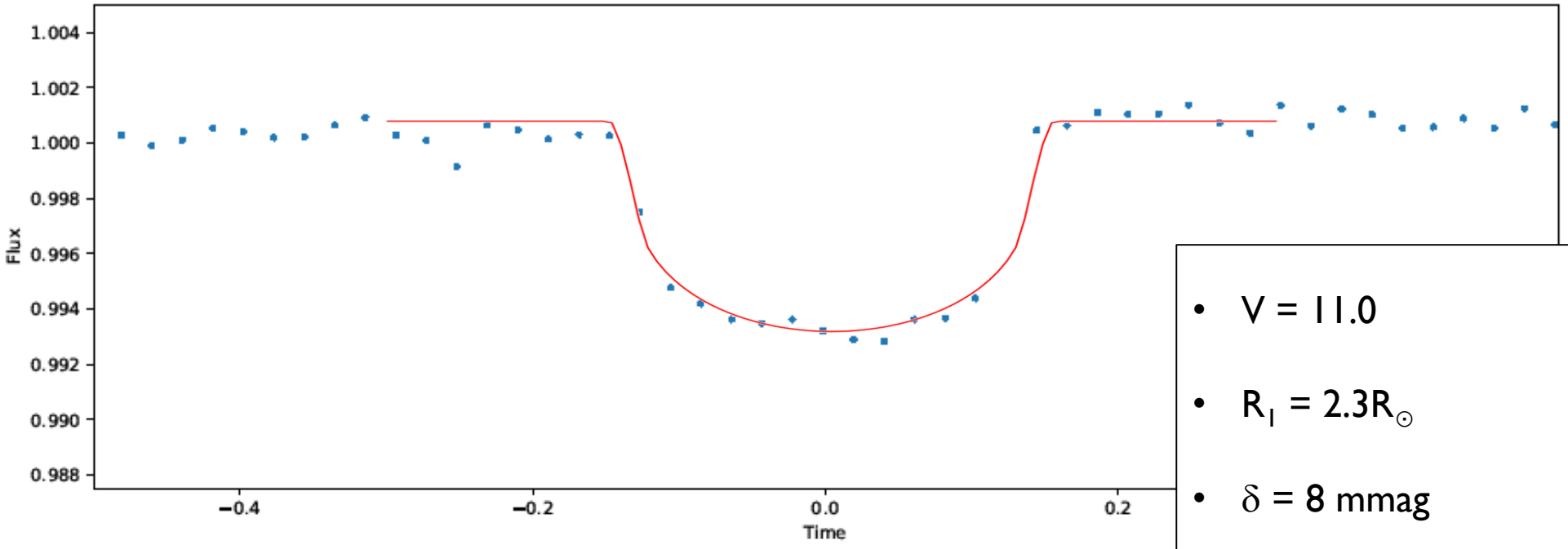


- $R_2 = 1.2R_J$ (joint NGTS TESS fit)
- $\Delta T = 360$ days
- Can exclude $P < 15$ days
- Have CORALIE RV points

