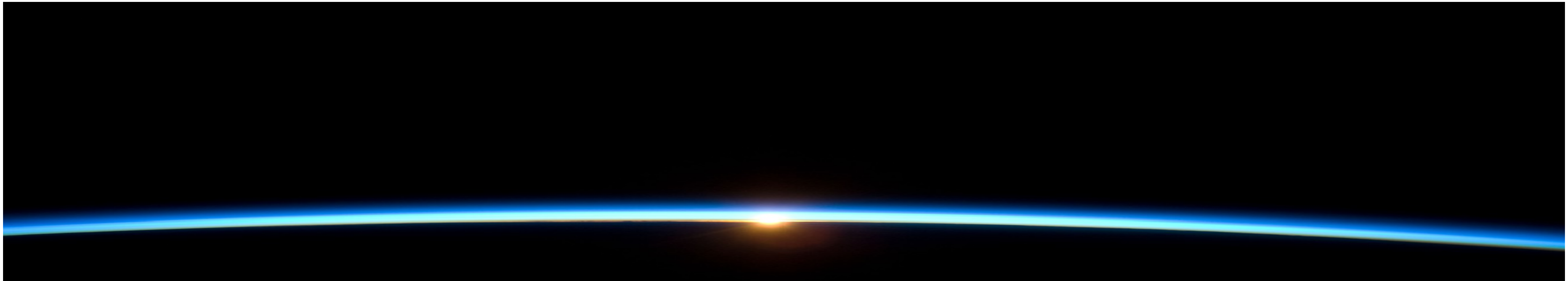


FIOS

Fabry perot Interferometer for Oxygen Searches

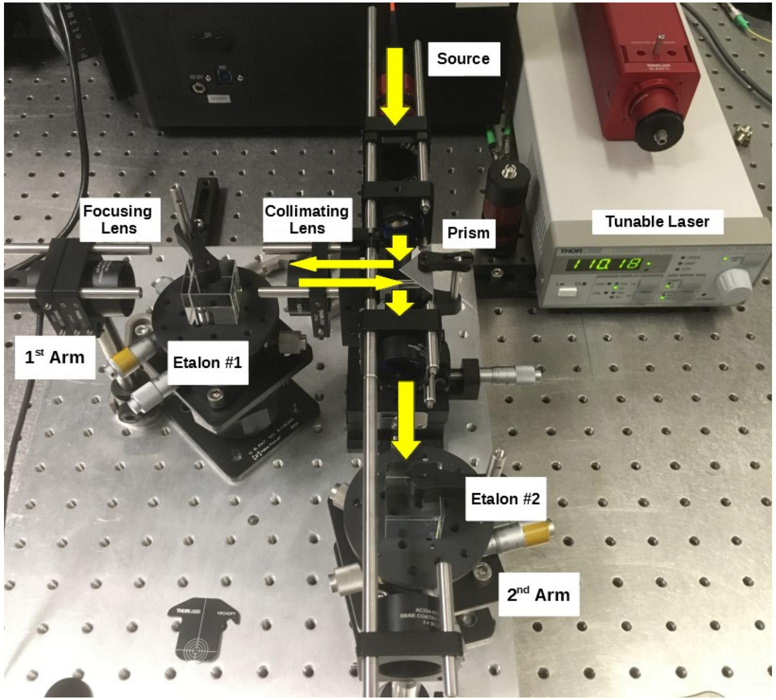
JOHN TEMPLETON FOUNDATION

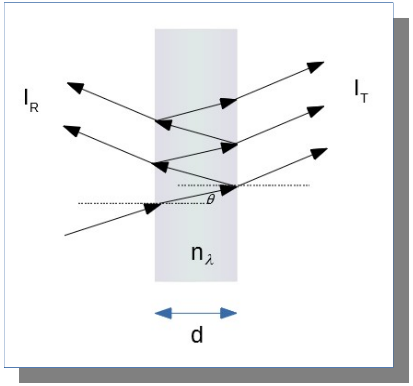
CENTER FOR ASTROPHYSICS HARVARD & SMITHSONIAN

S. Rukdee, S. Ben-Ami, M. López-Morales,

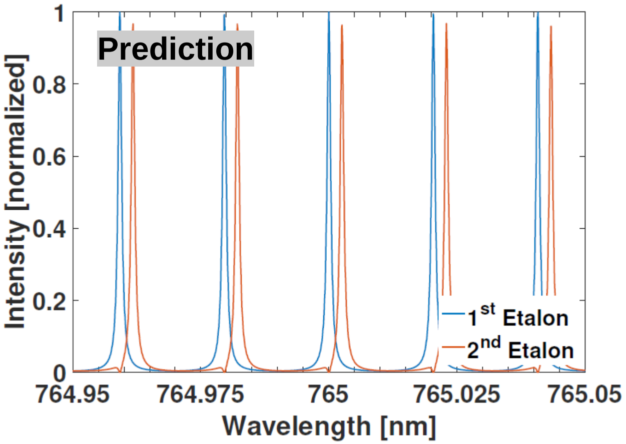
J. Garcia-Mejia, D. Charbonneau, A. Szentgyorgyi

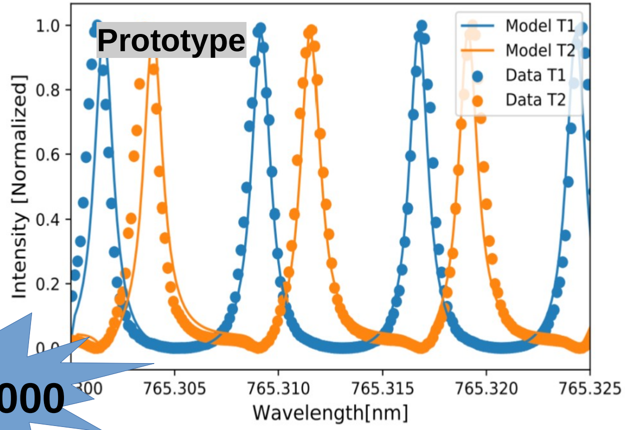
FIOS: Prototype





Ben-Ami et al. 2018

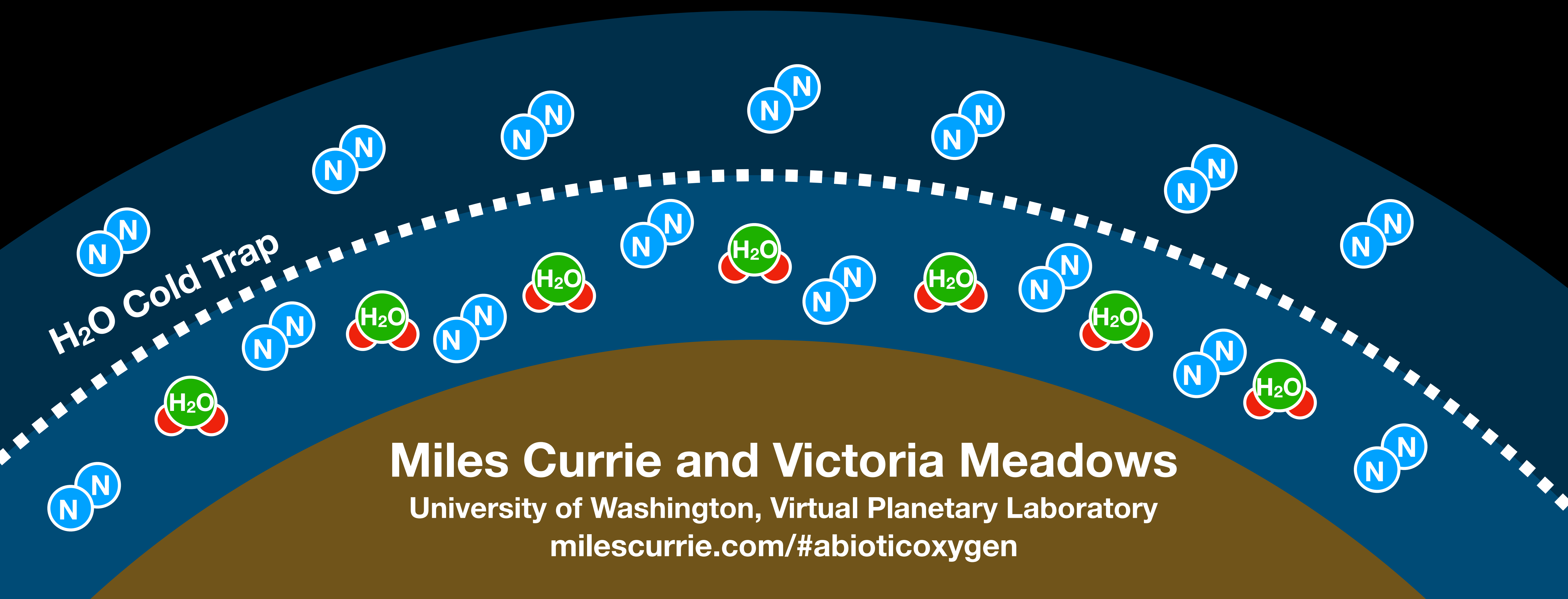




R ~ 600,000

Rukdee et al. (in prep.)

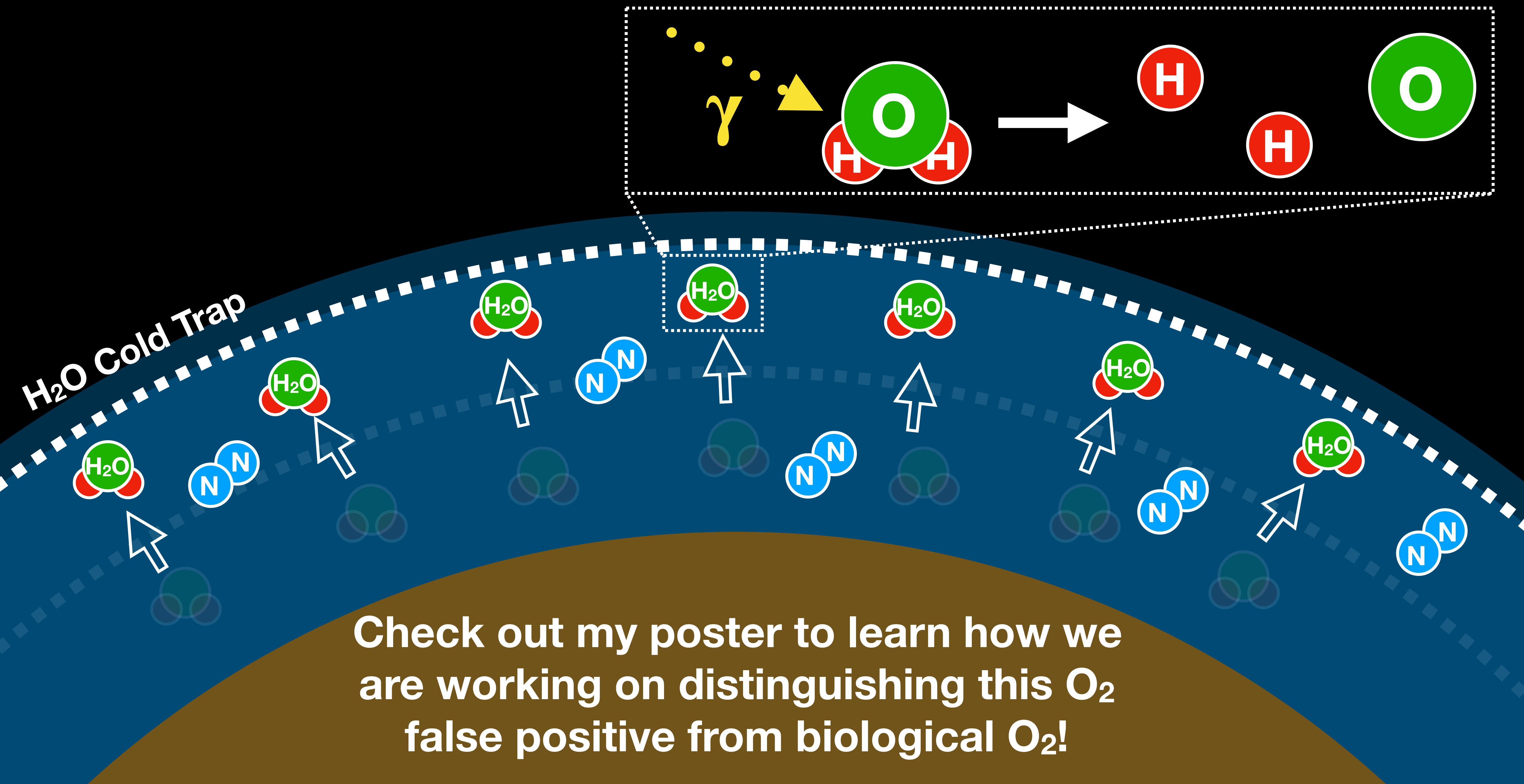
We are exploring how to use ground-based high-resolution spectroscopy to distinguish between abiotic O_2 formed from H_2O photolysis in the upper atmosphere, and well-mixed biological O_2.



