Secondary eclipses in the CoRoT Light Curves

A homogeneous search based on Bayesian model selection

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Summary

- Homogeneous search for secondary eclipses in the CoRoT light curves
  (Parviainen, H., Deeg, H., Belmonte, J.A, under 2nd review)
- Approach based on Bayesian model selection
- CoRoT planets 1b-23b
- Public light curves
- Results
  - 3 significant eclipse candidates
  - 4 marginal candidates
  - (Yet another) confirmation of the known eclipses for CoRoT-1b and CoRoT-2b

Motivation

- Science from eclipses
  - Constraints on albedo and brightness temperature estimate
  - Improved e and w estimate → improved stellar density estimate
- Eclipse searches reported in the CoRoT discovery papers
  - Varying approaches to detrending, search methods, prior assumptions, etc.
- Systematic & homogeneous search
  - All light curves go through same detrending and analysis steps
  - All eclipse candidates go through same false-positive tests
  - Candidates passing the tests go through same parameter estimation process

Theory – Bayesian model selection

Marginal likelihood Prior Likelihood

$$P(M) = \int P(\vec{\theta}) P(M|\vec{\theta}) \mathrm{d}\vec{\theta}$$

Model specific parameter vector

$$B_{i,j} = P(M_i)/P(M_j)$$

Bayes factor

$$P(M_i) = \frac{B_{i0}}{\sum_{j=0}^{N} B_{j0}}$$

Assuming equal prior model probabilities

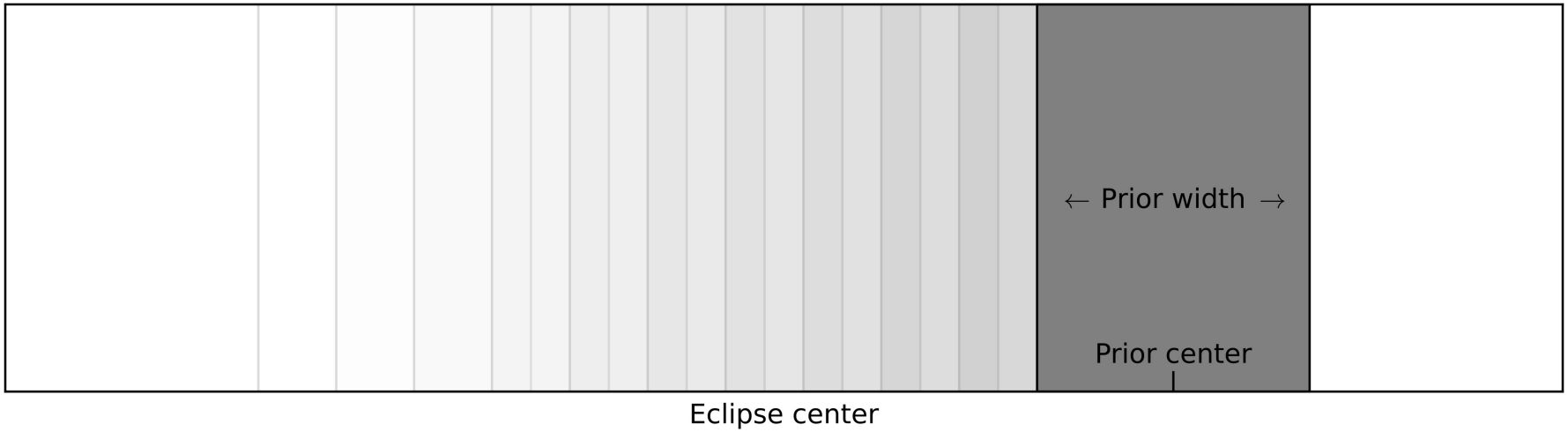
$$P(M_1) = \frac{1}{1 + 1/B_10}$$

All we need to do is to integrate the posterior over the prior ranges of all model parameters!

