Photometric Lightcurve Signatures of Black Holes and Neutron Stars with Main Sequence Stellar Companions

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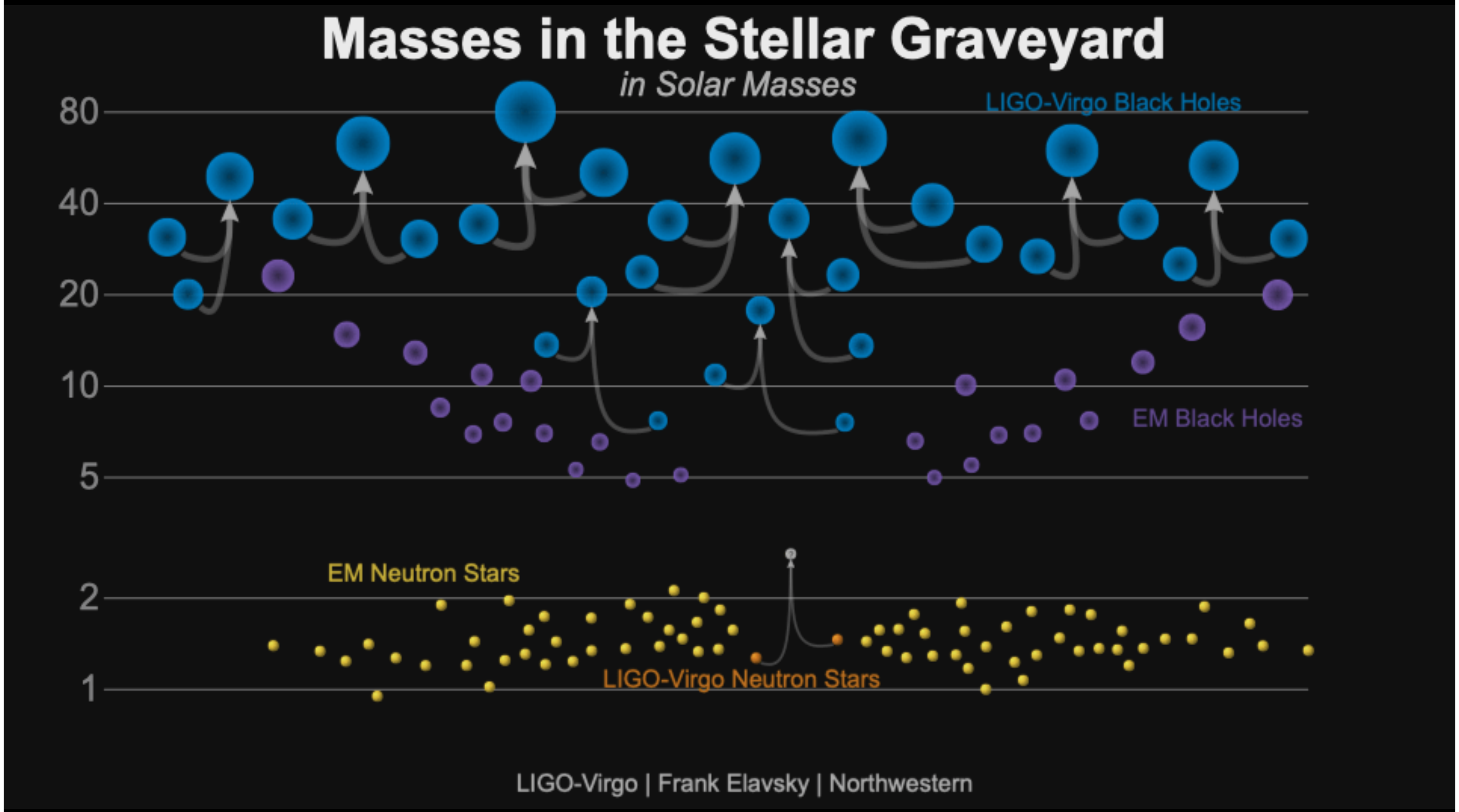
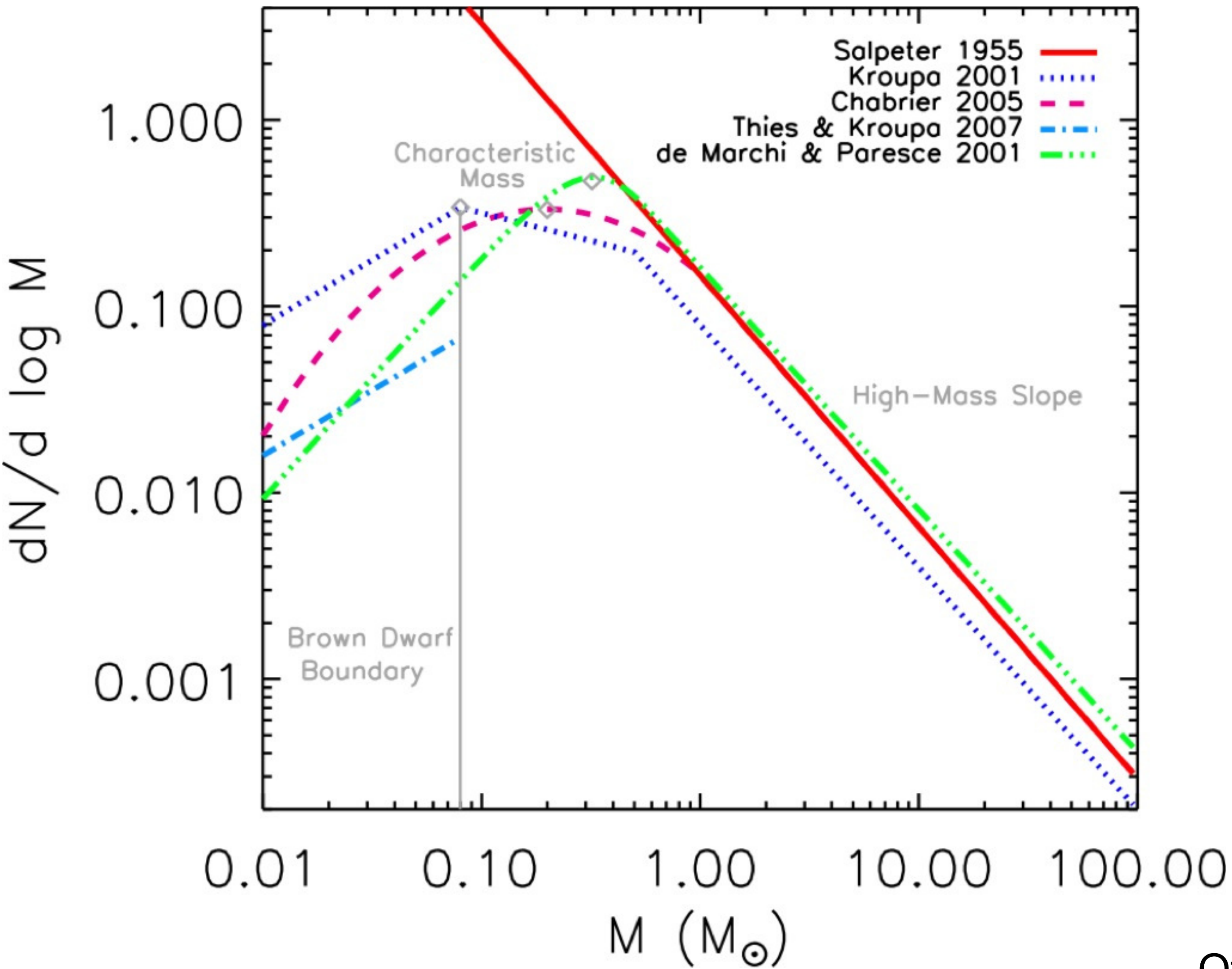
Tuesday, July 30, 2019