Miles Currie and Victoria Meadows
University of Washington, Virtual Planetary Laboratory
milescurrie.com/#abioticoxygen

Reducing the non-condensible gas (e.g. N_2) raises the cold trap

H_2O gets photolyzed and produces a buildup of O_2 in the upper atmosphere

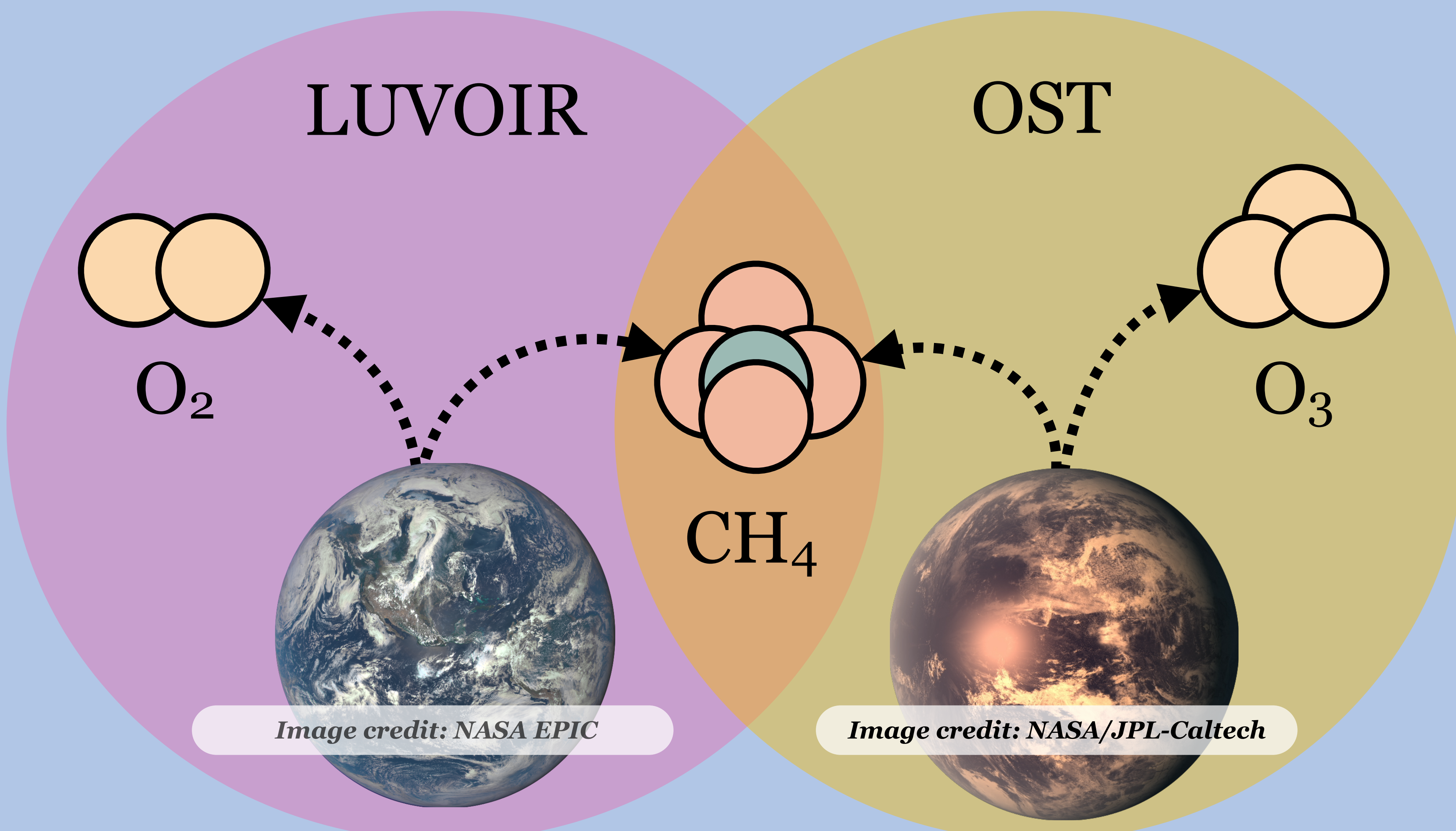


Check out my poster to learn how we are working on distinguishing this O_2 false positive from biological O_2!

Assessing Our Ability to Interpret Biosignatures via Transmission and Direct Imaging

Samantha Gilbert, Victoria Meadows, Andrew Lincowski, Jacob Lustig-Yaeger
University of Washington, Virtual Planetary Laboratory

The rate at which molecules are created at the surface can give us clues as to whether there is a biological or abiotic source. Surface fluxes are an important tool for discriminating between biological and abiotic sources.

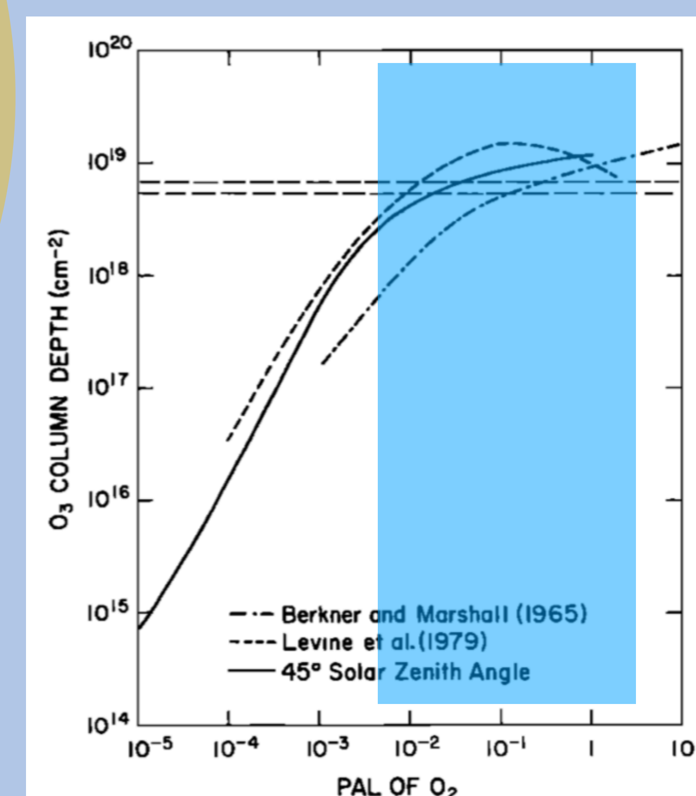


DIRECT IMAGING: G-dwarfs
TRANSMISSION: Some M-dwarfs

TRANSMISSION: M-dwarfs

Challenges

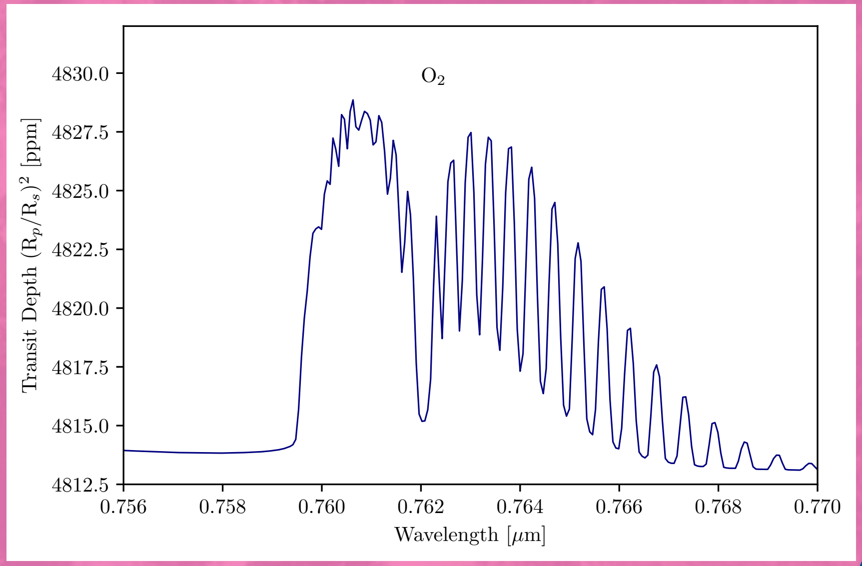
- Chemical abundance is not identical to surface flux
- Photochemical destruction rate depends on stellar type/activity
- O_3 must be used as an O_2 proxy in the mid-IR



(Kasting 1980)

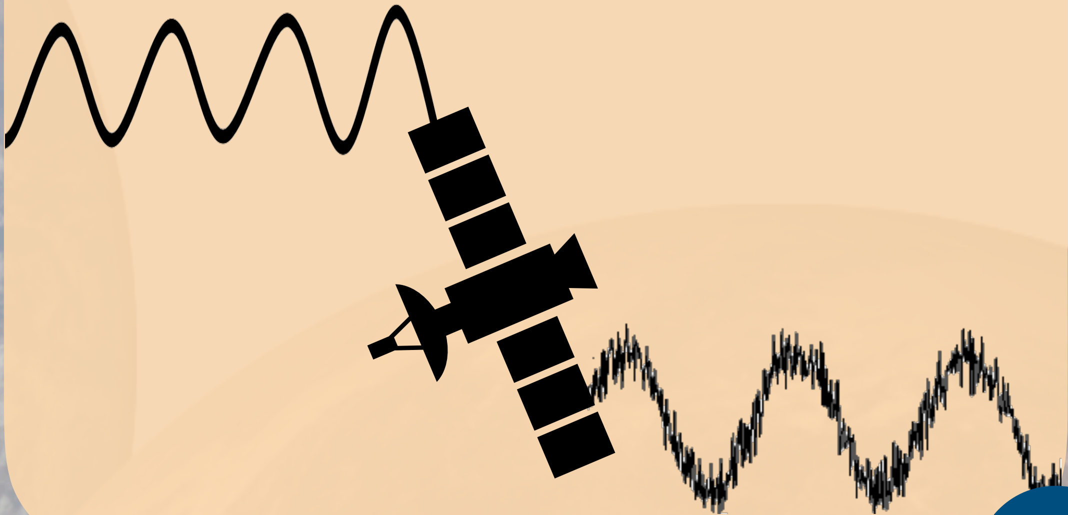
1

Simulate Spectra



2

Simulate Instrument Noise



3

Retrieve Chemical Abundances & Surface Fluxes

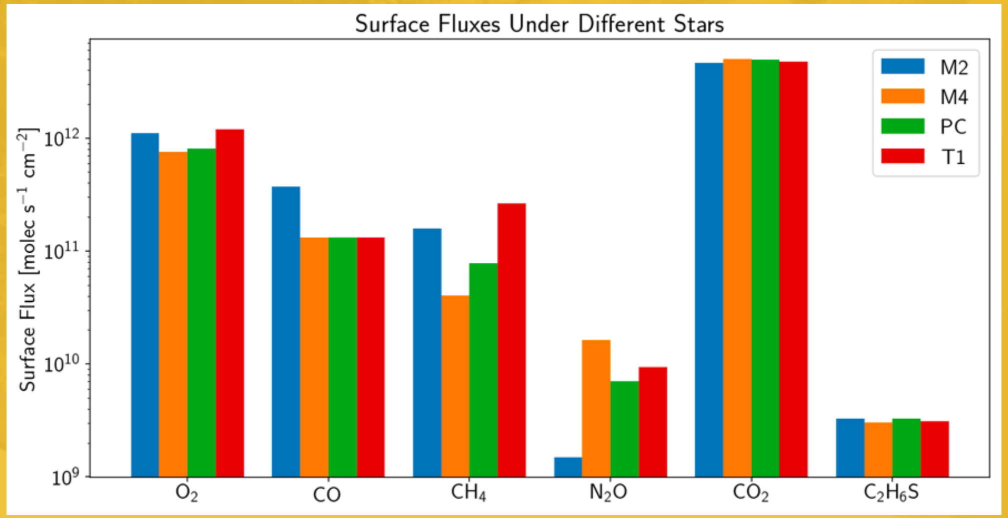
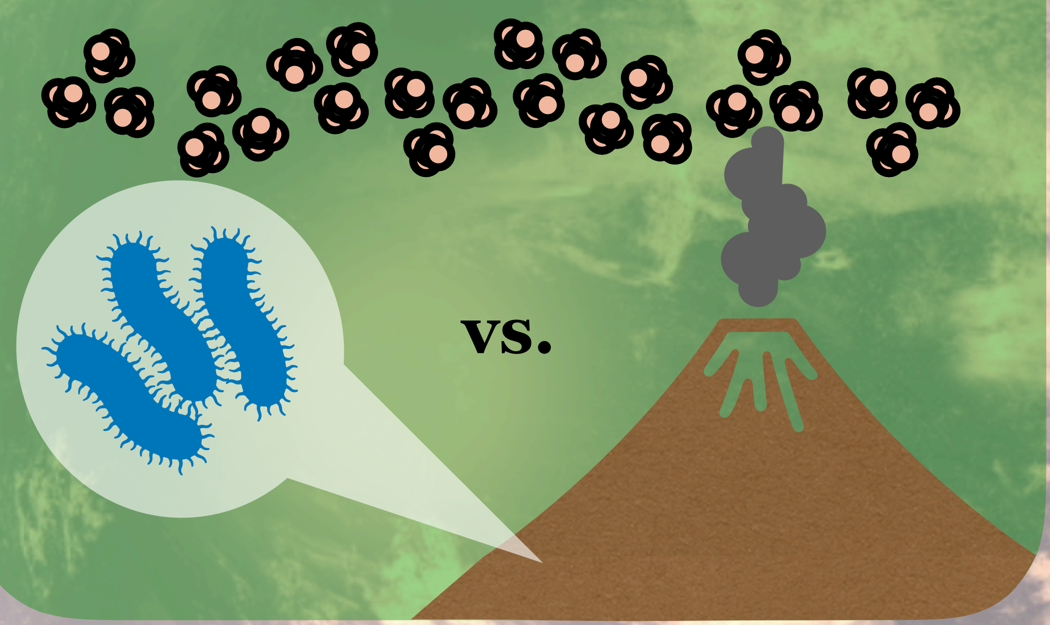


Figure credit: A. Lincowski

4

Distinguish Biological from Abiotic Fluxes



samroseg@uw.edu

@exoplamets

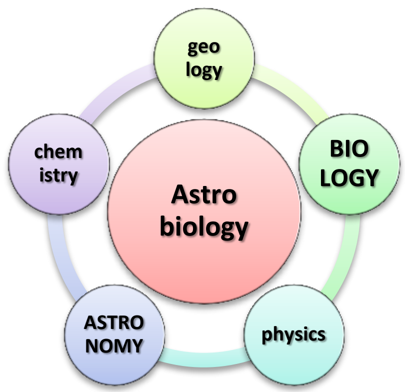
Which future instruments have the spectroscopic capabilities we need to achieve reasonable confidence levels?

