

Bibiana Prinorth

# HOTTER THAN HELL

Knut Lundmark Days 2023



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[@astro.bibi\\_](https://www.instagram.com/@astro.bibi_)



[@bibianaprinorth](https://twitter.com/bibianaprinorth)

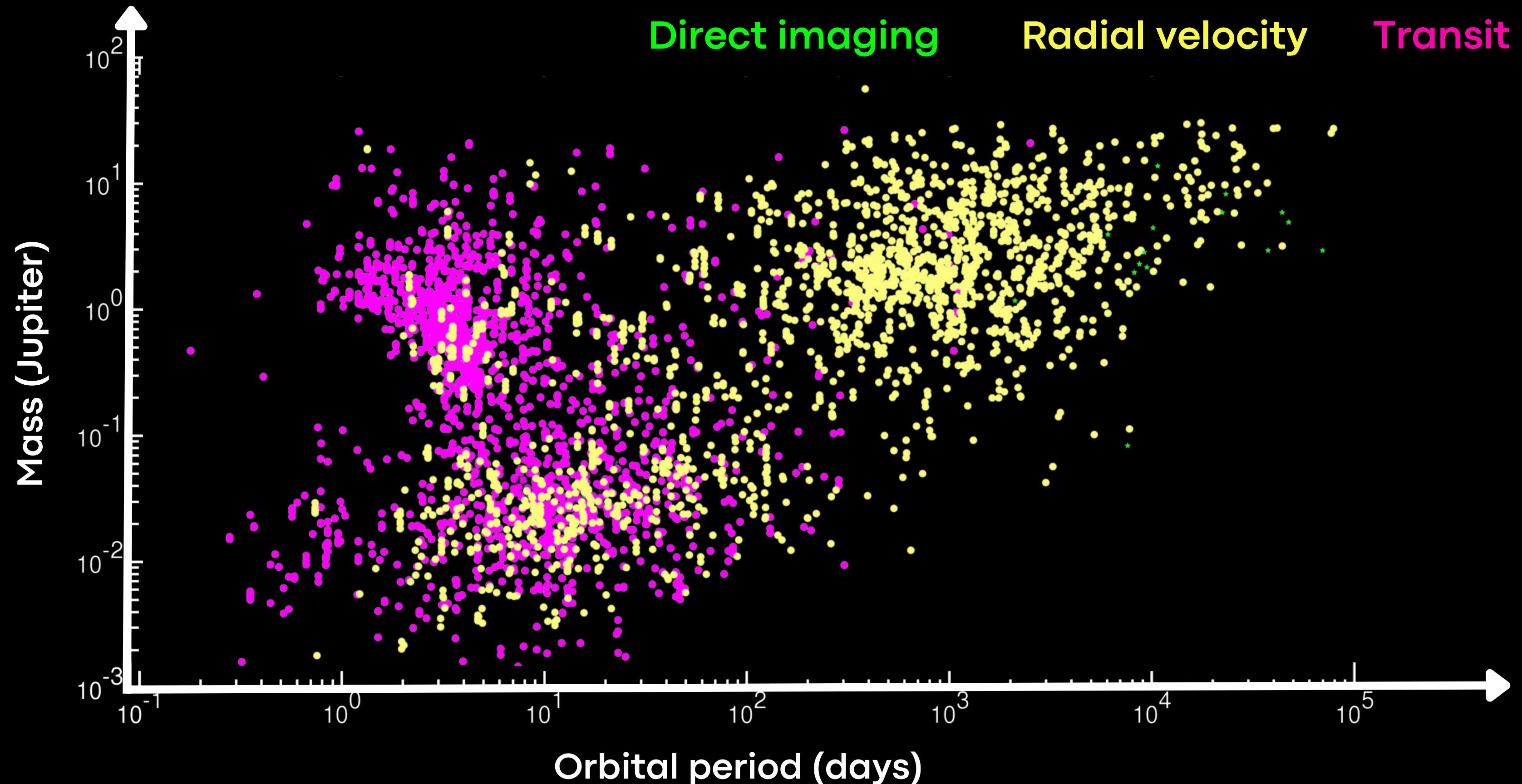


[@bibianaprinorth@astrodon.social](https://mastodon.social/@bibianaprinorth)

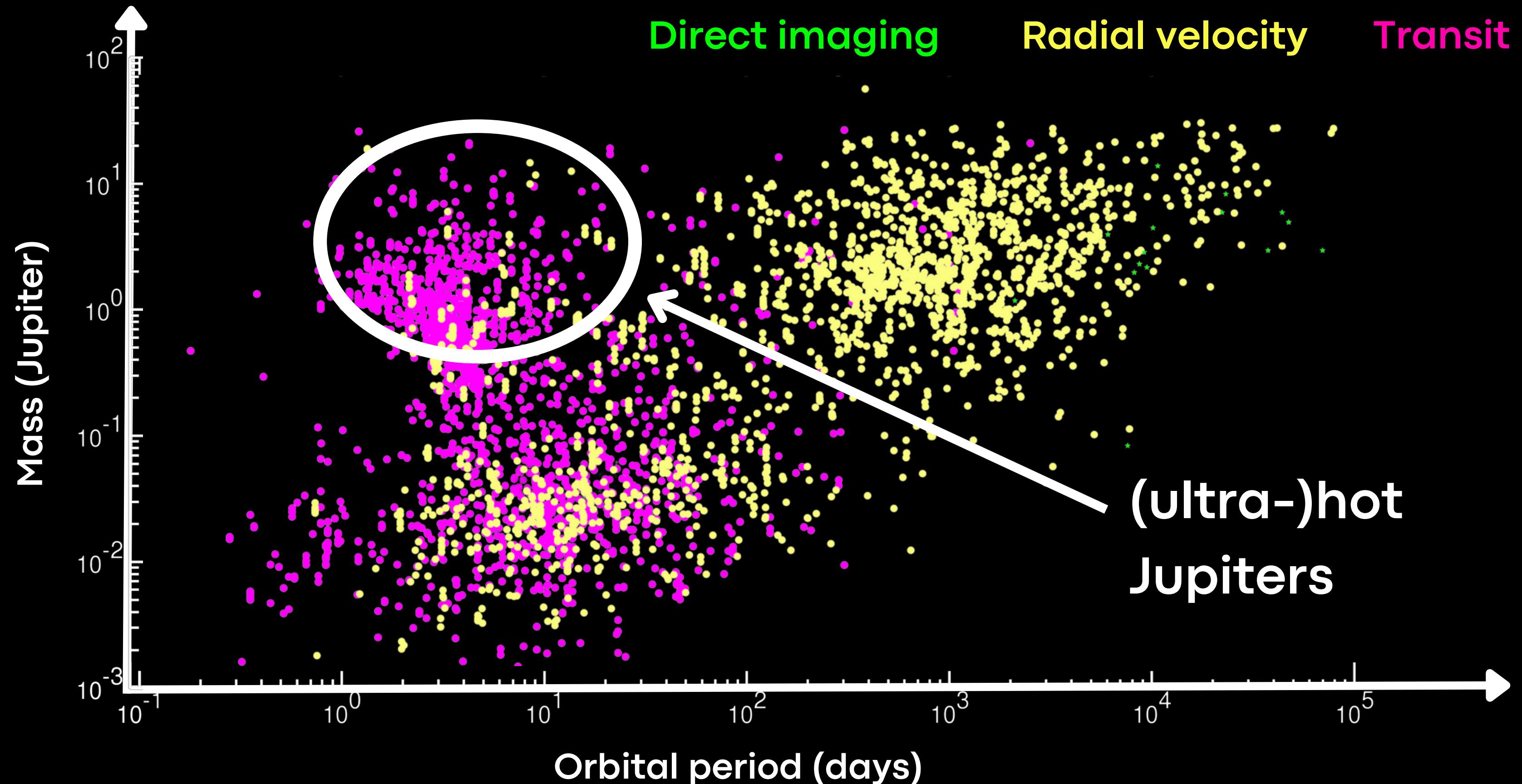


[bprinorth.github.io](https://github.com/bprinorth)

