UNIVERSITY OF PORTSMOUTH

HAMPSHIRE ASTRONOMICAL GROUP

Determining The Parameters of Exoplanetary Candidates From Transit Timing Variations

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Presentation Outline

Useful Information

Why look for variations in transit timing?

What can we do with TTV?

Data collection

Analysis

Developments

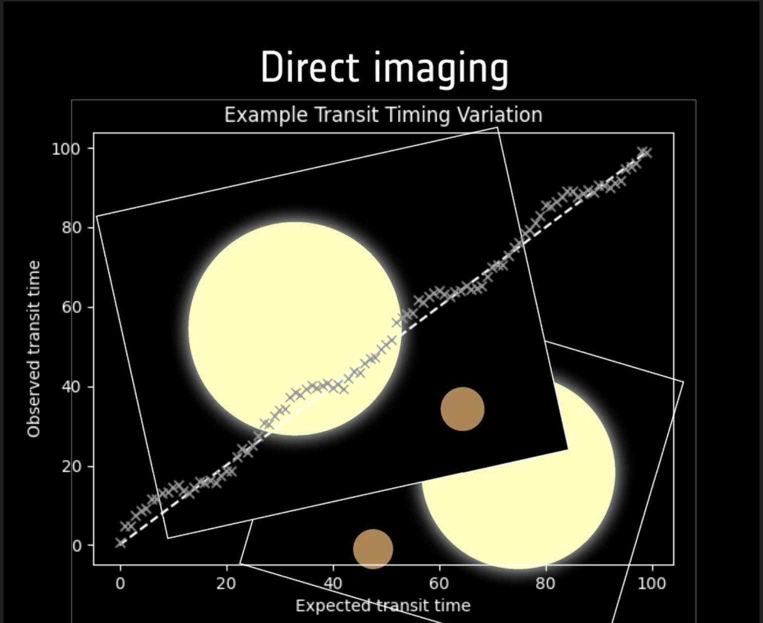
Discussion

Conclusion

Useful Information

- How do we discover exoplanets?
  - Transit Photometry
  - Doppler Spectroscopy
  - Gravitational Microlensing
  - Direct Imaging

- What are Transit Timing Variations?



Observational departure from expected timing

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Detecting exoplanets with [illegible]

ESA 2022

Rationale

What problem am I trying to solve?

Rationale

Methodology

Results

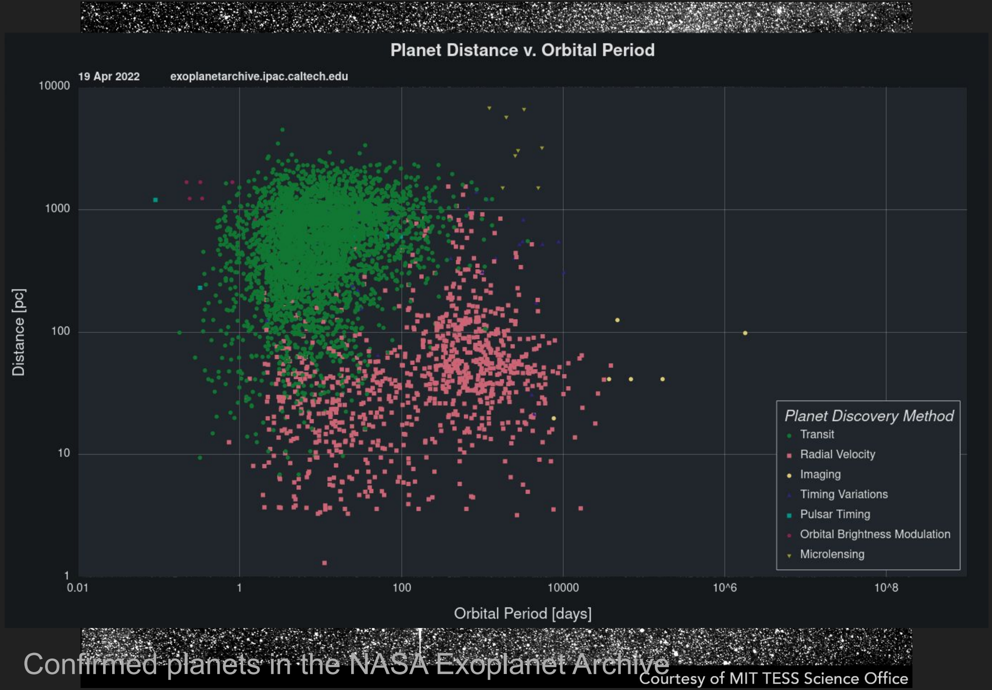
Discussion

Conclusion

Why look for variations in transit timing?

