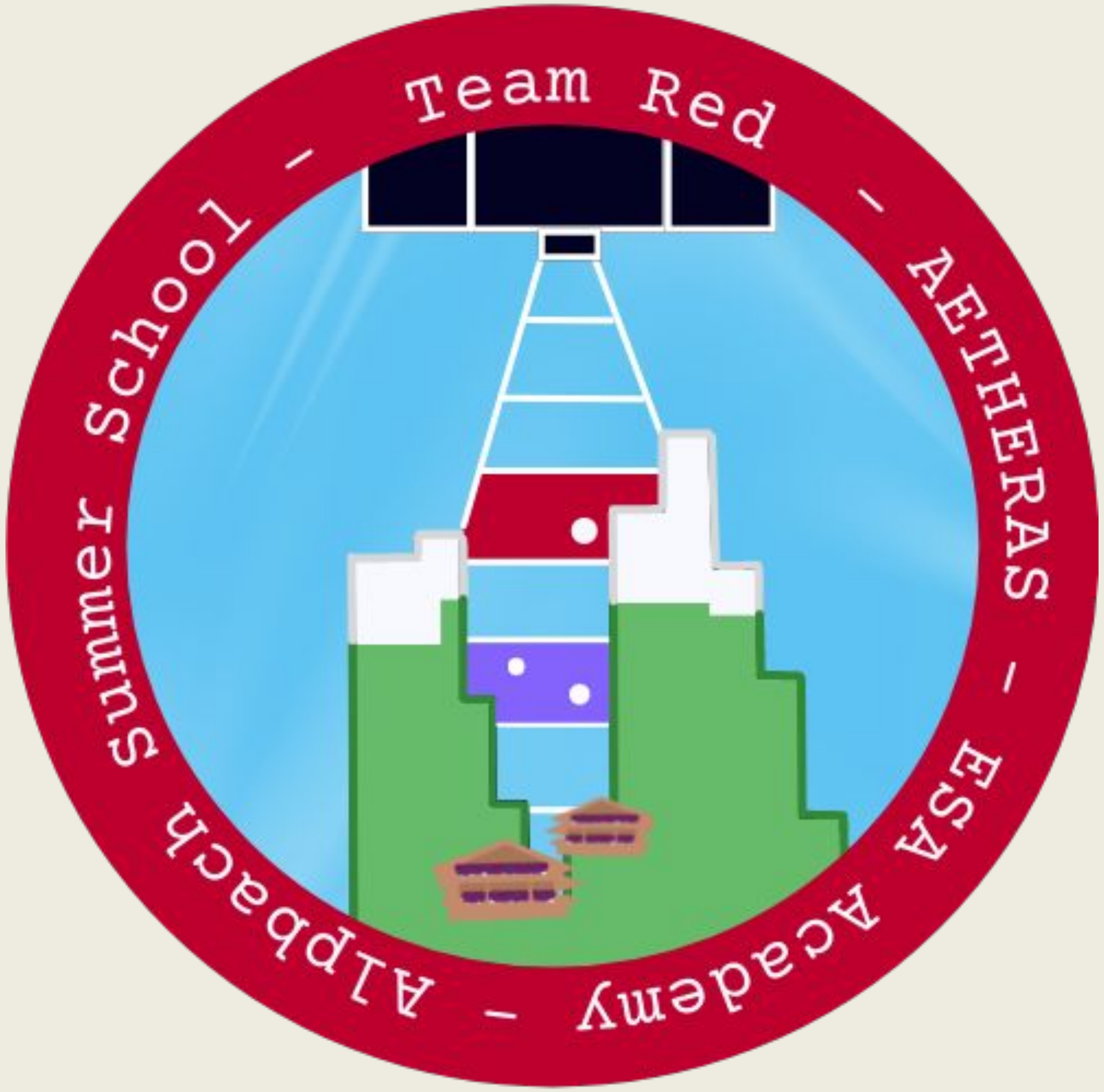
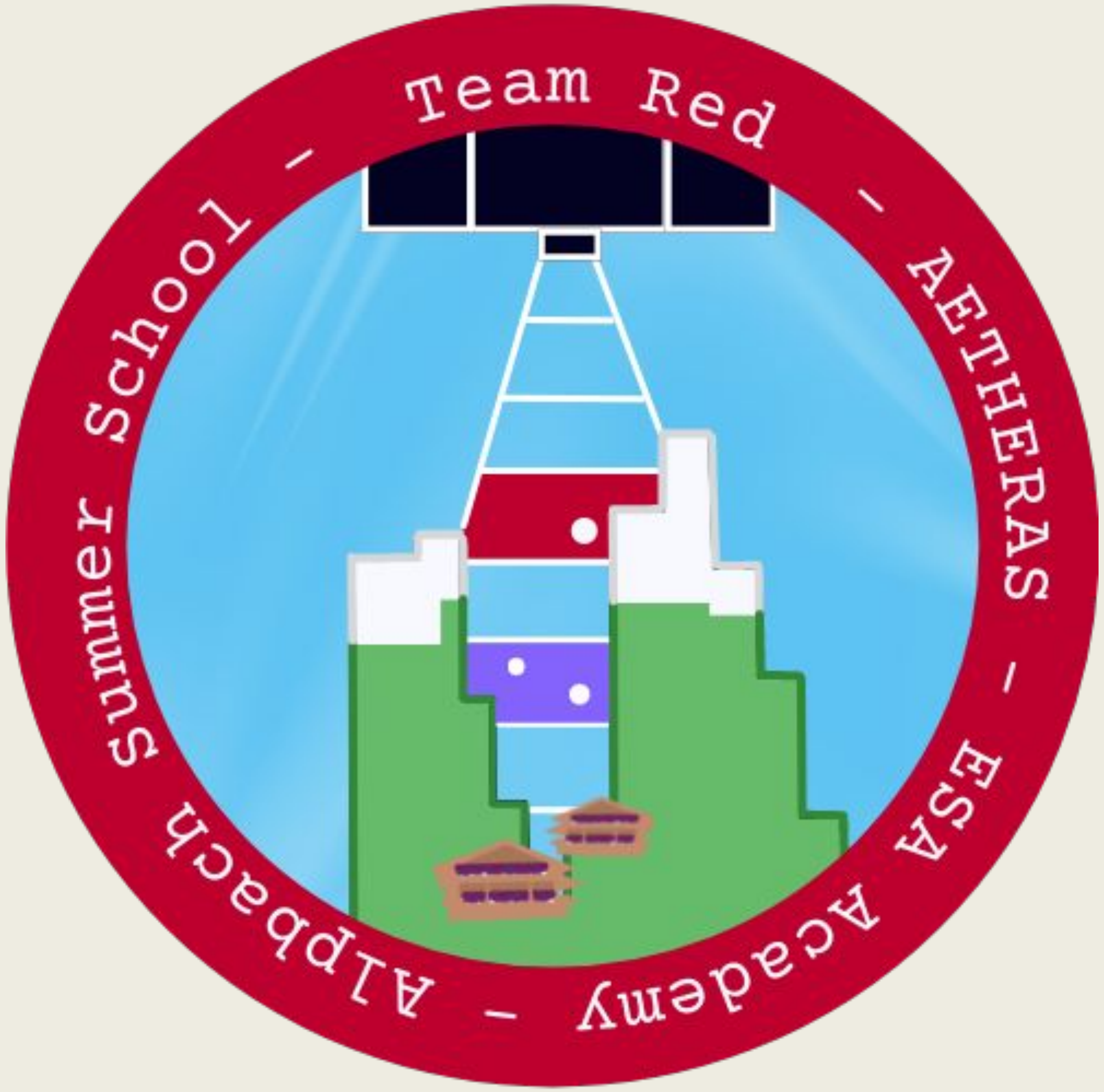
Aetheras

Team Red





“Deepening our knowledge of planetary system formation and evolution by studying atmospheric escape”

Content

Motivation → Science case → Observation strategy → Requirements

Speaker: Jo Ann Egger

Speaker: Elena Tonucci

Requirements → Mission concept → Subsystems → Risks, cost & plan

Speaker: Aksel Beltoft

Speaker: Noria Brecher

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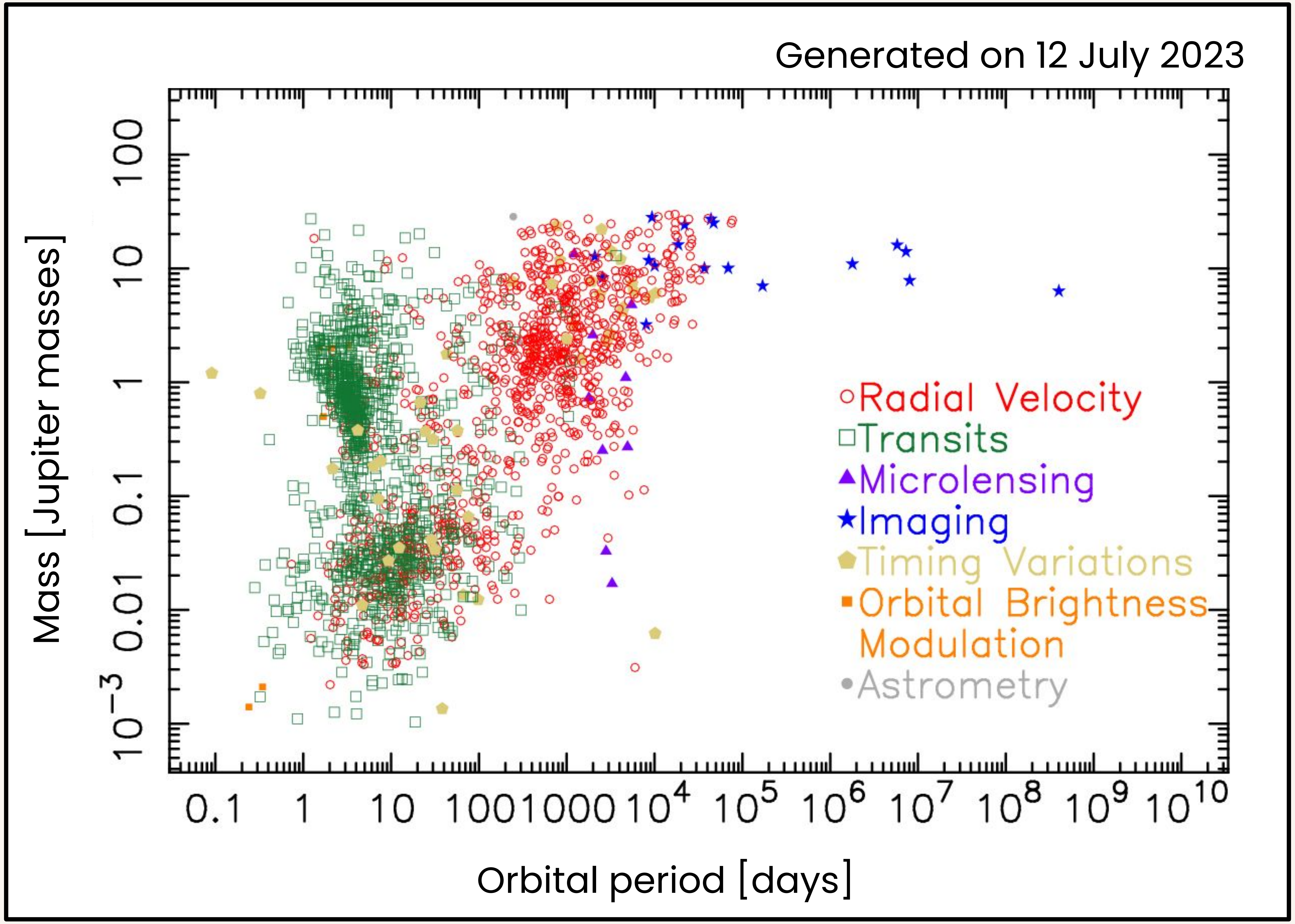
Motivation

Diversity of discovered exoplanets



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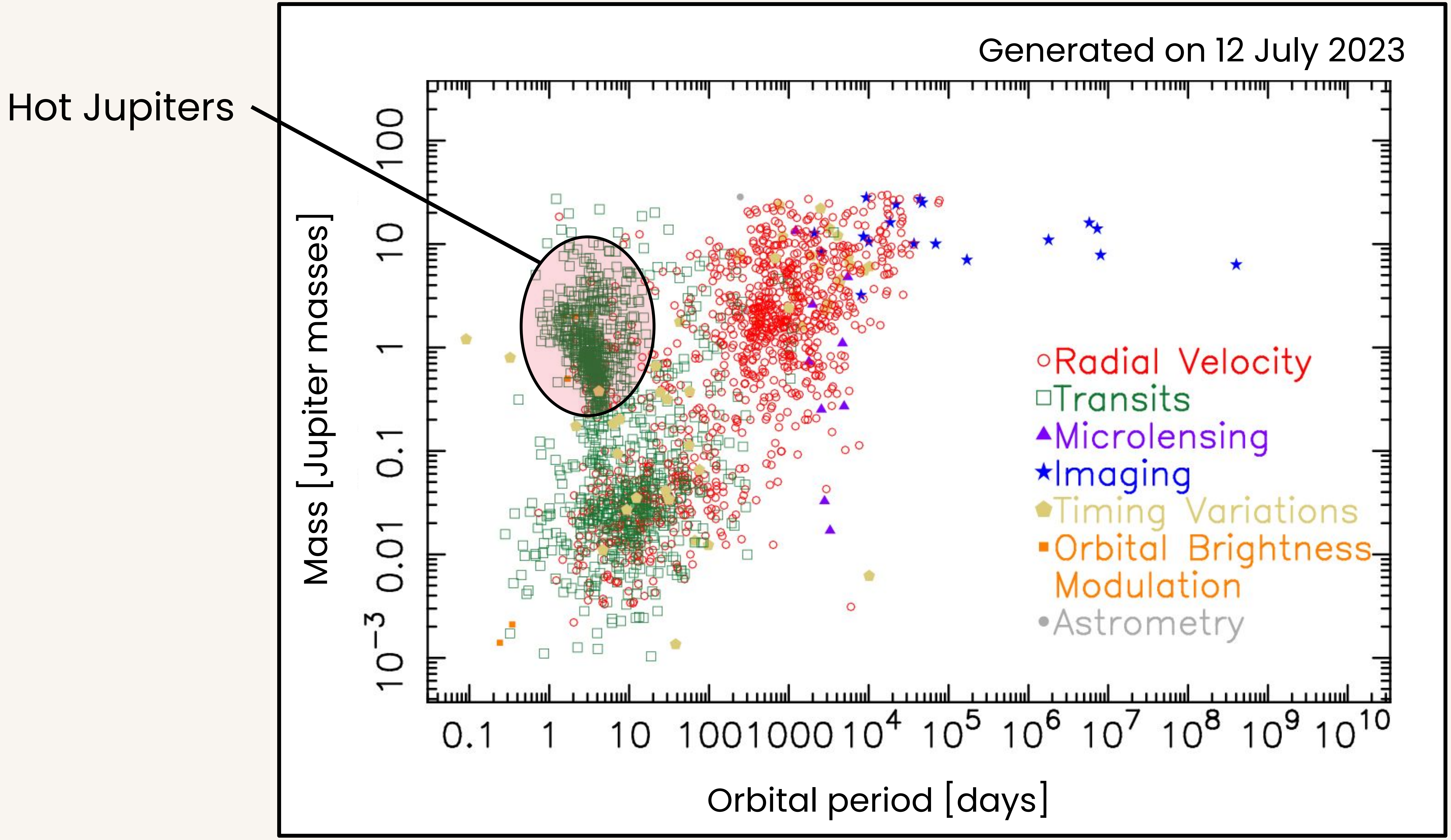

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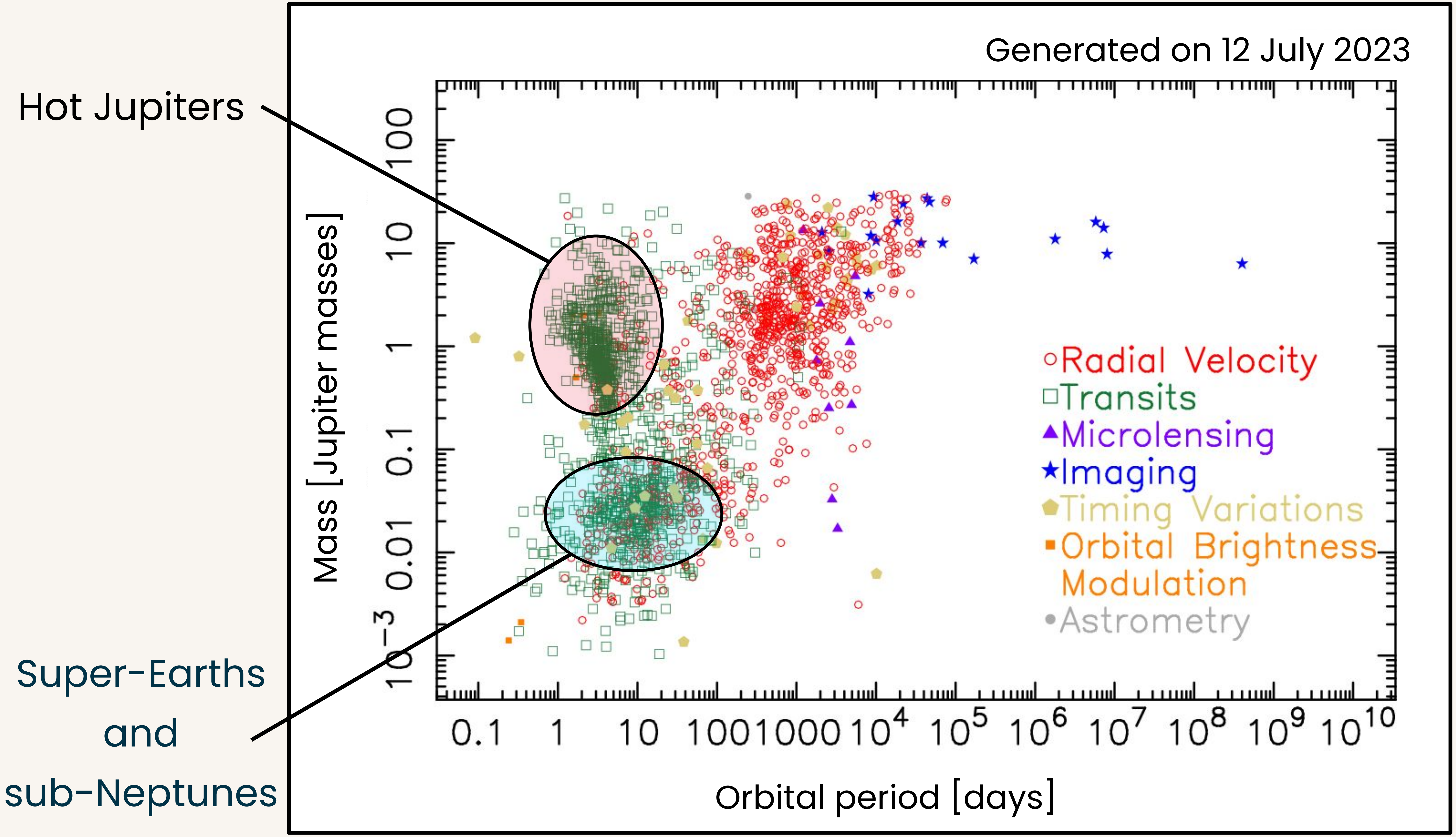
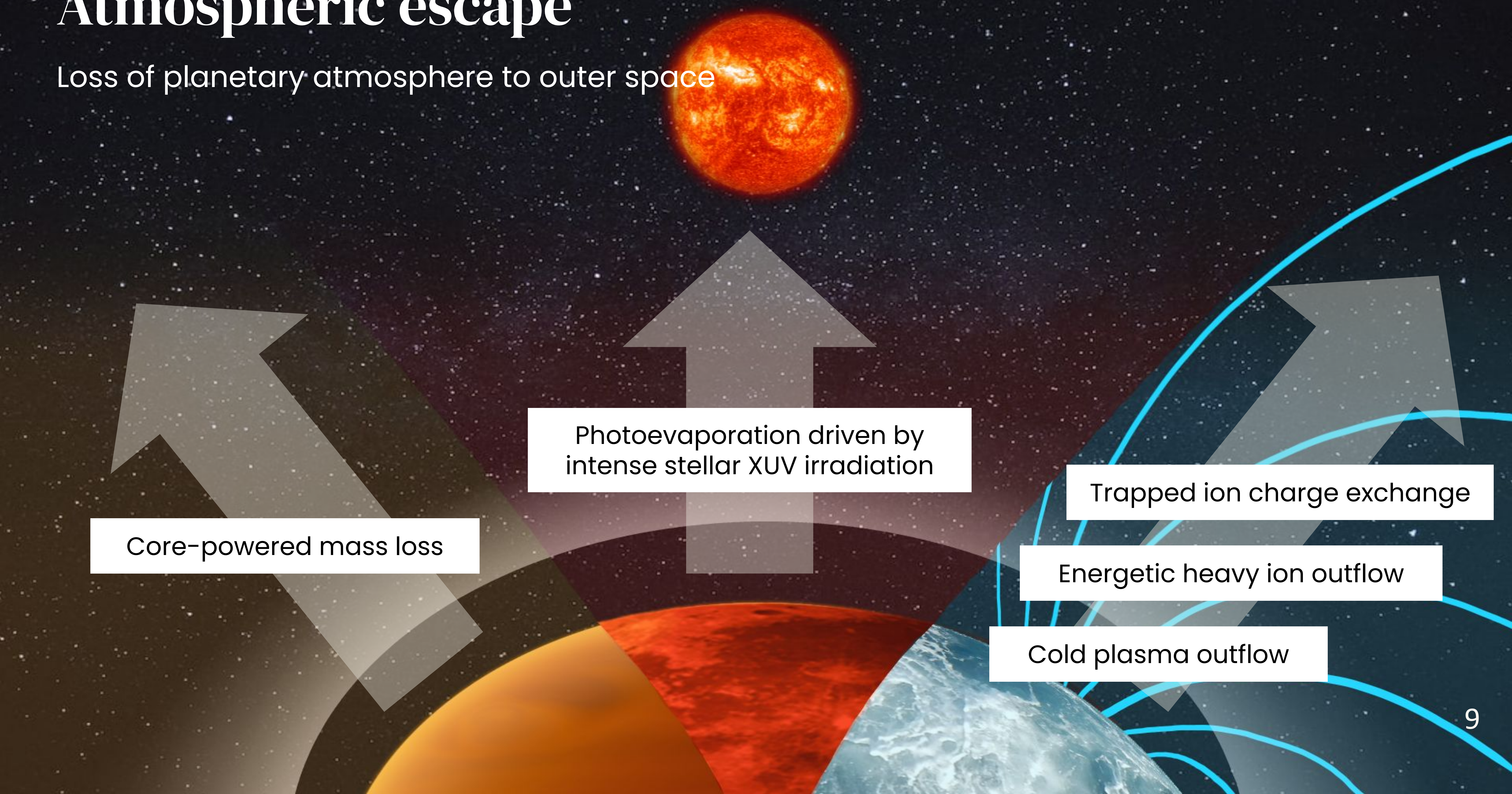
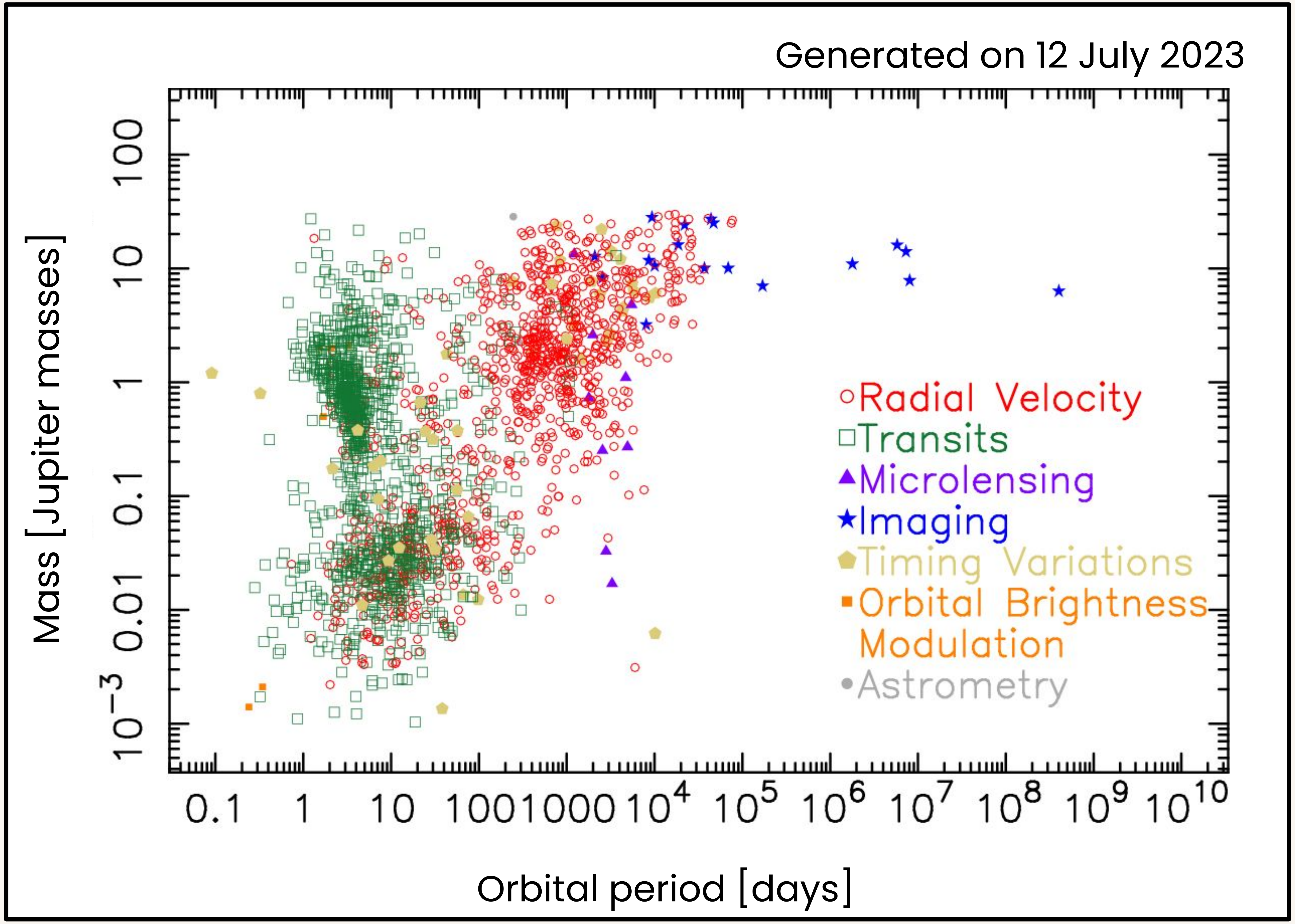