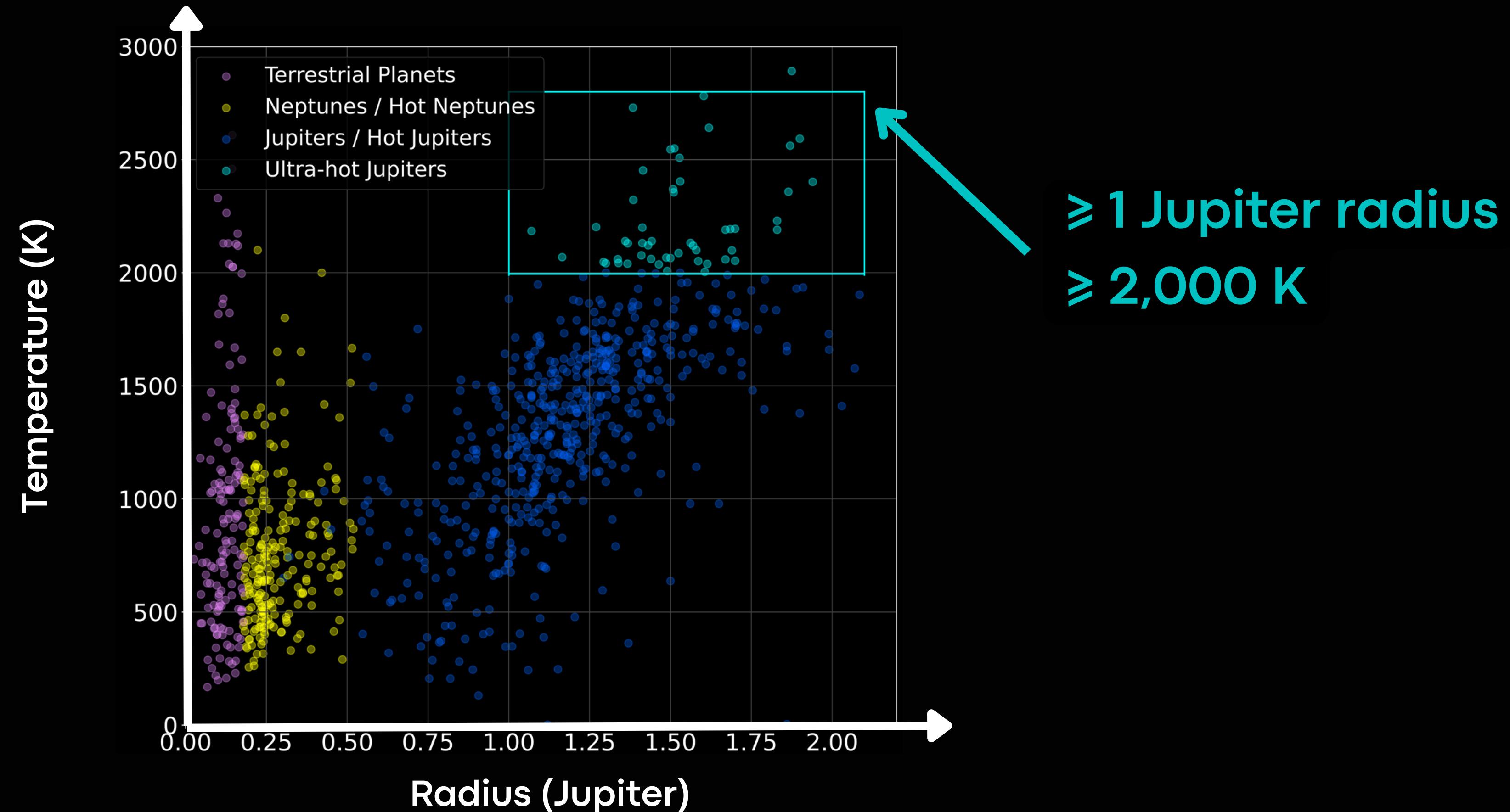
# The planets beyond our Solar System



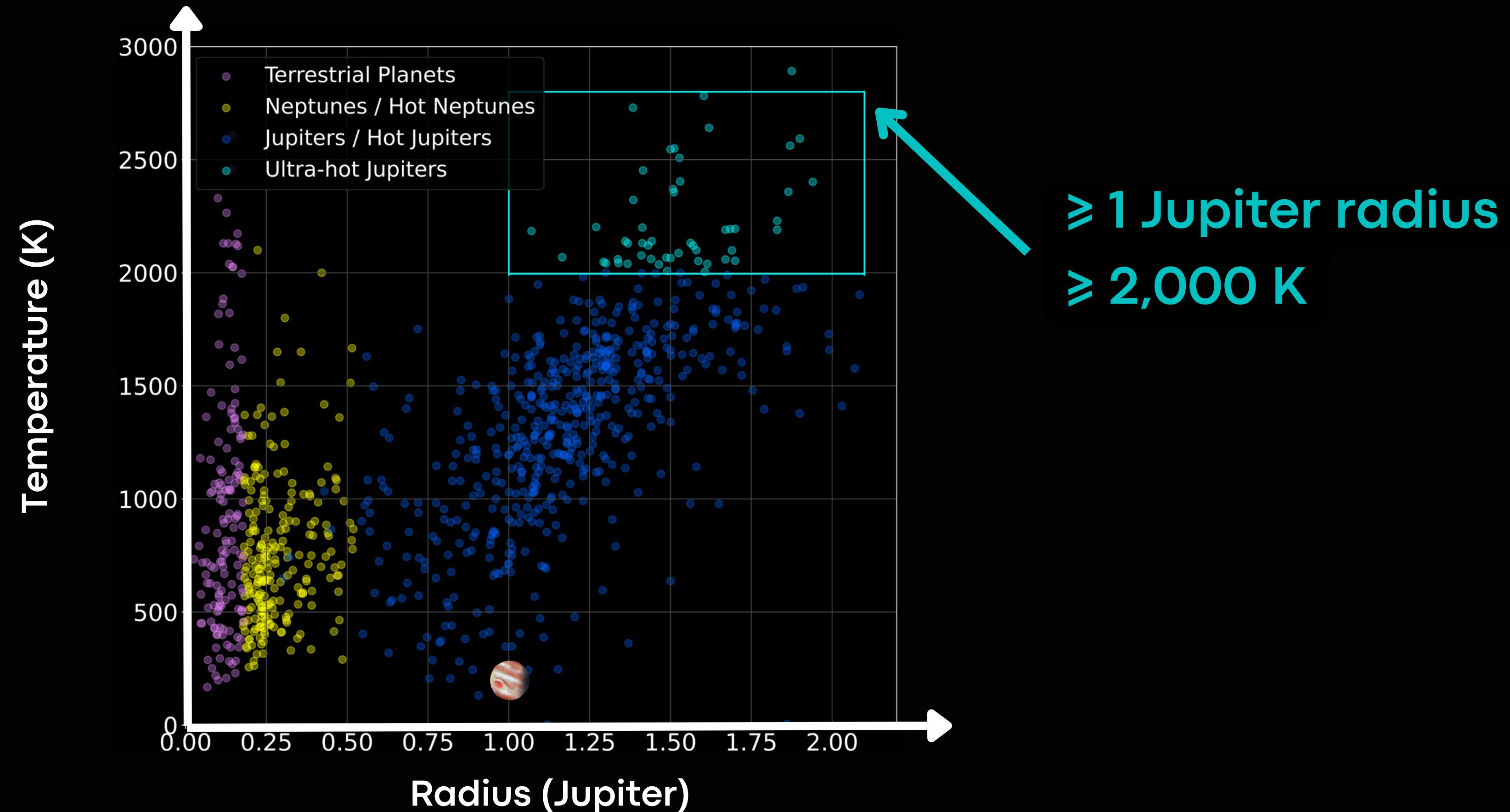
# The planets beyond our Solar System



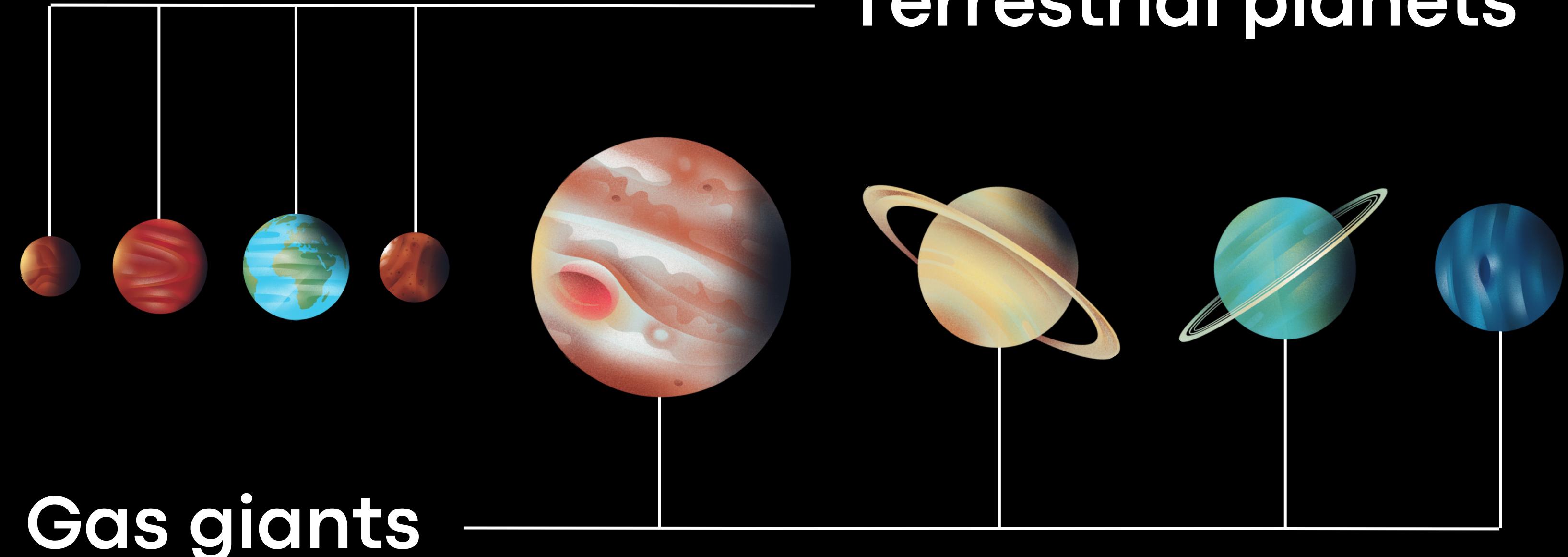
# Planets hotter than hell



# Planets hotter than hell

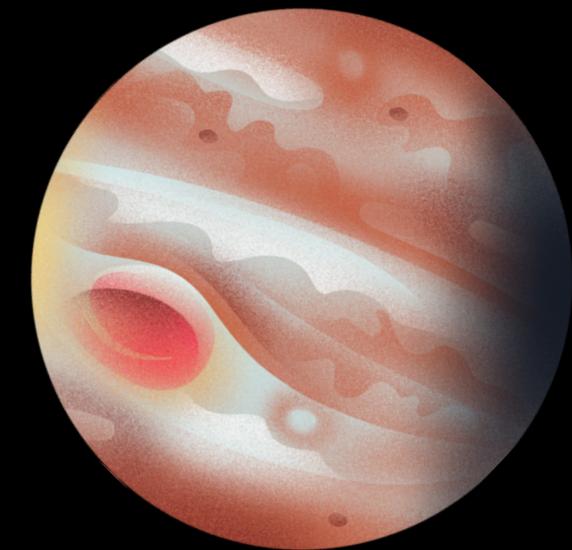


Terrestrial planets

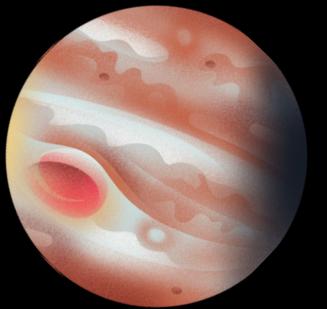


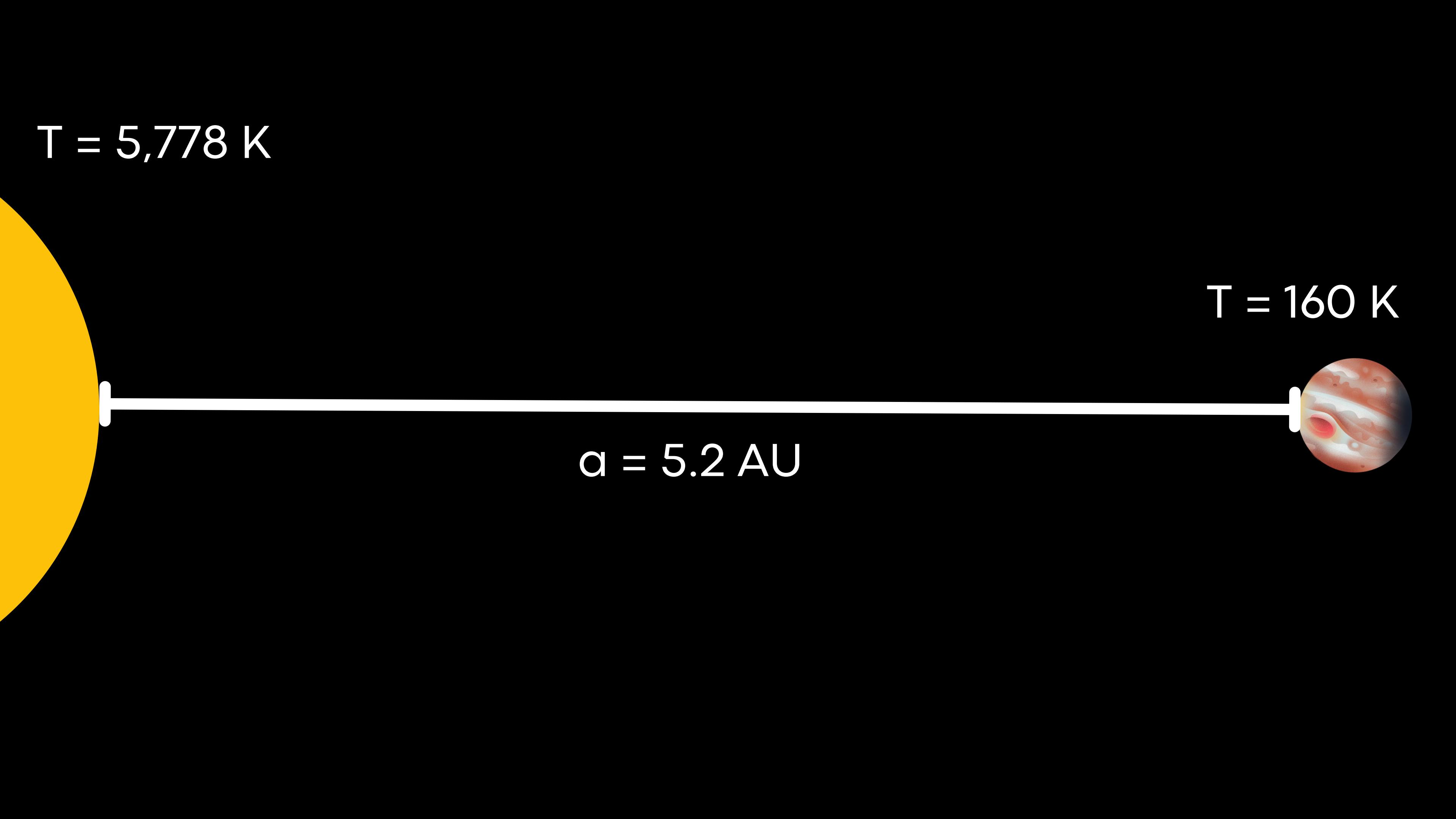
Gas giants

$T = 160 \text{ K}$



$T = 160 \text{ K}$





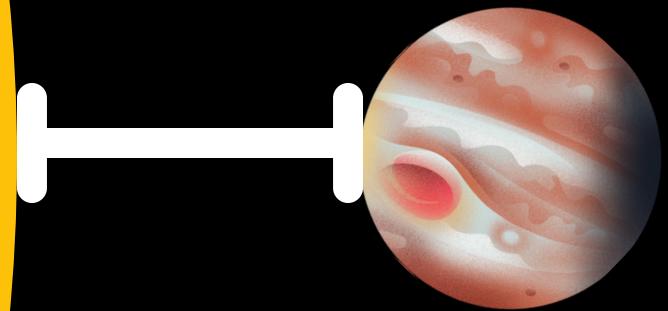
$T = 5,778 \text{ K}$

$T = 160 \text{ K}$

$a = 5.2 \text{ AU}$

How hot would  
Jupiter be  
now?

$T = 5,778 \text{ K}$

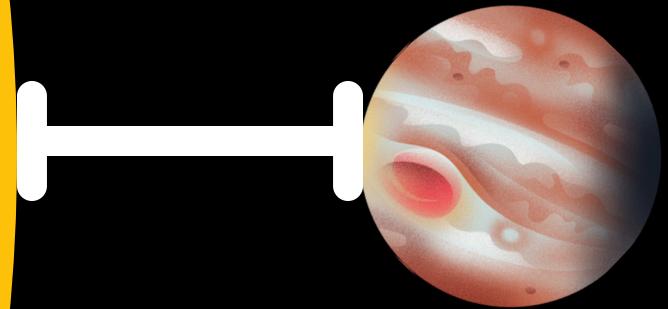


$a = 0.02 \text{ AU}$   
(over 50x closer to the  
Sun than Earth)

$T = 5,778 \text{ K}$

Not quite hot  
enough ...

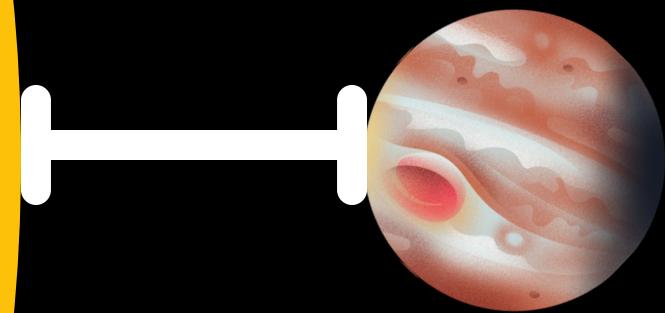
$T = 1,500 \text{ K}$



$a = 0.02 \text{ AU}$   
(over 50x closer to the  
Sun than Earth)

$T = 8,000 \text{ K}$

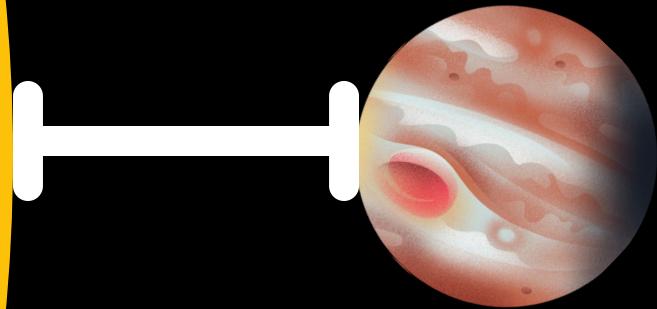
Let's heat up the  
star ...



