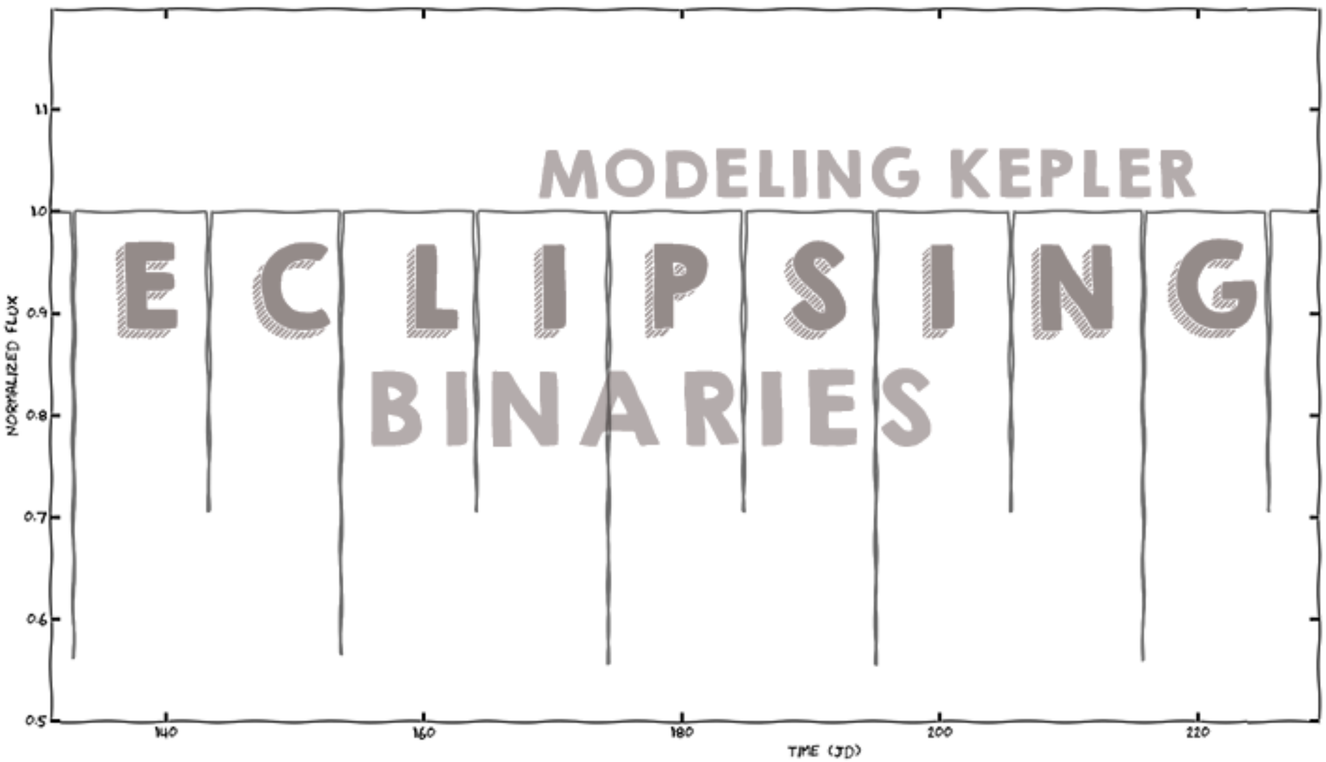
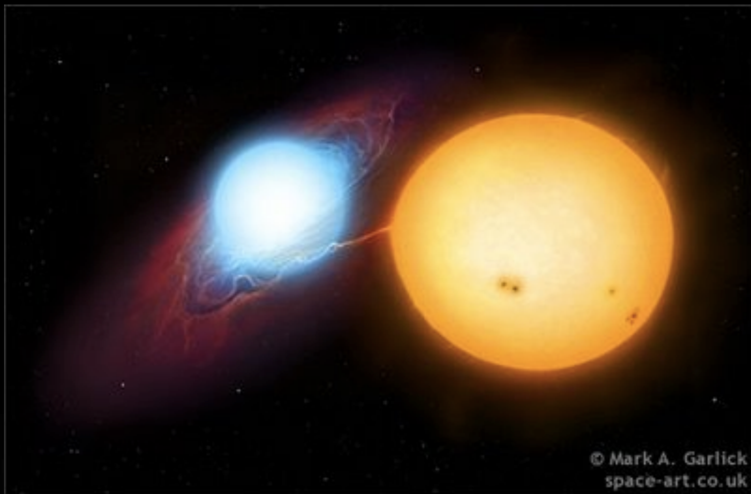
MODELING KEPLER ECLIPSING BINARIES



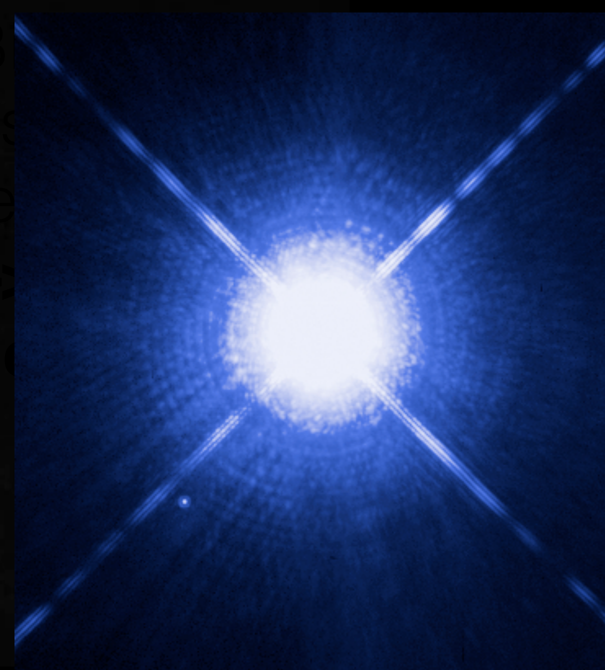
Diana Windemuth
Faculty Advisor: Eric Agol
Oct 9, 2015
Pre-MAP


What’s the deal with binaries?



What's the deal with binaries?

- Most stars are in binaries (or higher-order multiple systems)



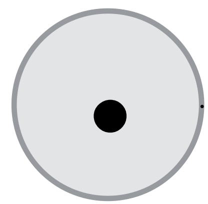
What's the deal with binaries?

- Most stars are in binaries (or higher-order multiple systems)
- Binaries are extremely useful tools to calibrate & test stellar evolution models

What’s the deal with binaries?

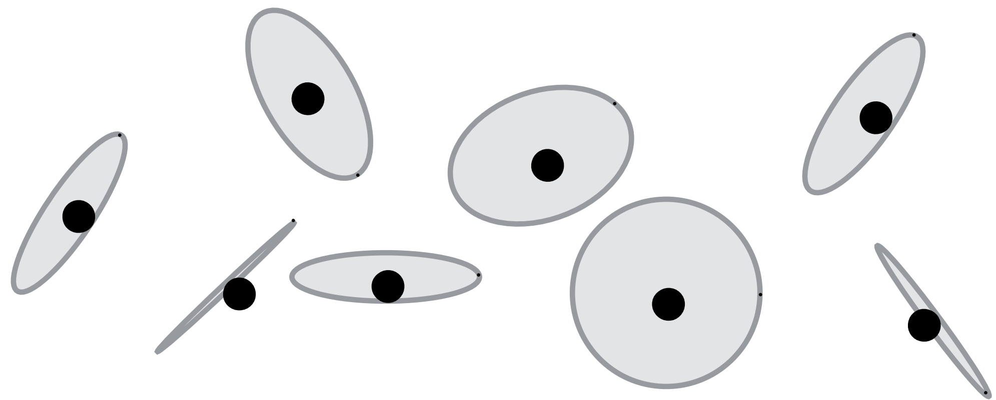
- Most stars are in binaries (or higher-order multiple systems)
- Binaries are extremely useful tools to calibrate & test stellar evolution models **>> propagates to many fields in astronomy**

Eclipsing Binaries

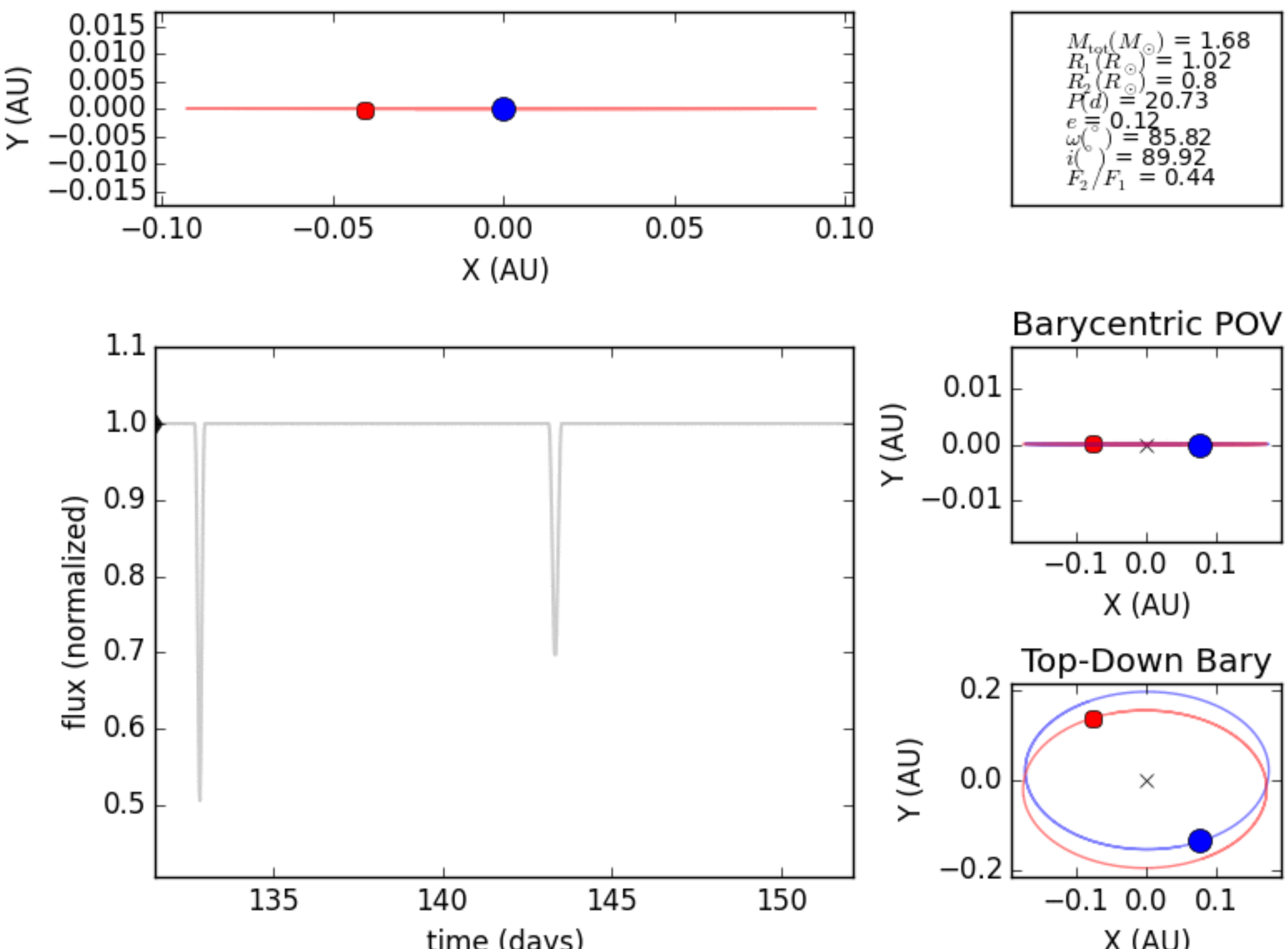


When two stars orbit around each other, they form a binary system.

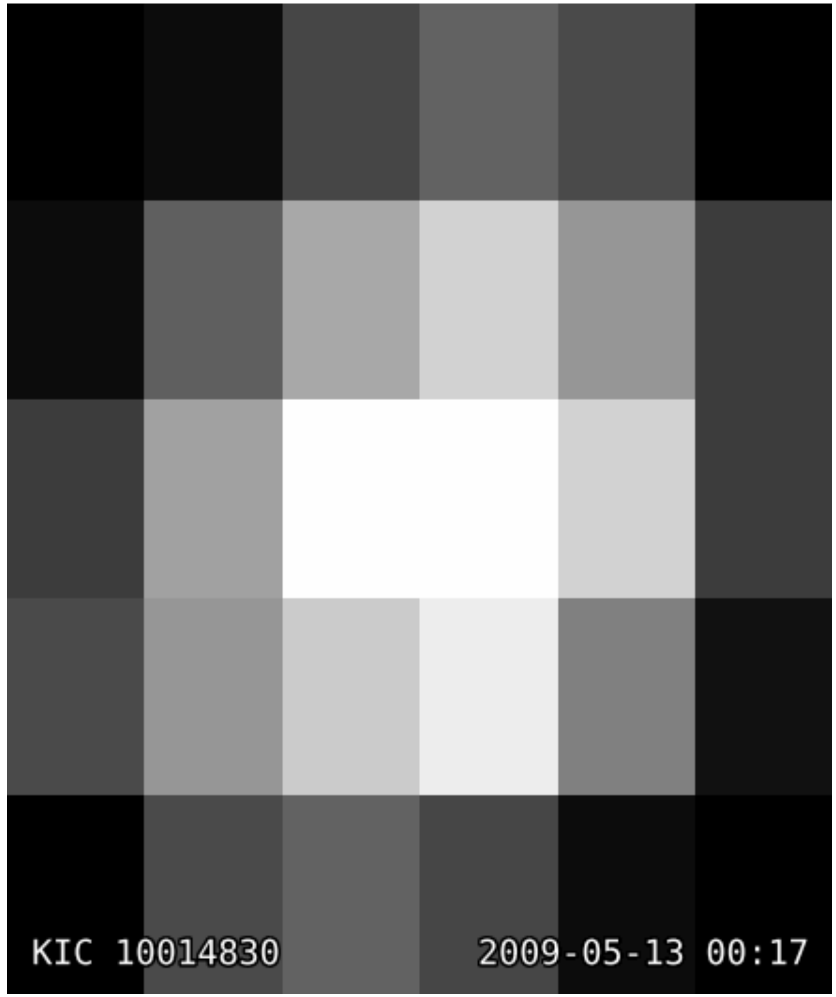
Eclipsing Binaries



When two stars orbit around each other, they form a binary system. In an eclipsing binary, one of the stars “eclipses” or passes in front of the other and blocks its light as viewed from Earth.



$M_{tot}(M_\odot)$ = 1.68
$R_1(R_\odot)$ = 1.02
$R_2(R_\odot)$ = 0.8
$P(d)$ = 20.73
e = 0.12
$\omega(^\circ)$ = 85.82
$i(^\circ)$ = 89.92
F_2/F_1 = 0.44
Y (AU)
X (AU)
flux (normalized)
time (days)
Barycentric POV
Top-Down Bary


KIC 10014830
2009-05-13 00:17

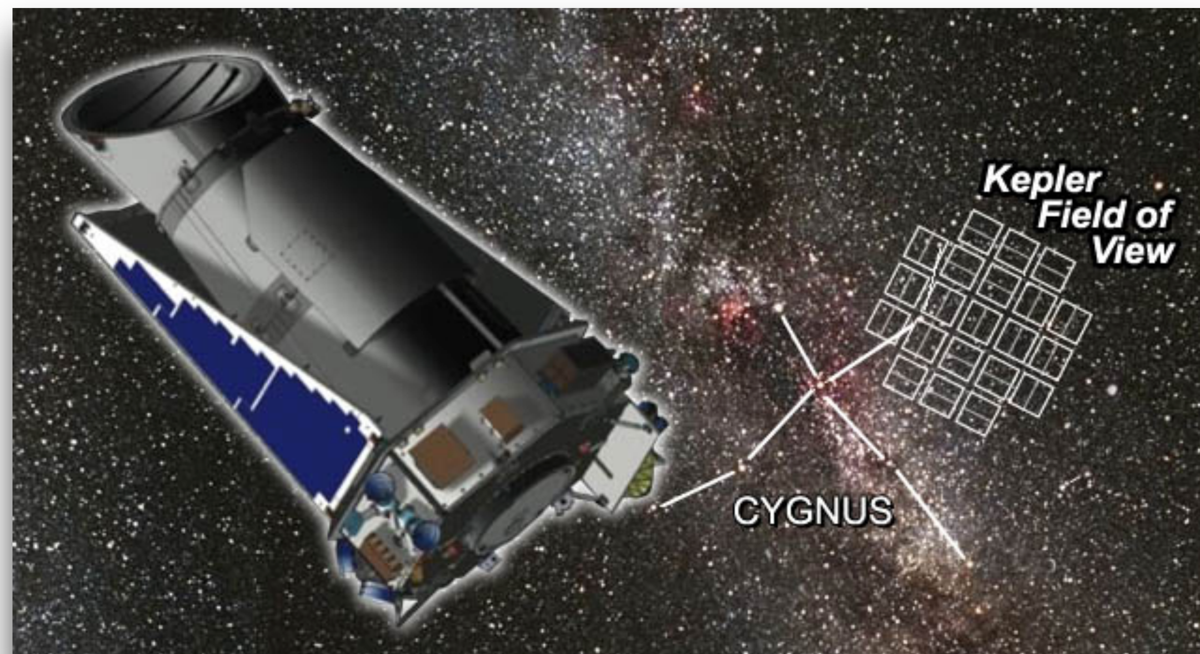
Take-away

The **chance alignment** between us and the binary allows us to **extract fundamental properties of the system**, such as the orbital geometry, mass, radius, and temperature of the stars

- validate stellar evolution models
- distinguish whether a transiting exoplanet is rocky like Earth or gaseous like Neptune
- understand how galaxies evolve with time

What will you be doing?

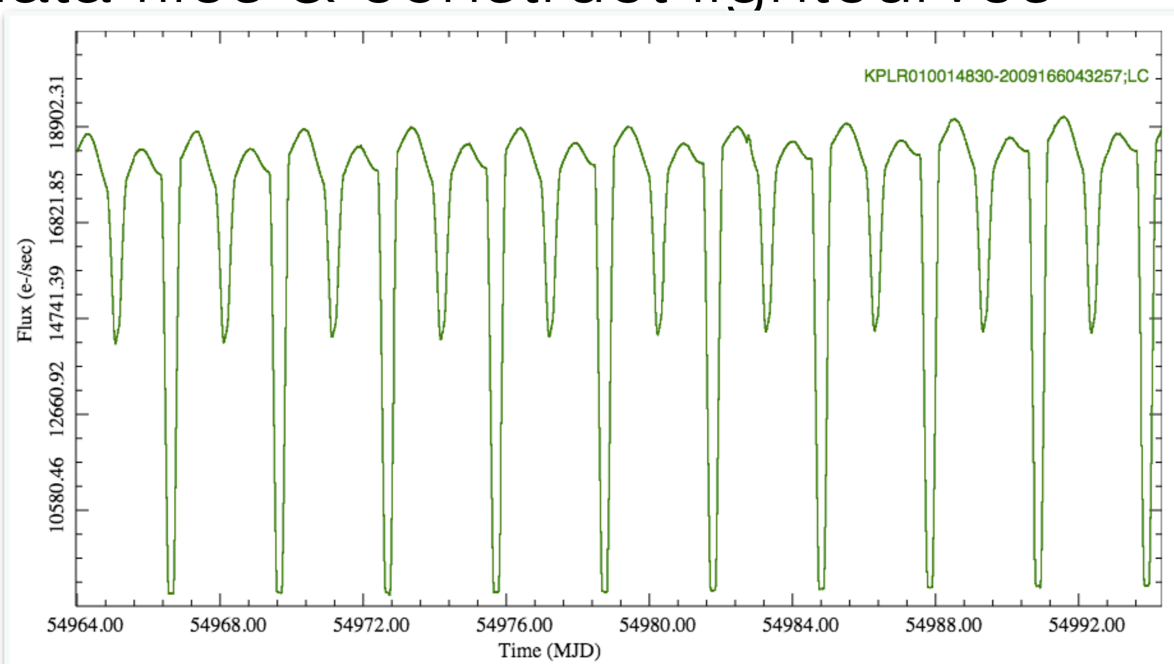
- Dataset: Villanova KEB catalogue (2800+ total, 1800+ detached)



What will you be doing?

