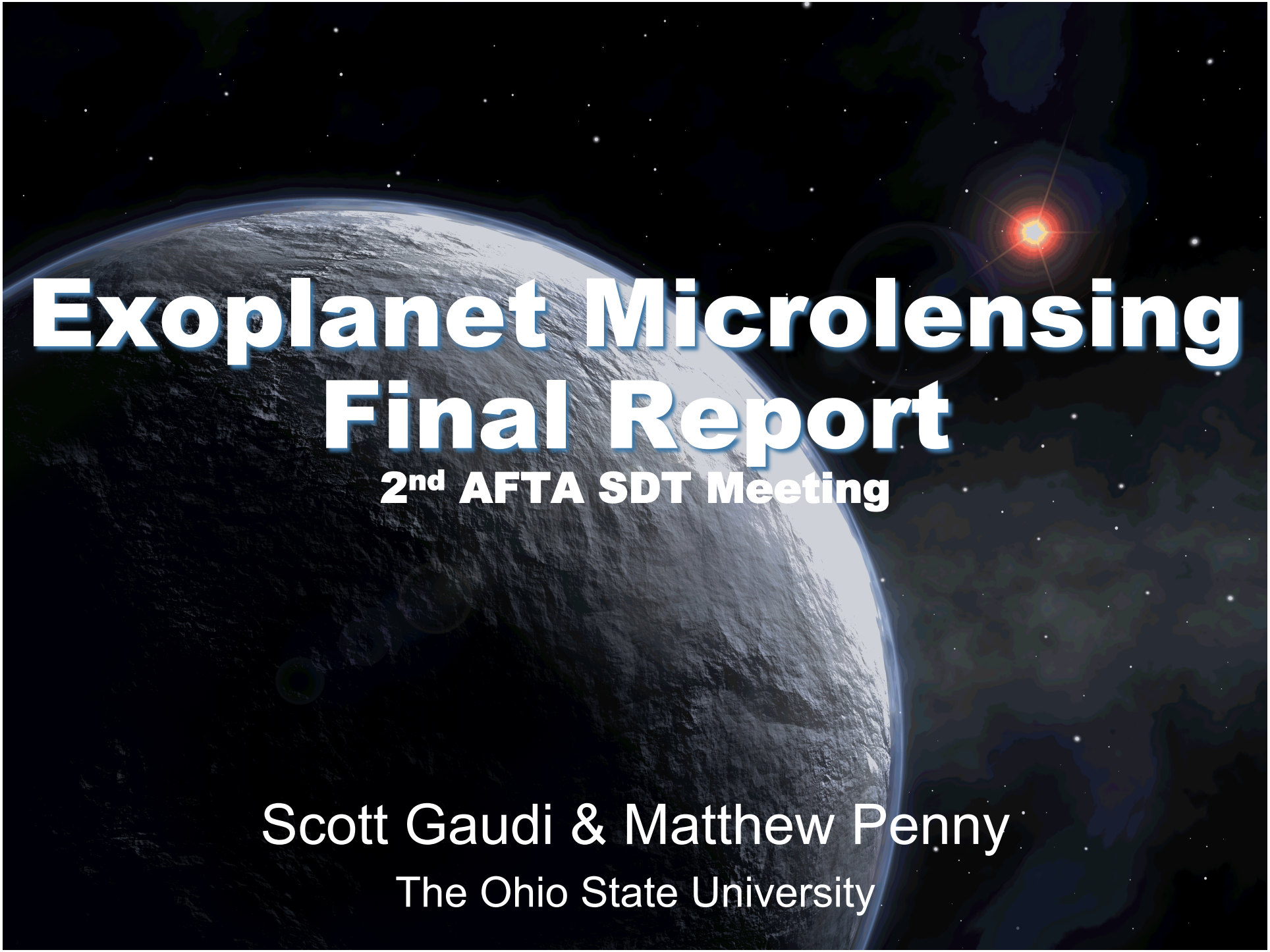
Exoplanet Microlensing
Final Report
2nd AFTA SDT Meeting
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The Ohio State University

Outline for Section.

- Brief recap of science justification.
- Brief recap of requirements.
- Revised yields.
  - Focus on relative yields, i.e., the effect of the changes in instrumentation on yield.
  - Absolute yields are uncertain for various reasons.
  - Free-floating planets.
- Parameter estimation.
  - Estimate the fraction of events for which mass measurements should be possible.
- Habitable planets?
  - Large differences in predictions from various models.
  - *Kepler* hints at a relatively low frequency (<10%) ?

Requirements.

- Monitor hundreds of millions of bulge stars continuously on a time scale of ~10 minutes.
  - Event rate ~10^{-5}/year/star.
  - Detection probability ~0.1-1%.
  - Shortest features are ~30 minutes.
- Relative photometry of a few %.
  - Deviations are few – 10%.
- Main sequence source stars for smallest planets.
- Resolve background stars for primary mass determinations.

