ExoPAG proposed SAG 13: Exoplanet Occurrence Rates and Distributions

Rus Belikov on behalf of SAG13

Angerhausen, Daniel
Apai, Daniel
Batalha, Natalie
Belikov, Ruslan
Bendek, Eduardo
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Blackwood, Gary
Boss, Alan
Brown, Robert
Bryden, Geoff
Burke, Chris
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Cowan, Nick
Danchi, William
Domagal-Goldman, Shawn
Dressing, Courtney
Foreman-Mackey, Daniel
Fressin, Francois
Gaudi, Scott
Ge, Jian
Gould, Andy
Hogg, David W
Howard, Andrew

Kasting, Jim
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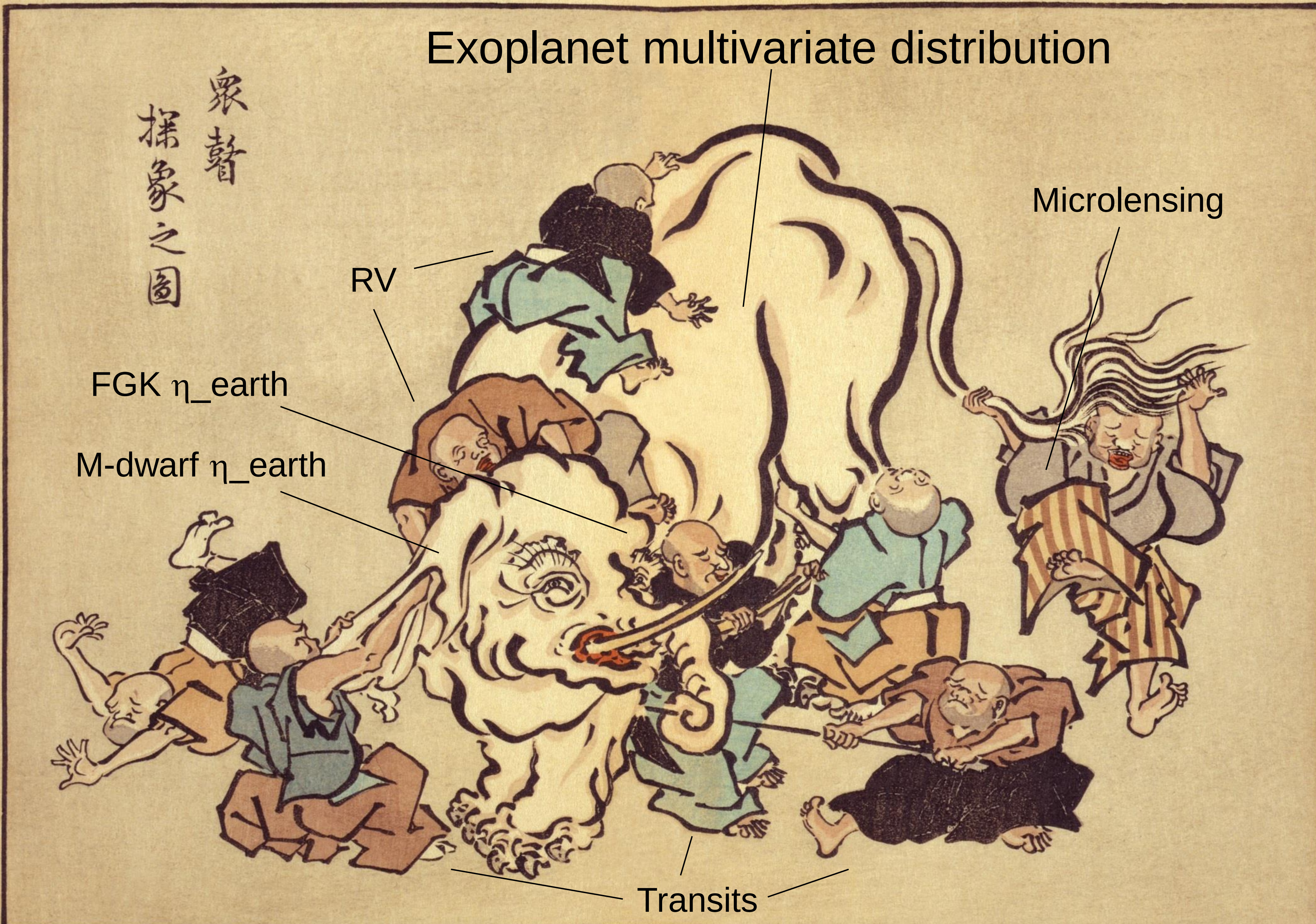
Morgan, Rhonda
Mulders, Gijs
Nielsen, Eric
Petigura, Erik
Ragozzine, Darin
Roberge, Aki
Savransky, Dmitry
Serabyn, Gene