Stellar-Mass Black Holes



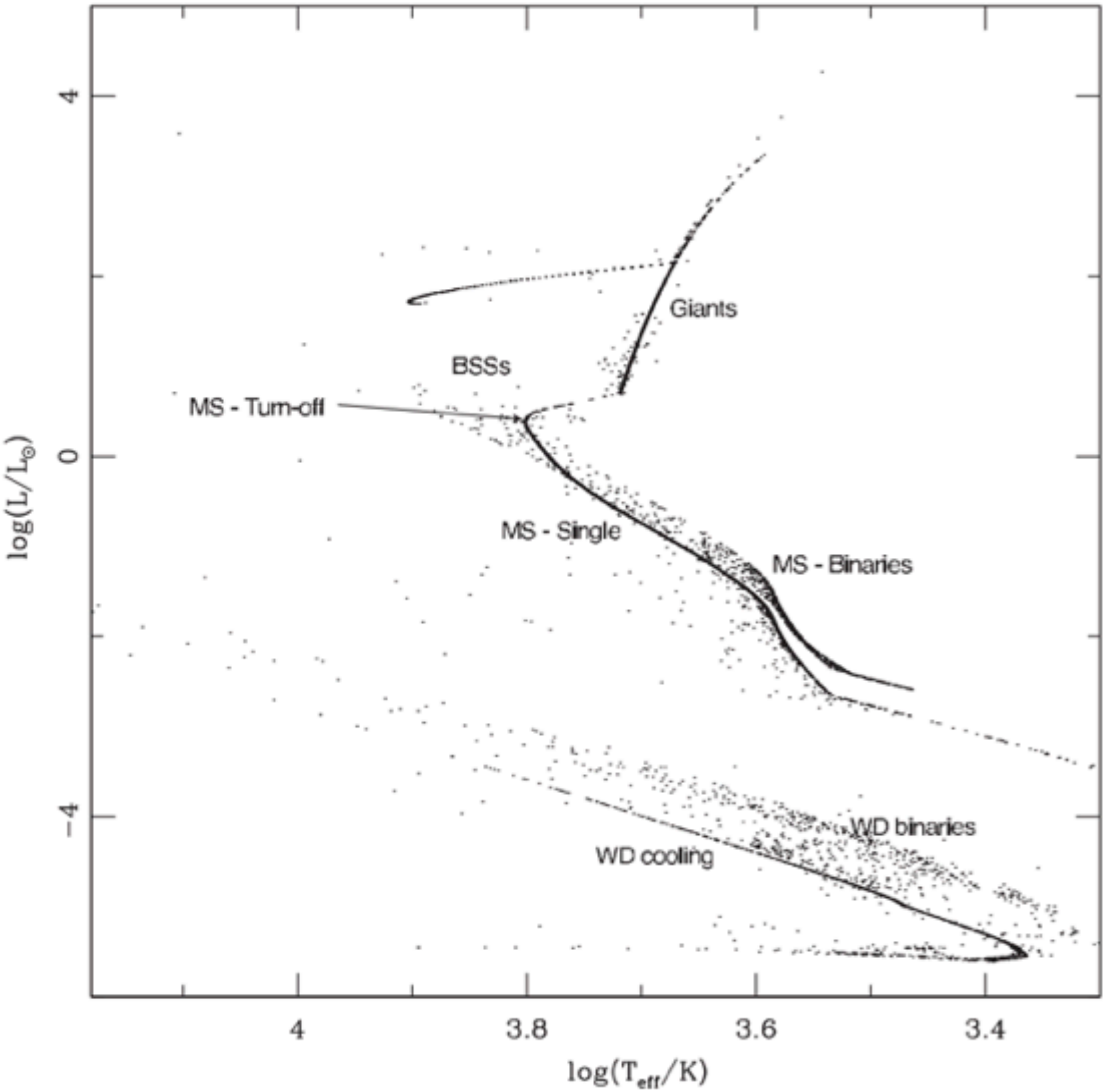
Stellar-Mass Black Holes



For 1000 MS stars, expect:
760 M dwarfs
120 K
75 G
30 F
10 A
1 B, O
10 NS
1 BH

Offner et al 2014

Population Synthesis Code



Cosmic Object Synthesis and Monte-carlo Investigation Code

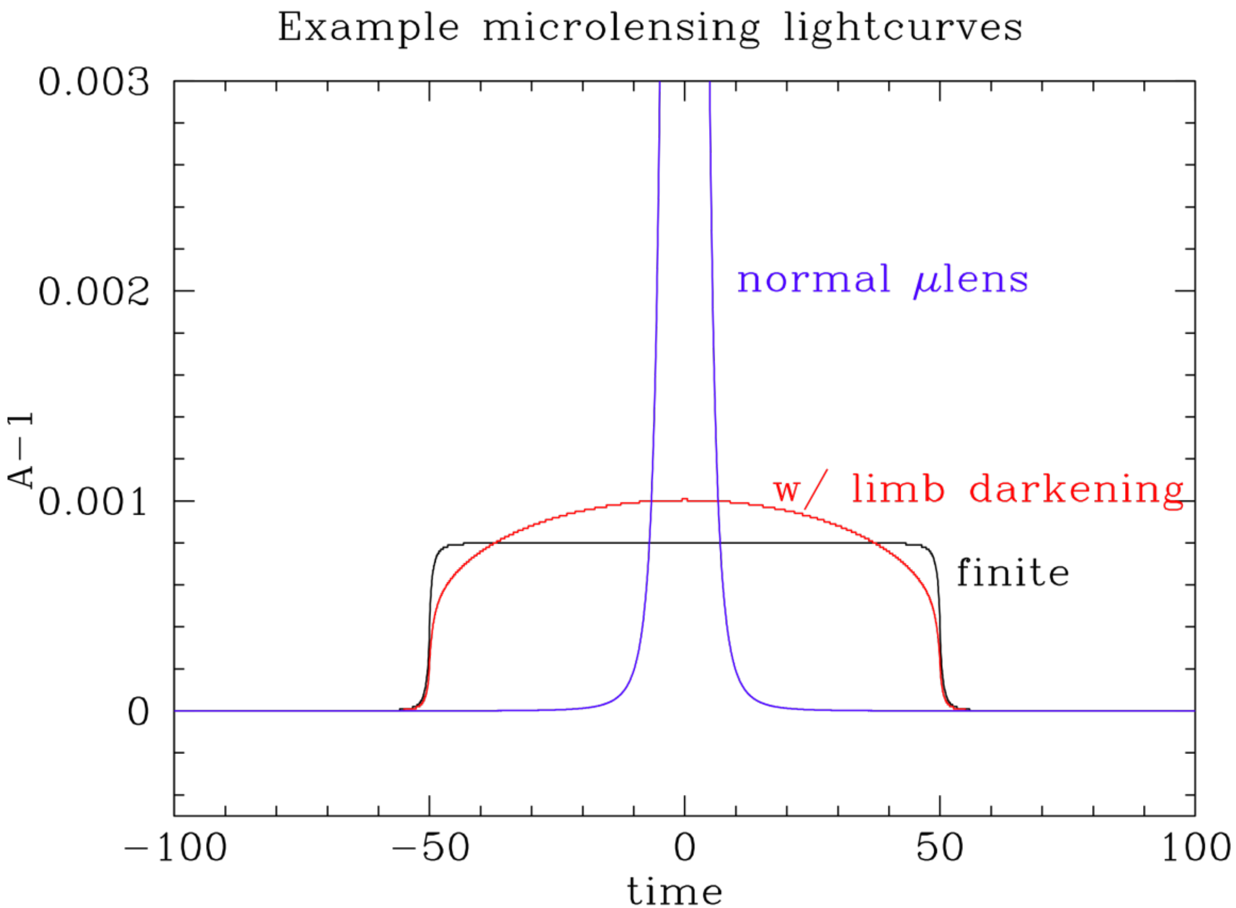
For T<11, P<100d, we expect:
300 BHs
1200 NSs