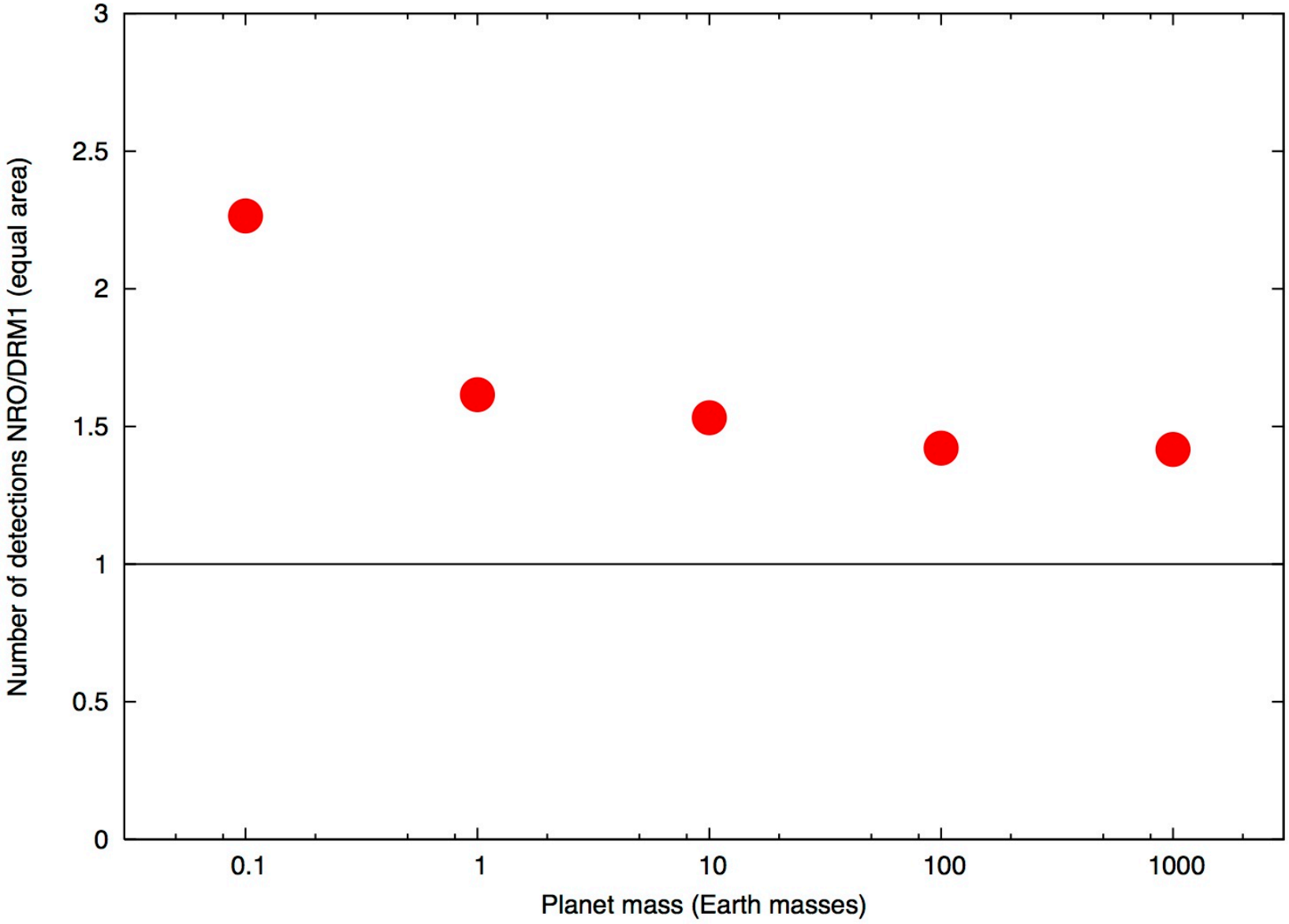
Yields.

- Use the MaBμLS simulator (Besancon models).
- Known to underestimate the microlensing event rate, but not by how much.
- Scale to clump giant optical depths – conservative.
- Focus on relative yields, more robust.
- Event rates might be higher, but will require additional observations to confirm.

Yields: NRO vs DRM1 vs DMR2.

