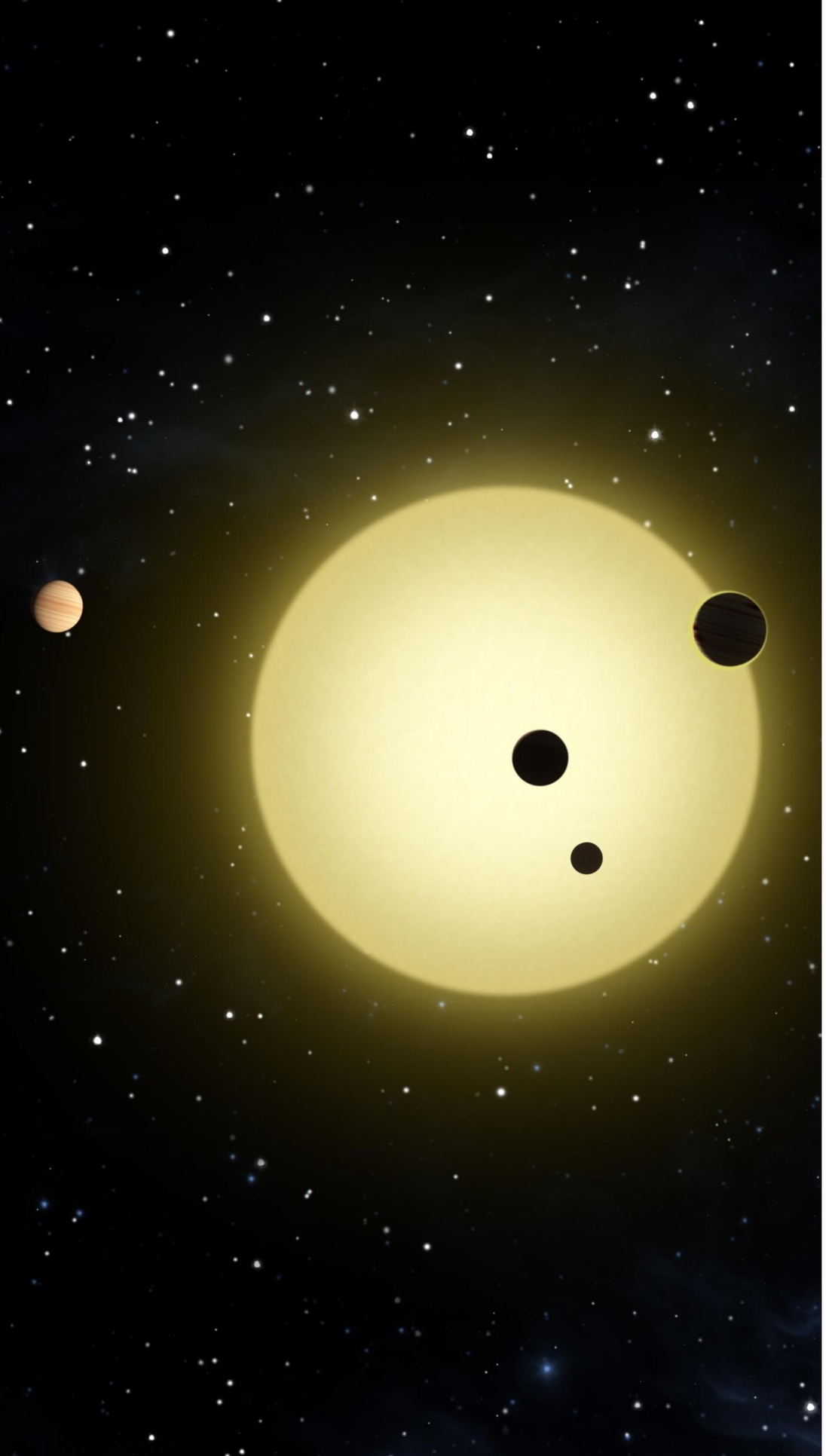


The Efficiency of Geometric Samplers for Exoplanet Transit Timing Variation Models