$a = 0.02 \text{ AU}$

(over 50x closer to the  
Sun than Earth)

$T = 8,000 \text{ K}$



$T = 2,500 \text{ K}$

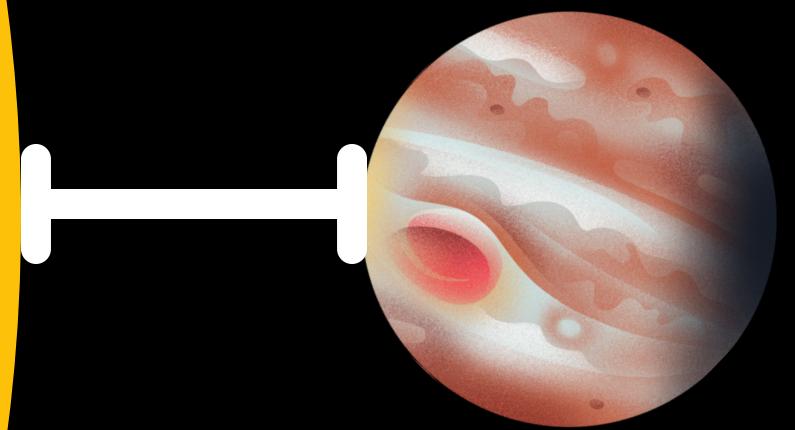
$a = 0.02 \text{ AU}$

(over 50x closer to the  
Sun than Earth)

We did it!

$T = 8,000 \text{ K}$

$T = 2,500 \text{ K}$

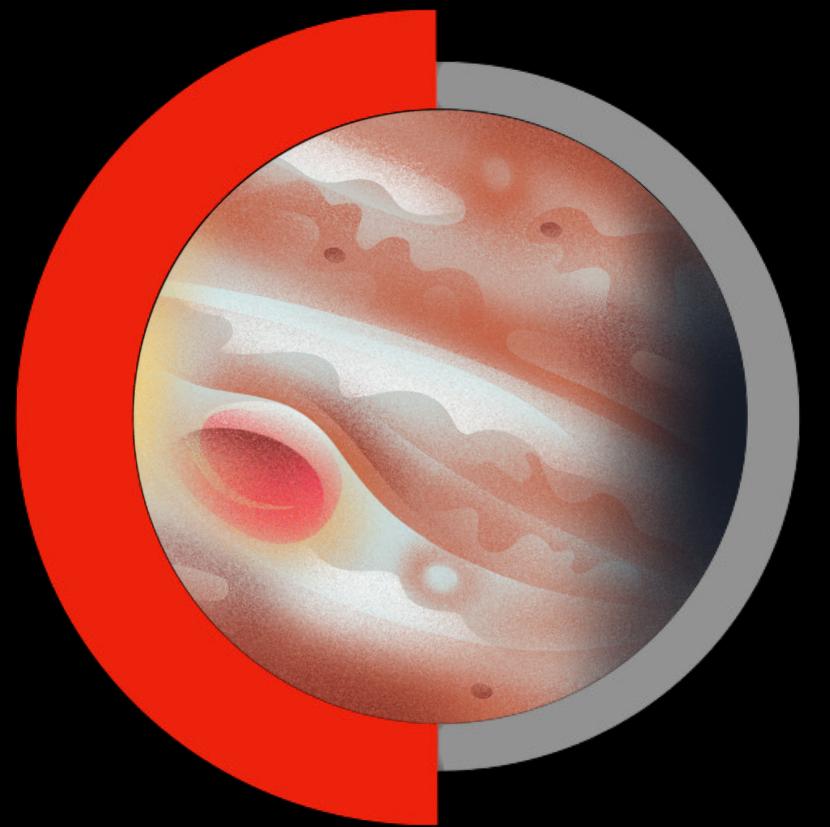


$a = 0.02 \text{ AU}$

(over 50x closer to the  
Sun than Earth)

$T = 2,500 \text{ K}$

Hot dayside

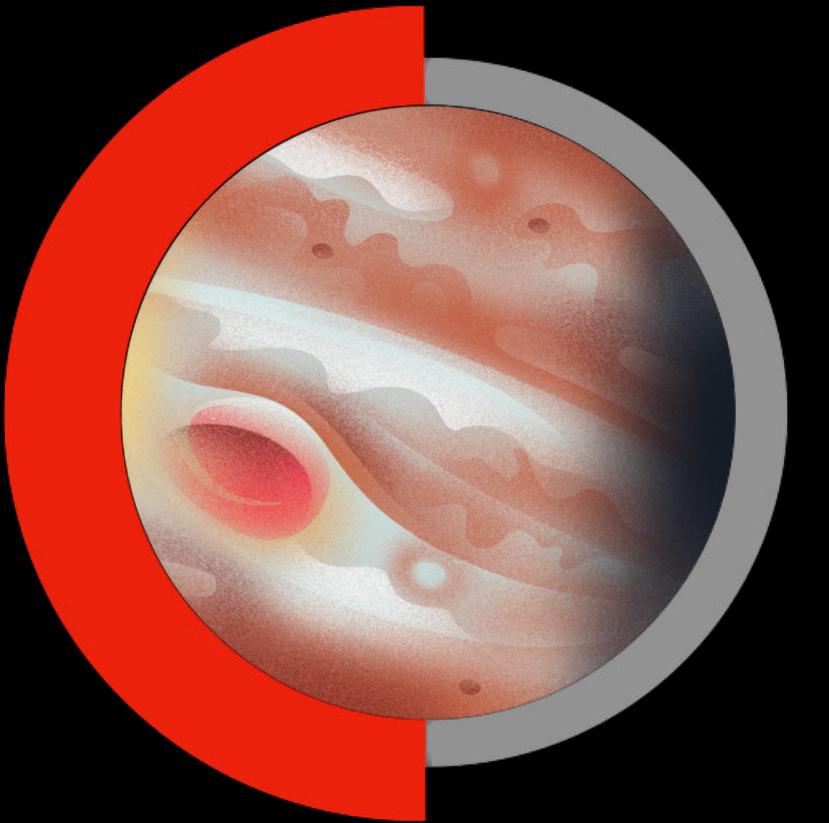


Tidally-locked planet

Cold nightside

Tidal locking  
in the Solar  
System:  
Earth-Moon

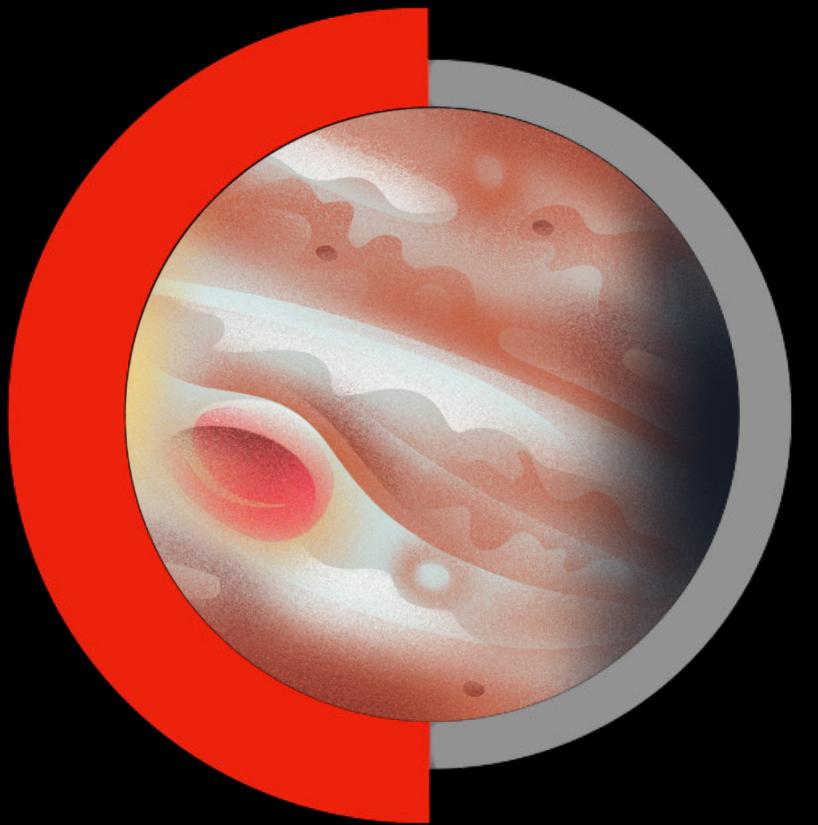
Hot dayside



Cold nightside

- photoionisation
  - dissociation
  - evaporation
  - temperature inversions
- 
- clouds
  - condensation
  - rain-out
  - recombination
  - cold-traps

