Tutorial on light curve extraction

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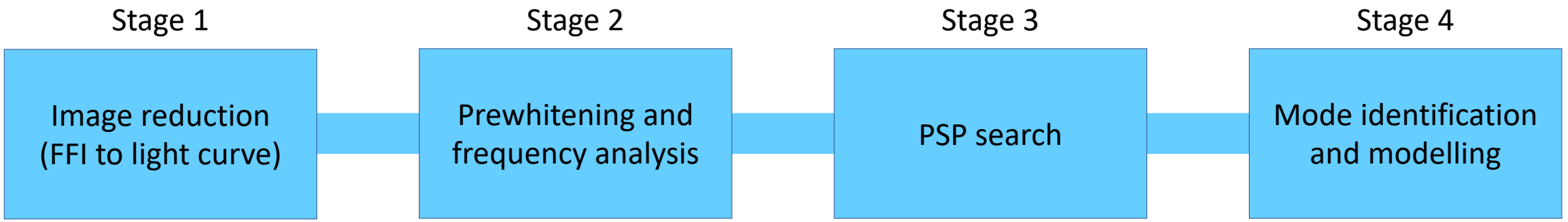
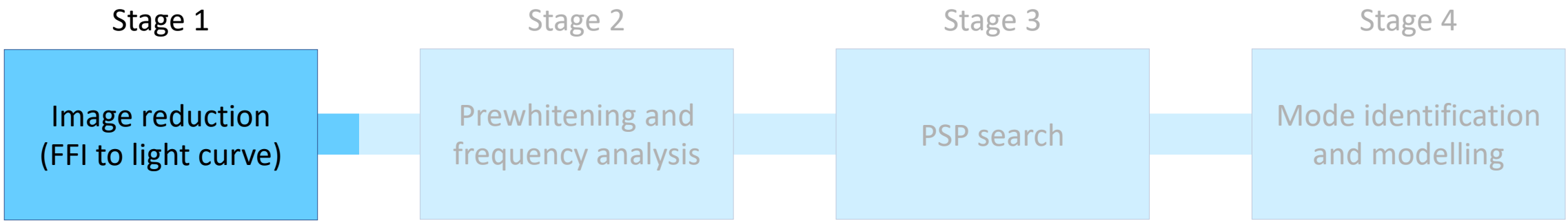
25/08/2022

Raw data to useful frequencies

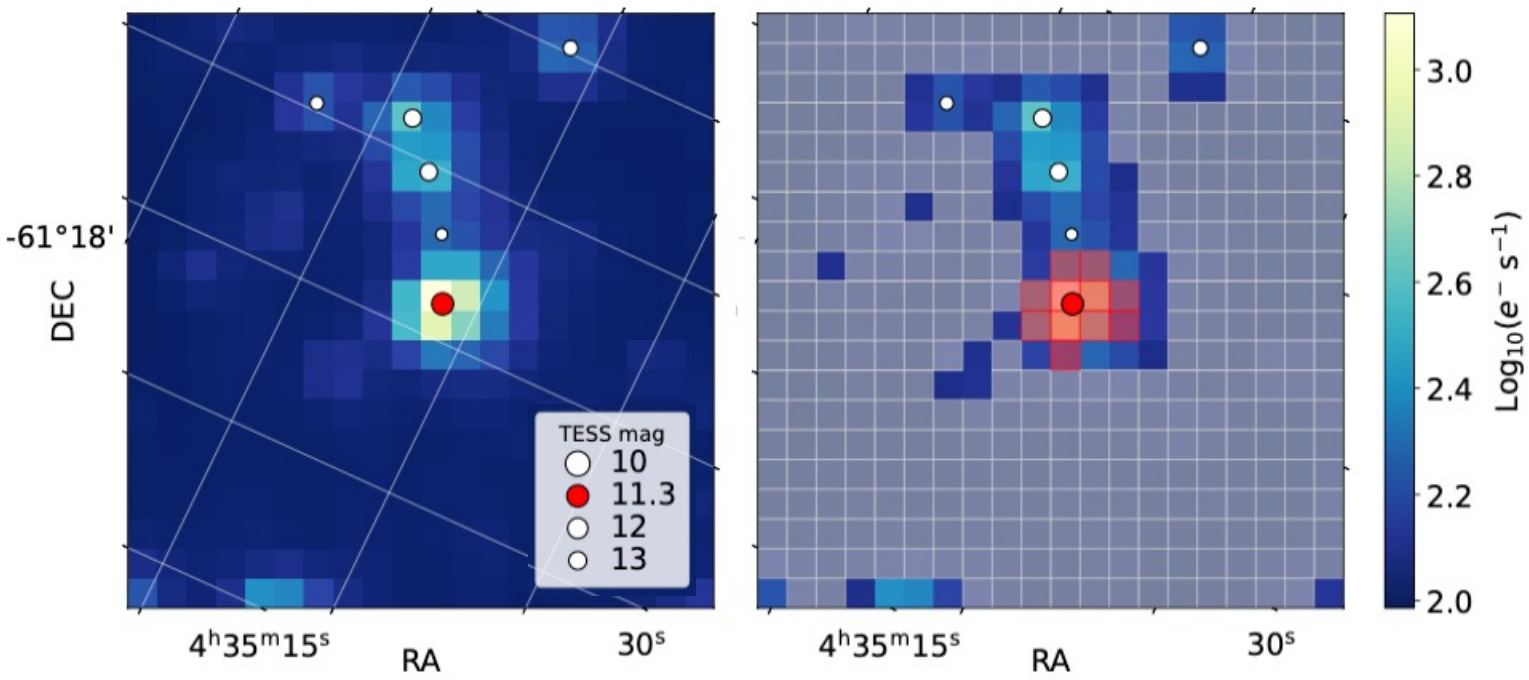


Raw data to useful frequencies



Find aperture mask
(star and bkg)