Atmospheric escape

Loss of planetary atmosphere to outer space



Diversity of discovered exoplanets



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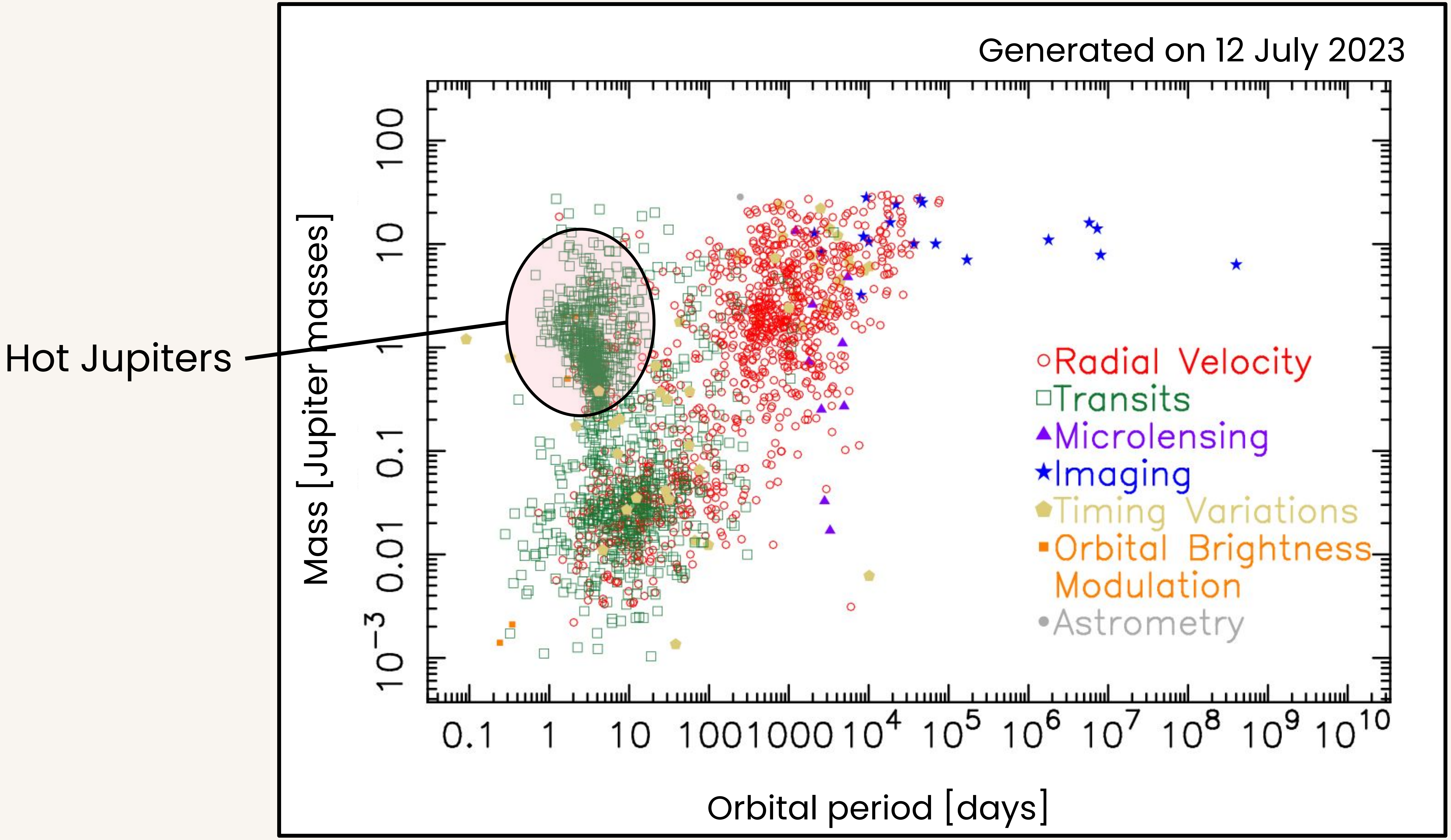
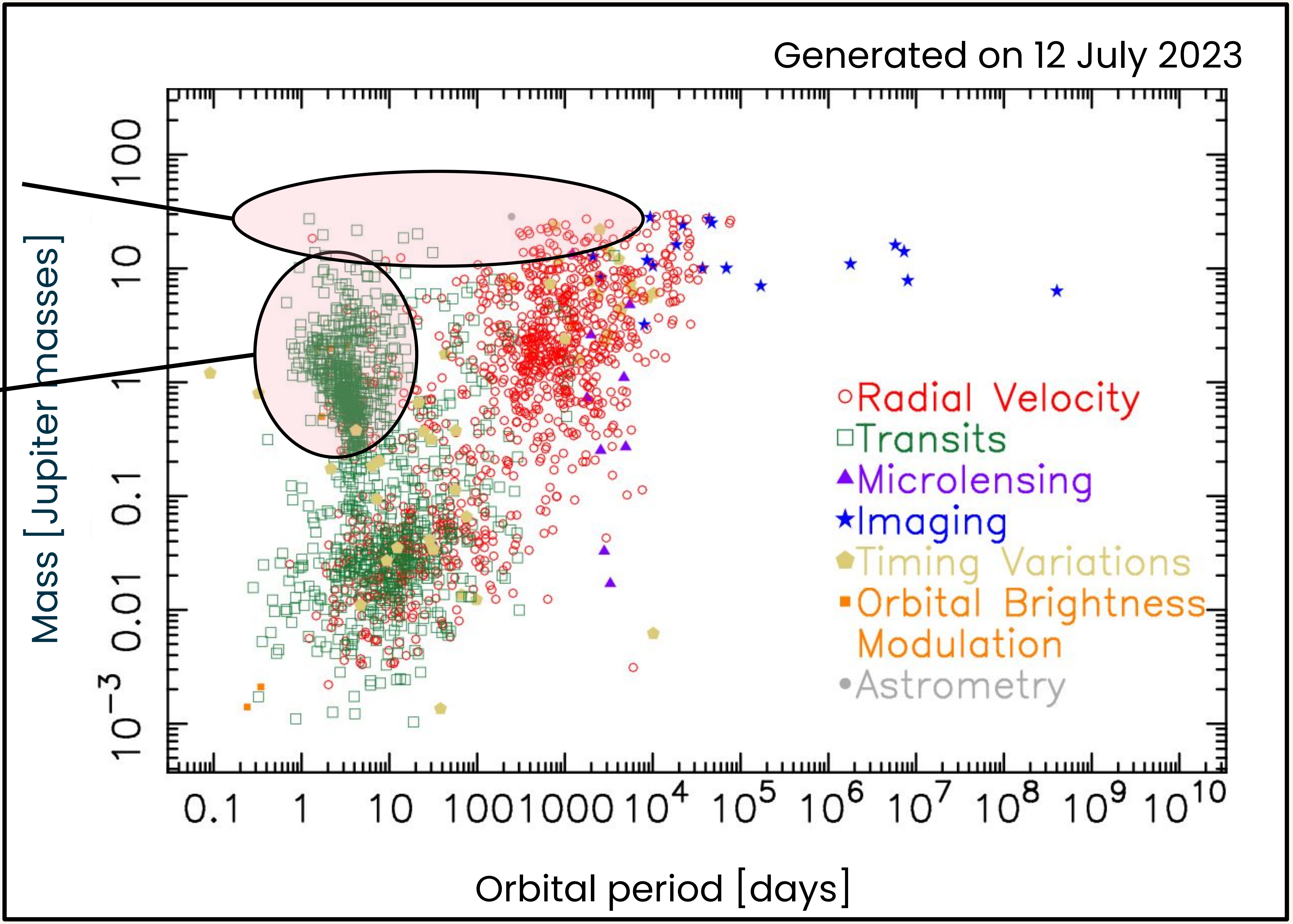


Diversity of discovered exoplanets

Brown dwarfs

Hot Jupiters



Hot Jupiters and brown dwarfs

Large objects expected to have magnetic fields

Hot Jupiters

Close-in gas giants

Magnetic fields expected from models, also some observational evidence

Atmospheric escape expected because of closeness to host stars, also some observational evidence

Batygin+2013, Rogers+Showman 2014, Oklopčić+2020, Vidal-Madjar+2003, Spake+2018

Brown dwarfs

Objects heavy enough to fuse deuterium but not hydrogen

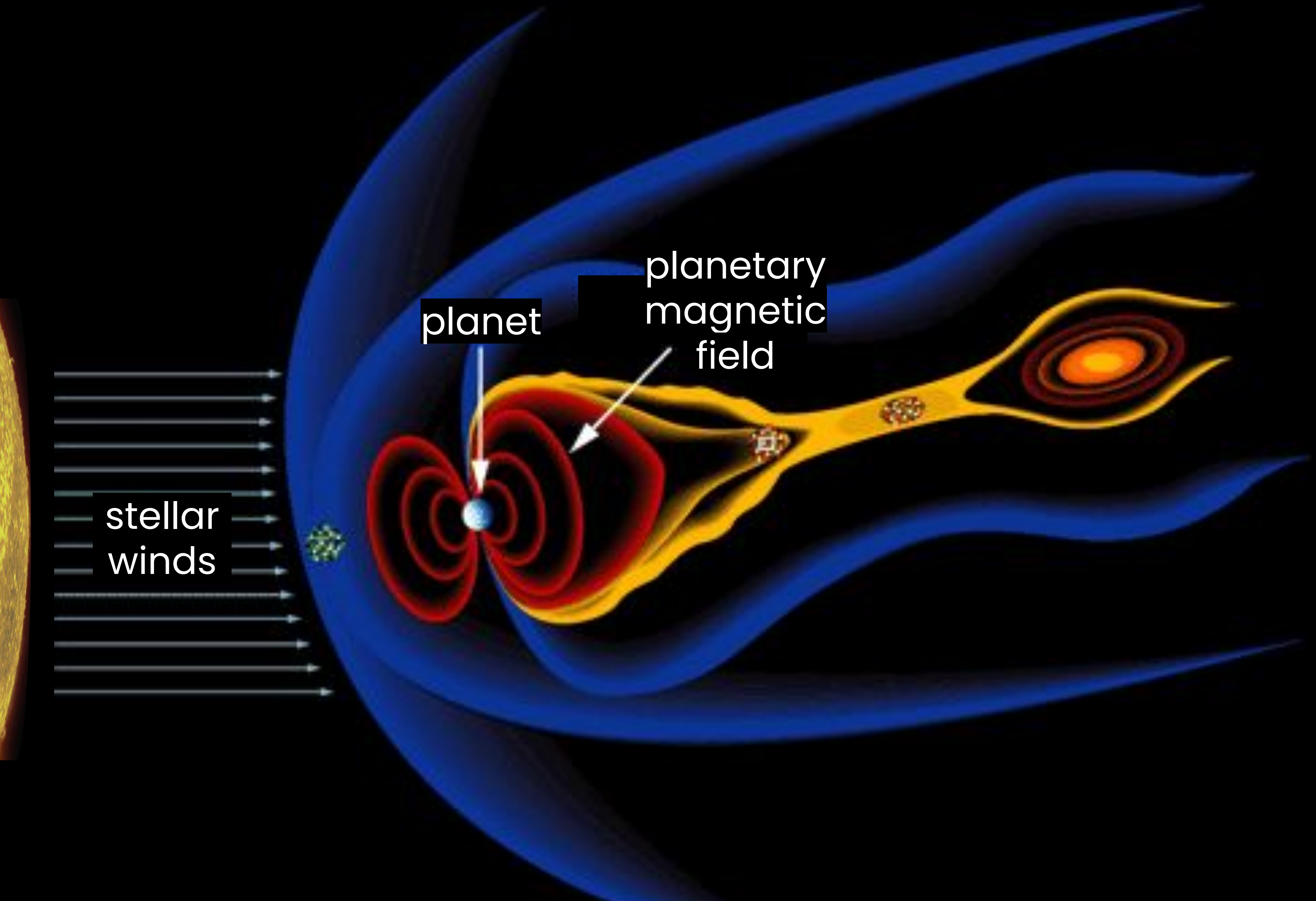
Magnetic fields expected from models, also some observational evidence

Proxies for **atmospheric escape** observed in at least one transiting brown dwarf

Pineda+2017, Saur+2021, Ruíz-Rodriguez+2022

Atmospheric escape and magnetic field

Influence of planetary magnetic field on atmospheric escape still debated



Presence of a magnetic field might:

Preserve atmosphere

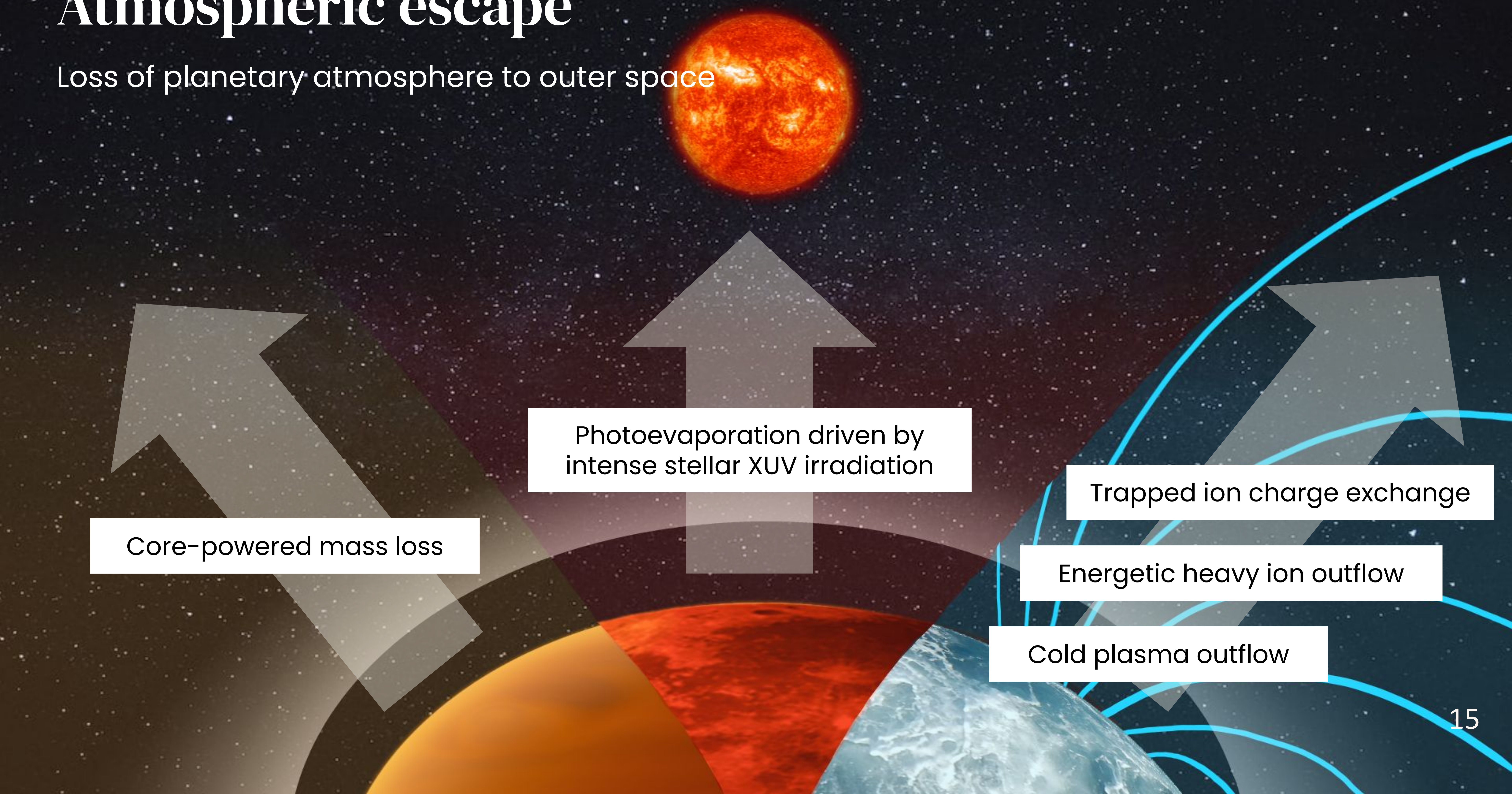
or

Enhance atmospheric escape

Lundin+2006, Gunell+2018

Atmospheric escape

Loss of planetary atmosphere to outer space



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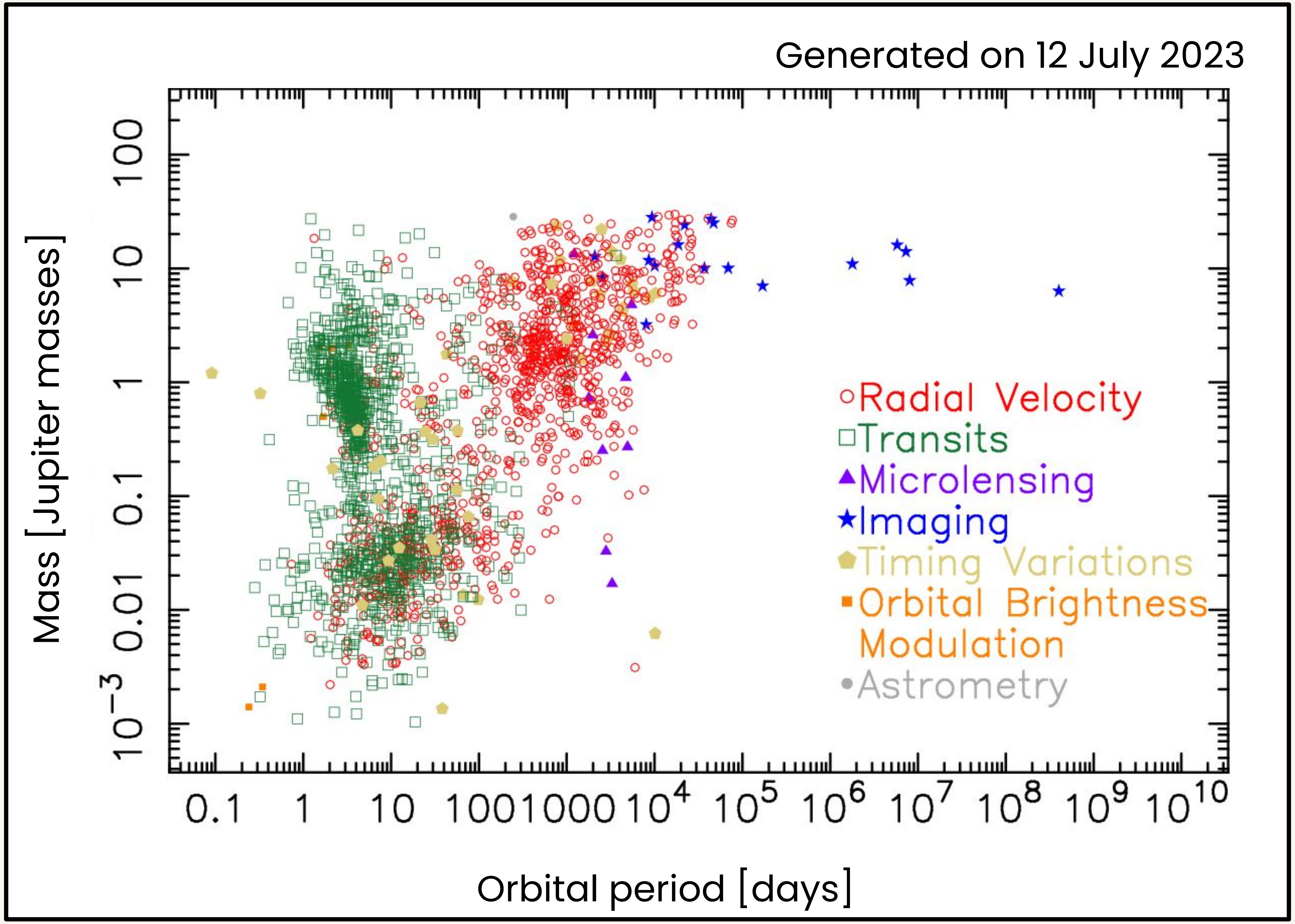
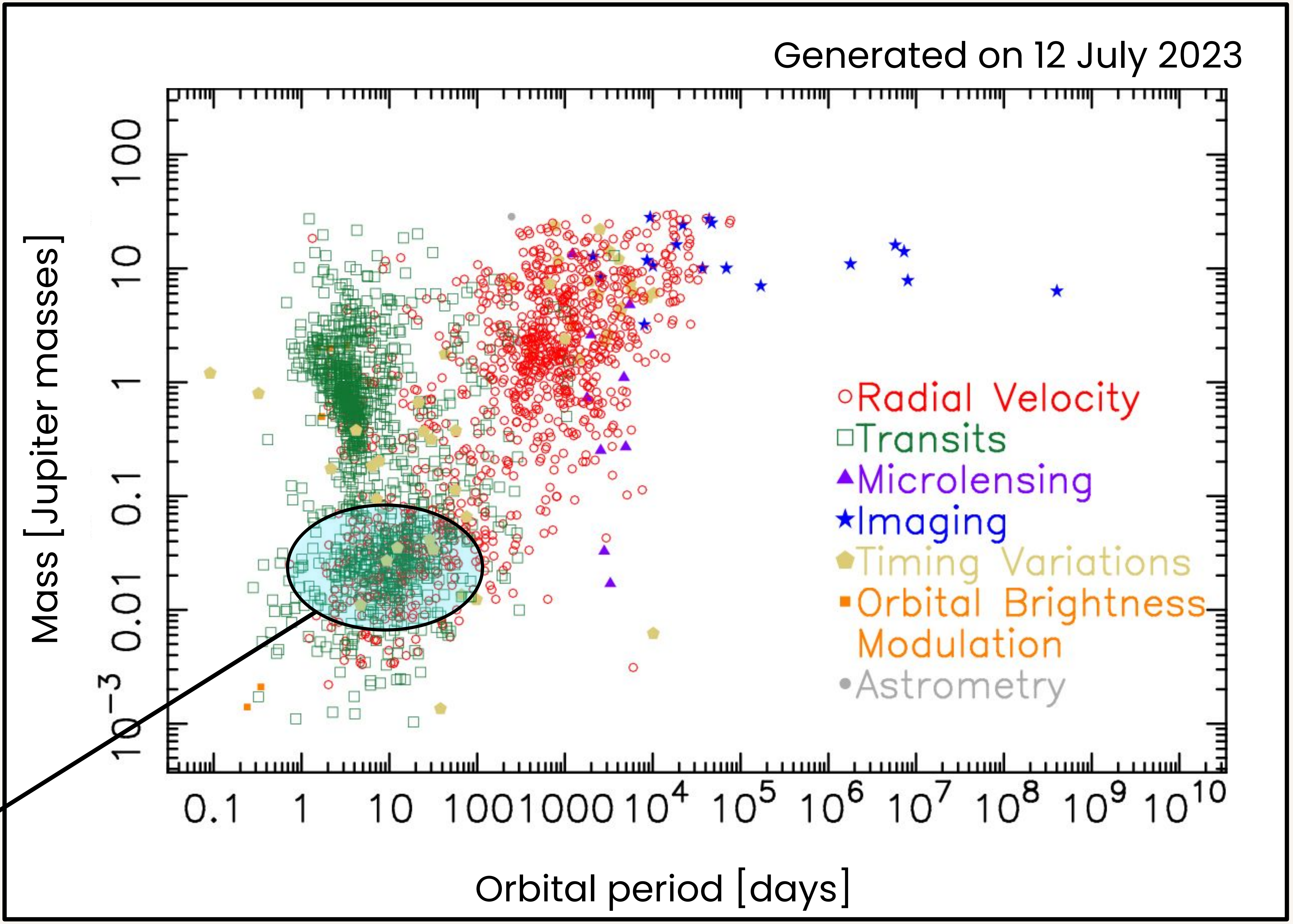


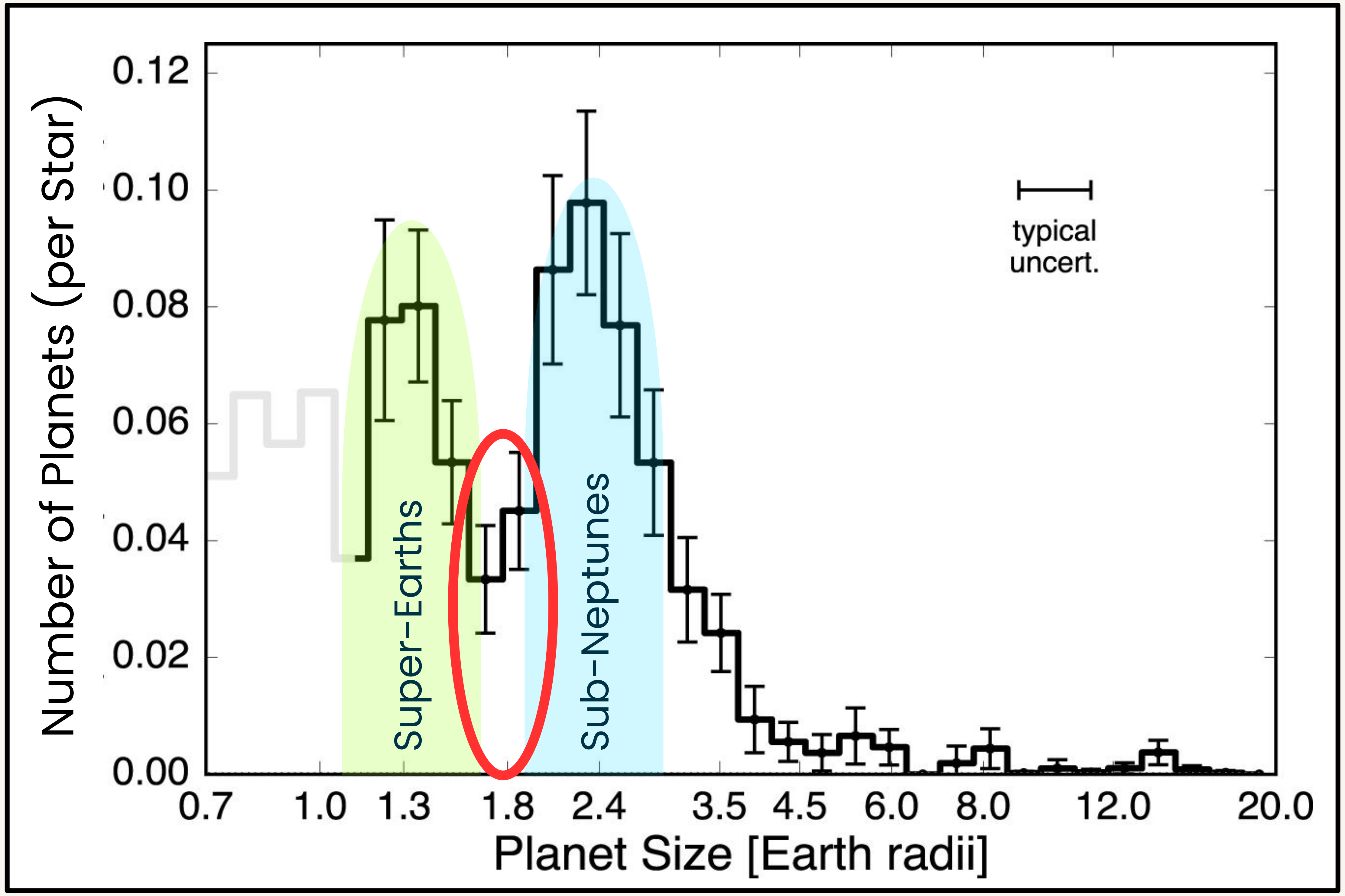
Diversity of discovered exoplanets



Super-Earths and sub-Neptunes

The planetary radius valley

Apparent gap in number of detected planets between roughly 1.5 and 2.0 R_{Earth}



- First predicted in 2013, observational evidence using Kepler results in 2017
- Origin **unclear** and heavily debated
- Planets inside radius valley potentially in **transition state** and undergoing **atmospheric escape**

Fulton+2017, Owen+Wu 2013

The planetary radius valley

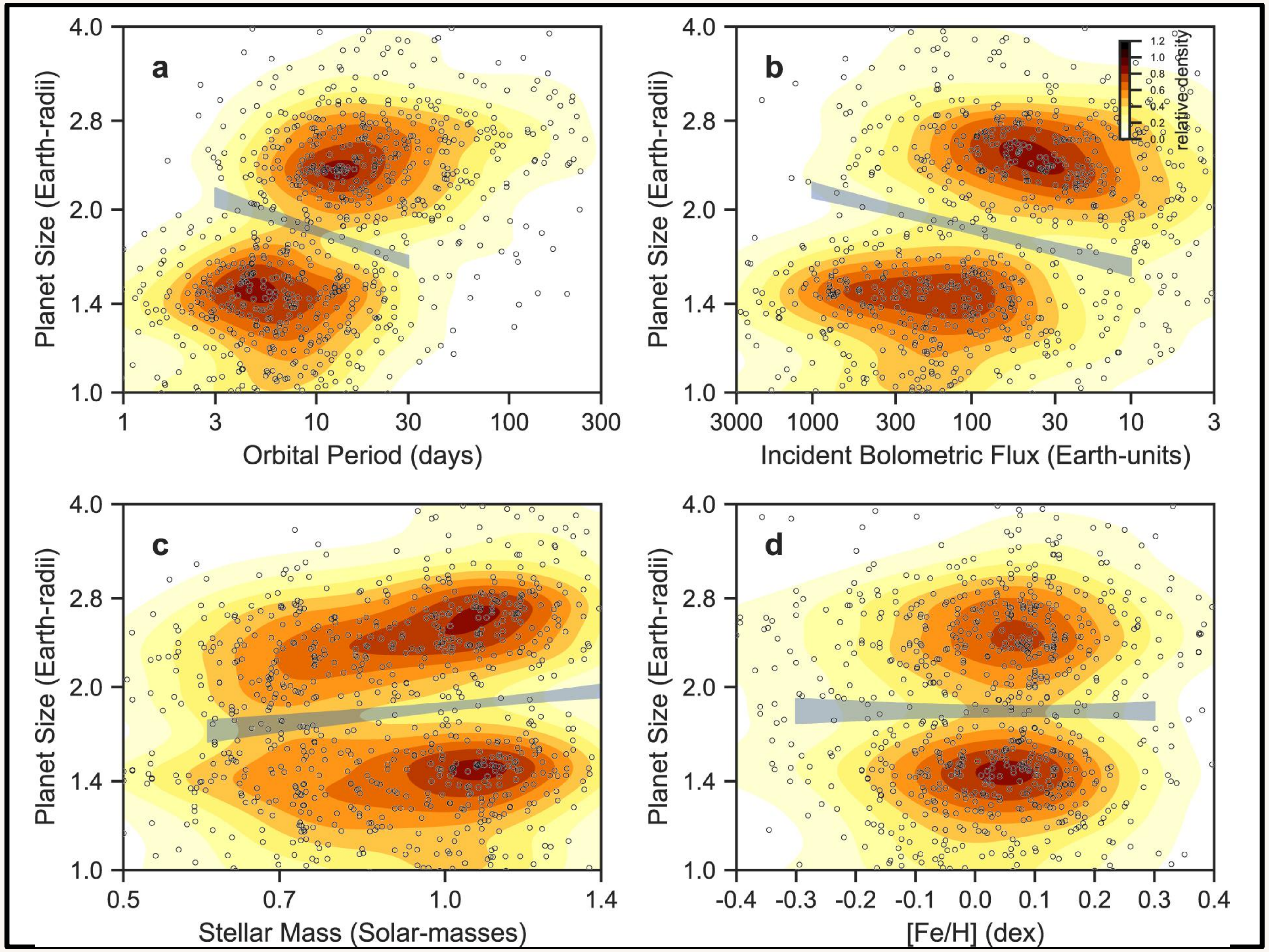
Exact location of radius valley also depends on stellar properties