Chatterjee et al 2010

TESS

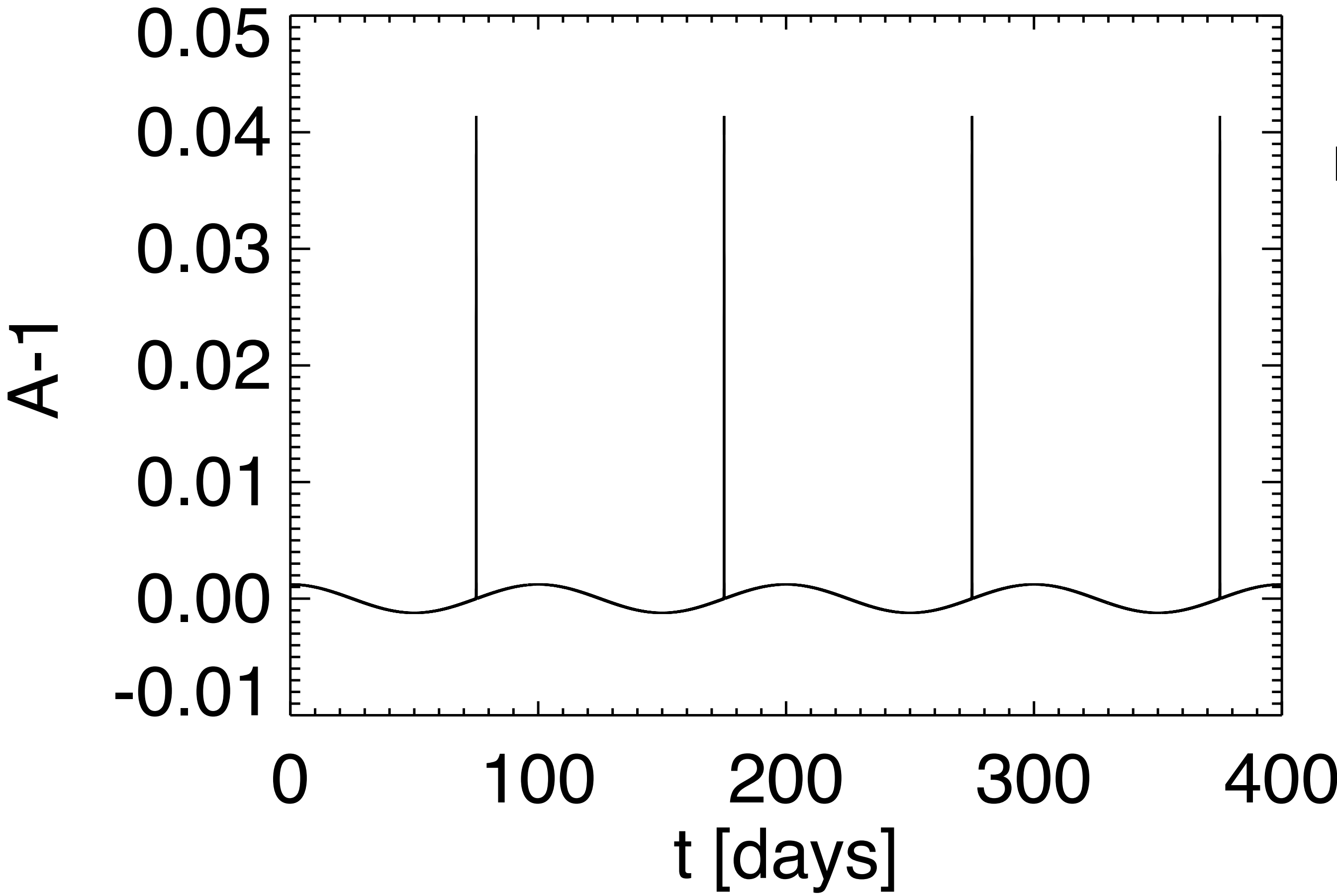
- Awarded GI program to look for Self-Lensing Binaries in TESS using signatures in the photometric lightcurves:
  - Microlensing
  - Doppler Beaming
  - Ellipsoidal Variations