Hot dayside



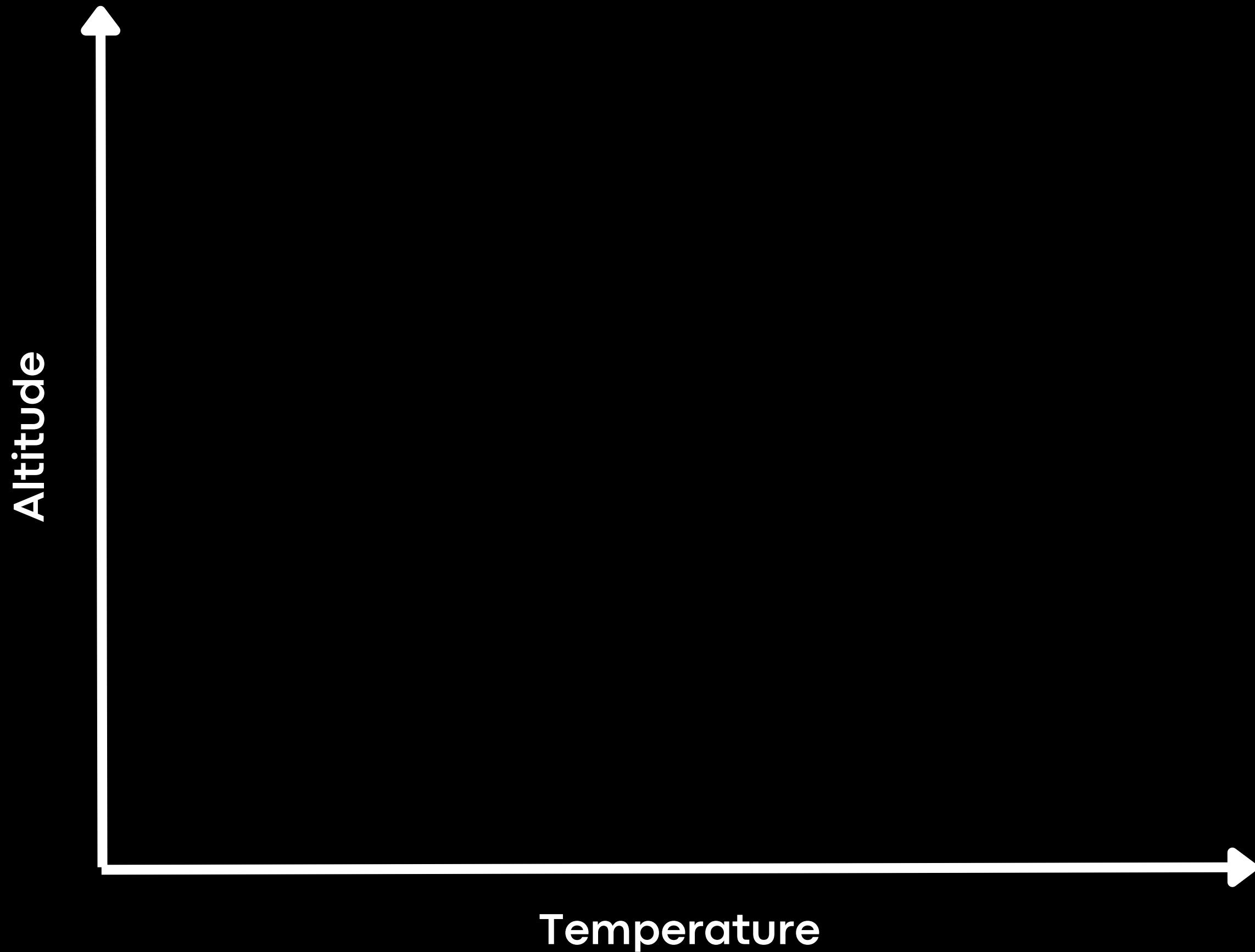
Cold nightside

# Temperature inversions



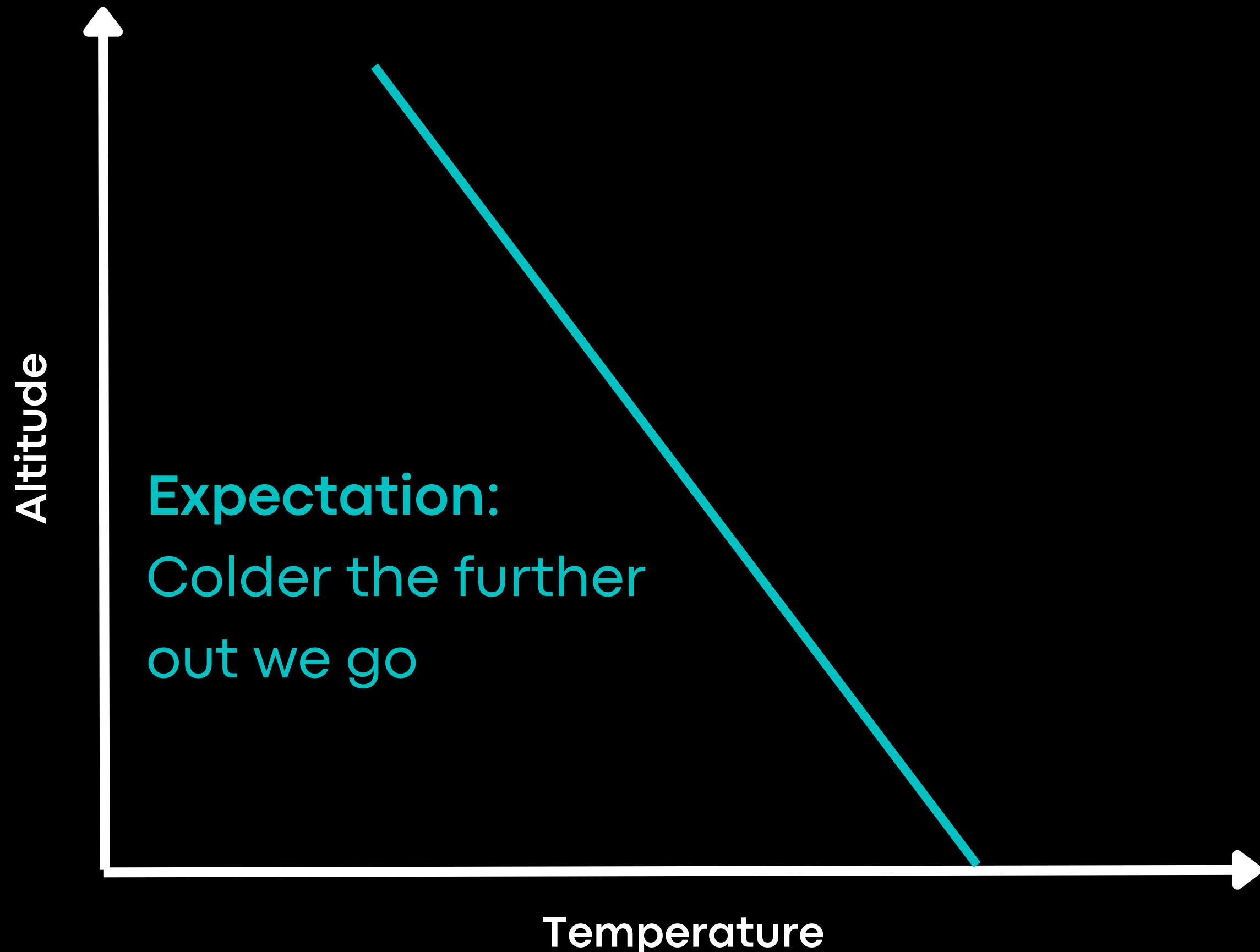
**WASP-189 b**  
 $(T = 2,600 \text{ K})$

# Temperature inversions



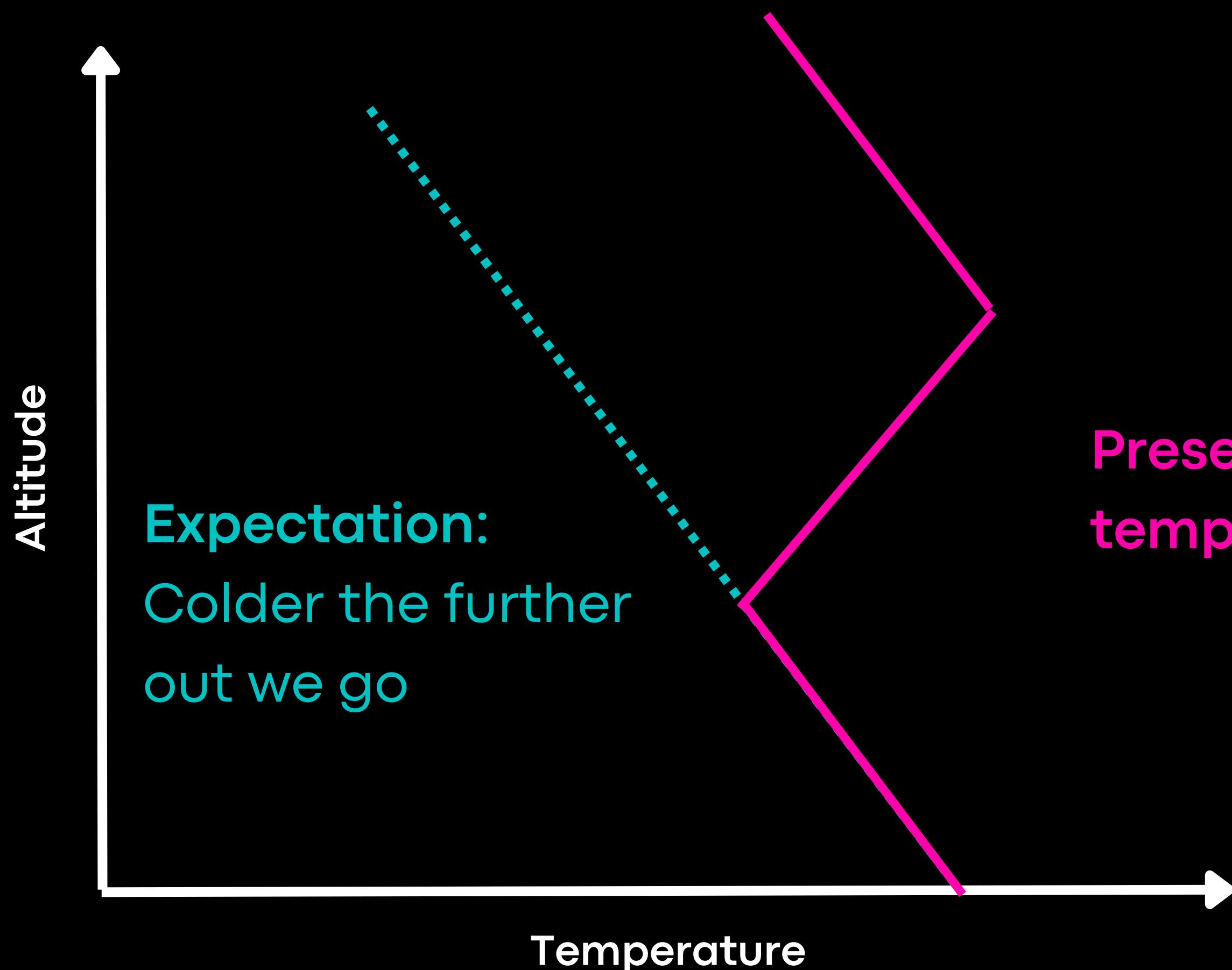
**WASP-189 b**  
( $T = 2,600$  K)

# Temperature inversions



WASP-189 b  
( $T = 2,600$  K)

# Temperature inversions



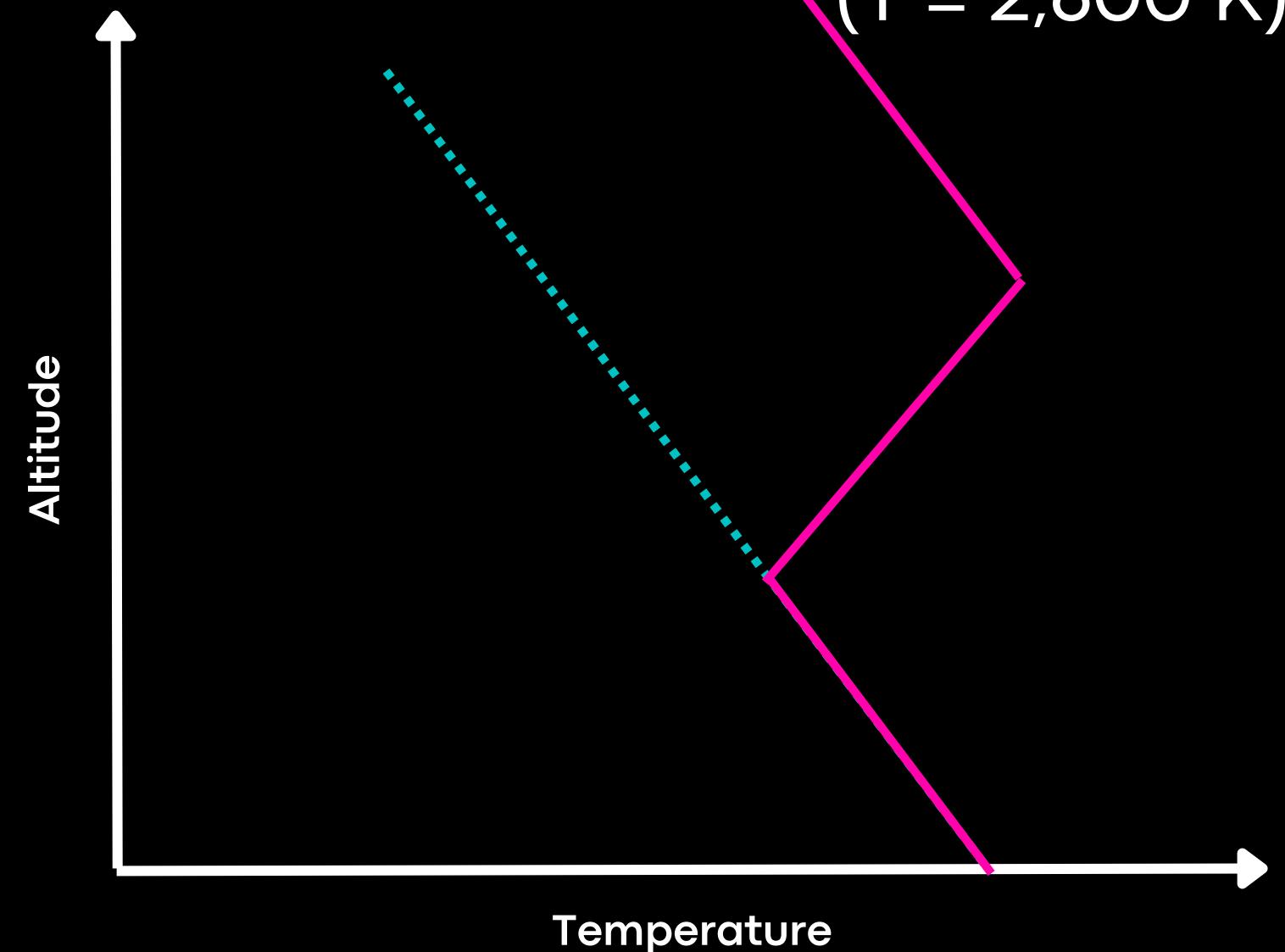
WASP-189 b  
( $T = 2,600$  K)

# Temperature inversions

This is caused by absorbing species in the atmosphere: Titanium- and vanadium oxide.



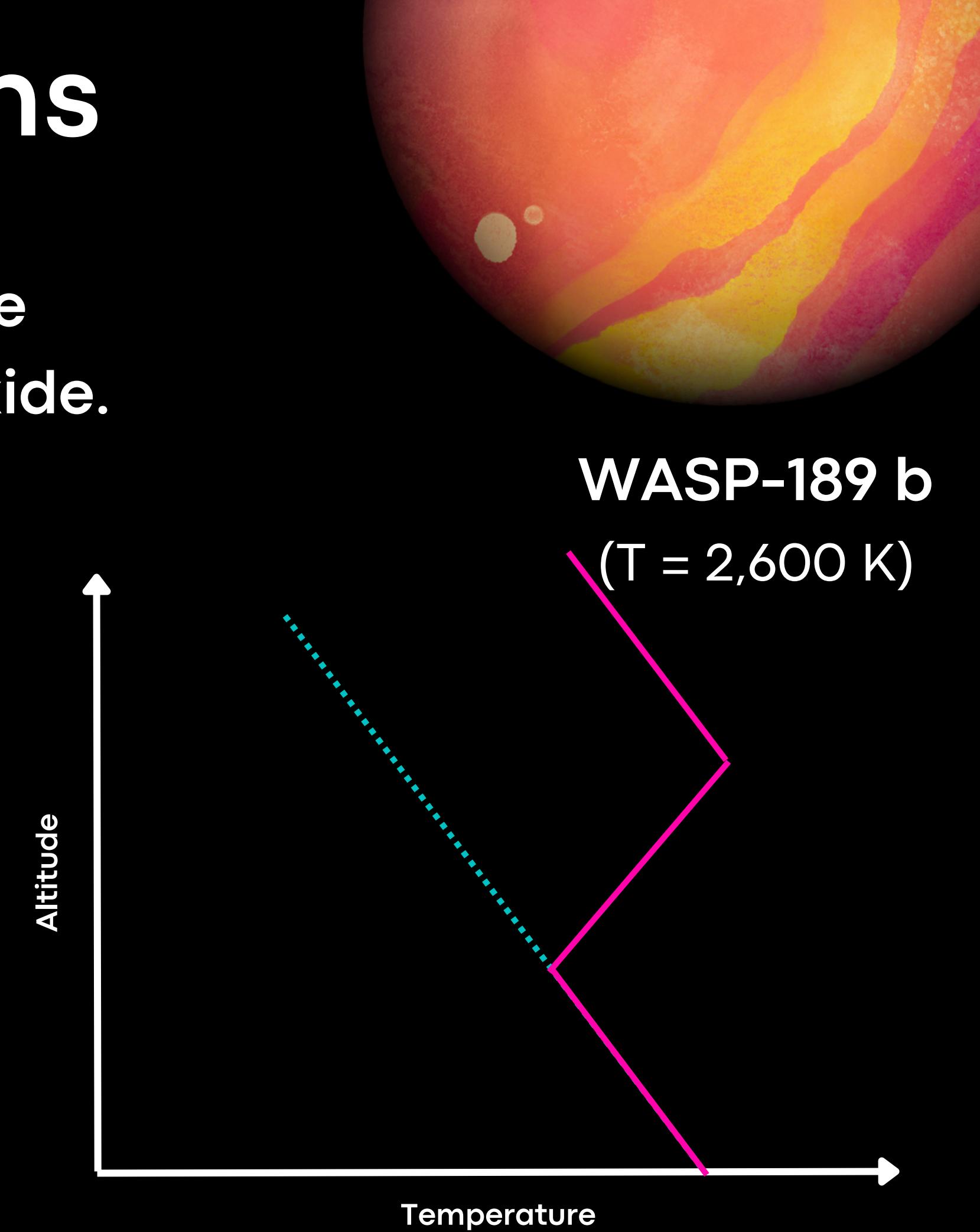
**WASP-189 b**  
 $(T = 2,600 \text{ K})$