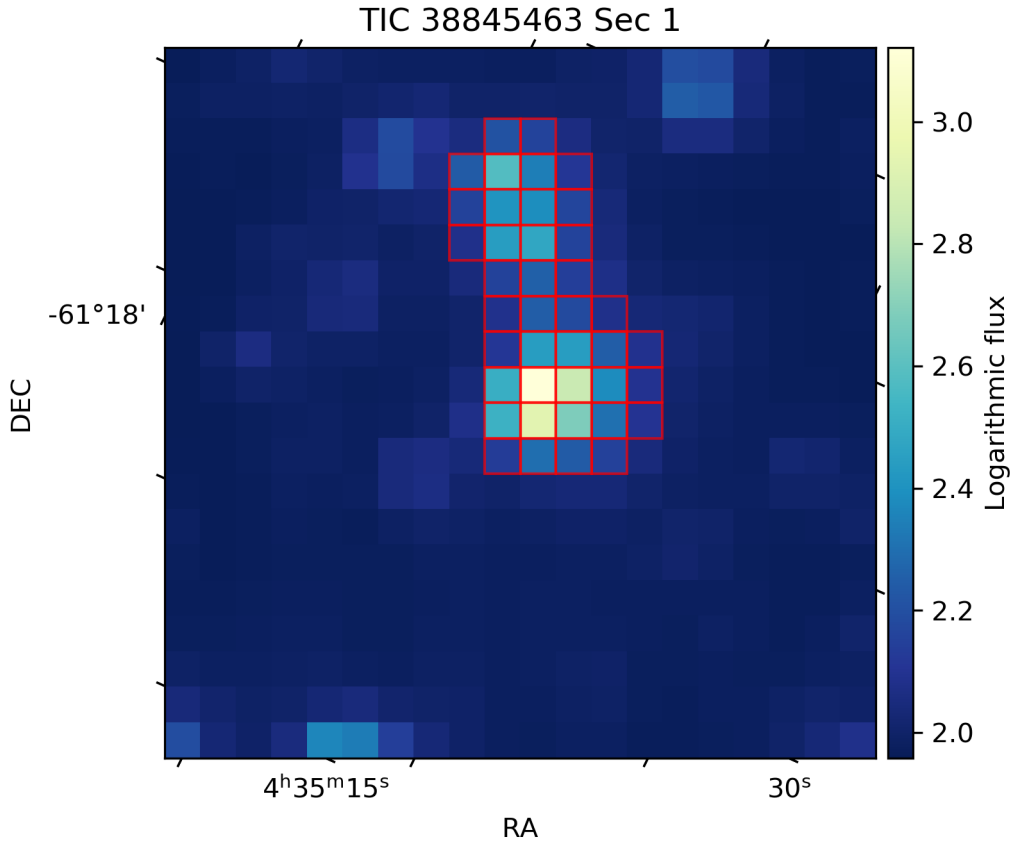
Thresold criterium + Coordinate info



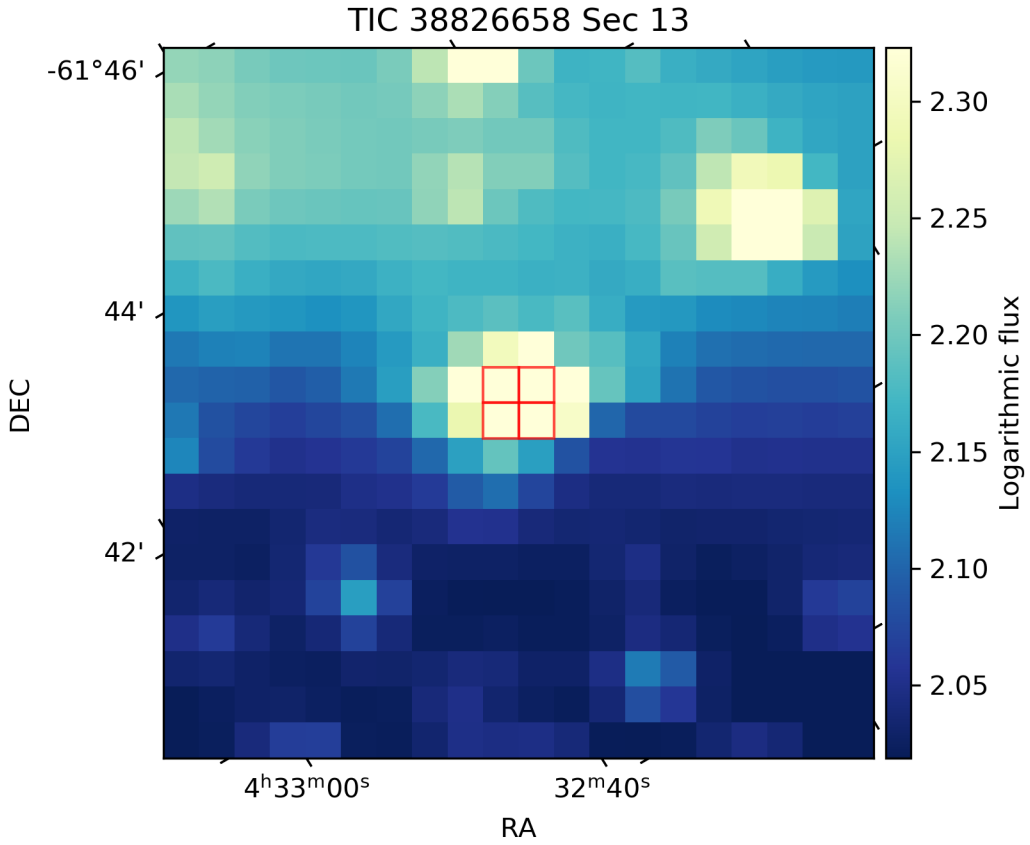
Find aperture mask

(challenging cases)

Contaminated aperture mask



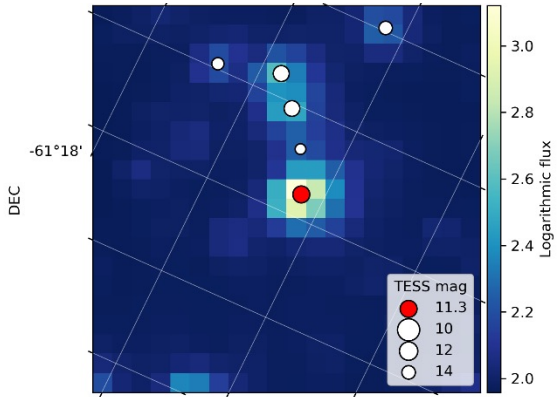
Non-constant background



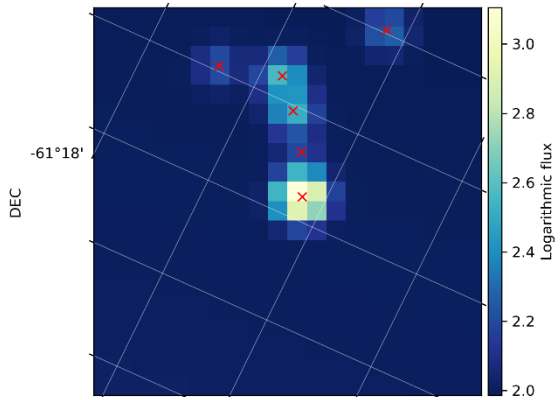
Find aperture mask

(challenging cases -> model data)

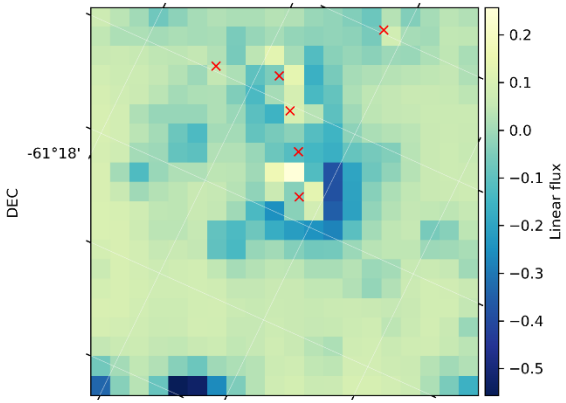
TESS image
and neighbor stars



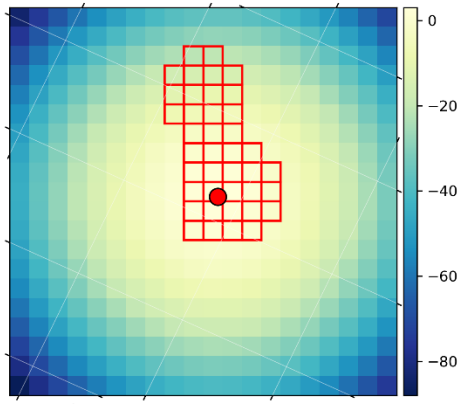
Non-linear fit of Gaussians
(2 free parameters: relative amplitude & 2D sigma)