4 - TESS

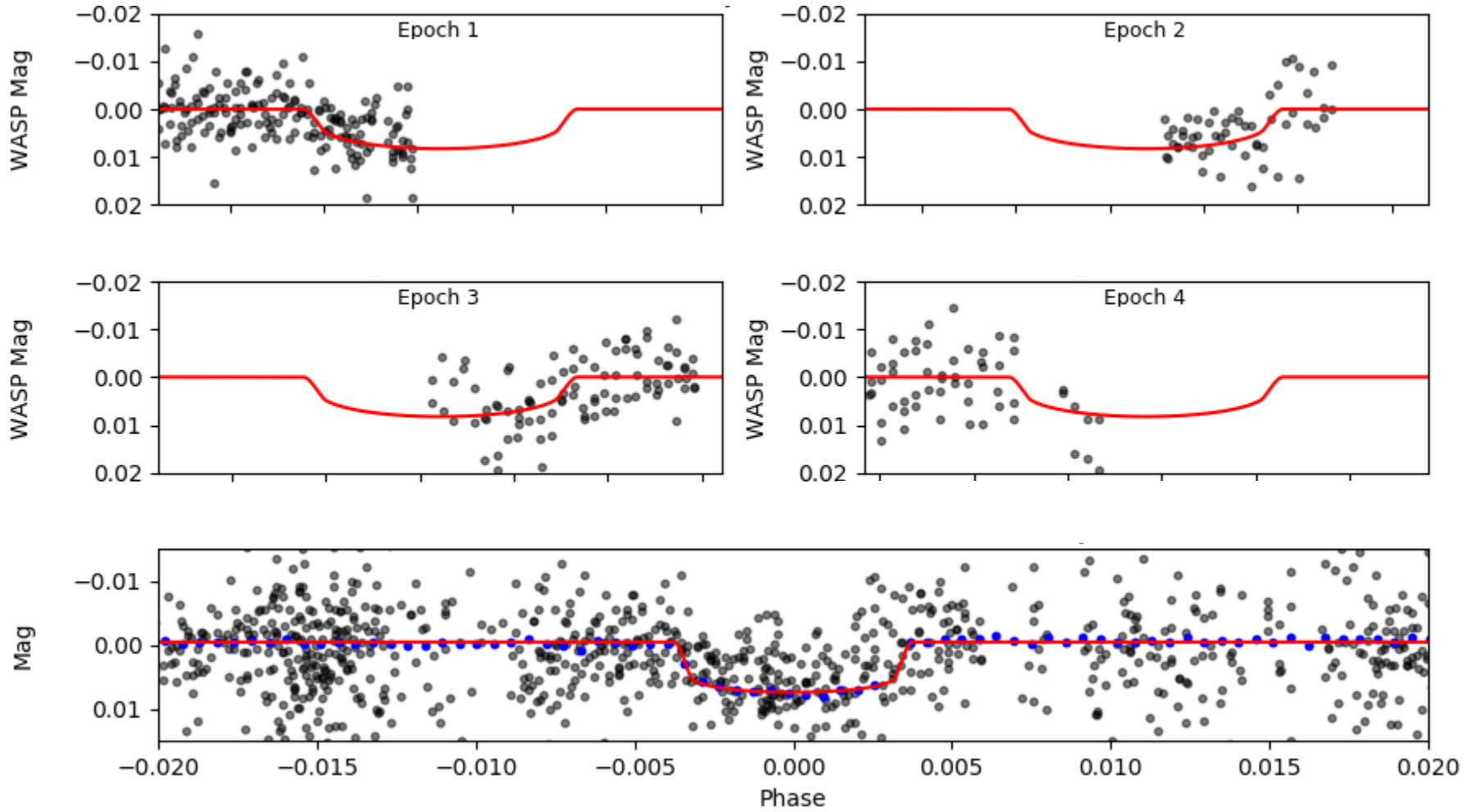

1.004
1.002
1.000
0.998
0.996
0.994
0.992
0.990
0.988
Flux
−0.4
−0.2
0.0
0.2
0.4
Time