Shao, Mike
Solmaz, Arif
Sparks, William
Stahl, Philip
Stapelfeldt, Karl
Stark, Christopher
Still, Martin
Suzuki, Daisuke
Swain, Mark
Traub, Wes
Turnbull, Margaret
Unwin, Stephen
Vanderbei, Bob
Walkowicz, Luzianne

Motivation

- Mission planning, design, and cost critically depend on planet occurrence rates and distributions (and other astrophysics)
  - E.g., eta_Earth directly drives mission size, cost, capability of Exo-S, Exo-C, LUVOIR, HabEx, etc.
- Growing number of individual studies estimate parts of this distribution (some conflicting with each other, e.g. eta_Earth estimates have ranged from 0.02 – 0.6 in the past few years alone)
  - Need a holistic, self-consistent description of how much we as a community currently know about this distribution
    - This is a job for scientists active in occurrence distribution estimation, but a SAG can help facilitate / catalyze this process while preserving credit due to them
  - Formatted in a way that maximally aids ExEP mission design and planning



"Blind monks examining an elephant", an ukiyo-e print by Hanabusa Itchō (1652–1724).

Charter

Over 5000 exoplanets and exoplanet candidates have been discovered to date. Many studies have been published and are on-going to determine exoplanet occurrence rates and distributions, particularly for potentially habitable worlds. These studies employ different statistical and debiasing methods, different definitions of terms such as eta_Earth and habitable zone, different degrees of extrapolation, and present distributions in different units from each other. The primary goal of this SAG is to evaluate what we currently know about planet occurrence rates, and especially eta_Earth, by consolidating, comparing, and reconciling discrepancies between different studies. A secondary goal is to establish a standard set of occurrence rates accepted by as much of our community as possible to be used for mission yield estimates for missions to be considered by the decadal survey.

Key objectives and questions:

1. Propose standard nominal conventions, definitions, and units for occurrence rates/distributions to facilitate comparisons between different studies.
2. Do occurrence estimates from different teams/methods agree with each other to within statistical uncertainty? If not, why?
3. For occurrence rates where extrapolation is still necessary, what values should the community adopt as standard conventions for mission yield estimates?

Current membership

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Vanderbei, Bob
Walkowicz, Luzianne

Science Focus Group:

(scientists active in occurrence estimation)

Confirmed:
Batalha, Natalie
Bennett, David
Burke, Chris
Catanzarite, Joe
Foreman-Mackey, Daniel
Howard, Andrew
Kopparapu, Ravi
Mulders, Gijs
Petigura, Erik
Traub, Wes

Pending:
Dressing, Courtney
Fressin, Francois
Gaidos, Eric
Silburt, Ari
Yodin, Andrew
Clanton, Christian
Dong, Subo
Rogers, Lesle
Wolfgang, Angie

May need a “Steering committee”

(help with SAG organization / leadership)

Confirmed:
Batalha, Natalie
Belikov, Rus
Stark, Chris

Summary of Proposed Process

1. SAG standardizes a set of parameters representing some measures of occurrence rates and/or distributions to be computed by focus team.
   - As few parameters as possible
     - maybe just 2 at first, and add more after we go through the process successfully once
   - Prioritize parameters that have the highest impact on DI mission design, planning, and expected yields
   - Pick definitions that make it trivial for FG members to estimate parameters

η_1: [definition based on observables]
η_2: [definition based on observables]
...
η_N: [definition based on observables]