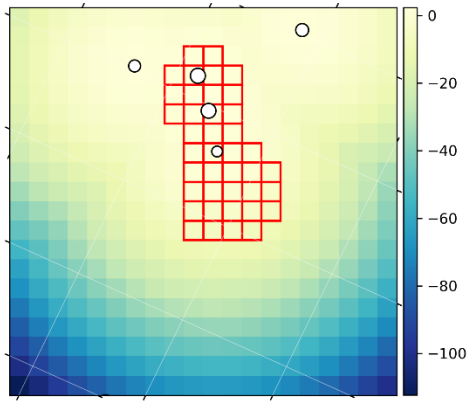
Residuals / original



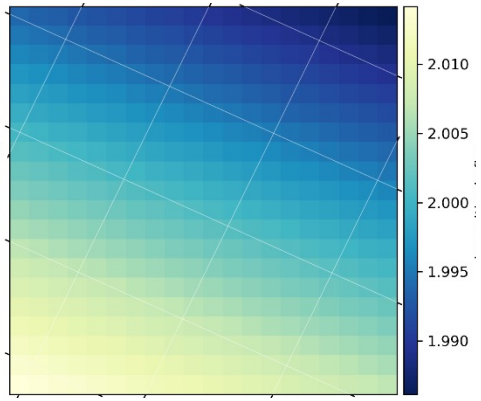
Target star



Neighbor stars



Background



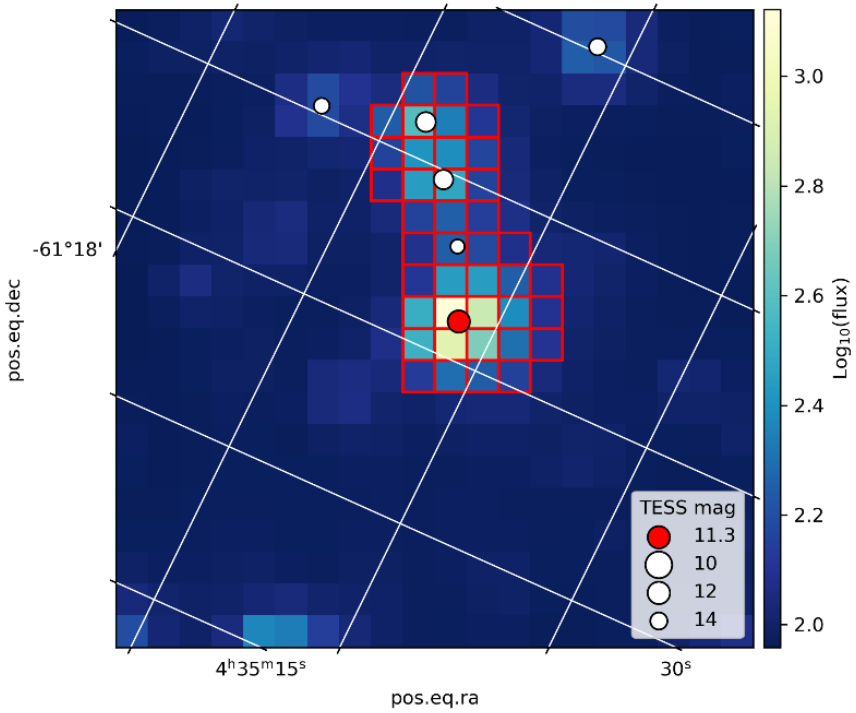
Contamination

$$C = \frac{\text{Flux neighbor stars}}{\text{Flux target star}}$$

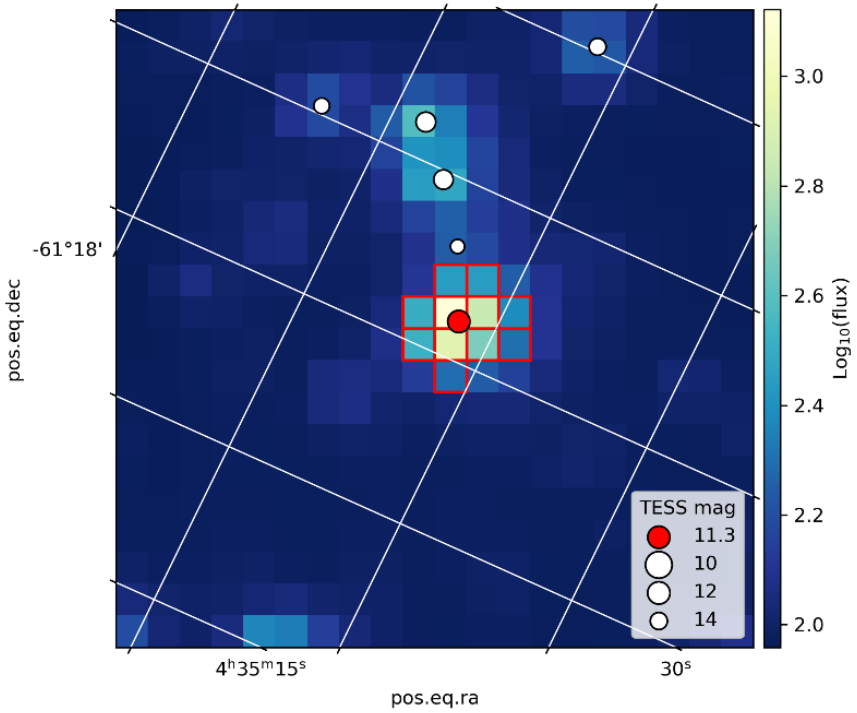
Find aperture mask
(challenging cases)

Identify bad cases. Correct them if possible

Contamination = 41%,

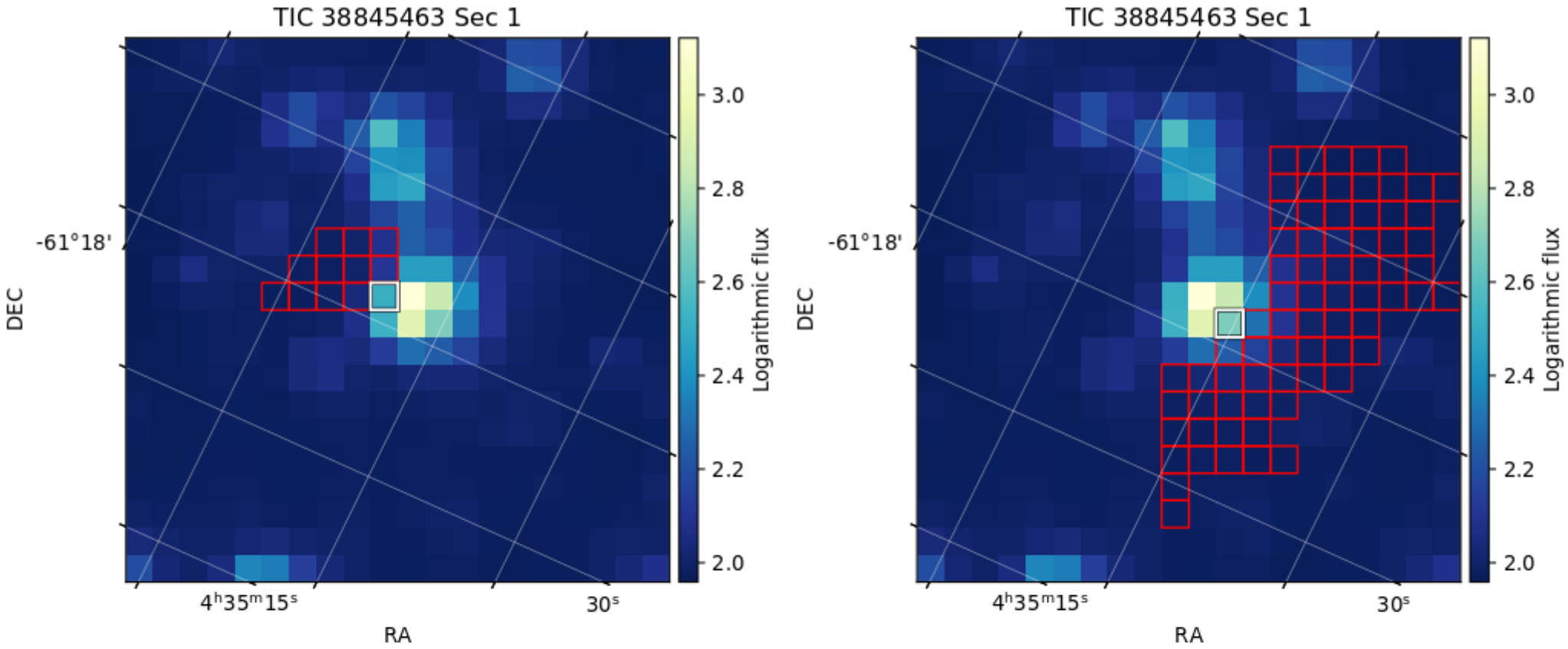


Contamination = 0.6%



Find aperture mask
(last check)

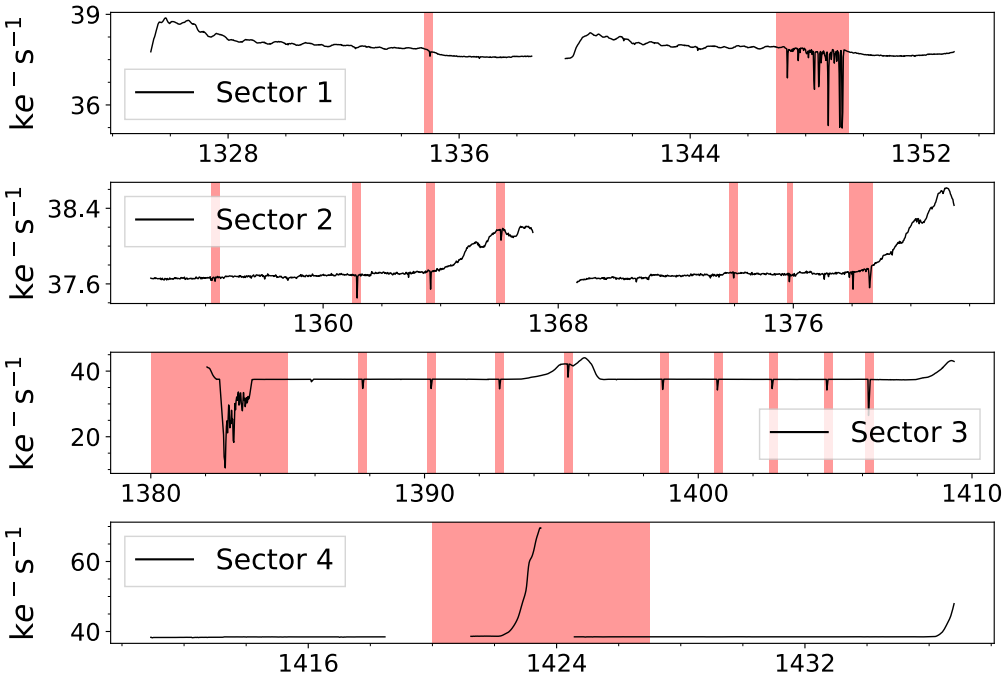
Flux must decrease radially away from the star

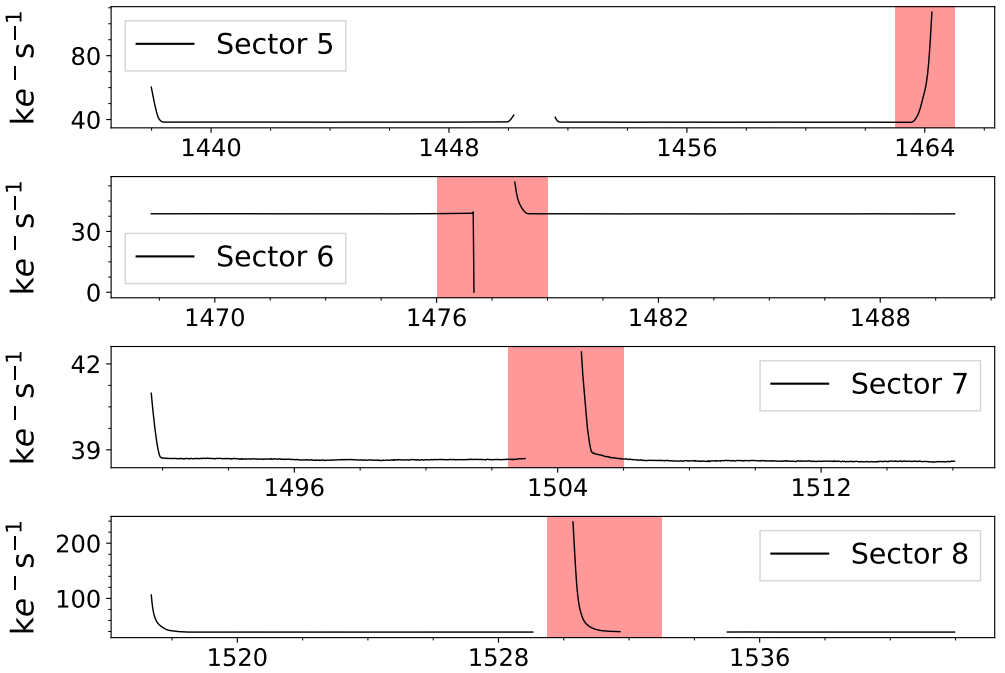


Extract light curve

(simple aperture photometry)

Some systematics: fine pointing, thermal transients, Earth pointing telescope jittering, and loss of fine pointing, etc.