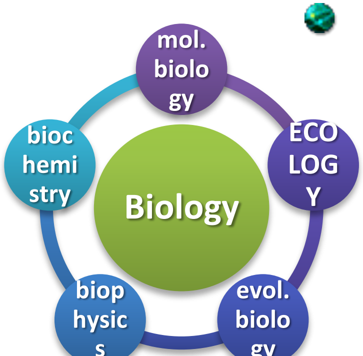
Metabiosphere dynamics – astronomical processes impact life on multiple planets linked by lithopanspermia

Prof. Milton Mendonça, Jr. – Dept. Ecology, UFRGS (Brazil) UFRGS UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL + Dept. Ecol. Evol. Biol., UCLA

Astrobiology = astro + *biology*, but ecology contributed little...

- Ecological theory can suggest unexpected astrobiological phenomena
- Metabiospheres[1]: biospheres linked through dispersal (lithopanspermia[2])

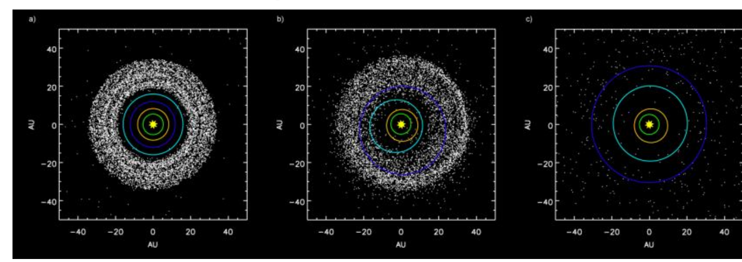




- Different solar system structures and developmental stages could change expectations about how metabiospheres function, if at all

Temporal astronomical dynamics and metabiospheres

- Periods of higher impact fequency could increase the likelihood of transfer/dispersal
  - LHB? ➔ *spread of early life (from Mars[3]?)*

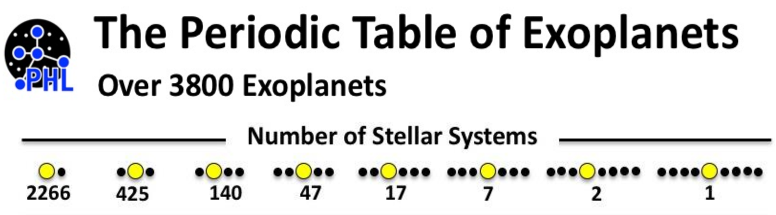


- Solar system trajectory through Galaxy = disruption of Kuiper belt/Oort cloud = periods of higher impact frequency
  - mass extinctions = mass lithopanspermia? = mass seeding of life

Metabiosphere dynamics – astronomical processes impact life on multiple planets linked by lithopanspermia

Solar system structure and metabiospheres

- The more the merrier! Systems with more life-supporting astronomical bodies have higher likelihood of life persisting long term[1] (and more complex evolutionary dynamics?)
  - Trappist-1 and similar systems much more likely to have metabiosphere dynamics

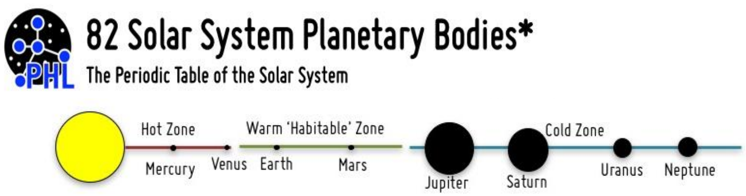


http://phl.upr.edu/projects/habitable-exoplanets-catalog/media/pte

  - Icy moons with underground oceans, terrestrial planets, ocean planets would seed different life forms?

Future directions

- Is our own solar system likely to have or have had a metabiosphere?
  - Life on Mars/Europa/Enceladus same as here?



http://phl.upr.edu/projects/habitable-exoplanets-catalog/media/pte

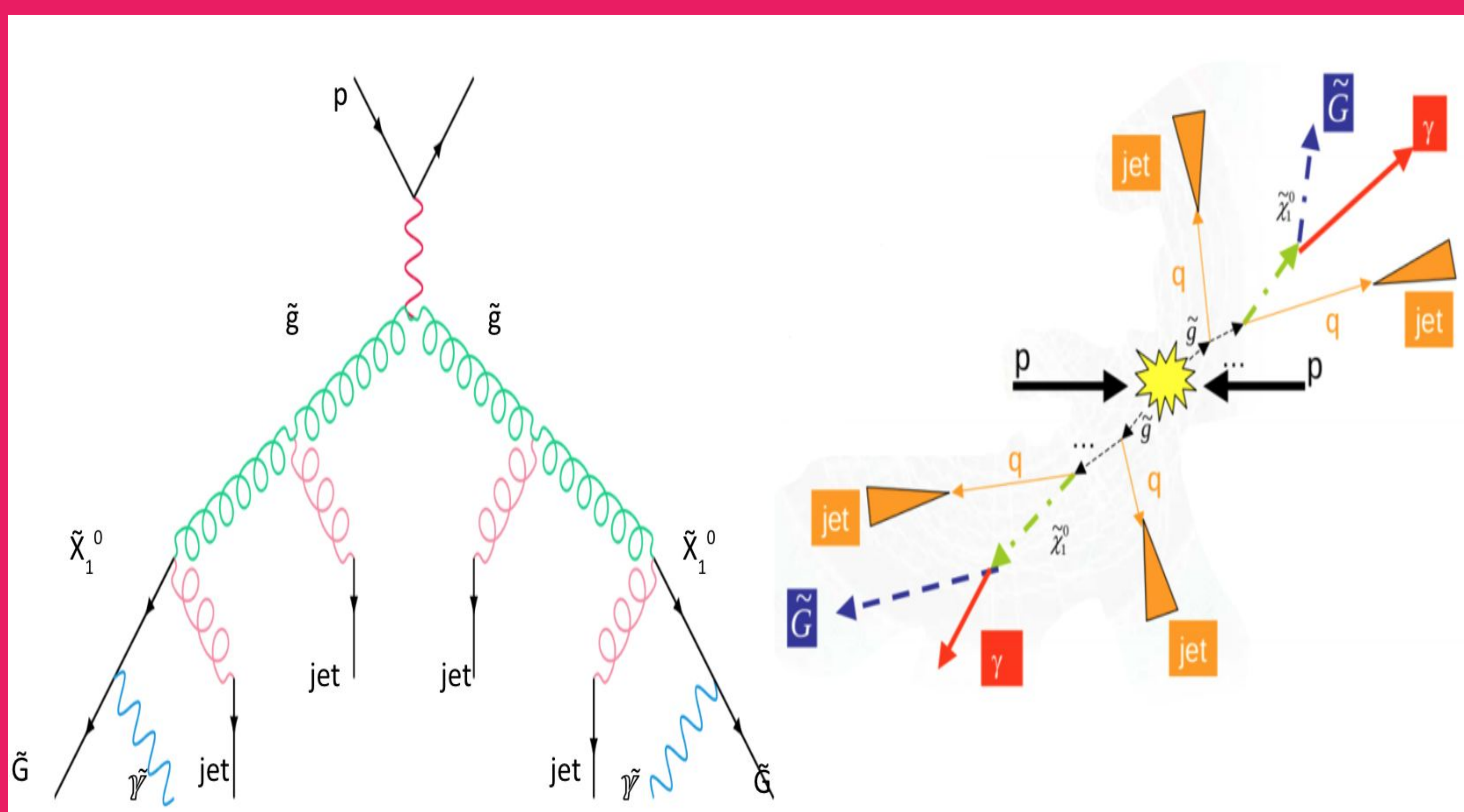
- How to model these dynamics together in terms of predicting long-term life persistence for a population of significant systems?

References

1. Mendonça, MDS, Jr. 2014. Ecology goes to space. *Icarus*.
2. Horneck, Stöffler, Ott, Hornemann et al. 2008. Microbial Rock Inhabitants Survive Hypervelocity Impacts on Mars-Like Host Planets: First Phase of Lithopanspermia Experimentally Tested. *Astrobiology*.
3. Benner & Kim 2015. The case for a Martian origin for Earth life, *Proc. SPIE 9606*

Life as Gauge-Mediated SUSY Breaking (GMSB) and the Quantum Computational Complexity of Majorana Neutralinos in CPT Symmetry

Shanna Dobson
California State University at Los Angeles



$\mathbb{C}\ell\,(\,d,\,g\,) \;\longrightarrow\; \mathcal{GAUGE}$

□ ↓

$\mathcal{QPU}$?

Commutativity ⇶ Computational Complexity
Noncommutative Algebras ↭ MSTA

Caltech - NExScI - NASA Exoplanet Science Institute

Possibility that CPT symmetry is actually conserved if a mirror universe of equal and opposite CPT violation were to exist, duality (CPTD Symmetry)

$$\begin{array}{ccccccc} & & & h^{33} & & & \\ & & h^{32} & & h^{23} & & \\ & h^{31} & & h^{22} & & h^{13} & \\ h^{30} & & h^{21} & & h^{12} & & h^{03} \\ & h^{20} & & h^{11} & & h^{02} & \\ & & h^{10} & & h^{01} & & \\ & & & h^{00} & & & \end{array}$$

(a)

$$\begin{array}{ccccccc} & & & 1 & & & \\ & & 0 & & 0 & & \\ & 0 & & h^{11} & & 0 & \\ 1 & & h^{21} & & h^{21} & & 1 \\ & 0 & & h^{11} & & 0 & \\ & & 0 & & 0 & & \\ & & & 1 & & & \end{array}$$

(b)

$$\mathcal{SCFT}\,a\,(\mathcal{X}) \simeq \mathcal{SCFT}\,b\,(\mathfrak{X})$$

Merge Weak AI with Blockchain using Geometric Algebras to screen false positives.

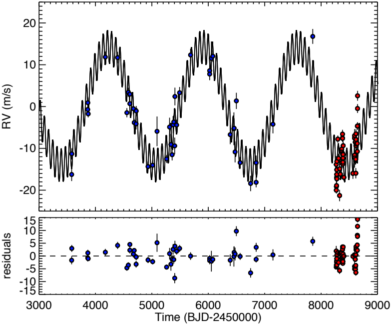
Role of CPT Symmetry and Massive Gravity on Geocycles.

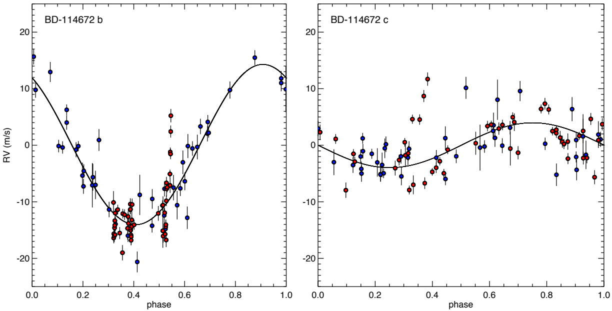
Quantum Computational Complexity drives Emergence.