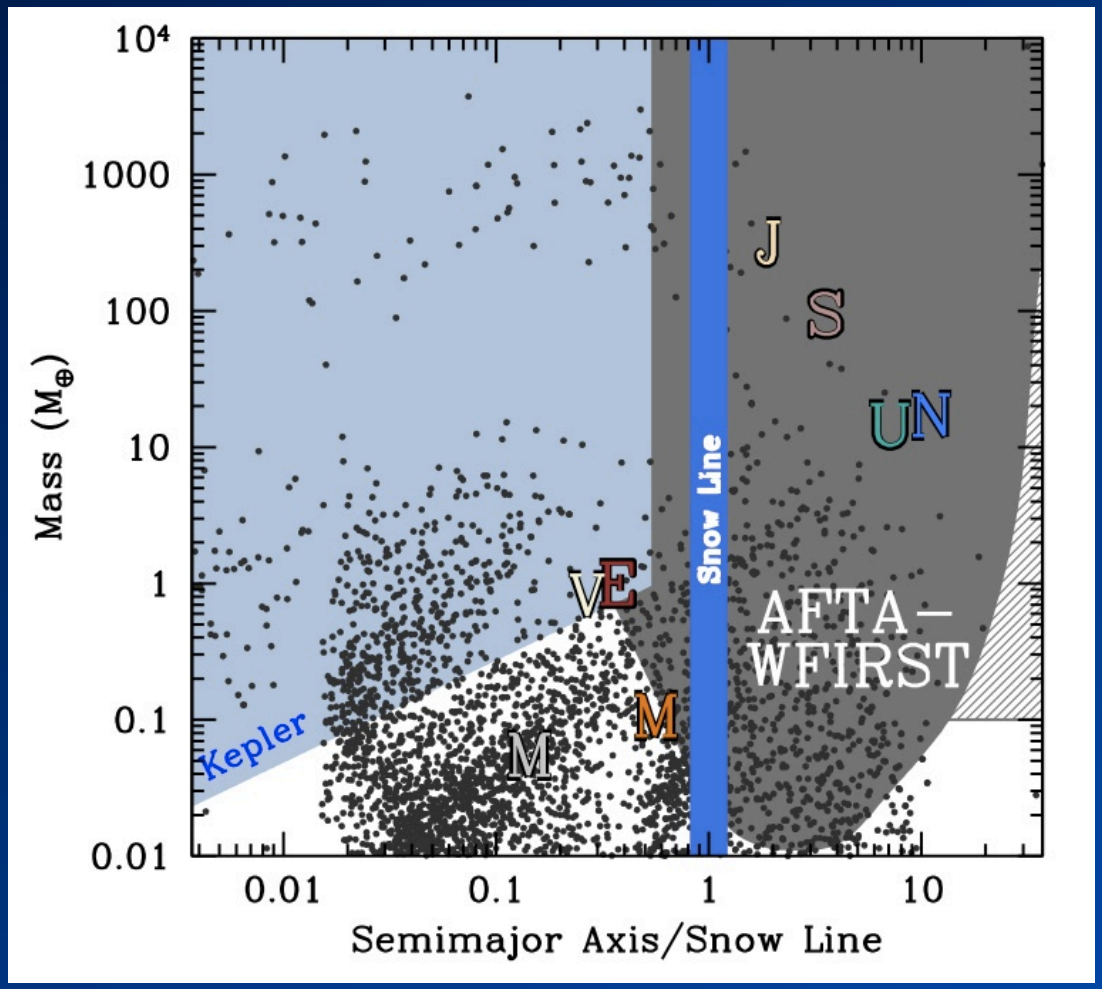
M/M_{Earth}	DRM1	DRM2	NRO
0.1	30	29	58
1	239	279	336
10	794	918	1060
100	630	733	781
1000	367	442	453
10,000	160	199	180
Total	2221	2600	2868

- Total time = 432 days, 0.29 deg^2 FOV.
- Yield ~propto FOV
- Yield ~propto (photon rate)$^{\alpha}$, with α~0.3 to 1.2
- DRM2 versus DMR1:
  - DMR2 FOV 1.55 larger, photon rate 0.72 of DMR1
  - Assumes same total observing time for direct comparison of hardware.
- DRM1 versus NRO
  - DMR1 FOV = 1.14 x NRO FOV, photon rate 2.28 times DMR1
  - Assumes same total observing time.


Number of detections NRO/DRM1 (equal area)
3
2.5
2
1.5
1
0.5
0
0.1
1
10
100
1000
Planet mass (Earth masses)

Exoplanet Demographics with AFTA-WFIRST.