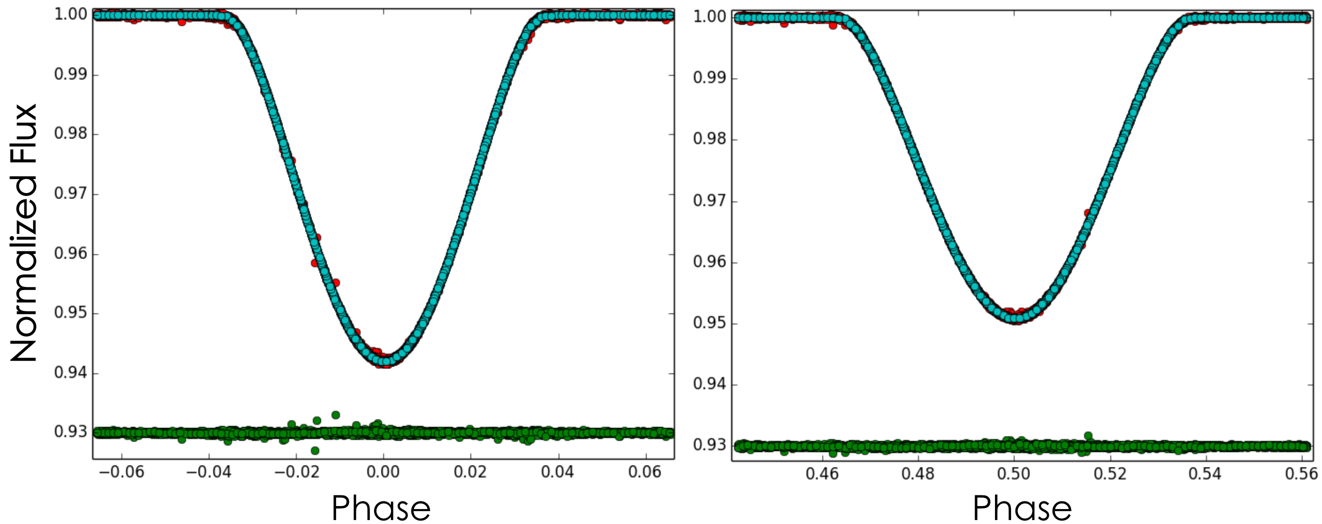
- Dataset: Villanova KEB catalogue (2800+ total, 1800+ detached)

- retrieve data files & construct lightcurves



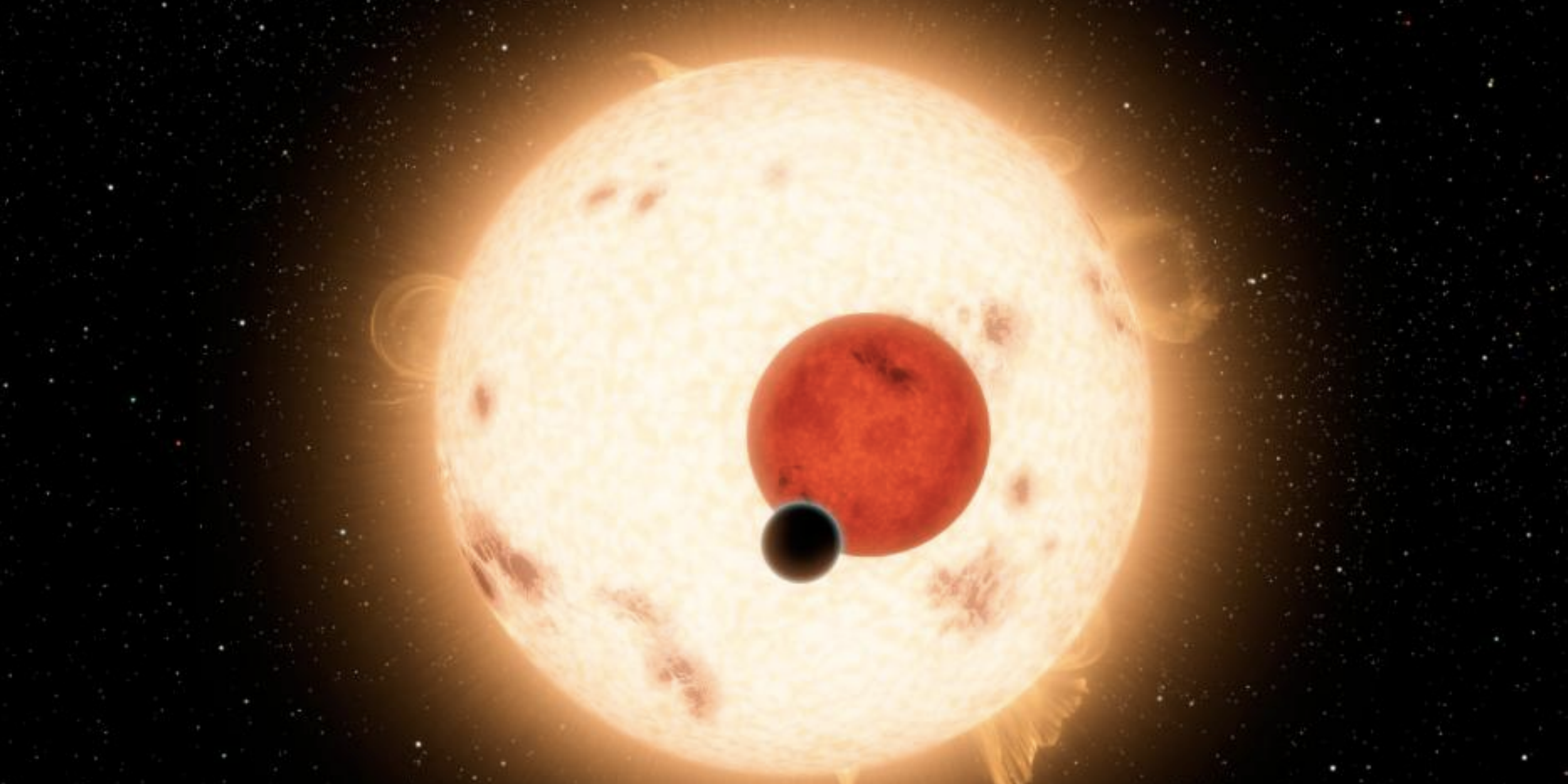
What will you be doing?

- Datas
  1800+
- retriev

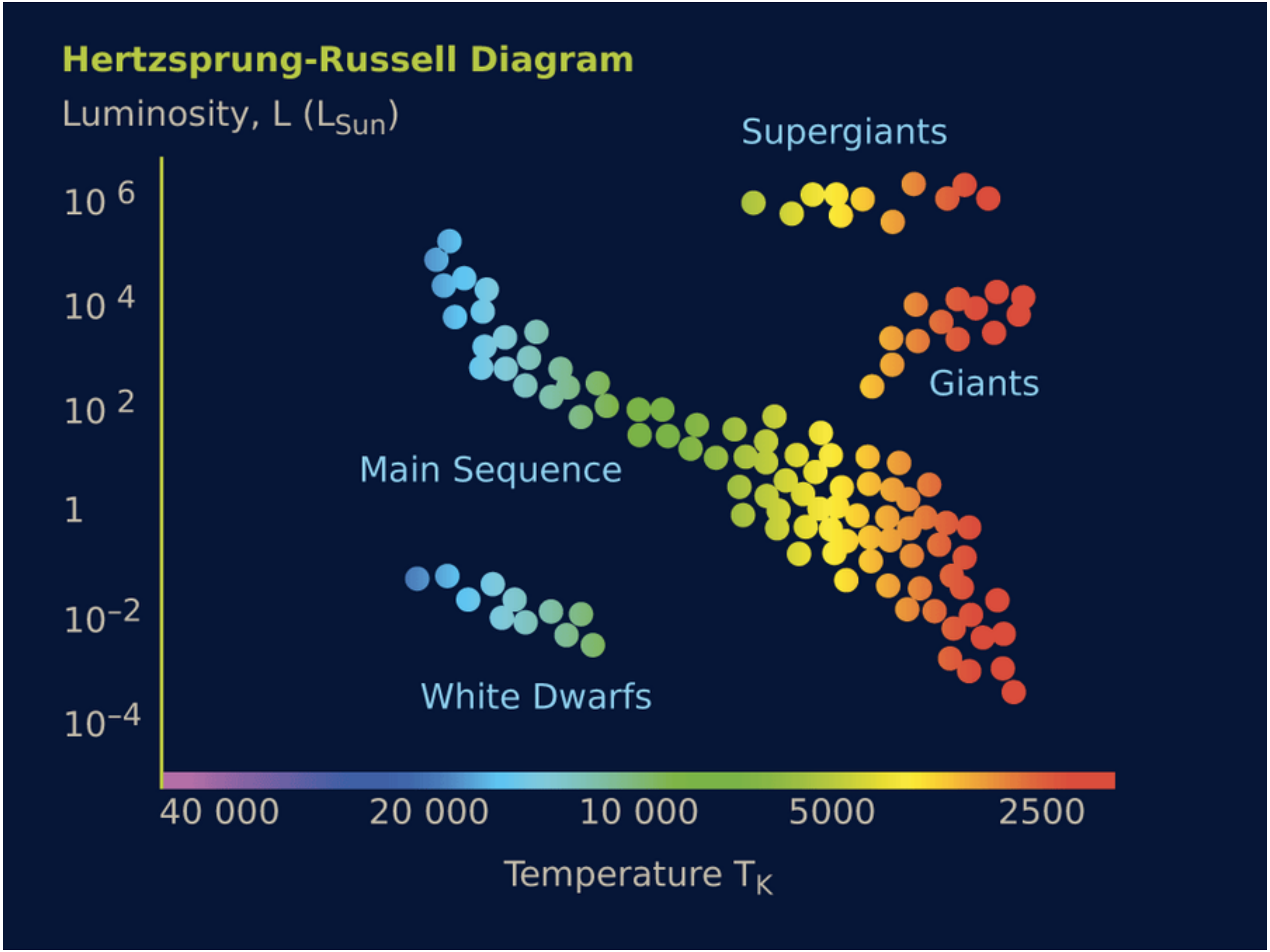


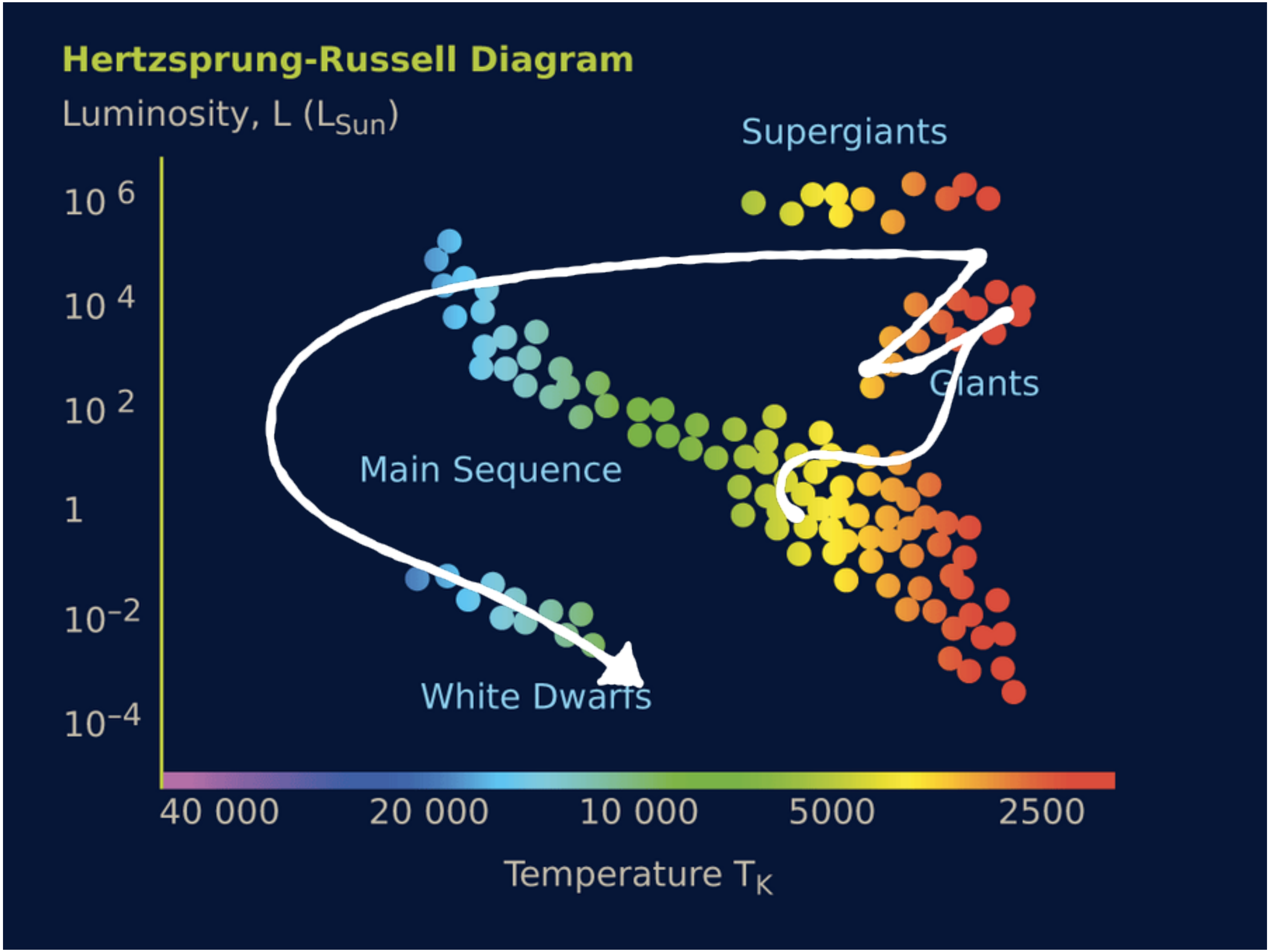
- analyze total light as a function of time
- make models for each system to solve for its orbital & stellar parameters

Circumbinary Planet Search



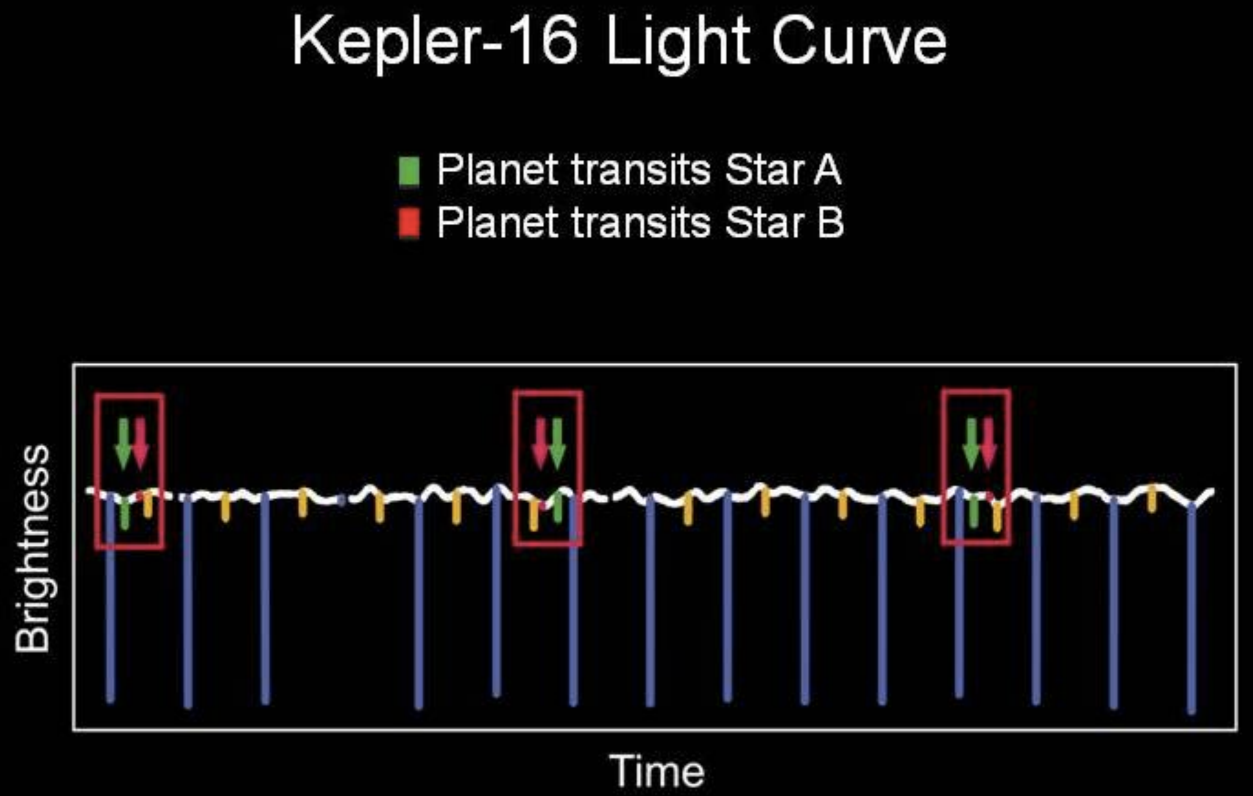
Application: use accurate binary model to mask out binary signals and strengthen search for circumbinary planet signal


Hertzsprung-Russell Diagram
Luminosity, L (L_{Sun})
Supergiants
Giants
Main Sequence
White Dwarfs
10^6
10^4
10^2
1
10^{-2}
10^{-4}
40 000
20 000
10 000
5000
2500
Temperature T_K



Hertzsprung-Russell Diagram
Luminosity, L (L_{Sun})
Supergiants
Giants
Main Sequence
White Dwarfs
10^6
10^4
10^2
1
10^{-2}
10^{-4}
40 000
20 000
10 000
5000
2500
Temperature T_K

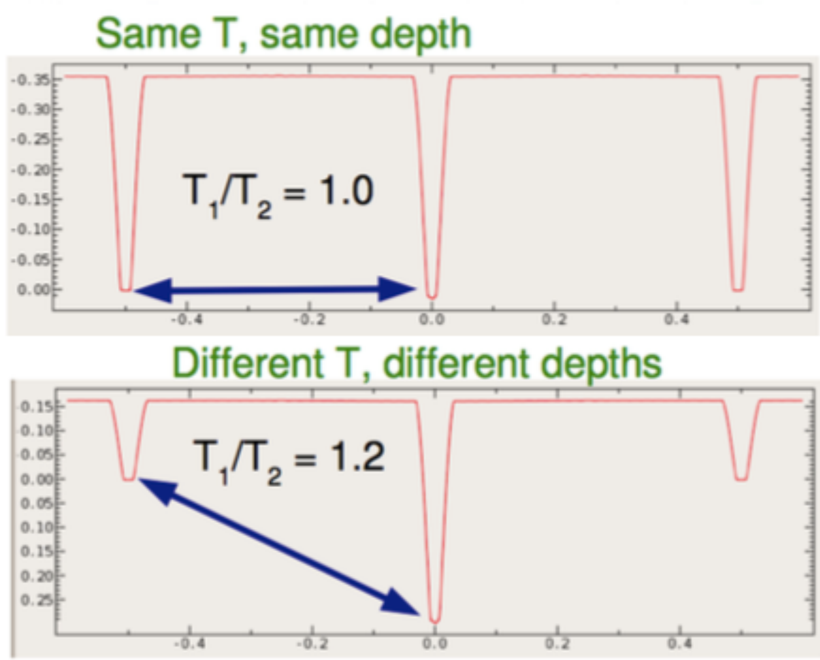
Circumbinary Planet Search



binary model to mask out binary
for circumbinary planet

Properties constrained from light curves:

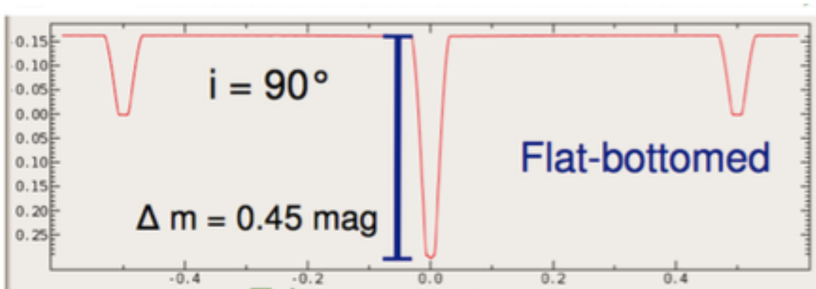
- Temperature ratio derived from ratio of the eclipse depths

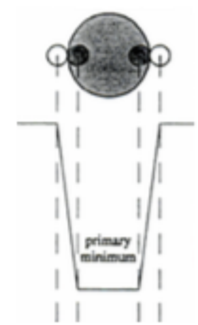


slide courtesy of Leslie Hebb

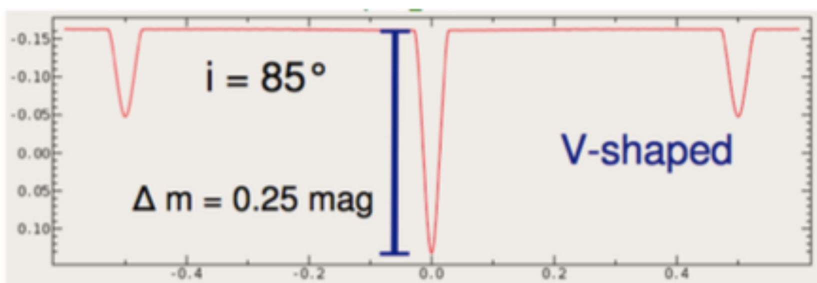
Properties constrained from light curves:

- Inclination angle of the binary system





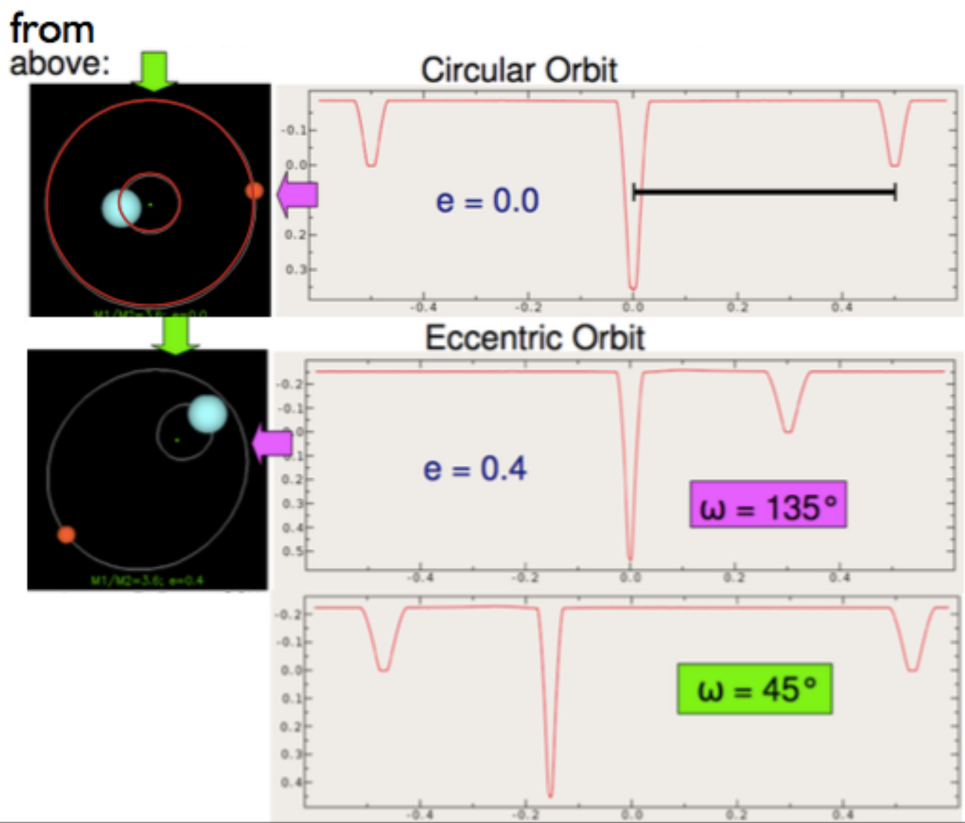
Edge-on system



slide courtesy of Leslie Hebb

Properties constrained from light curves:

- eccentricity & argument of periastron



slide courtesy of Leslie Hebb

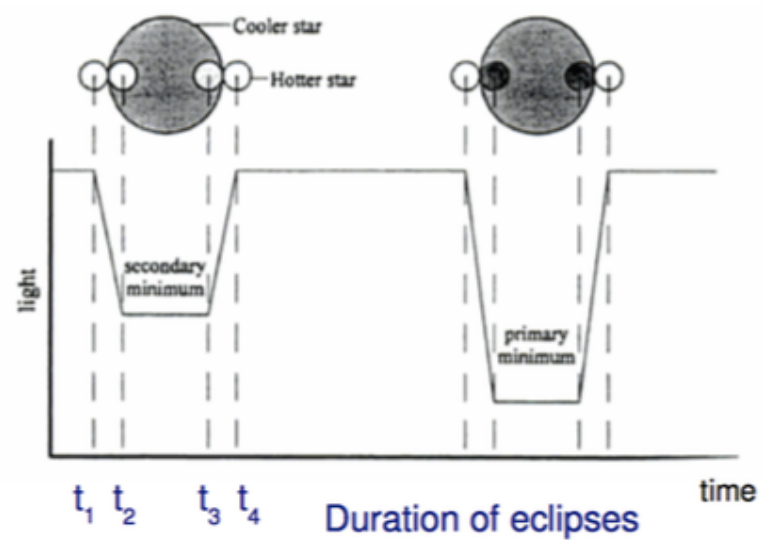
Properties constrained from light curves:

- Radius of Primary & Secondary:

In general, the radii of both components are determined by the duration of the eclipses