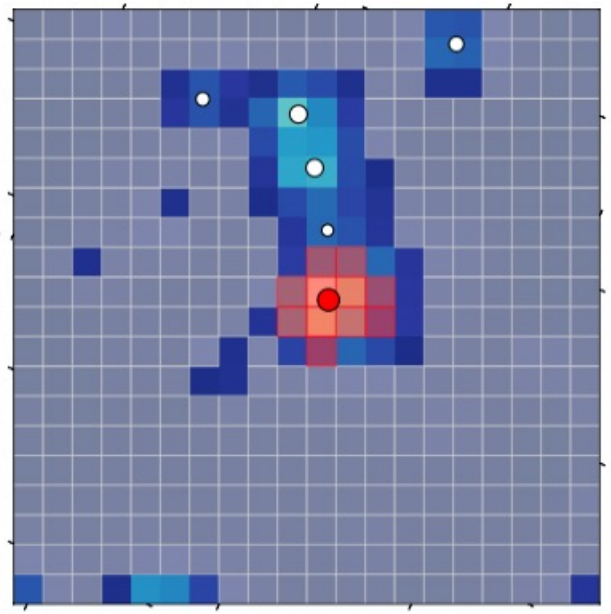




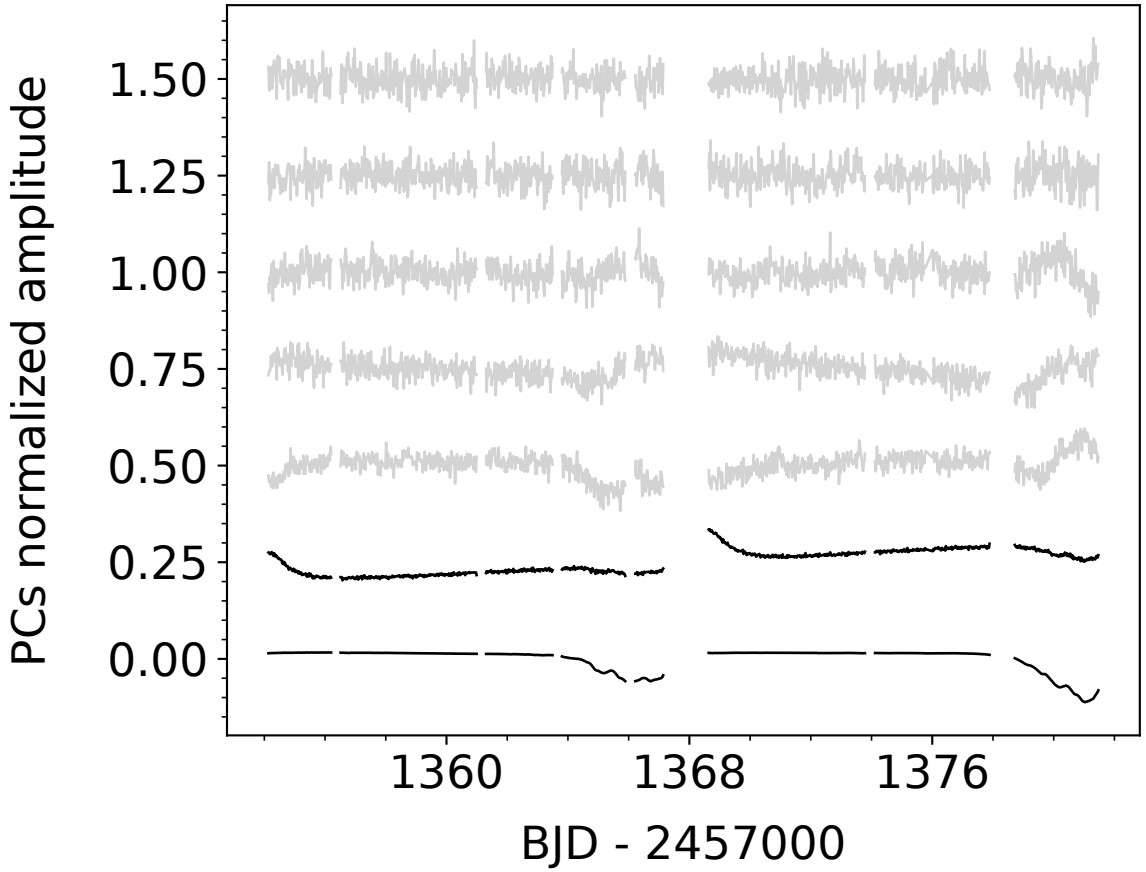
Extract light curve

(Principal component analyses or PCA)

PCA captures dominant flux variability from the background mask.

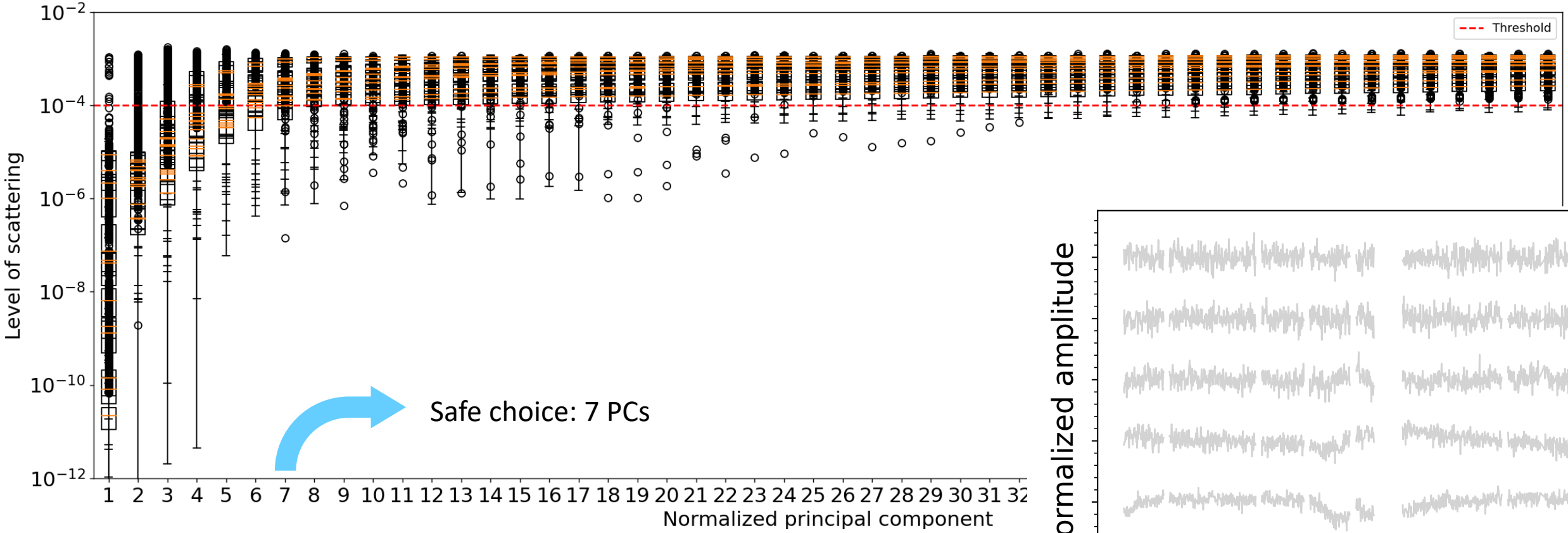


- Systematic variations are captured by early PCs.
- White variations are captured by late PCs.