Caltech - NExScI - NASA Exoplanet Science Institute
2019 Sagan Exoplanet Summer Workshop

A temperate Uranus-mass planet in the BD-11 4672 system

D. Barbato, M. Pinamonti, A. Sozzetti and the GAPS team



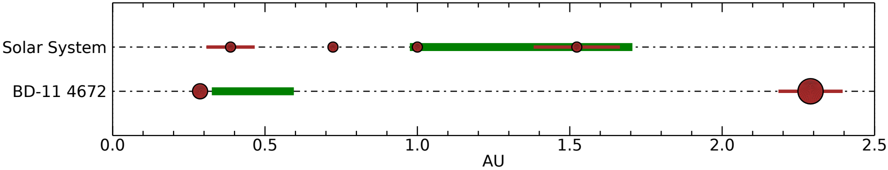


BD-11 4672 (GJ 717)	
Sp	K7 V
Mass ($M_\odot$)	0.571 ± 0.014
Radius ($R_\odot$)	0.52 ± 0.02
Age (Gyr)	4.4 ± 4.0
T_{eff} (K)	4475 ± 100
[Fe/H]	-0.48 ± 0.05
$\log g$ (cgs)	4.10 ± 0.36
P_{rot} (d)	~ 250

	BD-11 4672 b (discovered by Moutou et al. 2015)	BD-114672 c
K (m/s)	$14.22^{+0.97}_{-1.11}$	2.88 ± 0.60
P (days)	1654^{+11}_{-13}	$74.27^{+0.13}_{-4.29}$
e	$0.046^{+0.053}_{-0.032}$	0 (fixed)
ω (deg)	183 ± 145	90 (fixed)
$M\sin i$ (M_J)	0.57 ± 0.03	0.041 ± 0.003
a (AU)	$2.27^{+0.06}_{-0.07}$	0.287 ± 0.008

A temperate Uranus-mass planet in the BD-11 4672 system

D. Barbato, M. Pinamonti, A. Sozzetti and the GAPS team



Planet c (Msin $i \sim 15$ $M_\oplus$) orbits very close to the inner boundary of circumstellar habitable zone (0.32 – 0.59 AU as per Kopparapu et al. 2014). We use the MERCURY n-body integrator to investigate the dynamical stability of closely-packed Earths and super-Earths in HZ.

		a_{inj} (AU)									
		0.32	0.35	0.38	0.41	0.44	0.47	0.50	0.53	0.56	0.59
M_{inj} ($M_\oplus$)	1										
	5										
	10										
	15										

(assuming $e_c = 0$)

		a_{inj} (AU)									
		0.32	0.35	0.38	0.41	0.44	0.47	0.50	0.53	0.56	0.59
M_{inj} ($M_\oplus$)	1										
	5										
	10										
	15										

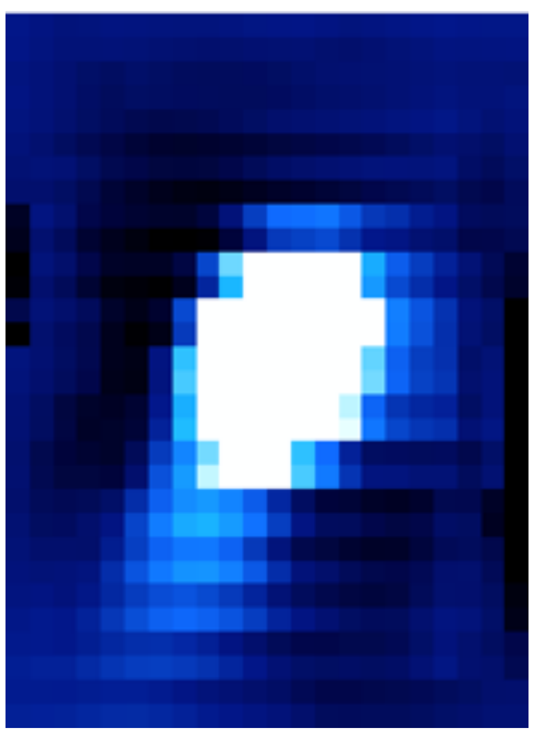
(assuming $e_c = 0.2$)

Come see me at my poster!

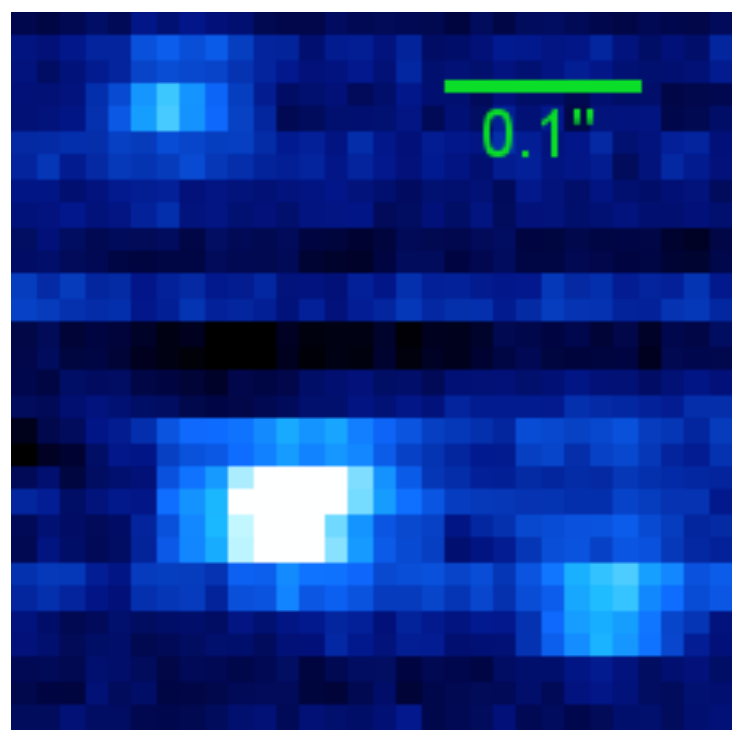
Spectral characterization of newly detected young substellar binaries

Per Calissendorff
Department of Astronomy, Stockholm University, Sweden

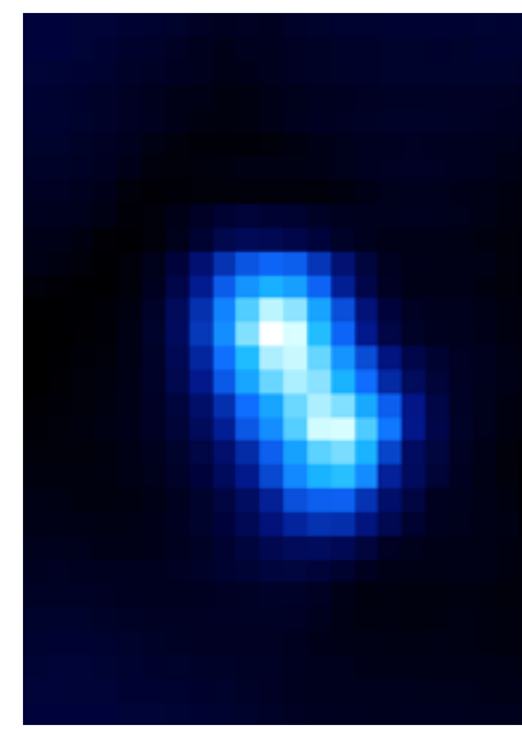
2MASS J15104786-2818174



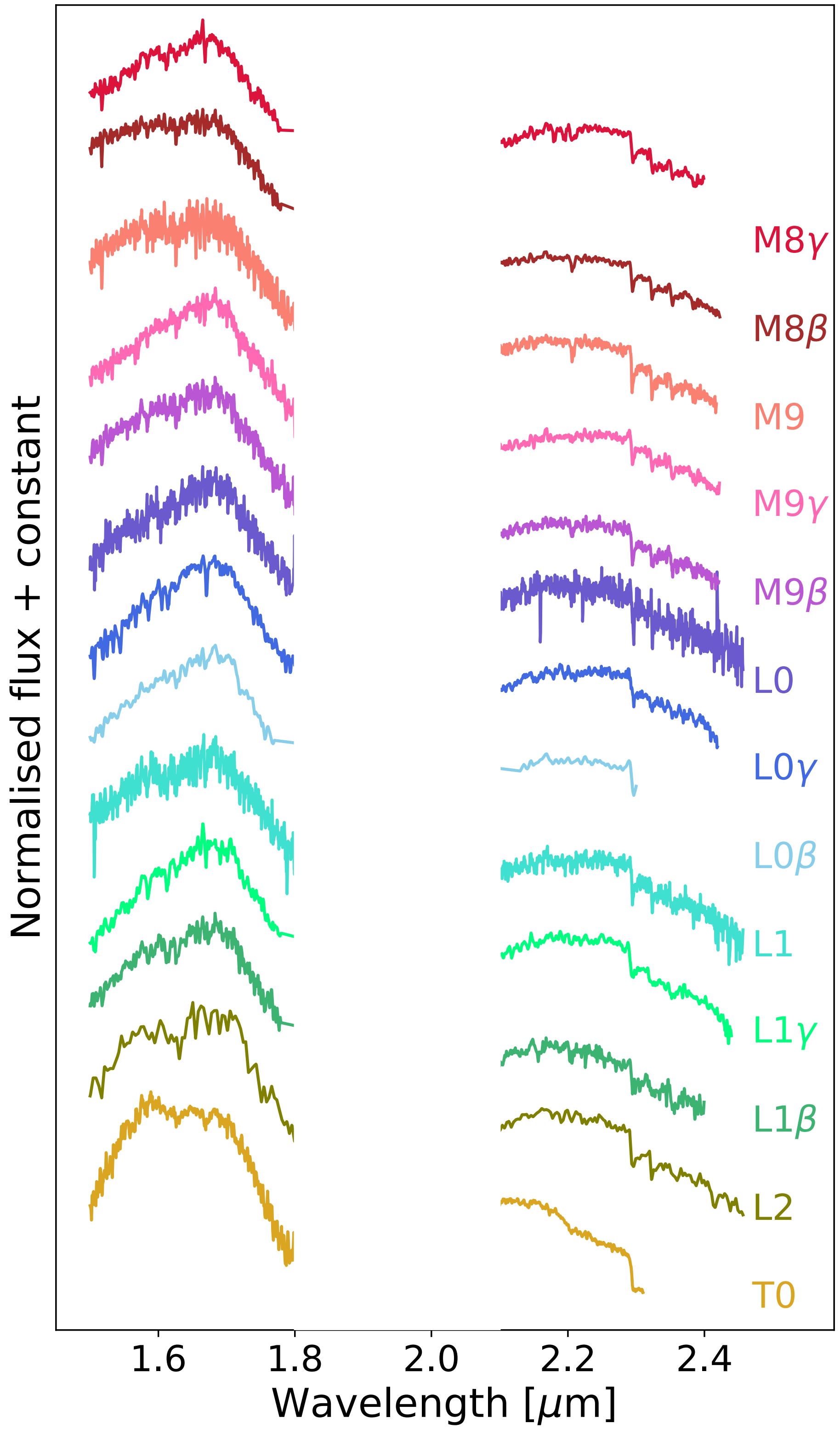
2MASS J15474719-2423493



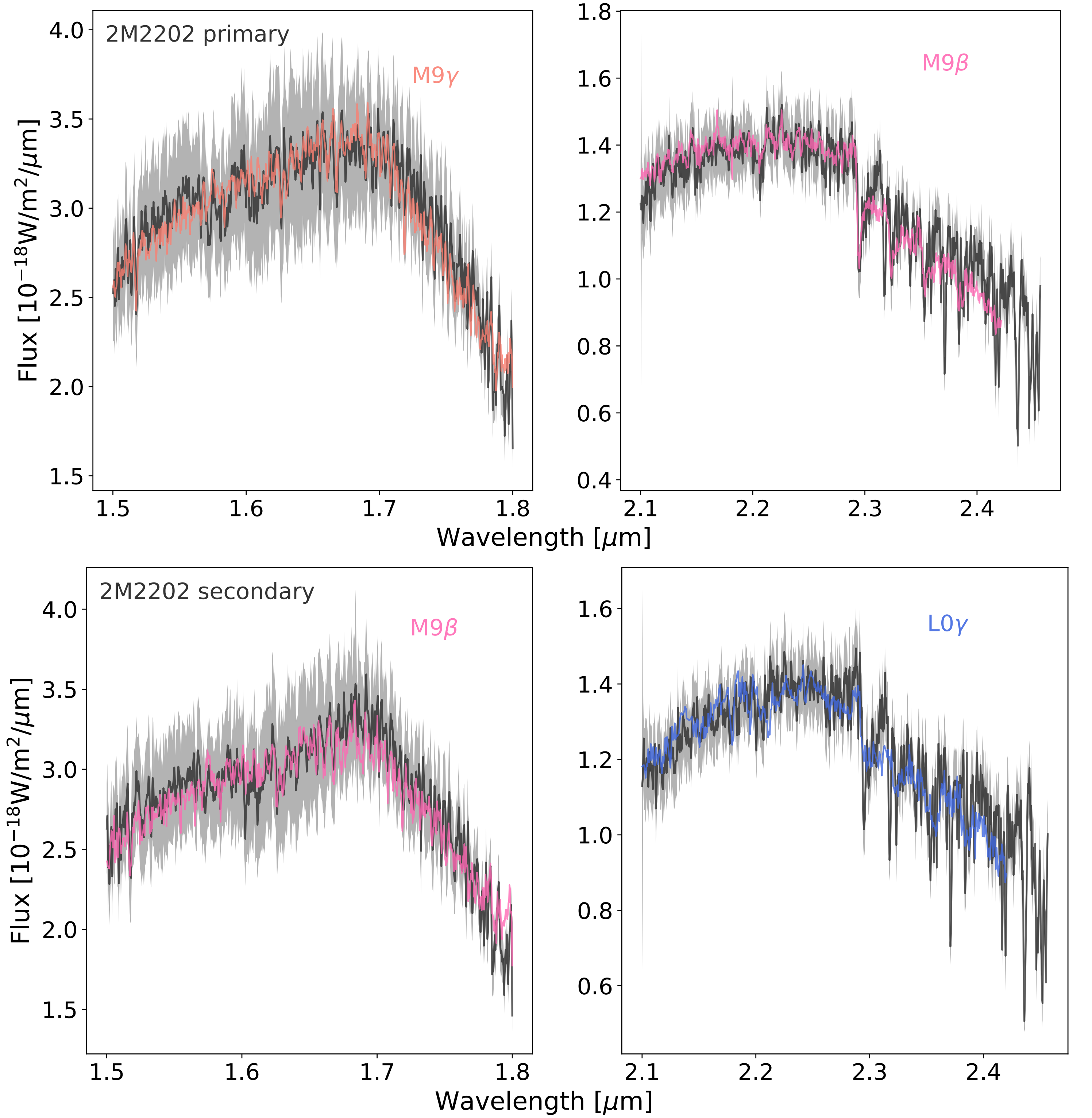
2MASS J22025794-5605087



Spectral templates



Resolved binary spectra

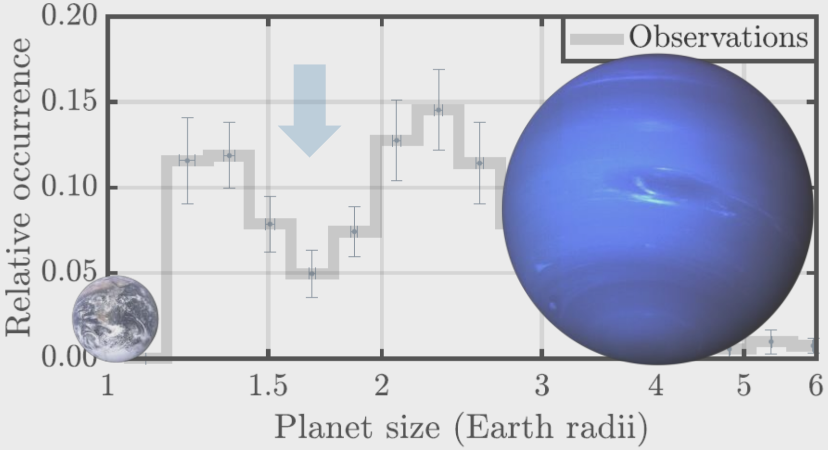


The Radius Valley as a by-product of Planet Formation under the Core-Powered Mass-Loss Mechanism