Noah W. Tuchow, Eric B. Ford, Theodore Papamarkou and Alexey Lindo

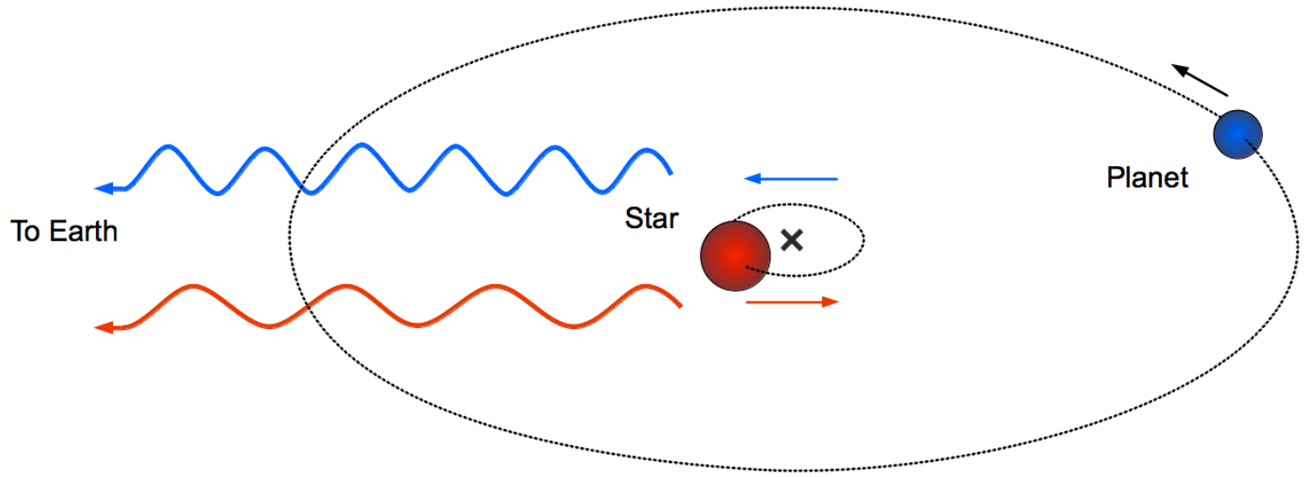
How can efficient sampling help to determine the composition of exoplanets?

- Detection of exoplanets
- Creative sampling
- How to evaluate the efficiency

EXOPLANET DETECTION

EXOPLANET DETECTION

- Radial velocity –> mass



EXOPLANET DETECTION

- Radial velocity –> mass
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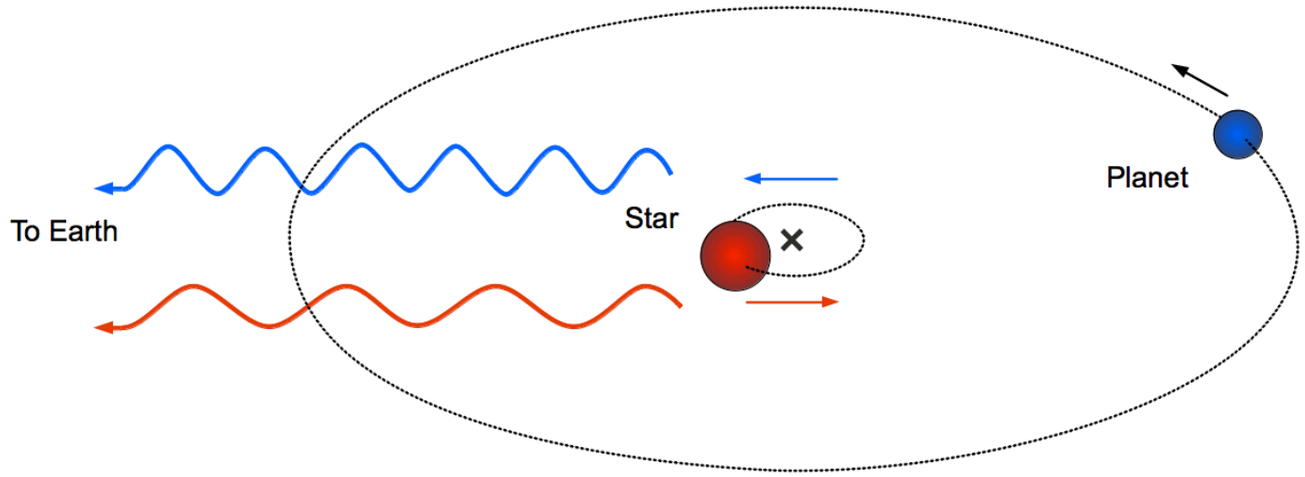
Often not combinable