- Observing many stars for transits is easy

- Strong historical data
  - ~3800 Transiting planets
  - >100,000,000 Light curves



Confirmed planets in the NASA Exoplanet Archive

NASA Filtergraph 2022

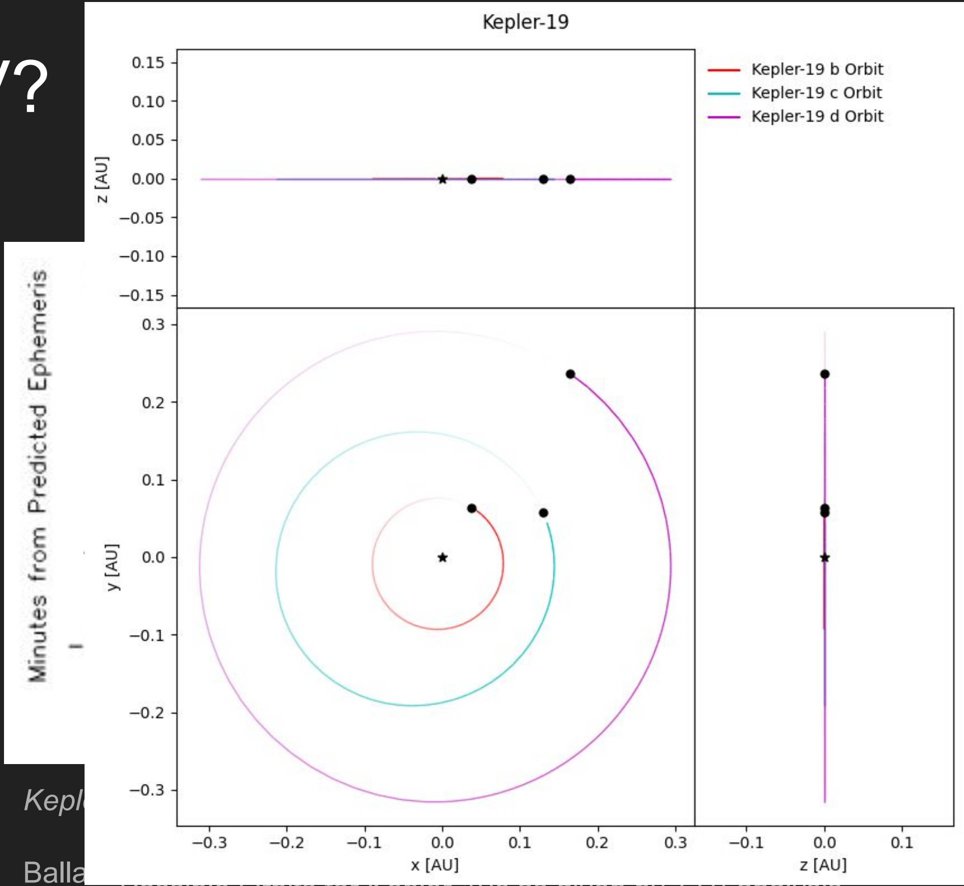
TESS Star field

NASA/MIT/TESS 2018

What can we do with TTV?

- Verify the properties of known planets

- Discover new orbiting bodies



Kepl

Balla

Possible Orbits for Kepler-19c as given by TTV analysis

SystemTRAPPIST-f1rDKeplamic-al Orbital Solutions.

Ballard S. et al. 2011

LloydWalters et al 202217

Methodology

How am I going to solve the problem?