Extract light curve

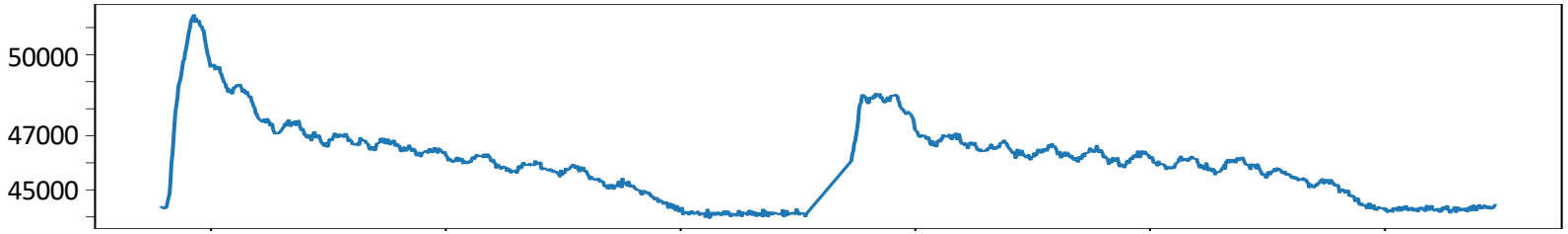
(How many PCs are need?)

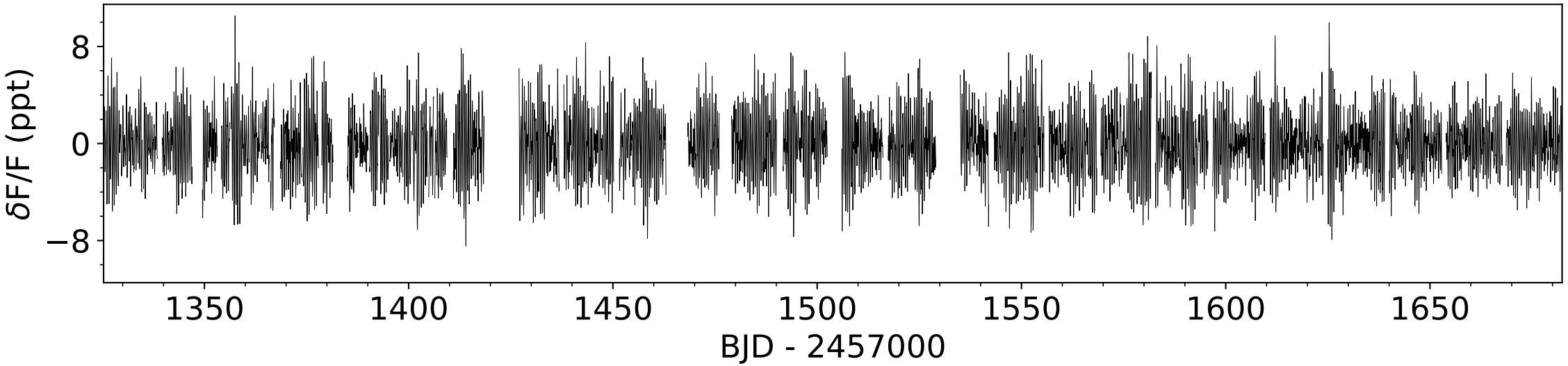


- Each abscissa shows 13 box plots, one per TESS sector
- Plot based on ~2000 TESS light curves in the S-CVZ

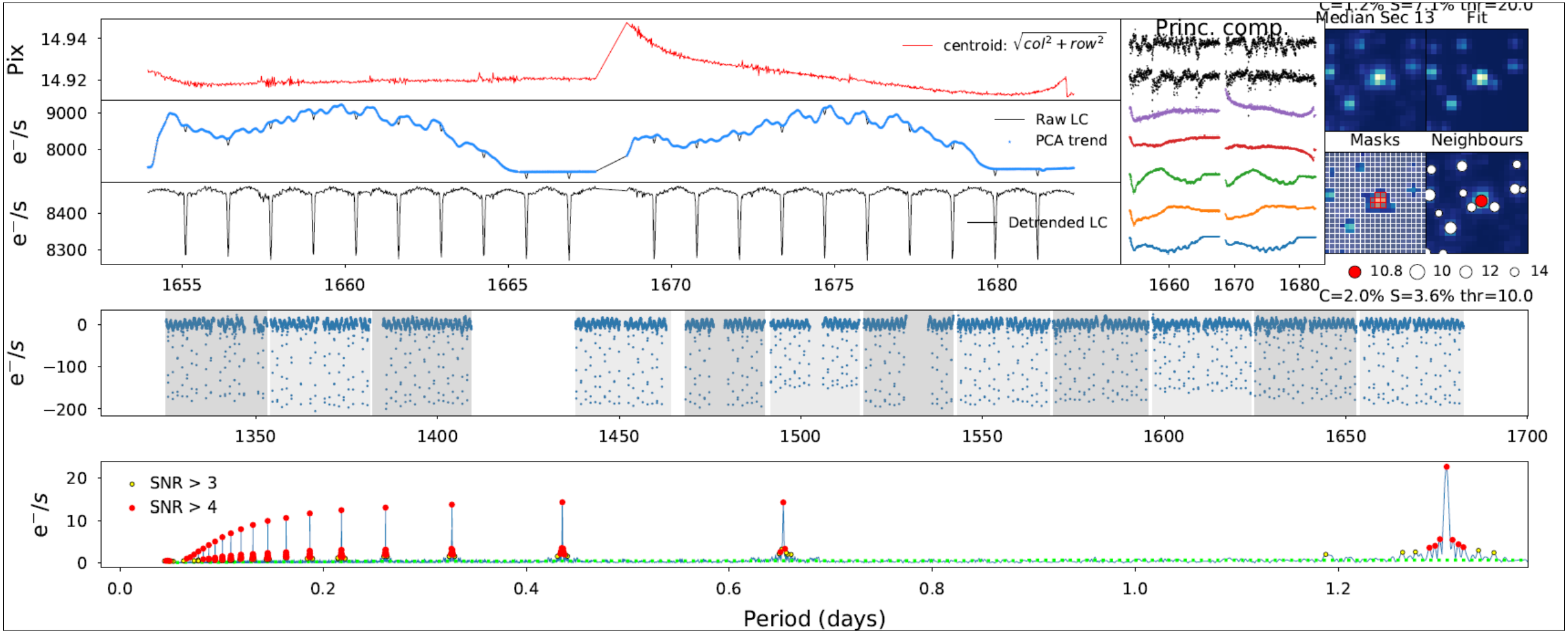
Extract light curve

(Results)