Microlensing



Cieplak and Griest 2013

Orbital Equations



$P = 100\ days$

M_BH = 10 solar masses

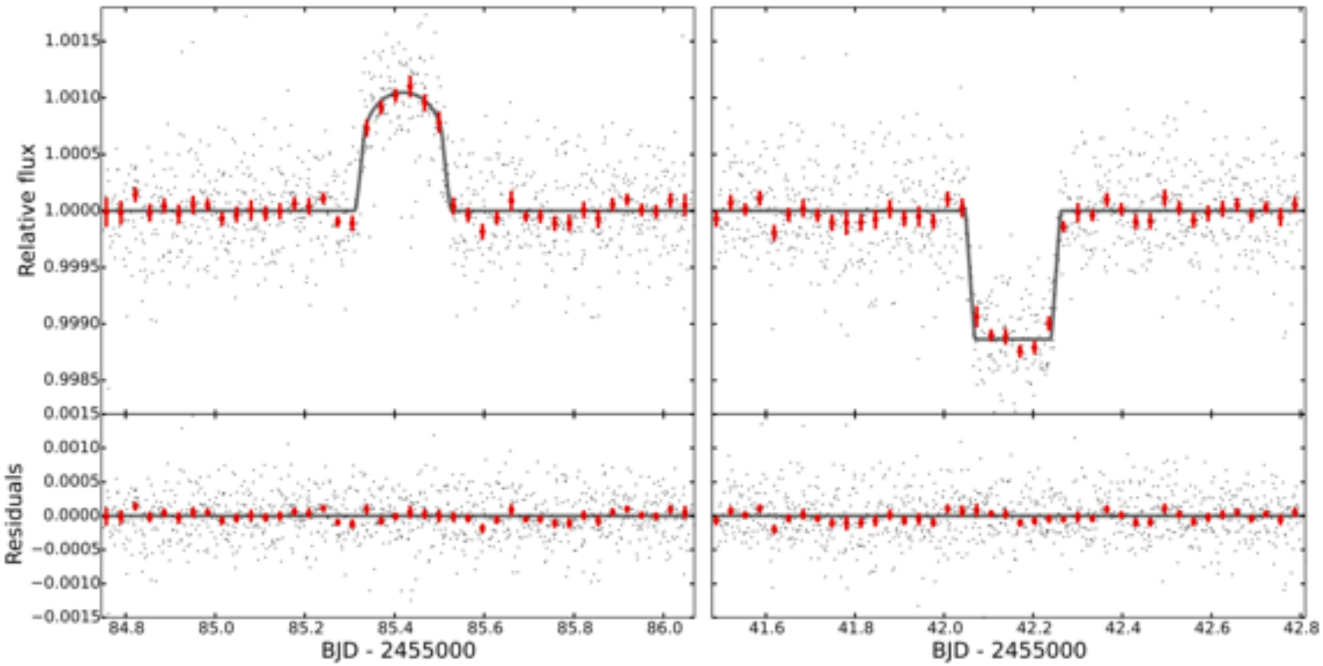
M_star = 1 solar mass

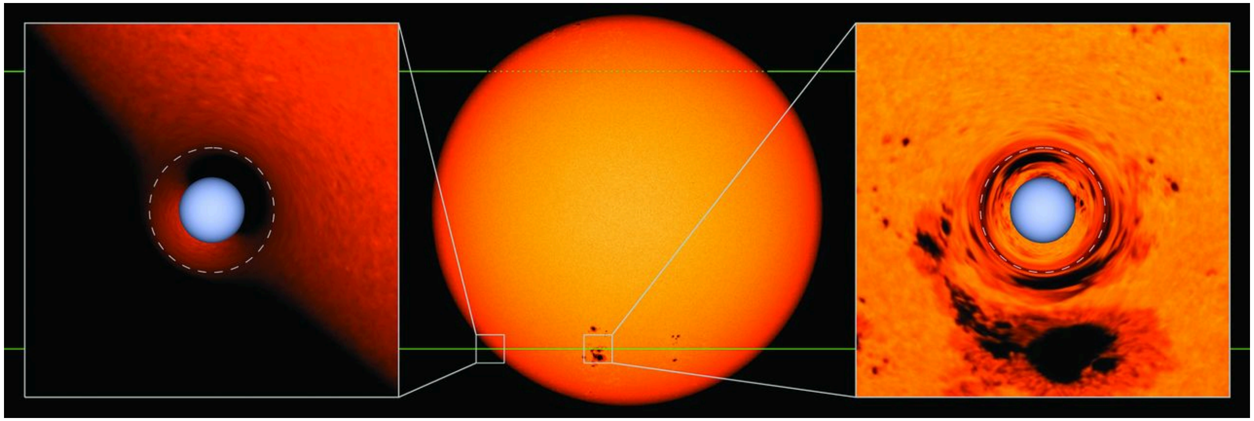
i = 90 deg

e = 0

In prep, 2019

First WD Self-Lensing Binary





Ethan Kruse, and Eric Agol
Science 2014;344:275-277

WD Self-Lensing Binaries

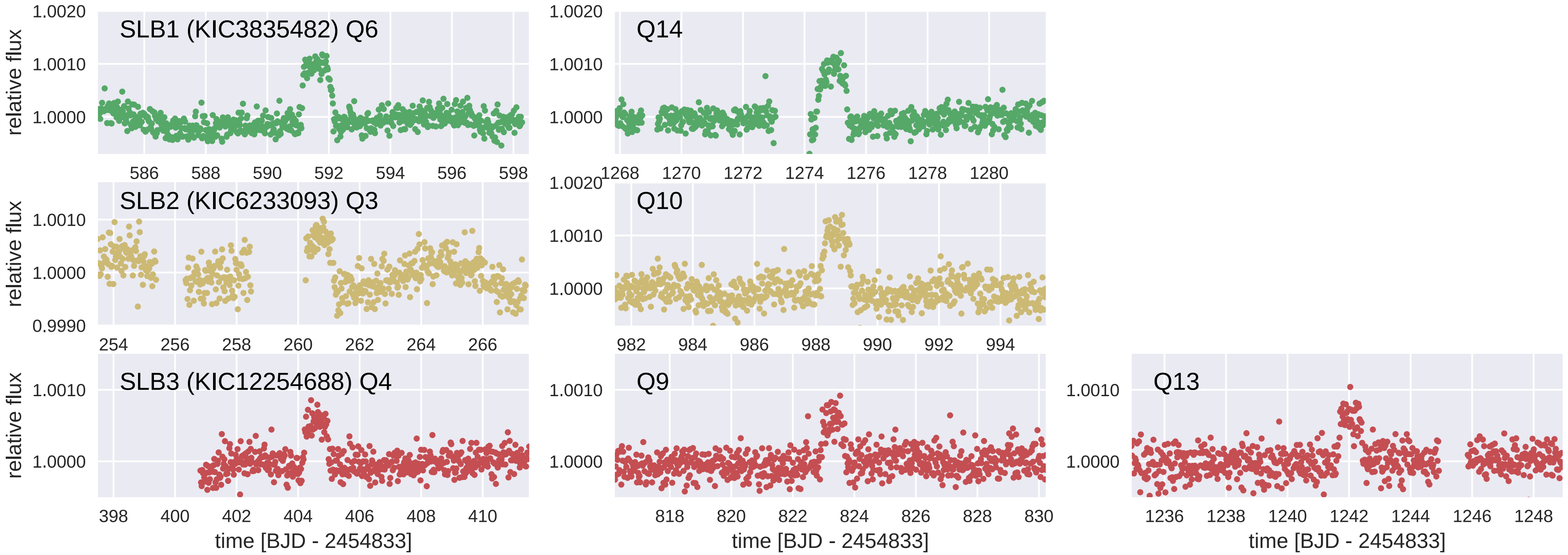
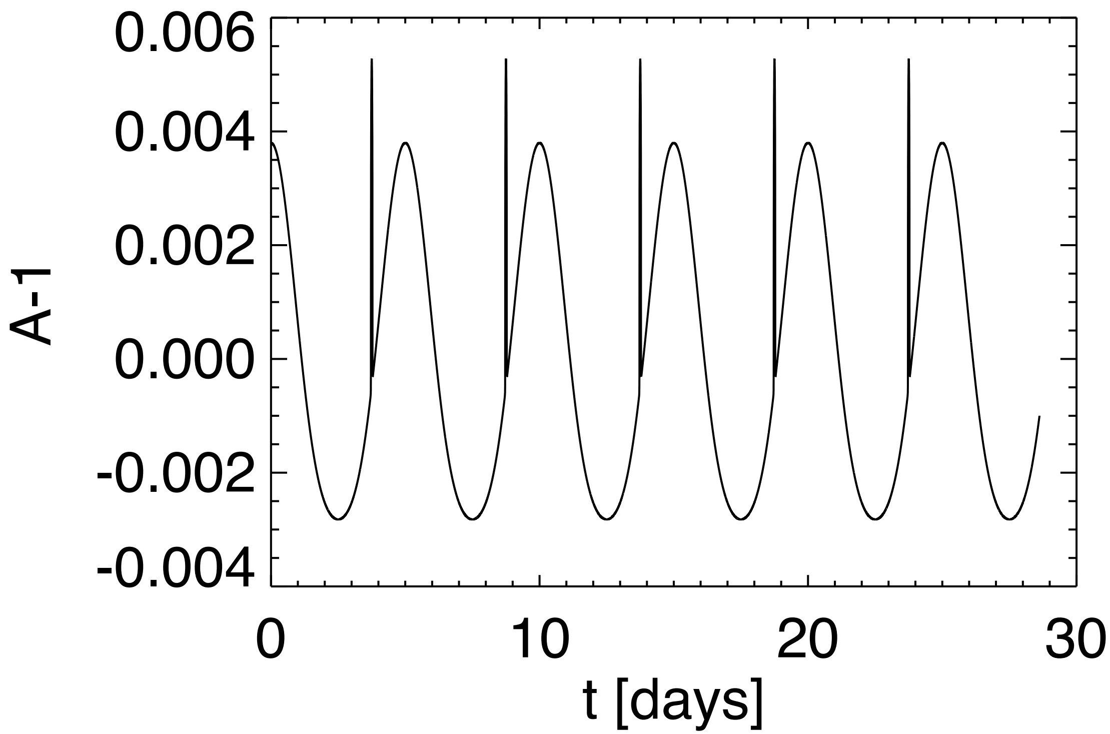


Figure 1. The observed pulses of the SLBs. The light curves are PDCSAP flux of the *Kepler* long-cadence data.

Kawahara et al. 2018

Doppler Beaming

$$|A_{doppler}| = 2.8\times10^{-3}\alpha_{beam}\sin i\ \left(\frac{P}{1day}\right)^{-\frac{1}{3}}\left(\frac{M_T}{M_{sun}}\right)^{-\frac{2}{3}}\left(\frac{M_L}{M_{sun}}\right)\ /\sqrt{1-e^2}$$