2. Crowdsourcing: "focus group" members estimate parameters and their uncertainties
   1. Focus group members are meant to be those who have done occurrence estimates already

FG member 1 :		FG member M :
η_1 = [value] +/- [uncertainty]	...	η_1 = [value] +/- [uncertainty]
η_2 = [value] +/- [uncertainty]		η_2 = [value] +/- [uncertainty]
...		...
η_N =[value] +/- [uncertainty]		η_N =[value] +/- [uncertainty]

3. Organize / analyze the data from #2
   1. Check for statistical agreement
   2. Trace and attempt to resolve any outliers and discrepancies
   3. Document reasons for unresolvable discrepancies

4. Final product – report including:
   1. Mean and variance of each parameter estimate across FG members
   2. Explanation for any discrepancies
   3. Recommendation of what values to use for ExEP

η_1: = [mean] +/- [variance]
η_2: = [mean] +/- [variance]
...
η_N: = [mean] +/- [variance]

η definitions, example 1:

$\eta 1$: Value of occurrence distribution for FGK stars vs. SMA and planet radius, in natural log space, evaluated at Earth size and 1 AU (i.e. delta-function "bins")

$$\left.\frac{dN}{dln(a)\; dln(R)}\right|_{R=1\ Earth;\ a=1\ AU}$$

$\eta 2$: Same for M-dwarfs, except evaluated at 0.1 AU.

- Main advantage: avoids the need to specify integration bins
- Main disadvantage: no easy way to compute statistical uncertainty (without defining characteristic bin size)

η definitions, example 2:
(a few specific integrated bins)

FGK stars		
	Planet size range (Earth size)	
SMA (AU)	0.5-1.5	>1.5
< 0.75	$\eta 1$	$\eta 2$
0.75-1.77	$\eta 3$	$\eta 4$
1.77 - ?	$\eta 5$	$\eta 6$

M-dwarfs		
	Planet size range (Earth size)	
SMA (AU)	0.5 - 1.5	>1.5
<0.049	$\eta 7$	$\eta 8$
0.049-0.128	$\eta 9$	$\eta 10$
0.128 - ?	$\eta 11$	$\eta 12$

Example of a general template for observable-based definition of an η

		planetary orbit			planetary body		host star
parameter	*Planet type or name*	*SMA range (or period)*	*eccentricity*	*inclination*	*planetary radius*	*planetary mass*	*stellar type*
η_Earth	Rocky planet in HZ	eq. X from paper Y	0 - ?	all	0.5 - 1.5	? - ?	FGK
η1							
η2							
η3							
η4							

(Table adopted from R. Brown, with modifications)

Current status

- People signed up for SAG13 (still open)
  - 52 on full list
  - 10 on science focus group
  - 3 on organizational / leadership "steering committee"
- Kickoff telecon on 6/11 was a success
- Reached consensus on charter and process
- Working on step 1 of process: defining a standard set of parameters for focus group members to estimate. (Please feel free to submit a well-defined set.)
- Establishing synergies with related science efforts (e.g. Oct. meeting at NASA Ames) to see how SAG can best help
- For further discussions about this SAG:
  - Do not hesitate to contact Belikov
    - ruslan.belikov@nasa.gov
    - at AbSciCon Wed-Fri
  - Chris Stark will be available today+tomorrow in my absence

BACKUP SLIDES

Complementarity and synergy with science efforts

Science efforts

Independent science results

SAG

Combined results processed for maximal usefulness to ExEP

Missions

	Science efforts (what SAG is not)	SAG efforts
Objective	Answering science questions (e.g. what is eta_Earth)	"Coordinating community input into the development and execution of NASA's ExEP" (e.g. how much do we currently know about eta_Earth and how do we format that knowledge for maximum usefulness to ExEP?)
Process	Individuals or small teams generate new science	Collect and interpret already available science from entire community for ExEP
Product	Science papers, representing individual teams	Final report endorsed by (ideally) the entire community
Emphasis on	New science results and scientific rigor	Community representation and consensus (to show strength for the decadal survey)