Statistics and Observation of Exoplanets

Sean McCloat
Masters Student, Space Studies, UND

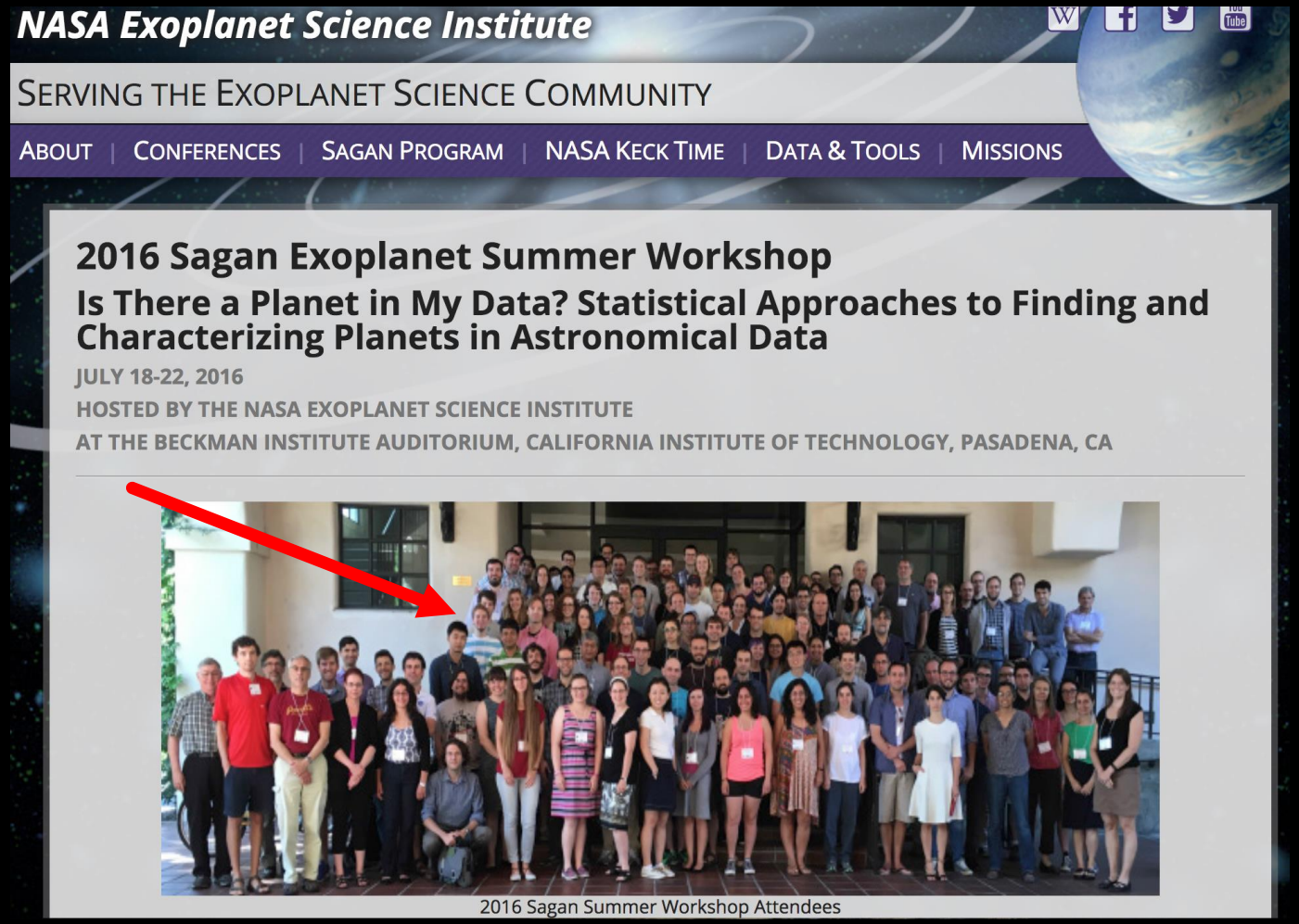
North Dakota Space Grant Fellowship Summer 2016