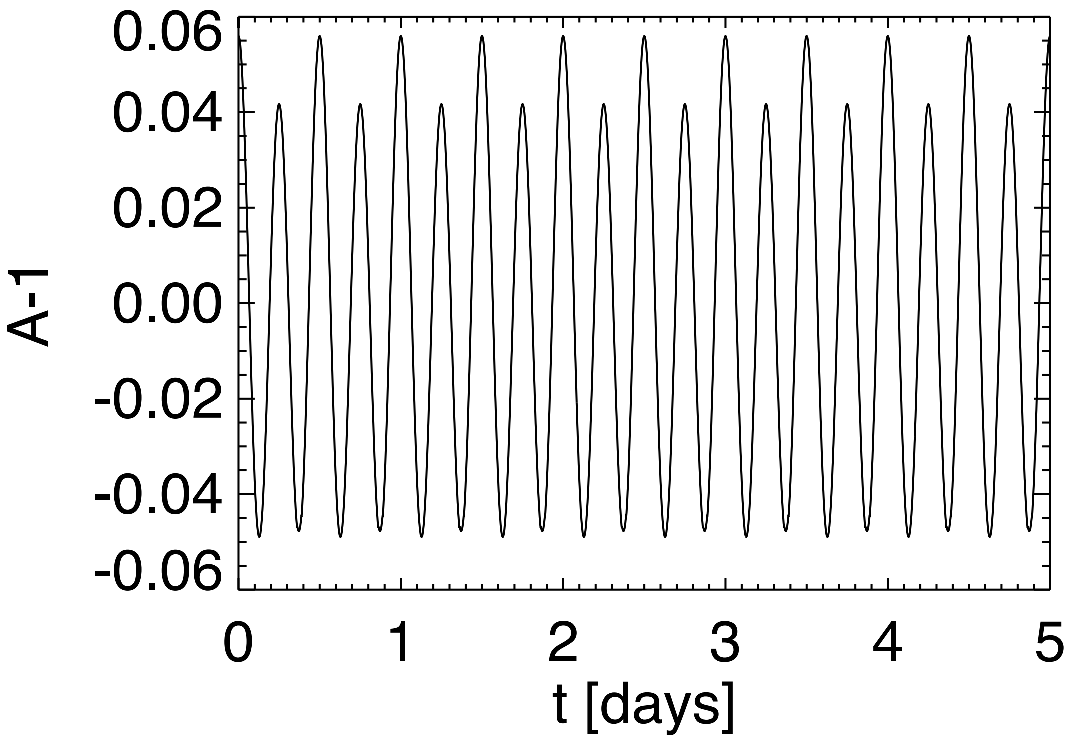


$P = 5\ days$
M_BH = 10 solar masses
M_star = 1 solar mass
i = 90 deg
e = 0

In prep 2019, e.g., Loeb & Gaudi 2003

Ellipsoidal Variations

$$|A_{EV}| = \alpha_{EV} \sin^2 i \left(\frac{R_{star}}{r}\right)^3 \left(\frac{M_L}{M_{star}}\right)$$