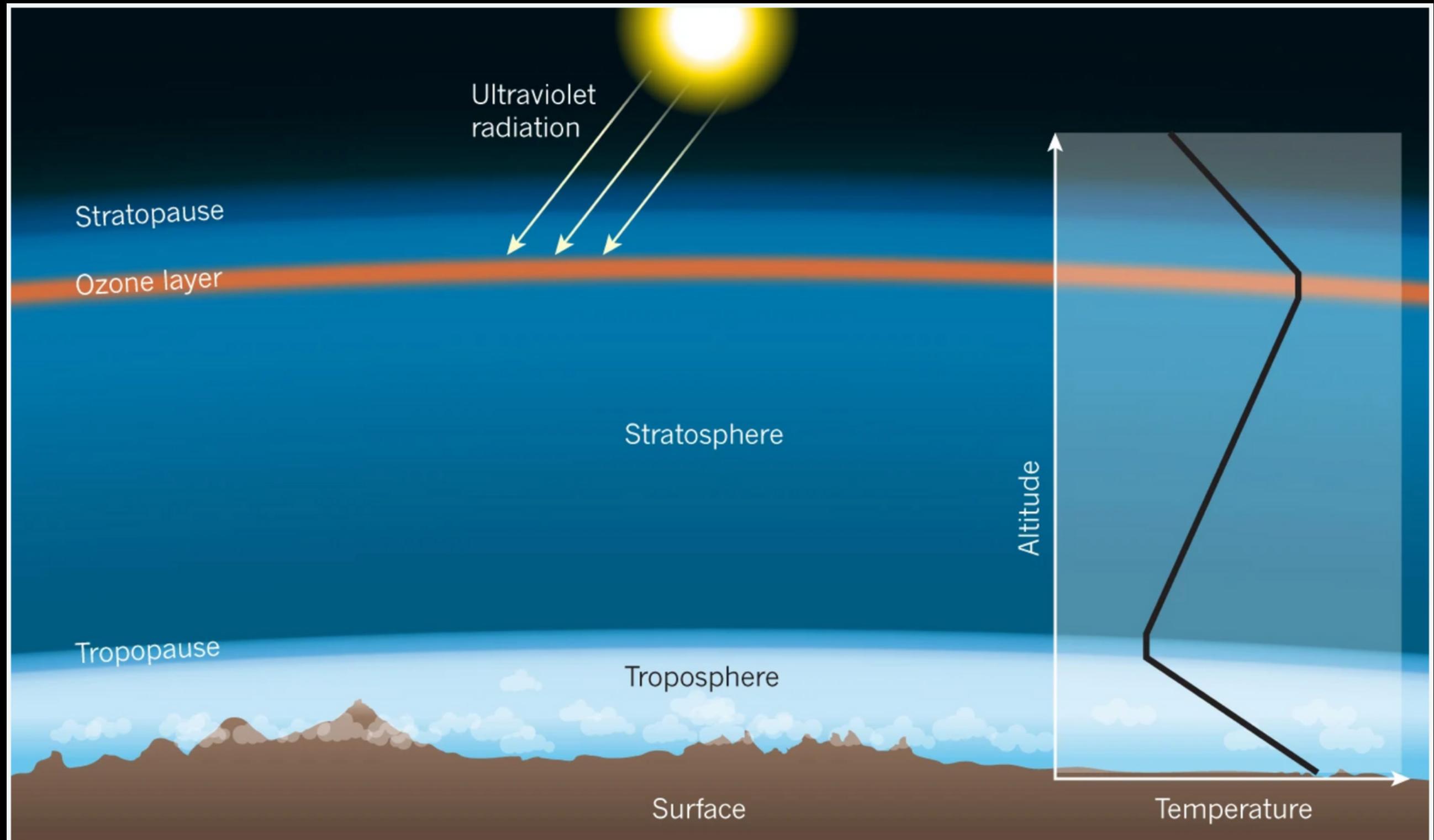
# Temperature inversions

This is caused by absorbing species in the atmosphere: Titanium- and vanadium oxide.

We know this from our own planet: The ozone layer!



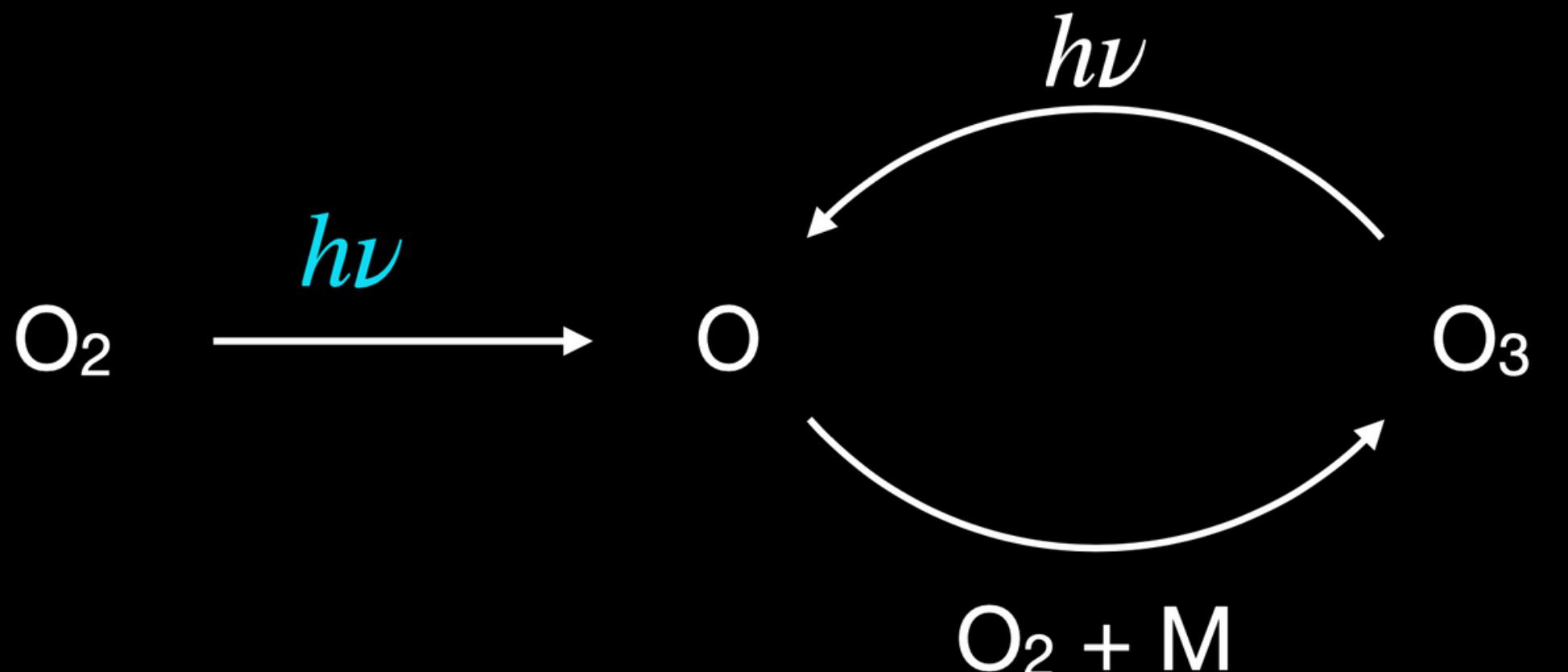
# Temperature inversions



Earth

# Temperature inversions

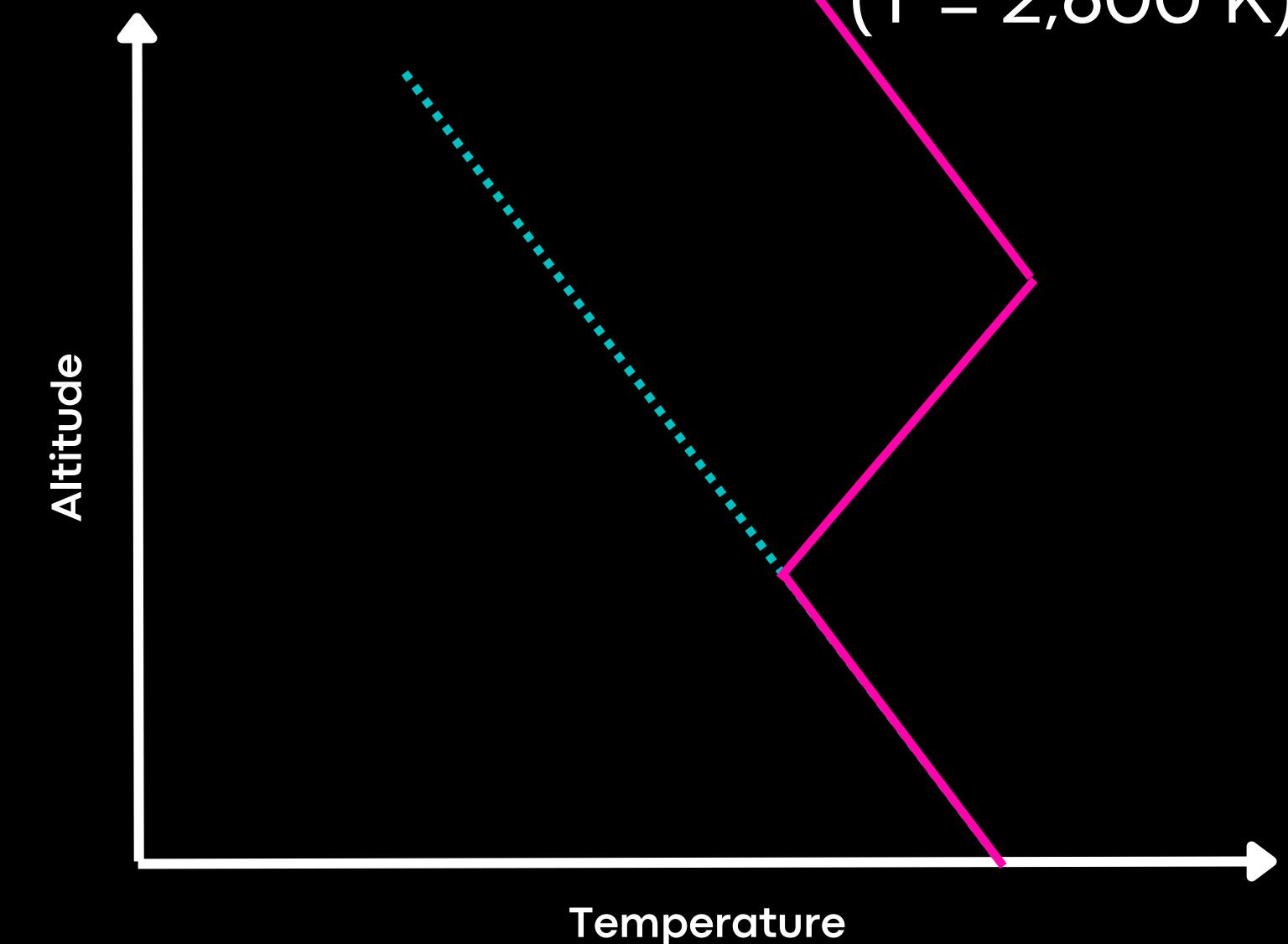
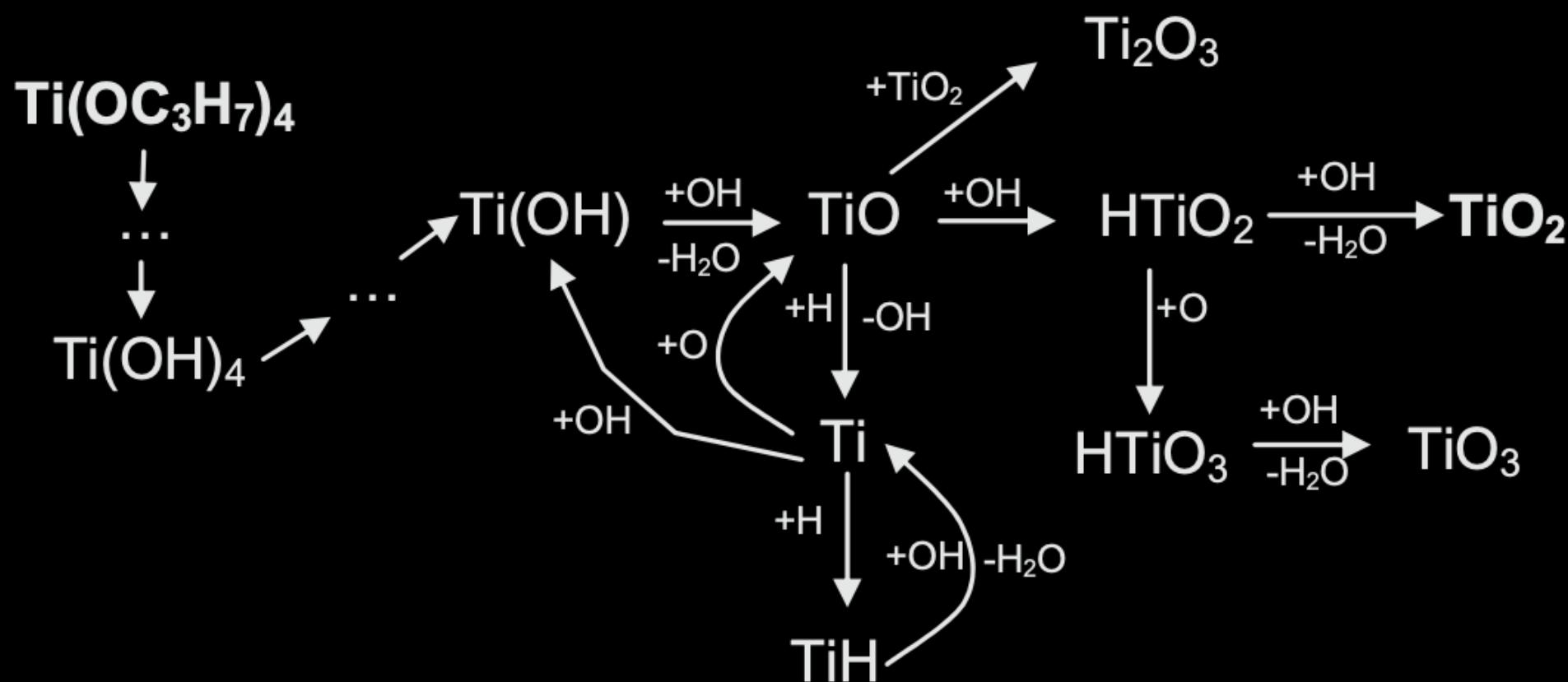
Ozone is responsible for the temperature inversion in Earth's atmosphere. The inversion is explained in a process called the Chapman Cycle.