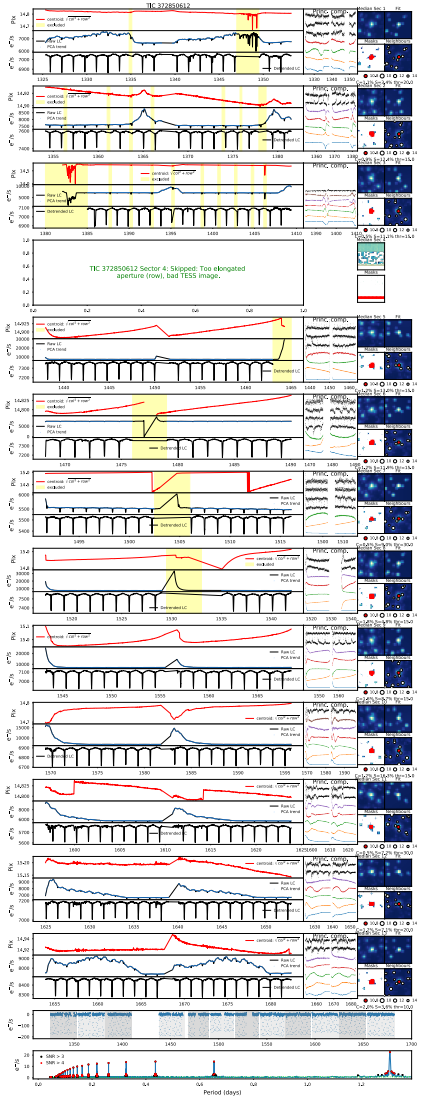


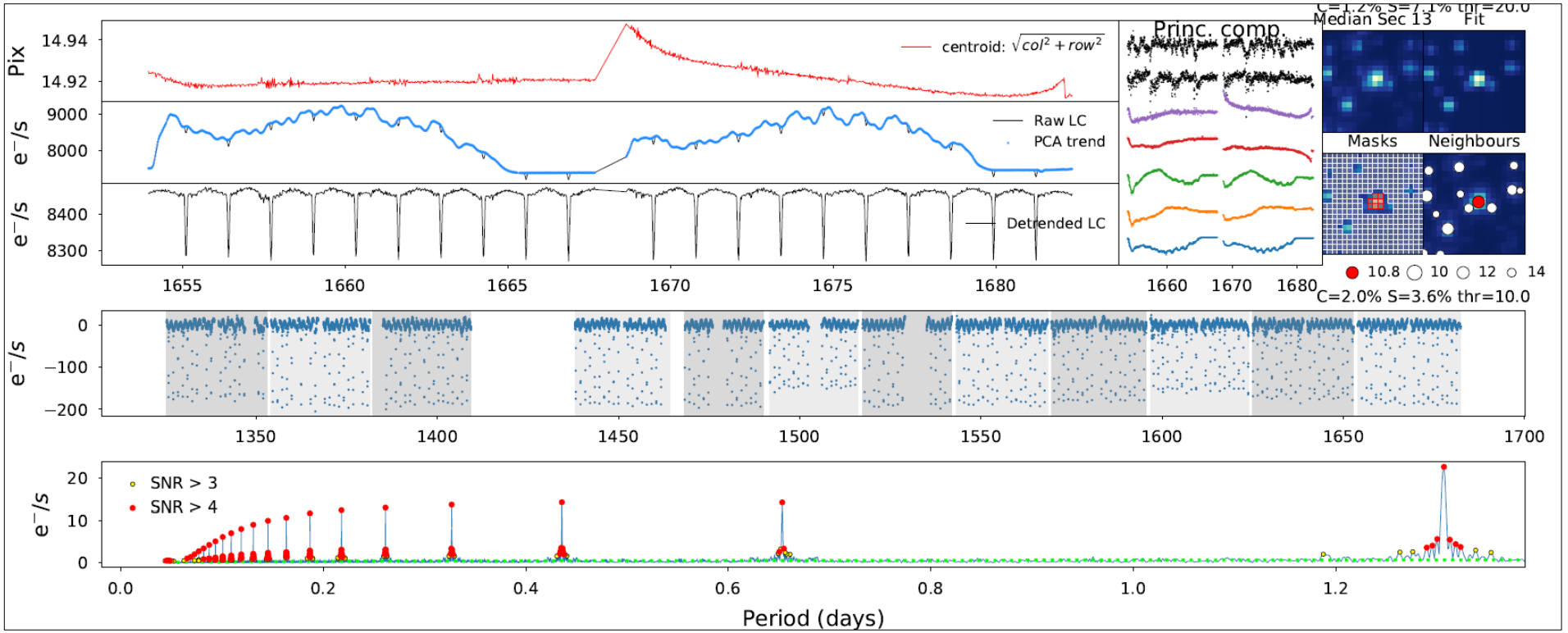
Extract light curve
(diagnostic plots)



Extract light curve

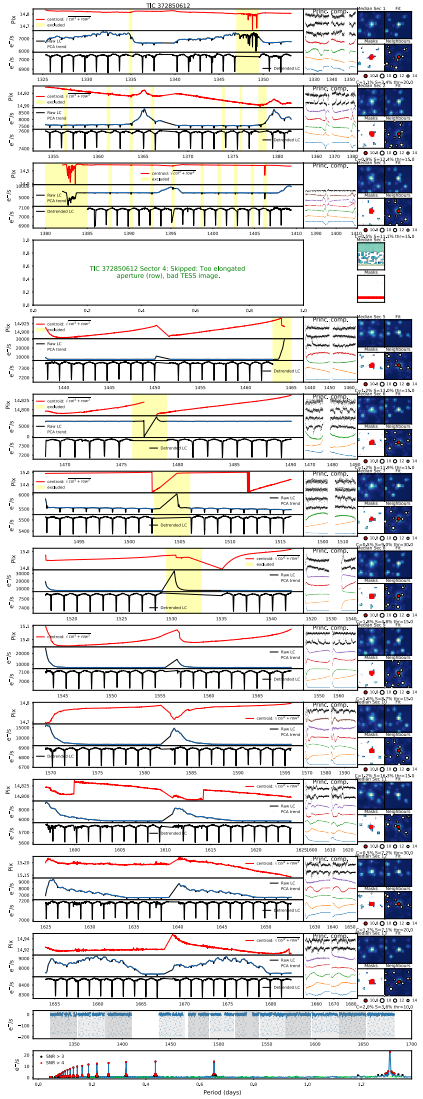
(diagnostic plots)

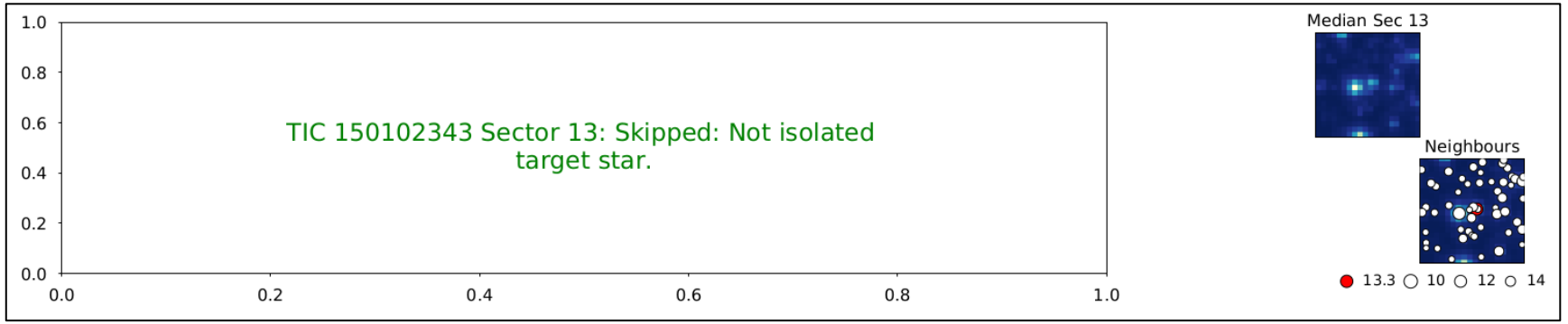


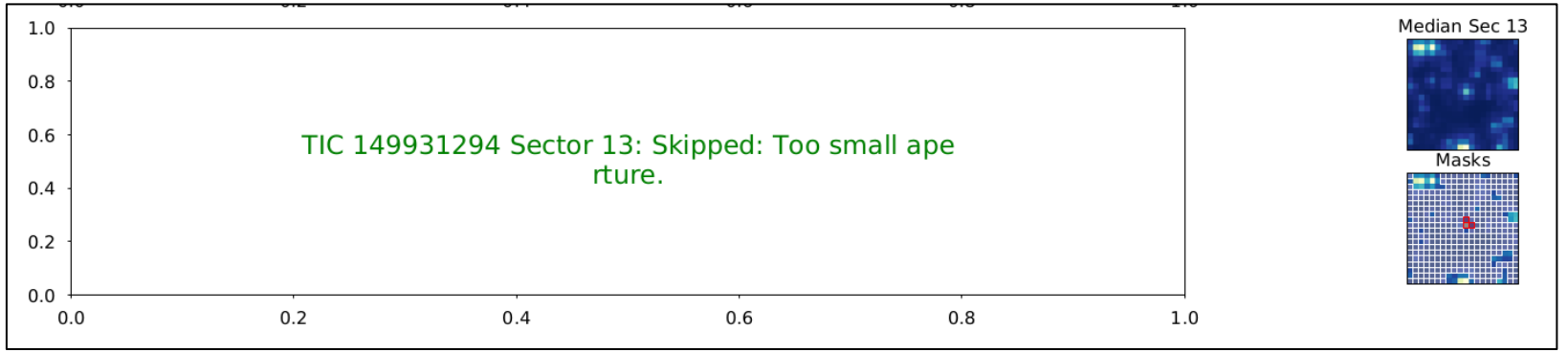


Extract light curve

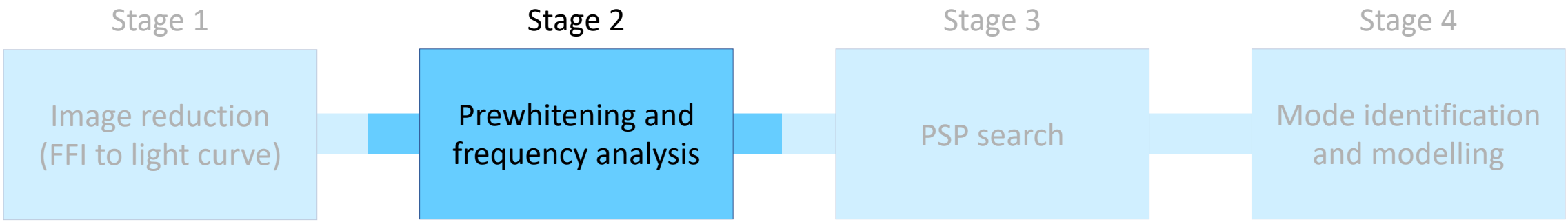
(diagnostic plots)