4 - TESS

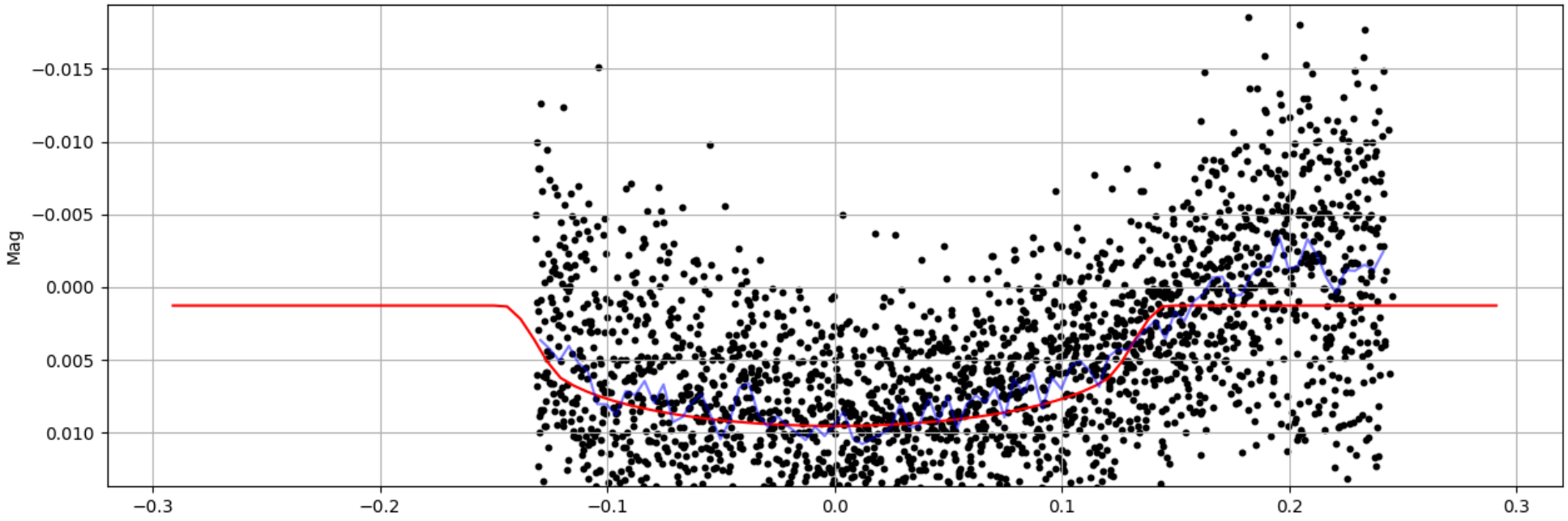


- V = 11.0
- $R_1 = 2.3R_\odot$
- δ = 8 mmag
- 1 TESS sector

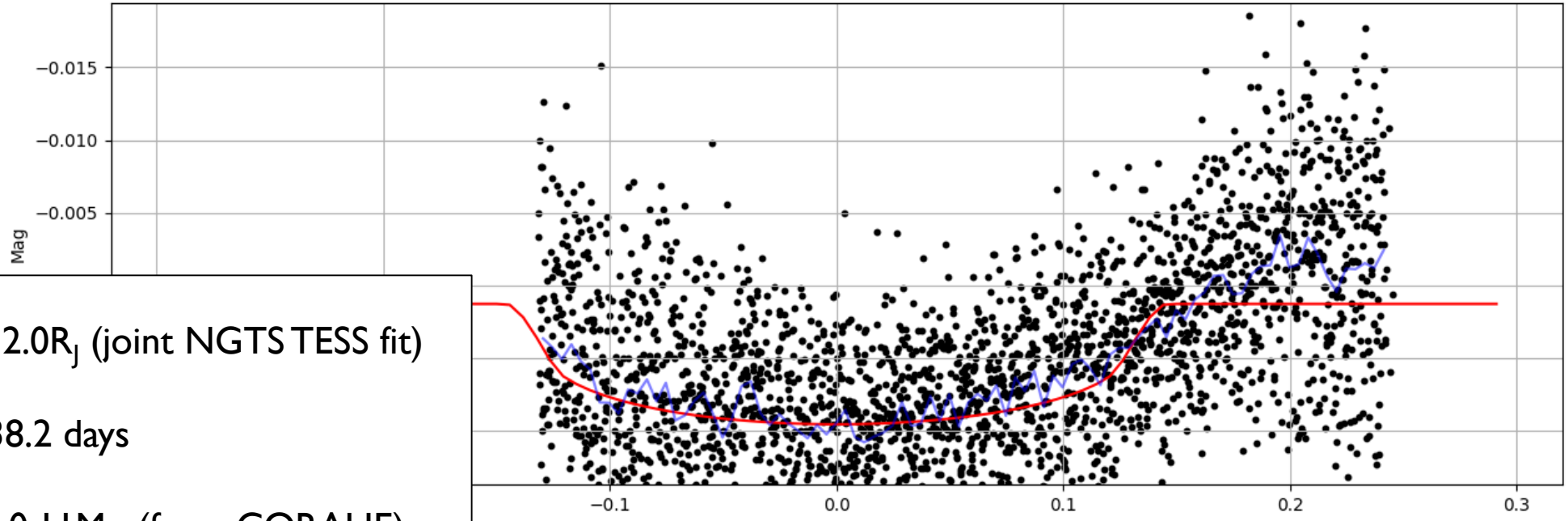
4 - WASP


Epoch 1
Epoch 2
Epoch 3
Epoch 4
WASP Mag
Mag
Phase
−0.02
−0.01
0.00
0.01
0.02
−0.020
−0.015
−0.010
−0.005
0.000
0.005
0.010
0.015
0.020

4 - NGTS



4 - NGTS



- $R_2 = 2.0R_J$ (joint NGTS TESS fit)
- P = 38.2 days
- $M_2 = 0.11M_\odot$ (from CORALIE)

TESS EXTENDED MISSION

- Now know the TESS extended mission is a reality
- TESS is confirmed to return to the southern hemisphere ~3 years later
- Current predictions suggest ~75% of year 1 monotransits will be re-observed (Cooke 2019 in prep.)
  - Have already proved we can recover targets well before TESS will return
- Simulations suggest 2 TESS transits 3 years apart will do little to constrain period – will still need additional follow-up
- Combined with new year 4 monotransits we predict approximately 150 monos even after extended southern mission (south only)

CONCLUSIONS

- Searching for TESS FFI monotransits
- Attempting pre-recovery with WASP
- Following-up best candidates with NGTS (targeted or stare mode)
- Already have multiple detections
- Currently attempting to push to smaller radius targets