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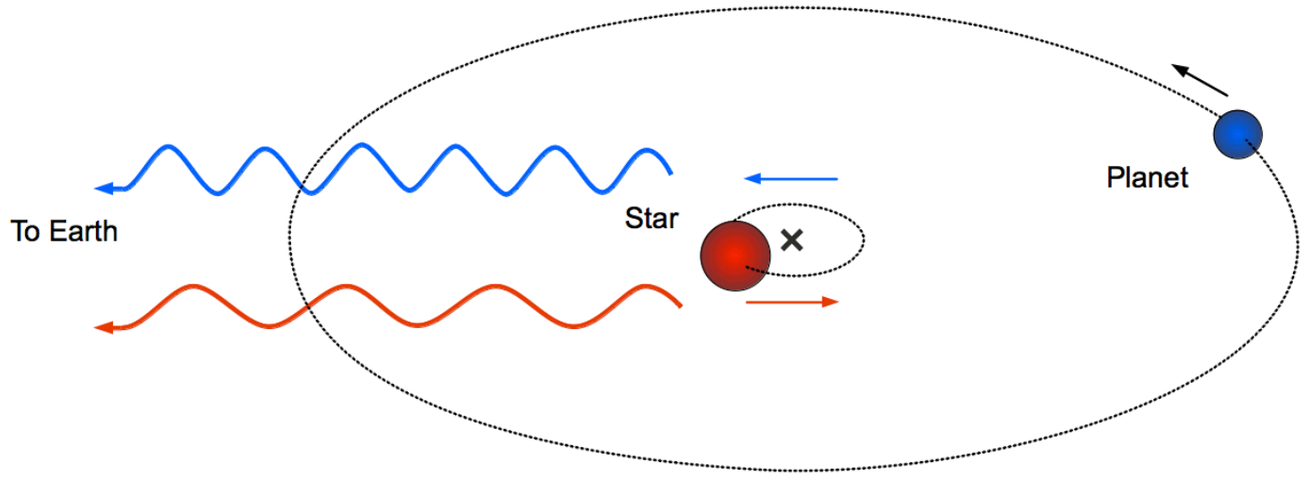
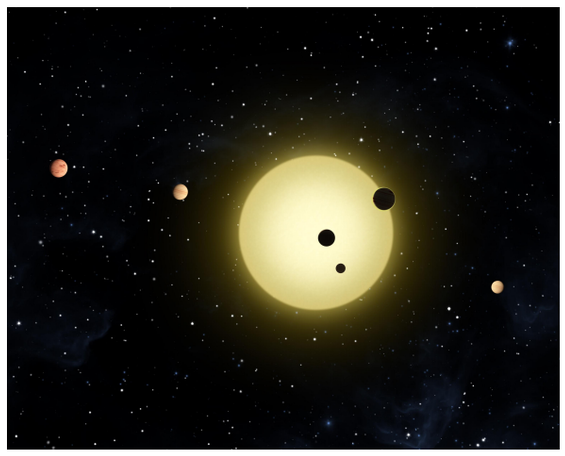


- Transit Timing Variation (TTV) –> mass



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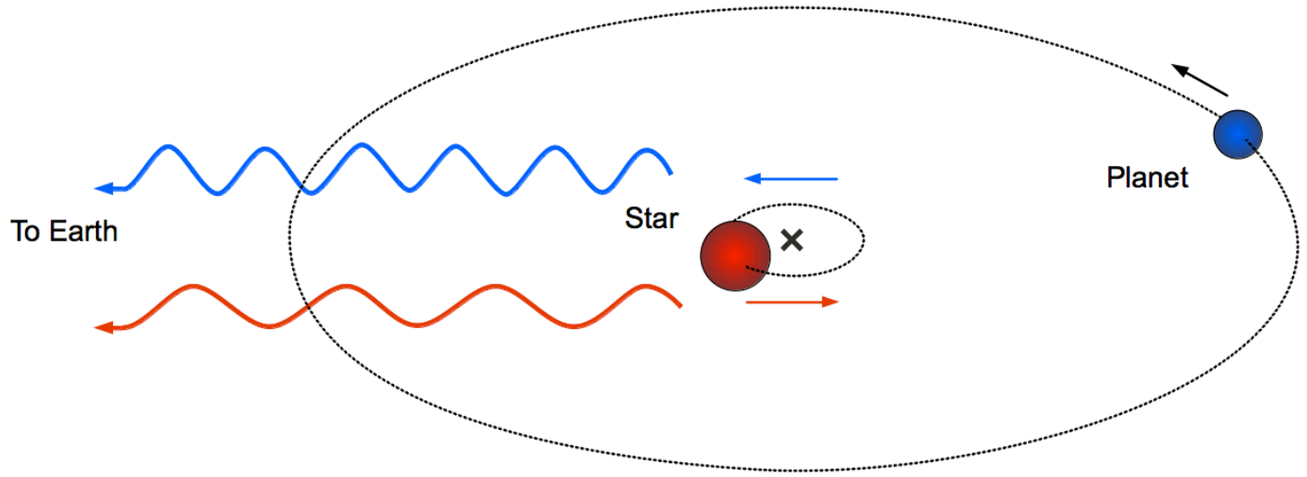