Orbital Period

Incident flux

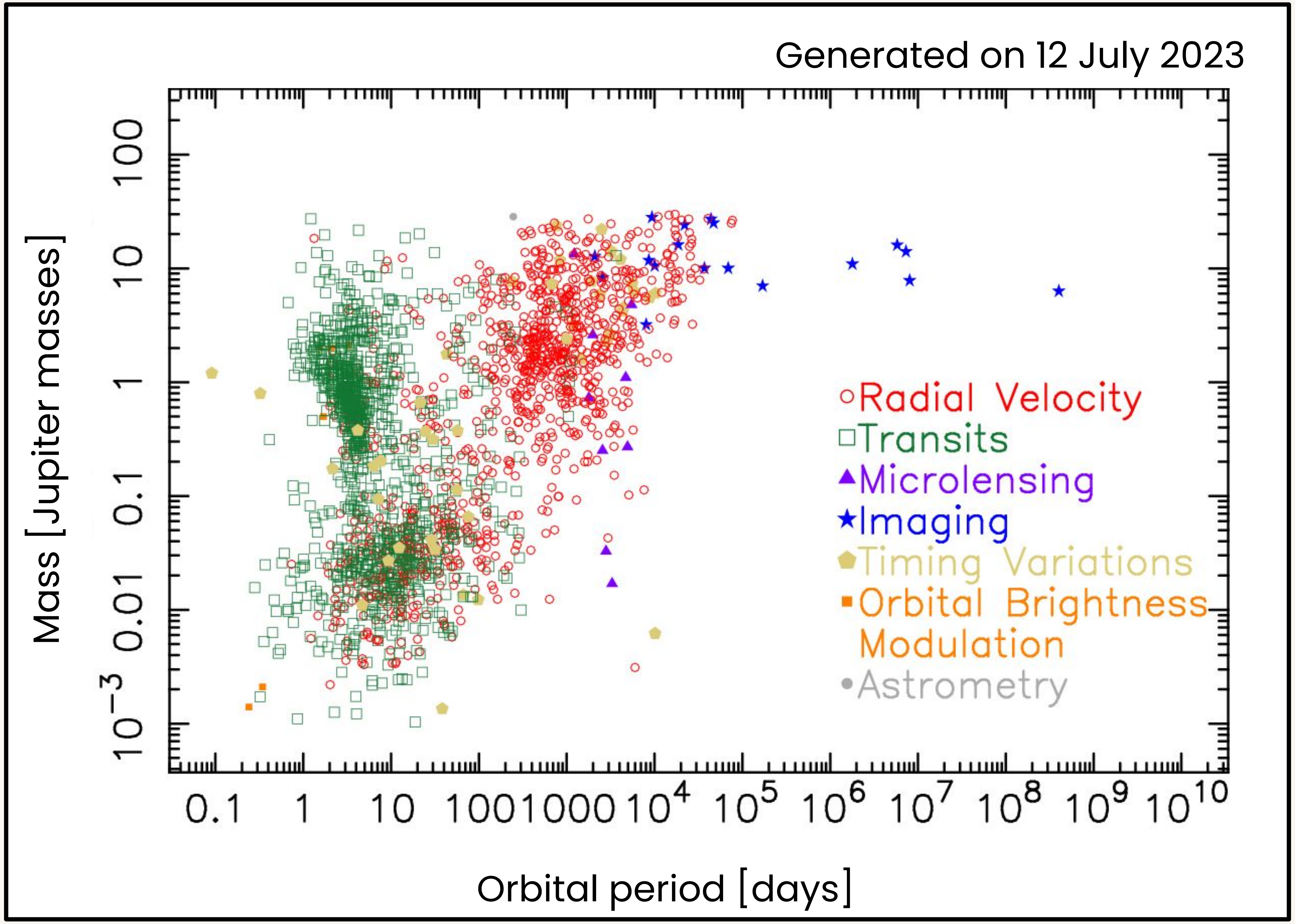
Stellar mass

Stellar metallicity



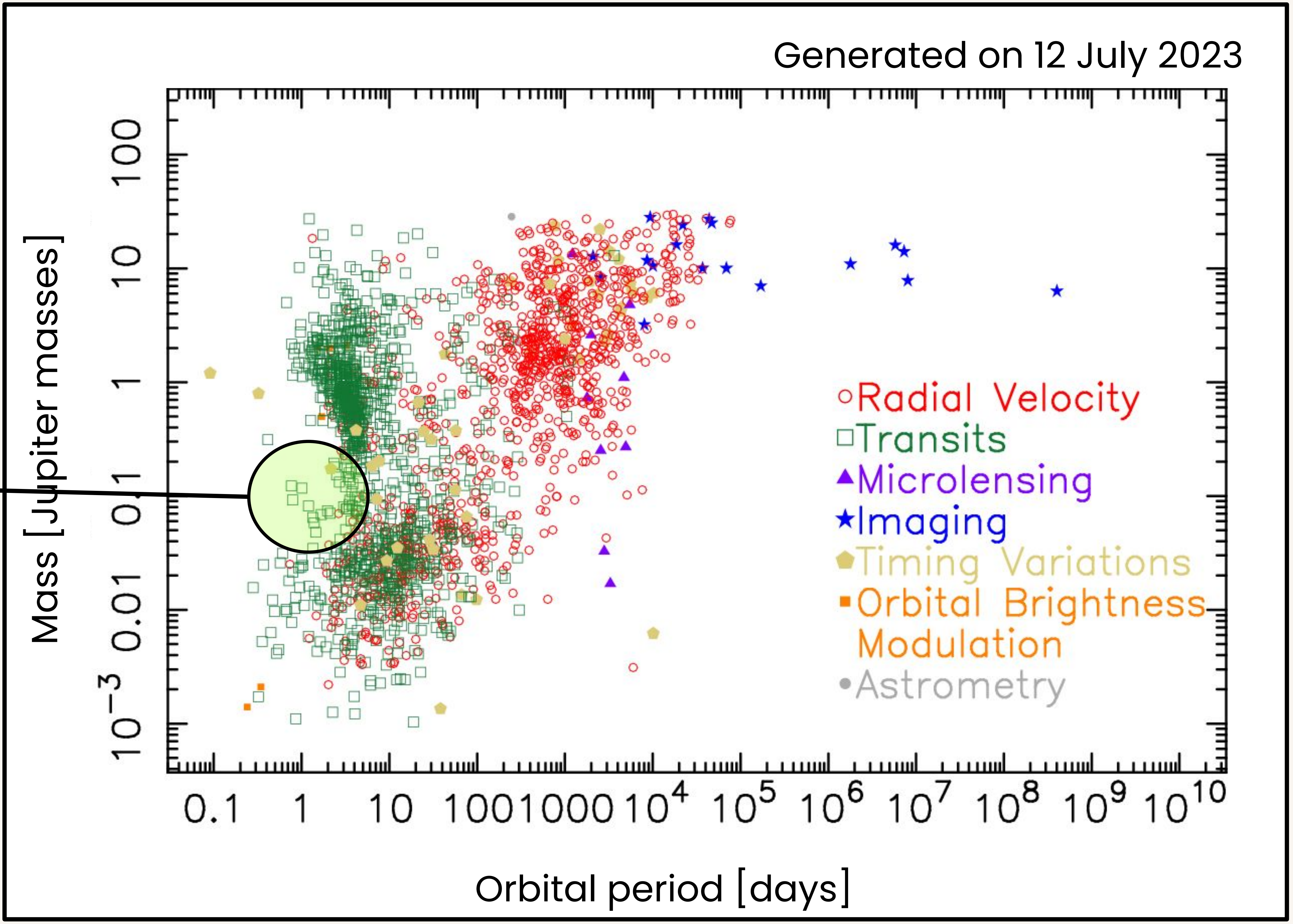
Petigura+2022

Diversity of discovered exoplanets

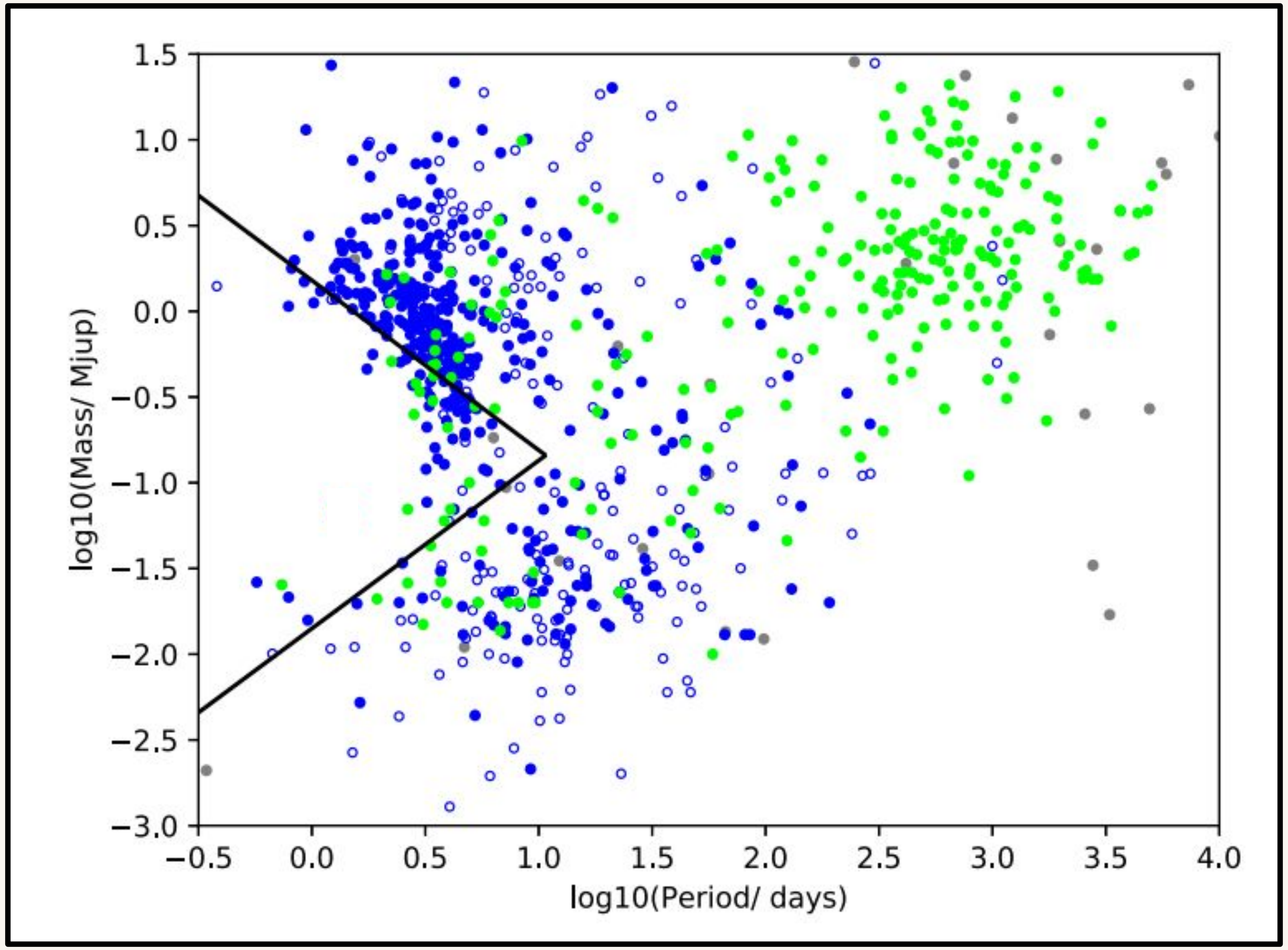


Diversity of discovered exoplanets

Hot Neptune desert



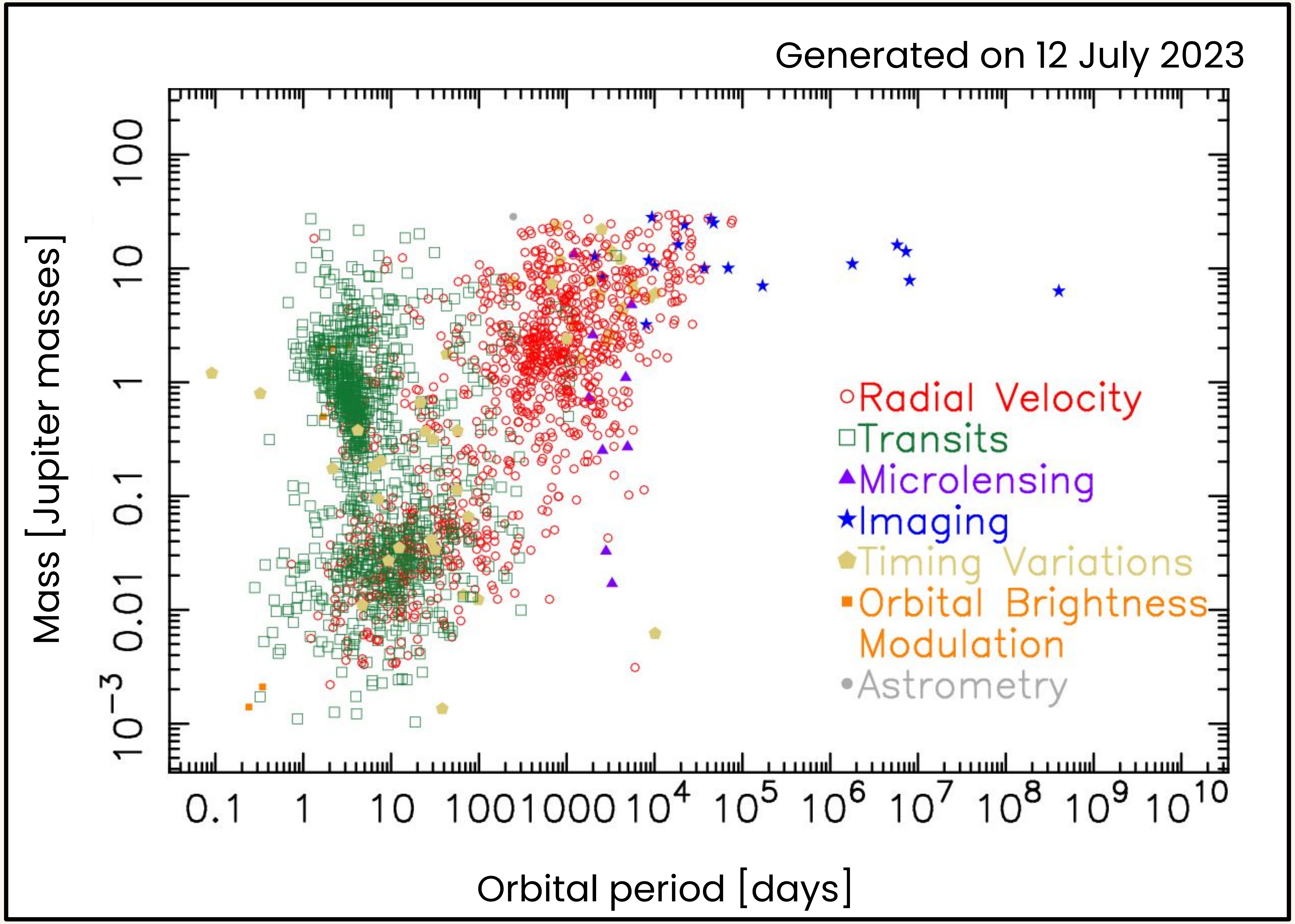
Hot Neptune desert



- Not explained by observational biases
- Possible explanations:
  - Planet formation
  - Migration
  - Atmospheric escape

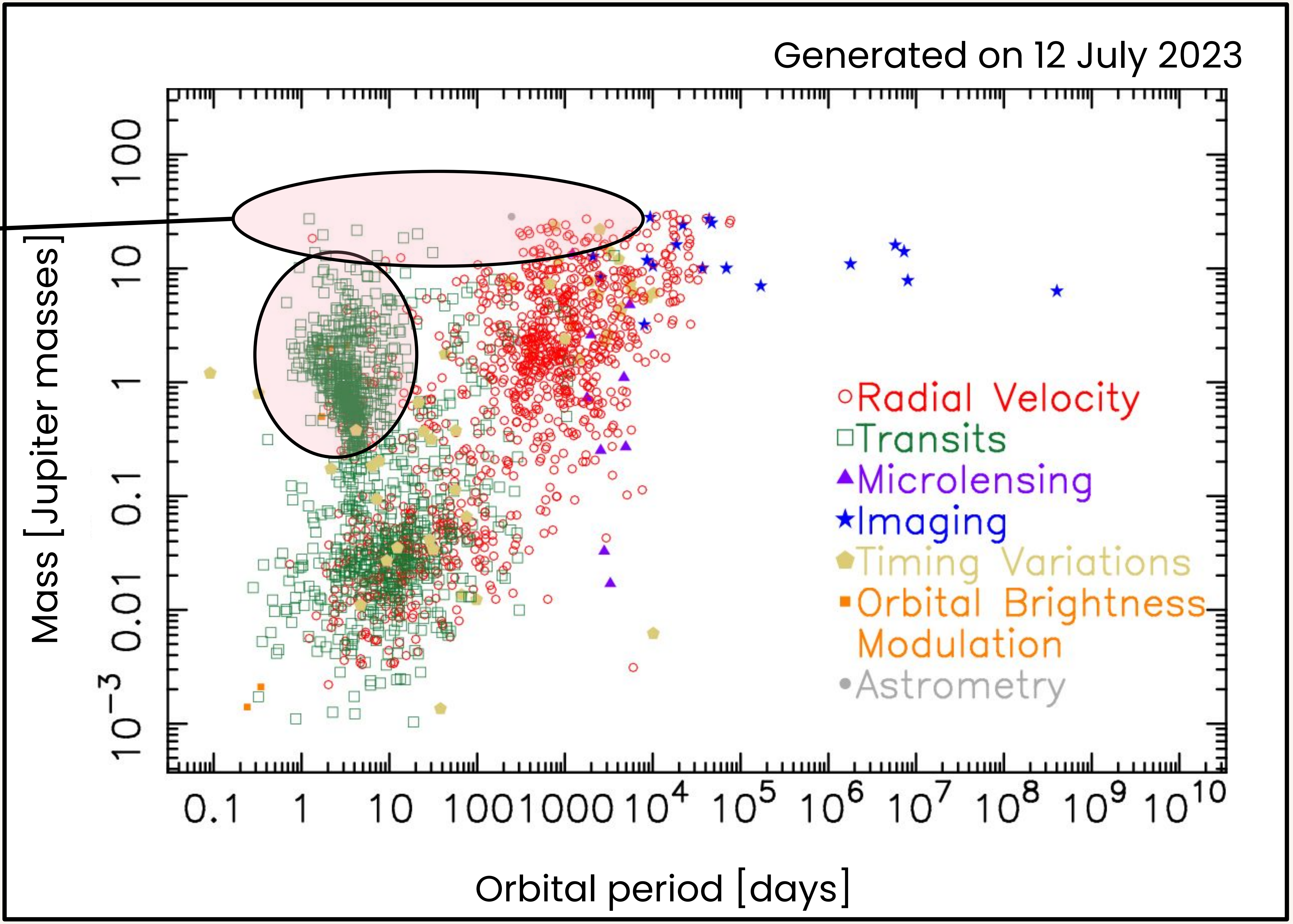
Mazel+2016, Szabo+2019, West+2019

Recap - regions of interest



Recap - regions of interest

Hot Jupiters and brown dwarfs



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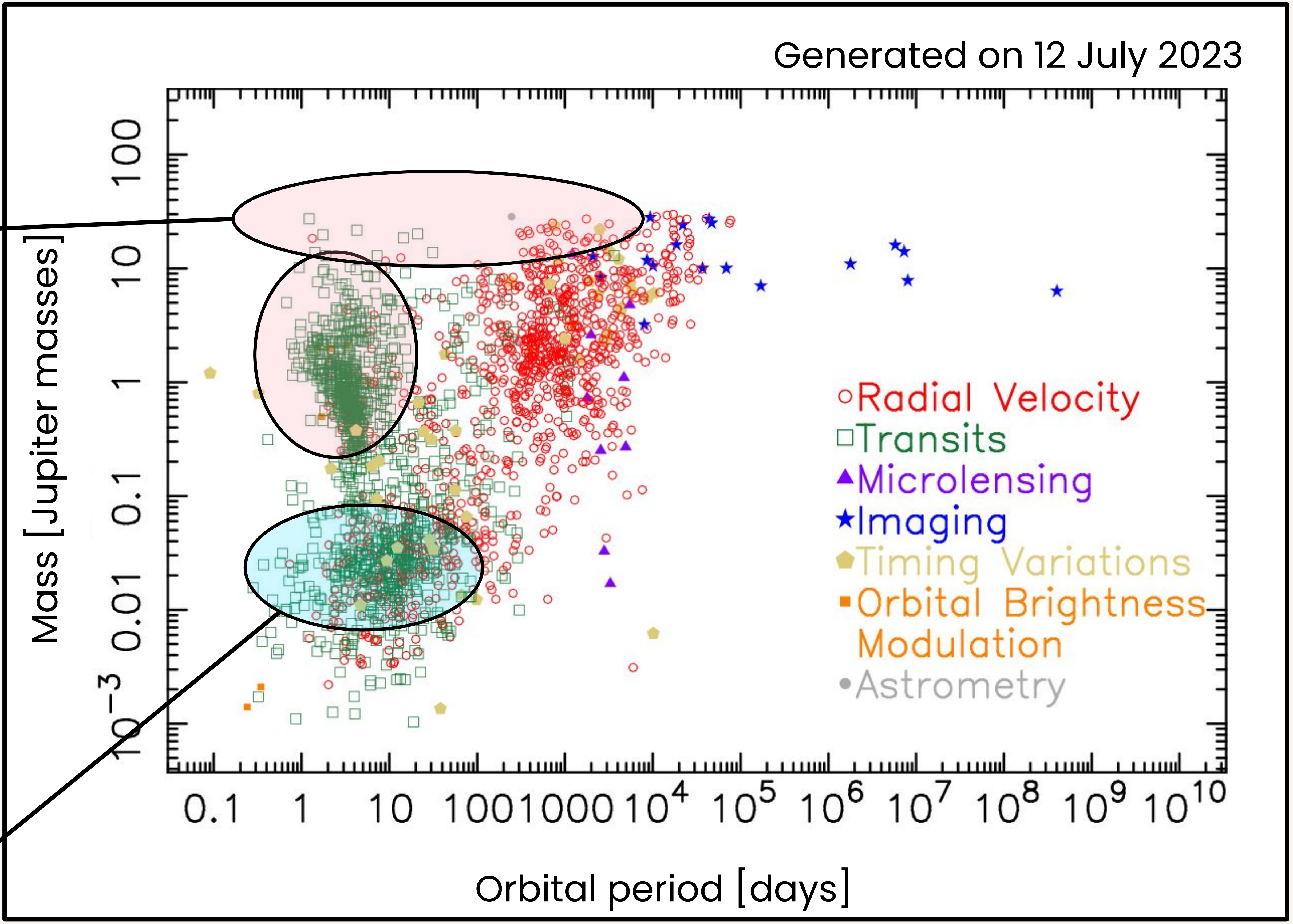


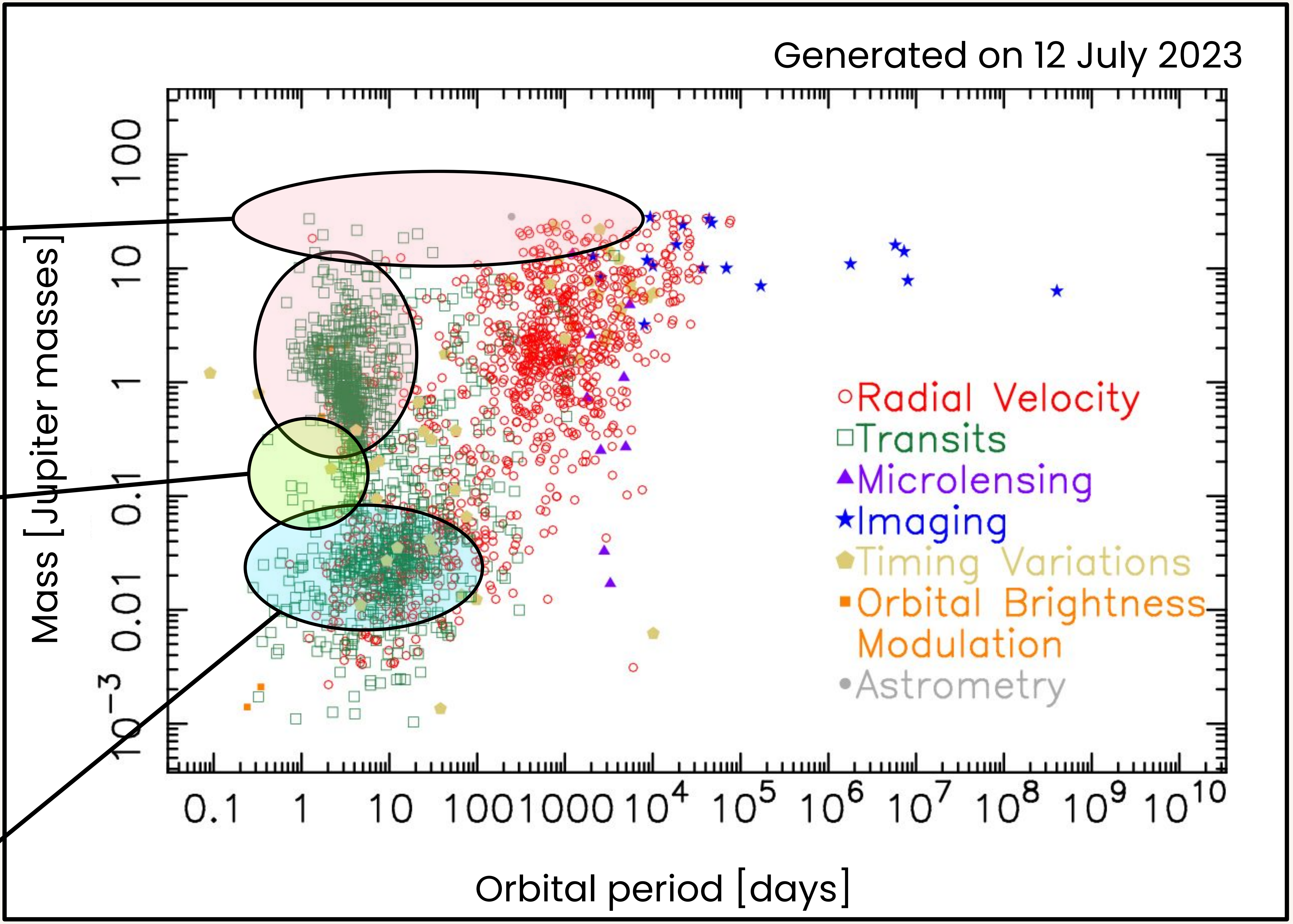
Super-Earths and sub-Neptunes

Recap - regions of interest

Hot Jupiters and brown dwarfs

Hot Neptune desert

Super-Earths and sub-Neptunes



Science case

Deepening our knowledge of planetary system formation and evolution by studying atmospheric escape

Science Objectives

SO1. Are there correlations between the characteristics of exoplanets, the properties of their host stars and atmospheric escape?

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Science Objectives

SO1. Are there correlations between the characteristics of exoplanets, the properties of their host stars and atmospheric escape?

SO2. Is atmospheric escape a factor in creating the radius valley?

SO3. Is atmospheric escape a factor in creating the hot Neptune desert?

Deepening our knowledge of planetary system formation and evolution by studying atmospheric escape

Science Objectives

SO1. Are there correlations between the characteristics of exoplanets, the properties of their host stars and atmospheric escape?

SO2. Is atmospheric escape a factor in creating the radius valley?

SO3. Is atmospheric escape a factor in creating the hot Neptune desert?

SO4. How does the magnetic field of exoplanets influence atmospheric escape?