Theory - Models

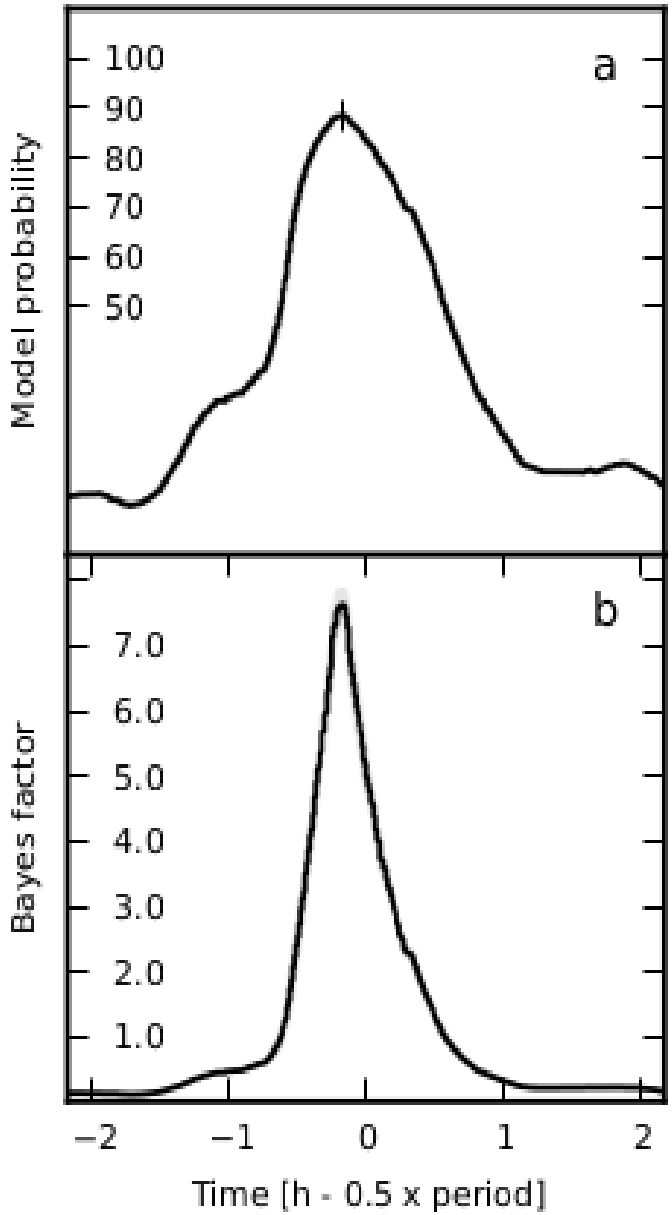
- M_0 - no eclipse
  - 2 - 3 free parameters (constant zeropoint and a point-to-point error estimate per time cadence)
- M_1 – eclipse
  - 10 - 11 parameters, includes parameters from M0
    - Radius ratio, period, scaled semi-major axis, inclination, contamination (marginal posterior prior dominated)
    - Flux ratio, eccentricity, argument of periastron (marginal posterior likelihood dominated)
  - Priors based on published parameter estimates from transit light curves and RV data

Search Overview



- MC sampling of the likelihood space
  - Simple MC practical due to the simple parameter space
- Bayes factor mapped as a function of eclipse center using a sliding uniform prior
  - Eclipse centers derived from e and w