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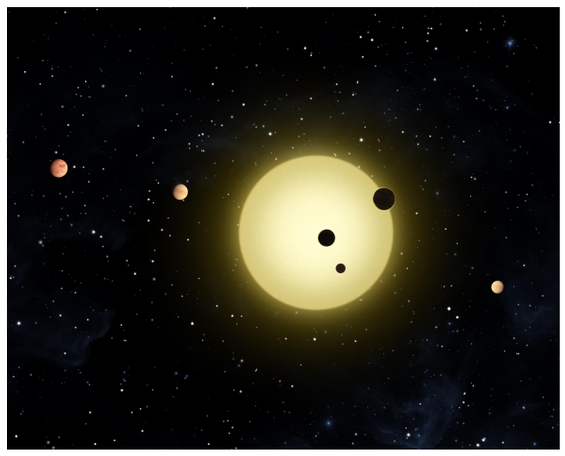
Planetary properties → TTV



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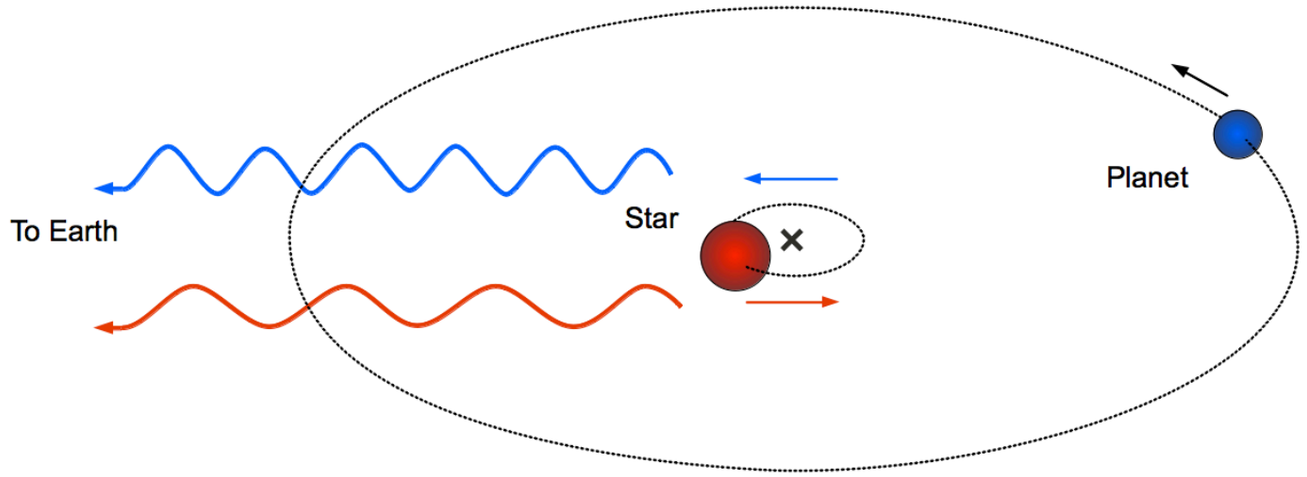

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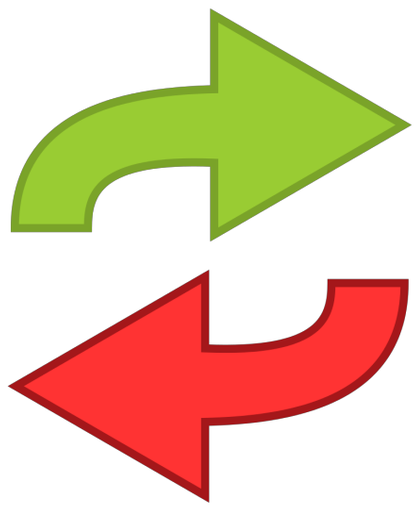