Content

Motivation → Science case → **Observation strategy** → **Requirements**

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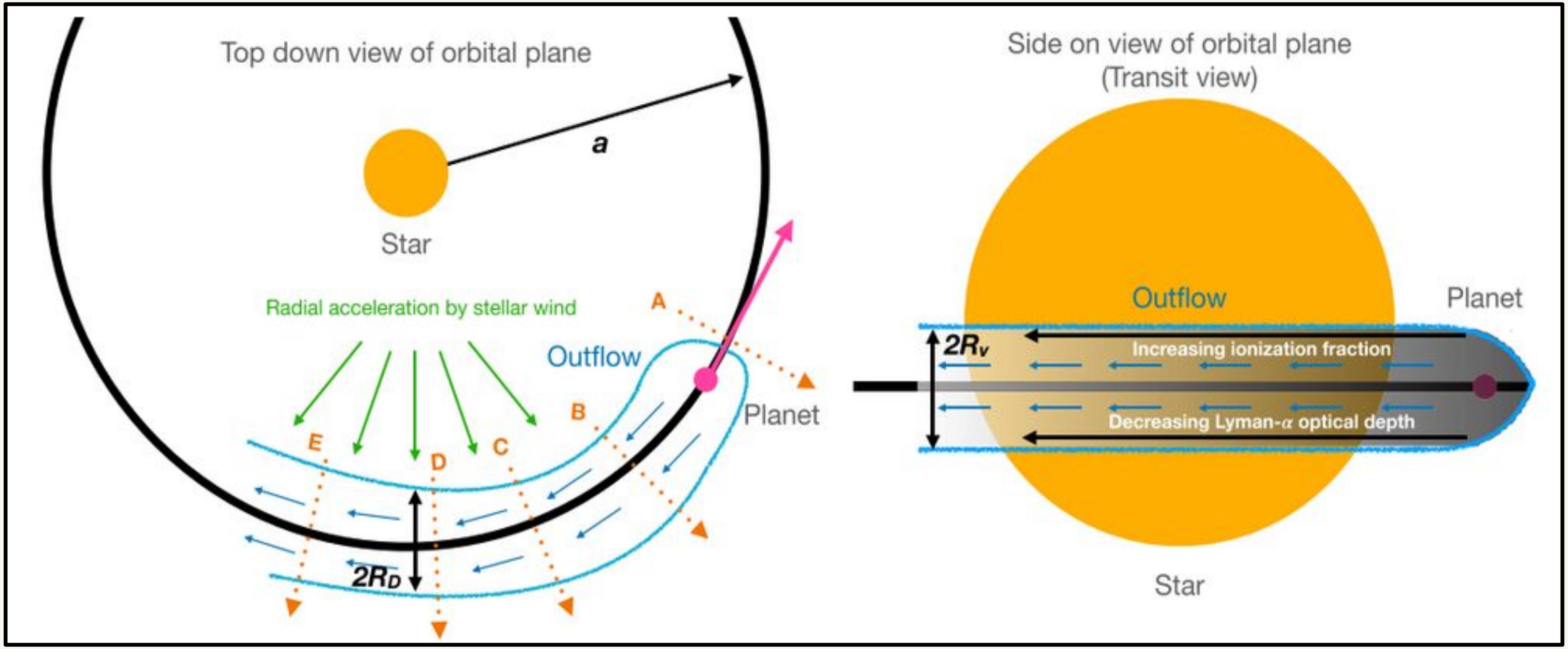
Observation strategy

Techniques for atmospheric escape detection

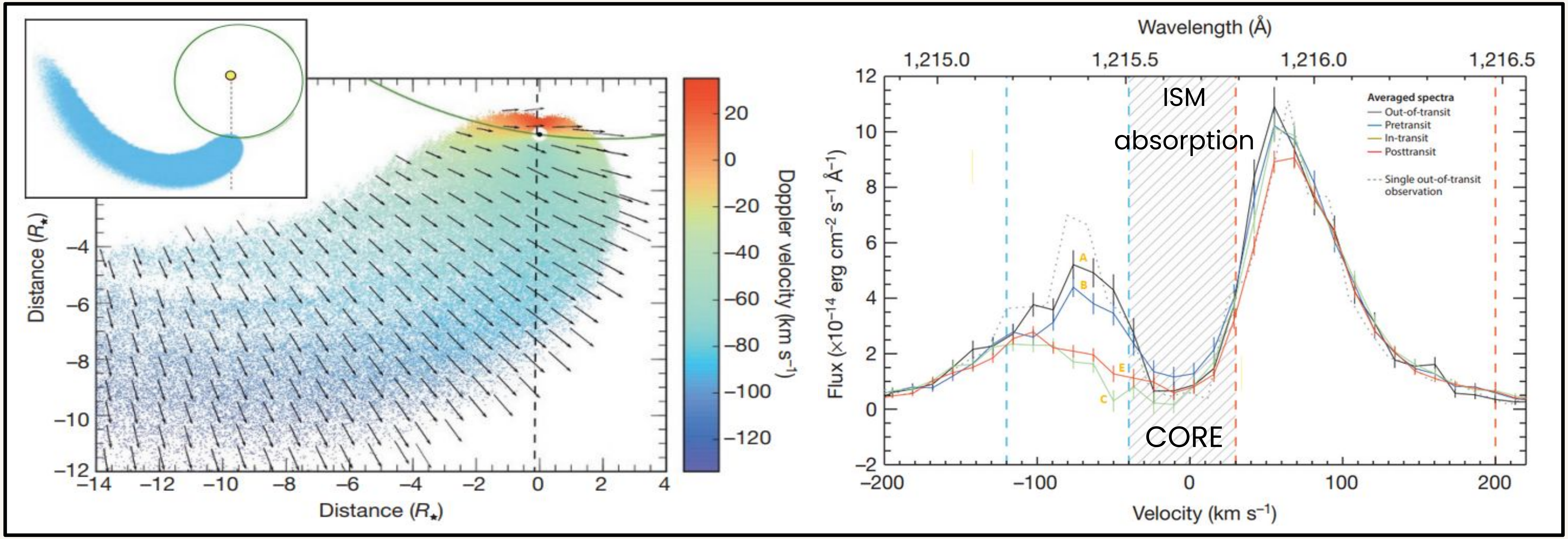
Hydrogen Ly-α emission line (121.6nm)



Owen+2023

Techniques for atmospheric escape detection

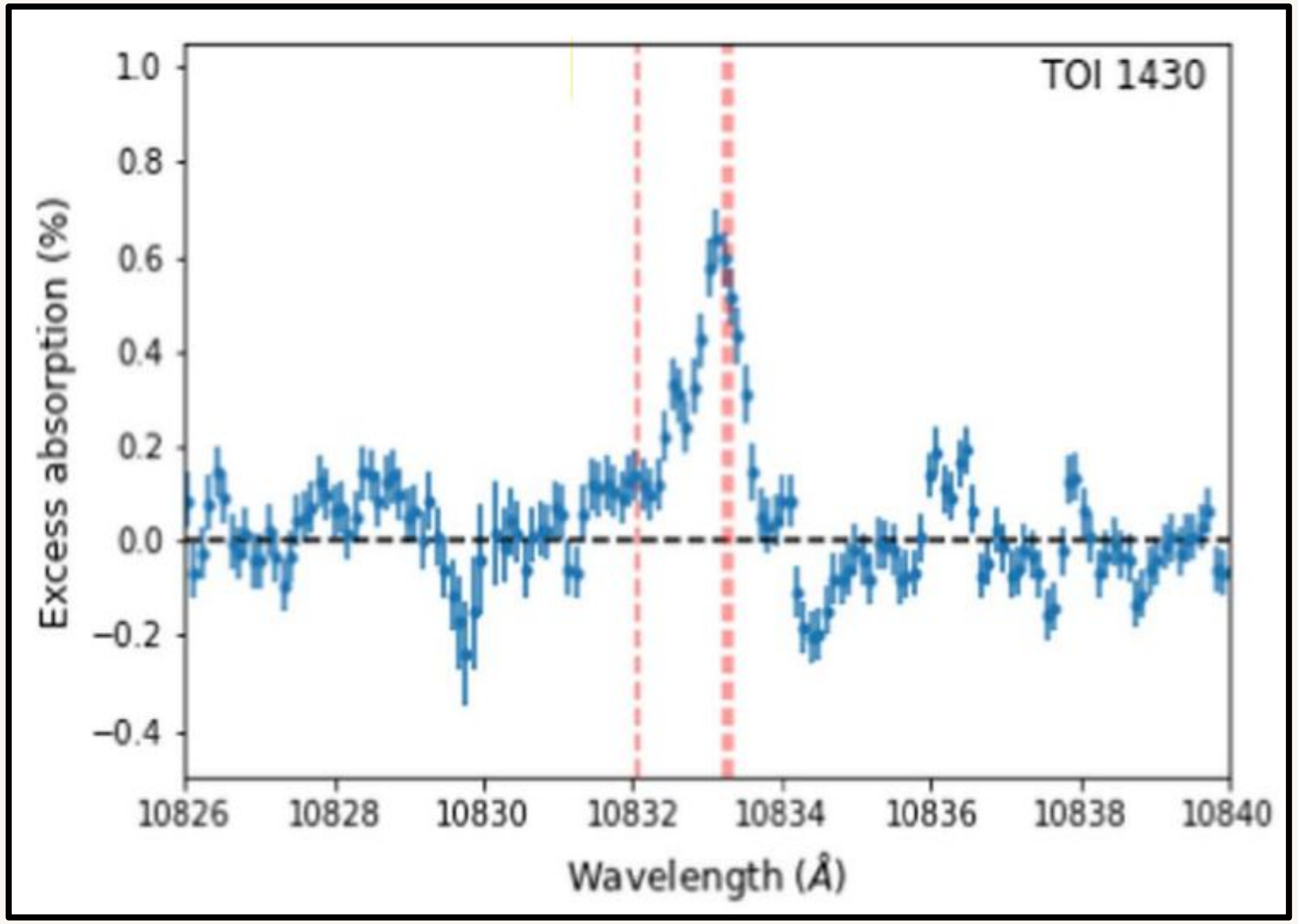
Hydrogen Ly-α emission line (121.6nm)



Ehrenreich+2015

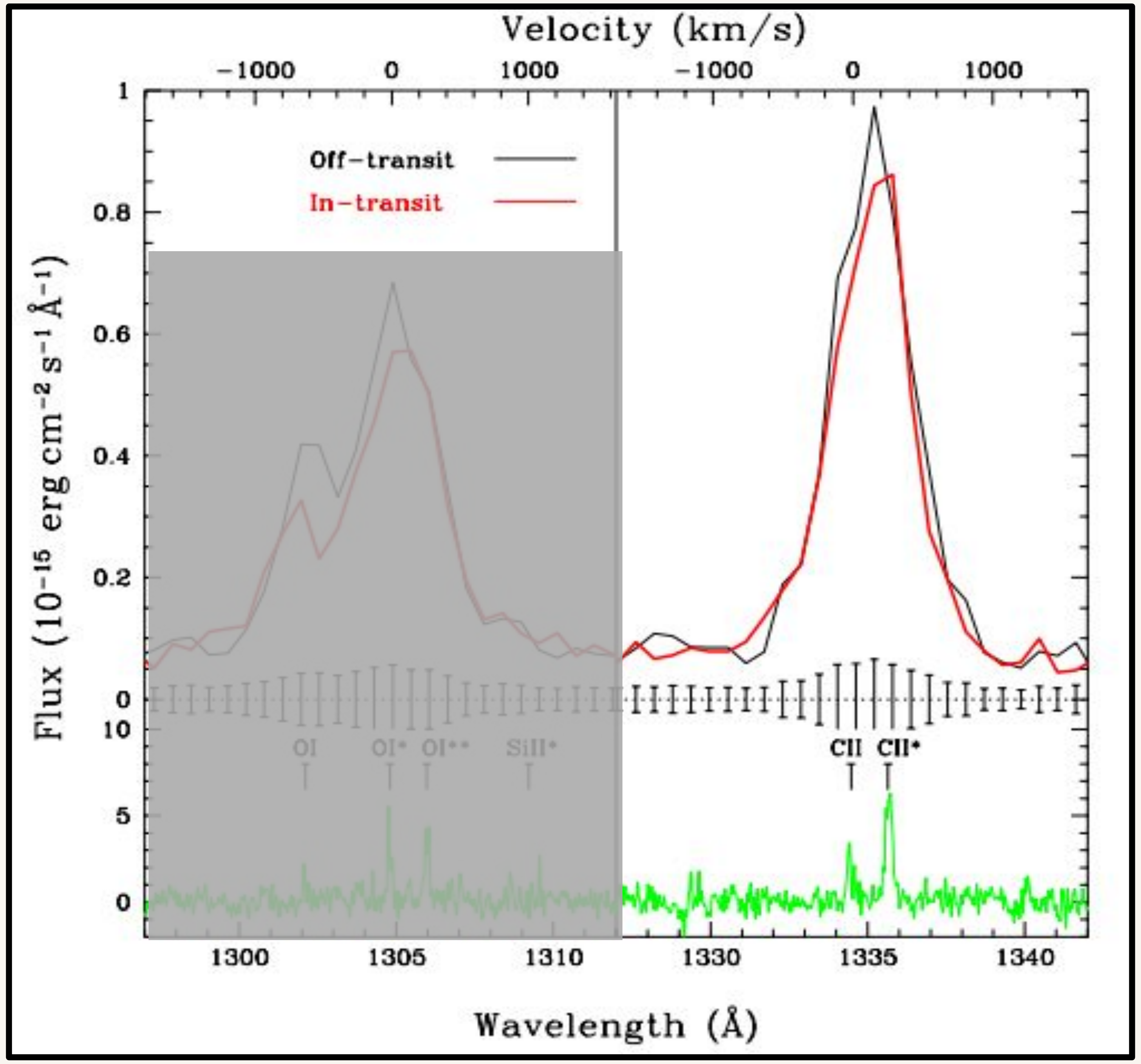
Techniques for atmospheric escape detection

Helium I line (1083.0nm)



Zhang+2023

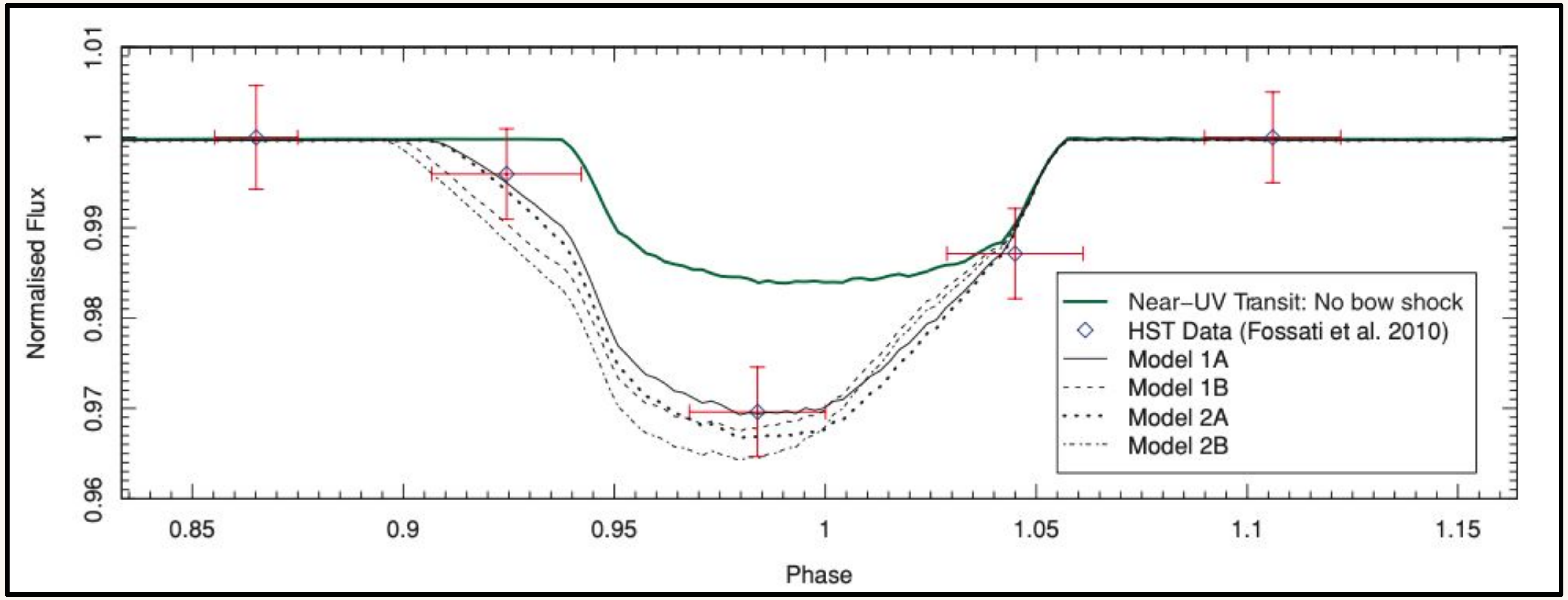
Carbon II (133.45nm)



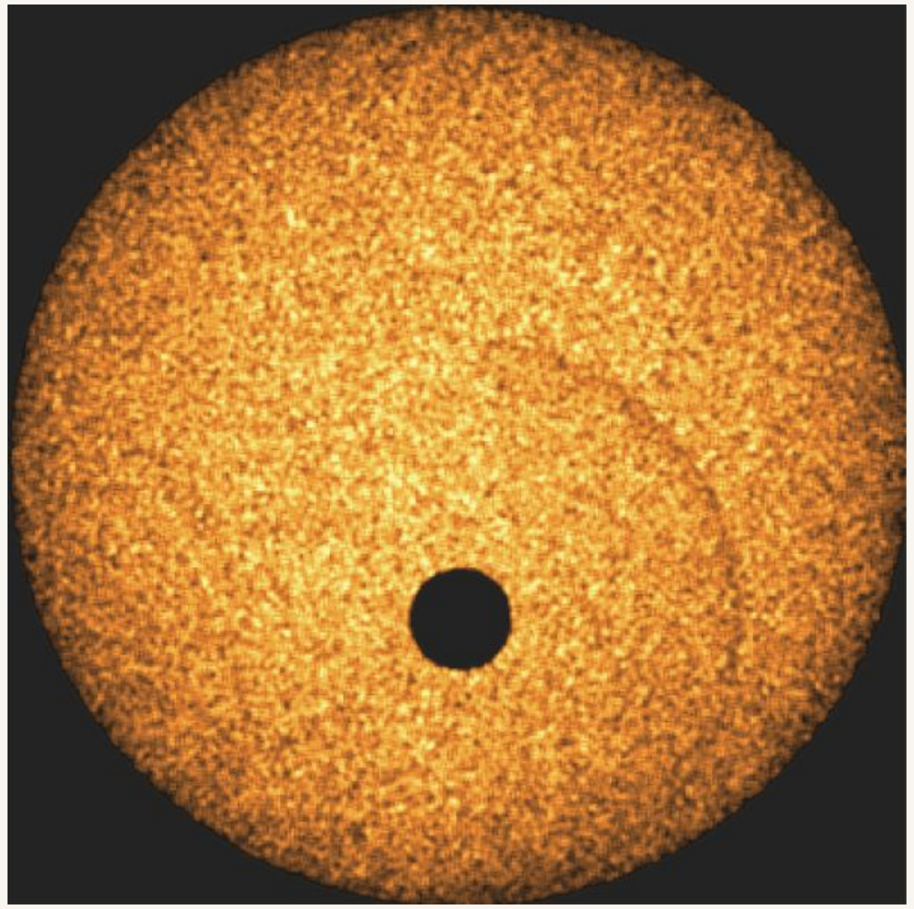
Vidal-Madjar+2018

Magnetic fields

- **Bow shock** → higher density region → **early ingress in the UV** (Mg II)
- Magnetic field can influence the **radial velocity** of **gas clouds**
- **C II** in the **magnetosphere tail** sensitive to magnetic fields → asymmetric transit curve

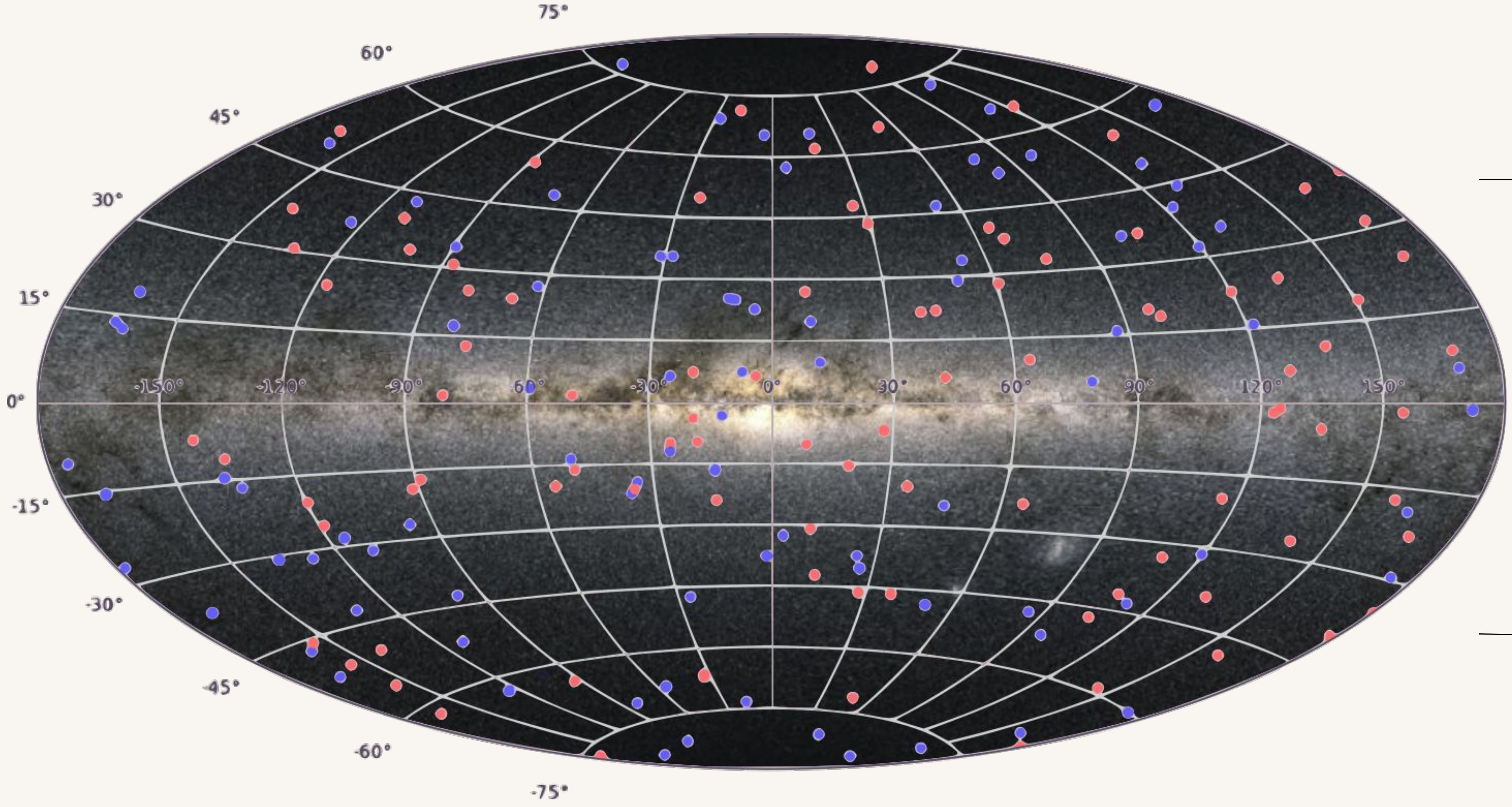


J. Llama+ 2011



Simulation of a transit with bow shock

Candidate target list

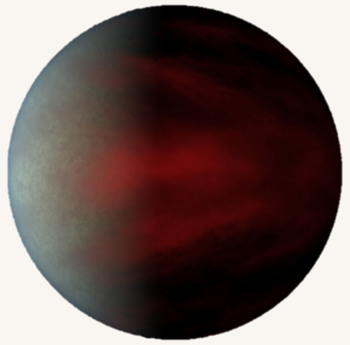


120 in and around radius valley

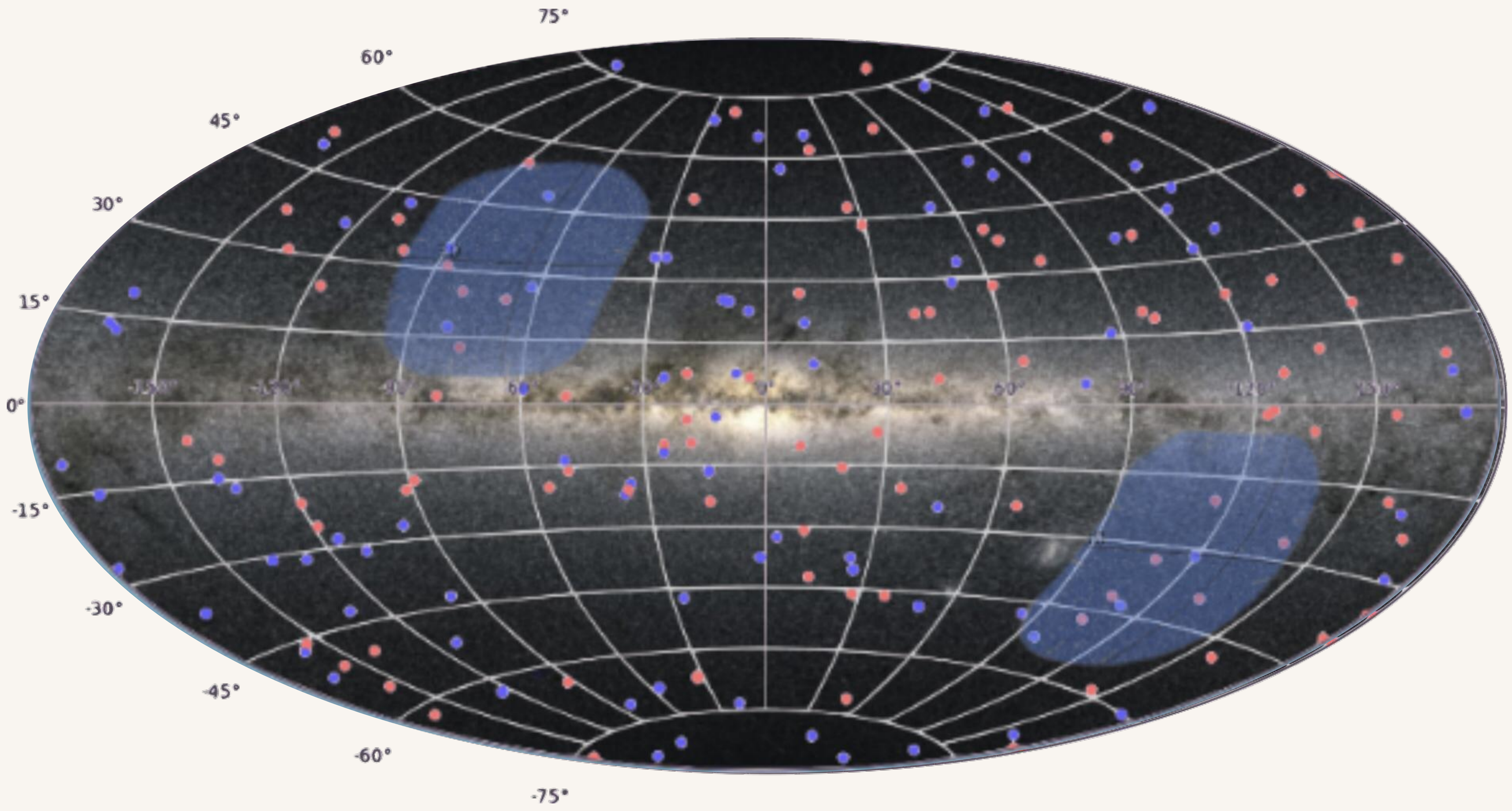
30 brown dwarfs

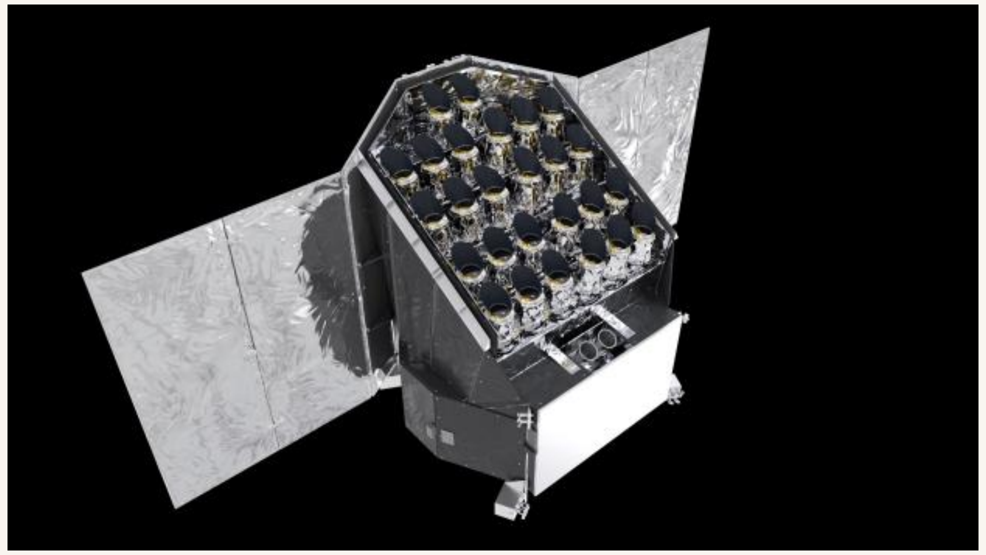
and 100 hot Jupiters

50 hot Neptunes



Candidate target list - synergy with PLATO





ESA

- Radius valley targets: 450-1500 (M-dwarfs), 1000- 8000 (FGK stars)
- Hot Jupiters: 6000-20000

Why can't other observatories answer these questions?

Ground-based observatories

- Earth's atmosphere **absorbs UV**

HST

- Observations **limited** by Earth occultations
- Planets may remain **undetectable** due to limited sensitivity
- Ly-a **contaminated** by interstellar absorption and Earth geocoronal emission

Ariel

- No UV instrument - **no detection of magnetospheres**
- **Low resolution** IR spectrometer (R=30-200) with spectral range over He I line

JWST

- Need for observation is at least **12.000 hours** - **too long** for proposal
- No UV instrument - **no detection of magnetospheres**

Dos Santos 2021, Owen+2023, Ben-Jaffel+2022

Science requirements

Science requirements

SR1. The mission shall measure proxies for atmospheric escape and magnetic fields in the NIR and UV, including the absorption lines:

- H Ly-α (121.40-121.75)±0.05nm
- C II (130.00-137.00)±0.05nm
- Mg II (277.00-281.00)±0.05nm
- He I (1082.60-1084.00)±0.05nm

[SO1, SO2, SO3, SO4]

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[SO1, SO2, SO3, SO4]

SR2. The mission shall observe at least 100 transiting exoplanets that lie in the radius valley and on its edges ($1.2<R<2.3$ Earth radii) using spectroscopy. [SO1, SO2, SO4]

Science requirements

SR3. The mission shall observe at least 100 transiting objects with a mass of at least 0.1 Jupiter masses. [SO1, SO4]

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SR4. The mission shall observe at least 25 transiting Neptune-sized exoplanets with orbital periods of less than 4 days. [SO1, SO3, SO4]

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SR5. The mission shall observe a minimum of 4 full transits per target, including ingress and egress, with a 2h margin before and 50% transit duration margin after, acquiring at least 40 equidistant measurements per transit. [SO1, SO2, SO3, SO4]

Science requirements

SR6. The spectral resolution in the NIR shall be sufficient to resolve a Doppler shift of at least 85 km/s in the He I absorption line. [SO1, SO2, SO3, SO4]

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SR7. The spectral resolution in the UV shall be able to at least separate the Si III absorption line from the Ly-α absorption line. [SO1, SO2, SO3, SO4]

Content

Motivation → Science case → Observation strategy → Requirements

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Instrument & mission requirements

Instrument requirements

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IR2. The photometric aperture shall capture 99.5% of the stellar flux in the NIR and the UV. [SR2, SR3, SR4, SR5]

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IR3. The resolving power shall be at least 3600 for the NIR. [SR6]

IR4. The resolving power shall be at least 500 for the UV. [SR7]

Instrument requirements

IR5. The photometric stability shall be better than 50 ppm (1σ) for the NIR instrument. [SR2, SR3, SR4, SR5]

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Instrument requirements

IR5. The photometric stability shall be better than 50 ppm (1σ) for the NIR instrument. [SR2, SR3, SR4, SR5]

IR6. The photometric stability shall be better than 1% (1σ) for the UV. [SR2, SR3, SR4, SR5]

IR7. The signal-to-noise ratio of the transition contrast shall be at least 8 for NIR. [SR2, SR3, SR4, SR5]

Instrument requirements

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IR7. The signal-to-noise ratio of the transition contrast shall be at least 8 for NIR. [SR2, SR3, SR4, SR5]

IR8. The signal-to-noise ratio of the transition contrast shall be at least 4 for UV. [SR2, SR3, SR4, SR5]

Instrument requirements

IR9. The instrument boresight shall not be pointed within a 15° cone towards Sun during operations. [SR2, SR3, SR4, SR5]