Earth

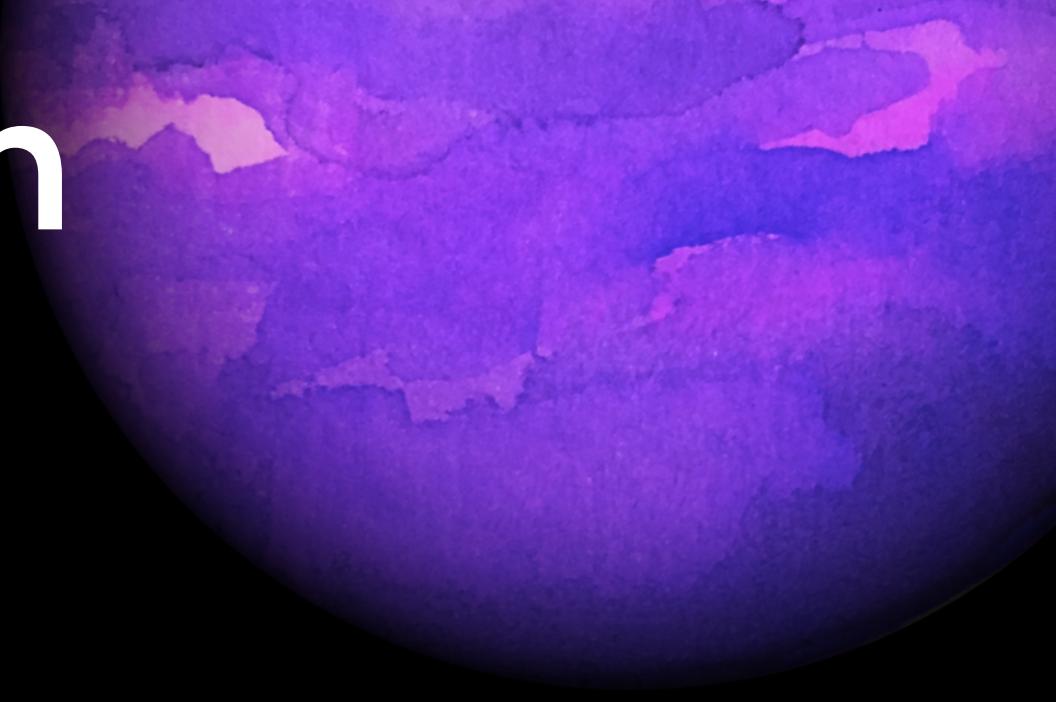
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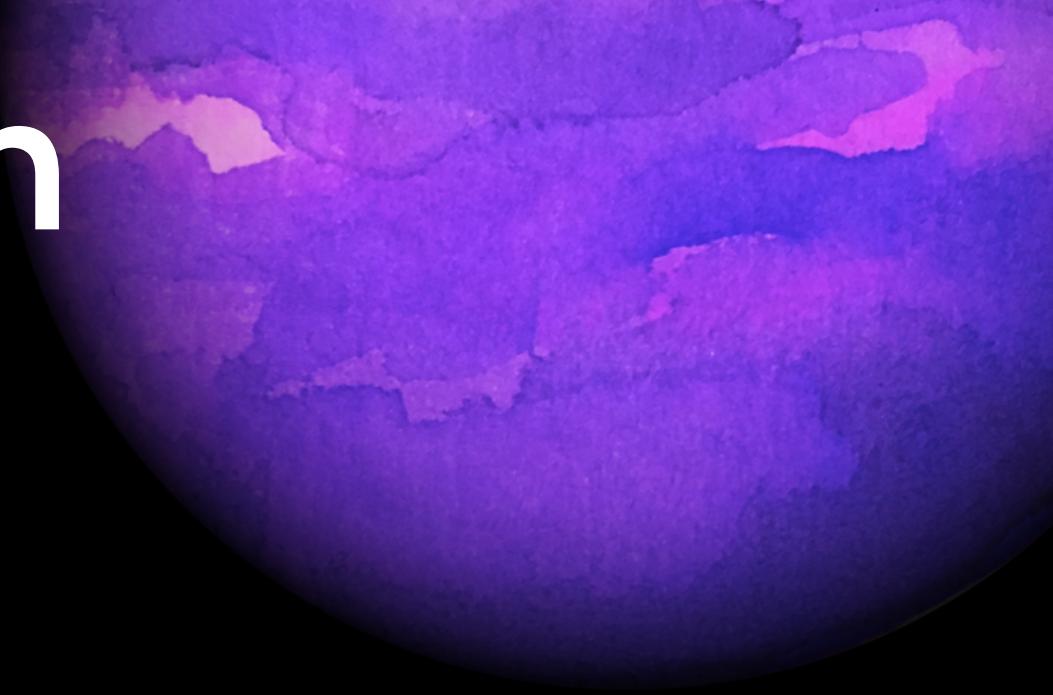


# Condensation & evaporation

**WASP-76 b**  
 $(T = 2,160 \text{ K})$



# Condensation & evaporation



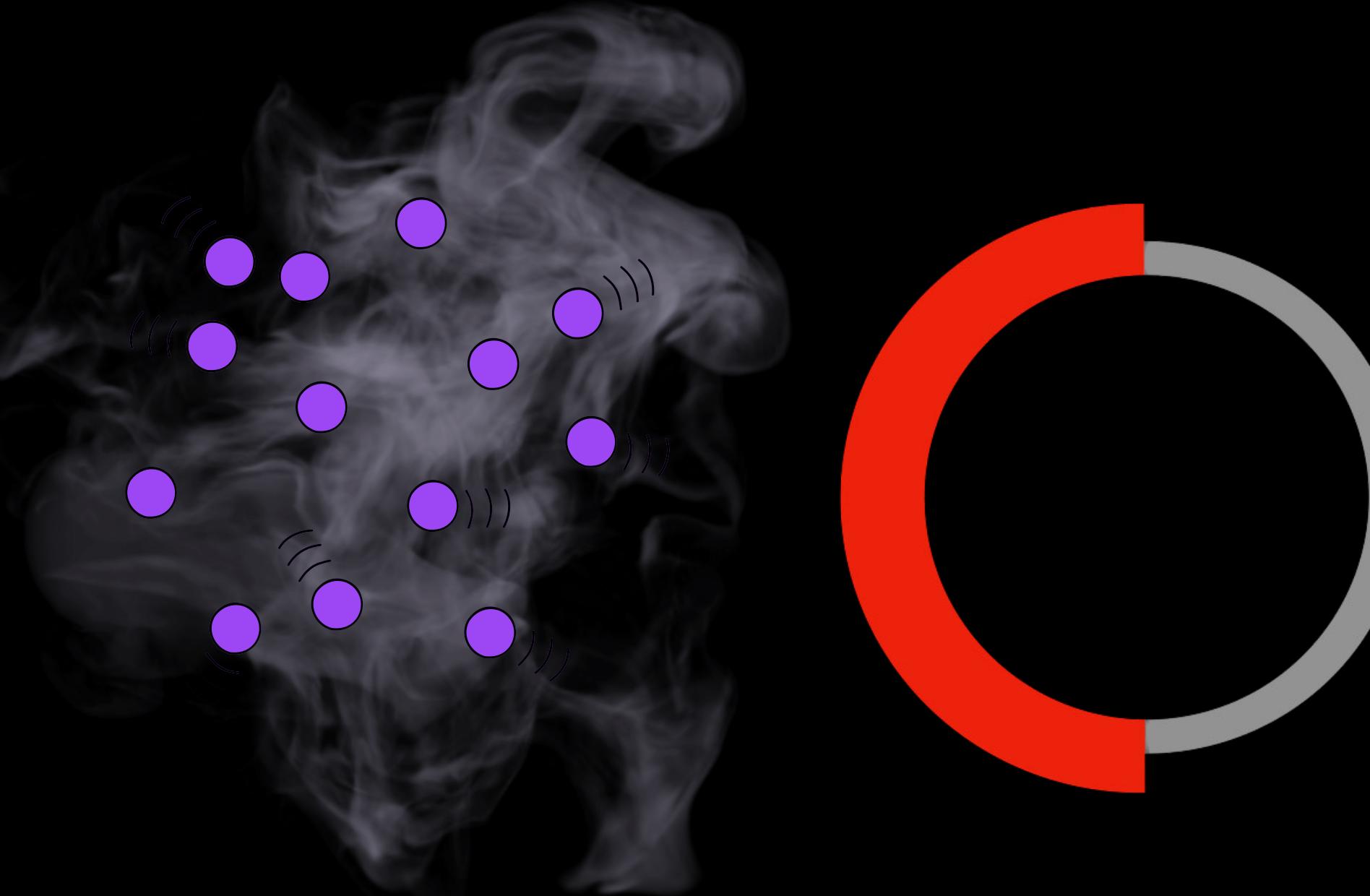
Hot dayside



WASP-76 b  
( $T = 2,160$  K)