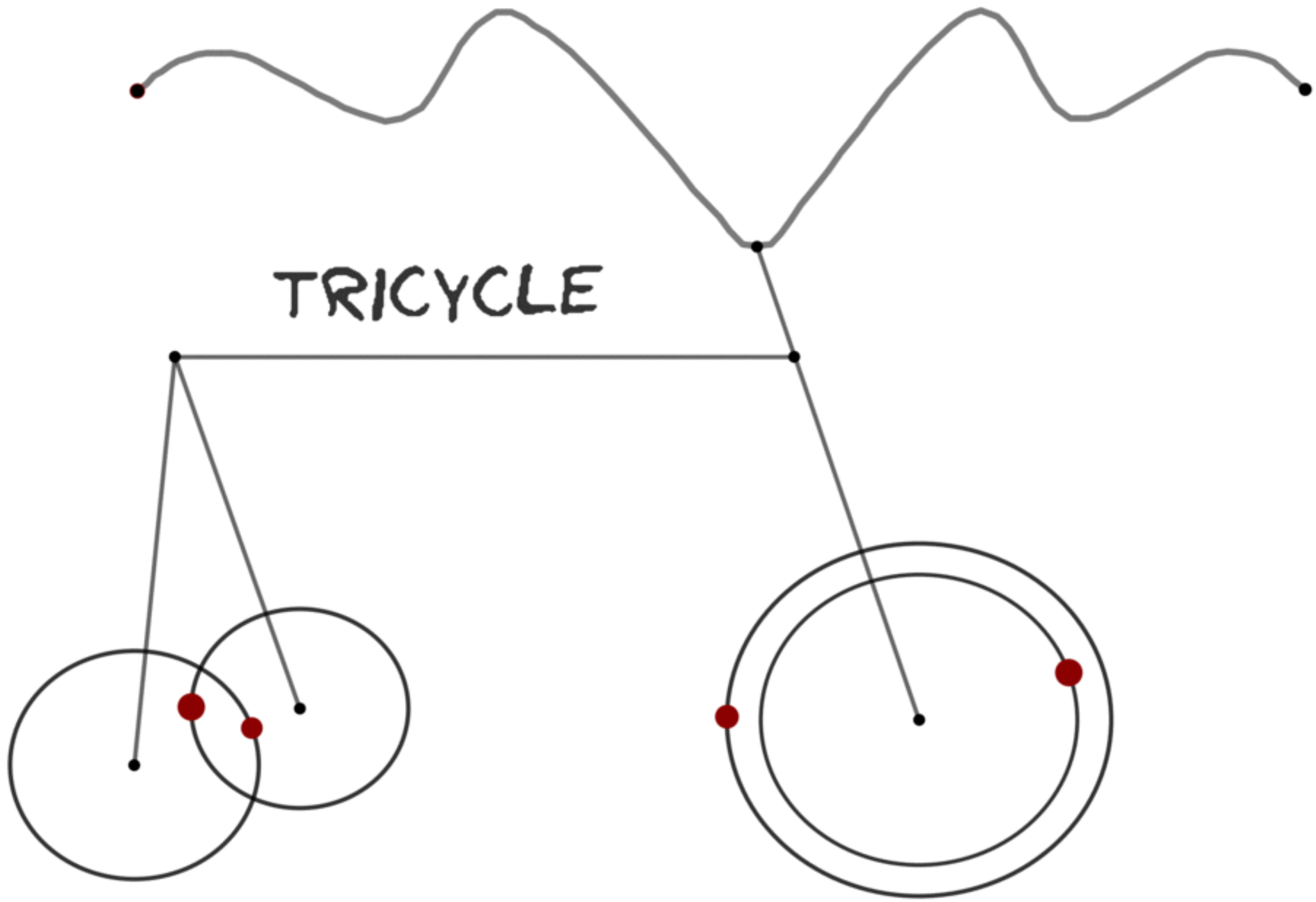
$$R_{small} = V_{rel}/2*(t_2-t_1)$$

$$R_{big} = V_{rel}/2*(t_3-t_1)$$

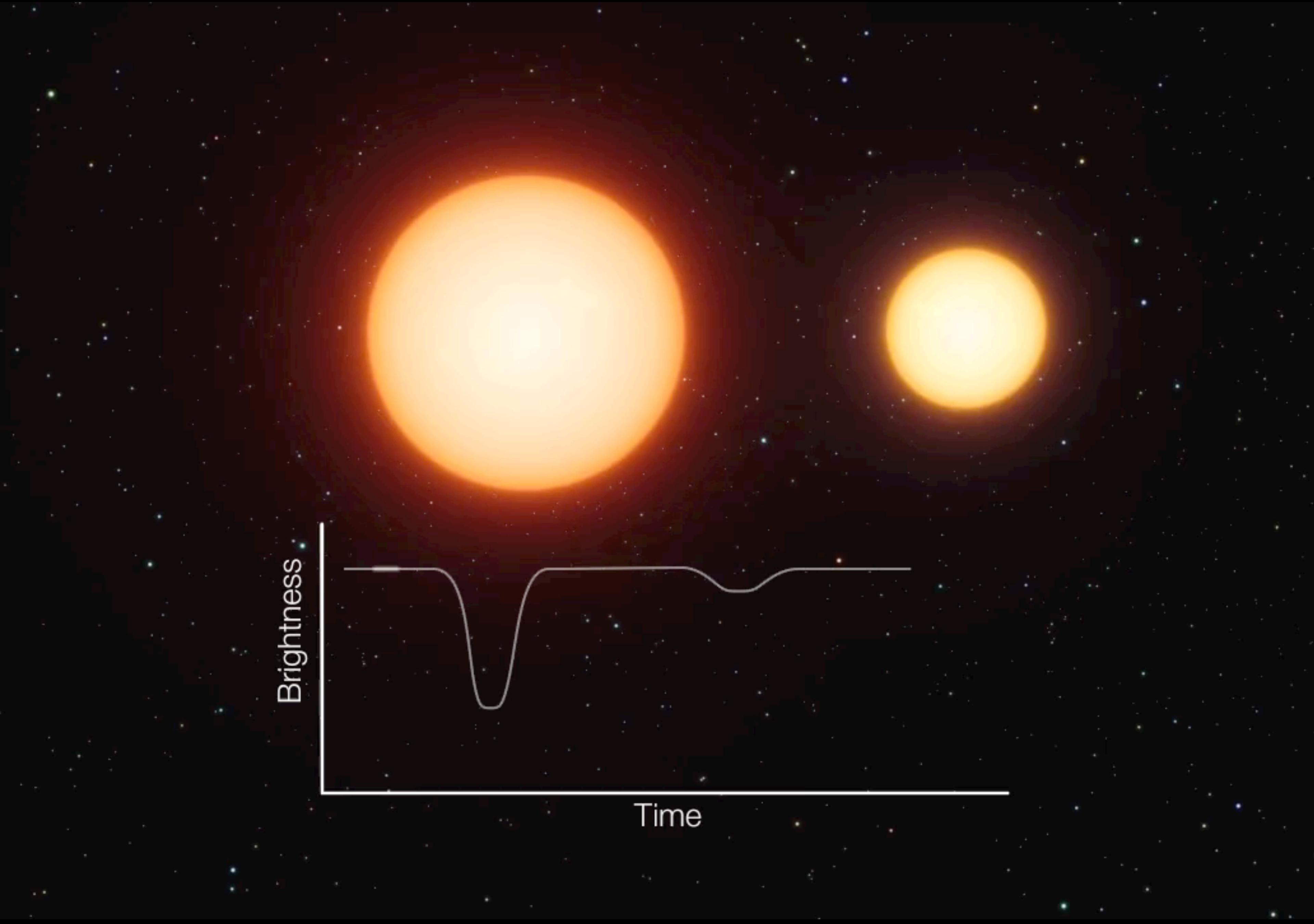


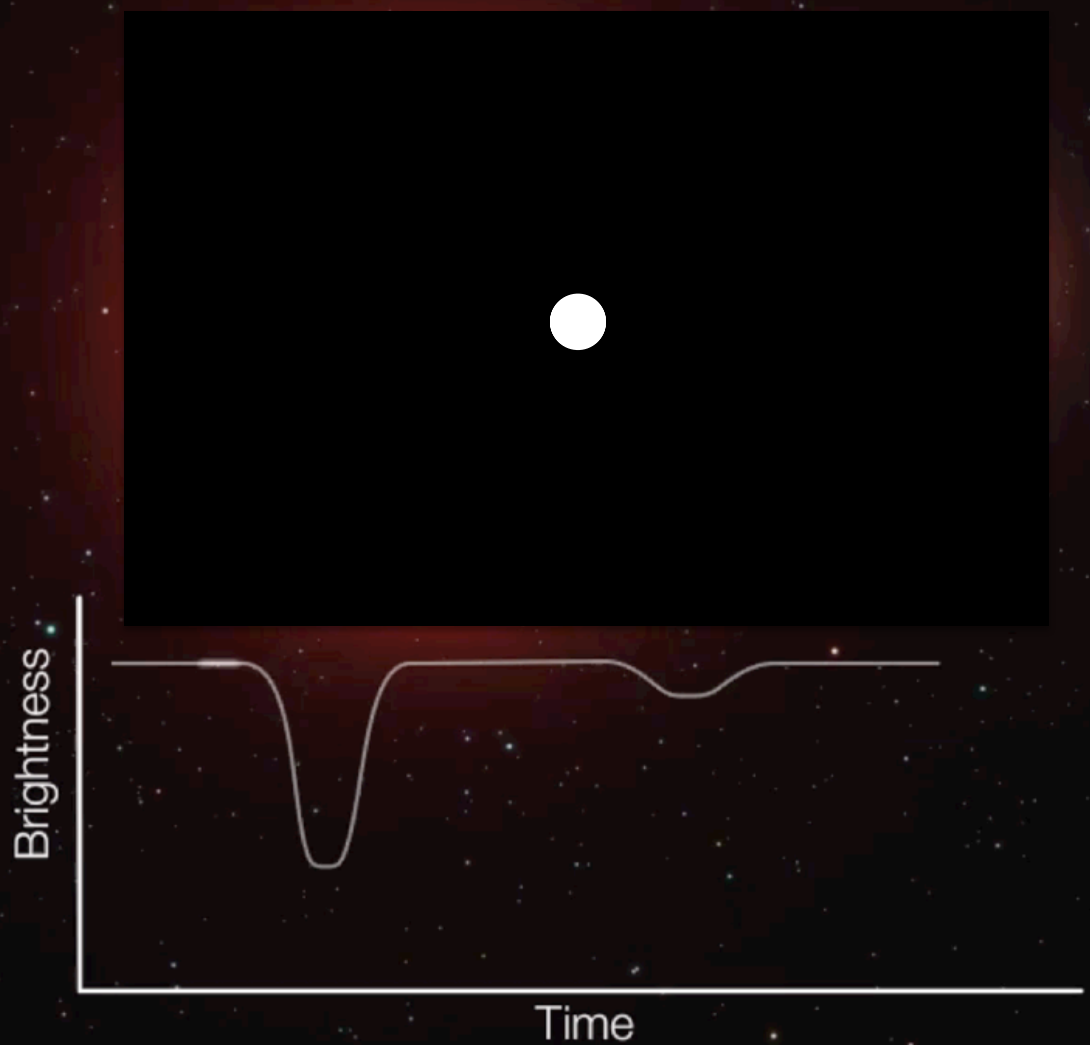
slide courtesy of Leslie Hebb

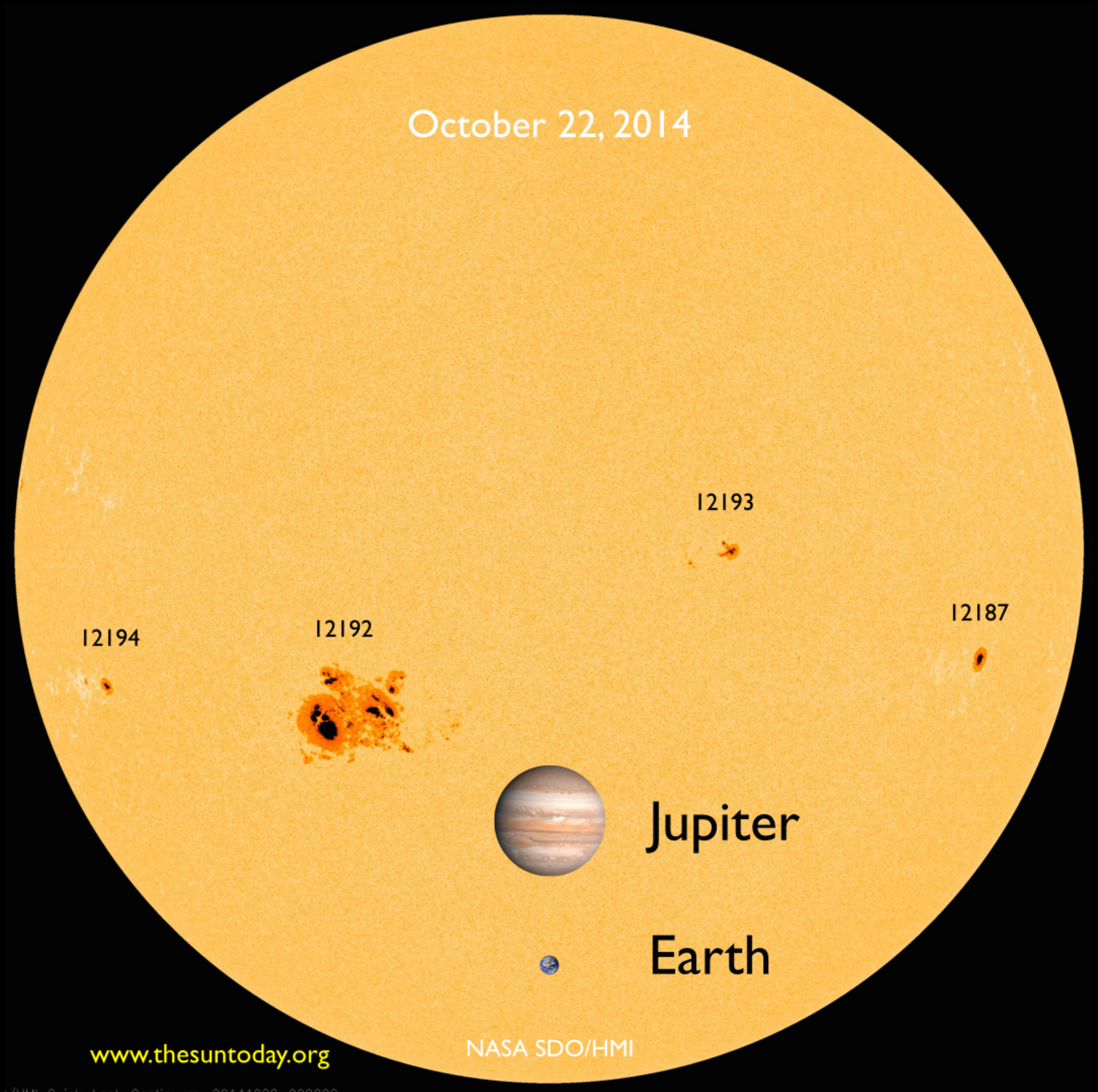
Spotting Stars That Wheel and Spin

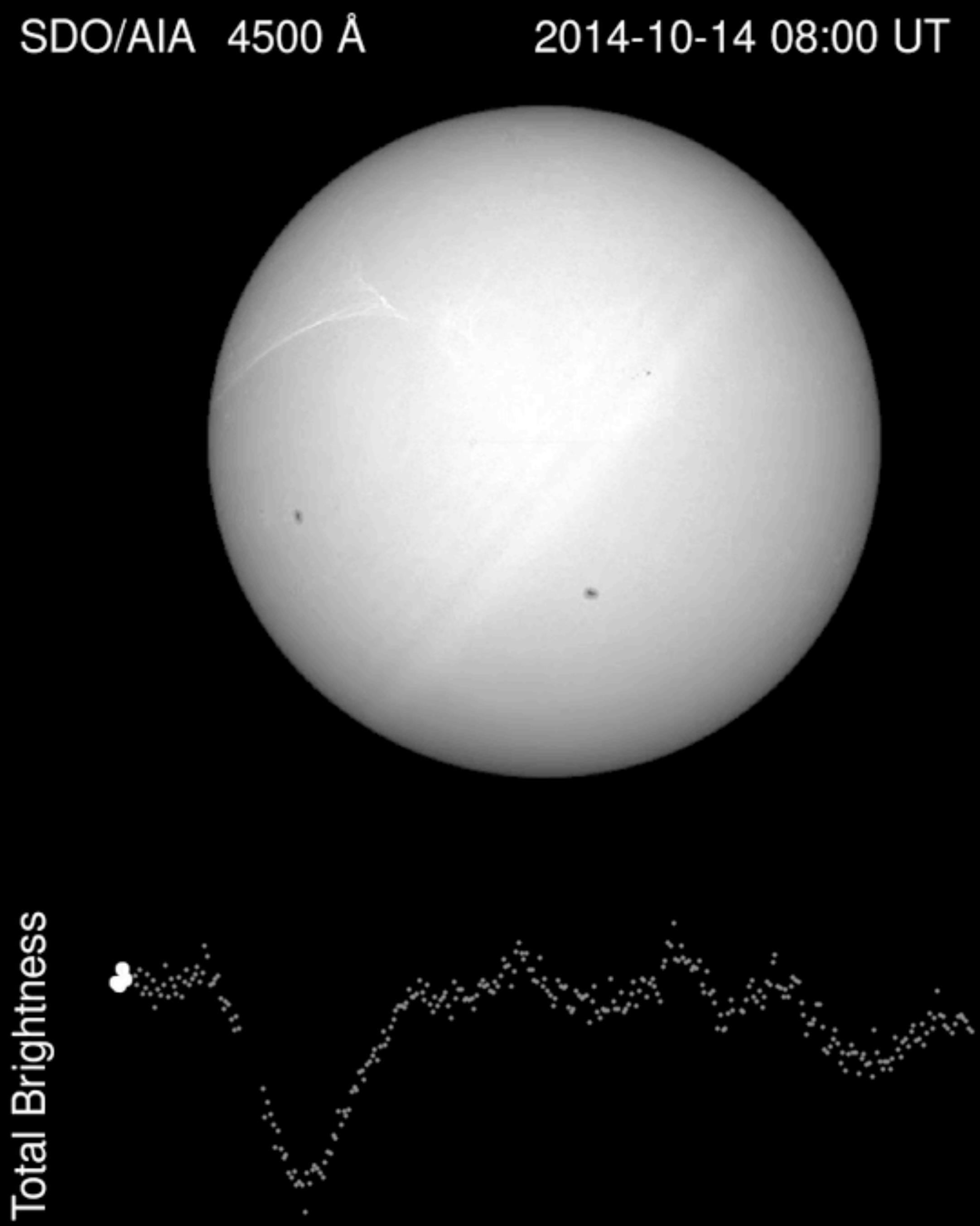


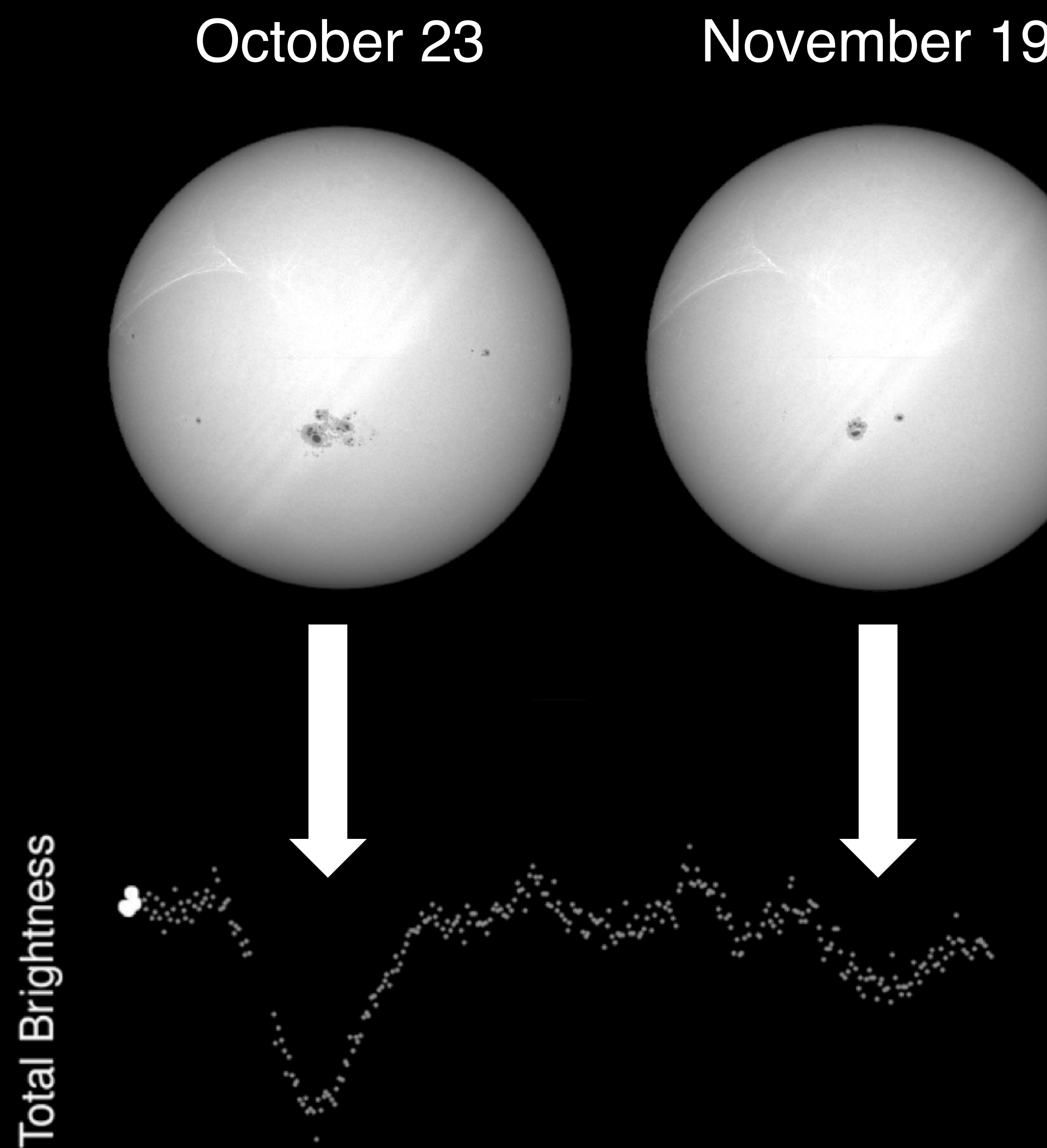
John Lurie, Kolby Weisenburger, and Prof. Suzanne Hawley


Brightness
Time

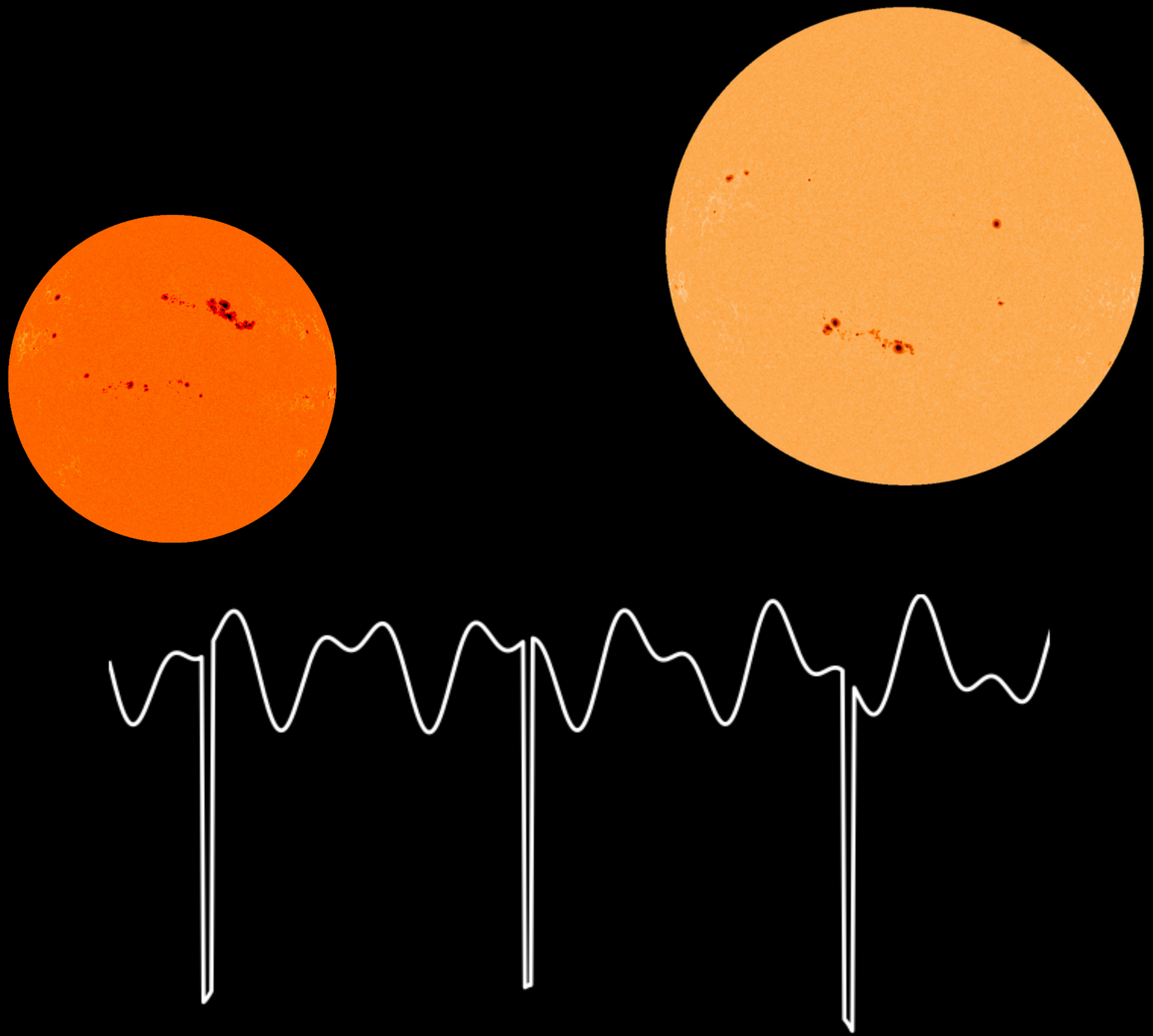

Brightness
Time


October 22, 2014
12193
12194
12192
12187
Jupiter
Earth
www.thesuntoday.org
NASA SDO/HMI


SDO/AIA 4500 Å
2014-10-14 08:00 UT
Total Brightness



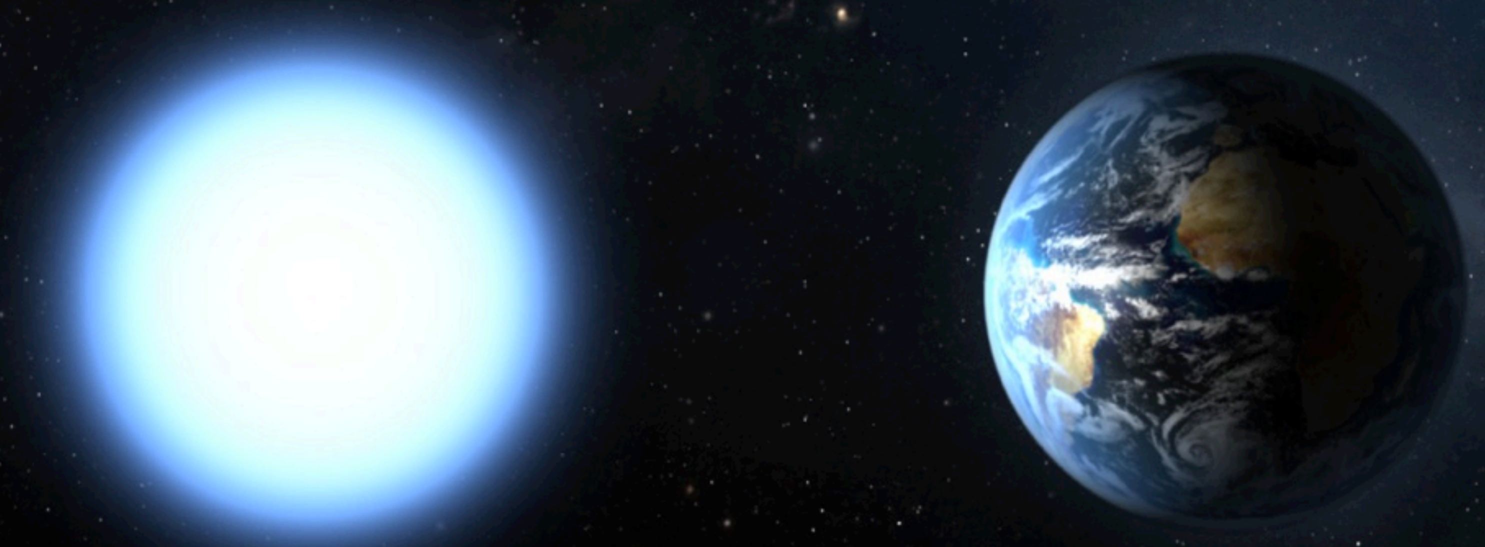
October 23
November 19
Total Brightness



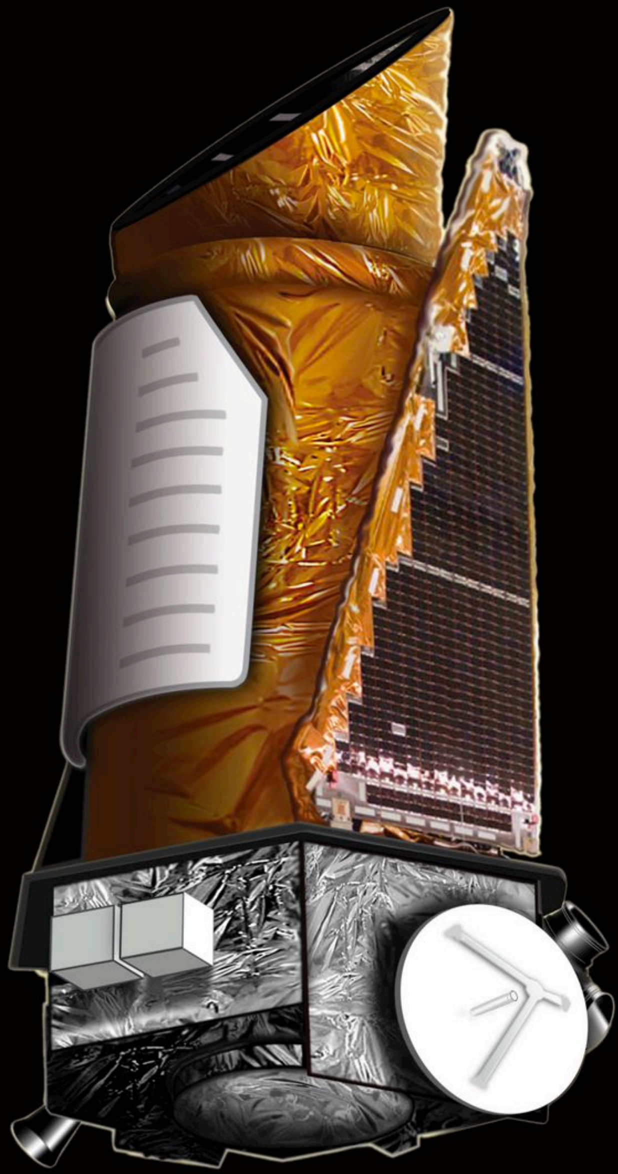
python™

GitHub

SPAMS
Search for Planets Around post-Main sequence Stars



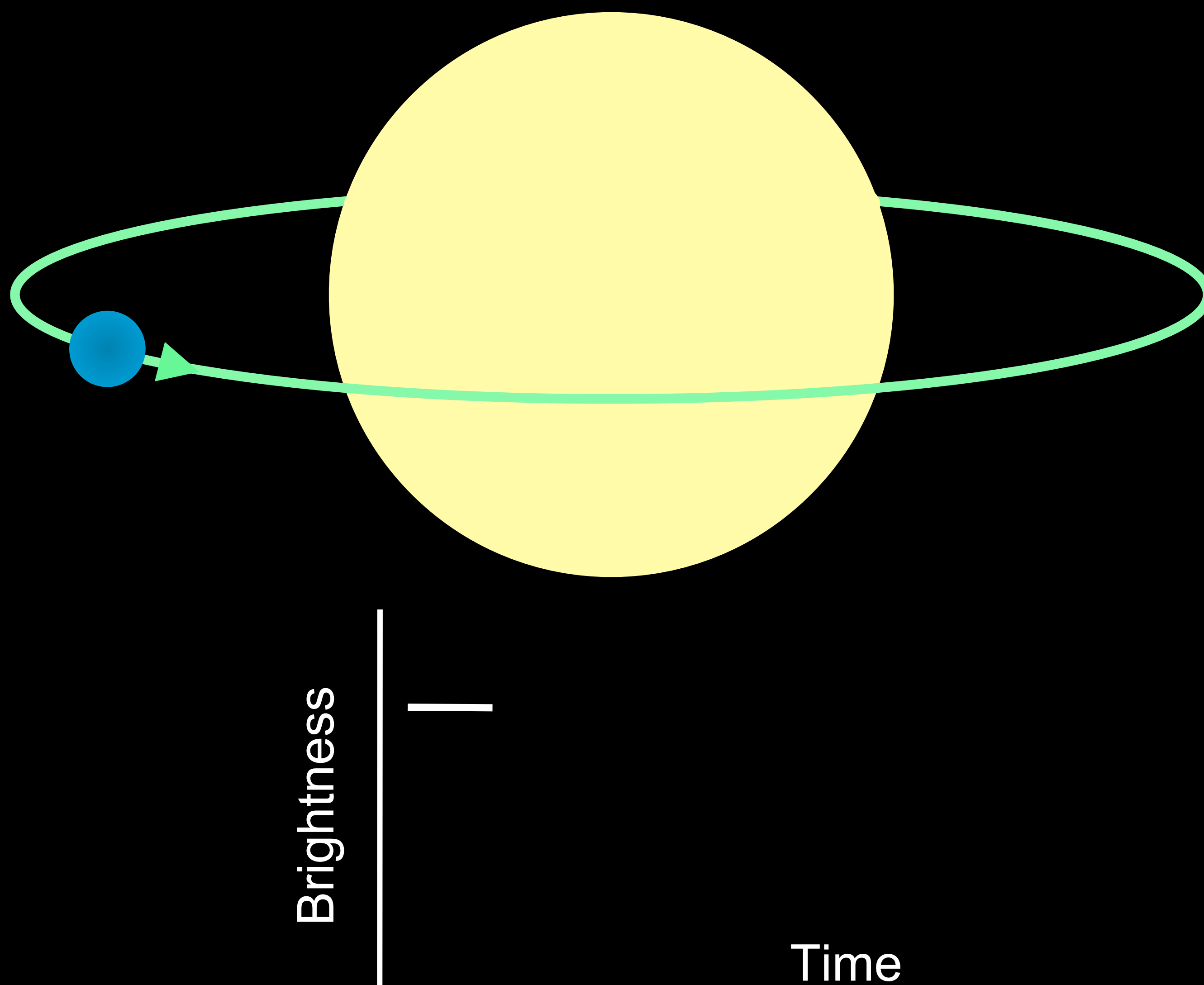
Brett Morris
University of Washington



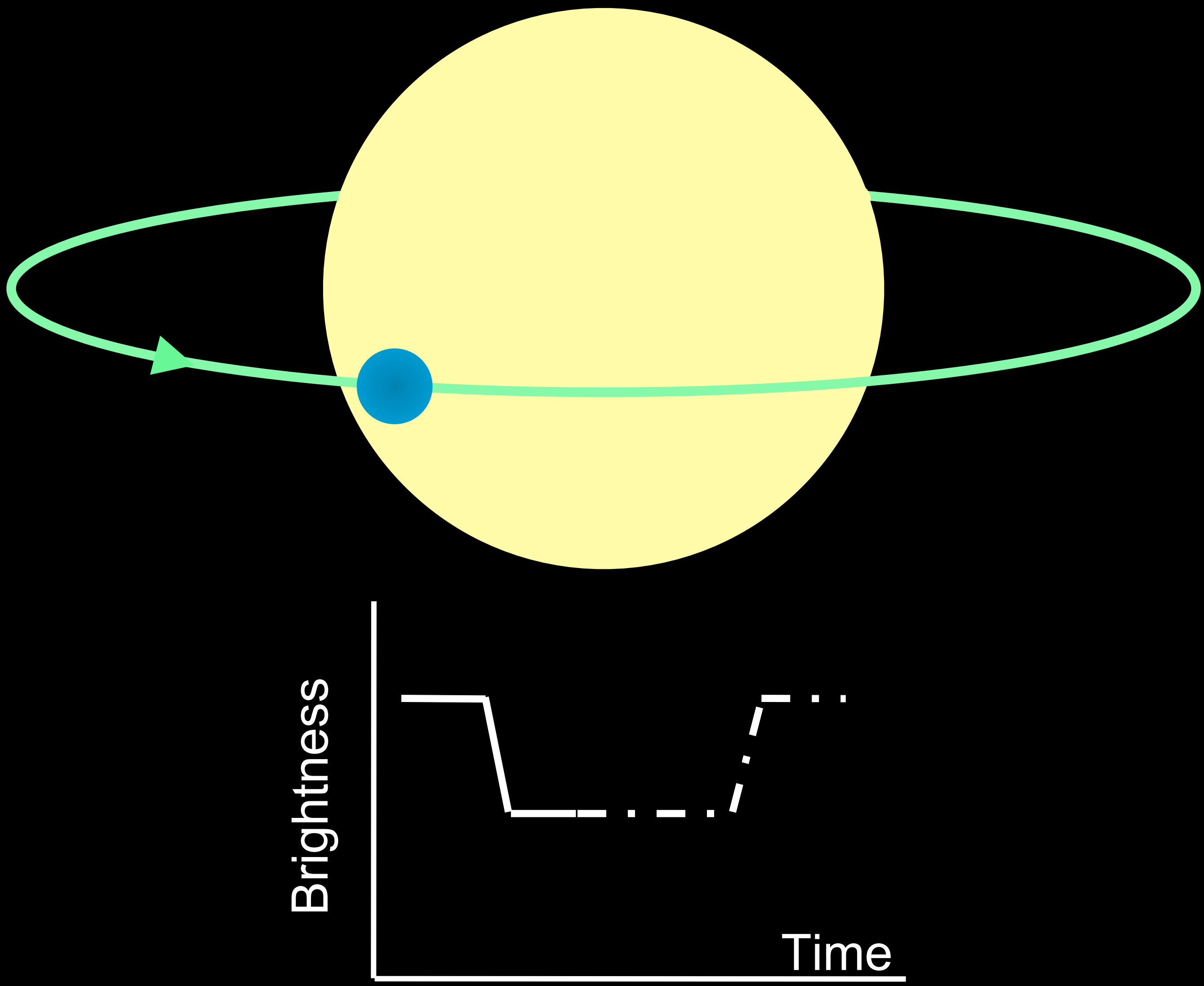
Kepler Mission:

Planet-finder extraordinaire

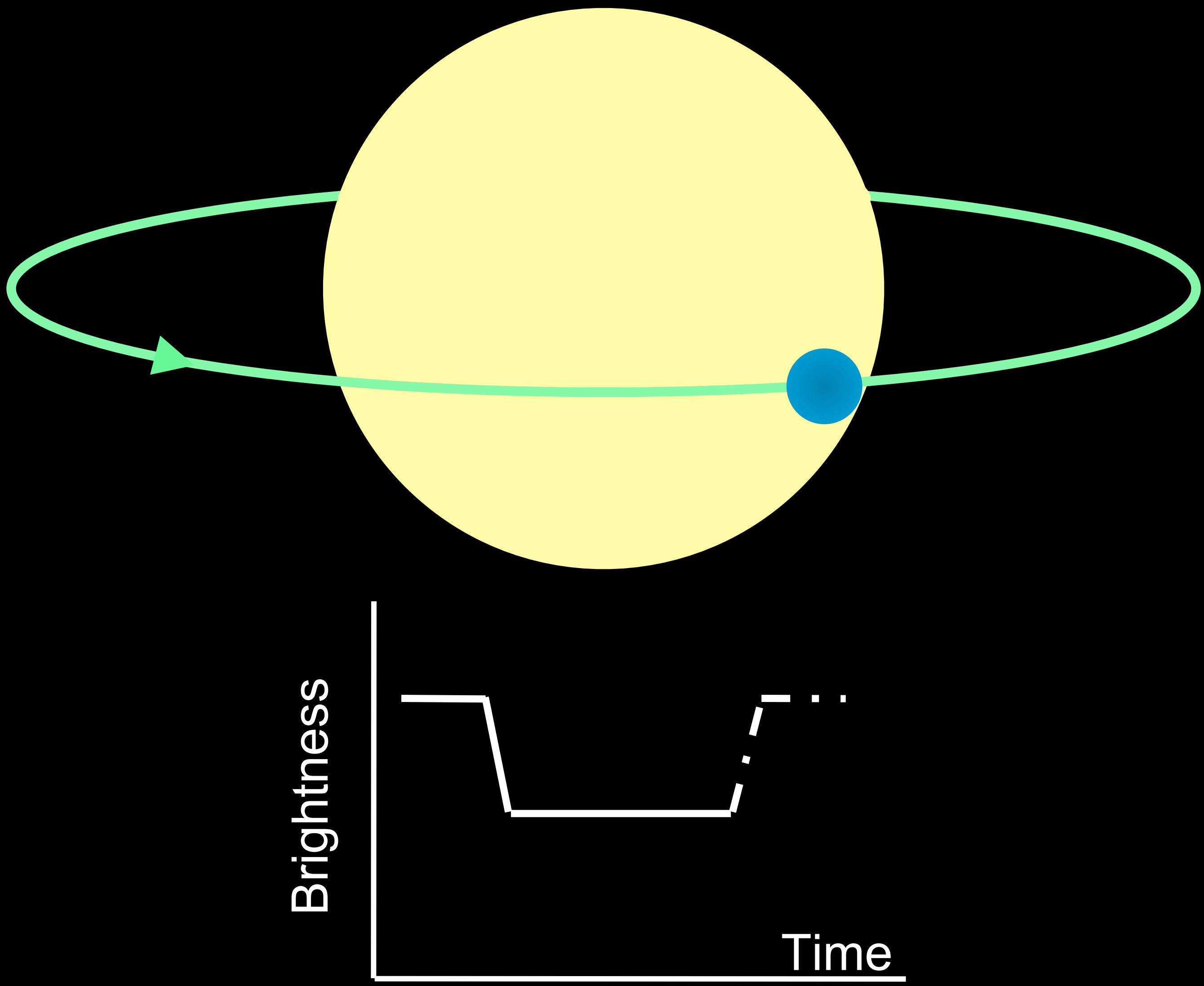
Finding Planets: Transit Method



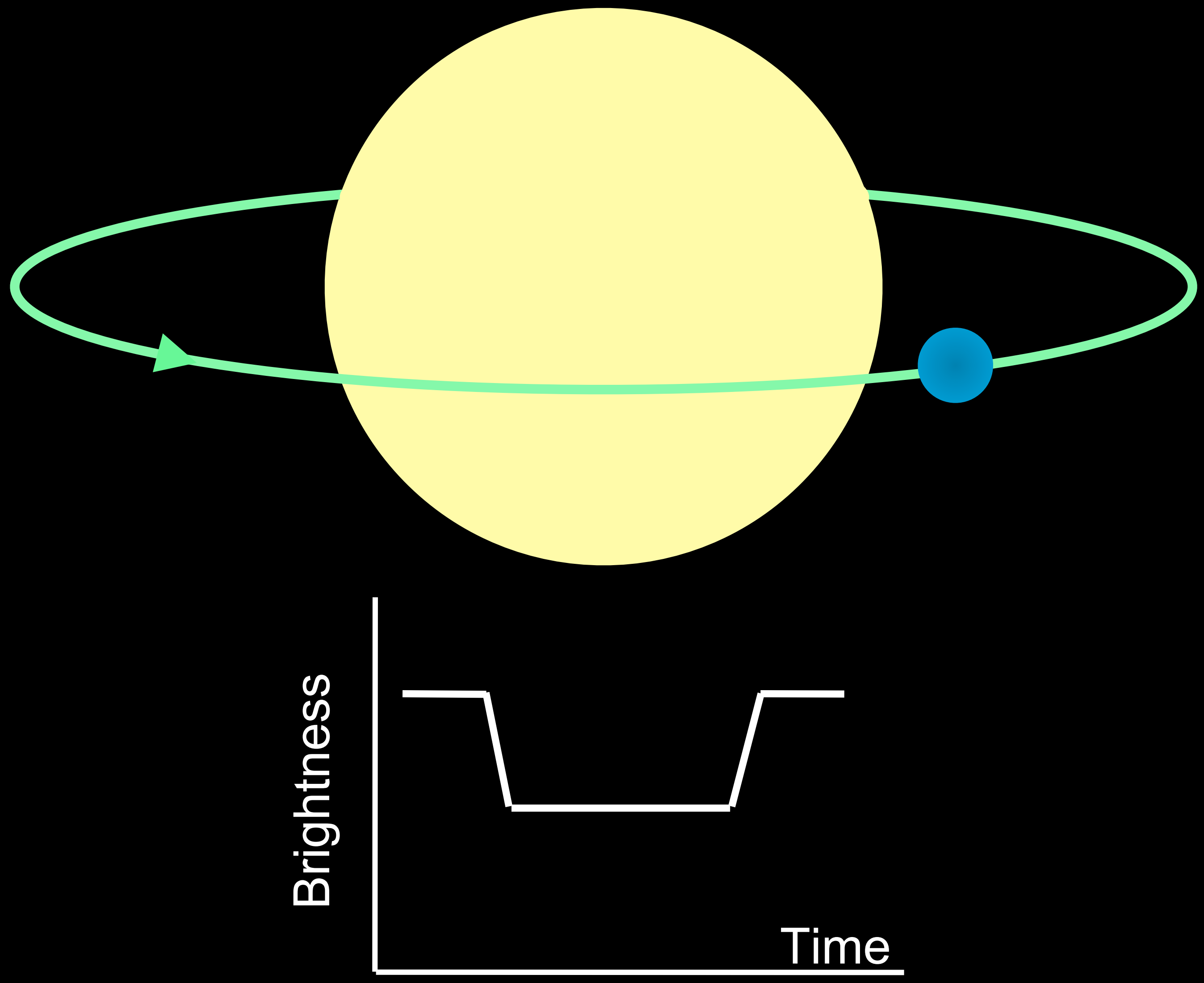
Finding Planets: Transit Method

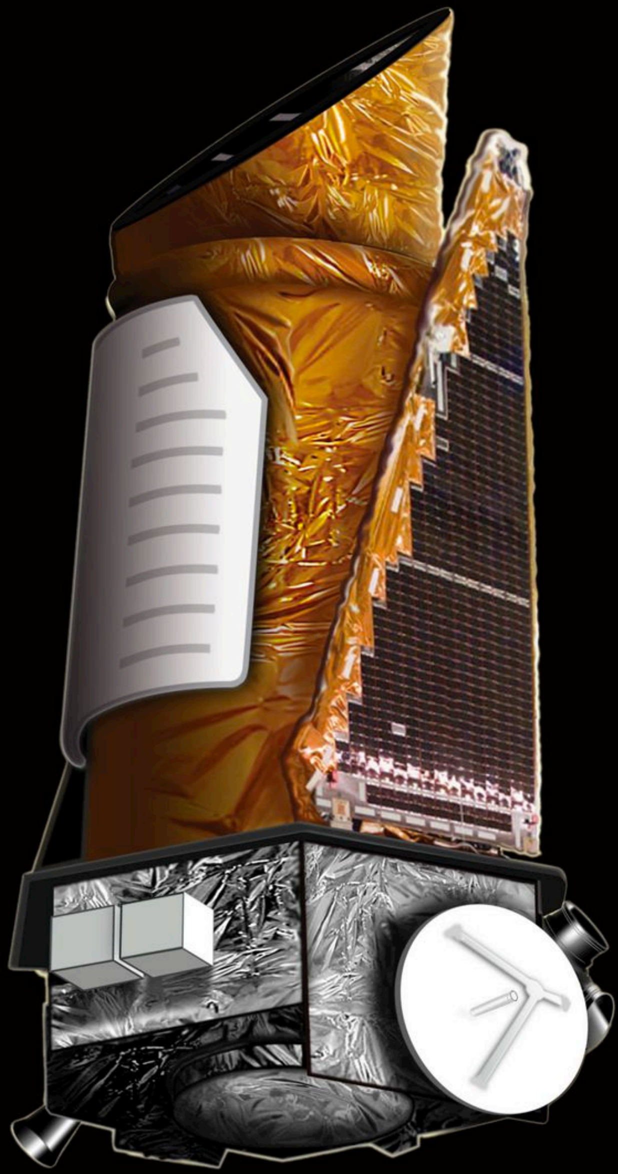


Finding Planets: Transit Method



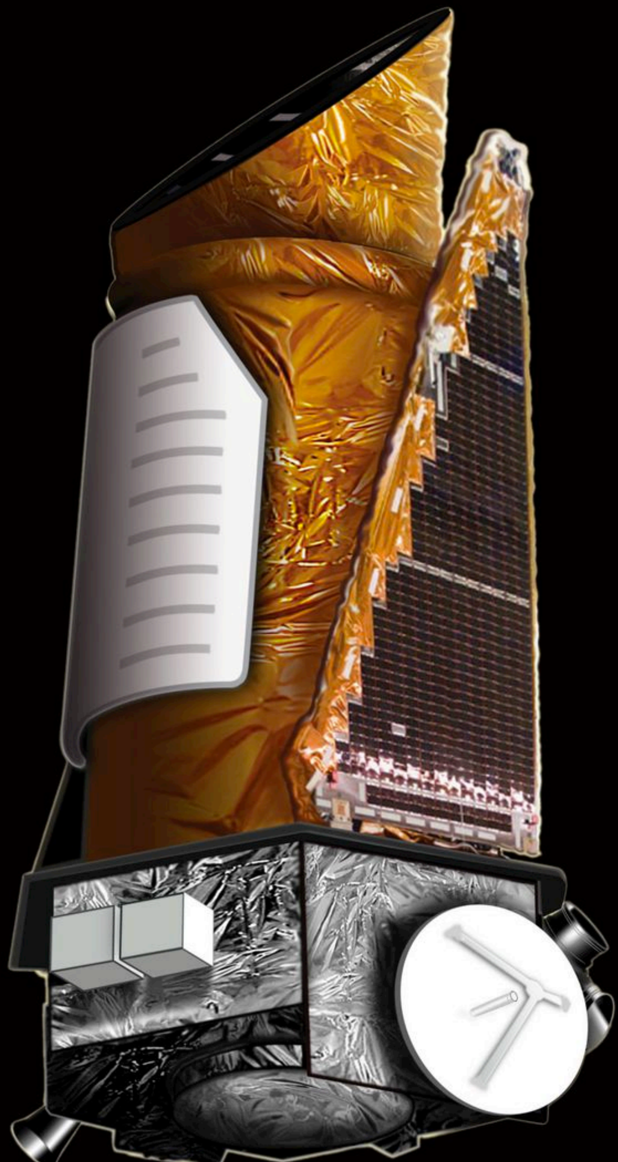
Finding Planets: Transit Method





Lessons from
Kepler Mission:

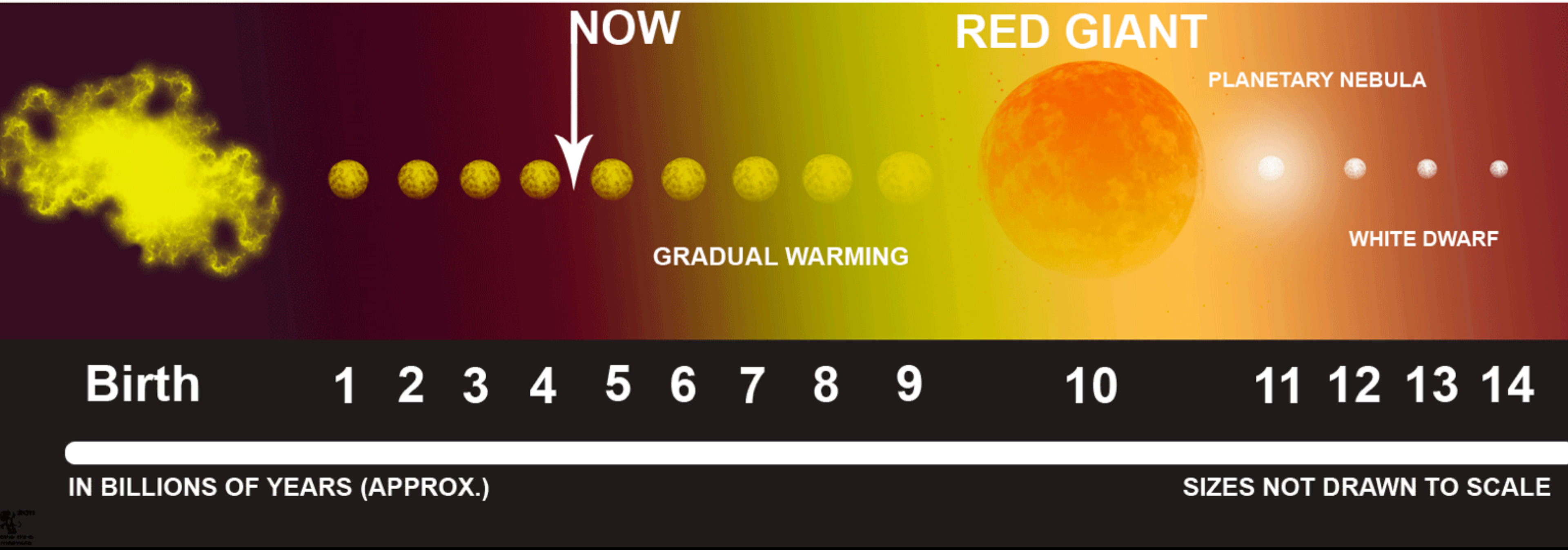
Sun-like stars host planets

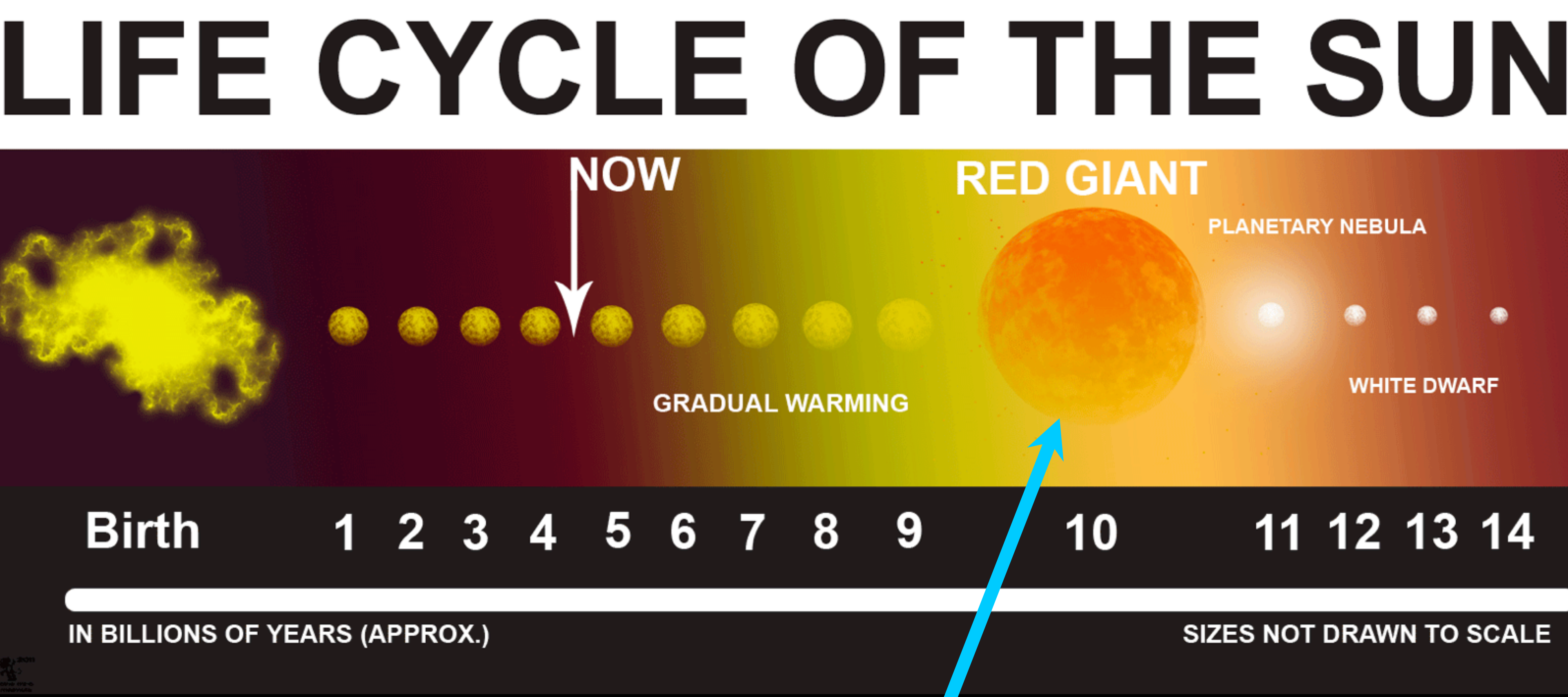


Morbid questions post-Kepler Mission:

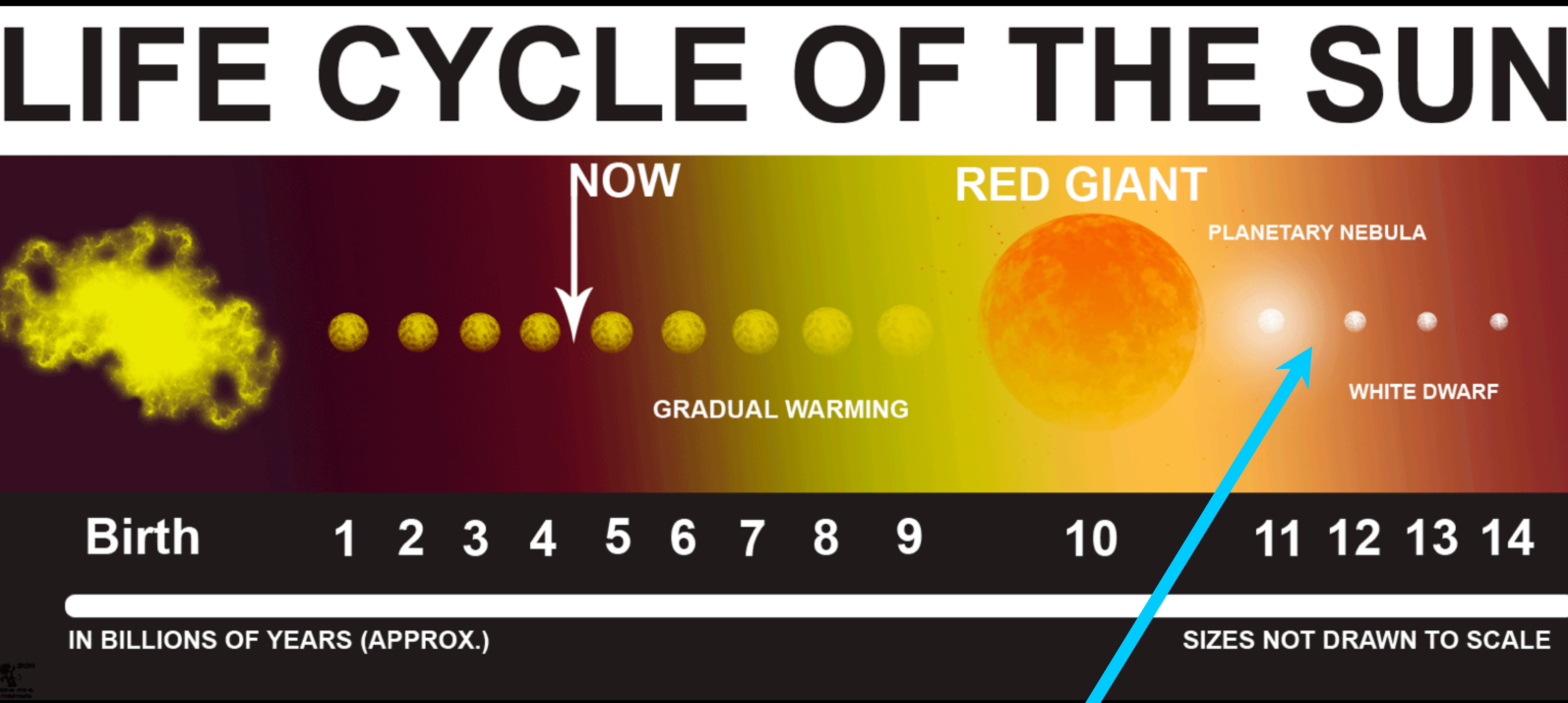
What happens to all those planets when their stars die?

LIFE CYCLE OF THE SUN





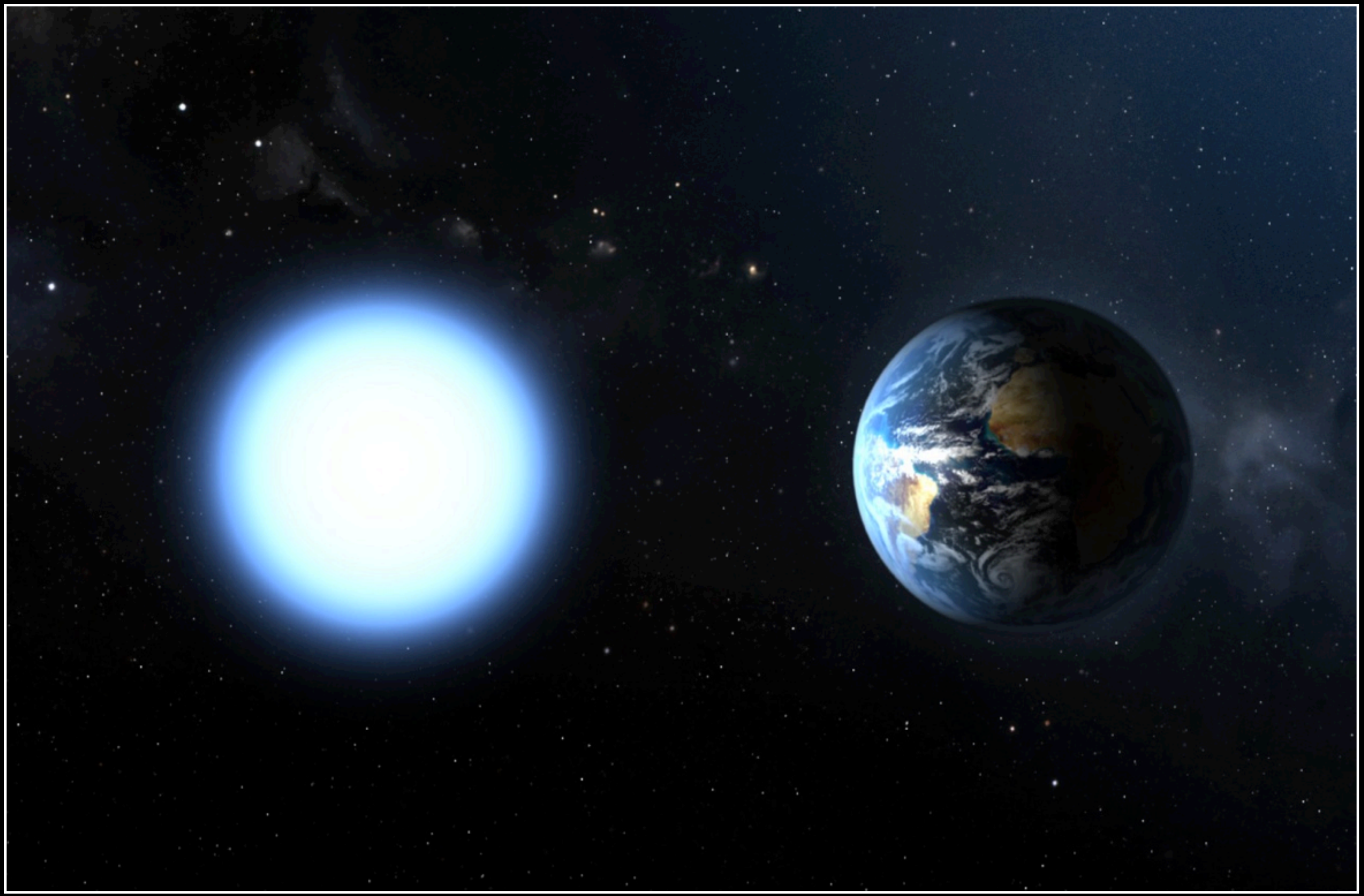
Mercury, Venus (+ Earth?) destroyed



Mars and outer planets survive?

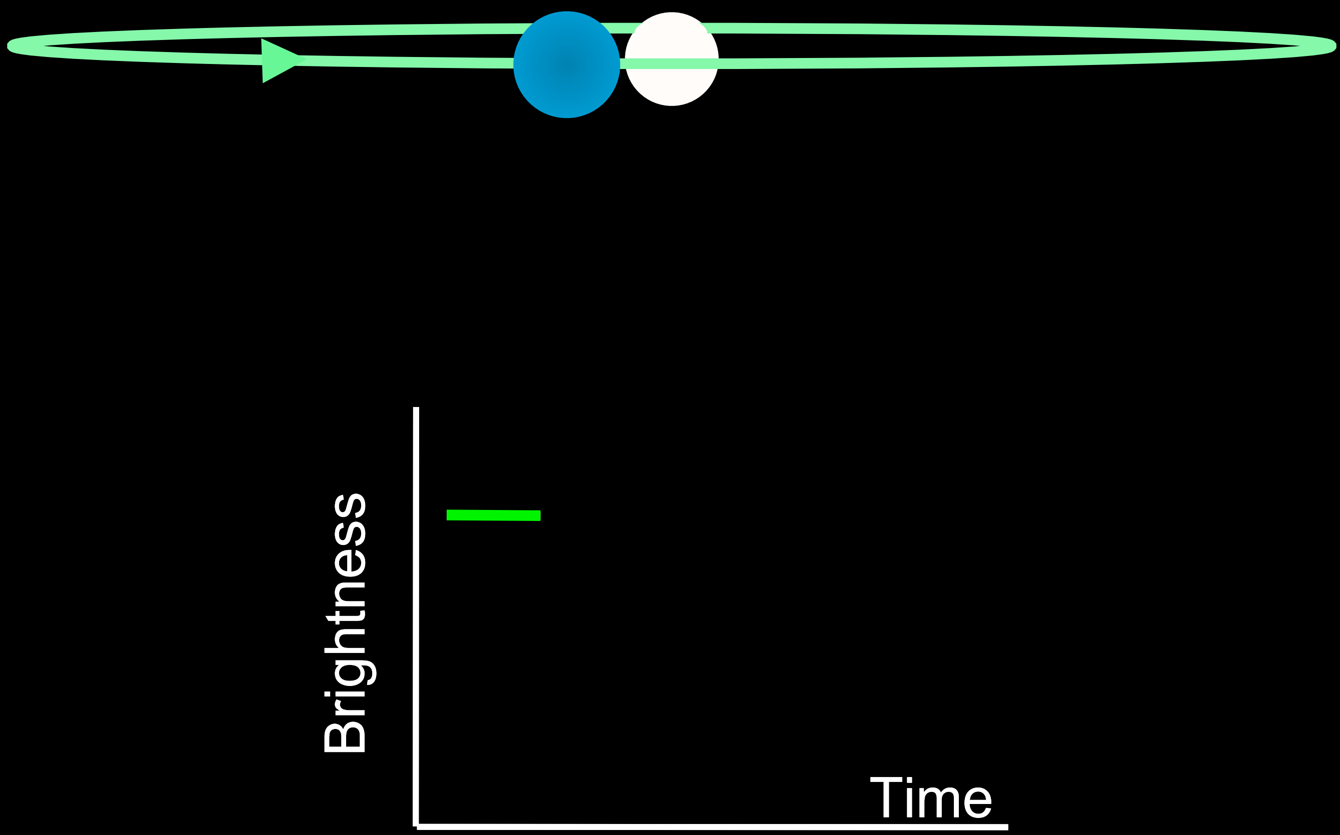
What if we looked at White Dwarfs?

Smaller Stars = Bigger Transit Signal



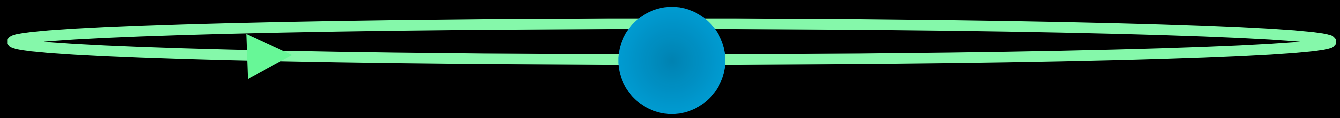
What if we looked at White Dwarfs?

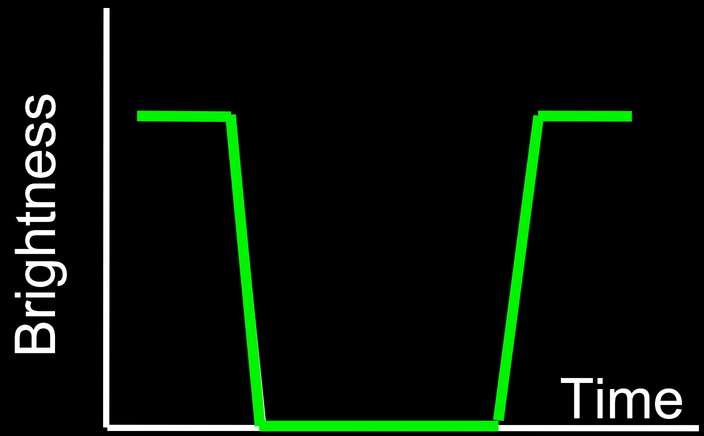
Smaller Stars = Bigger Transit Signal



What if we looked at White Dwarfs?

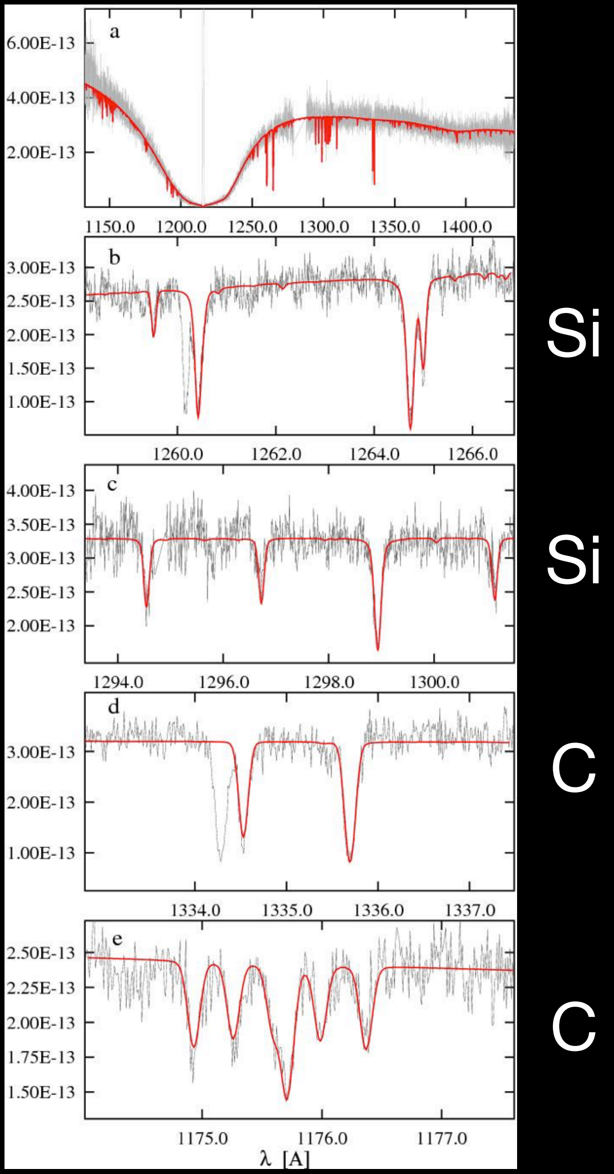
Smaller Stars = Bigger Transit Signal





Do White Dwarfs Have Planets?

- Spectroscopy shows rock/metals fall on some WDs
- Is the rock/metal from rocky planetary debris (i.e. dying zombie planets)?



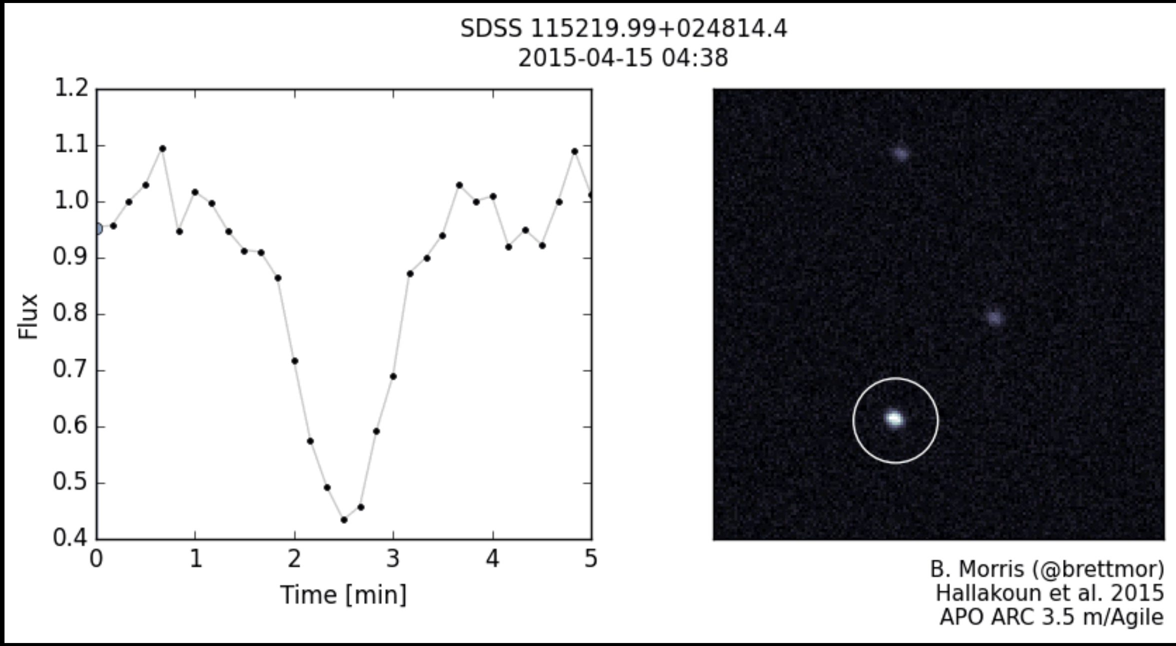
Koester et al. 2014

SPAMS Search for Planets Around post-Main sequence Stars

Apache Point Observatory ARC 3.5 m

SPAMS Search for Planets Around post-Main sequence Stars

Pre-MAP students Ada Beale, Doug Branton



High-Speed Photometry with Agile

SPAMS Search for Planets Around post-Main sequence Stars

- **We will work together in python™ to:**
  - Scan light curves for transits
  - Measure confidence of null detections
  - Reevaluate SPAMS search strategy

SPAMS Search for Planets Around post-Main sequence Stars

- **Ultimate goals:**
  - Search for planets
    - Candidates? Propose for follow-up
    - Nothing? Search some more!
- **If you continue on with this project:**
  - Provided we get telescope time, we will reduce and analyze more data
  - Hunt for planets!

SPAMS Search for Planets Around post-Main sequence Stars

- Questions?

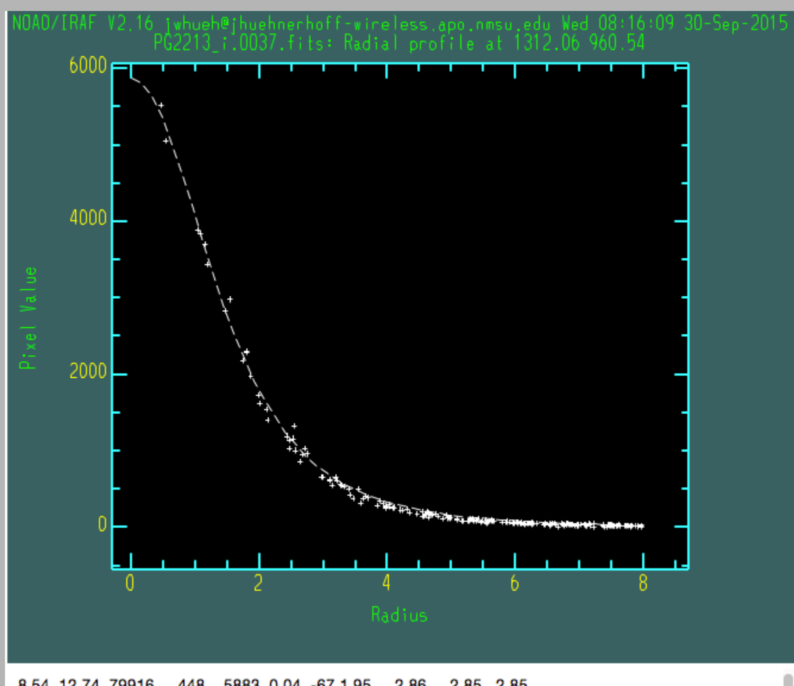
Dome Flow Analysis

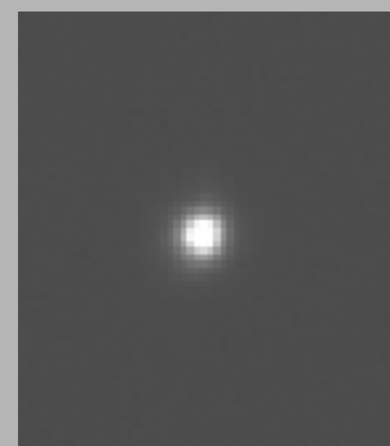
Apache Point Observatory 3.5m Telescope

Joseph Huehnerhoff

What is Seeing?