Akash Gupta

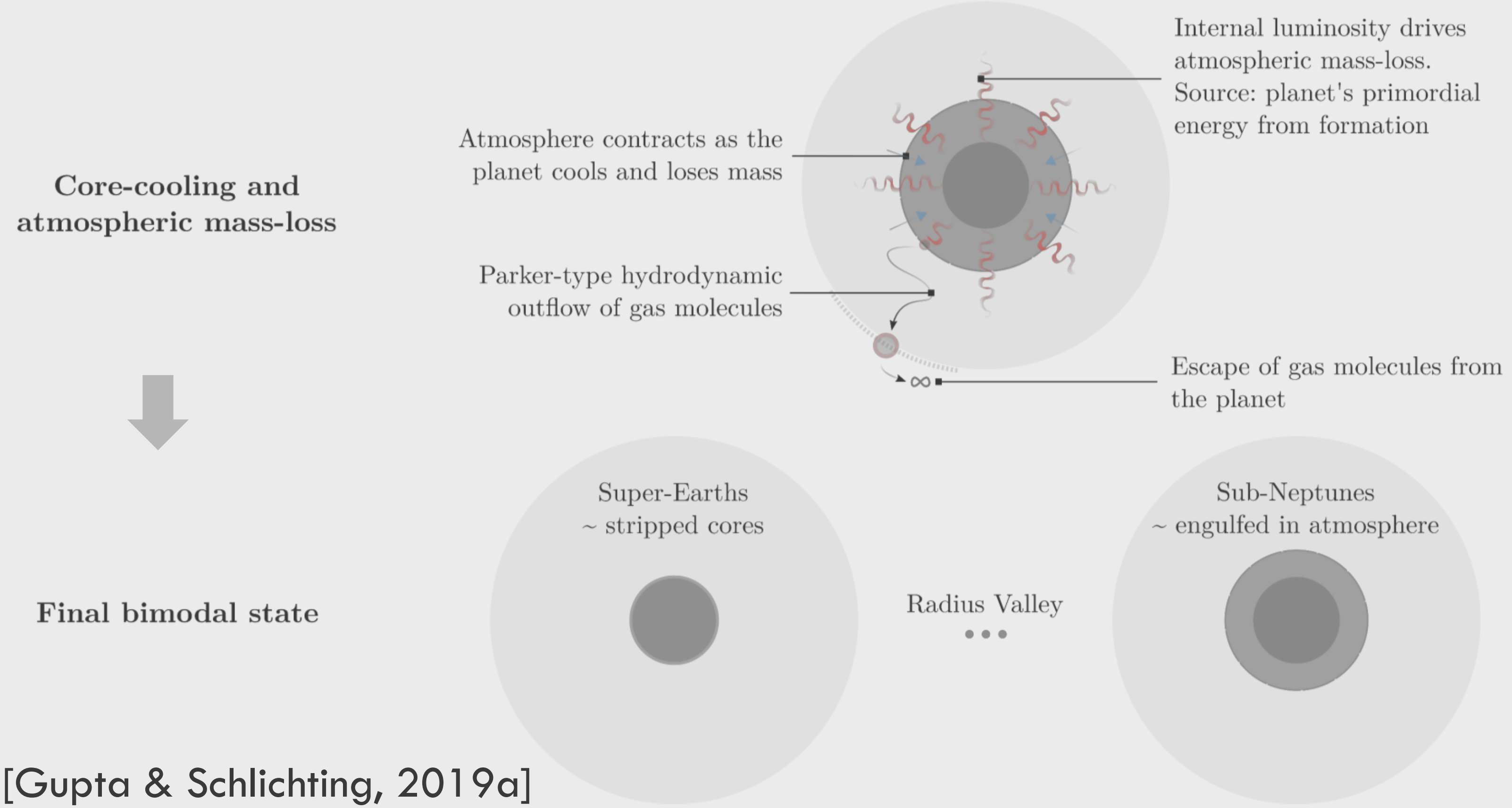
UCLA

Observations: Radius Valley



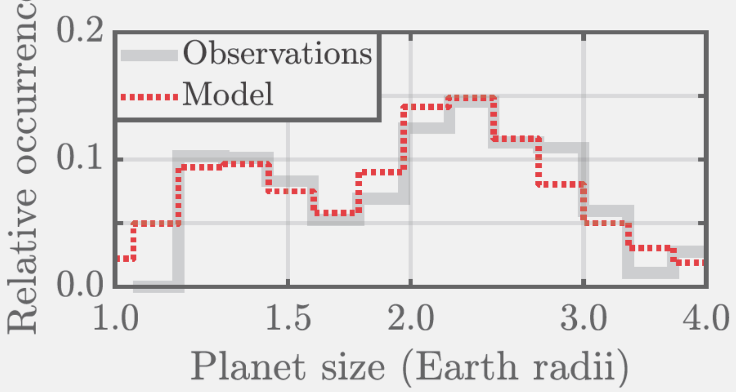
[Data from Fulton et al. 2017]

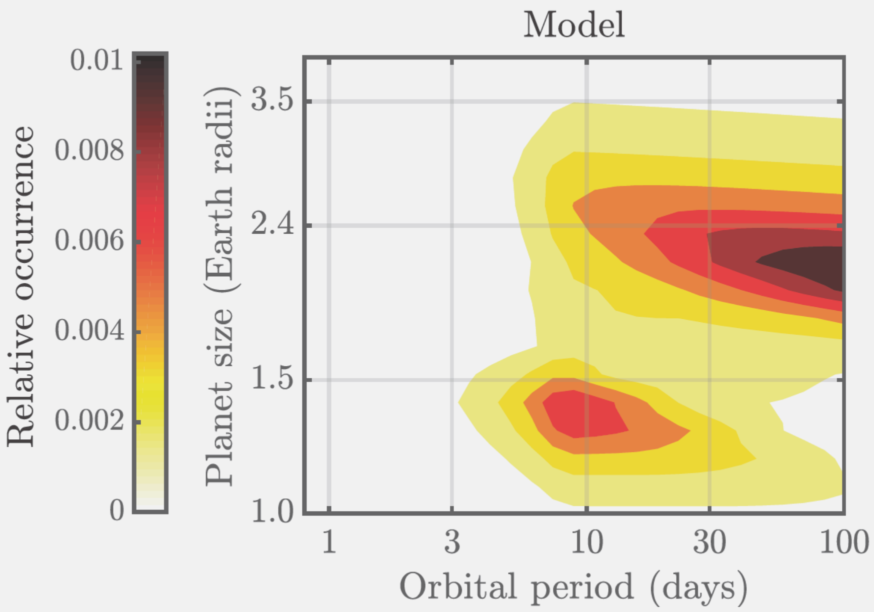
Core-powered mass-loss mechanism

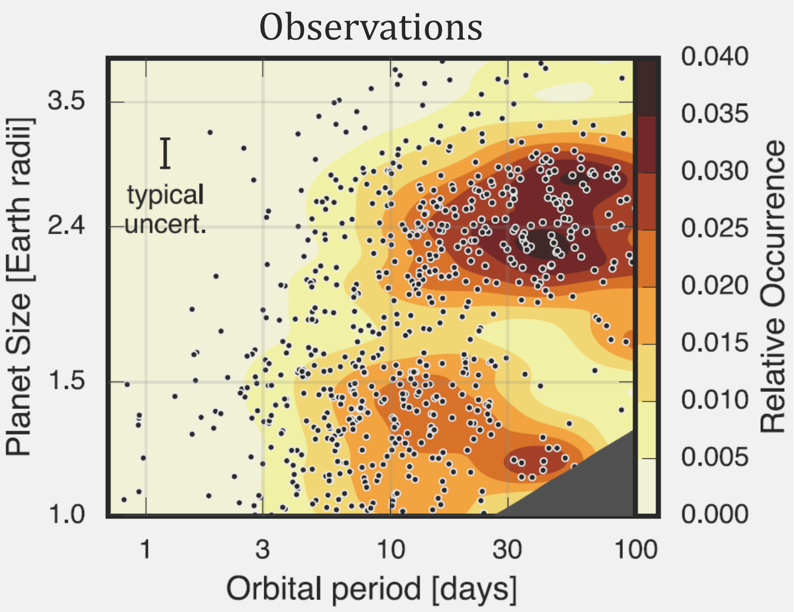


[Gupta & Schlichting, 2019a]

Comparison with observations







[Gupta & Schlichting, 2019a and 2019b, *in prep*]

The core-powered mass-loss mechanism can not just reproduce and explain the planet size distribution with orbital period but even with stellar mass, metallicity and age and insolation flux.

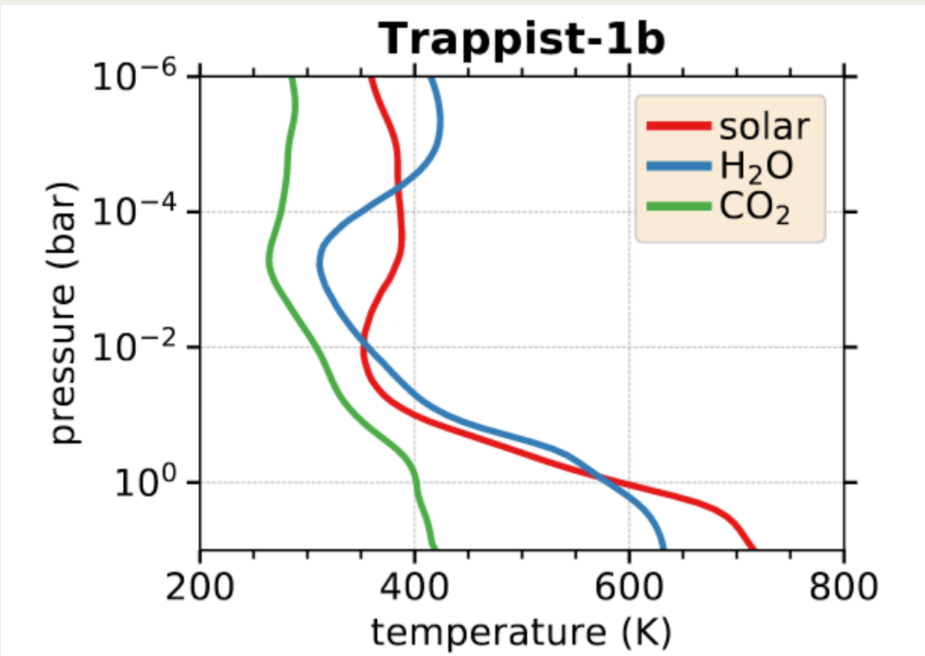
Finding Atmospheres on M-Dwarf Terrestrial Planets

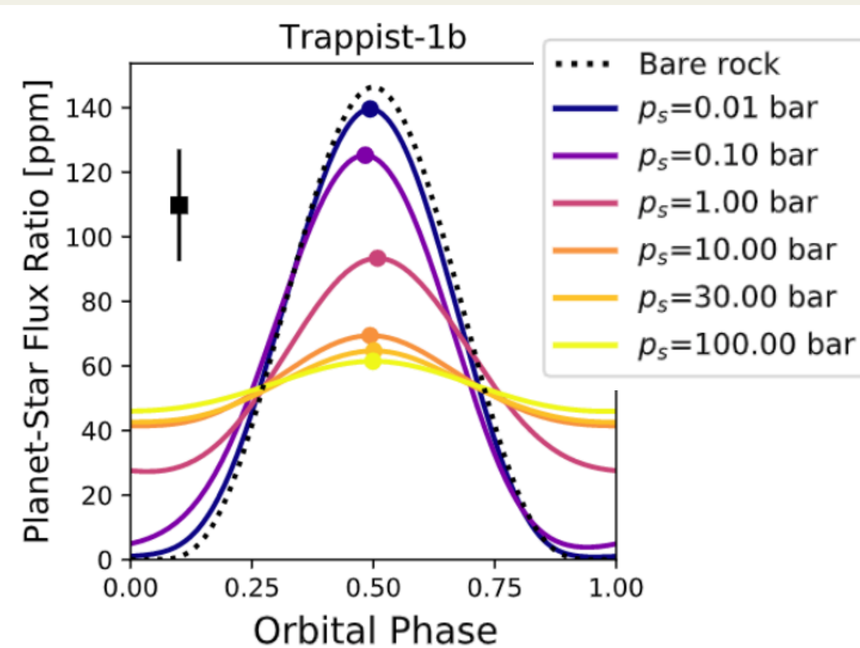
Megan Mansfield, Daniel Koll, Matej Malik, Eliza M.-R. Kempton, Edwin Kite, Jacob Bean, Dorian Abbot, Renyu Hu