Instrument requirements

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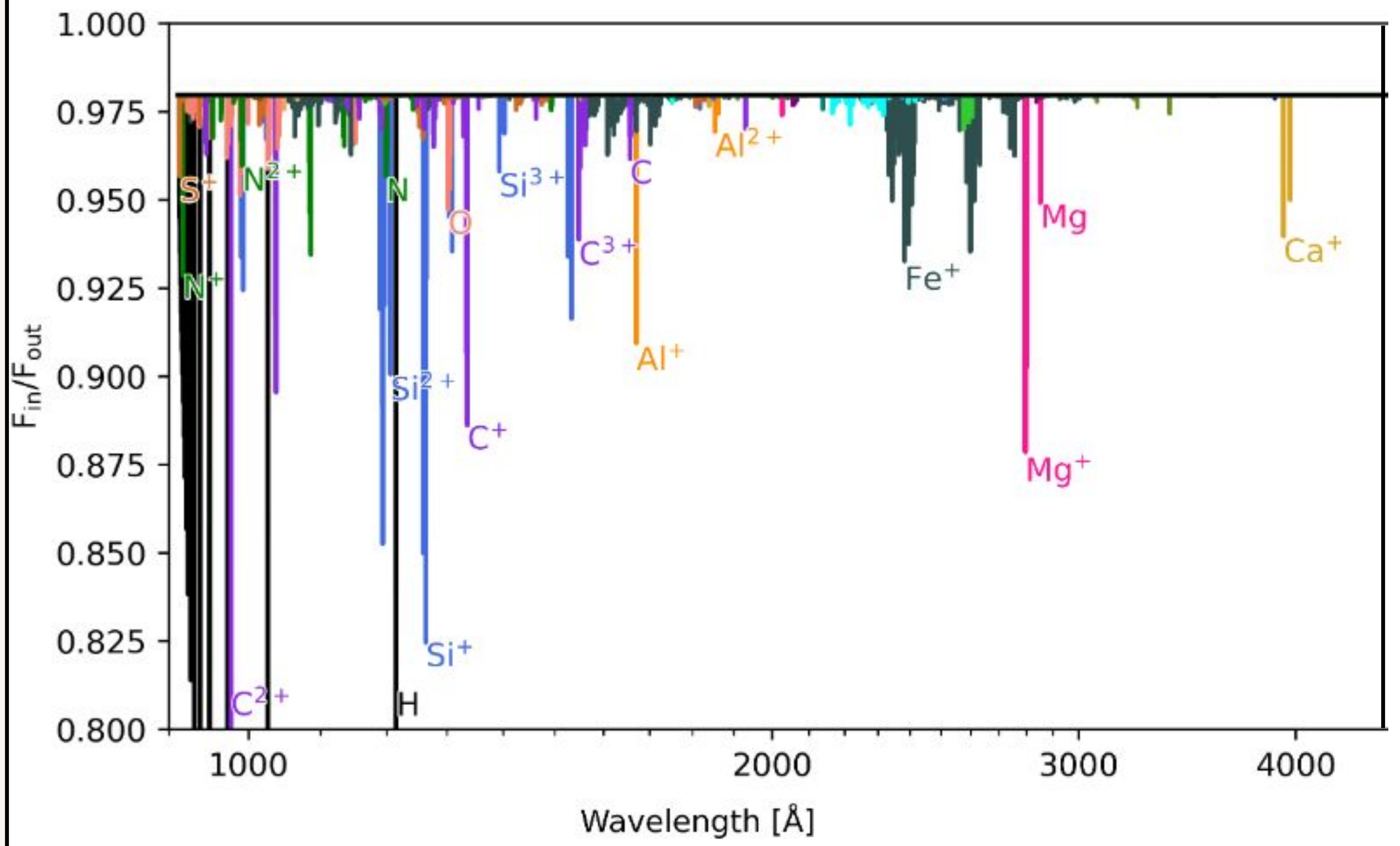
IR10. The instrument shall be pointed with a pointing accuracy of 0.07 arcsec with a stability of 5% over at least 10h towards the targets. [SR2, SR3, SR4, SR5]

Additional absorption lines

Wavelength [nm]	Atom/Molecule/Ion
119.9[1]	N I
124[2]	Si I
128[1]	H_2O
130.4[1]	O
150[2]	Si III
155[2]	C III
169[2]	Al I
280.9[1]	Na II