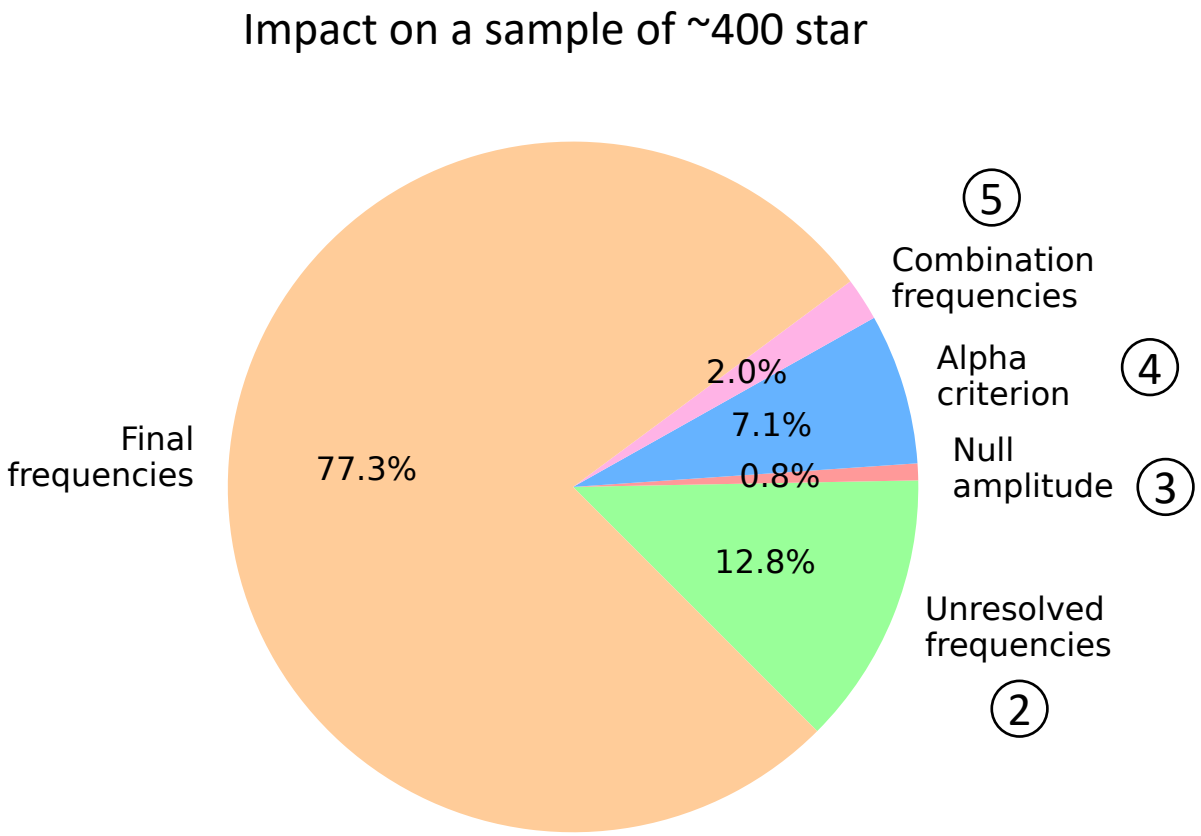


Raw data to useful frequencies



Prewhitening and frequency analysis

1. Prewhitening.
2. Unresolved frequencies: conservative difference of at least $2.5 \times T^{-1}$.
3. Simultaneous non-linear optimization.
4. Alpha-criterium: periodogram amplitude vs prewhitened one.
5. Combination frequencies.



Raw data to useful frequencies

Period-spacing patterns
(Linear model)

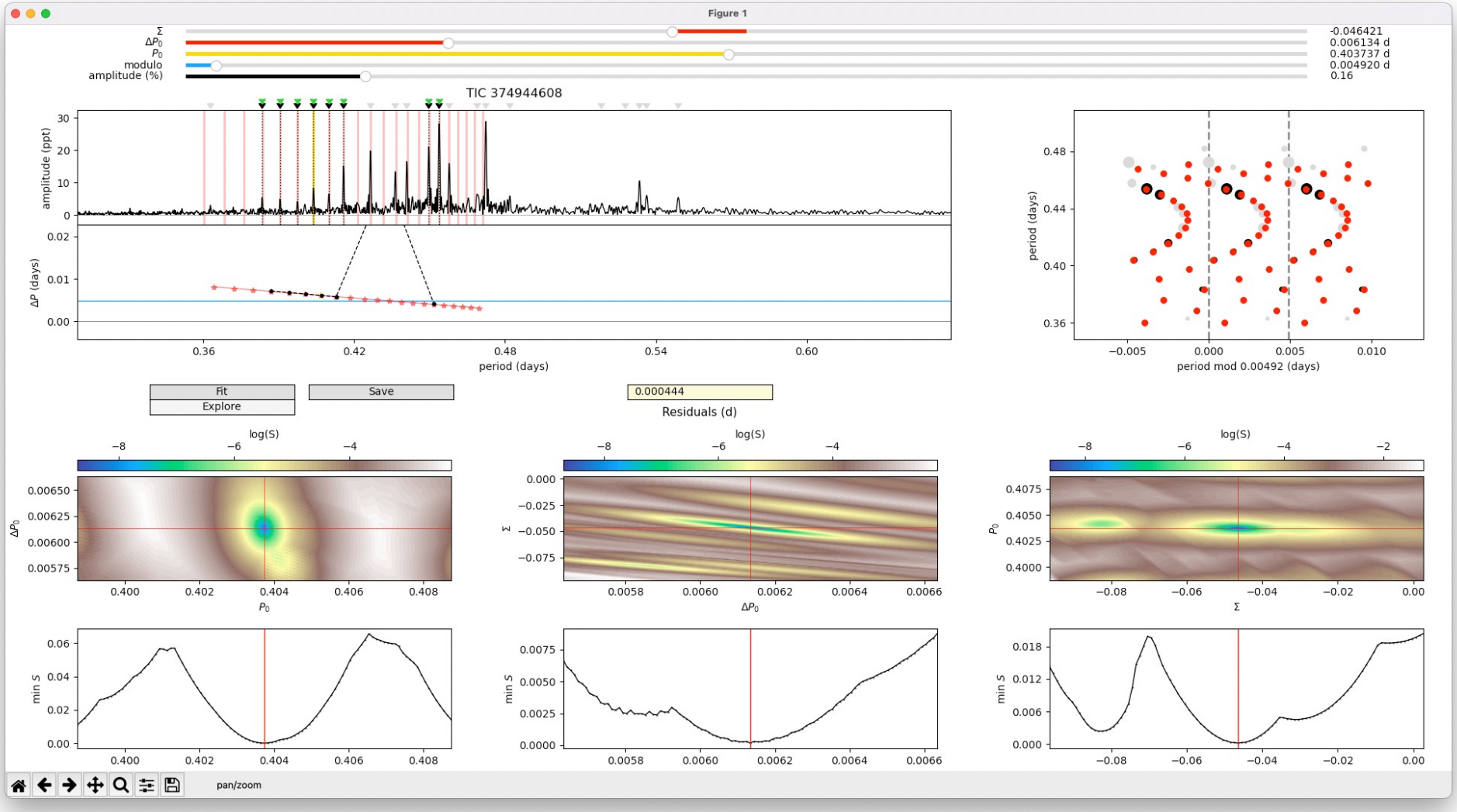
Three parameters: $P_0, \Delta P_0, \Sigma$

$$P_i = \sum_{j=0}^{i-1} \Delta P_j + P_0 = \Delta P_0 \frac{(1+\Sigma)^i - 1}{\Sigma} + P_0$$

Period-spacing patterns
(cost function)

$$S\left(P_0, \Delta P_0, \Sigma\right) = \sum_{i=1}^{n} \frac{A_i}{A_{\max}} \frac{\left(P_i^{\mathrm{obs}} - P_i\right)^2}{\sigma_i^2 + \Delta P_i^2}$$

Period-spacing patterns
(FLOSSY)