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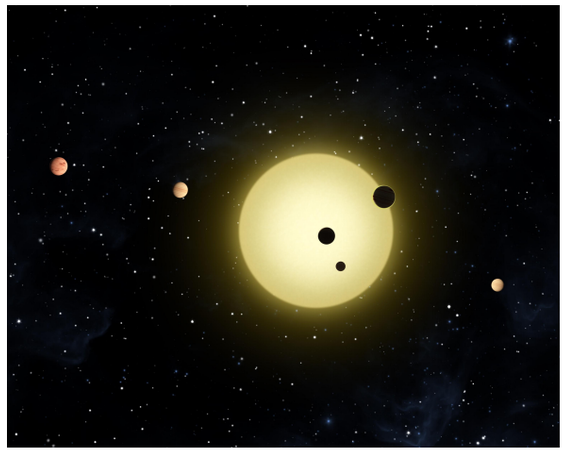

CREATIVE SAMPLER METHODS

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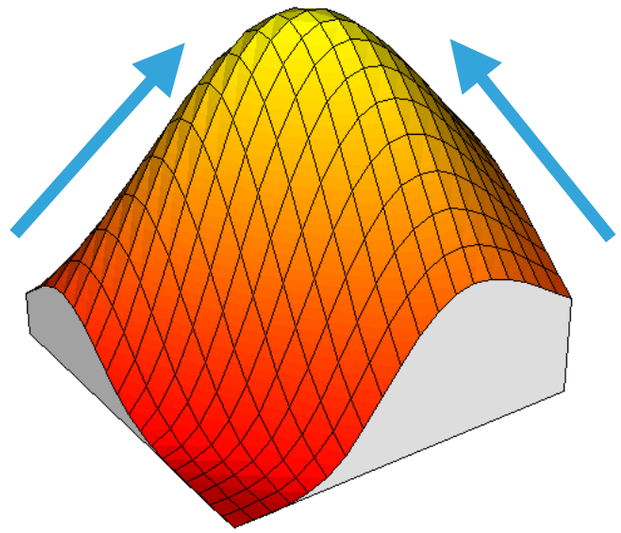
- MALA: Uses the gradient of posterior distribution
- DEMCMC and AIMCMC: Walkers communicate
- SMMALA and GAMC: Uses the Hessian
- HMC (Hamiltonian Monte Carlo)



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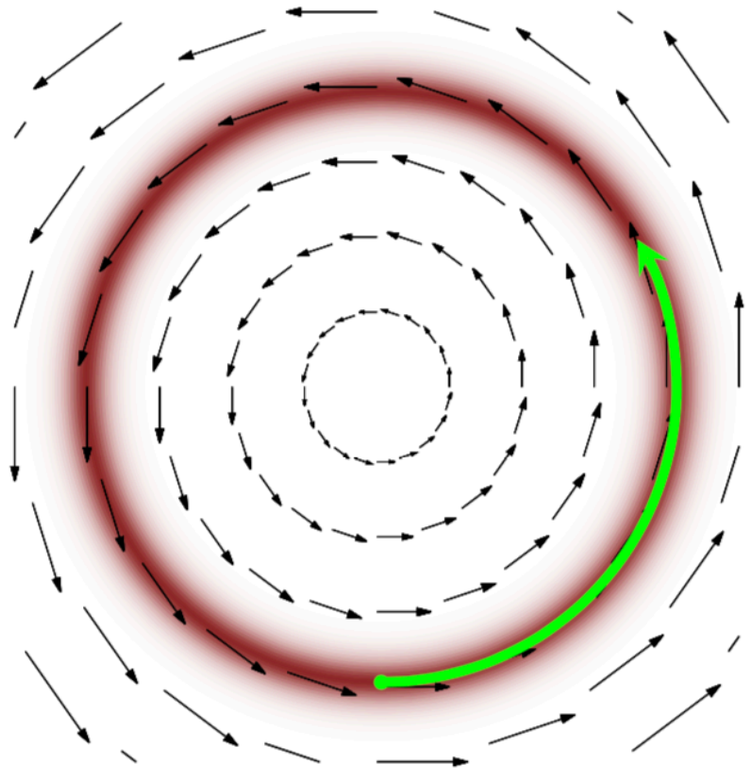