- Supported travel and participation in workshop
- "2016 Sagan Summer Exoplanet Workshop: Is There a Planet in my Data? Statistical Approaches to Finding and Characterizing Planets in Astronomical Data"
- Funded thesis research over the summer using UND Internet Observatory to observe exoplanet transits

2016 Sagan Summer Exoplanet Workshop

- On campus as the CIT, Pasadena CA
- Week-long
- Discussions, presentations, hands-on activities, poster presentations
- Attendees grad students from around the country and the world
- A who's-who of the world's exoplanet experts (and future experts)

- Financial aid from the workshop, and Space Grant helped with travel expenses
- Gave 2-minute "POP Presentation" and had a poster



On the Agenda

- Quick look at titles gives sense of what was talked about:
  - Bayesian Analysis
  - Markov Chain Monte Carlo
  - Upcoming instrumentation
    - WFIRST, JWST and beyond!
- Made the very strong case that astronomy research is really astro-statistics and discovery = statistical probability

Monday, July 18

8:30 am: Welcome and Opening Comments — **Chas Beichman (NExScI), Dawn Gelino (NExScI)**
9:00 am: Statistics and the Astronomical Enterprise — **Eric Feigelson (Penn State)**
10:00 am: An Introduction to Bayesian Analysis — **Jessi Cisewski (Yale)**
11:00 am: *Morning Break*
11:30 am: Introduction to Hands-on Sessions: Overview , Transits Intro , RV Intro — **Roberta Paladini (NExScI), Xavier Dumusque (Universite de Geneva), Nikole Lewis (STScI)**
12:30 pm: *Lunch*
1:45 pm A Beginner's Guide to Monte Carlo Markov Chain (MCMC) Analysis — **David Kipping (Columbia)**
2:30 pm: Attendee Pops (7)
2:45 pm: Bayesian Priors for Transits and RVs — **David Kipping (Columbia)**
3:30 pm: Attendee Pops (7)
3:45 pm: *Afternoon Break and Poster Session 1 (even # posters)*
4:30 pm: Statistical Approaches for Exoplanetary Science — **Eric Feigelson (Penn State)**
5:30 pm: *Adjourn*

Tuesday, July 19

8:30 am: Survey of Radial Velocity: Technique and Results — **Debra Fischer (Yale)**
9:15 am: Astrophysical and Instrumental Noise Sources: Radial Velocity — **Xavier Dumusque (Universite de Geneva)**
9:55 am: Dangers of Frequentist Estimates of FAP and Other Pretenders (e.g. AIC and BIC) — **Eric Ford (Penn State)**
10:35 am: *Morning Break*
11:05 am: Bayesian Model Comparison for Radial Velocity: 1, 2, 3, or Many Planets? — **Benjamin Nelson (CIERA/Northwestern)**
11:45 am: *Lunch*
1:15 pm: Attendee Pops (7)
1:30 pm: Survey of Transit Photometry: Technique and Results — **Jason Rowe (University of Montreal)**
2:15 pm: Astrophysical and Instrumental Noise Sources: Transits — **Jessie Christiansen (NExScI)**
2:55 pm: *Afternoon Break*
3:25 pm: Hands-on Session
5:30 pm: *Adjourn*

On the Agenda

- Presenters:
- Chas Beichman: Executive Director of NASA's exoplanet research program
- Eric Feigelson: Statistical Scientific Editor of the American Astronomical Society Journals, considered a founder of the field of astrostatistics
- David Kipping: invented way detecting exomoons
- Nikole Lewis: Astronomer at Space Telescope Science Institute, preparing JWST

- And on…and on…and on….