- How well an optical system (i.e. telescope) can resolve a star
- Types of seeing
  - Atmospheric
  - External localized environment (from the ground)
  - Internal localized environment (in the dome)
- The ability to resolve a star has direct impact on the scientific information





Data

Raw Data:

2011-08-27 00:00:04,1.7,1.8,4,4.9,6.1,44,0.0,0.0,0,0.00,0.00,0.00,108,8.90,233.08,98.08,16.8,302.518,4.998,4.998,4.998,182

Cadence: 10 seconds

Loggers: 2

Stations: 3 per logger

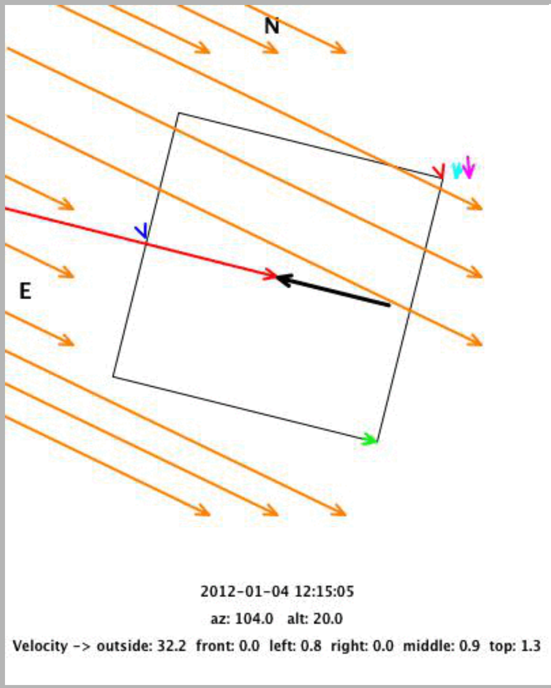
Lines per day: ~10,000

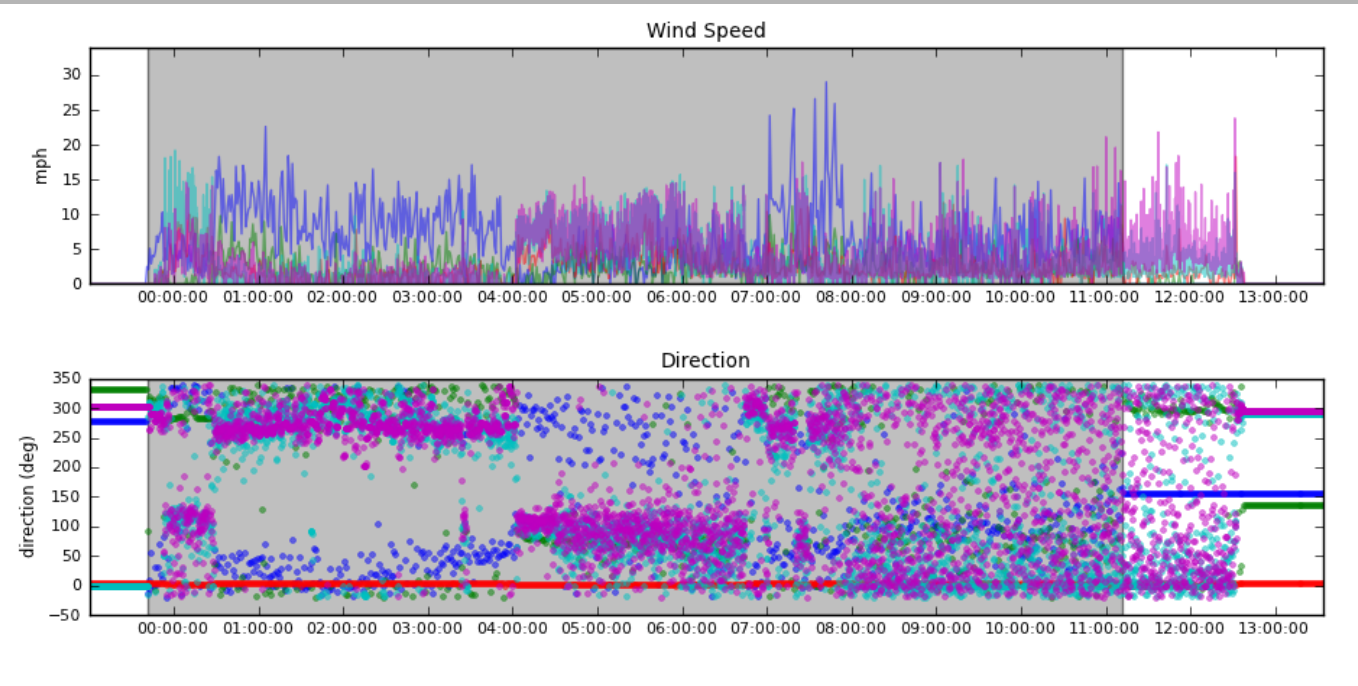
Days: >200

Data points per station: 2,000,000

Data points to correlate: 12,000,000

Key: Good Record Keeping





Data

Zone Parsed Data:

2011-11-08 04:52:11 0.0 1.4 0.00 open open

???? Correlate Multiple Zones ????

This project will be to correlate the data based on zonal overlap to create a complete data set.

Future

Determine if there are systematic correlations with nightly seeing

Research Goals

- Long Term
  - Characterize efficiency of heat rejection of 3.5m dome
  - Implement changes to increase this efficiency
    - More louvres?
    - Active louvre control?
- Goals this Quarter
  - Correlate anemometer data into single data set
- Methodology
  - Look for patterns between stations with same known times
  - Look for similar external and verify
  - Add next station and verify
  - Look for inconsistencies in data, optimize algorithm
  - Re-run on data
  - **Verify**

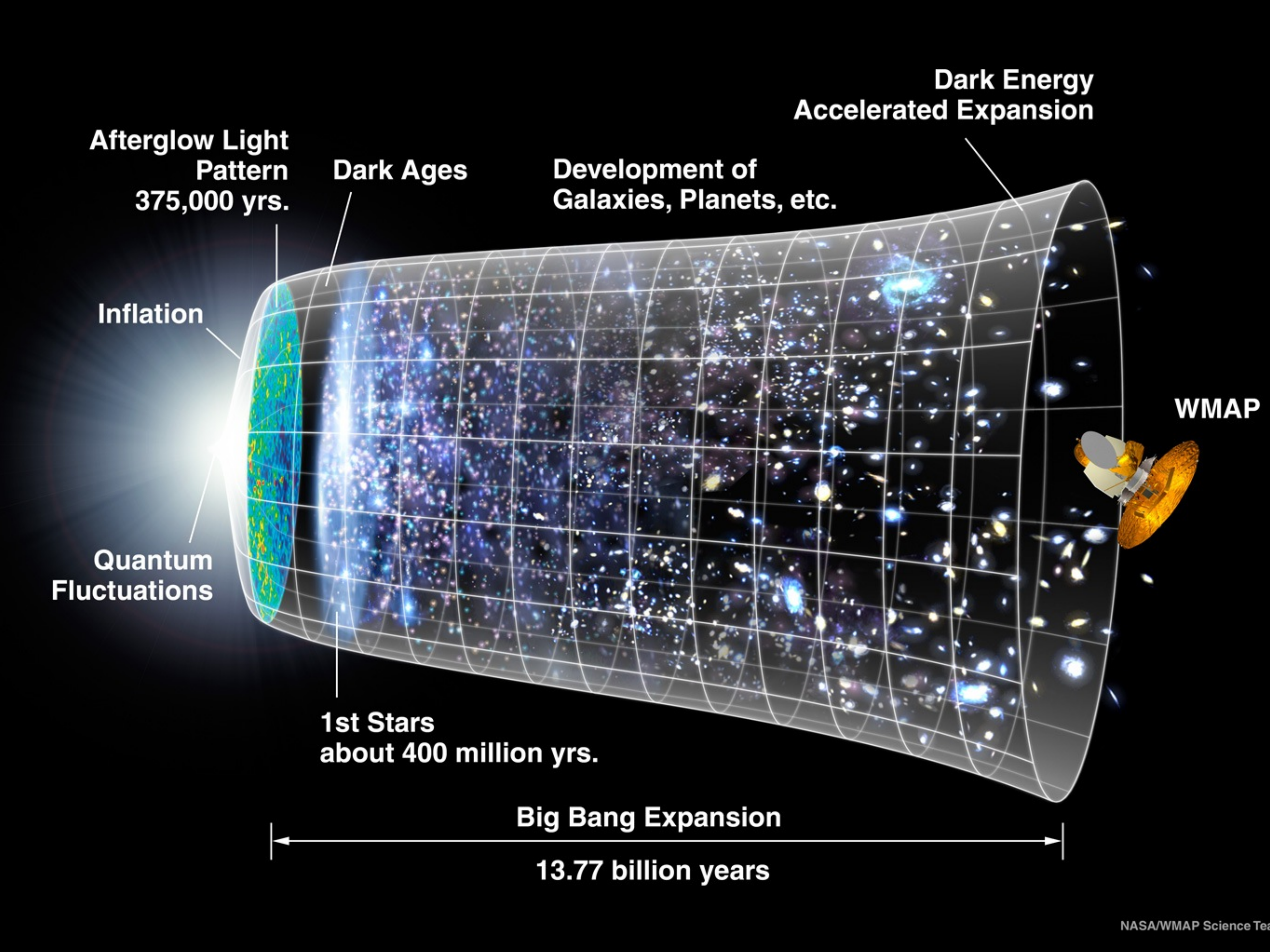
Light Curve Analysis and Photometric Redshifts of Supernova Type Ia

Rahul Biswas and Lisa McBride
University of Washington
October 9, 2015

Why are we interested?

(besides the fact that exploding stars are cool)

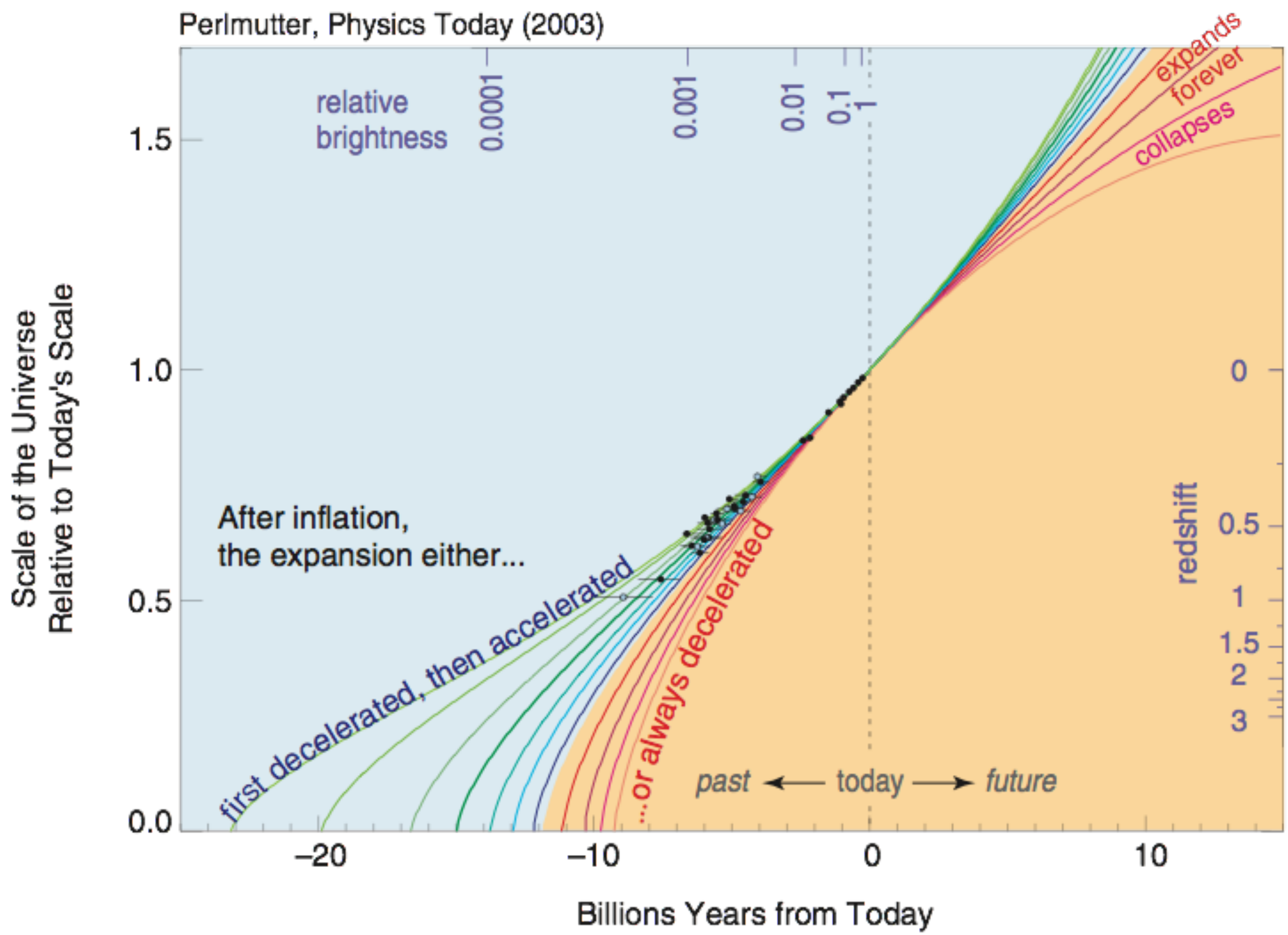
we use them as
‘standard candles’
to measure cosmic expansion



Dark Energy
Accelerated Expansion
Afterglow Light
Pattern
375,000 yrs.
Dark Ages
Development of
Galaxies, Planets, etc.
Inflation
WMAP
Quantum
Fluctuations
1st Stars
about 400 million yrs.
Big Bang Expansion
13.77 billion years
NASA/WMAP Science Tea

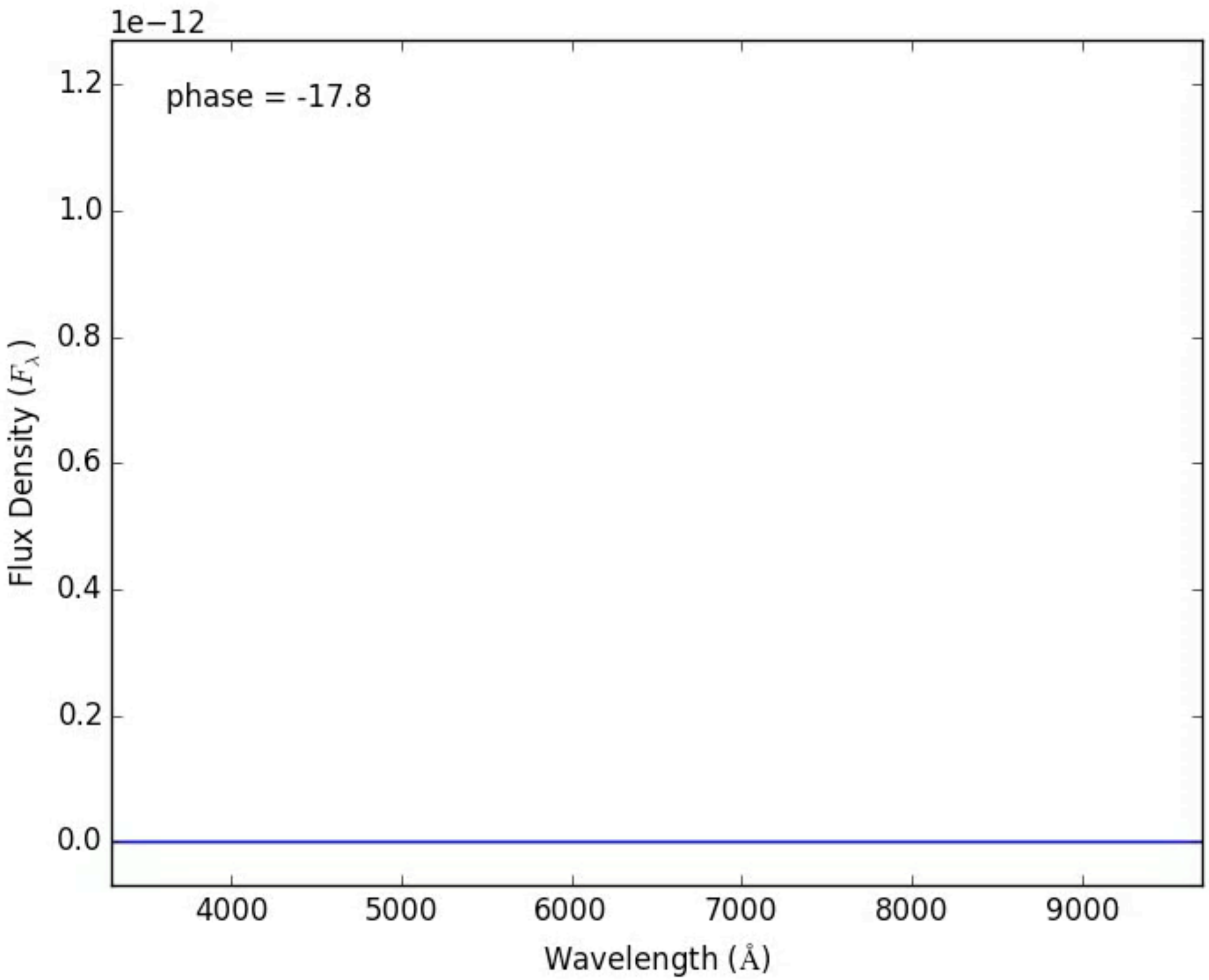
Expansion History of the Universe

Perlmutter, Physics Today (2003)



What does Type 1a supernovae data look like?

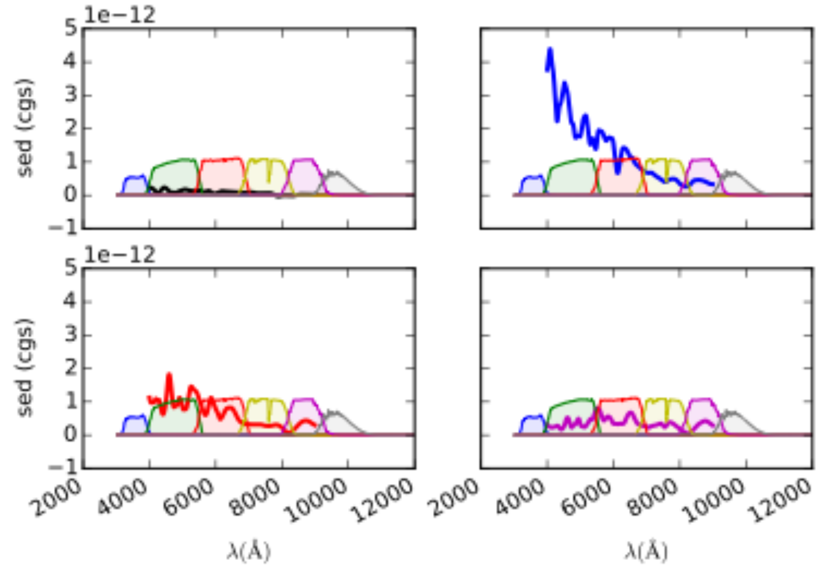

SN 2011fe


1e−12
phase = -17.8
Flux Density (F_λ)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
4000
5000
6000
7000
8000
9000
Wavelength (Å)

But, spectra is slow and not always possible.