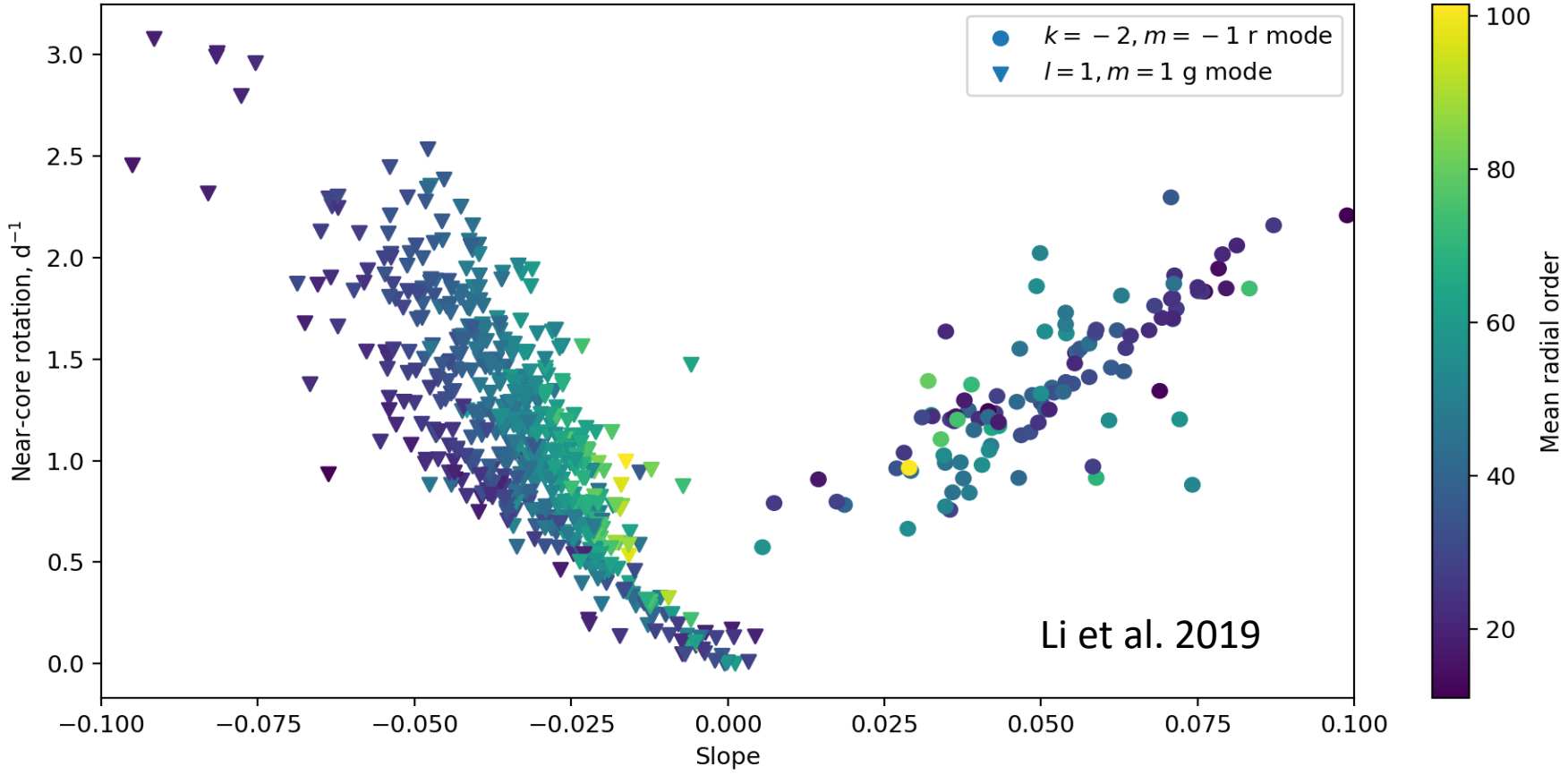
Period-spacing patterns
(FLOSSY: output)

period	e_period	freq	e_freq	match	imatch
0.24473663428735848	1.2525451702565722e-05	4.086024975018027	0.0002091199326537	0	-1
0.252760296513122	5.112858339642671e-06	3.9563175617183424	8.002875261169132e-05	0	-1
0.2538657247906436	1.8311685659218568e-06	3.939090244753102	2.841320245365852e-05	0	-1
0.2549255163439921	6.002962808103011e-06	3.922714423967734	9.237172148005928e-05	0	-1
0.25599800911297216	9.36130653555548e-06	3.9062803787614575	0.0001428444235411	0	-1
0.2581100801557337	1.1073085945317717e-05	3.8743159484381176	0.0001662106084756	0	-1
0.2643012482415441	1.0530106135662356e-05	3.783561396903064	0.0001507420163365	0	-1
0.2678067969086238	9.419901894188336e-06	3.7340351758928727	0.0001313418682139	0	-1
0.27083841201405656	1.808458085104236e-05	3.692238455260548	0.0002465403055975	0	-1
0.2727677209926896	1.8446390714629757e-05	3.6661229428492415	0.0002479279291756	0	-1
0.27624982078751975	1.841553134168886e-05	3.619911850618574	0.000241312736237	0	-1
0.284366408081056	1.2298119447365015e-05	3.5165897644104267	0.0001520835082524	0	-1
0.2950120261688721	1.9228405489869946e-05	3.389692321992241	0.0002209346490026	0	-1
0.3074777926726835	2.137451056600788e-05	3.252267395663663	0.0002260833968133	0	-1
0.3627938599026148	2.522501104593772e-05	2.7563862306501856	0.0001916511848731	0	-1
0.3833530553458031 6	1.7458430416333276e-05	2.6085614450051824	0.0001187975101262	0	-1

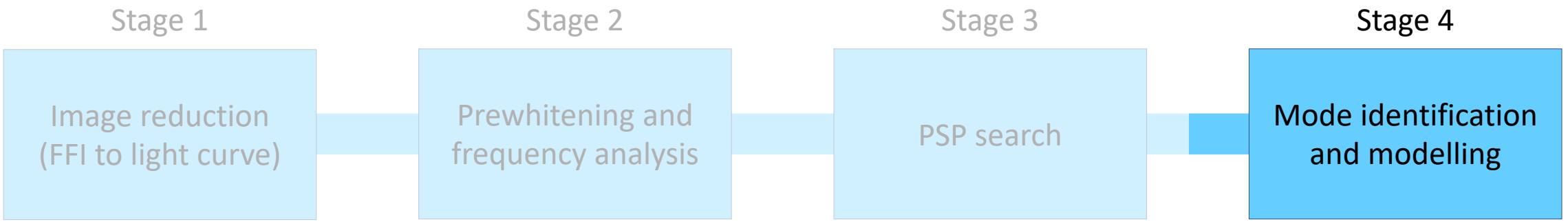
i	period	period_spacing	missing
0	0.40335753396340823	0.009521975502892485	0
1	0.4128795094663007	0.01095027182832636	1
2	0.42382978129462706	0.012592812602575311	1
3	0.43642259389720234	0.014481734492961607	0
4	0.450904328390164	0.01665399466690585	1
5	0.4675583230570698	0.019152093866941722	1
6	0.4867104169240115	0.022024907946982978	1
7	0.5087353248709945	0.025328644139030423	1
8	0.5340639690100248	0.029127940759884983	0
9	0.5631919097699098	0.03349713187386773	1

Period-spacing patterns

(physics)



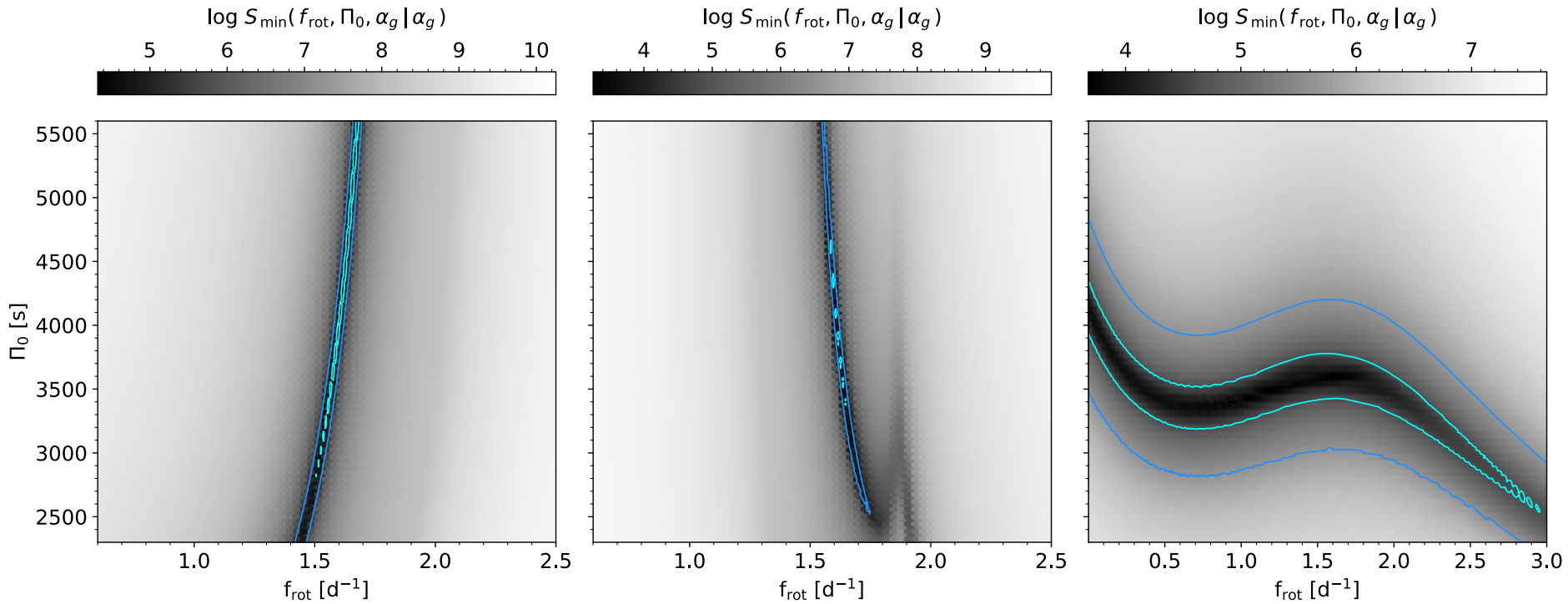
Raw data to useful frequencies



Traditional Approximation of Rotation

(TAR)

$$P_{\mathrm{CO}} = \frac{\Pi_0}{\sqrt{\Lambda_{nlm}(s)}}(n + \alpha_g) \qquad s = \frac{2f_{\mathrm{rot}}}{f_{\mathrm{co}}}$$



Thank you