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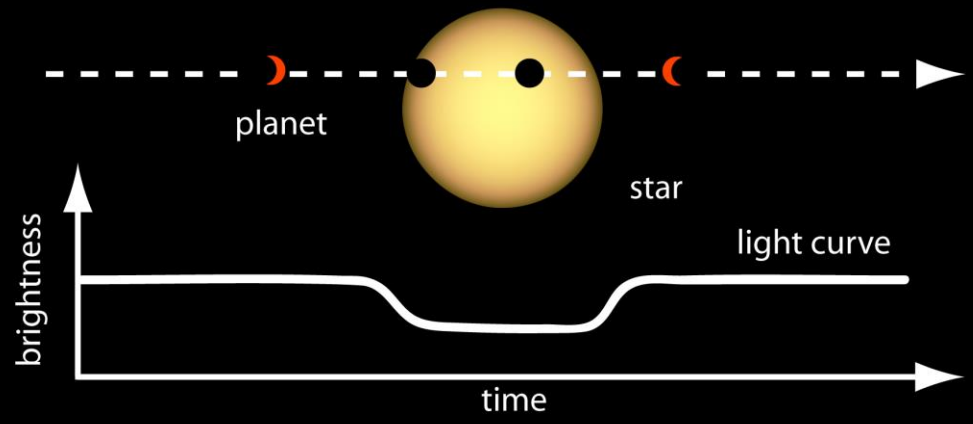
Overall Impact

- Got to interact with THE experts and my peers at other universities
  - Get a sense of what's really going on
  - Networking opportunity
- Introduced to many many MANY new types of math, statistics that have come in handy for my thesis project
- Good dose of inspiration

Thesis Project – Observing Exoplanet Transits

- If a star and exoplanet are lined up just right, the exoplanet will pass in front of the star as seen from Earth
- Motivated astronomers can measure light from star, called flux and watch dip in flux as exoplanet blocks it
- Plot the flux, you make a lightcurve!



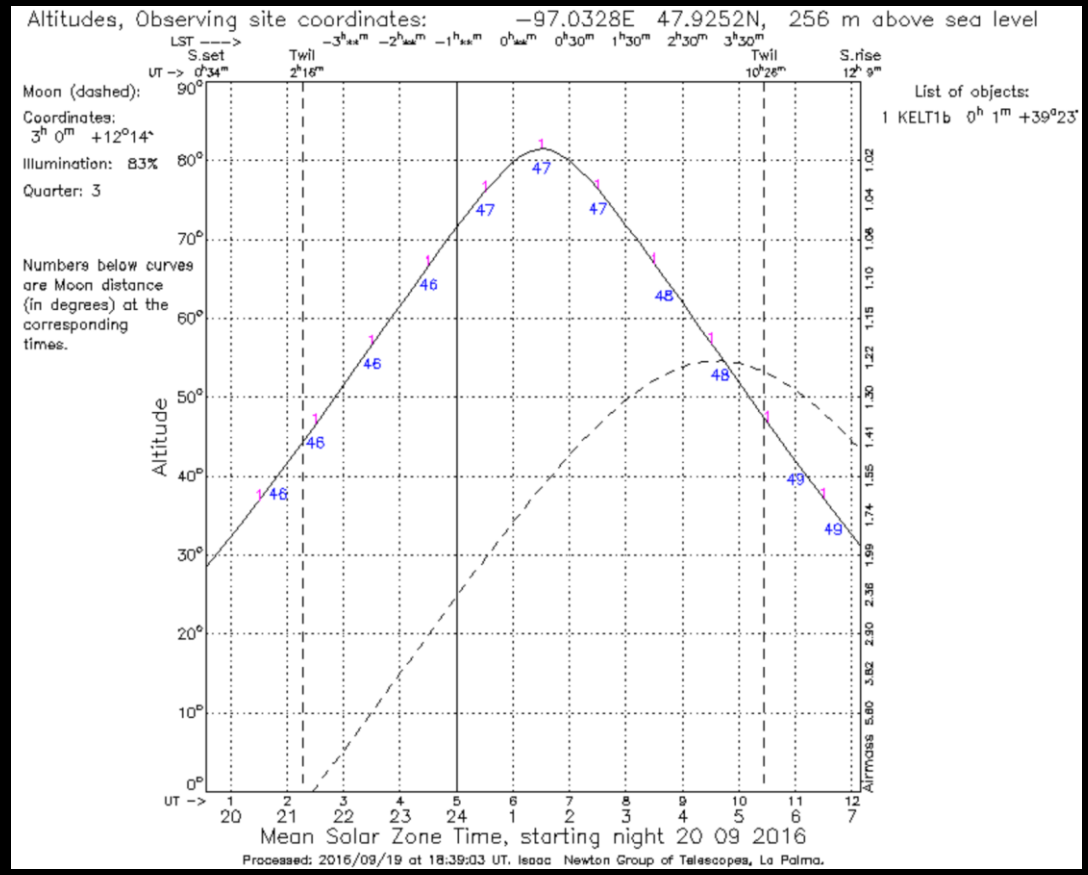
- Measure the exoplanet
  - Period
  - Radius
  - Semi-major axis (distance from star)
    - Habitable zone?
- Combine with mass measurements from radial velocity
  - Density of the planet
  - Rocky or Gas giant?