1: NIST, 2: Linssen+2023



Transmission spectrum of hot Jupiter planet around G2 star

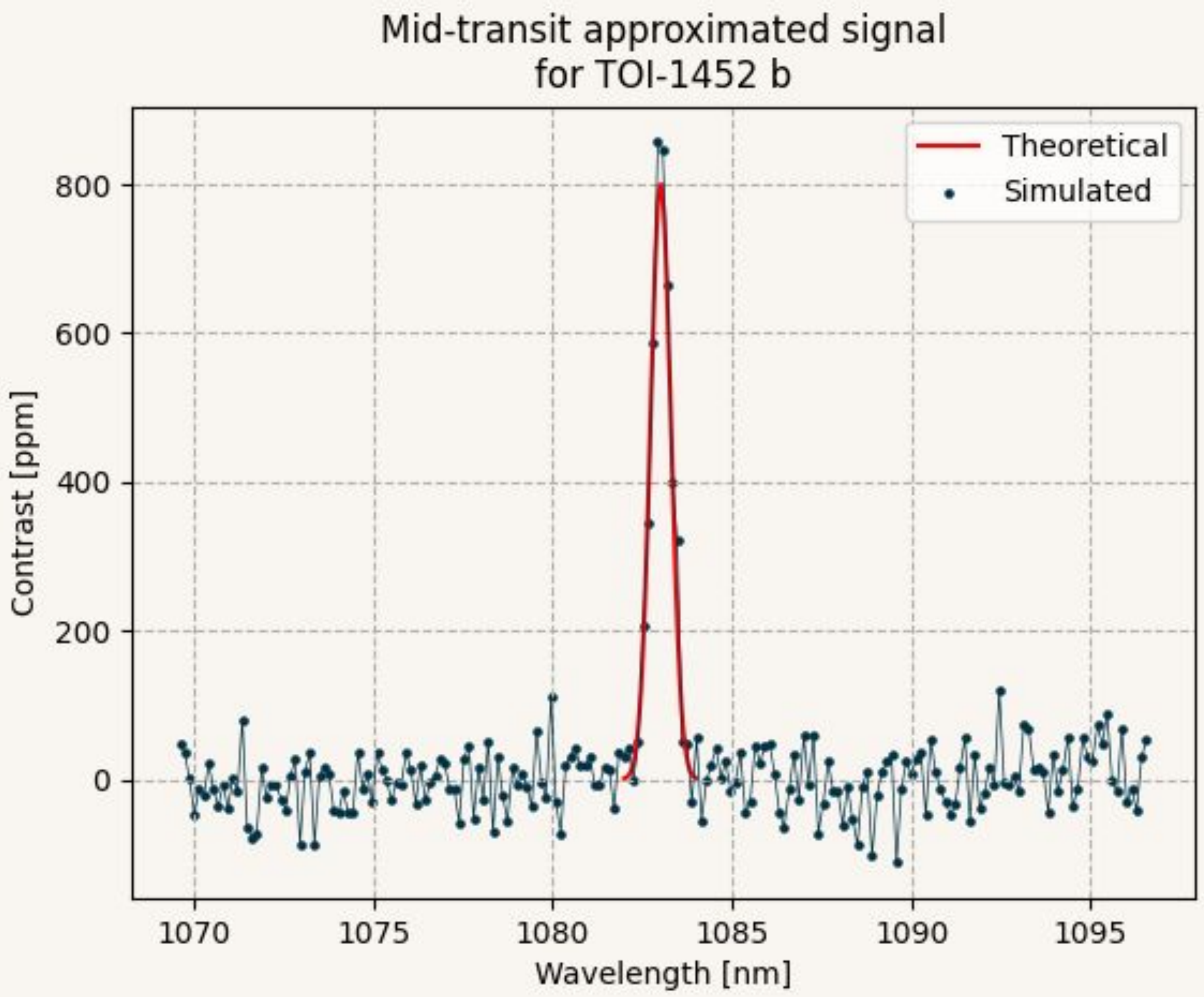
Linssen+2023

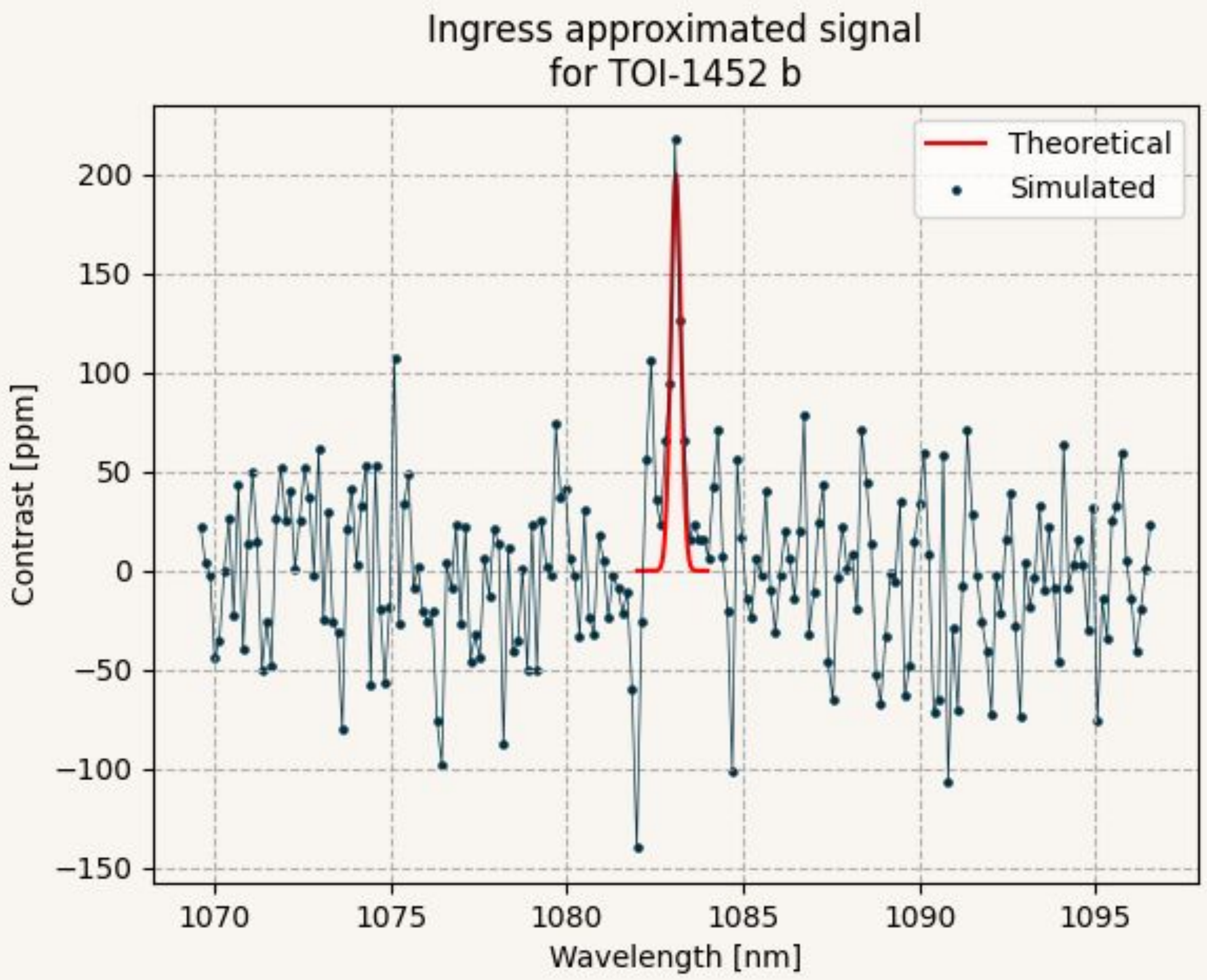
Feasibility of NIR measurements

Worst-case NIR

Line: He I

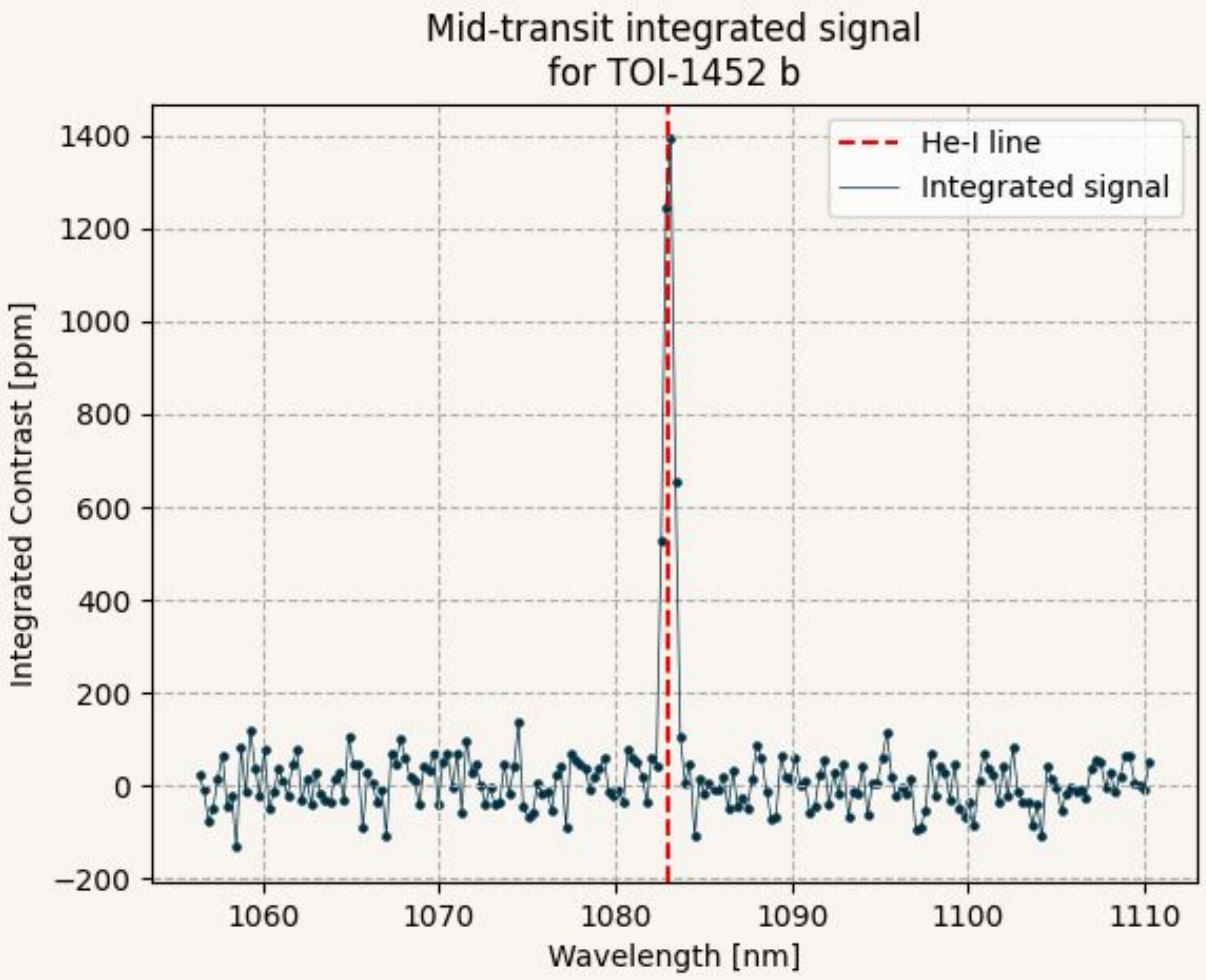
Noise limit: 50ppm

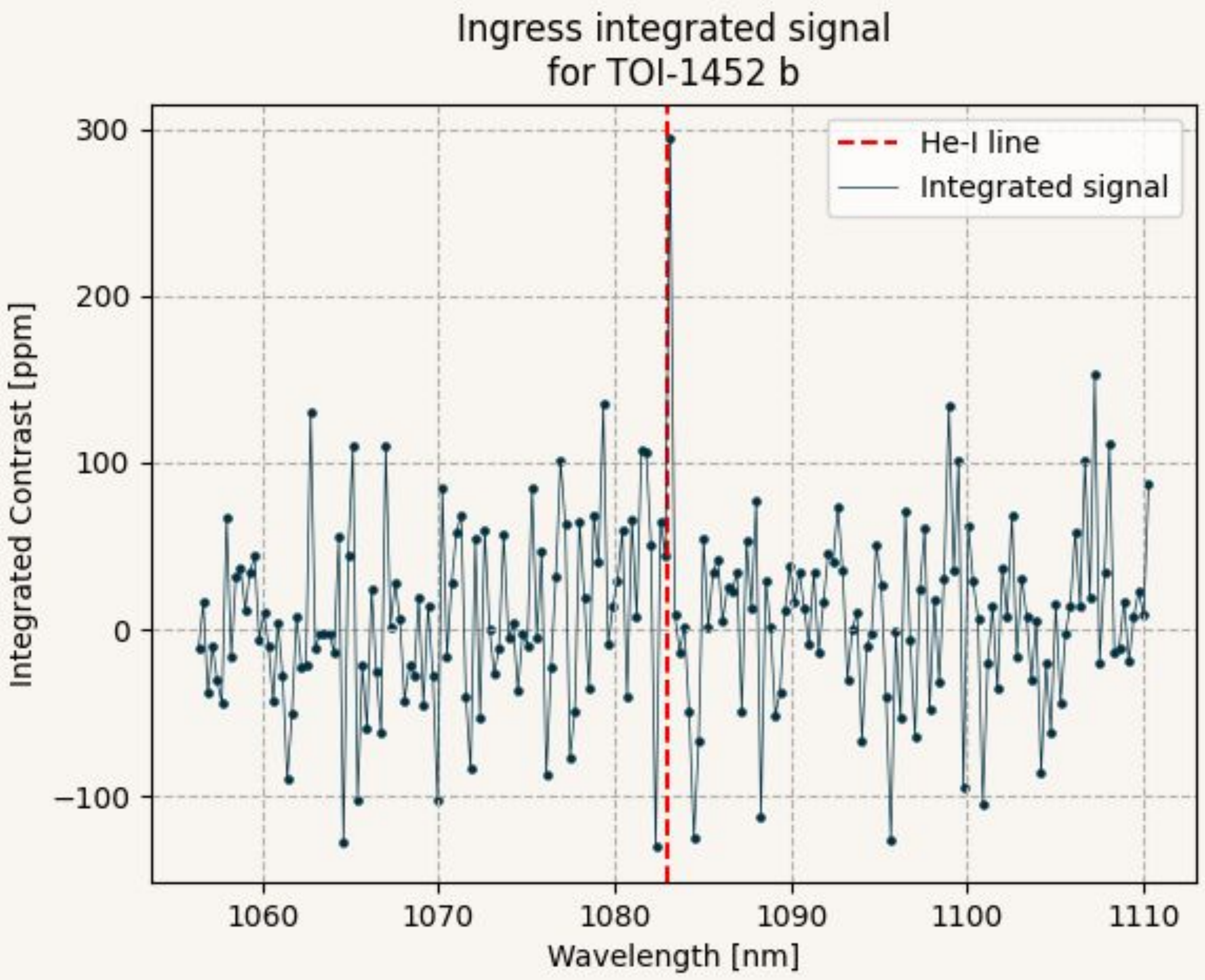




NIR integrated signals

Min Resolution: 3600



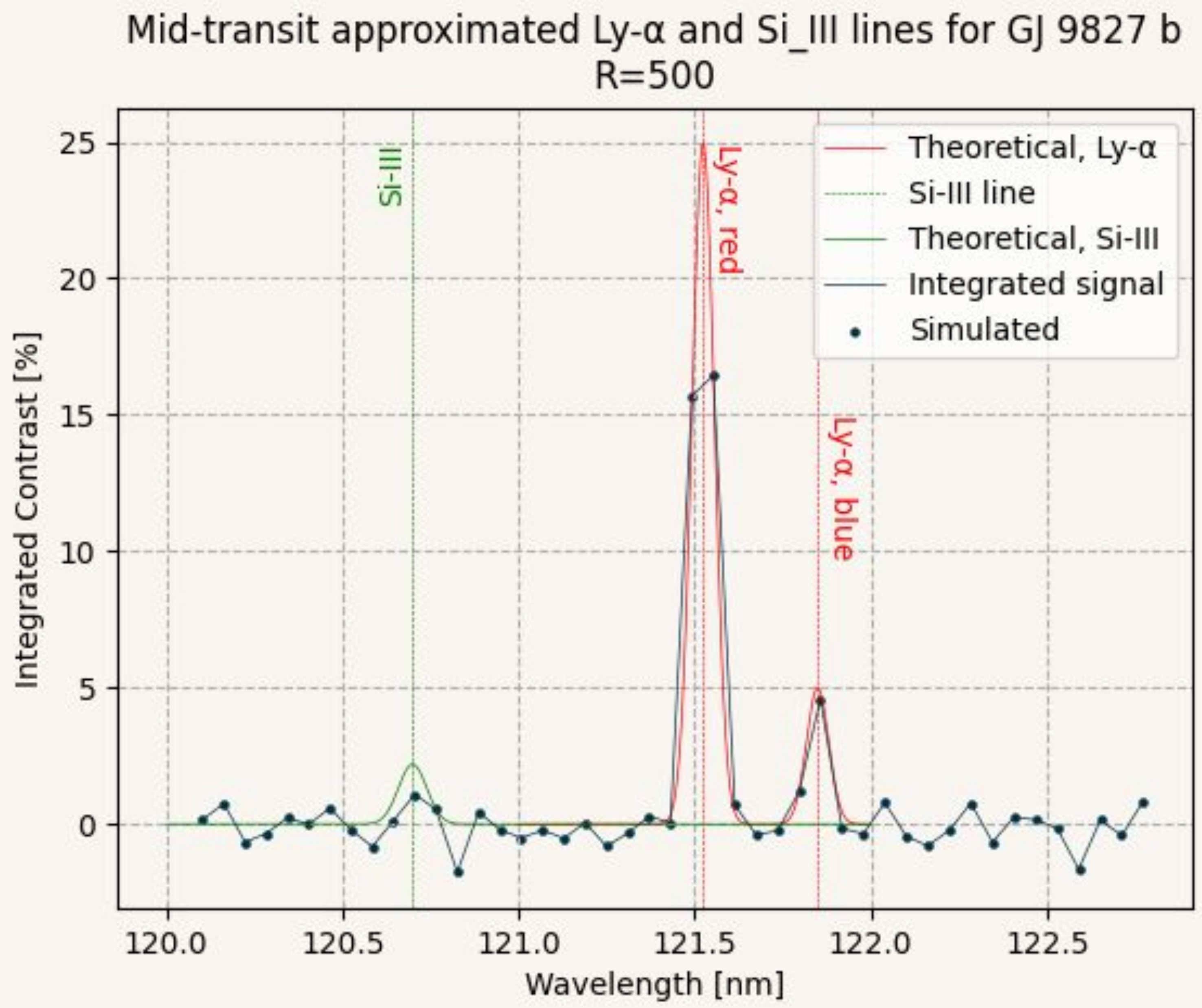


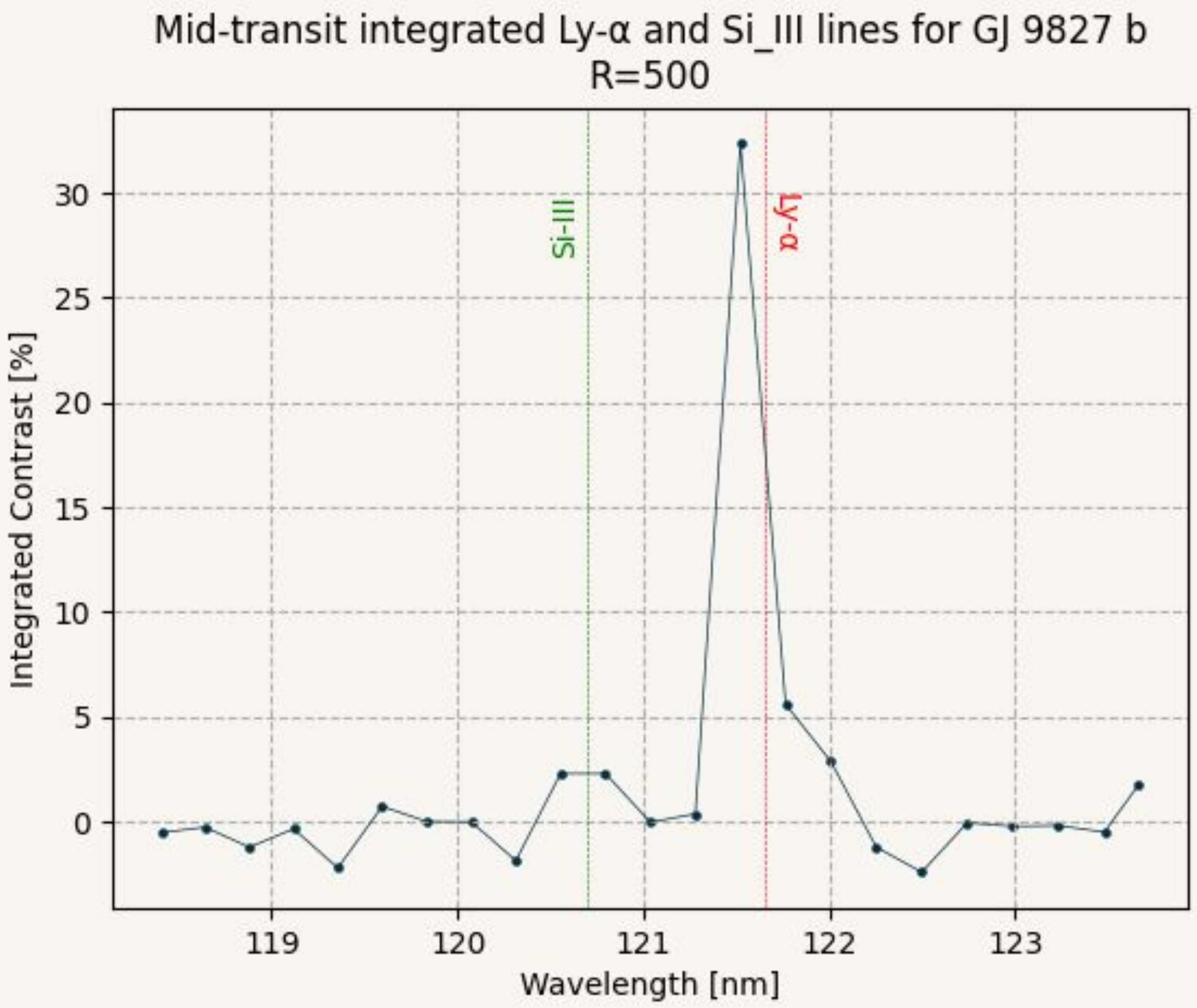
Feasibility of Ly-α measurements

Worst-case UV

Line: Ly-α

Noise limit: 1%



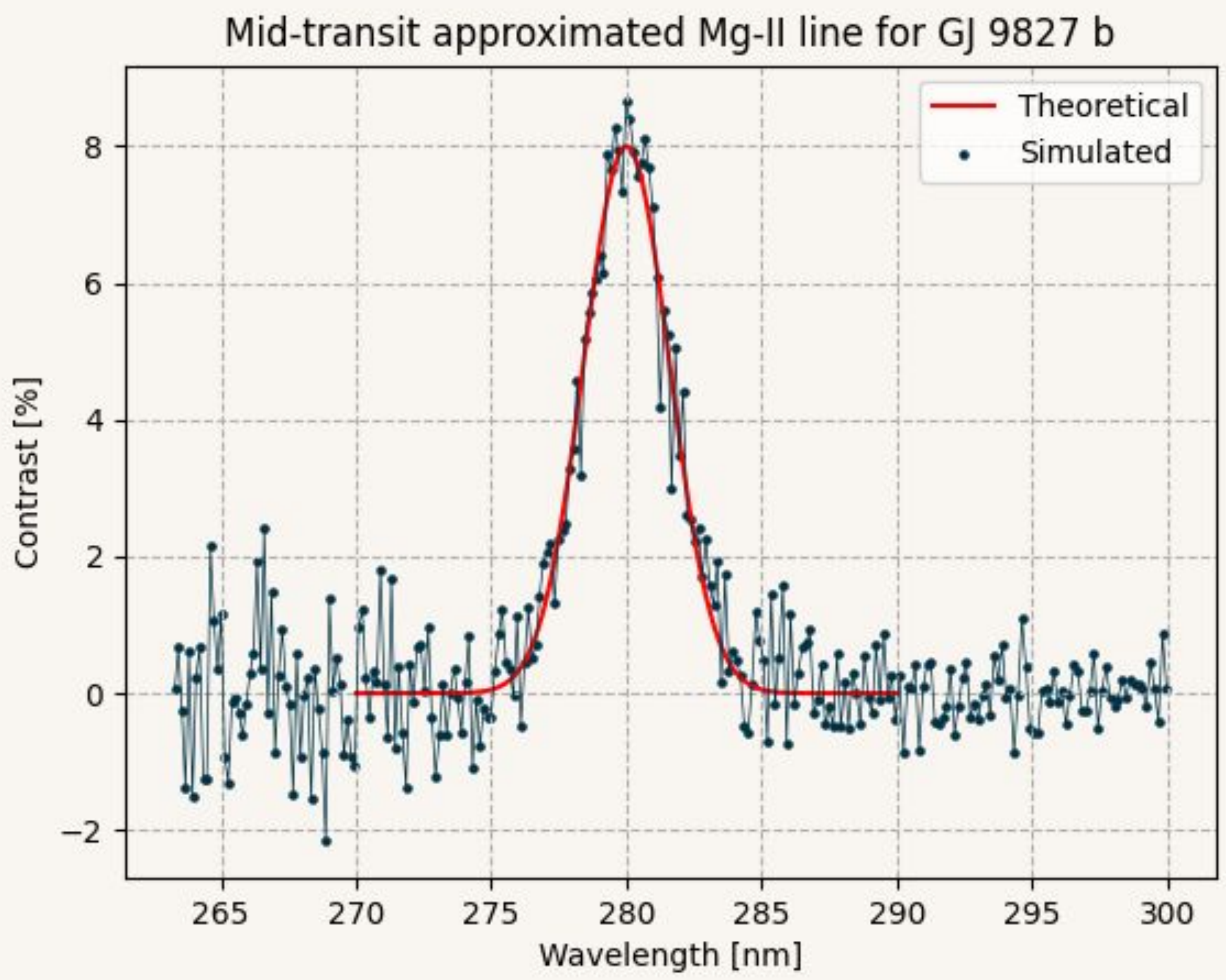


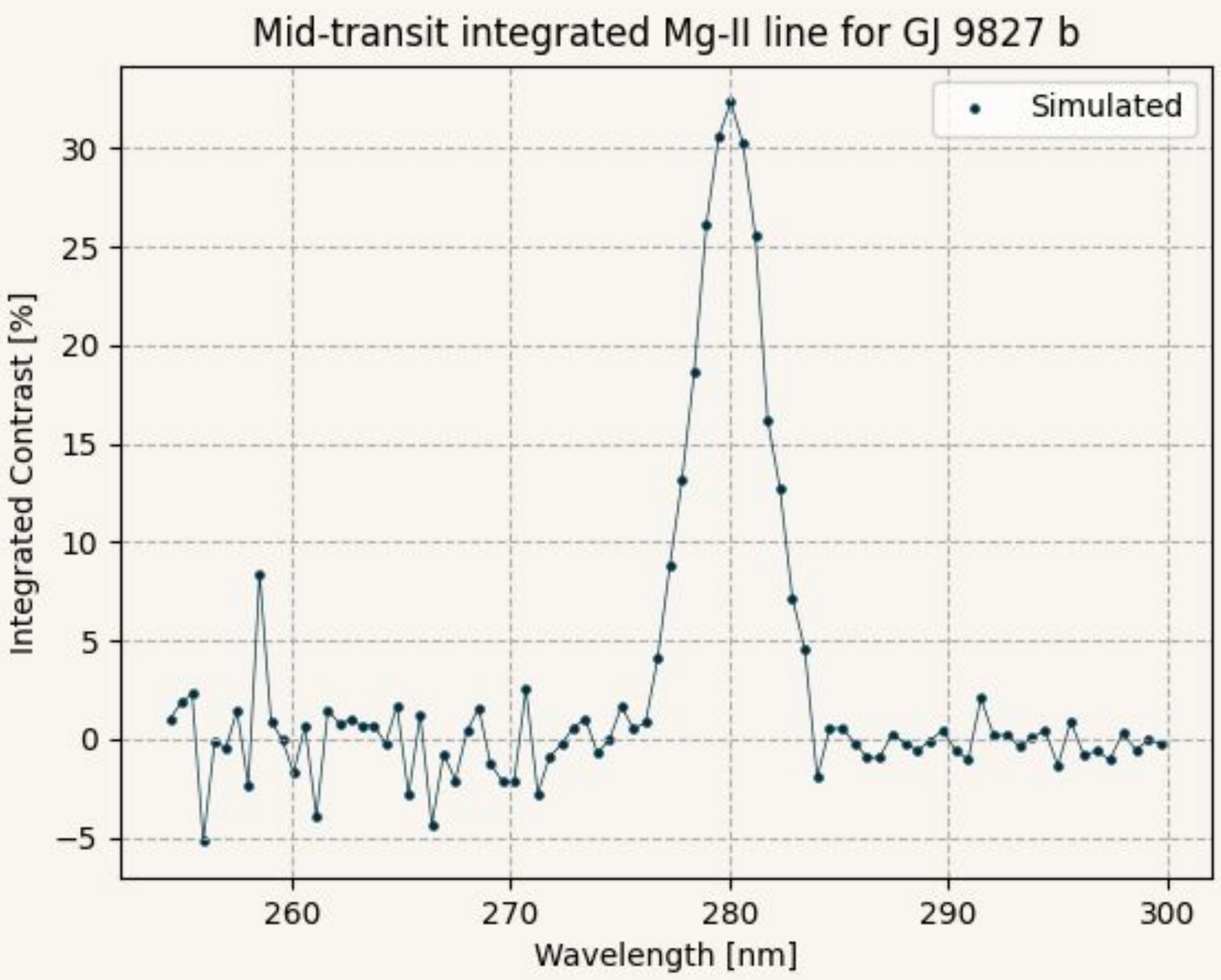
Feasibility of Mg II measurements

Worst-case UV

Line: Mg II

Noise limit: 1%

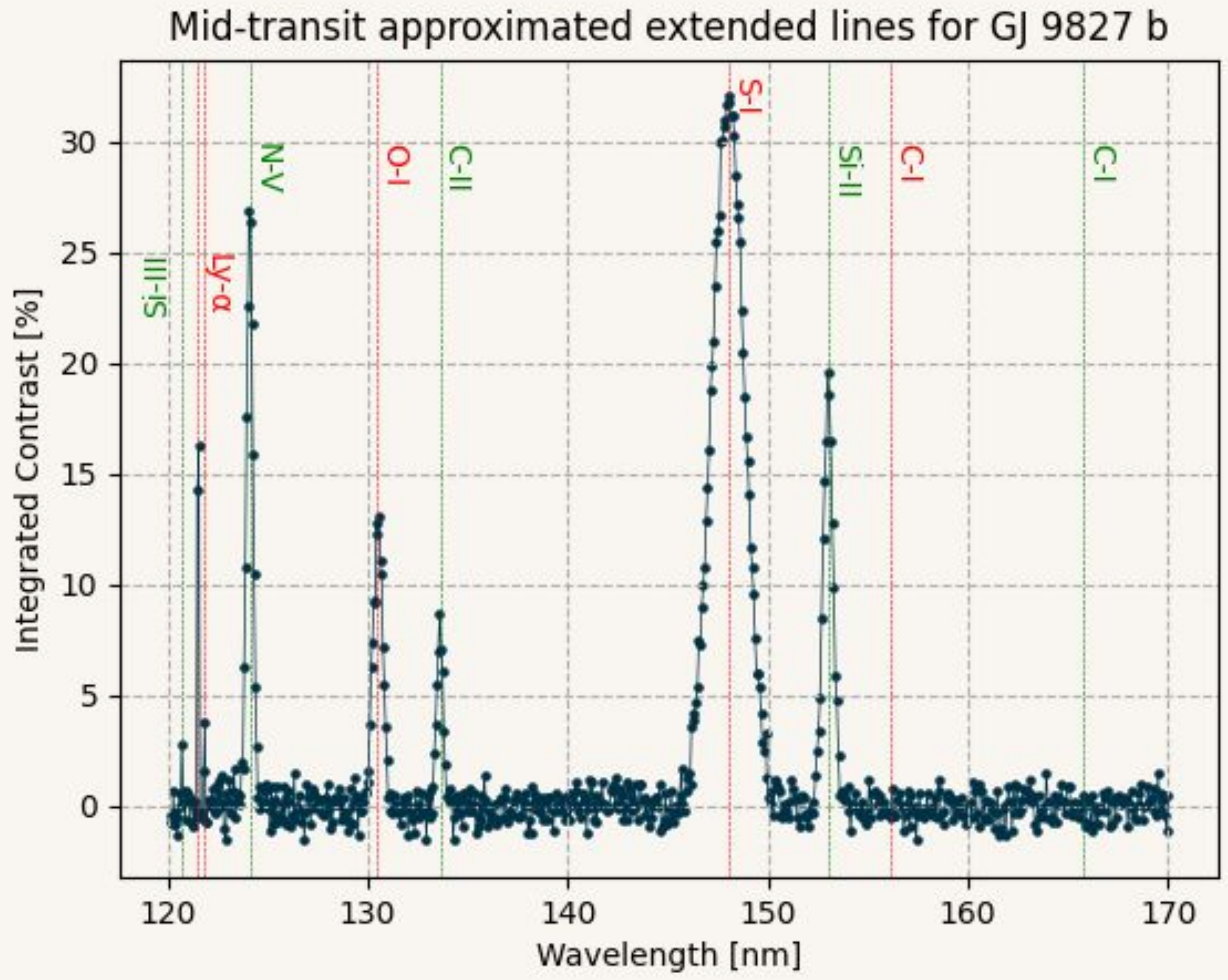


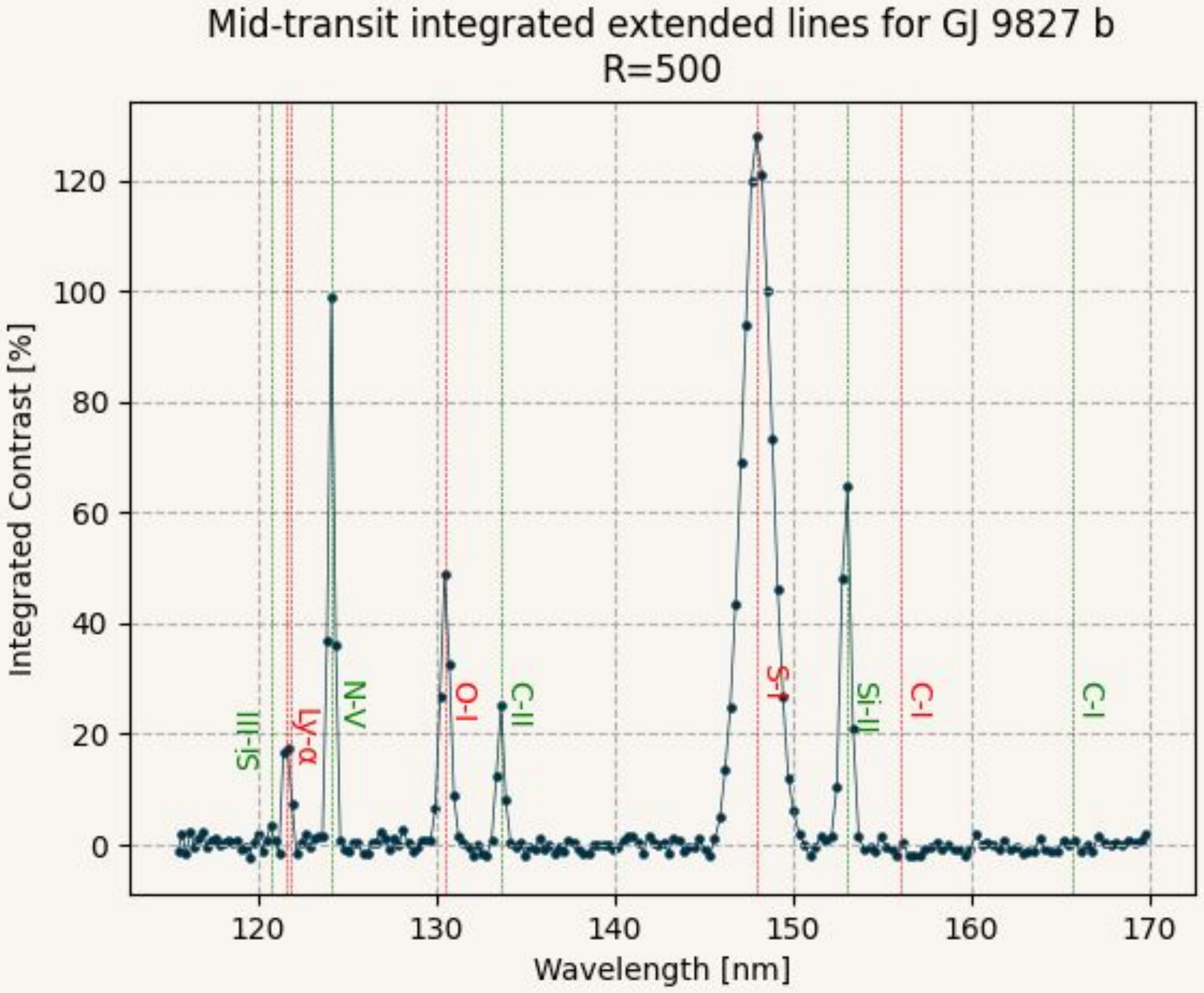


Feasibility of extended measurements

Worst-case UV

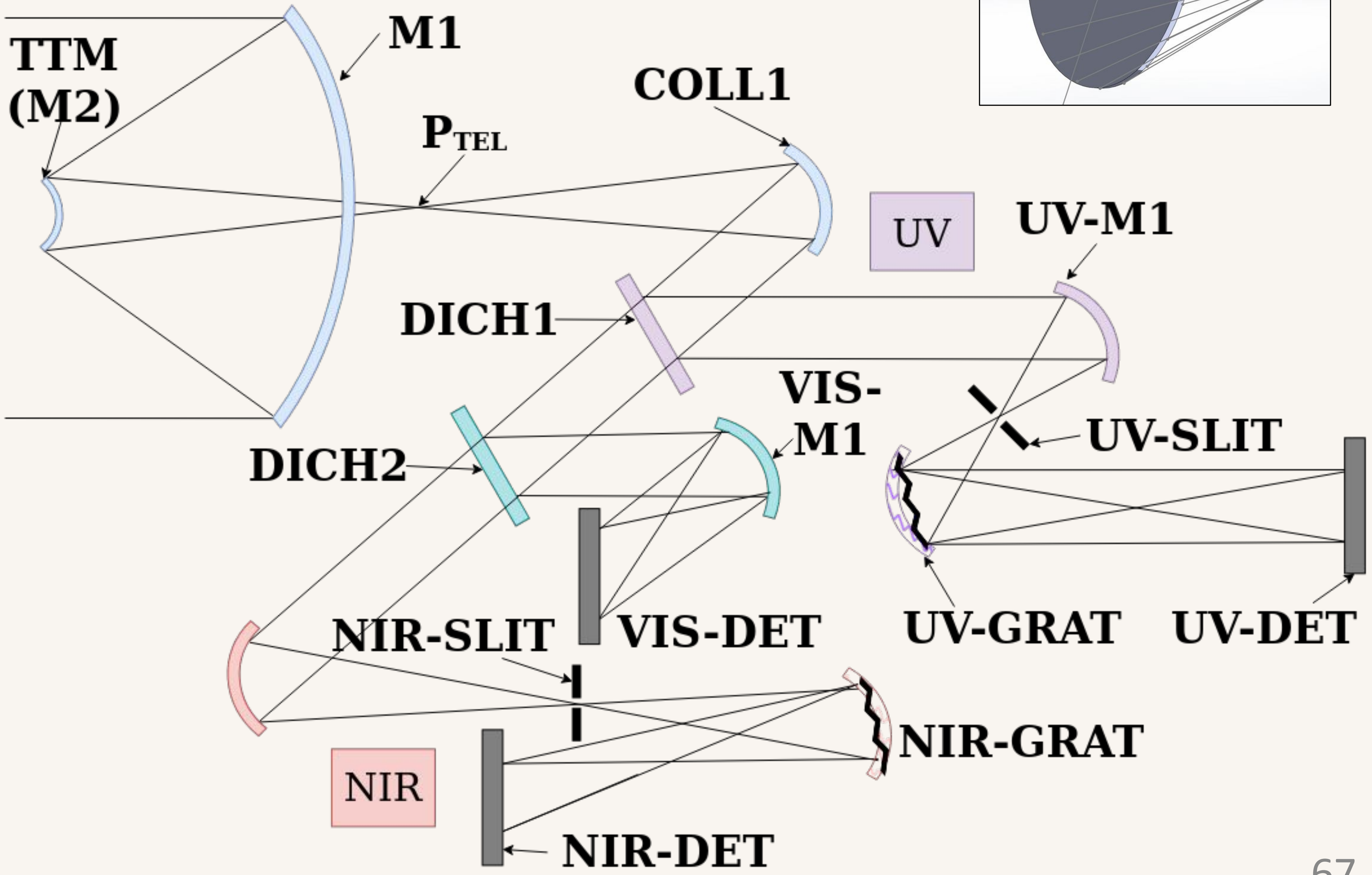
Noise limit: 1%

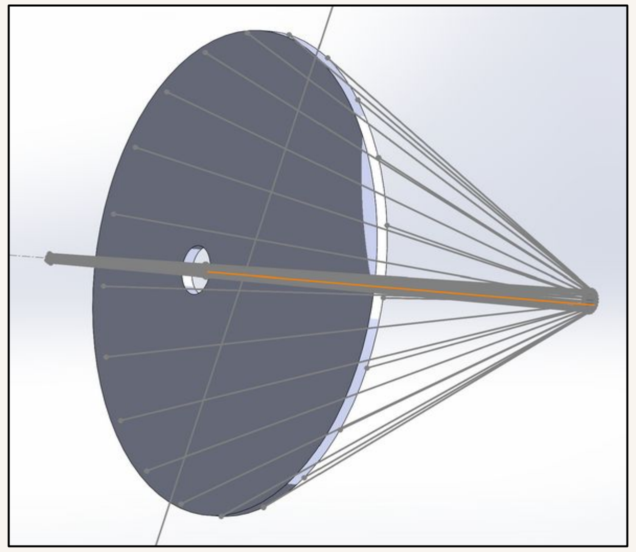




Instrument design

M1	1.5 m
AFOV	3.14 deg
NIR	1070-1090 nm
UV	115-285 nm
NIR Spec Res.	3724
UV Spec Res.	571
Throughput UV	1.94%
Throughput NIR	38.65%
Throughput VIS	35.10%
Compressed data rate	13.2 Gb/day





Mission requirements

MR1. The mission shall be conducted from outside the Earth's exosphere (38 R_{Earth}). [IR1, IR2, IR8, IR9, IR10]

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Mission requirements

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MR2. The mission shall provide a total scientific observation time of at least 9.120 hours. [SR2, SR4]

MR3. The mission shall optimize the observations. [SR2]

Mission constraints

MC1. The mission shall use an ESA launcher for the space segment.

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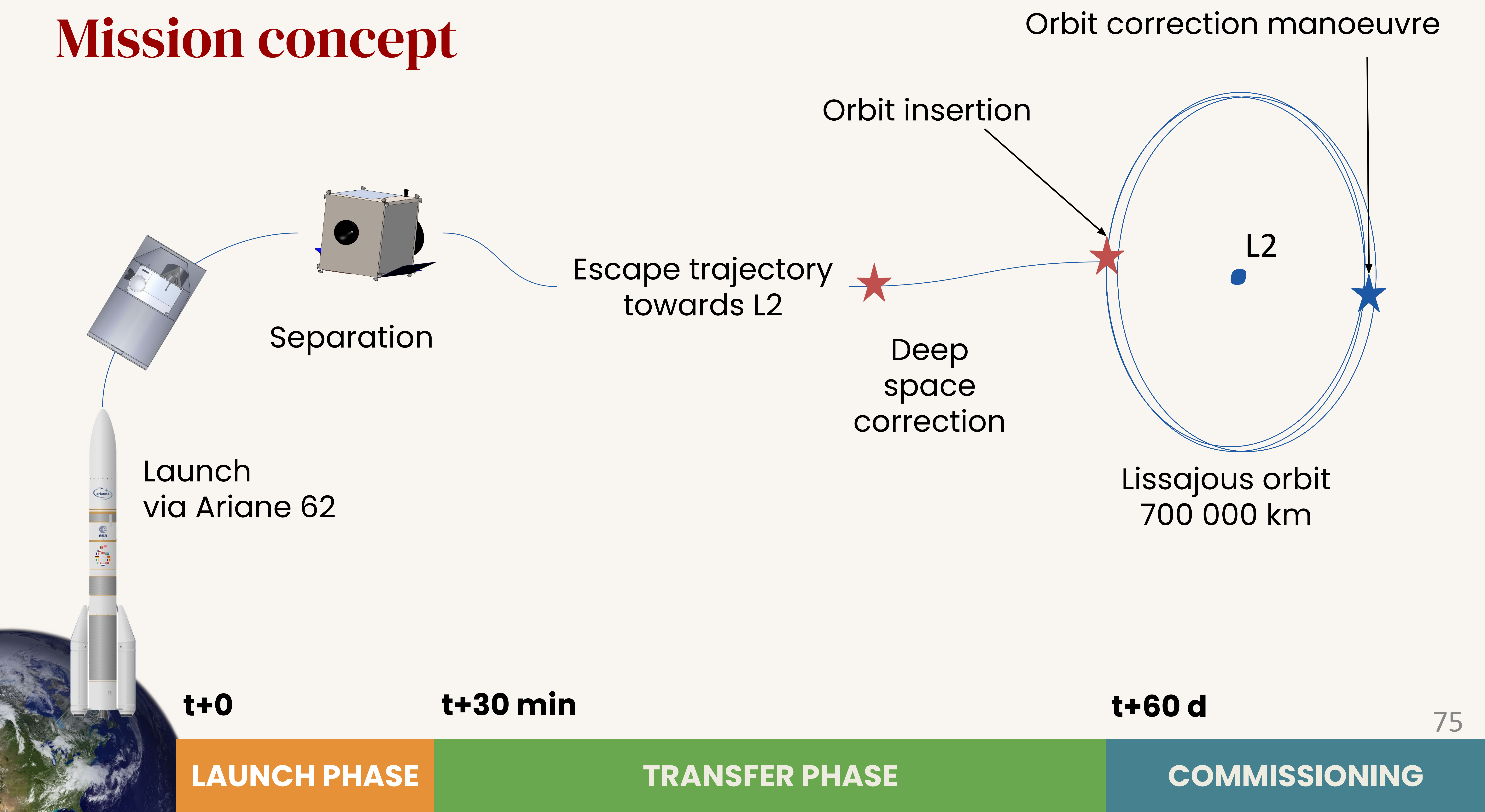
MC3. At the end of the lifetime, the mission shall be decommissioned by entering a graveyard orbit.

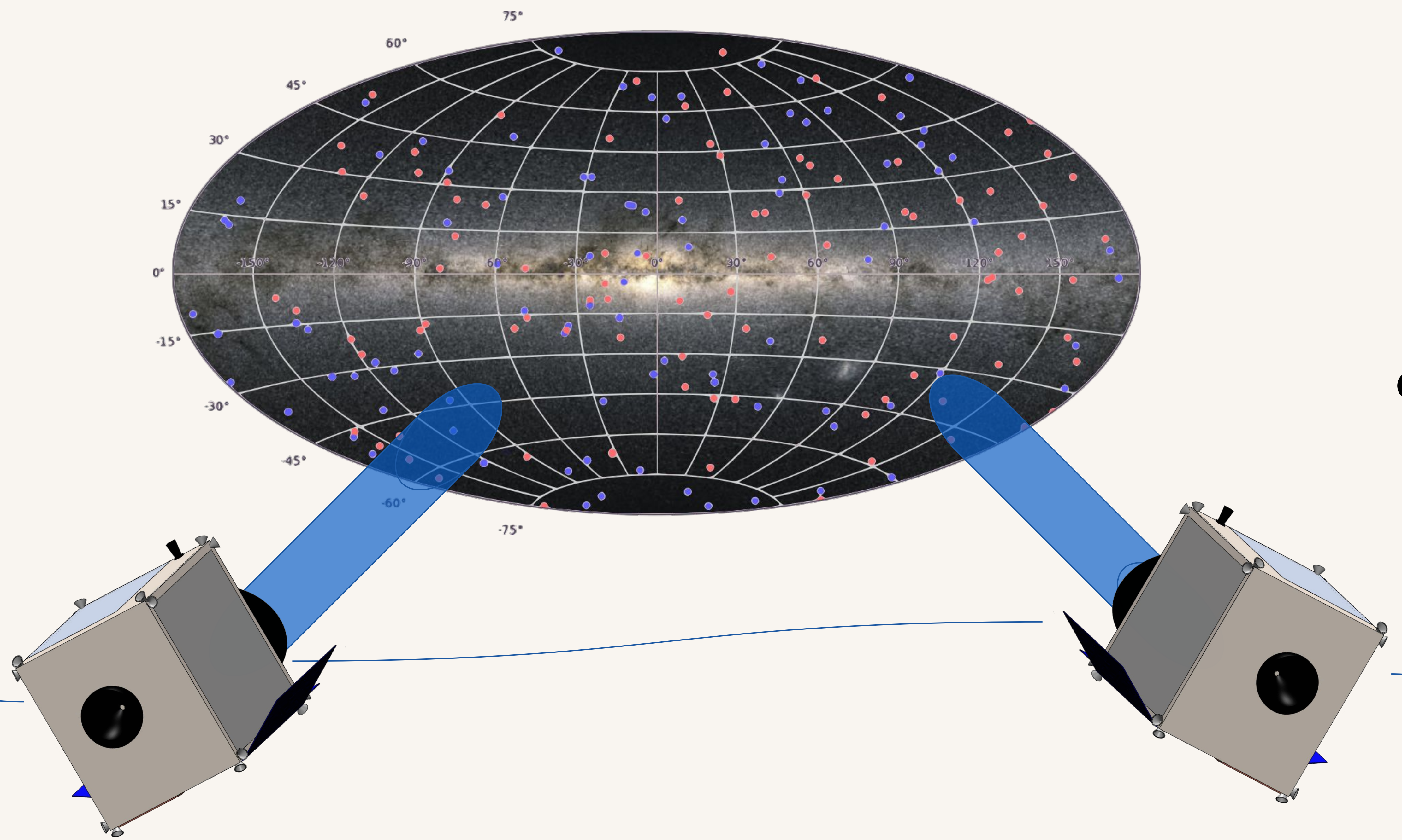
Mission concept

Mission concept



Mission concept

Instrument commissioning



End of life:

Unstable outbound orbit

Science observations

3 years nominal lifetime

1 month

COMMISSIONING **OBSERVATION PHASE** **DECOMMISSIONING**

System requirements

SysR1. The spacecraft shall possess 3-axis pointing stabilisation.
[IR5, IR6, IR7, IR8]

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SysR5. The spacecraft shall fit in the payload bay module of the launcher. [MC1]

SysR6. The spacecraft shall shield the instrument from straylight. [IR9]

System requirements

SysR7. The spacecraft shall be able to downlink 13.2 Gb of data per day. [IR3, IR4, IR5, IR6, IR7, IR8]

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SysR9. The spacecraft shall be able to store at least 26 Gb of data for at least 2 days. [IR3, IR4, IR5, IR6, IR7, IR8]

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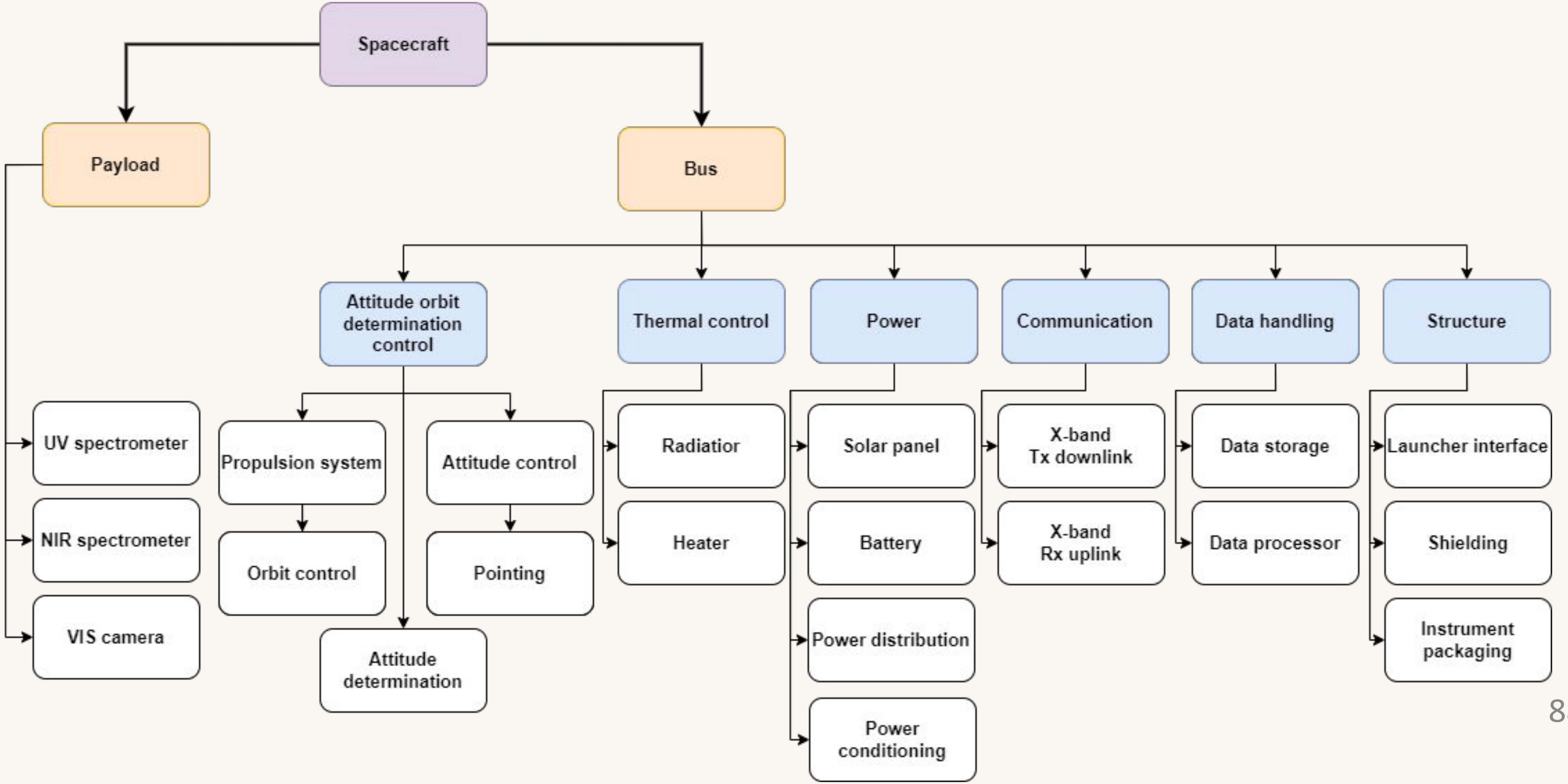
SysR10. The spacecraft shall provide the necessary power for all operational modes. [MR2, MR3]

SysR11. The spacecraft shall ensure that the temperature of the NIR and UV detectors are lower than 140 K and 303 K respectively. [IR9, IR10, IR11, IR12]