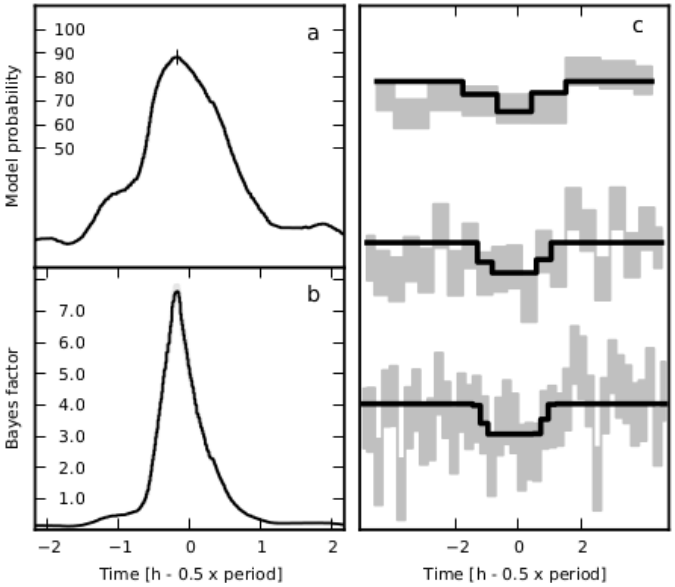
Search overview

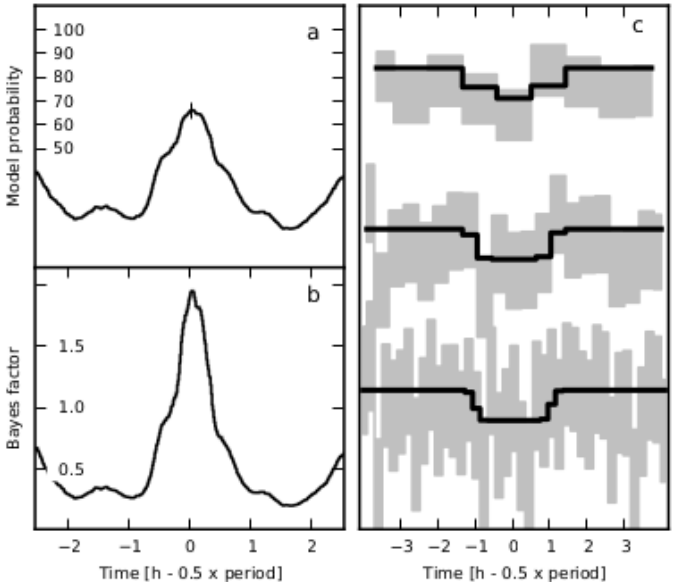


- After candidate identification
  - False positive tests for
    - Single events
    - Correlated noise
- Significant candidates characterized using MCMC
  - Planet brightness temperature from flux ratio
  - Eccentricity and w

Results – Known Eclipses

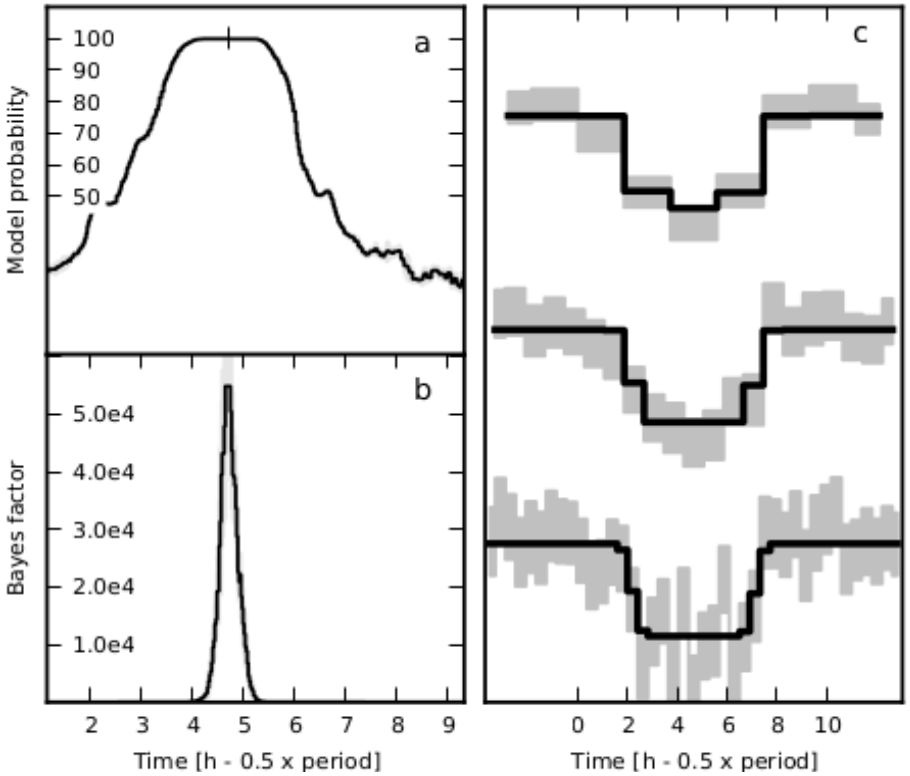
- CoRoT-1b
  - Significant detection
  - Parameter estimates agree with previously reported values
- CoRoT-2b
  - Marginal detection
    - What comes to Bayes factor
    - Due to the prior on flux ratio
  - Parameter estimates agree with previously reported values