UND Internet Observatory

- Observations will be conducted using UND Space Studies' Internet Observatory #1
- Includes:
  - 16-inch (0.4 meter) aperture Schmidt Cassegrain Telescope on a Paramount ME Germen Equatorial mount
  - Finger Lakes PL16803 CCD, 4096 x 4096 array, 9x9 microns
  - FOV = 30 x 30 arcminutes
- Observation schedule from May – November of 2016

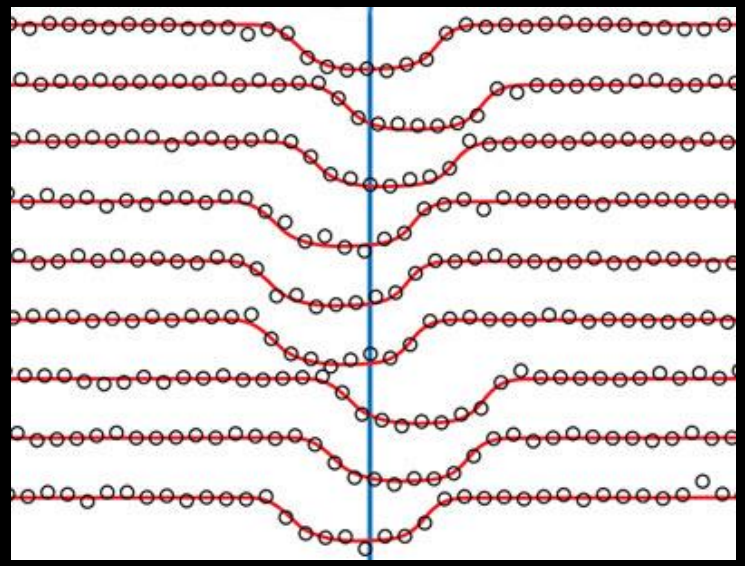
The Plan

- Look at the transits of hot Jupiter exoplanets
- Parsed down list of 3,480 exoplanets 95 based on their size, brightness, how recently they've been discovered, and visibility at our location
  - Find planets that are easier to see and have the least data
- Looked at every predicted transit for those 95 targets between May – Nov, figured out if it would high enough in the sky and dark enough to actually see



Transit Timing Variation Analysis

- Watch same exoplanet and predict the pattern of when it will show up
- If its all alone, the pattern of when it will transit the star will not change
- But if there are other planets in this alien solar system that we can not see (do not transit) they can be detected
- As the planets orbit the star, gravitational interactions will disturb the pattern of the planet that we can see
- Changes in pattern can reveal:
  - Size of other planets
  - Location of other planets
  - Ex. Earth-size planet in habitable zone



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