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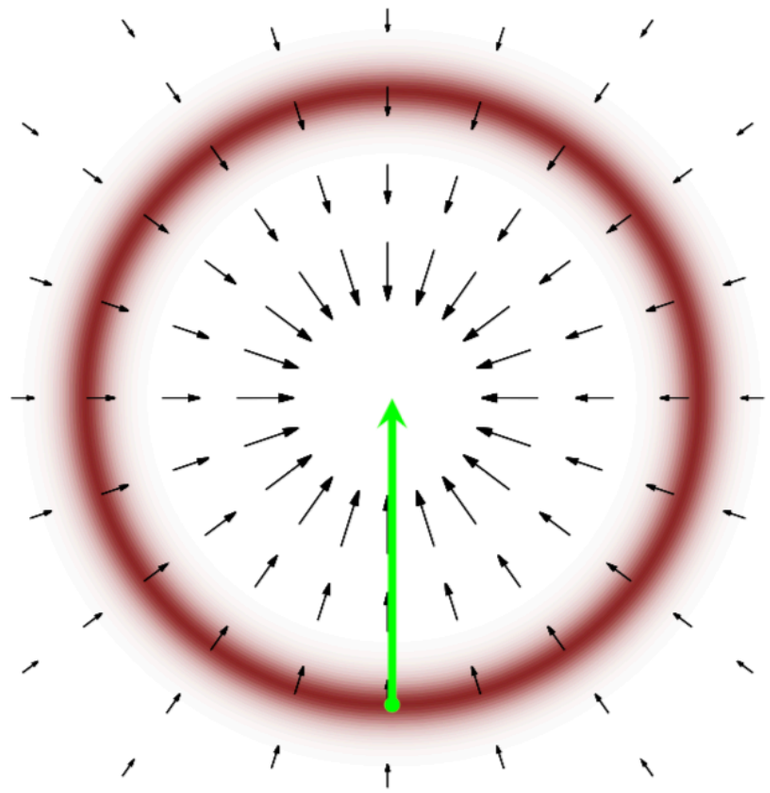
However, the gradient is always directed inwards



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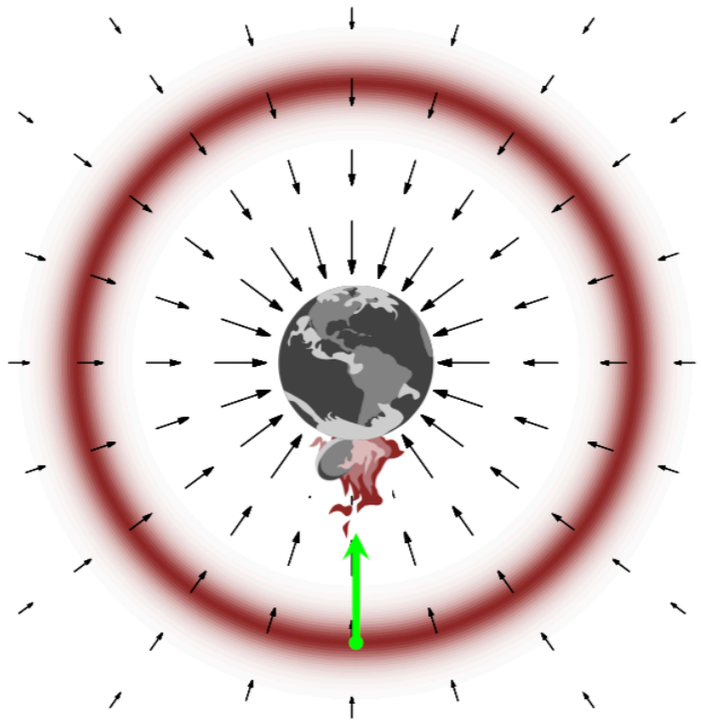

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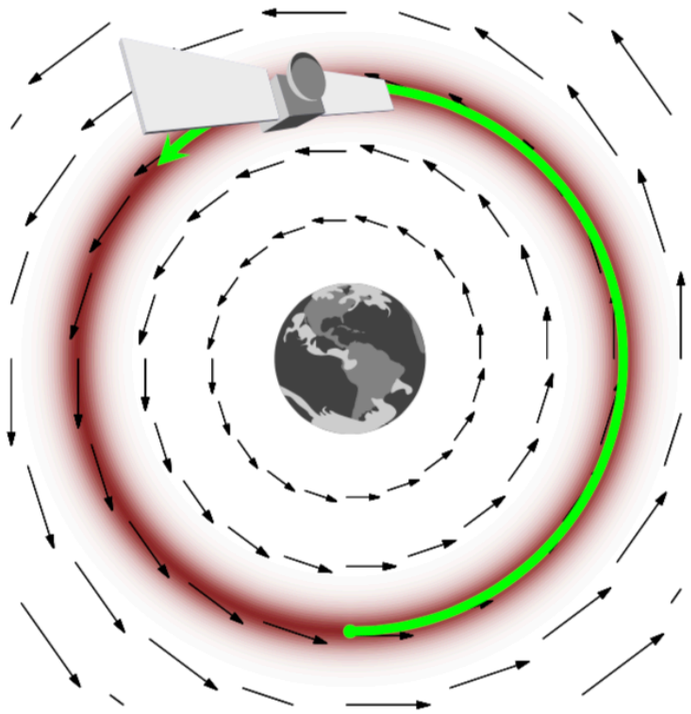
Physical analogy: planet orbiting a star

Need *momentum* to maintain a stable orbit.