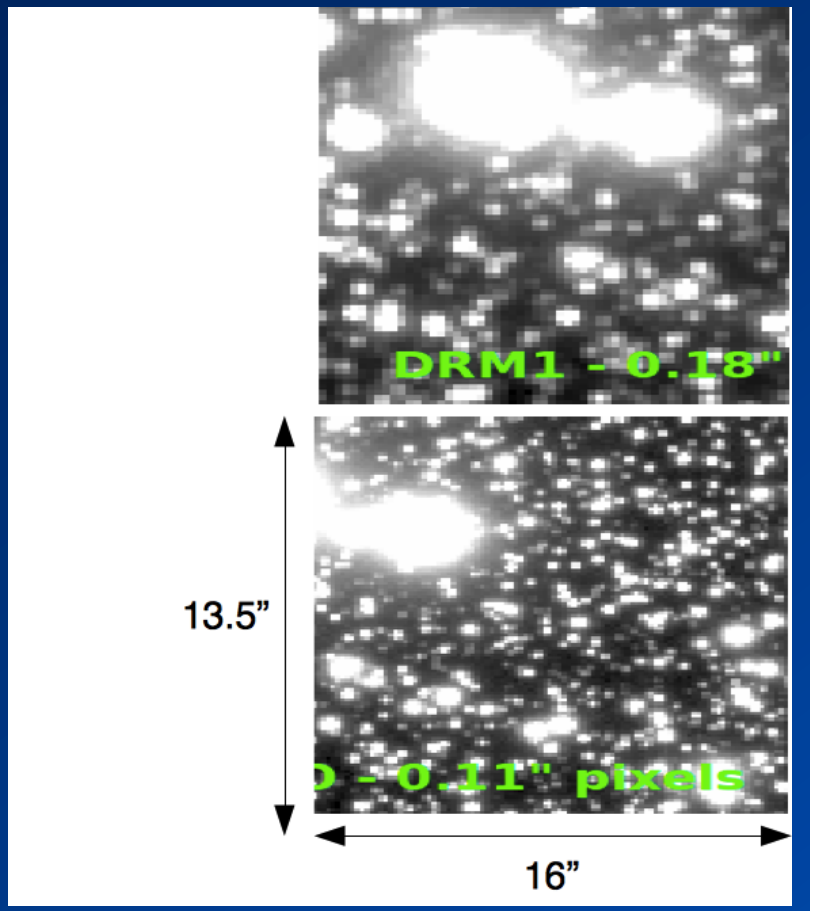
- With *Kepler*, AFTA-WIFRST will "complete the census" of planets.
- Some sensitivity to analogs of all Solar System except Mercury.
- Some sensitivity to massive, "outer" habitable zone (Mars-like orbits).
- Free-floating planets down to ~Mars mass.
- AFTA-WFIRST estimated yields:
  - 2900 bound planets (0.5-30 AU).
  - 400 < 3xEarth, 1500 < 30xEarth
  - 45 free-floating Earths.
  - Average of 30% higher yields per unit time relative to DRM1.
  - 2x higher yields for Mars-mass planets..



Points are simulated planets by Ida & Lin

Parameter Estimation.

- Characterizing lens stars:
  - Measure angular source size.
  - Resolve unrelated stars.
  - Measure proper motion or centroid shifts.
  - Measure parallax.
- Improved angular resolution allows better characterization of the host stars.
- Don’t know by how much!
- Use crude estimates to determine ability to measure mass of individual host stars.



Habitable Planets?

- Shallow, brief dips.
  - Depth of features scales strong with separation near Einstein ring.
  - Depth also very sensitive to source size.
- Very difficult to predict the yields, near sensitivity ‘cliff’.
  - Precise source size distribution.
  - Precise luminosity function.
  - Precise noise distribution.
  - Precise Einstein ring radii distribution.
  - Precise mass/luminosity relation.

ExoPAG.

In June 2009, NASA formed the *Exoplanet Exploration Program Analysis Group* (ExoPAG), responsible for soliciting and coordinating community input into the development and execution of NASA's Exoplanet Exploration Program (ExEP). The ExoPAG serves as a community-based, interdisciplinary forum for analysis in support of activity prioritization and for future exploration.

- Articulate the key scientific drivers for exoplanet research.
- Evaluate the expected capabilities of potential ExEP missions for achieving the science goals of the program.
- Evaluate ExEP goals, objectives, investigations, and required measurements on the basis of the widest possible community outreach.
- Articulate focus areas for needed mission technologies.
- Identify related activities that enhance the ExEP mission portfolio such as ground-based observing, theory and modeling programs, and community engagement.

ExoPAG 7.

- Met January 5+6.
- Scheduled talk from David Spergel on AFTA, but…
- Brief summary of AFTA SDT activities to date.
- Group discussion:
  - "Does the community endorse putting a coronagraph on AFTA/WFIRST, even if it means forgoing some future technology development opportunities and/or other small-scale direct imaging missions?"
- Unanimous yes!

Exoplanets + exoplanets.

- WFIRST-C has *two* exoplanet science goals.
  - Demographics of planets.
  - Discovery and characterization of disks and gas giants around nearby stars.
- *Both* will advance exoplanet science.
- We should join forces!