Rationale

Methodology

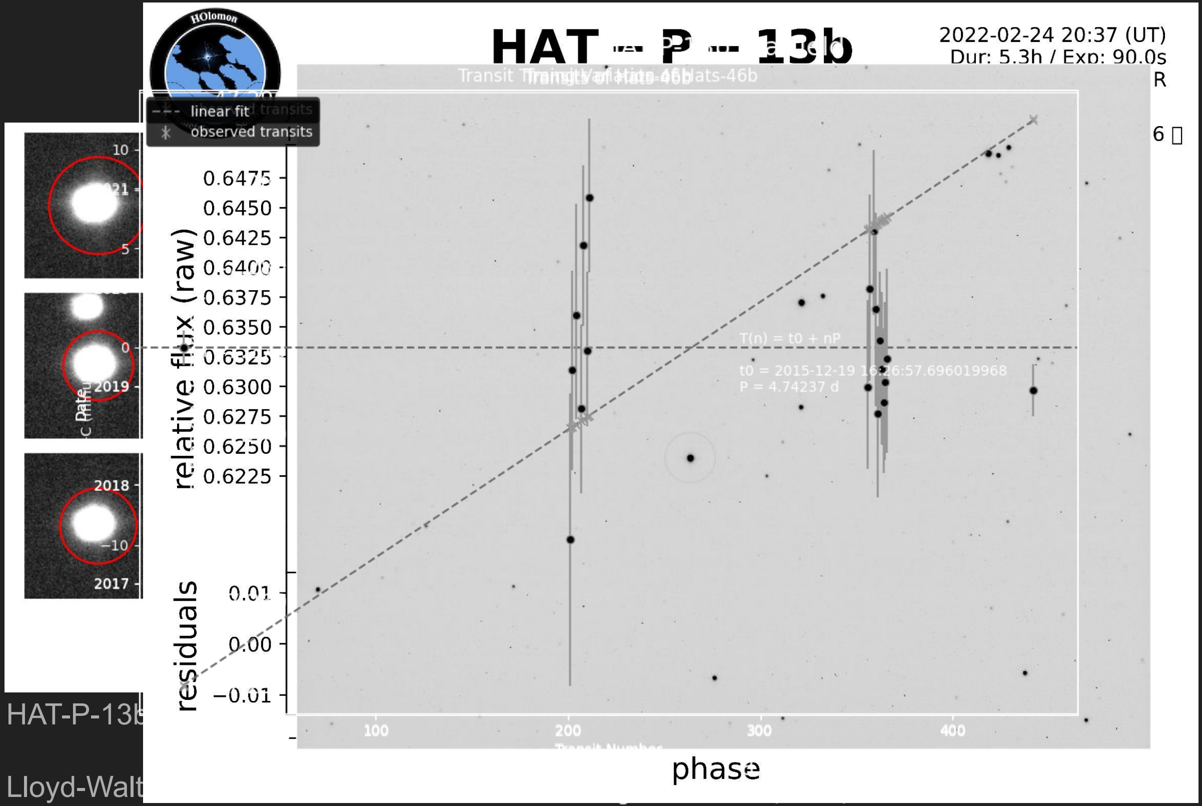
Results

Discussion

Conclusion

Data collection

- Planetary light curve
- Ephemerides and TTV



HAT-P-13b and companion stars

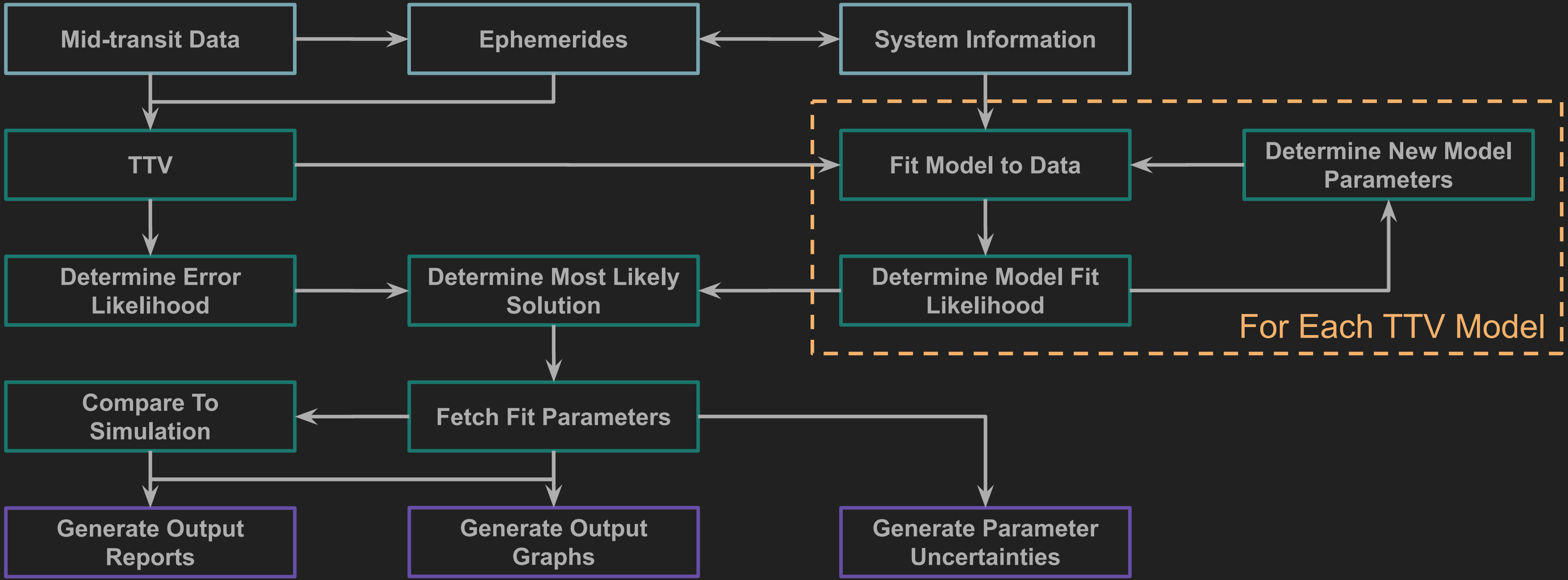
HAT-P-13b light curve, fit using HOPS Software