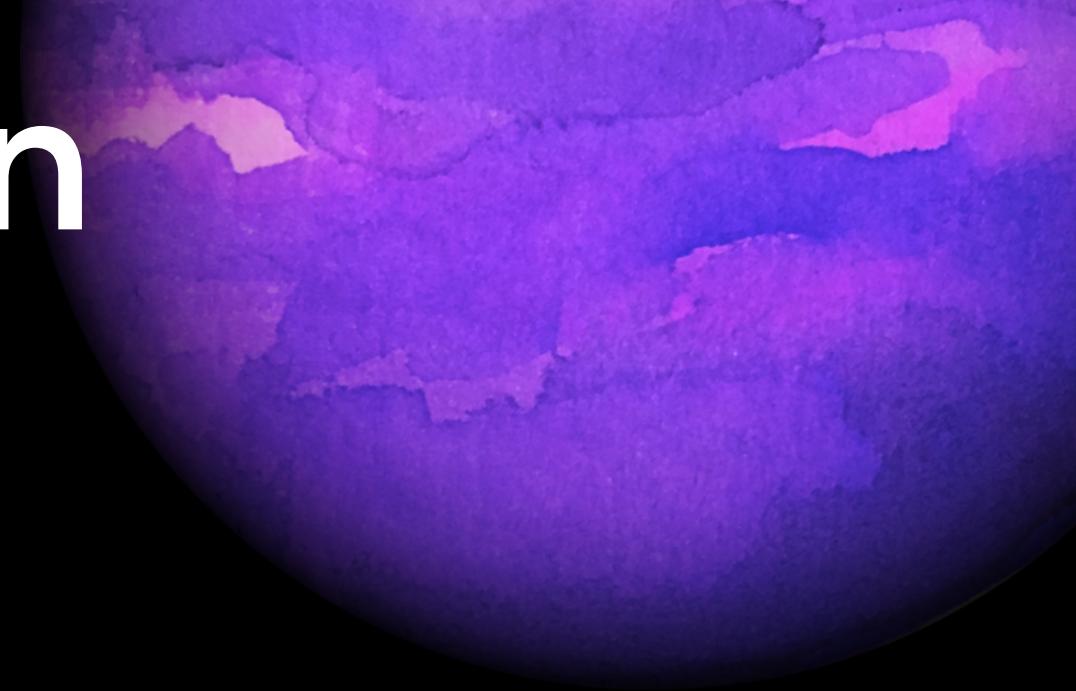
Cold nightside

# Condensation & evaporation

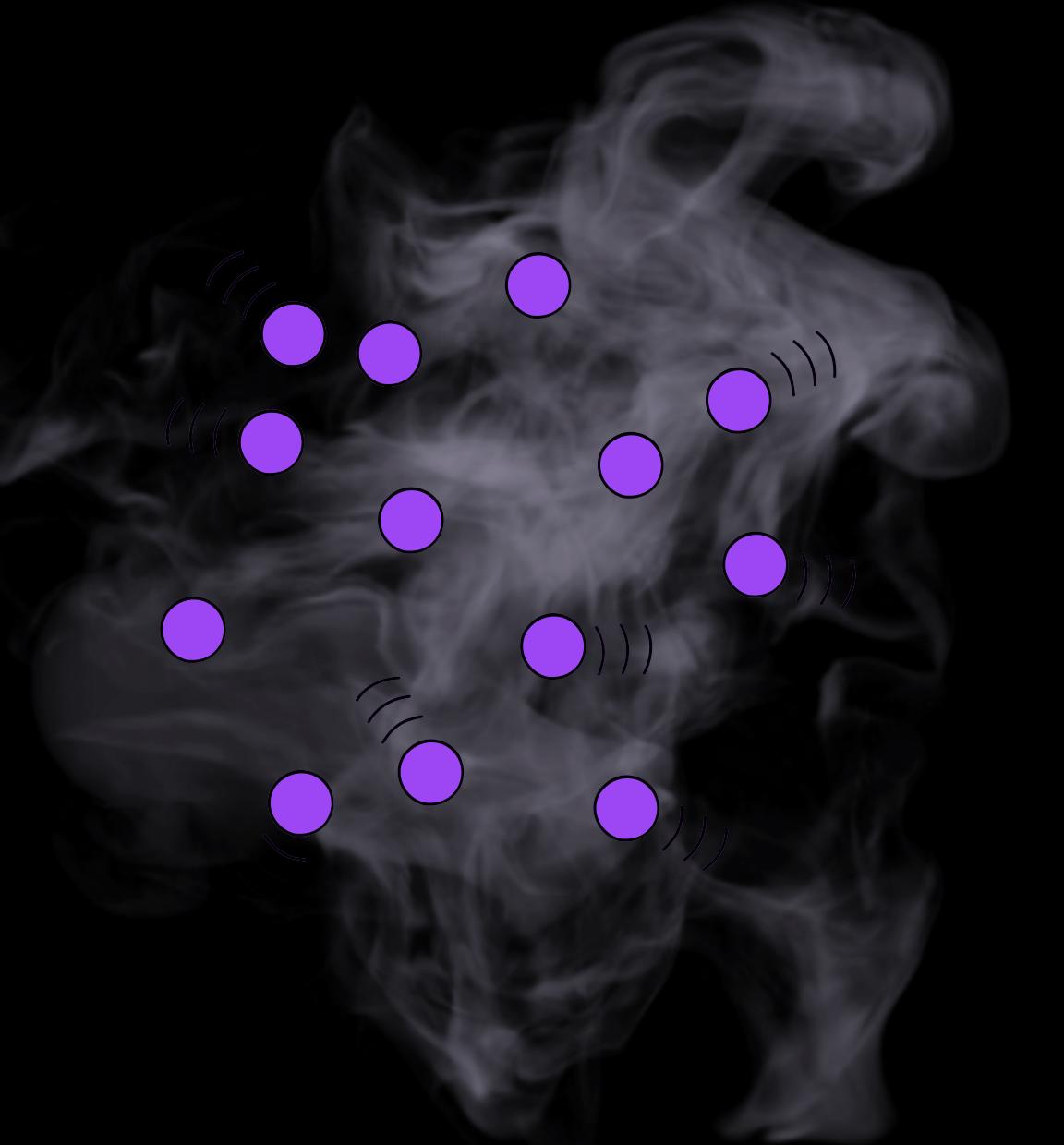


Iron is present in gas  
form on the dayside.

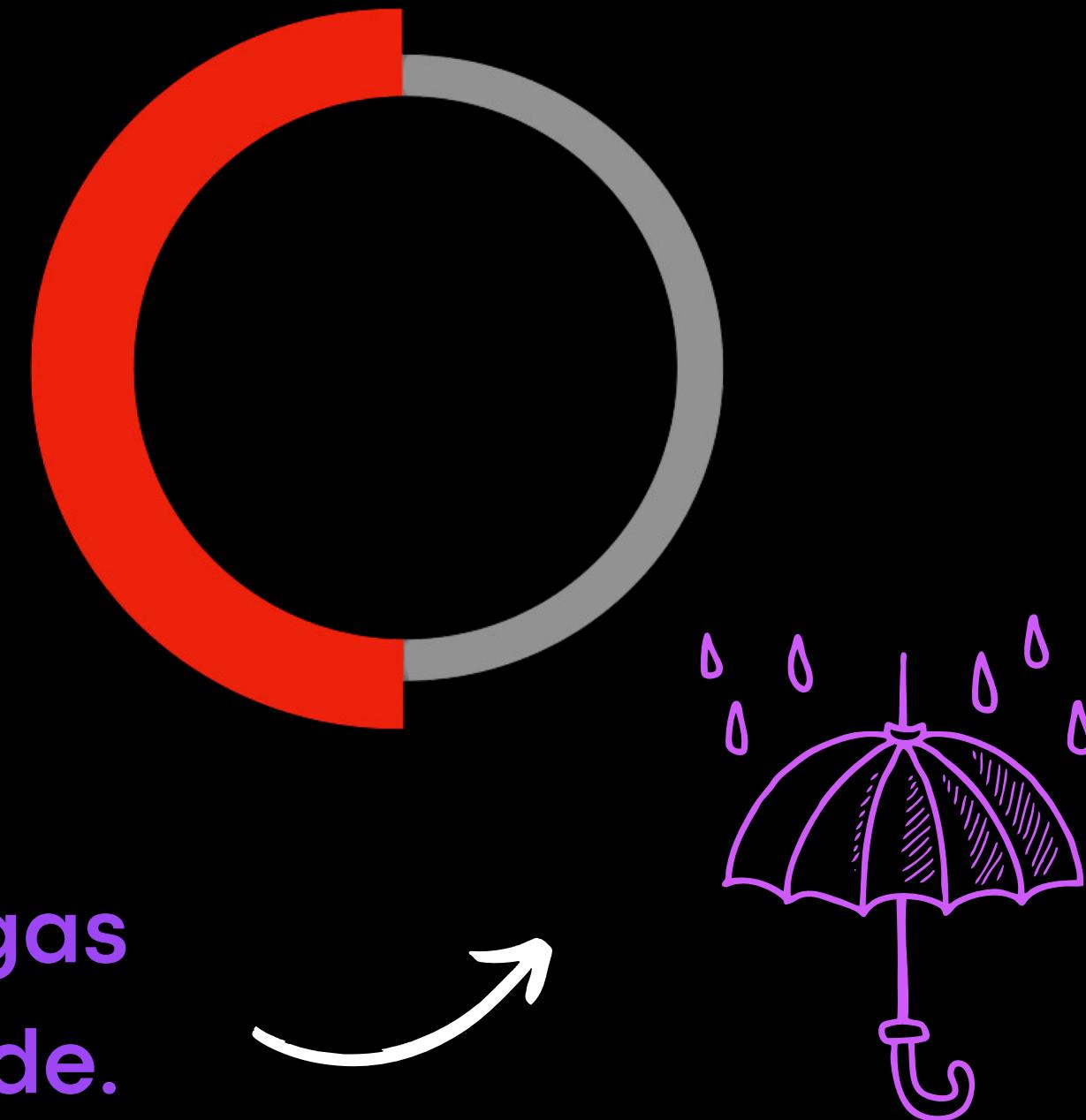
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( $T = 2,160$  K)



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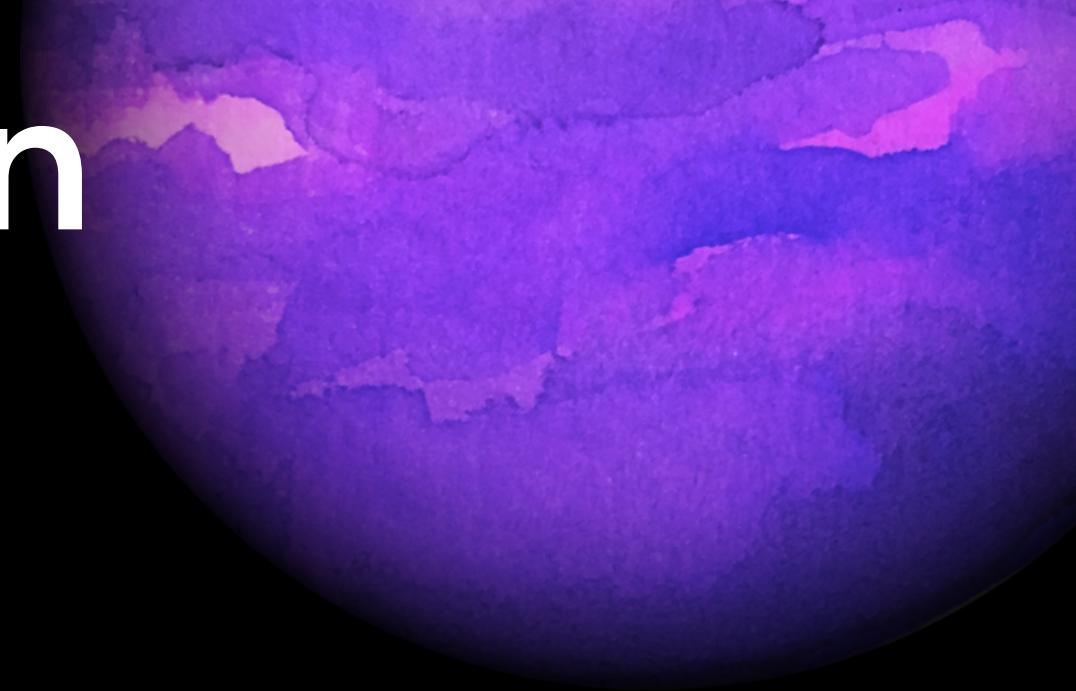


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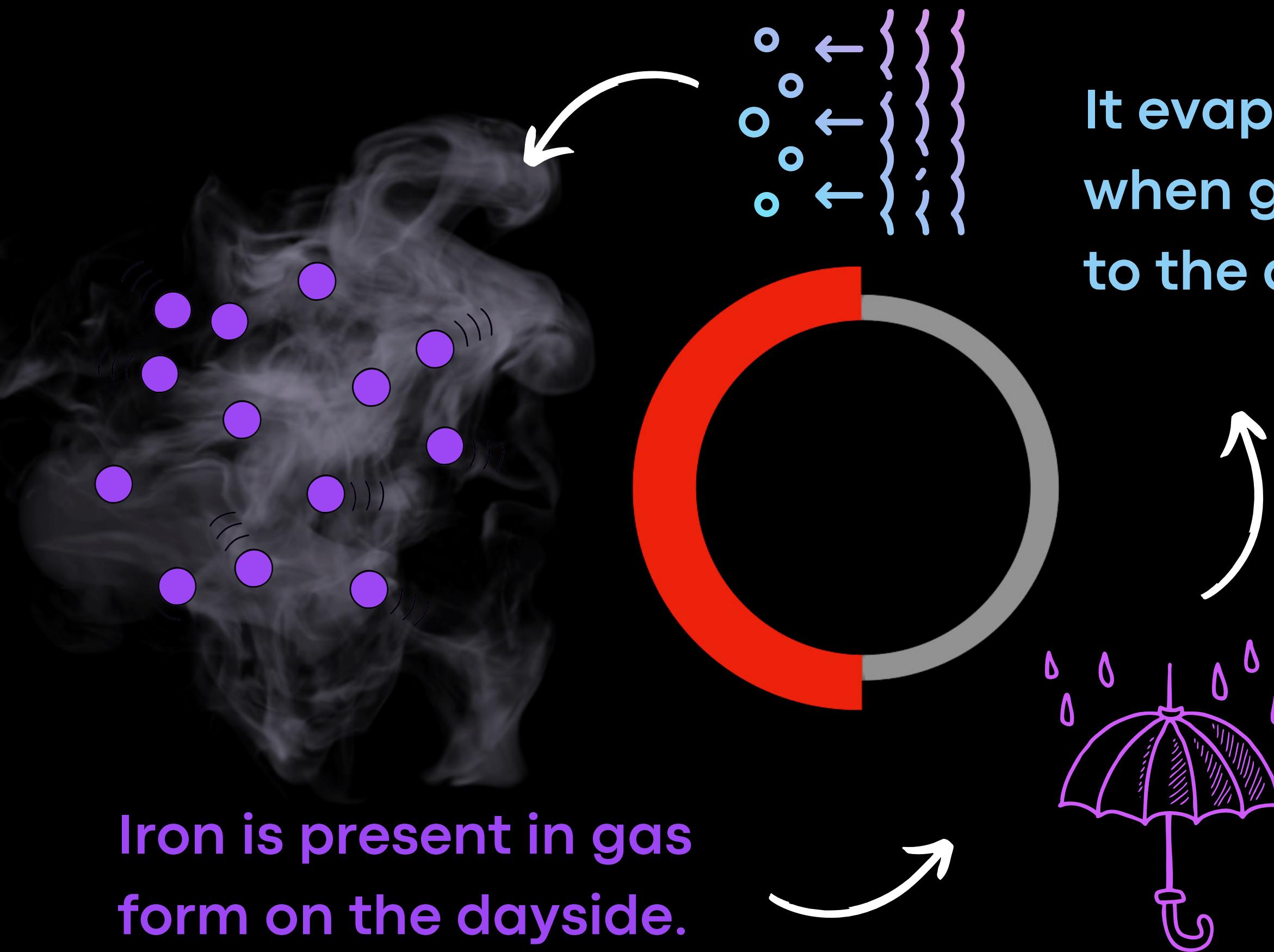


WASP-76 b  
( $T = 2,160$  K)

It rains out on the nightside because it is colder.