$P = 0.5\ days$

M_BH = 10 solar masses

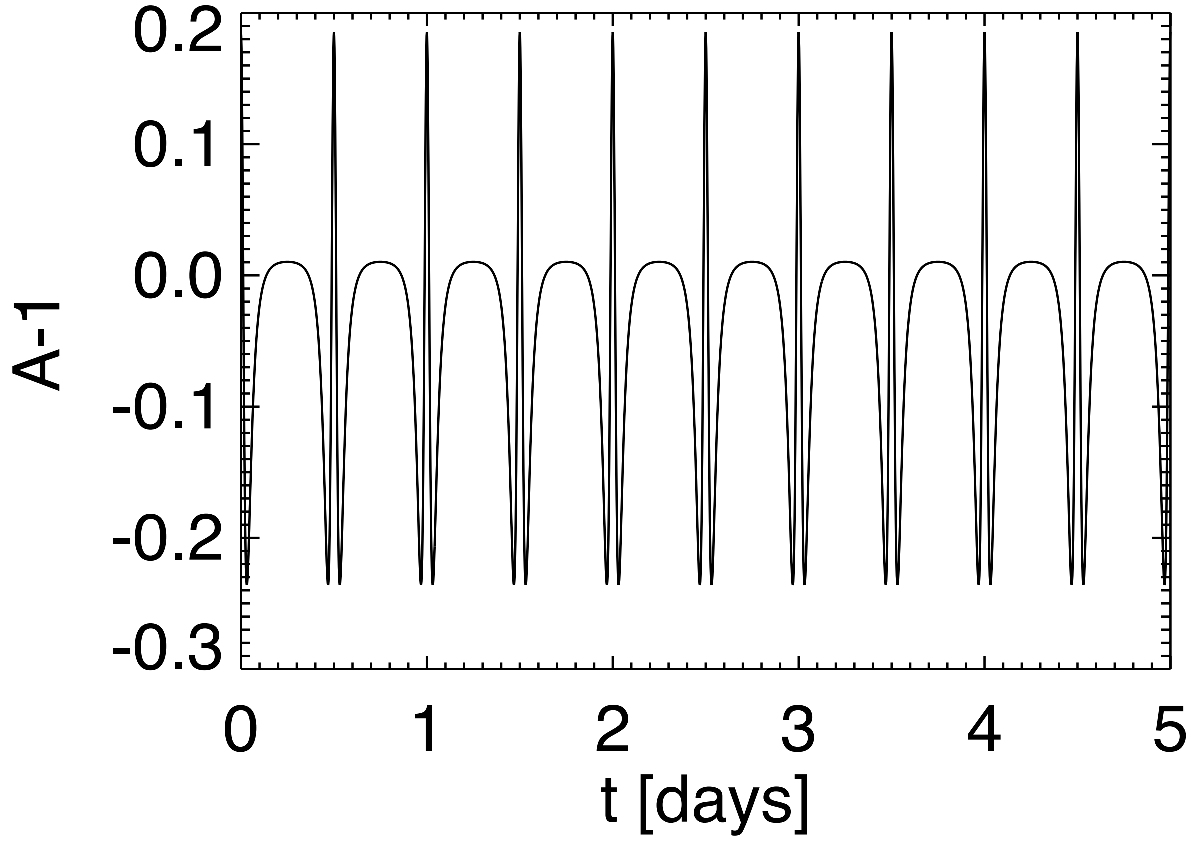
M_star = 1 solar mass

i = 90 deg

e = 0

In prep 2019, e.g., Kopal 1959

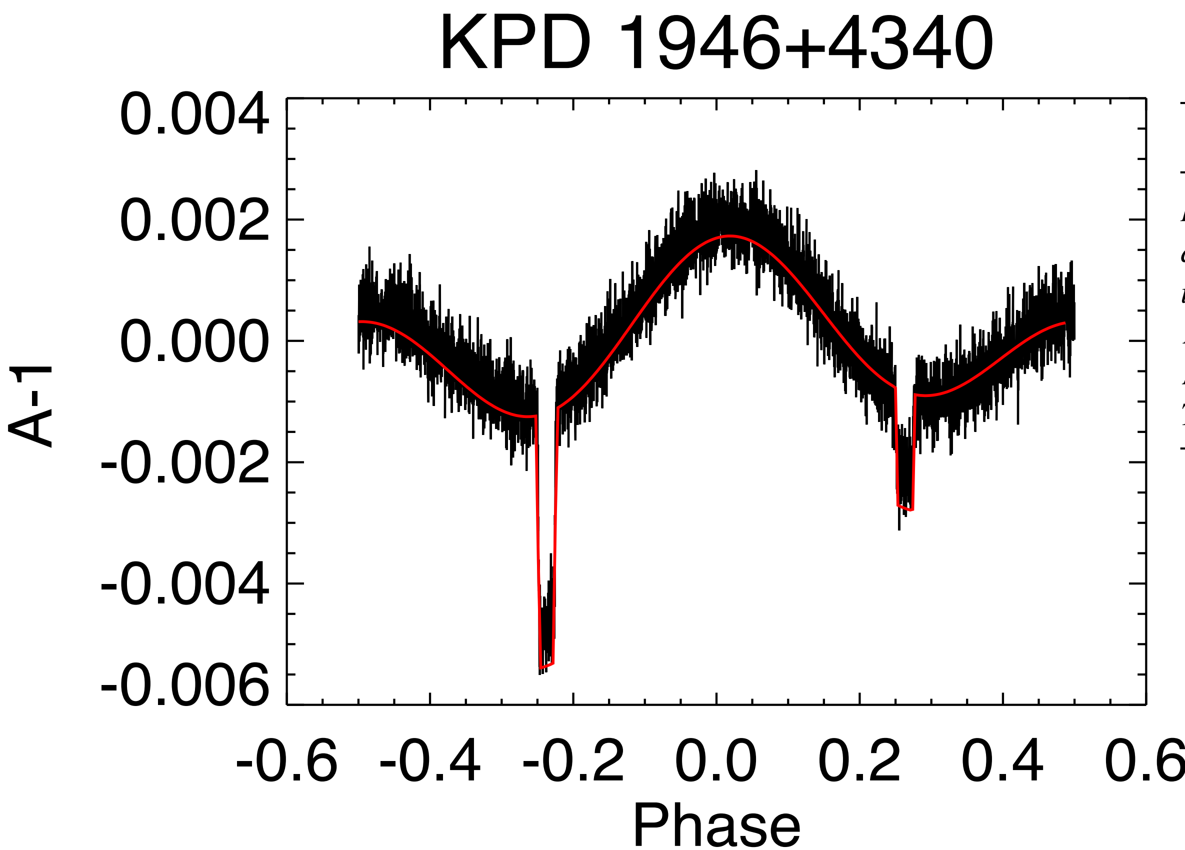
Ellipsoidal Variations



$P = 0.5\ days$
M_BH = 10 solar masses
M_star = 1 solar mass
i = 90 deg
e = 0.5

In prep, 2019

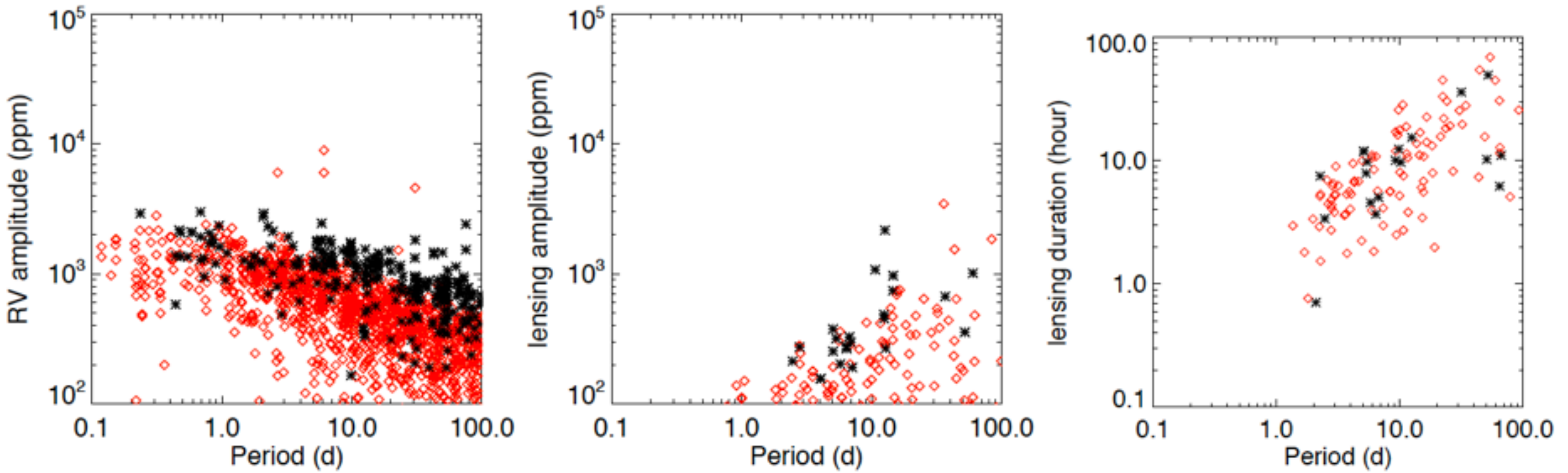
WD-sdB Binary in Kepler



	Primary (sdB)	Secondary (WD)
P_{orb} (d)	0.403 750 26(16)	
q	1.27 ± 0.06	
i (°)	87.14 ± 0.15	
R ($R_{\odot}$)	0.212 ± 0.006	0.0137 ± 0.0004
M ($M_{\odot}$)	0.47 ± 0.03	0.59 ± 0.02
T_{eff} (K)	34 500 ± 400	15 900 ± 300

In Prep, 2019, Bloemen, et al 2011

Predictions



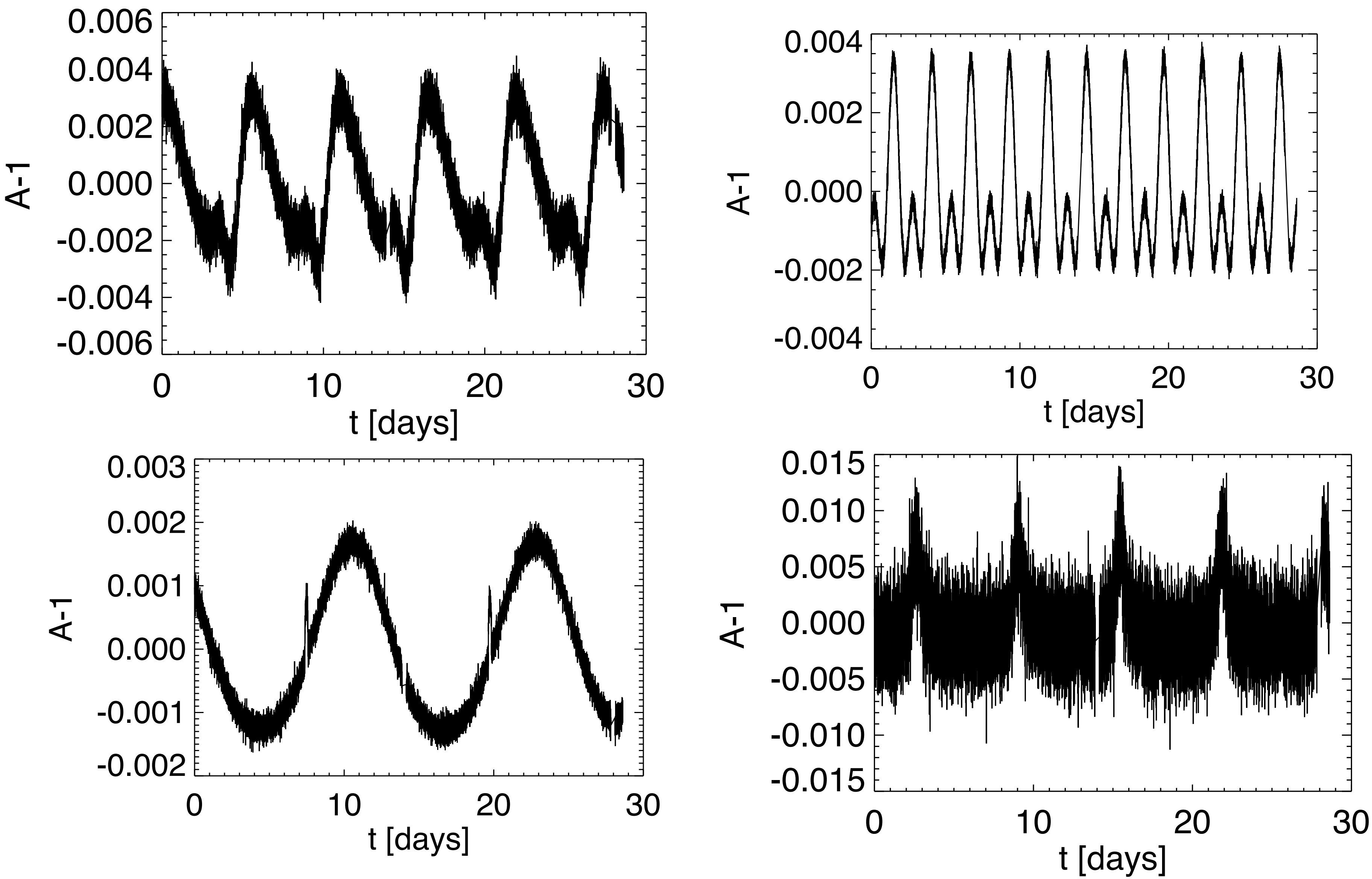
For T<11, P<100d, we expect:
300 BHs and 1200 NSs
20 SLB BHs and 50 SLB NSs