Lloyd-Walters J. Futcher S. 2022

Lloyd-Walters J. Futcher S. 2022

Lloyd-Walters J. 2022

Analysis



Mid-transit Data
Ephemerides
System Information
TTV
Fit Model to Data
Determine New Model Parameters
Determine Error Likelihood
Determine Most Likely Solution
Determine Model Fit Likelihood
For Each TTV Model
Compare To Simulation
Fetch Fit Parameters
Generate Output Reports
Generate Output Graphs
Generate Parameter Uncertainties

Results

What did I achieve in trying to solve the problem?

Rationale

Methodology

Results

Discussion

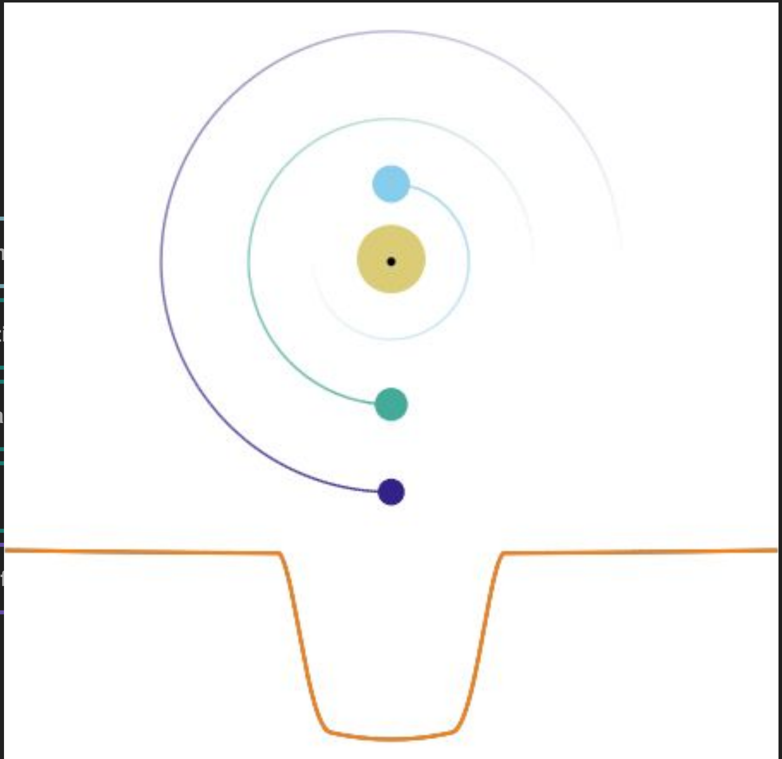
Conclusion

Developments

- Analytical TTV Models
  - Arbitrarily many planets
  - Extensible
- Computational Pipeline
  - Fully Automatable
  - Self-Verifying

fetchData.py	Fetch reported m
TTVCandidates.py	Order and prioriti
processing.py	Run data verifica
simulationPipeline.py	Simulate system
plotOrbitalConfig.py	Generate plots of

$$\delta_t = -\frac{P_t}{2\pi a_t}\sum_{i}^{n}\left[a_i\mu_i \sin\left(\frac{2\pi\left(t - t_{i,0}\right)}{p_i}\right)\right]$$