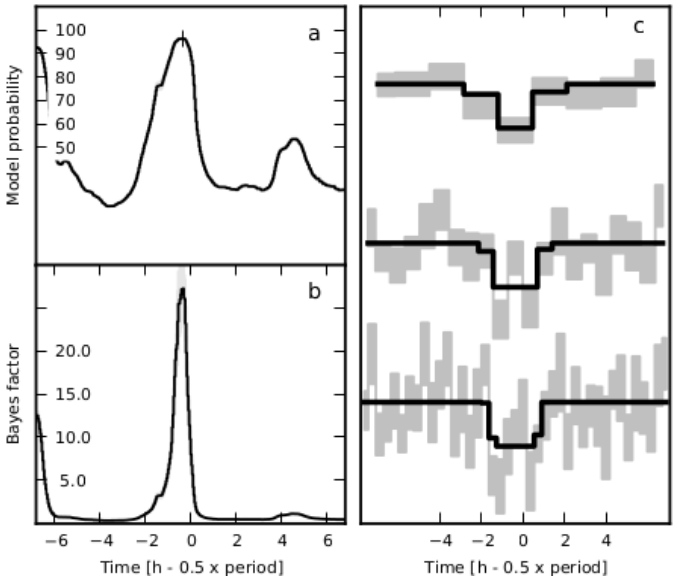
Results – New Eclipse Candidates

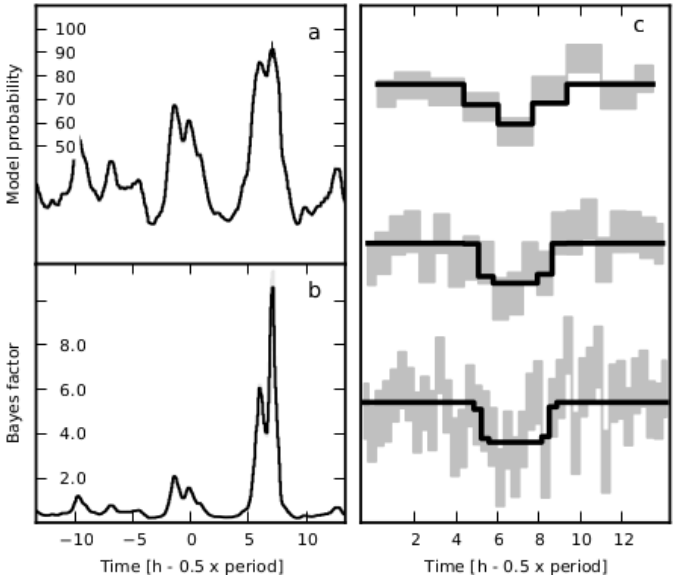
- CoRoT-11b
  - Significant detection
    - Max Bayes factor 50000
  - Passes the tests
    - Not from a single event
  - However
    - Eccentricity 0.36
    - Tbr 2600 – 3000 K
    - Teq 1600 – 2200 K
  - Needs confirmation!



Results – New Eclipse Candidates

- CoRoT-15b
  - Inflated brown dwarf
  - 63 Mjup, 1.1 Rjup, P = 3 d
  - Tbr = 3470 – 4710 K
- CoRoT-6b
  - 2.96 Mjup, 1.17 Rjup, P ~ 8 d
  - Tbr = 2230 – 2840 K
  - Teq = 970 – 1270 K
- Marginal candidates
  - CoRoT-3b, CoRoT-13b, CoRoT-18b, CoRoT-21b





Summary

- Approach based on Bayesian model selection
  - Powerful
  - Simple MC implementation feasible due to the low number of likelihood dominated parameters
- Problems & Open Questions
  - Correlated noise (stellar granulation) a problem
    - As with any other analysis approach
    - Improved noise model (with correlated noise) can improve the analysis
  - High brightness temperatures
    - Tbr calculated assuming the planet and star to be blackbodies
    - Also for Kepler eclipses by Coughlin & Lopez-Moralez (2012)
- All new candidates somewhat 'exotic' → need confirmation!

Thanks!