Spacecraft design



Content

Motivation → Science case → Observation strategy → Requirements

Speaker: Jo Ann Egger

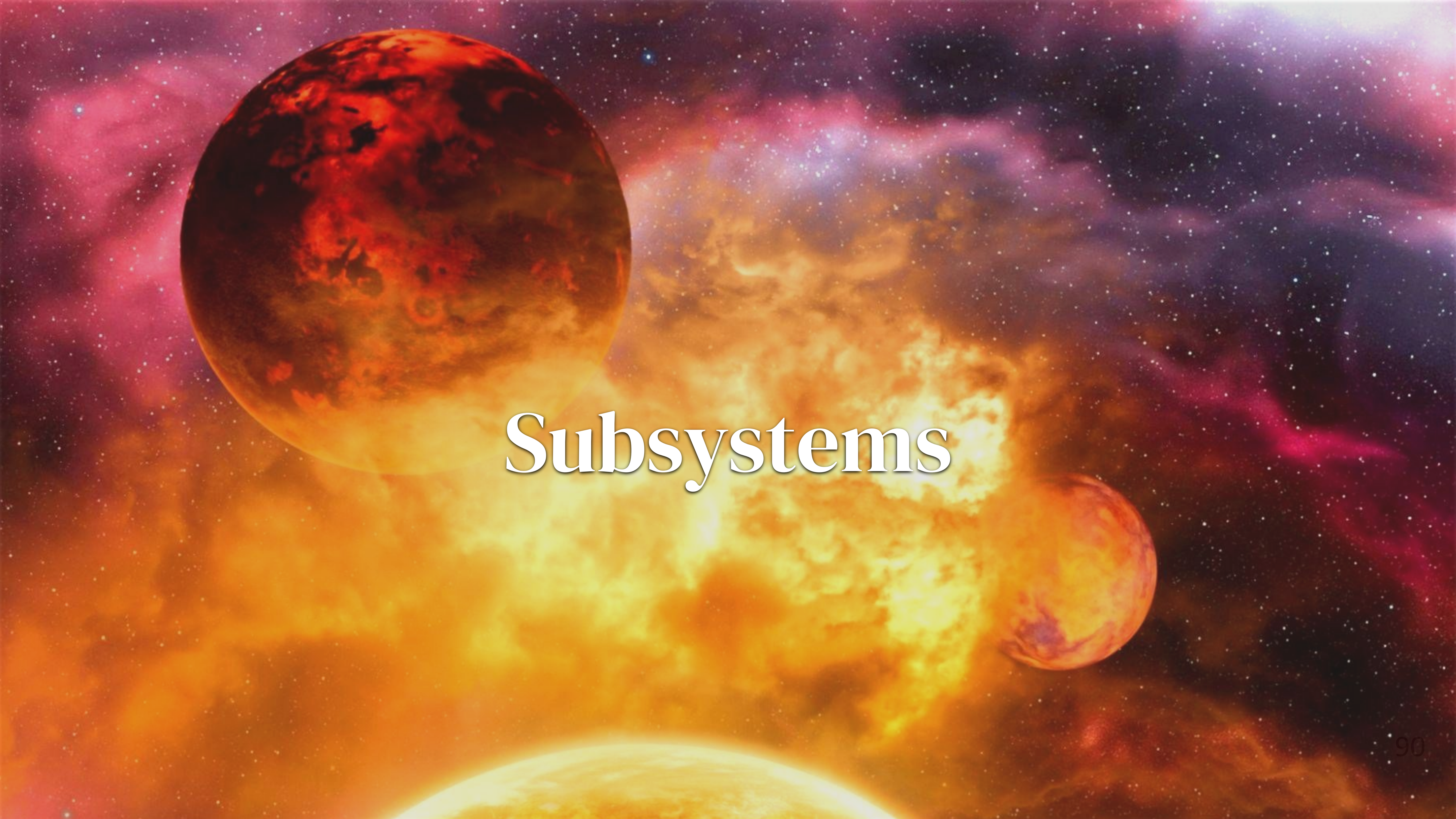
Speaker: Elena Tonucci

Requirements → Mission concept → **Subsystems** → **Risks, cost & plan**

Speaker: Aksel Beltoft

Speaker: **Noria Brecher**

Subsystems



Attitude & Orbit Determination and Control System

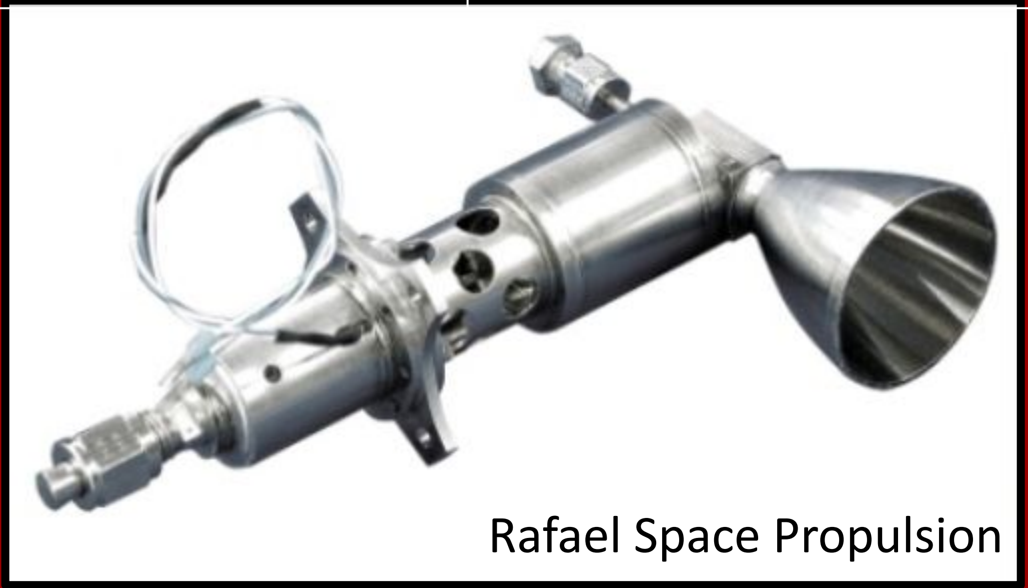
Requirement

- 3-axis stabilisation with pointing accuracy of 0.07 arcsec
- Slewing rate of 0.05 deg/s
- Momentum storage capabilities of 6.78 Nms
- 40 N of thrust for propelled maneuvers
- 1 N of thrust for momentum dumping

Design

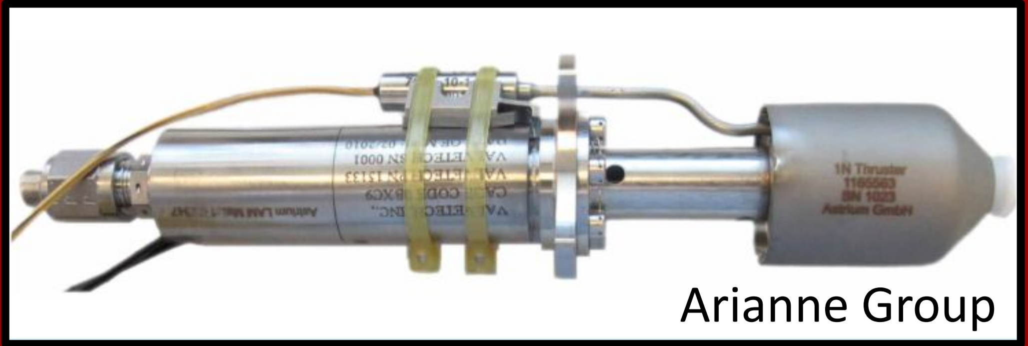
- 2 star trackers + 6 sun sensors
- 1 gyroscope
- 3+1 reaction wheels
- 20+1 hot-gas thrusters

Operation	Δv (m/s)
Orbit maintenance	1 (per year)
Launch Error	50
Decommission	20
Desaturation	10 (per year)
Total Δv + 20%	122.95



Rafael Space Propulsion

1x 45 N Hydrazine thruster



Arianne Group

20x 1 N Hydrazine thruster

Ground segment and spacecraft communication

Requirements

Downlink	13 Gb per day
Uplink	60 kbps
Datastorage	26 Gb for 2 days

Design

- Ground stations: **35 m** Deep Space Network, ESA
- Satellite: **1 m^2** phased array antenna
  -> reduces slewing maneuvers
- **X-band**
- **10 MHz** bandwidth
- **Nominal Communication window: 2h per day**

UPLINK

Frequency	**8.4 GHz**
EIRP	111.2 dB
Pointing accuracy	0.15 deg
Transmission loss	-236.5 dB
Receiver G/T	17 dB
Data rate	**72 kbps**
Final Eb/En	**18.7 dB**

DOWNLINK

Frequency	**7.75 GHz**
EIRP	47.1 dB
Pointing accuracy	0.1 deg
Transmission loss	-235.8 dB
Receiver G/T	39 dB
Data rate	**8.0 Mbps**
Final Eb/En	**9.4 dB**

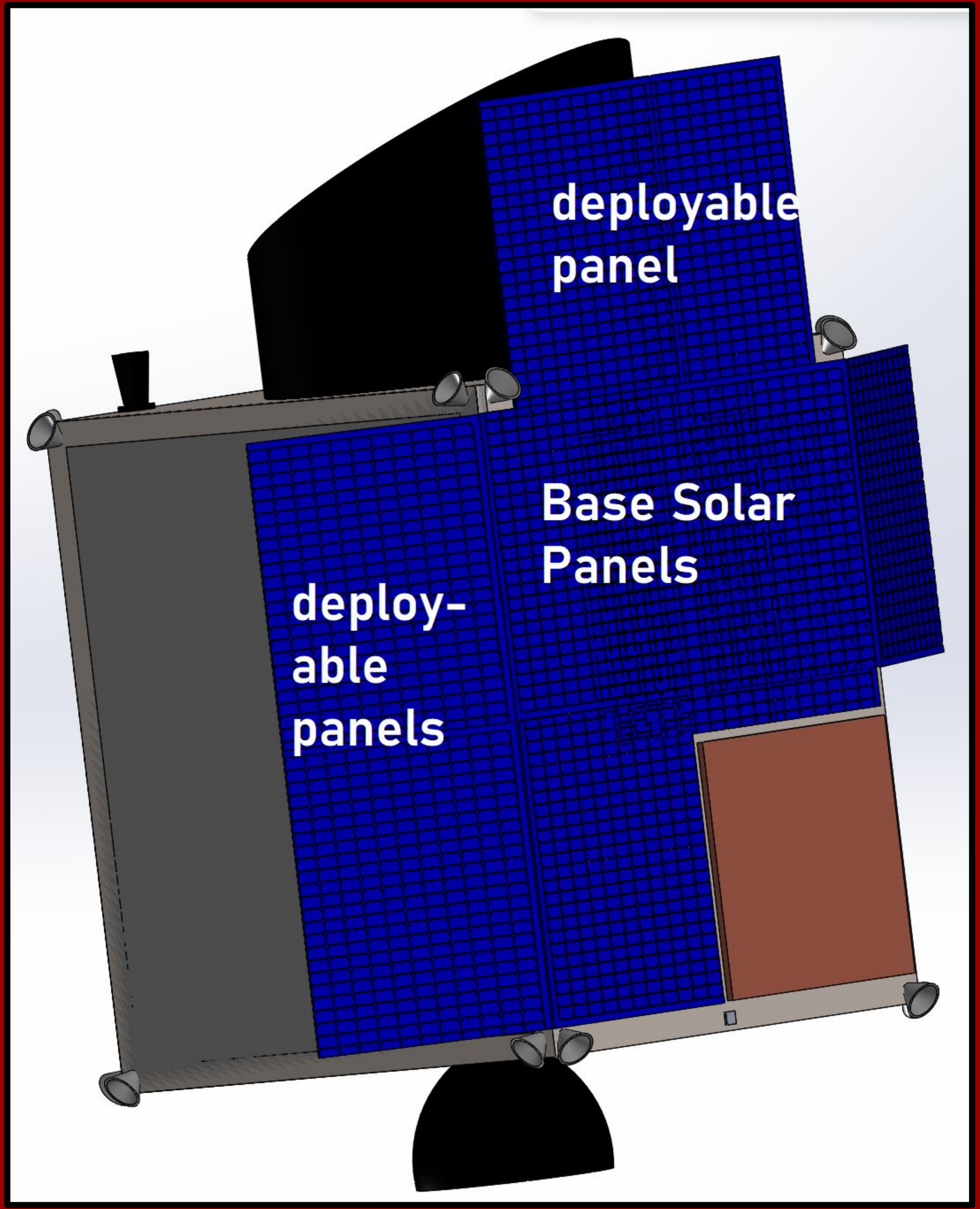
Spacecraft power segment

Requirements

- EOL: 464 W at 75° incidence angle
- 2 hours of operation in safe mode

Design

- Spring hinge deployable solar panels
- 2127 solar cells total - **6.49 m^2**
- Deployed panel **acts as a sun shield**
- 68 Li-Ion battery cells with 1000 Wh capacity
- Depth of discharge: **39.6%**



Power budget

Load	Max. Consumption (W)	Margin	Safe	Commissioning	Orbital Maintenance	Coarse Pointing	Science	Telecommunication
OBDH	10,00	2,0	5,0	10,0	10,0	10,0	10,0	10,0
AODCS / Control	60,00	12,0	30,0	60,0	60,0	60,0	60,0	60,0
- *Determination*	20,00	4,0	10,0	20,0	20,0	10,0	20,0	20,0
EPS/ MCU & Telemetry	40,00	8,0	20,0	30,0	30,0	30,0	30,0	40,0
- *Battery heating*	20,00	4,0	20,0	20,0	20,0	20,0	20,0	20,0
- *Regulation losses*	30,00	6,0	30,0	30,0	30,0	30,0	30,0	30,0
COM / Receiving	20,00	4,0	20,0	20,0	20,0	20,0	20,0	20,0
- *Transmitting*	50,00	10,0	30,0	30,0	30,0	30,0	30,0	50,0
Thermal	80,00	16,0		80,0	30,0	50,0	80,0	60,0
Telescope	86,4	17,3		86,4		17,3	86,4	17,3
Total (W)	386,4	83,28	165,0	**386,4**	**250,0**	277,3	**386,4**	327,3
Total + Margin(W)	**563,6**	20%	**198**	**463,7**	**300**	**332,8**	**463,7**	**392,7**

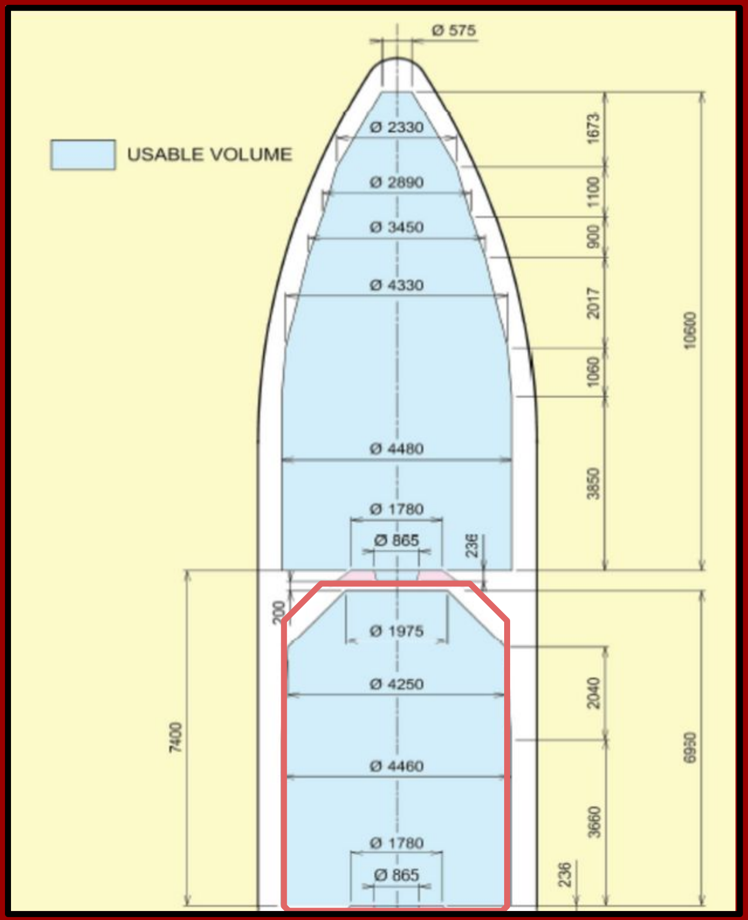
Spacecraft structure

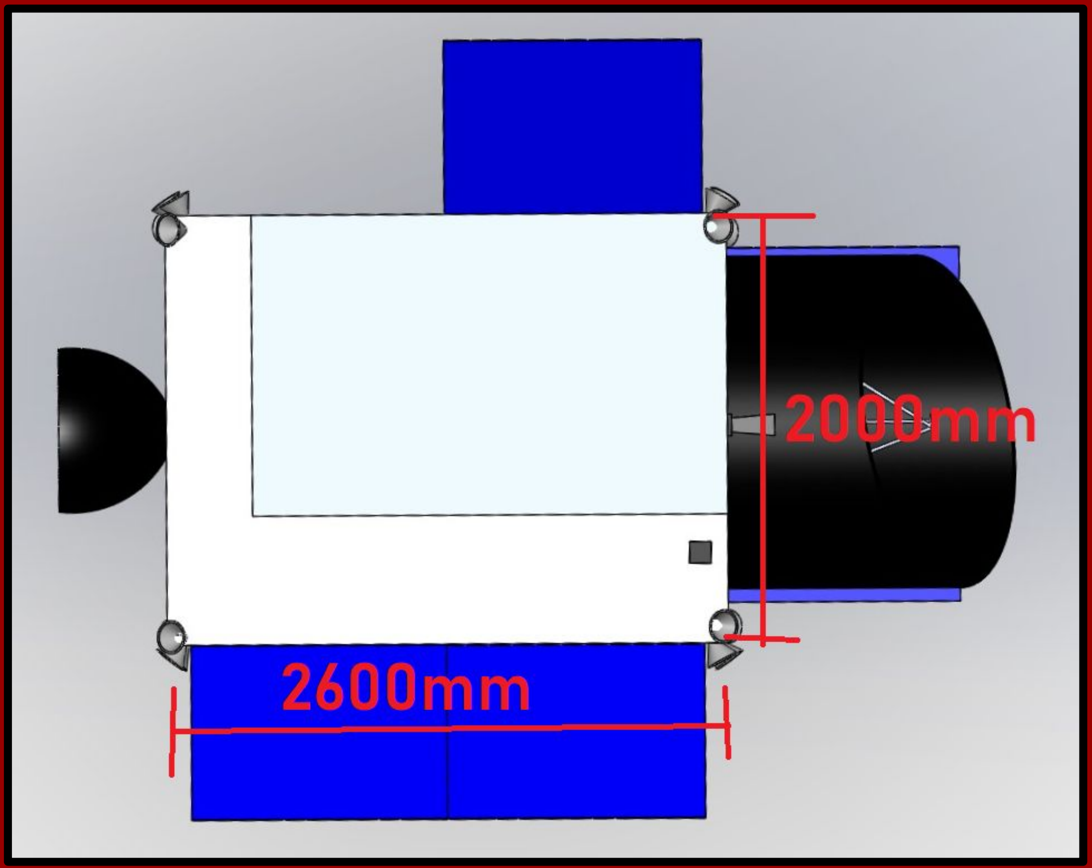
Requirements

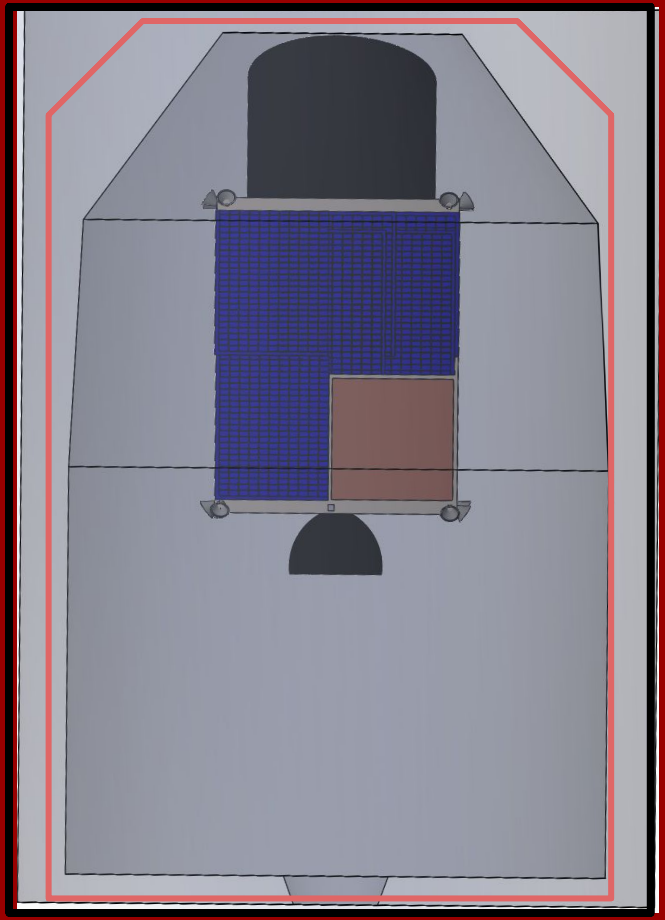
- Fit launcher payload bay
- Withstand vibration, acoustic noise and shock loads during launch
- Use space grade materials

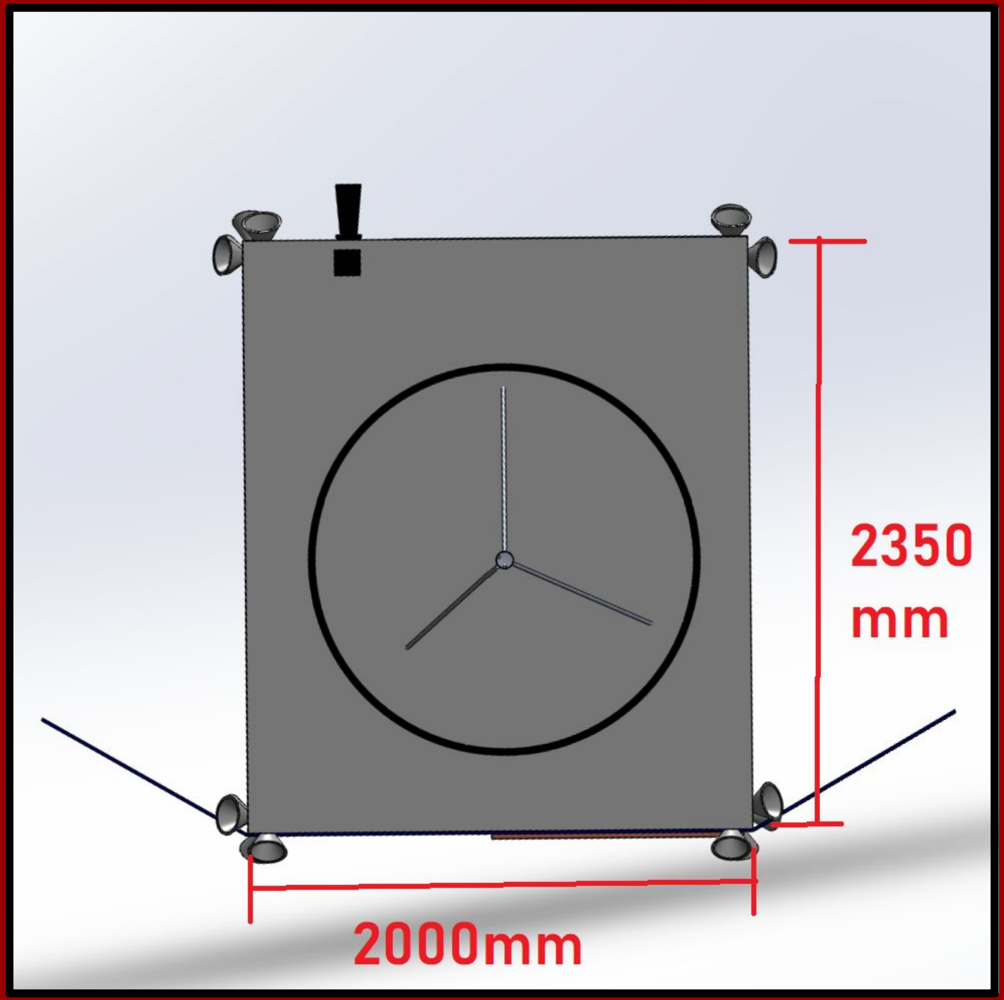
Design:

- Aluminium 7075 frame
- 2.6 m x 2.0 m x 2.35 m









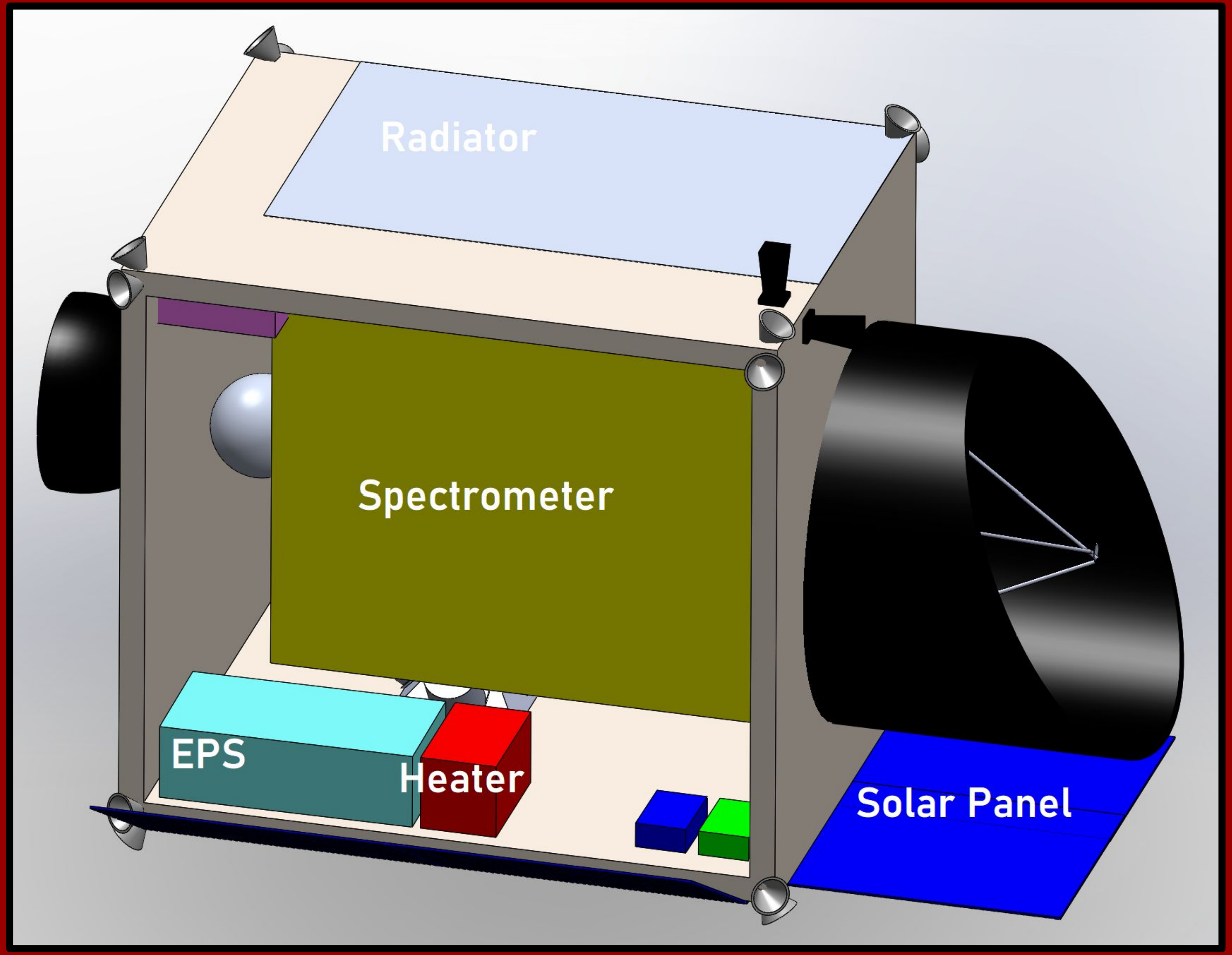
Spacecraft thermal design

Requirements

Battery	283-303 K
Fuel	288-313 K
NIR detector	120 ± 2 K
UV detector	293-303 K
UV optical mirrors	283 ± 1K

Design

- Simple Aluminium radiators
- Thermal management design based on Hubble radiators for IR
- Radiators focused on the area of the spectrometer
- Heater placed next to the battery



Mass budget

- The Ariane 62 maximum payload mass for L2: 3300 kg
  -> ~50% of the max. payload mass

System	Nominal Mass (kg)	Margin (%/kg)	Mass + margin (kg)
Payloads	286,3	57,3	343,6
Thermal	20,0	4,0	24,0
EPS	95,0	19,0	114,0
AODCS	154,5	30,9	185,4
COM	20,0	7,0	42,0
Structure	190,0	38,0	228,0
OBDH	7,0	1,4	8,4
Total Dry Mass			**945,4**
Fuel Mass			85,5
Wires & Harnesses		20%	189
System Level Margin		20%	244
Total Wet Mass			**1465,9**

Risks, cost and plan

Technology readiness

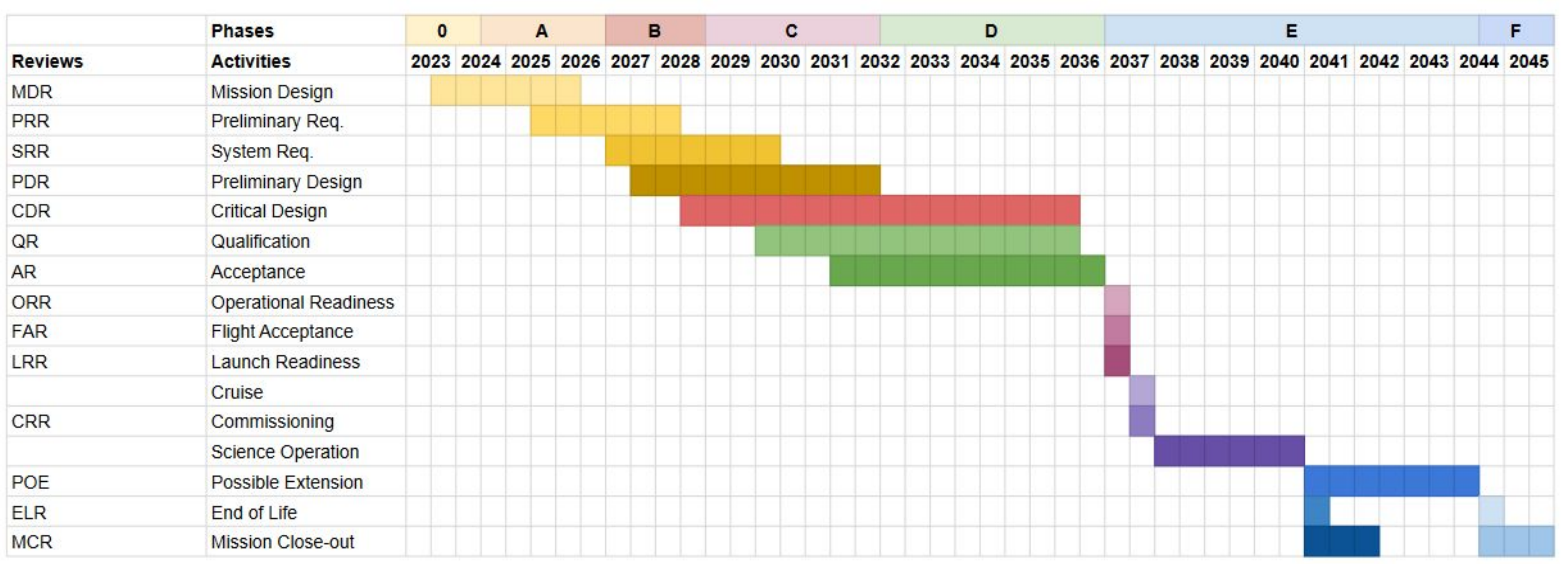
Payload Component	TRL
Telescope	4
Other mirrors & optics	5
UV instrument	5
NIR instrument	5
VIS instrument	5
System Component	**TRL**
Reaction wheels	9
Thruster	8
Star tracker	9
Sun sensor	9
Propulsion	8