New models of terrestrial planets:

1D radiative-convective equilibrium + solid surface (Malik et al. submitted)

Scaling laws for heat redistribution from GCM (Koll submitted)





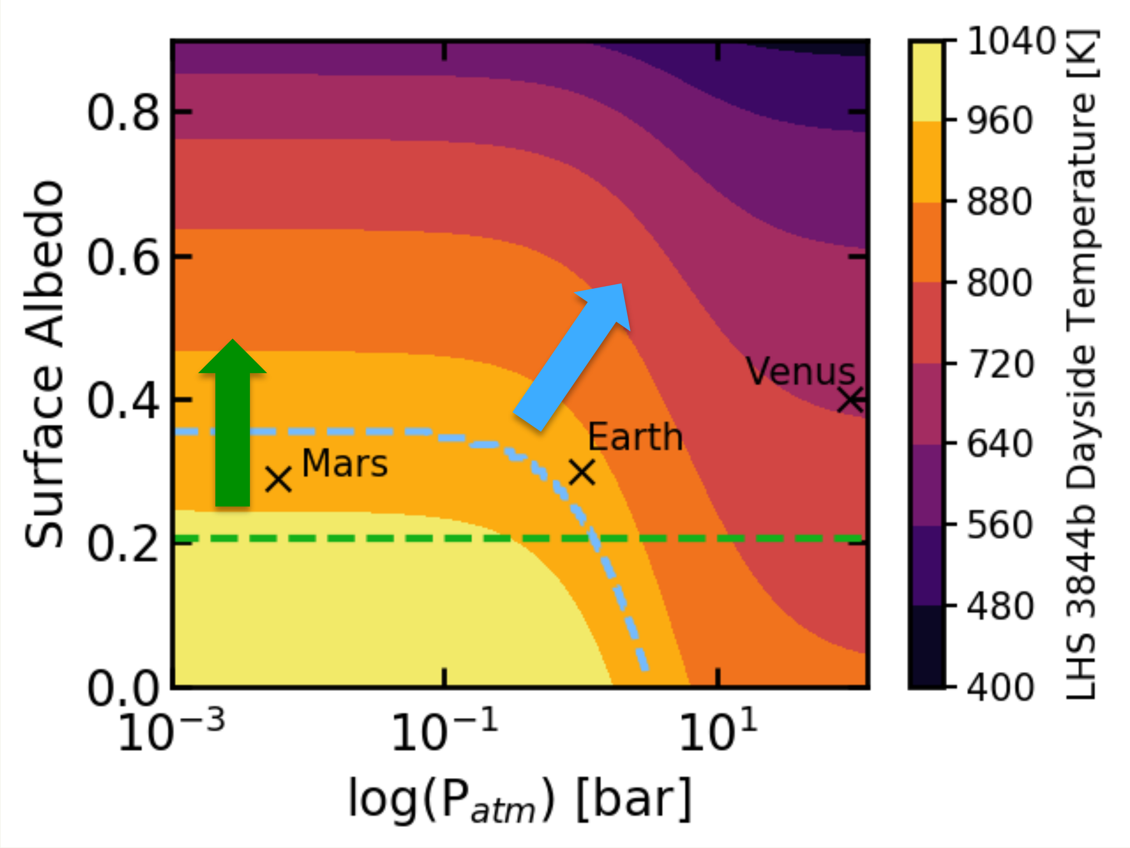
Finding Atmospheres on M-Dwarf Terrestrial Planets

Megan Mansfield, Daniel Koll, Matej Malik, Eliza M.-R. Kempton, Edwin Kite, Jacob Bean, Dorian Abbot, Renyu Hu

Eclipse photometry can detect terrestrial planet atmospheres efficiently with JWST

Lower dayside temperature due to:

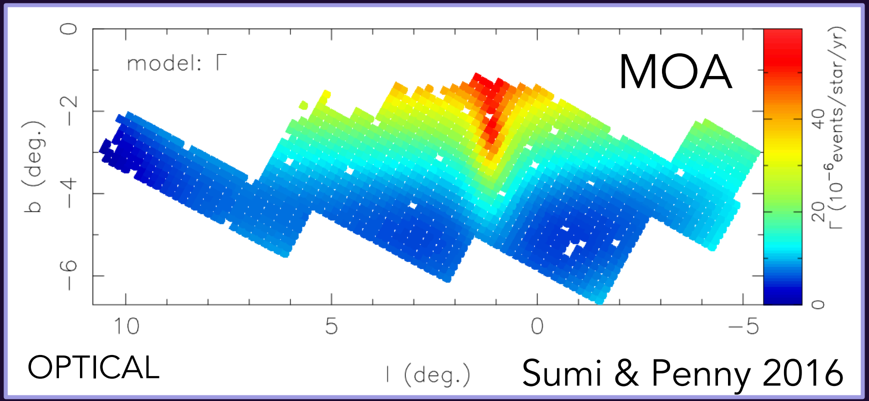
1. Energy transport in a thick atmosphere (Koll et al. submitted)
2. High-albedo clouds in a thin atmosphere (Mansfield et al. submitted)

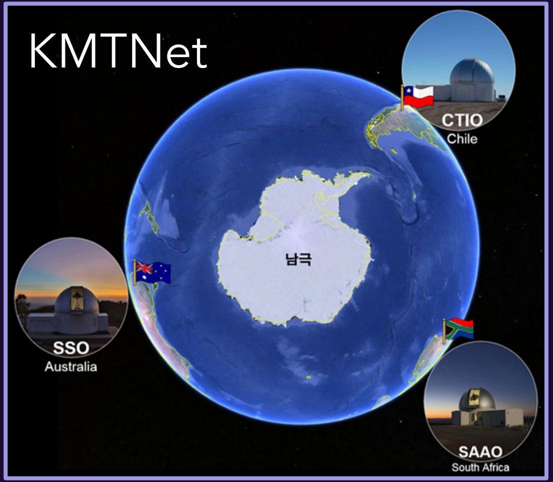


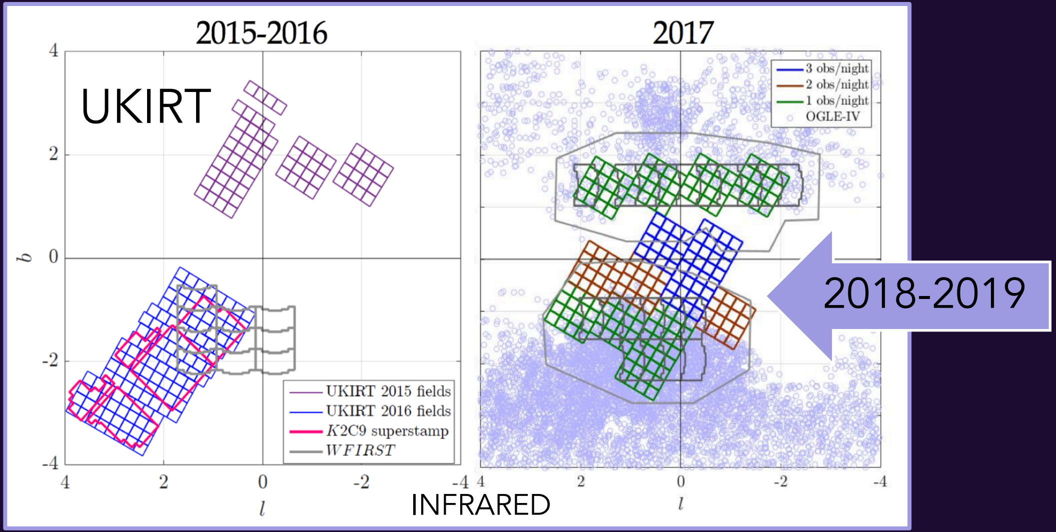
Mu and You:
Public Microlensing Analysis Tools and Survey Data

The Data

- Microlensing Observations in Astrophysics (MOA)
  - 2009-2014 high cadence microlensing survey
- Korea Microlensing Telescope Network (KMTNet)
  - 2015 and K2C9 data; continuous monitoring near Galactic center
- United Kingdom Infrared Telescope Microlensing Survey
  - 2015-2019 *H* and *K* NIR-band observations of Galactic center







Savannah R. Jacklin, Vanderbilt University

The Public Codes

AKA: What you use to fit microlensing light cuves

- *PyLIMA*
  - https://github.com/ebachelet/pyLIMA
- *MulensModel*
  - https://github.com/rpoleski/MulensModel
- *MuLAn*
  - https://github.com/muLAn-project/muLAn
- *VBBinaryLens*
  - MNRAS 479 (2018) 5157 and MNRAS 408 (2010) 2188

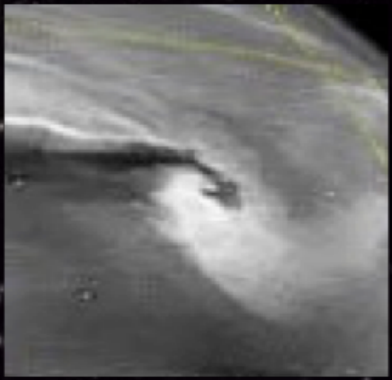
The Why

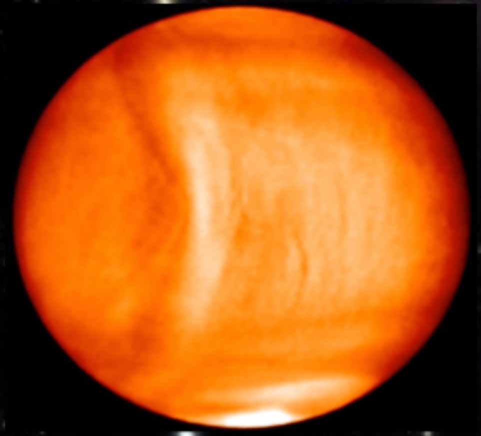
How does knowledge of Venus' atmospheric dynamics contribute to studies of exoplanets ?

Helen F. Parish
University of California Los Angeles

- May be a significant number of Venus analogs in exoplanet observations
- To understand atmospheres of Venus analogs we need to understand Venus' atmosphere better

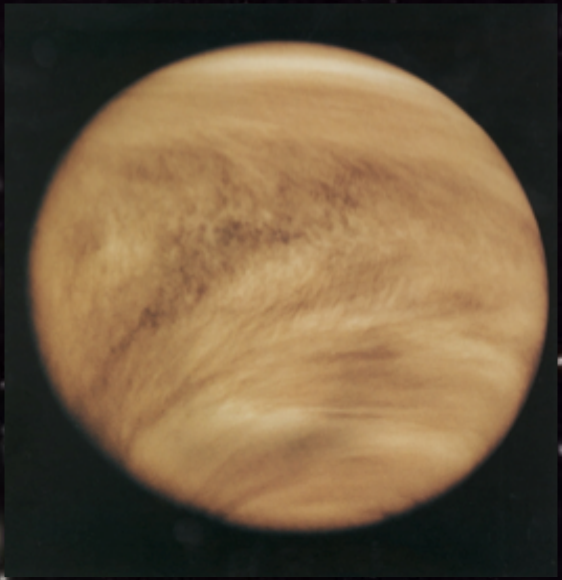
- Many different waves and wave-related features observed at cloud altitudes on Venus

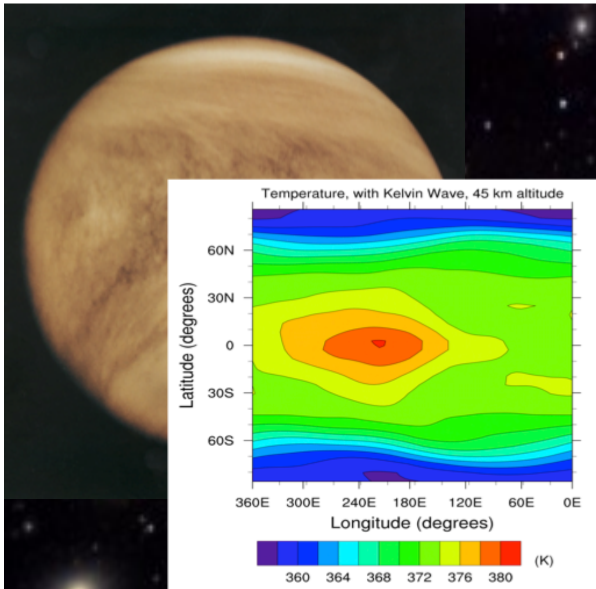


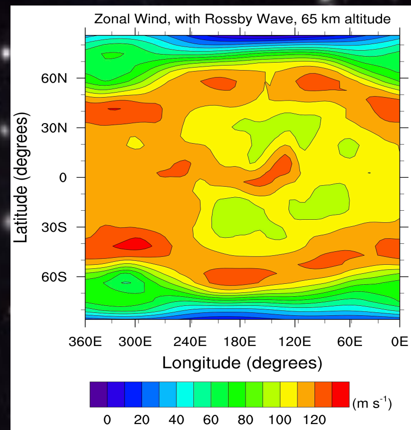


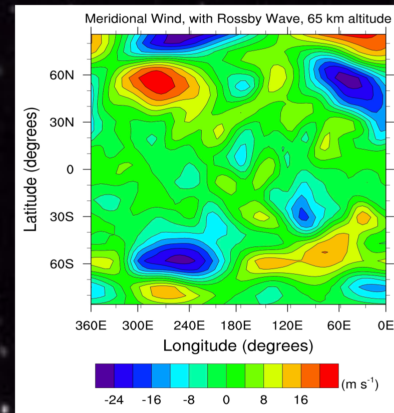
- Largest gravity wave in Solar System observed in Venus' clouds