Animation for TTV due to interior perturbation

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Discoveries—(wip slide)

- Take known TTV systems
- Apply the pipeline to the midtransit points
- Demonstrate that we can recover known exoplanetary parameters > Double check with the code which planet I used

Placeholder > Generate graphical output of the model + code working

Kepler-19b has a nice set of TTV Curves the code is working with

Discussion

What are the implications of the results for this problem?
How can we progress further?

Rationale

Methodology

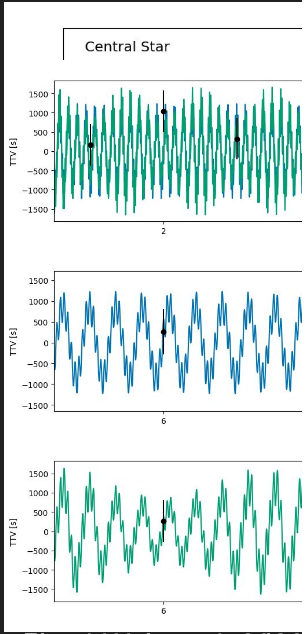
Results

Discussion

Conclusion

Discussion

- Quickly Generate TTV Curves
- Accurate to simulation
- Determine best fit parameters
- Develop additional models
- Search transit data for non-transiting planets



TTV curves using the

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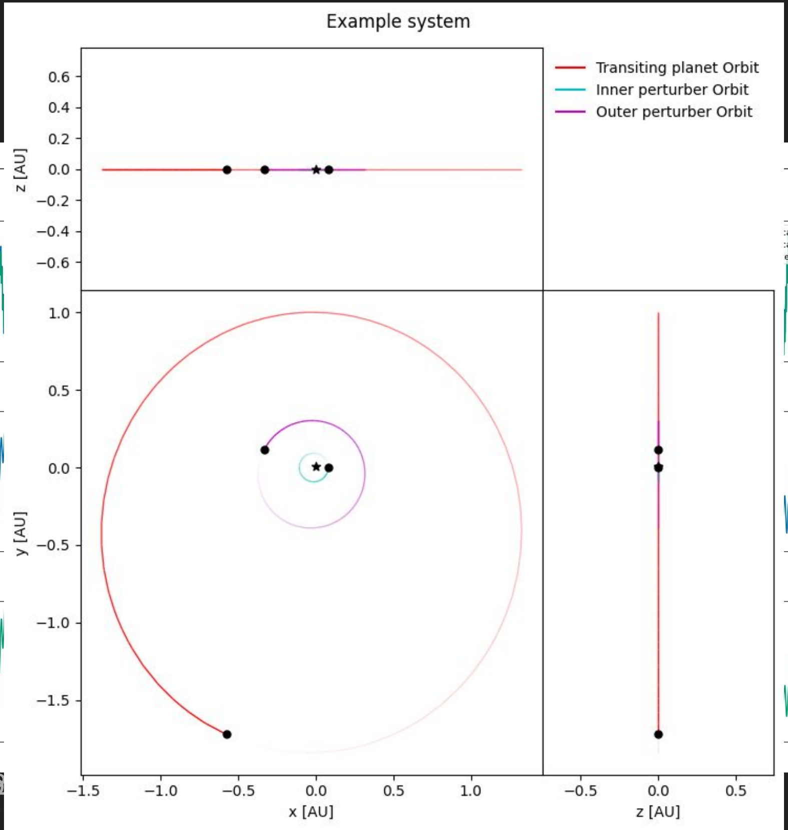

Example systems layout used in TTV model testing

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Conclusion

A Summary of the problem, results, and any future steps

Rationale

Methodology

Results

Discussion

Conclusion

Conclusion

- TTV can find and verify exoplanets
- Created analytical models for TTV
- Computational pipeline can search for TTV

- Additional models to be created
- Apply method to unknown systems

Thank you for your time!

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The data, software, and diagrams underlying this project are available in GitHub at https://github.com/SK1Y101/TransitProject. The datasets were derived from sources in the public domain.