HMC: introduce auxiliary momentum variable to system.

$$\mathcal{H} = T + V$$



SIMULATED DATA SETS

- Different TTV models: Simple Sinusoidal & TTVFaster

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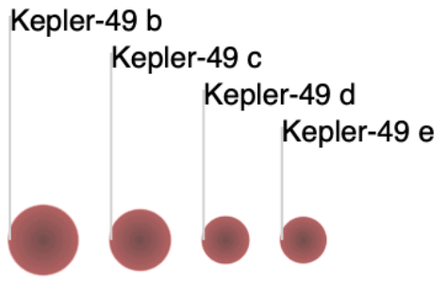
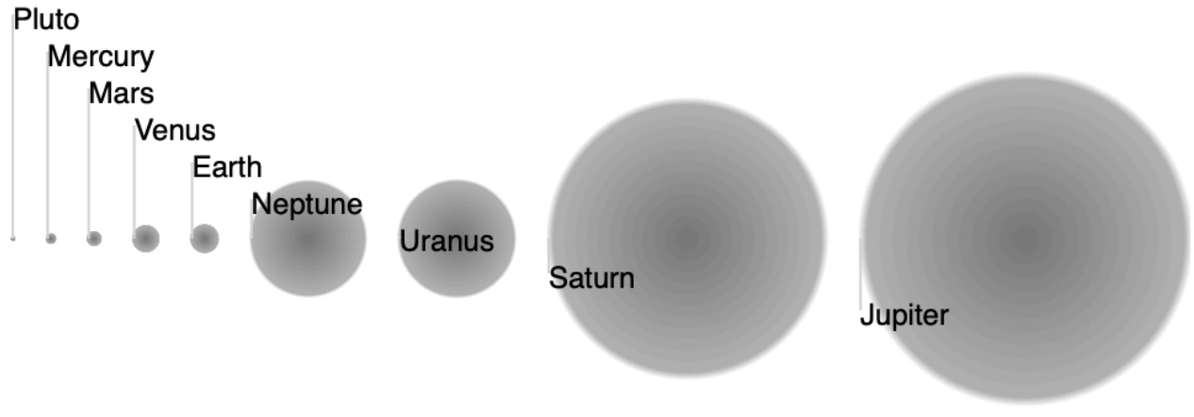
- Kepler-307 — Well understood system
- Kepler-49 — Two additional outer planets
- Kepler-57 — Bimodality in posterior distribution



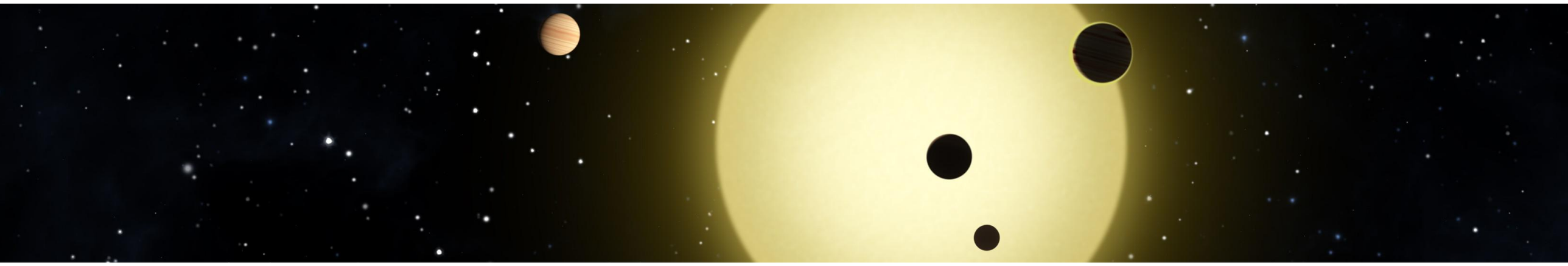


HOW TO DETERMINE THE EFFICIENCY

- Each of the samplers was first burned-in
- Then, they were ran for 10,000 iterations
- The Effective Sample Size / total elapsed time was evaluated
  Effective Sample Size: number of effectively independent draws from the posterior distribution.
- The best sampler was run for 2 million iterations to compare the final results with the true parameters of the model