- Irregular and variable dark features in Venus' clouds have been suggested as possible locations for some kind of microscopic life

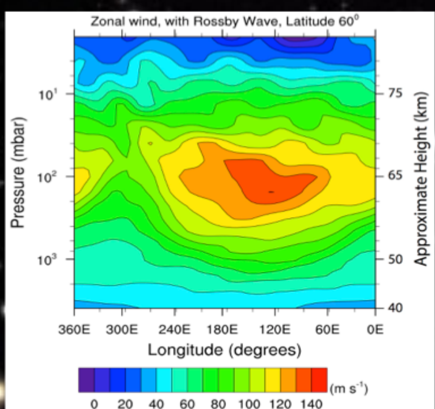




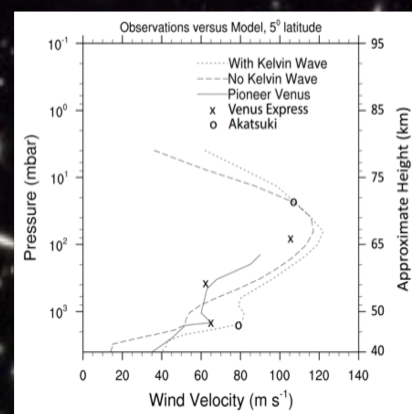




- Phase curves of exoplanets can give information on atmospheric structure
- Use a Venus middle atmosphere model to determine how propagating waves influence winds and temperatures at cloud altitudes



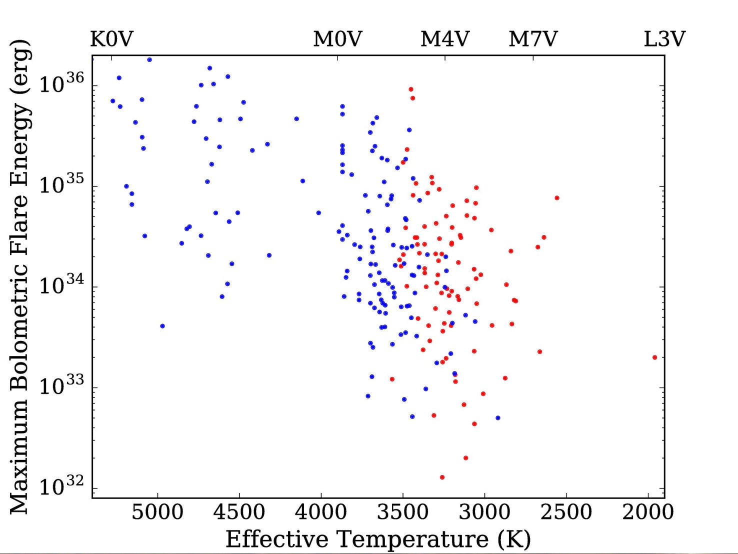
- Examine in comparison with measurements from Venus probes, and Venus Express and Akatsuki missions.



Stellar flares from the lowest mass stars with NGTS

James A. G. Jackman*, P. J. Wheatley, NGTS Consortium

- Use the 13 second cadence full frame images of NGTS to search for flares
- Probe how maximum flare energy and occurrence rates change down to the coolest and lowest mass stars
    - 100 - 1000x Carrington event for late M

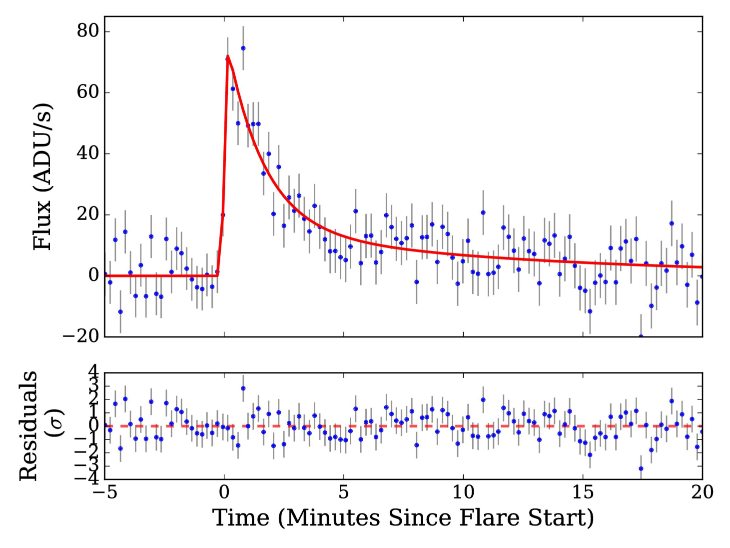


Jackman et al, in prep.

Stellar flares from the lowest mass stars with NGTS

James A. G. Jackman*, P. J. Wheatley, NGTS Consortium

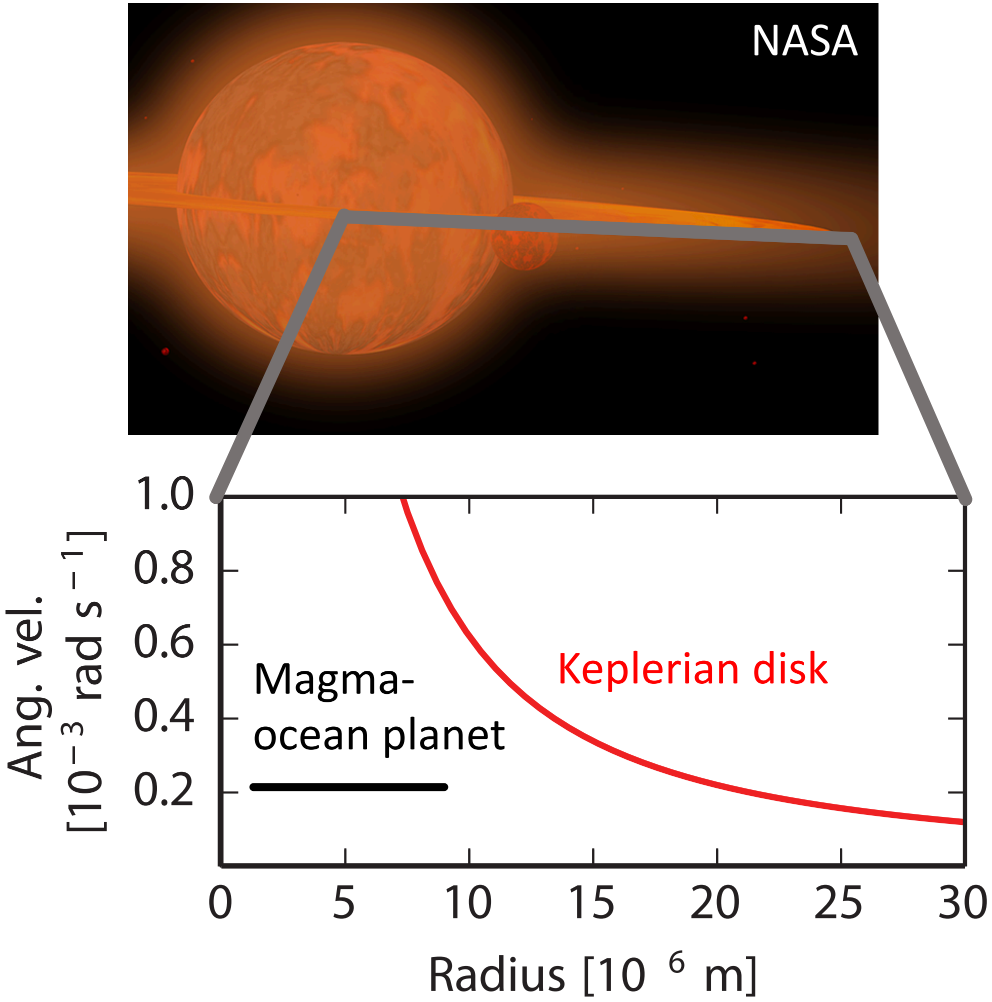
- Use the 13 second cadence full frame images of NGTS to search for flares
- Probe how maximum flare energy and occurrence rates change down to the coolest and lowest mass stars
- First detection of a white-light flare from an L2.5 dwarf - the coolest flaring star to date
    - 10x Carrington energy

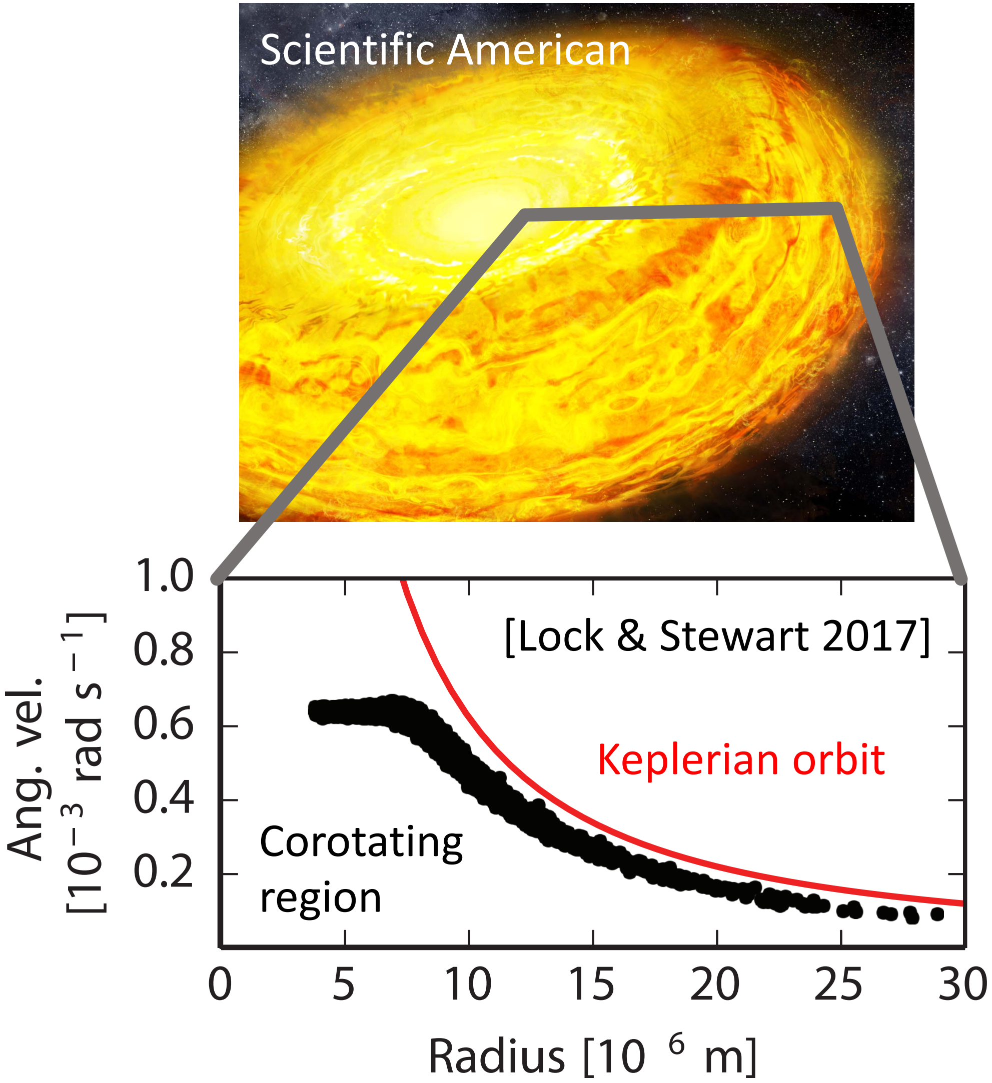


Jackman et al, 2019, MNRAS Letters

Synestias: A new type of planetary object

Simon Lock (Caltech)





Old: Giant impacts create a planet orbited by a disk of molten silicates

New: Most giant impacts create synestias, dynamically and thermally continuous bodies

…. and a new environment for satellite formation

Old:

Satellites form by spreading of disk material beyond the Roche limit [e.g., Salmon & Canup 2012]

Satellite forms in (near?) vacuum

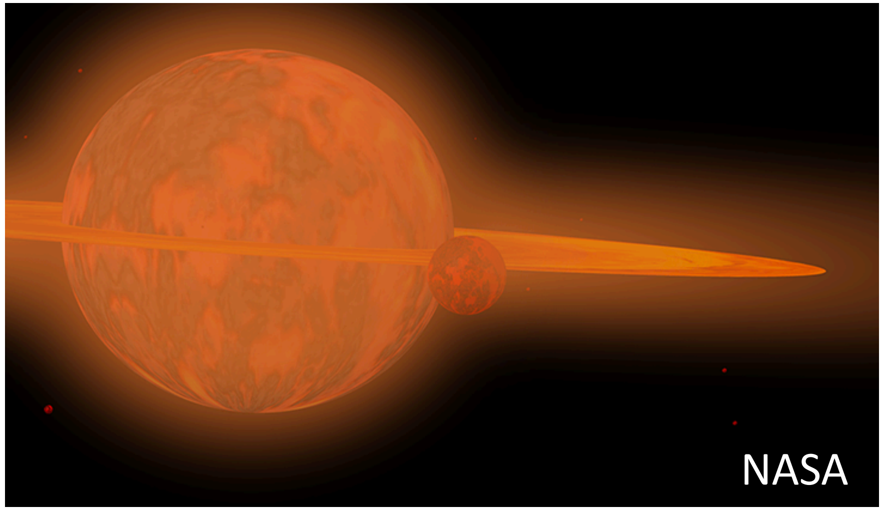
New:

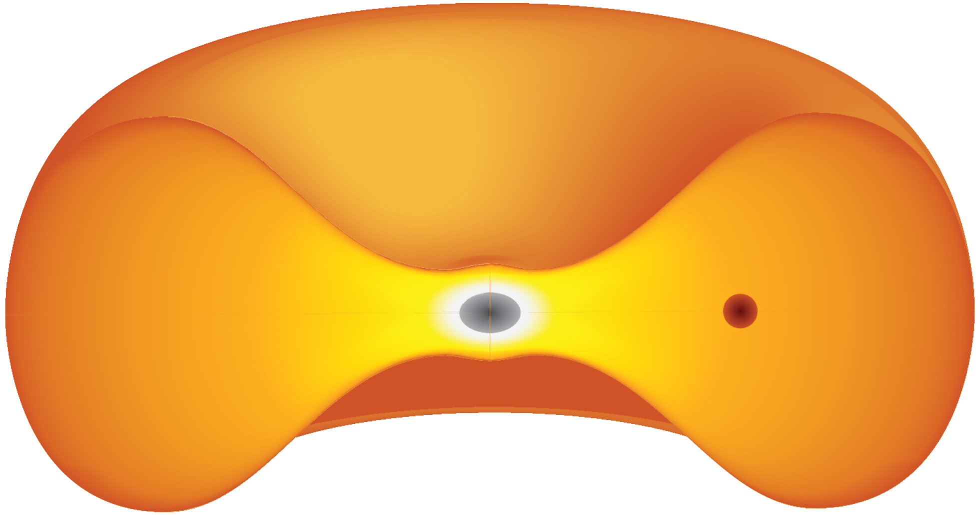
Synestias can extend beyond the Roche limit [Lock & Stewart 2017]

Satellites form inside the vapor of a synestia [Lock et al. 2018]

Produces satellites with different chemistry

Similar structures likely formed in collisions between ice giants

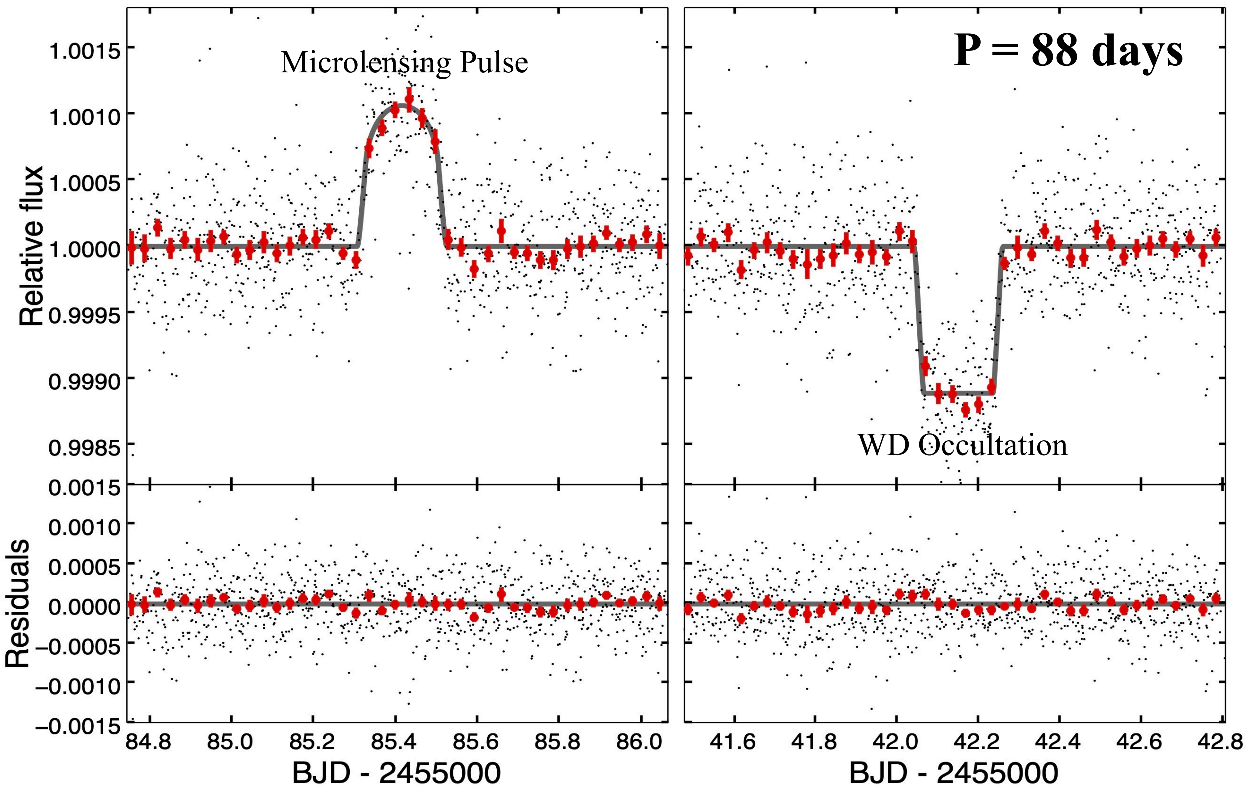




The Mass of the White Dwarf Companion in the Self-Lensing Binary KOI-3278: Einstein vs. Newton

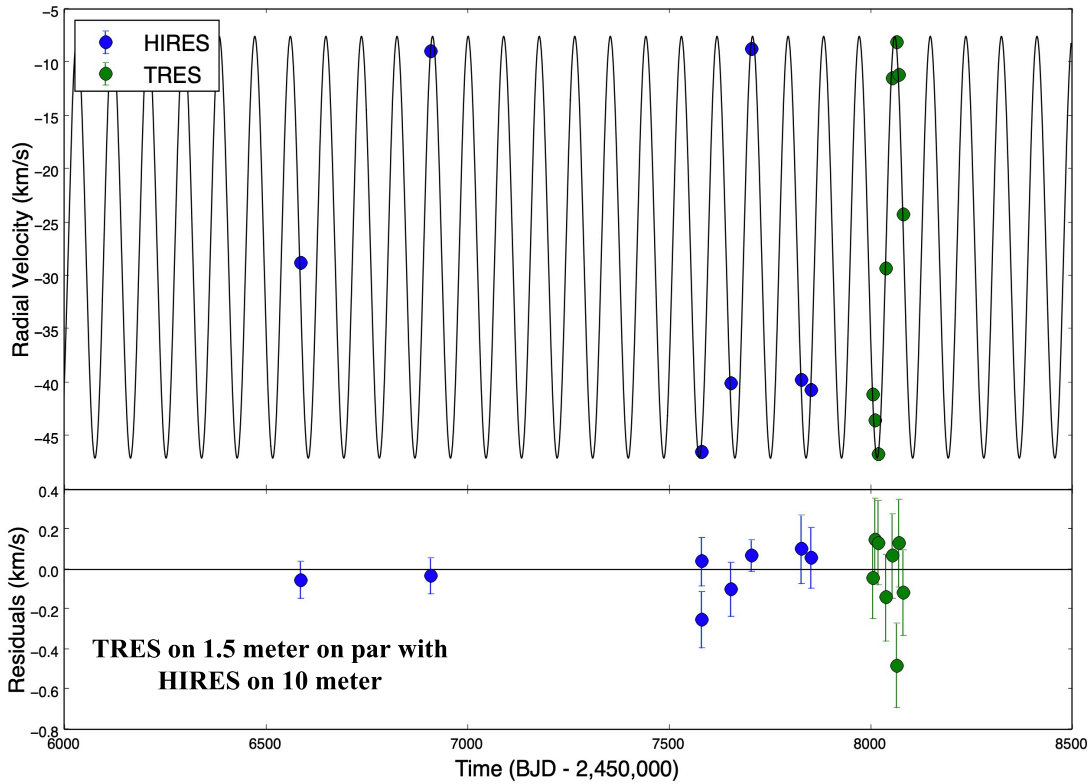
CENTER FOR ASTROPHYSICS
HARVARD & SMITHSONIAN

Einsteinian – Kepler Phase Folded LC Model + Observations



Modified Kruse & Agol (2014) MCMC fit
(with spectroscopic estimates of stellar parameters).

Newtonian – Unfolded Orbital Model + Observations

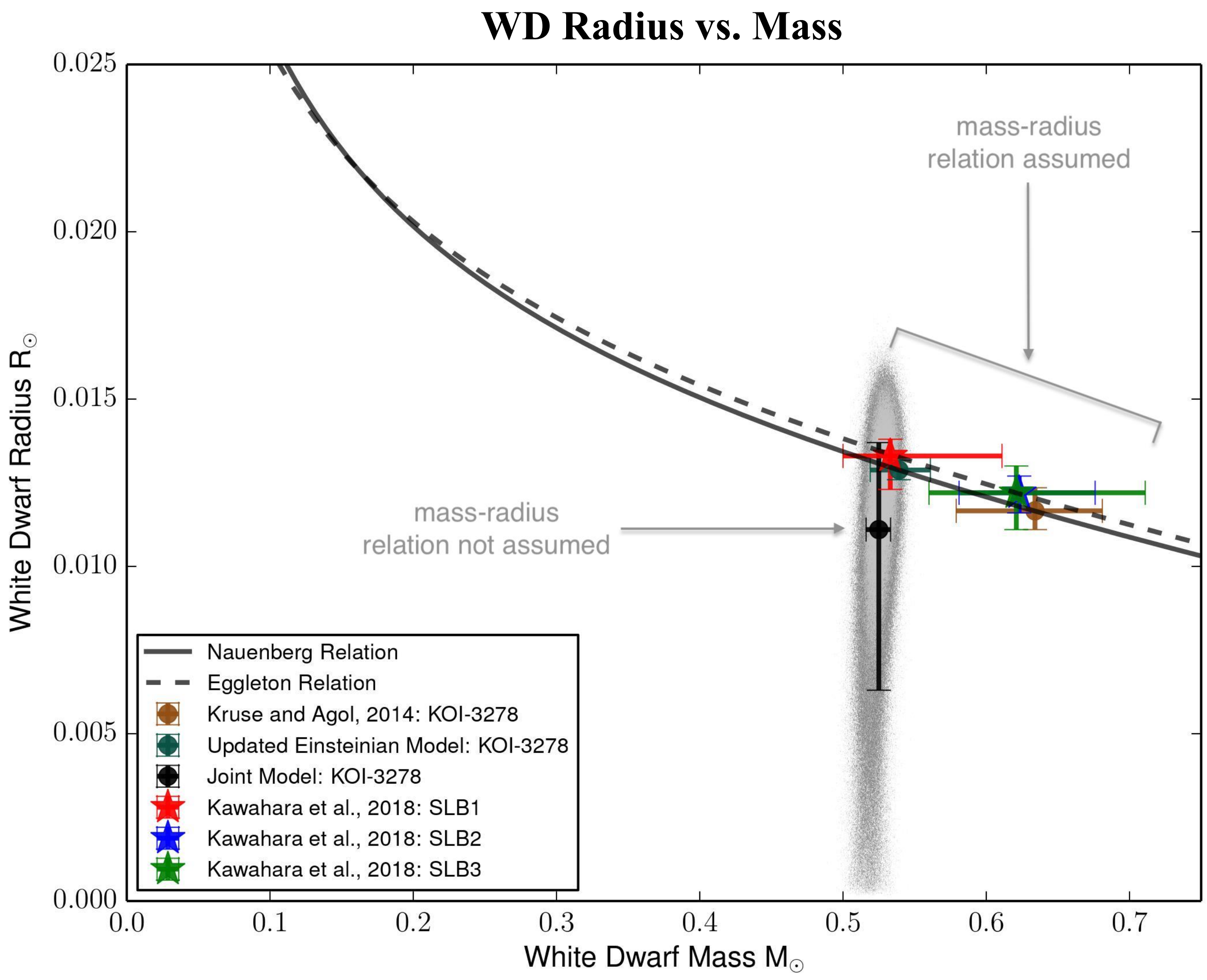


Inclination ≈ 90^{o} … can solve for M_2

Daniel A. Yahalomi – Sagan Workshop: July 2019

Yahalomi, Shvartzvald, Agol, et al. 2019, ApJ.

KOI-3278: Einstein vs. Newton



WD Mass Estimates

Kruse and Agol, 2014 Einsteinian: $0.634^{+0.047}_{-0.055}$ M_{sun} .

Updated Einsteinian: $0.539^{+0.022}_{-0.020}$ M_{Sun} .

Newtonian: $0.5122^{+0.0057}_{-0.0058}$ M_{Sun} .

Joint Model: $0.5250^{+0.0082}_{-0.0089}$ M_{Sun} .

Model independent test of WD Mass-Radius relation.

UV observations could better constrain WD radius.

Yahalomi, Shvartzvald, Agol, et al. 2019, ApJ.

How does CO gas abundance evolve with time and location in planet-forming disks?

Ke (Coco) Zhang
University of Michigan