Light Curves

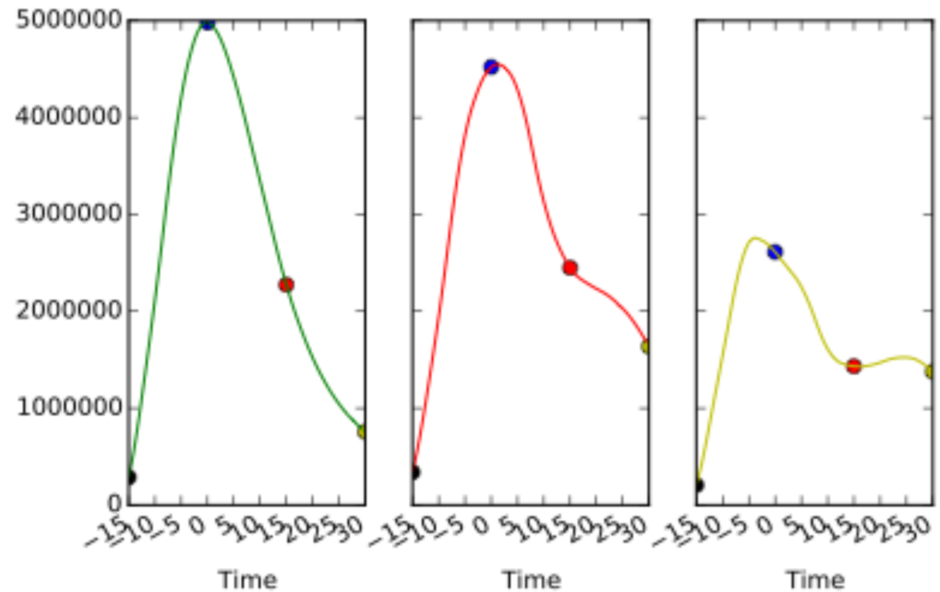
Instead pick a range of wavelengths and average all the photons together to get a light curve



Light curves

- luminosity over time

- light curve characteristics are related to the intrinsic brightness



What we are working on

(and maybe you…?)

Characterization of Light Curves

- develop and test better methods of analyzing light curves for these photometric surveys.
- use SNCosmo software package to,
    - ➡ simulate supernova light curves
    - ➡ run simulated data through different statistical fitting algorithms and compare results

IP[y]: Notebook host_extinction_demo Last Checkpoint: Oct 07 10:12 (autosaved)

File Edit View Insert Cell Kernel Help

Code Cell Toolbar: None

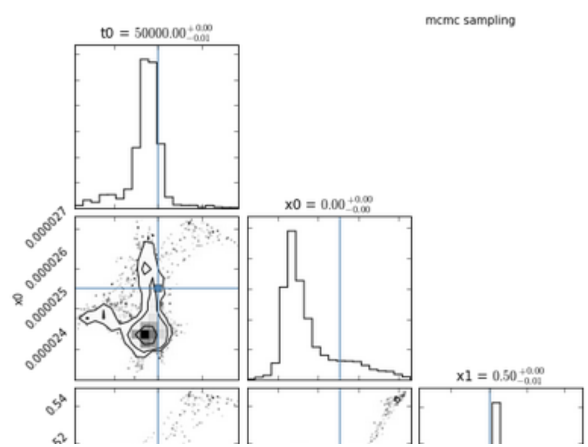
```
print "number of mcmc dimensions:", mcmc_ndim
print "number of mcmc samples:", mcmc_nsamples

nest_ndim, nest_nsamples = len(nest), len(nest_res.samples)
nest_samples = nest_res.samples

print
print "number of nest dimensions:", nest_ndim
print "number of nest samples:", nest_nsamples

# with host ext
#mcmc_ext_ndim, mcmc_ext_nsamples = len(mcmc_ext_res.vparam_names), len(mcmc_ext_res.samples)
#mcmc_ext_samples = mcmc_ext_res.samples

#nest_ext_ndim, nest_ext_nsamples = len(nest_ext_res.vparam_names), len(nest_ext_res.samples)
#nest_ext_samples = nest_ext_res.samples
```

```
number of mcmc dimensions: 5
number of mcmc samples: 10000

number of nest dimensions: 5
number of nest samples: 4248
```

In [34]:

```
figure_mcmc = triangle.corner(mcmc_samples, labels=[mcmc[0], mcmc[1], mcmc[2], mcmc[3], mcmc[4]],
                              truths=[model_noext.get(mcmc[0]), model_noext.get(mcmc[1]),
                                      model_noext.get(mcmc[2]), model_noext.get(mcmc[3]),
                                      model_noext.get(mcmc[4])],
                              range=mcmc_ndim*[0.9999],
                              show_titles=True, title_args={"fontsize": 12})

figure_mcmc.gca().annotate("mcmc sampling", xy=(0.5, 1.0), xycoords="figure fraction",
                           xytext=(0, -5), textcoords="offset points",
                           ha="center", va="top")
```

Out[34]: <matplotlib.text.Annotation at 0x113b5e910>



* Our current research goal is to better understand what we can learn from just photometric data.

  - for this project, particularly to see how effectively we can determine redshift without using spectra

  - learning and using statistical modeling (check out my tutorial in the github repository for this project)

  - opportunity for continuing this, or similar lines of research with LSST, a big collaboration with a large UW presence, doing a lot of different astronomy

This project will excite you if :

- ✓ You want to learn more Python
- ✓ You want to learn about statistical modeling
- ✓ You are interested in cosmology and dark energy
- ✓ You are curious about LSST

Hubble Ultra Deep Field
Hubble Space Telescope • Advanced Camera for Surveys

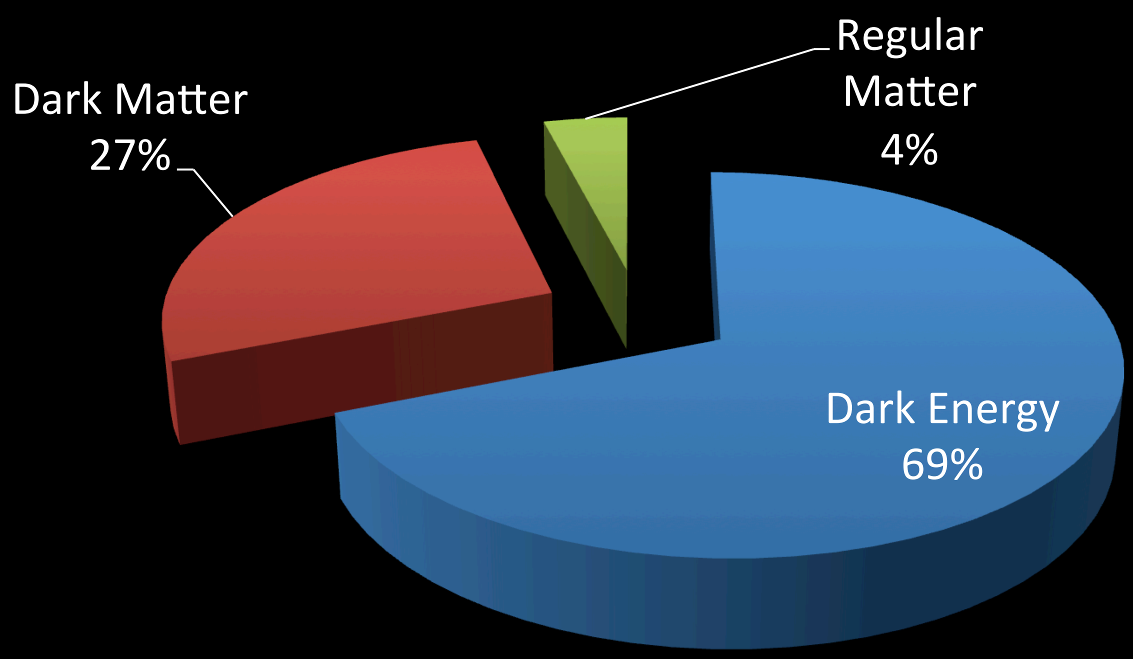
NASA, ESA, S. Beckwith (STScI) and the HUDF Team

STScI-PRC04-07a

testing our models for the stuff between galaxies

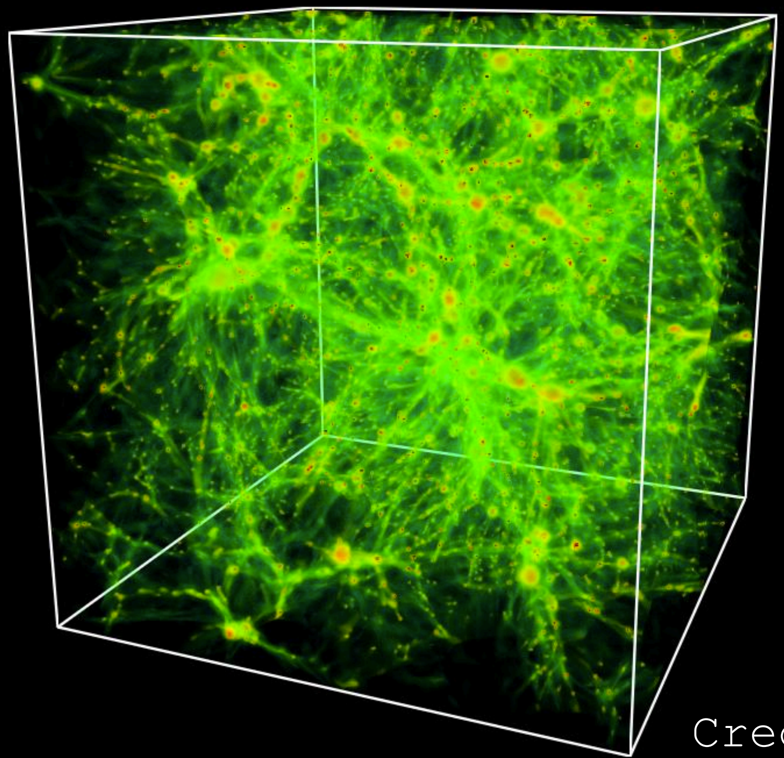
Advisors: Phoebe Upton Sanderbeck and Matt McQuinn

Composition of the Universe

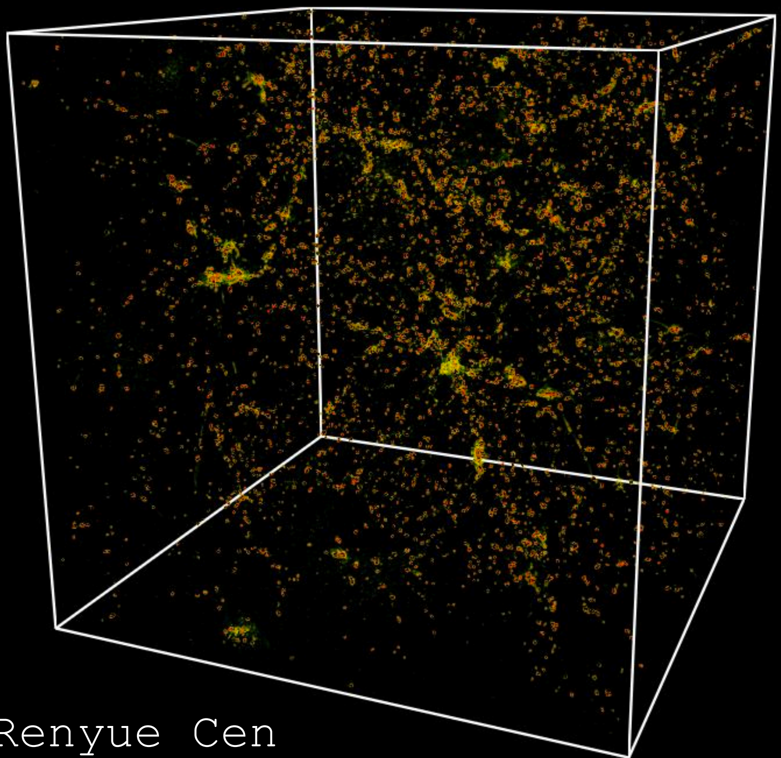


The intergalactic medium

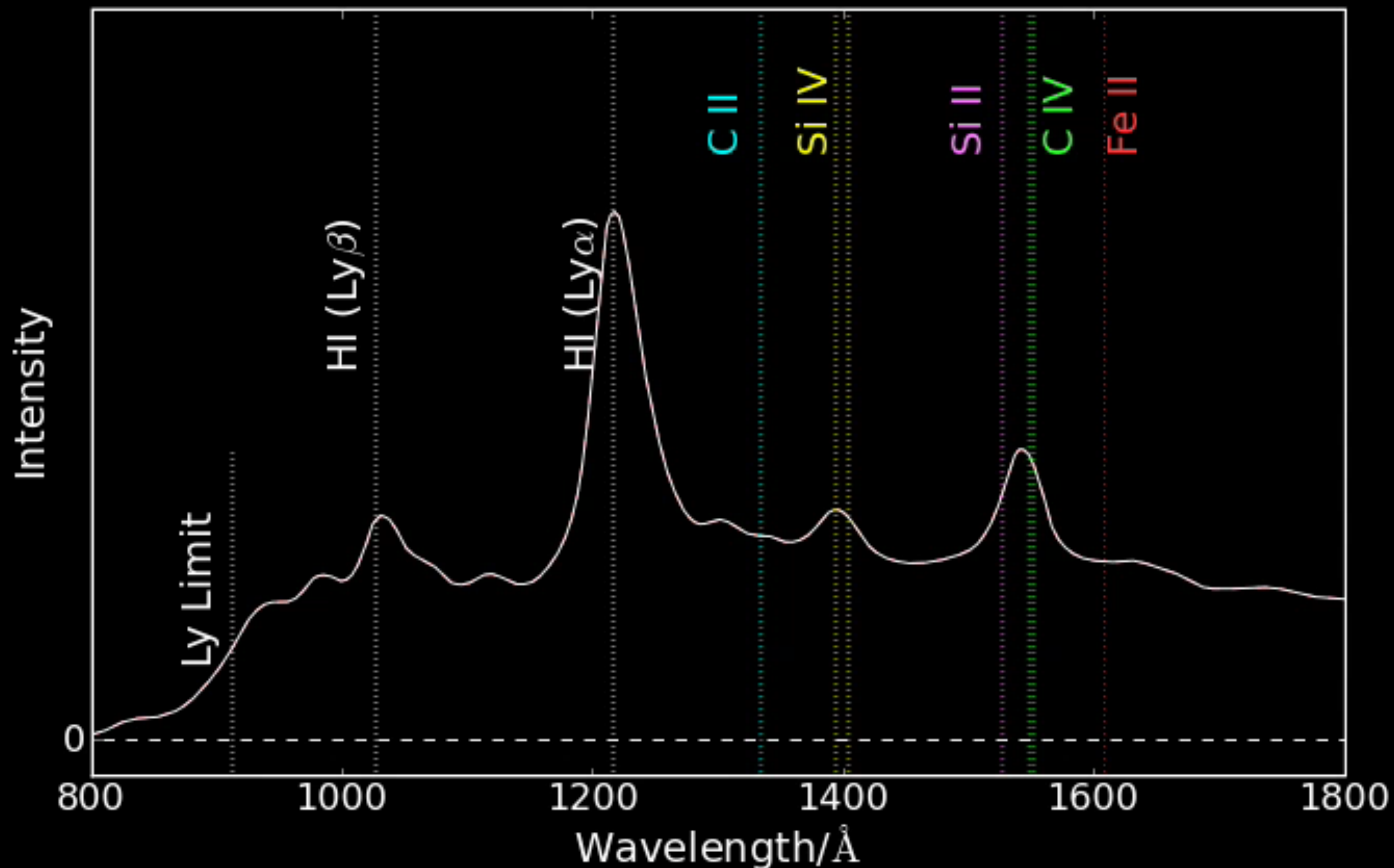
Intergalactic Gas
+ galaxies



Galaxies only

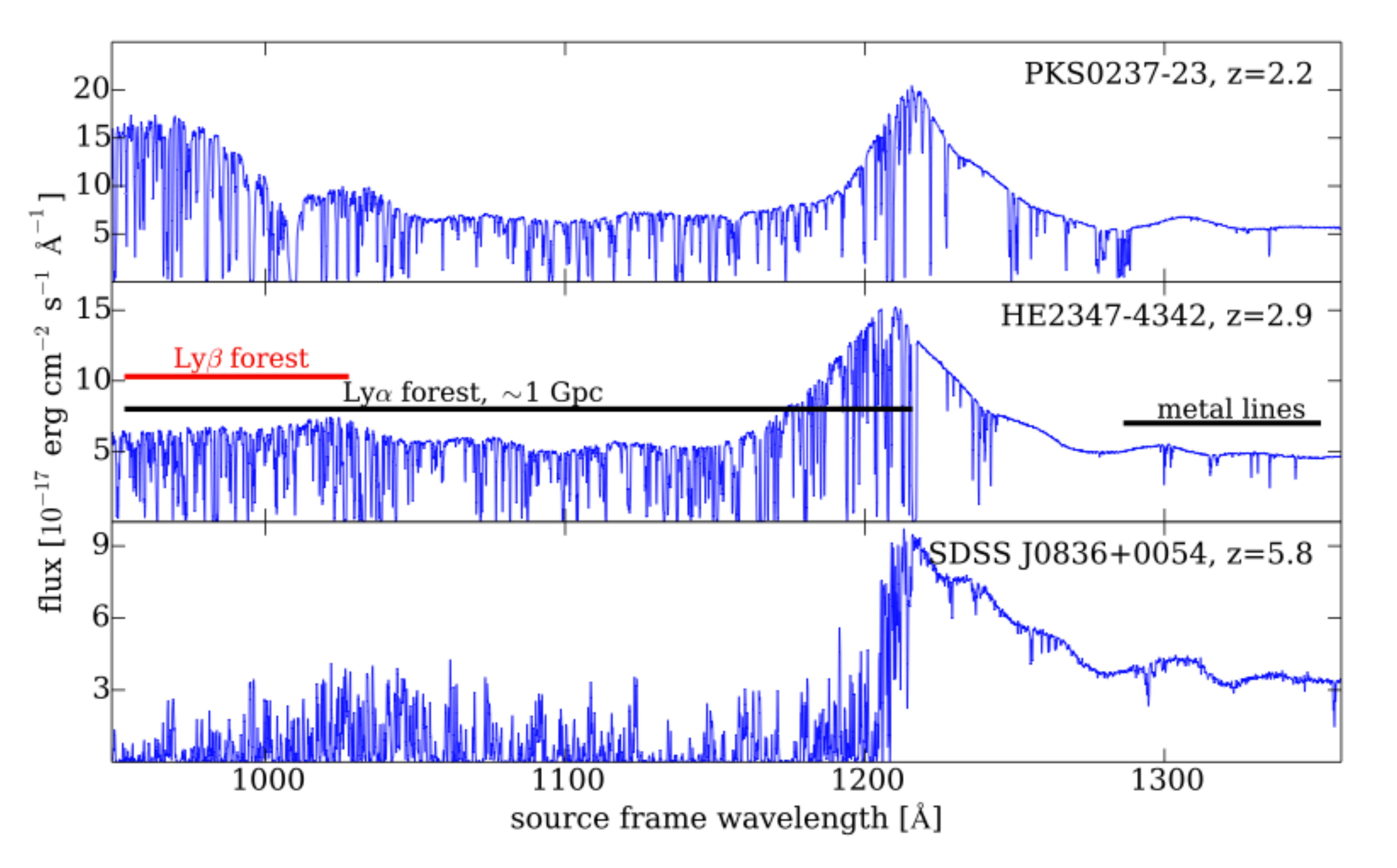


Credit: Renyue Cen

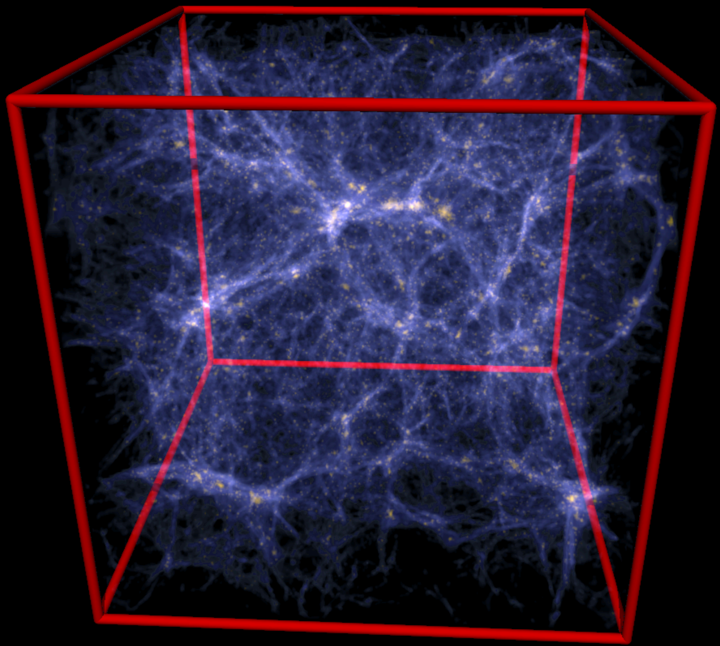


Credit: Andrew Pontzen

Lyman-alpha forest



Theory and Observation



Thank you! Questions?