RESULTS

- Kepler-307 HMC
- Kepler-49 GAMC
- Kepler-57 GAMC & DEMCMC



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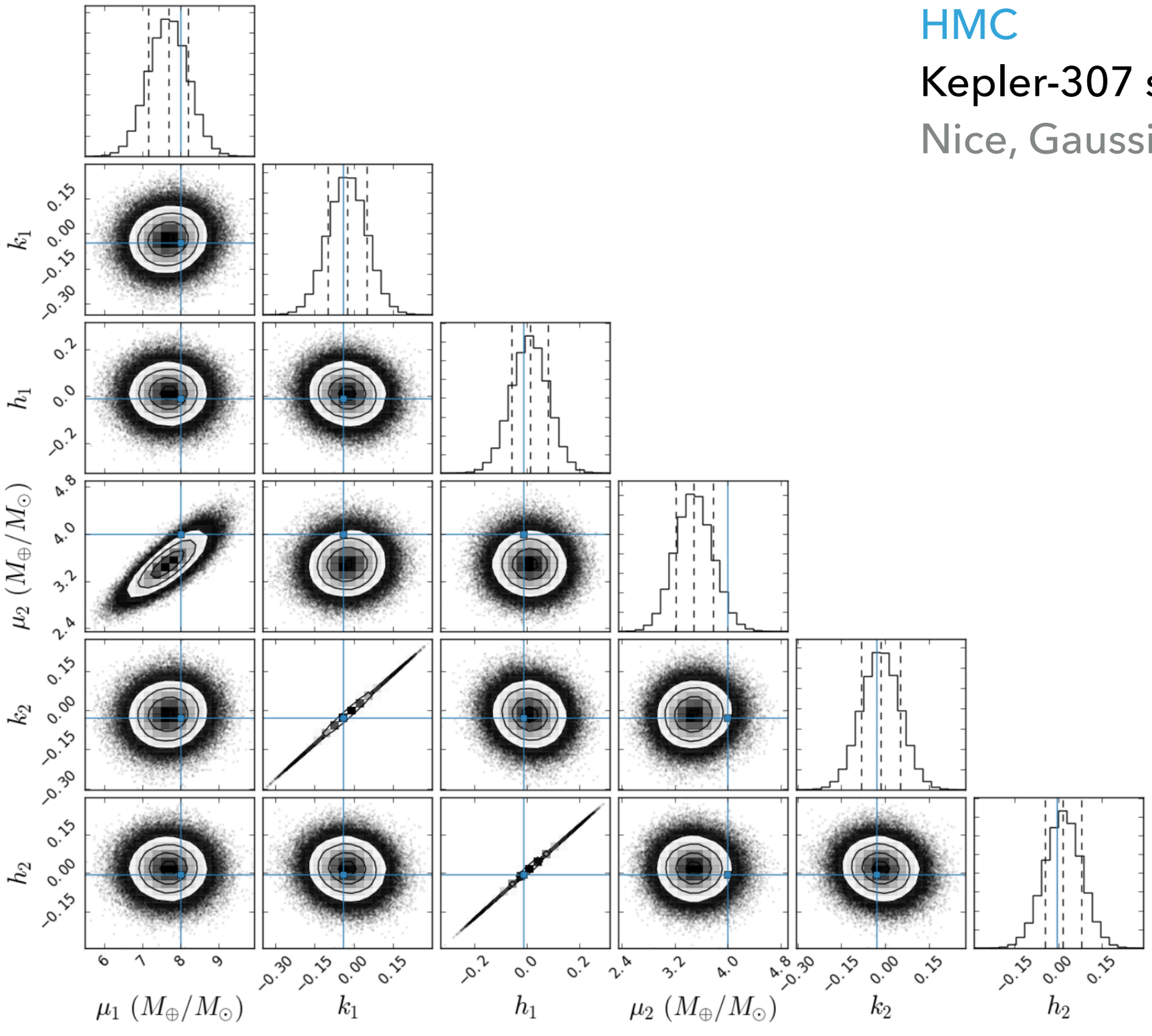

HMC

Kepler-307 system

Nice, Gaussian posteriors

CONCLUSIONS

- Different samplers for different scenarios
- HMC very suitable if posterior is near Gaussian
- GAMC and DEMCMC performed continuously alright
- Future research: investigate samplers performance on burn-in and with a more complicated TTV model