	Descriptions of Technology Readiness Levels
TRL 4	Component and/or breadboard functional verification in laboratory environment.
TRL 5	Component and/or breadboard critical functional verification in laboratory environment.
TRL 6	Model demonstrating the critical functions of the element in a relevant environment
TRL 7	Model demonstrating the element performance for the operational environment
TRL 8	Actual system completed and accepted for flight ("Flight Qualified")
TRL 9	Actual system "flight proven" through successful mission operations

Excerpt from the risk register

ID	Risk	Risk Index	Mitigation
MS.01	Instrument damage	B4 medium	Vibration testing/ flight spare
MS.02	Exposure to micrometer-size space debris	D3 high	Statistical simulation/ protective housing using Whipple Shields
MS.06	Not measuring certain proxies	C4 medium	Measuring proxies in different wavelength ranges
TC.04	Mission delay due to TRL 4-5 components	D2 medium	Early testing of telescope mirrors and instruments

Project Timeline



Cost

- Shared launch to **reduce cost**

Spacecraft segment	Million €
Telescope	150
UV instrument	80
NIR instrument	50
VIS instrument	30
Bus	150
Mission Segment / Sub-total	**460**
Development/AIT	120
Data analysis (8 scientists)	23
Launcher / Shared launch	75 / 40
Initial cost	**678 / 643**
Margin	20%
Total cost	**814 / 772**

Descoping options

a. Remove capacity to measure Ly-α in UV

i. Can be done with NIR, but not with all planetary targets

ii. Reduces the instrument wavelength range

→ Cheaper optics

b. Remove complete UV spectrometer

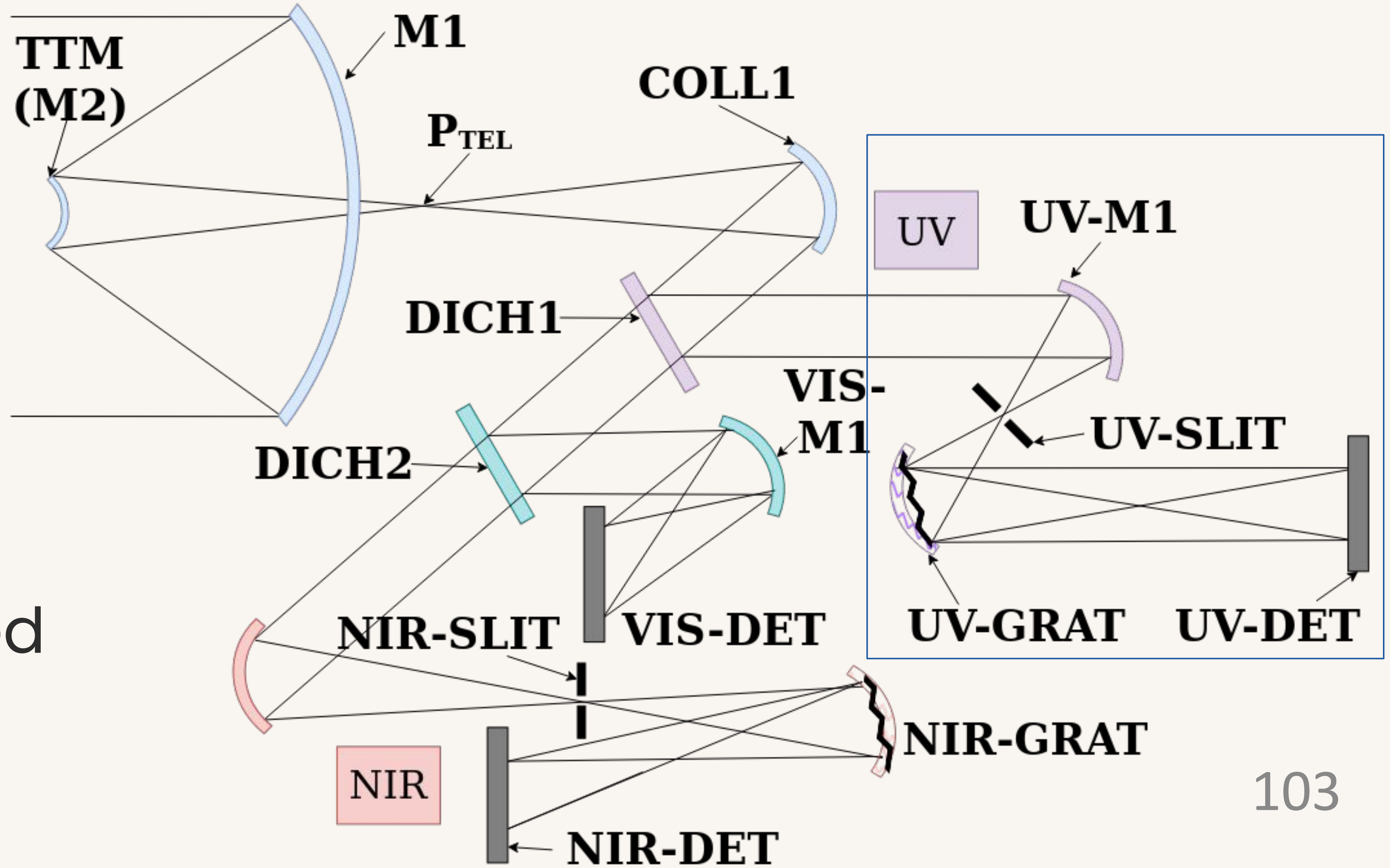
i. Simpler optics

→ Smaller telescope

c. Spectral resolution reduction in NIR

i. Line resolving is not any more ensured

→ Cheaper Optics



Outreach strategy

a. **Scientific community**

   i. Publications & attending scientific conferences
   ii. Different calls for observation proposals
   iii. Invite students to participate in mission meetings
   iv. Organize *Atmospheric Escape Symposium*

b. **General public**

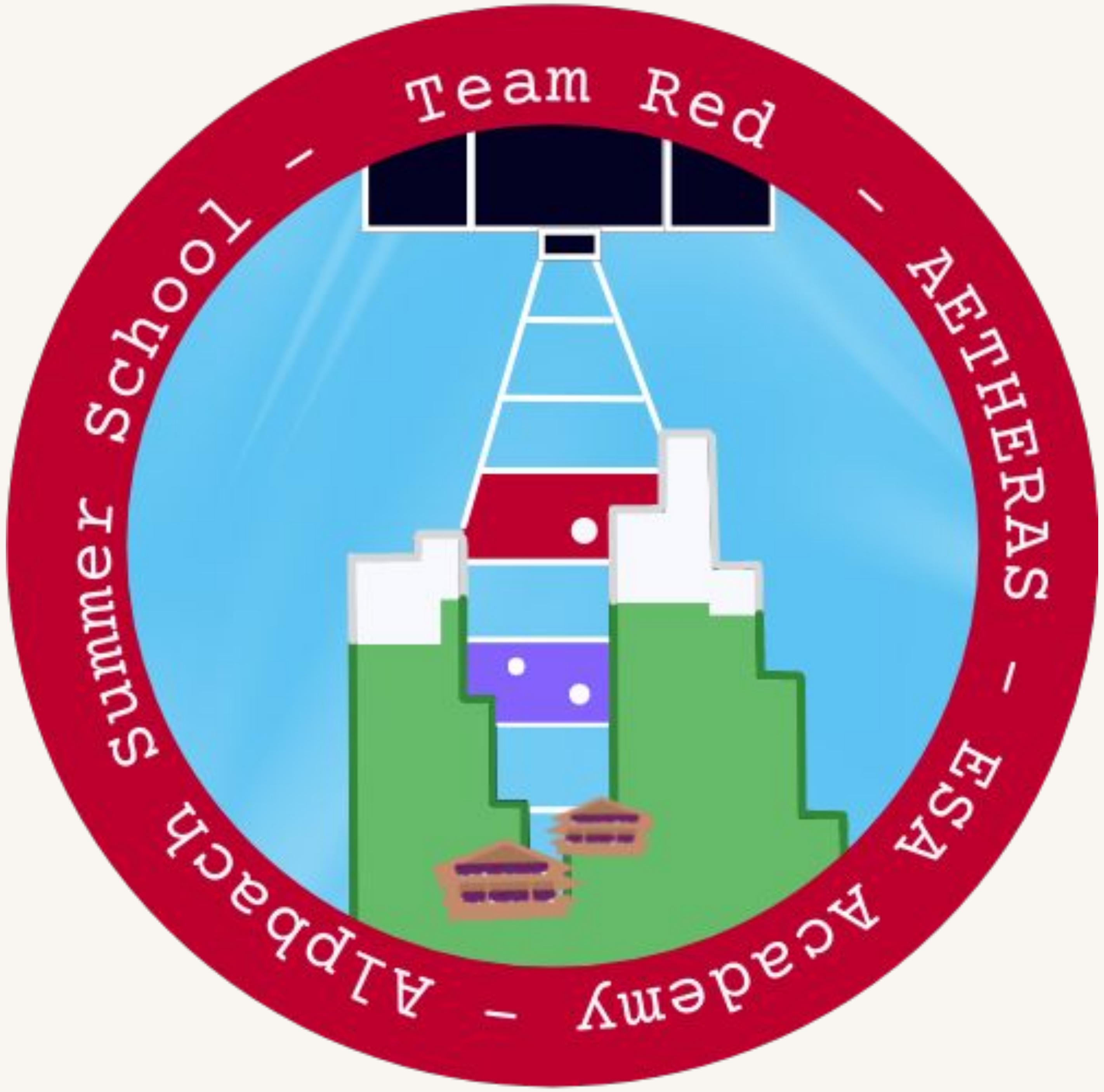
   i. Social Media, website & press releases
   ii. Podcast
   iii. VR/ App design to follow the telescopes observations
   iv. Provide educational resources
   v. Touring, interactive exhibition

@aetheras #eatheras

Conclusions

“Deepening our knowledge of planetary system formation and evolution by studying atmospheric escape”

Aetheras is the first space telescope to address the mysteries of the radius valley and the Neptunian desert, as well as the interactions between atmospheric escape and magnetic fields of exoplanets, to expand our knowledge on how planetary systems form and evolve.



Thank you for listening!

Any questions?

Team Red

Summer School

Alpbach 2023

Marius Anger, Aksel Søren Beltoft,
Noria Brecher, Antoine Corne,
Jo Ann Egger, Simone Filomeno,
Margarida Graça, Viktoria Keusch,
Guillem Khairy, Jakub Kowalczyk,
Dominik F. Loidolt, Melker Marminge,
Alex McDougall-Page, Lukas Tamulevicius,
and Elena Tonucci

Back-up slides

Trade-off for the Ly-α line

Pros:

1. PLATO might identify **targets with good emission spectrum in the UV (and Lyman-alpha)**.

2. Probing He I and H emission lines increase precision and helps disentangle ambiguous results.

3. Probing **C II and H I lines constraints the magnetic field measurements**. (Ly-alpha line used to break degeneracies in the model determination of magnetic field parameters)

Cons:

1. Our targets are M and K-type stars - **dim UV emission**. More photons in the NIR than in the UV.

2. ISM absorption can distort the Lyman-alpha line, reduce its accuracy.

3. **He I** - **rate of mass loss** - radial velocity of the cloud.

4. Reducing costs: money, size and weight.

5. **Detections using Lyman-alpha are more reliable**.

Notes:

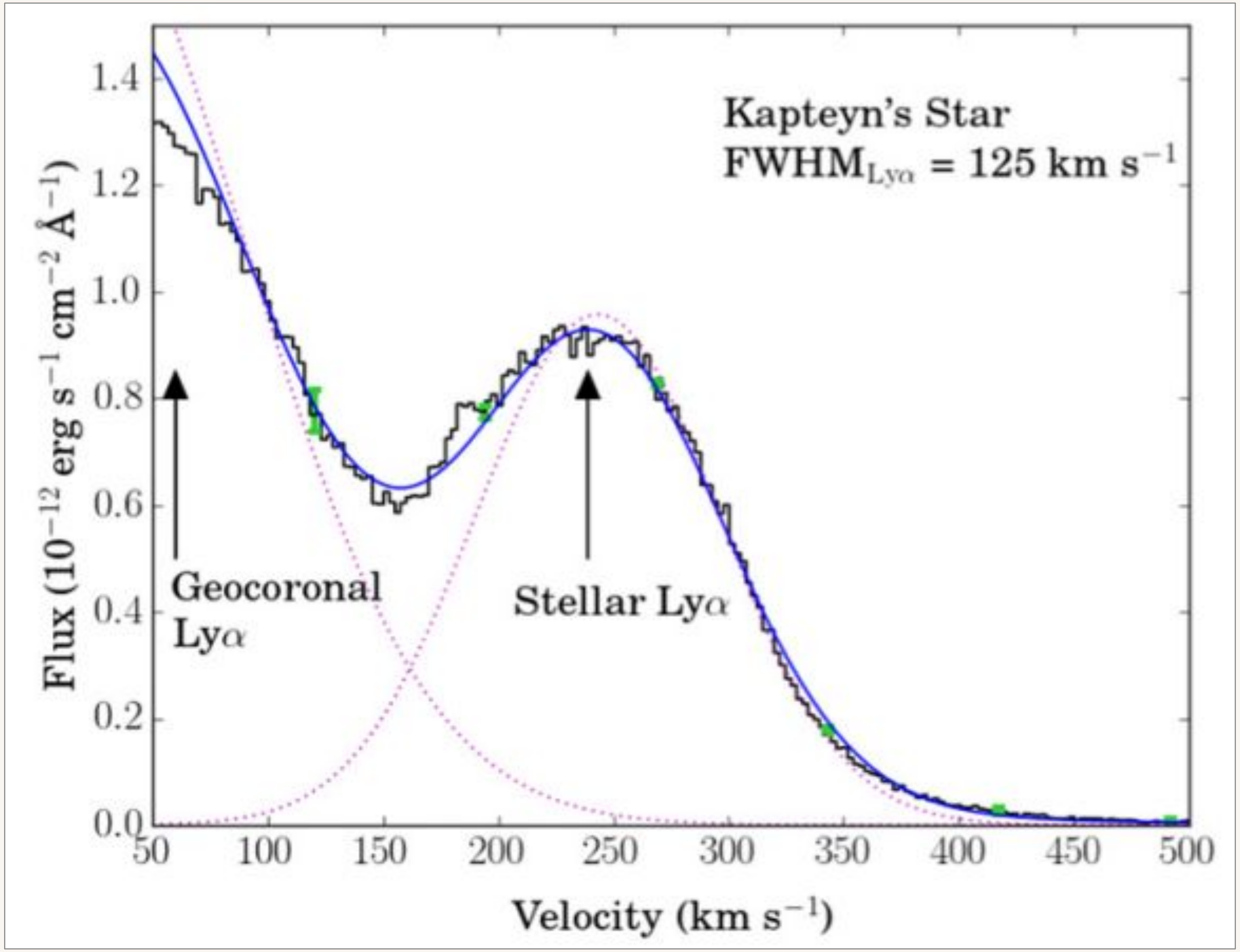
1. With lower resolution in the UV (500) and higher resolution in the NIR (3600) we can detect atmospheric loss and mass loss rate (He I). UV is only necessary to detect the magnetic field and low resolution is enough.

2. Since He is heavier than H, it has a lower escape rate.

3. The ratio of He I and H relative to the atmosphere are not significantly different.

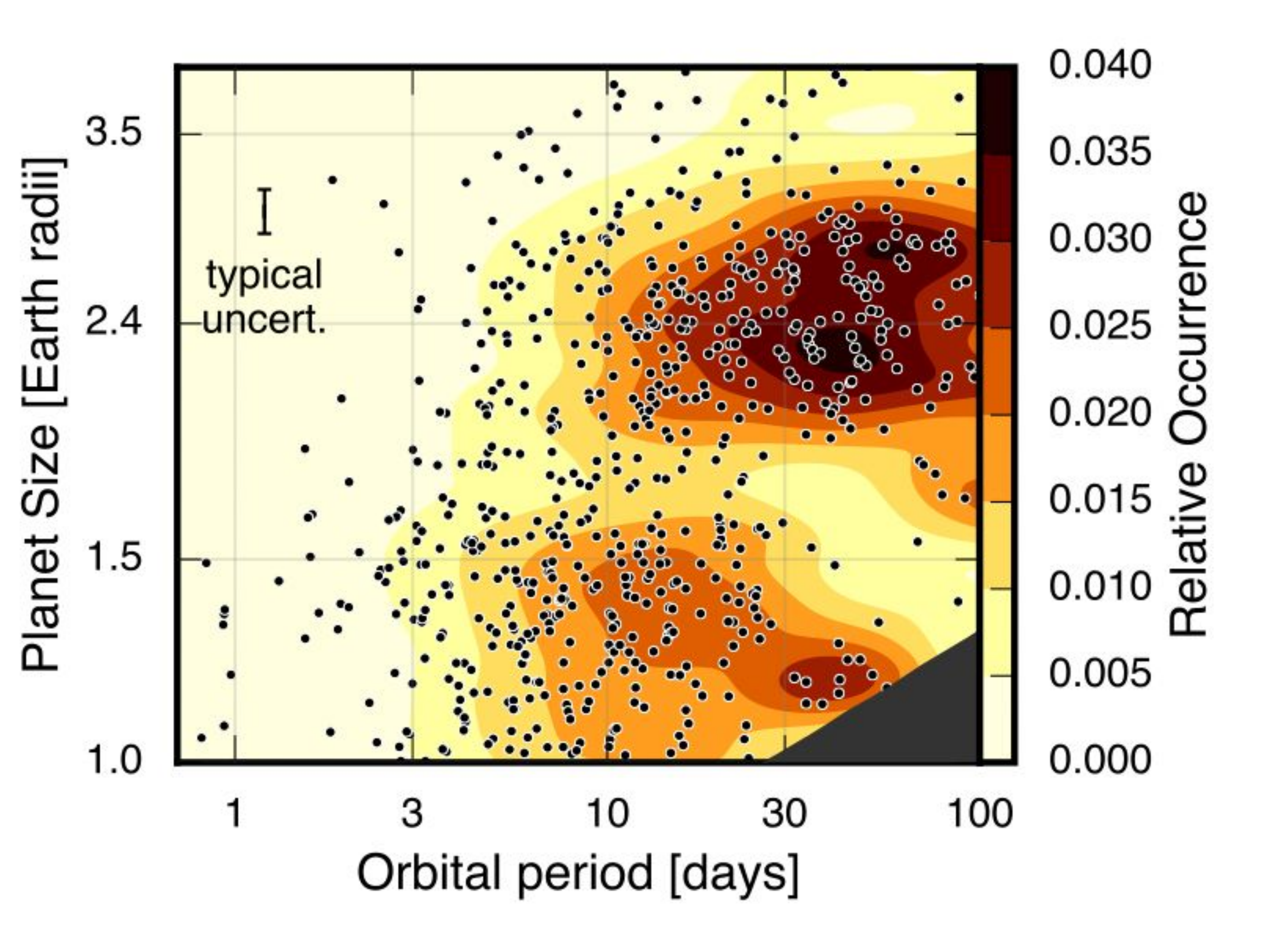
4. ARIEL can't resolve He I sufficiently to determine the atmospheric loss rate.

Why HST cannot answer our questions?



Diversity of Discovered Exoplanets

- Region in the graph with a lower density of planets - Radius Valley.
- Sub-Neptunes - Planets with smaller radius than Neptune but near 2.0Er.
- Super-Earths - Planets with bigger radius than Earths, yet lighter than ice giants.
- Hot-Jupiters - Gas giant exoplanets, most have a very short orbital periods.



Akash Gupta and Hilke E. Schlichting, 2019

Link Budget [Uplink]:

	Value	Unit
Uplink		
Frequency	**8.4**	**GHz**
Distance	1 500 000	km
Space loss	-234.4	dB
Attenuation loss	-2.1	dB
Transmission loss	-236.5	dB
Ground antenna diameter	35	m
Transmitter power	25 000	W
Antenna efficiency	50	%
Transmitter loss	-0.5	dB
Gain	66.8	dB
Beamwidth	0.071	deg
EIRP	**110.3**	**dB**

	Value	Unit
Uplink		
Phase array area	1	m^2
Antenna efficiency	70	%
Pointing accuracy	0.15	deg
Beamwidth	5	deg
Gain	16.8	dB
Receiver noise temperature	27.2	K
Receiver G/T	**2.5**	**dB**
Bandwidth	35	MHz
Data rate	70	kbps
Final Eb/En	**3.3**	**dB**

Link Budget [Downlink]:

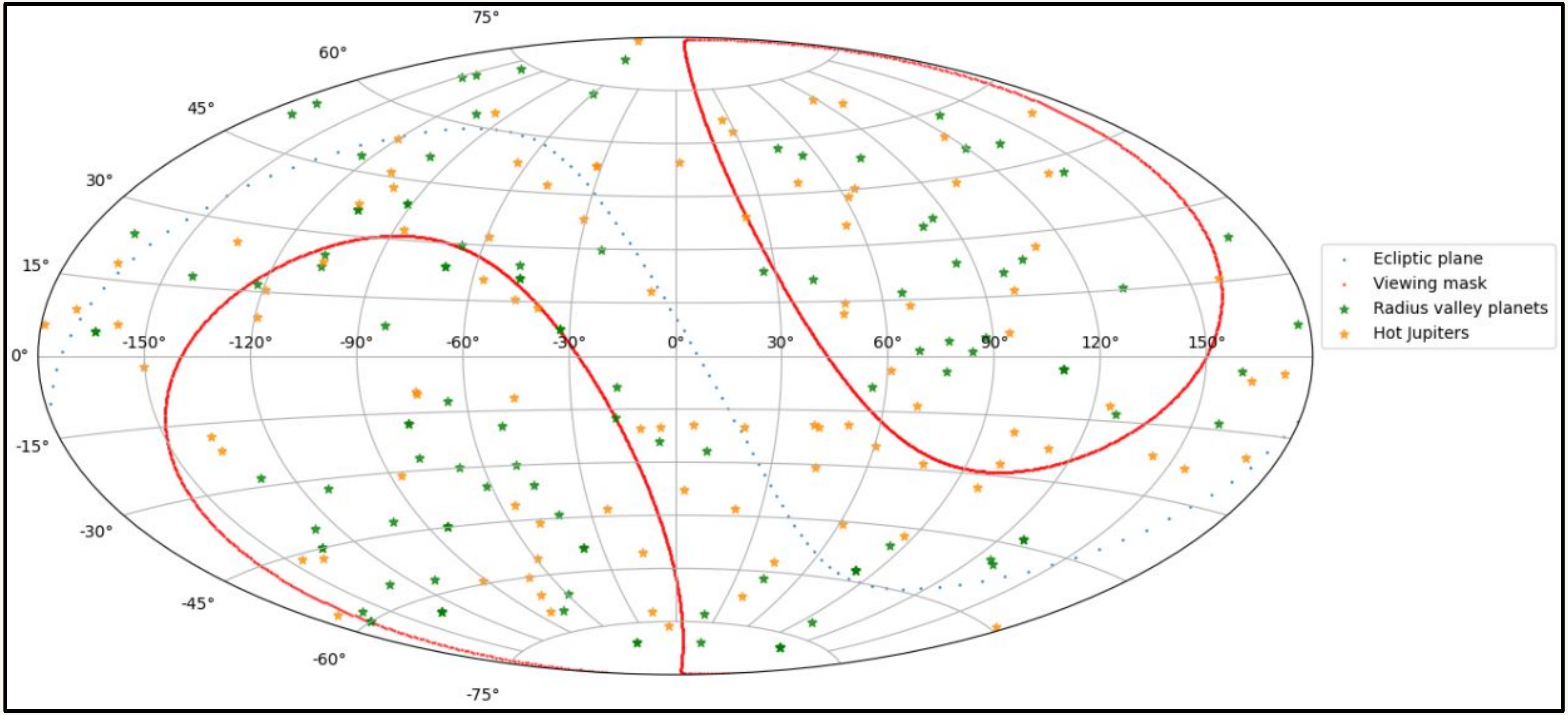
	Value	Unit
Downlink		
Frequency	**7.75**	**GHz**
Distance	1 500 000	km
Space loss	-233.7	dB
Attenuation loss	-2.1	dB
Transmission loss	-235.8	dB
Phase array area	1	m^2
Antenna efficiency	70	%
Transmitter loss	-0.5	dB
Gain	16.8	dB
Beamwidth	9.03	deg
EIRP	**33.3**	**dB**

	Value	Unit
Downlink		
Ground receiver diameter	35	m
Antenna efficiency	50	%
Pointing accuracy	0.1	deg
Beamwidth	0.077	deg
Gain	66.1	dB
Receiver noise temperature	27.2	K
Receiver G/T	**51.7**	**dB**
Bandwidth	35	MHz
Data rate	8 000	kbps
Final Eb/En	**8.7**	**dB**

Risk Matrix

Severity	A (Extremely unlikely)	B (Unlikely)	C (Likely)	D (Highly Likely)	E (Near certain)
5	Medium	Medium	High	Very High	Very high
4	**TC.02 - Tx/Rx failure** Low	**MS.01 - Instrument damage** **MS.04 - Solar damage** Medium	**MS.06 - Not measuring certain proxies** Medium	High	Very High
3	**TC.03 - Equipment failure** Very Low	Low	Medium	**MS.02 - Exposure to micrometer space debris** High	High
2	**TC.01 - IR signal contamination** Very Low	Very Low	**MS.03 - Measurement disruption** Medium	**TC.04 – Mission delay due to TRL4-5 components** Medium	Medium
1	Very Low	**MS.05 - Planetary transit miss** Very Low	Very Low	Low	Medium
	Likelihood				

Candidate target list - viewing mask [IR9]

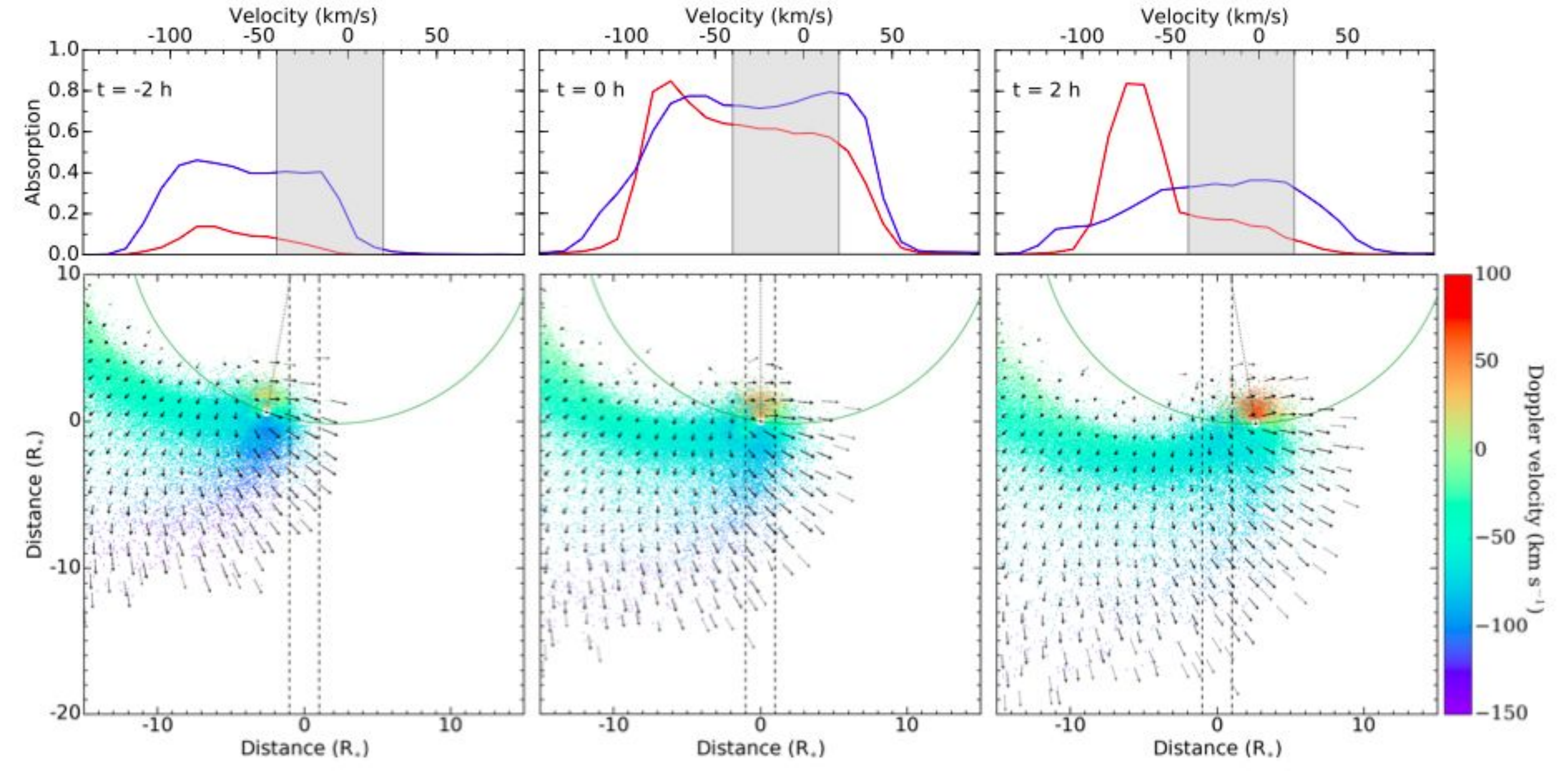


Satellite Modes

Safe	Troubleshooting
Commissioning	Instruments testing and health check
Orbital maintenance	Making L2 trajectory stable
Coarse pointing	Coarse pointing to target
Science	Fine pointing to target, instruments on and measuring
Telecommunication	Transmitting data to and from Earth

Interaction Magnetic Field Surrounding Cloud

- Effect of the stellar wind and magnetic field may be found in the velocity components of the surrounding cloud



V. Bourrier+ 2018