Two Scanning Approaches

1) Machine Learning

2) Traditional Approach

Machine Learning

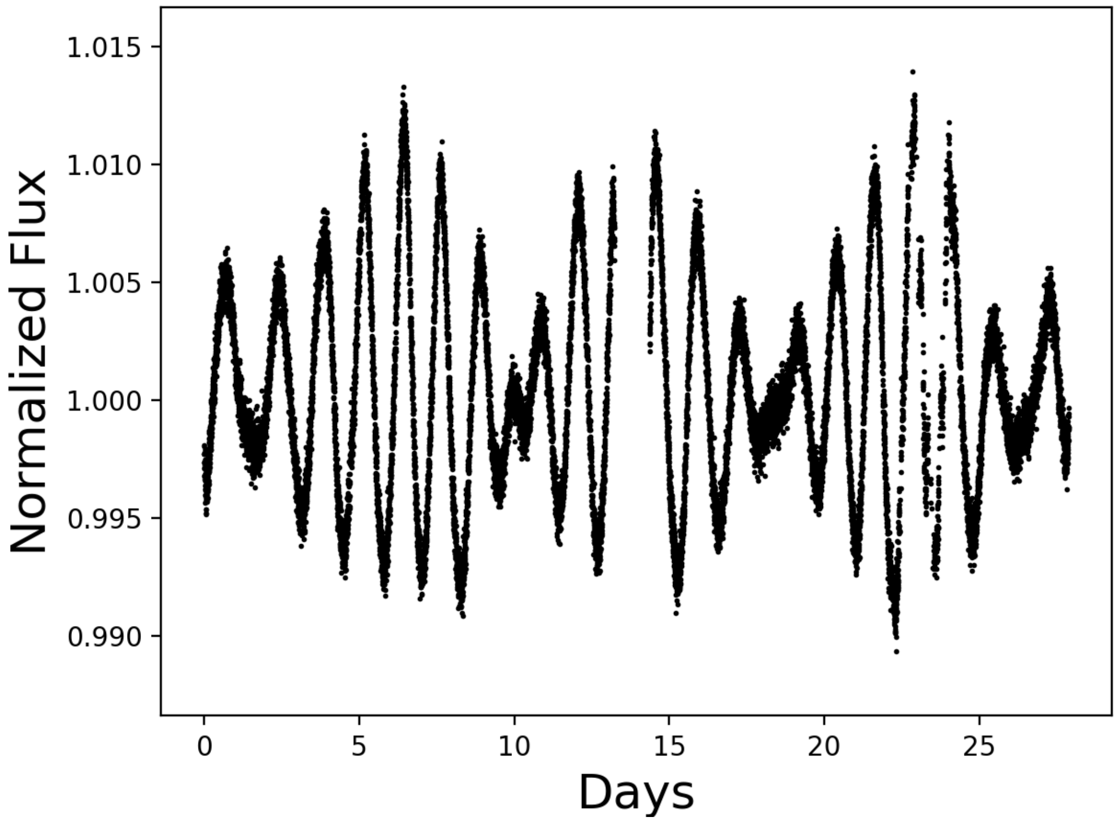


Traditional Scanning Approach

Based on:

- Magnitude cut
- Periodicity cut
- Chi-squared and MCMC fits
- Amplitude cuts
- Consistency across sector or sectors
- Stellar Type

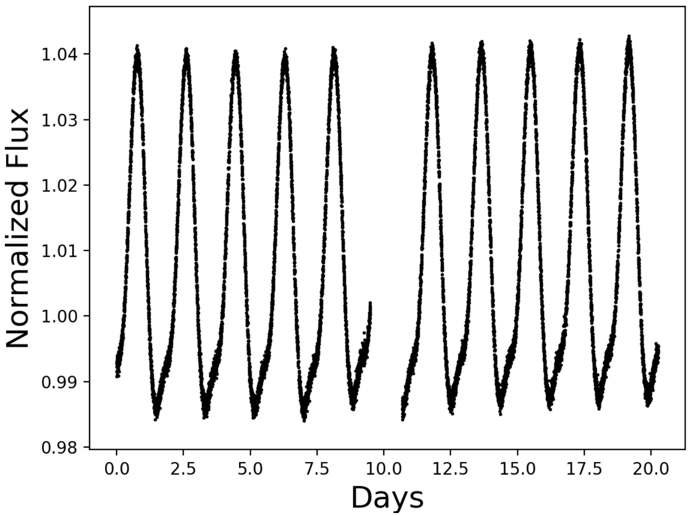
Periodicity



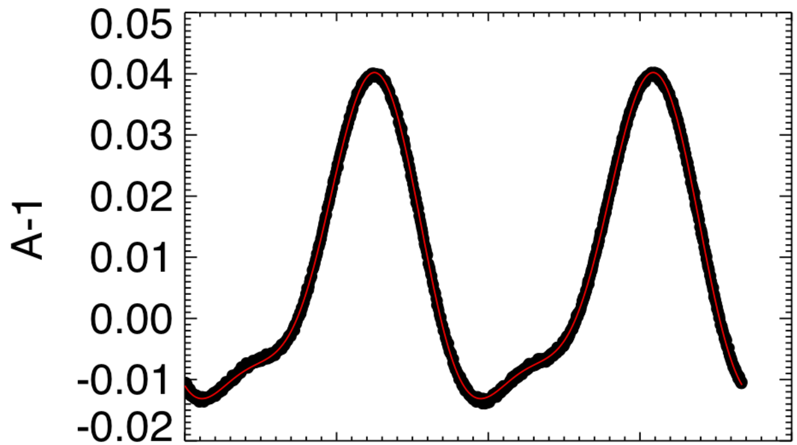
F0V classification

Chi-Squared Fits

Variable Star of alpha2 CVn type

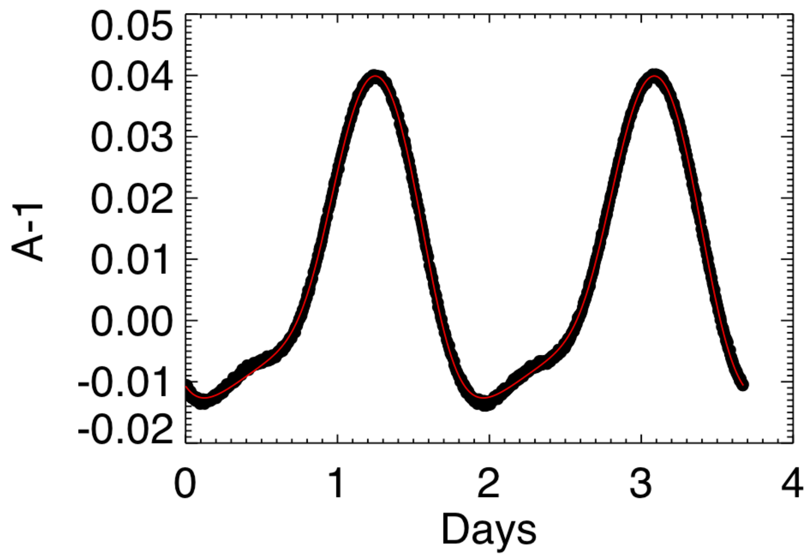


ApEuCr classification



Orbit Fit:

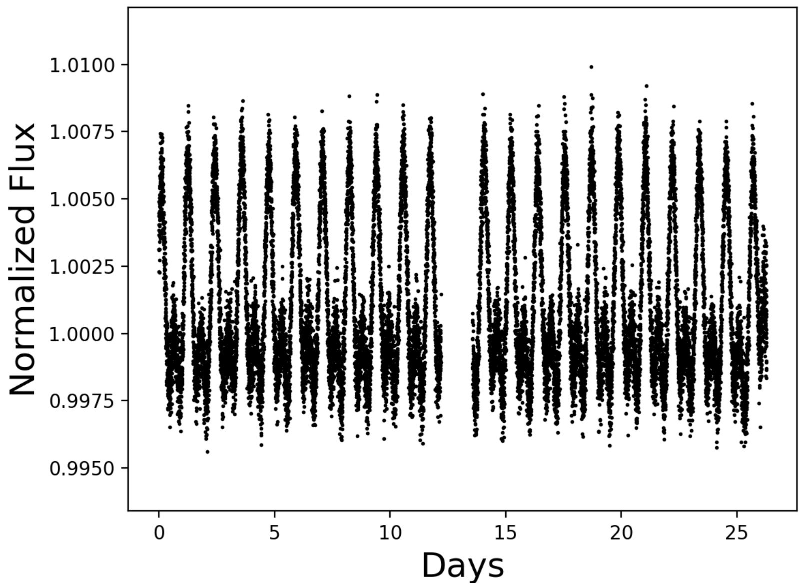
$X^2 = 2.44$

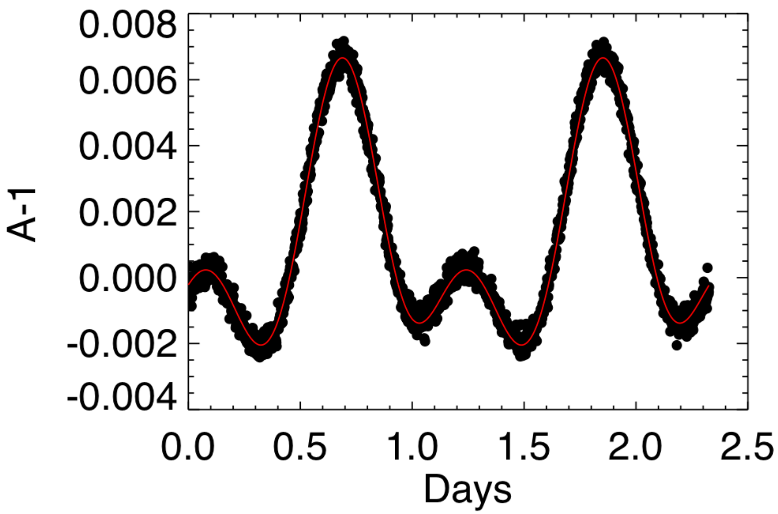


BH Fit:

$X^2 = 4.76$

Stellar Type



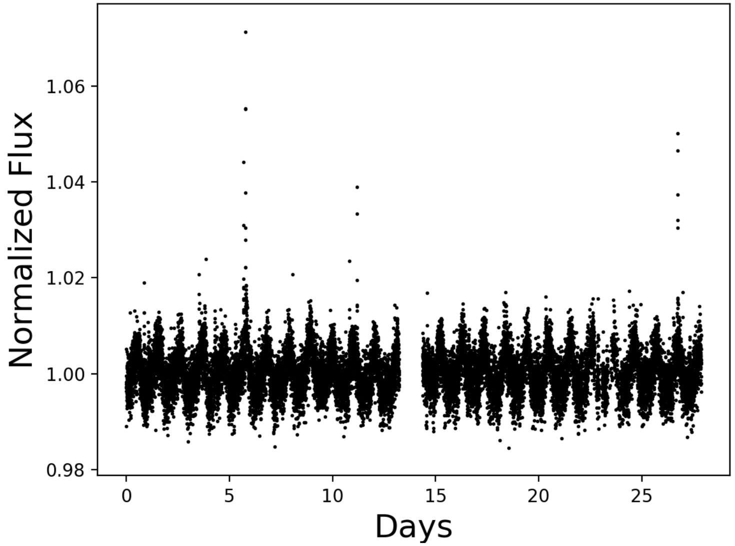


BH Fit:

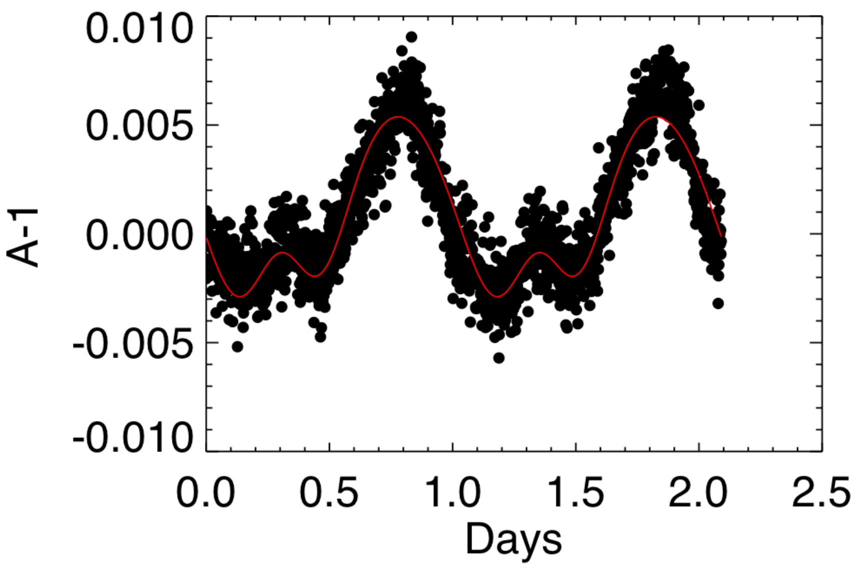
ApSrCrEu classification

$X^2 = 0.89$

Magnitude Cut



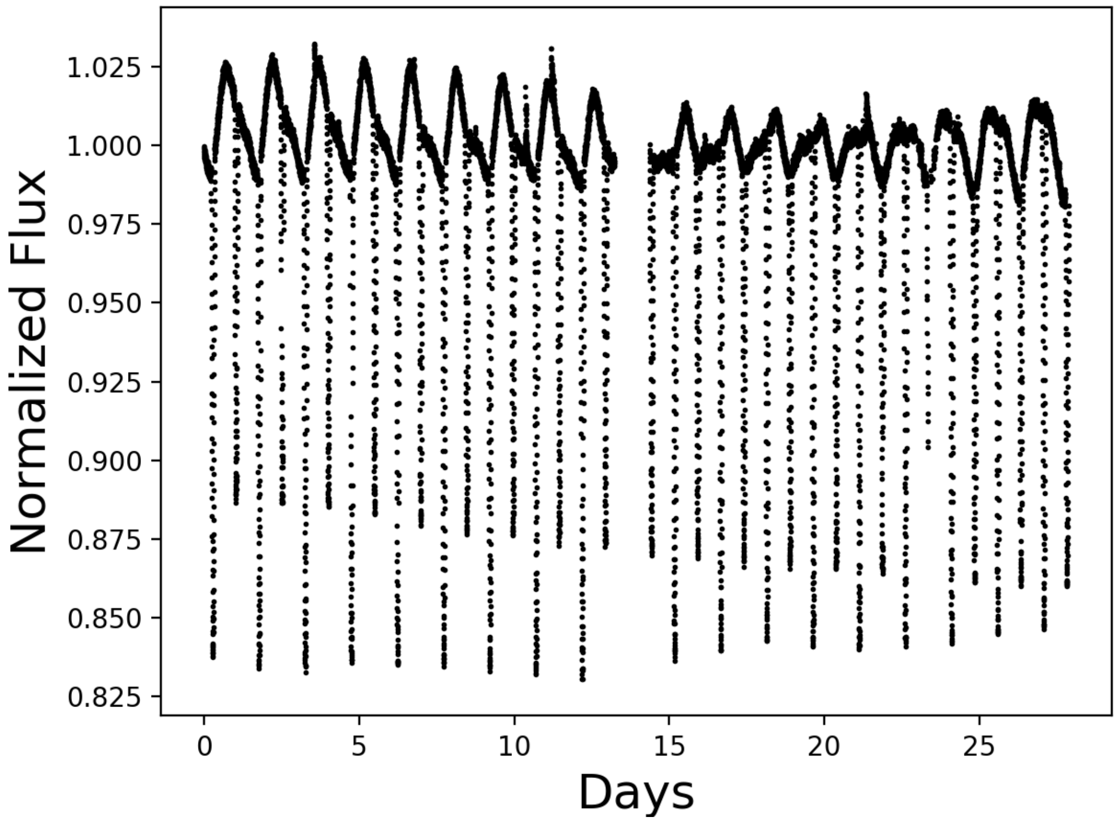
M 3.7 classification



BH Fit:

$X^2 = 1.31$

Consistency Across Sector/s



Algol Variable

Conclusion

- Developed a model and two parallel pipelines to search for self-lensing binary signatures in TESS data
- Simultaneously aggregating classes of interesting stellar lightcurves, including eclipsing binaries
- Hope to have new updates soon, with potential for exciting implications:
  - First truly quiescent black hole
  - Closest black hole
  - Rates of wide binary formation
  - Unbiased probe of BH mass function
  - Probe mass gap between NSs and BHs