# Condensation & evaporation

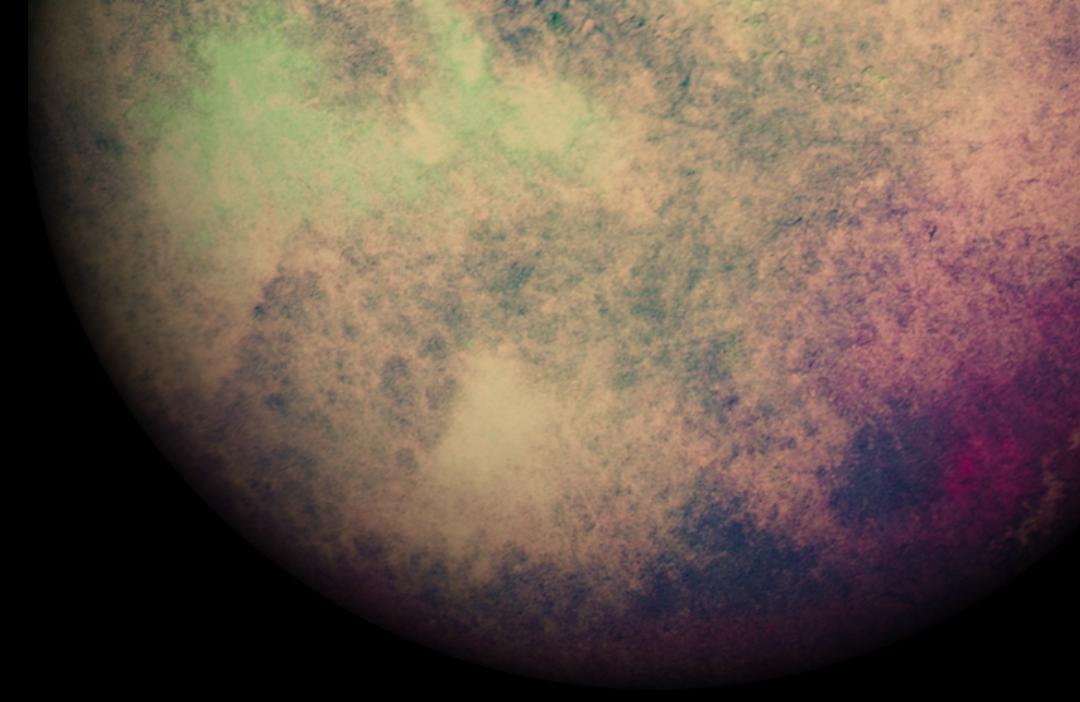


It evaporates  
when going back  
to the dayside.

WASP-76 b  
( $T = 2,160 \text{ K}$ )

It rains out on the  
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it is colder.

# Cold-traps

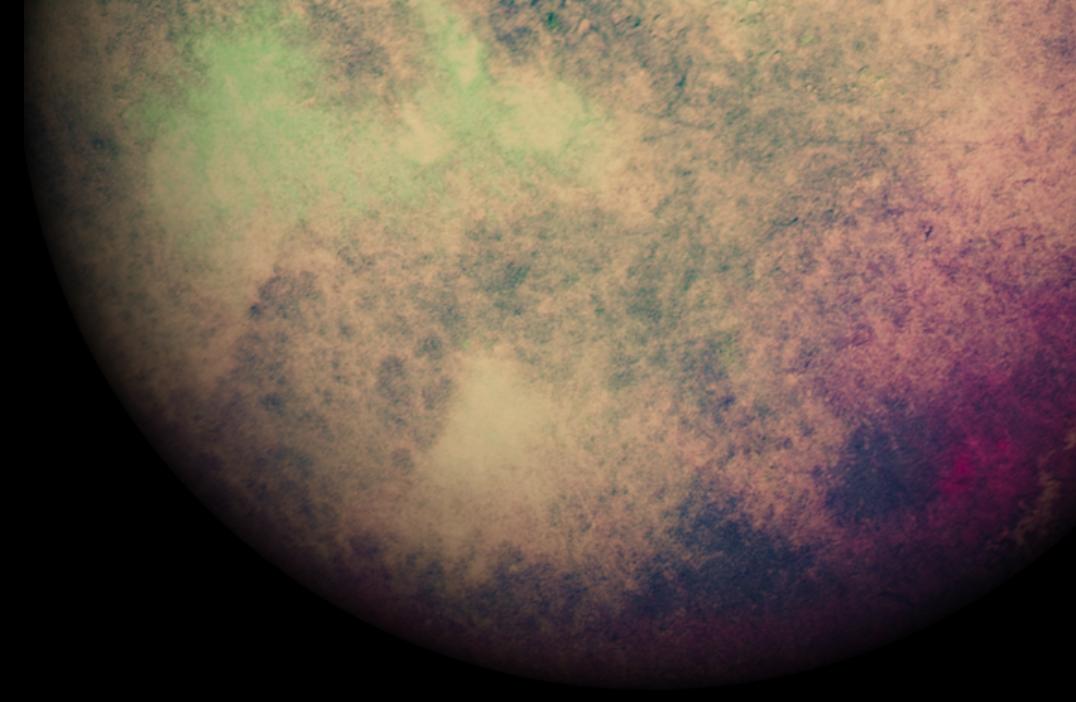


**WASP-121 b**  
 $(T = 2,360 \text{ K})$

# Cold-traps



**WASP-121 b**  
 $(T = 2,360 \text{ K})$



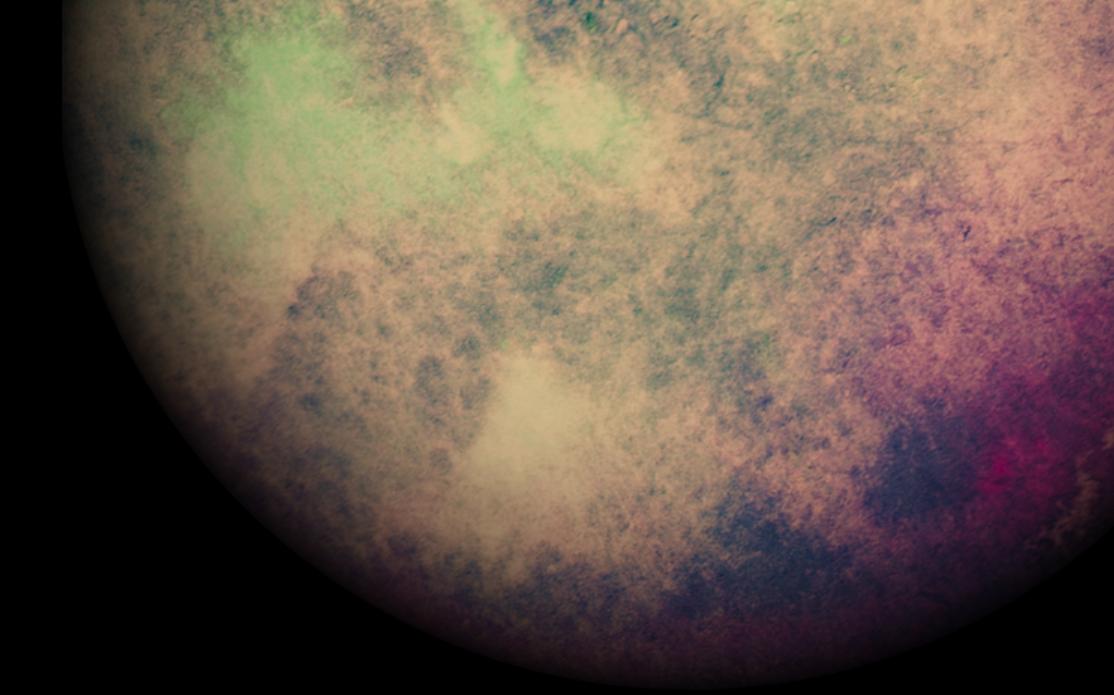
# Cold-traps



We expect titanium to  
be present because of  
the temperature...



WASP-121 b  
( $T = 2,360$  K)



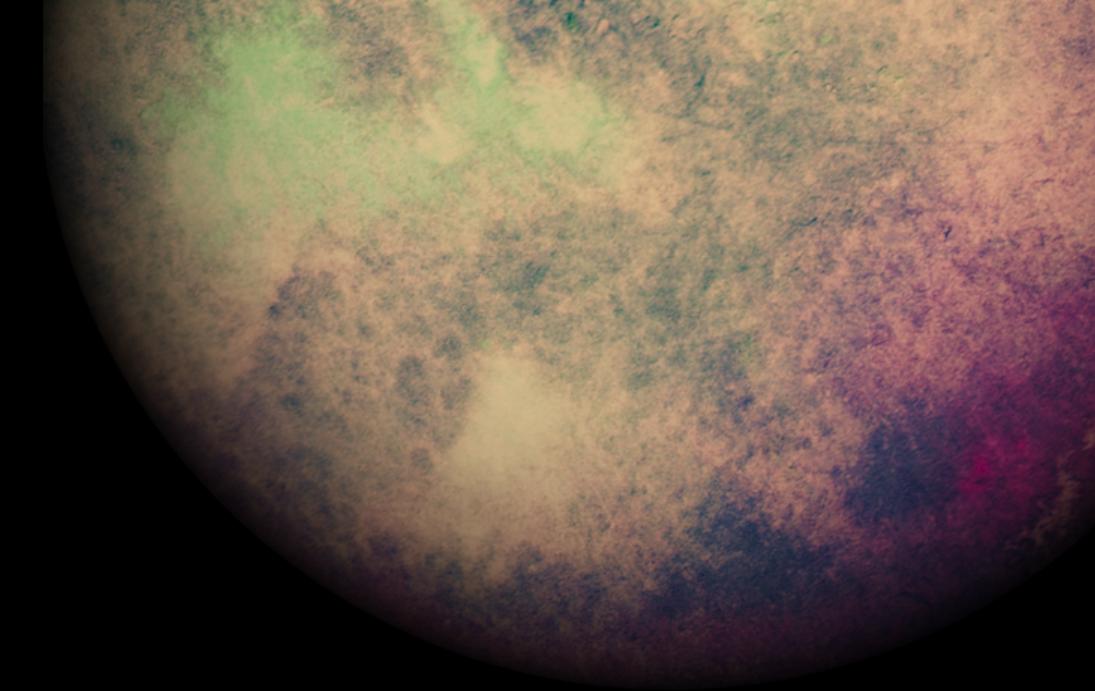
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... but our  
observations  
say no.

WASP-121 b  
( $T = 2,360$  K)



# Cold-traps

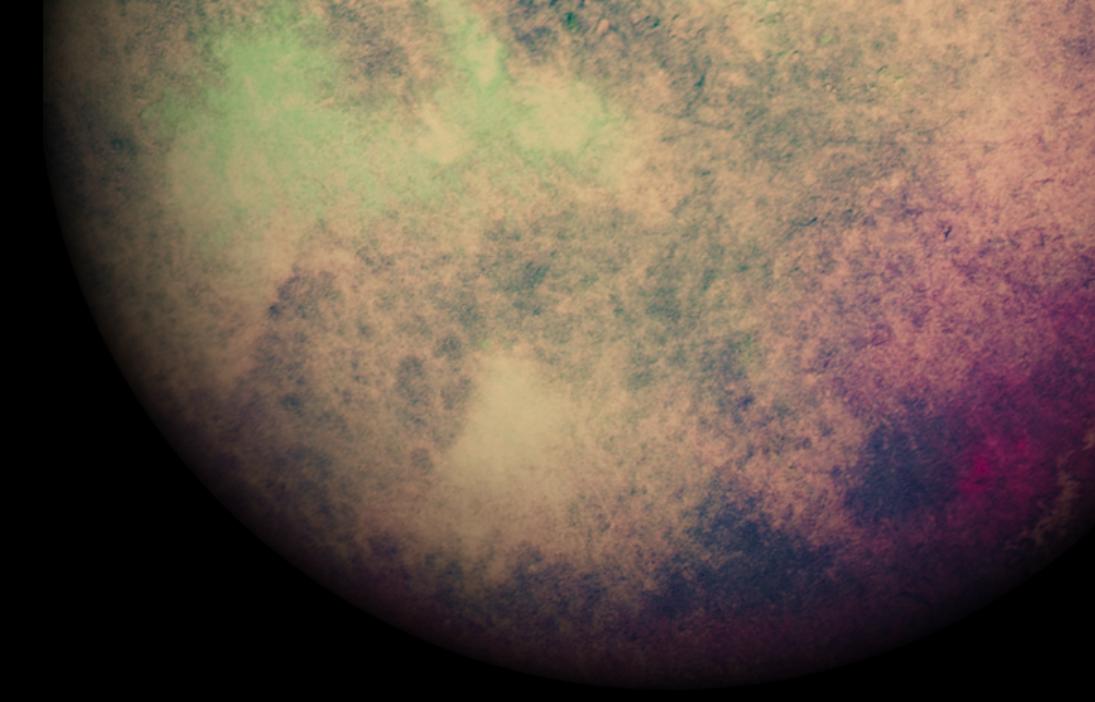
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WASP-121 b  
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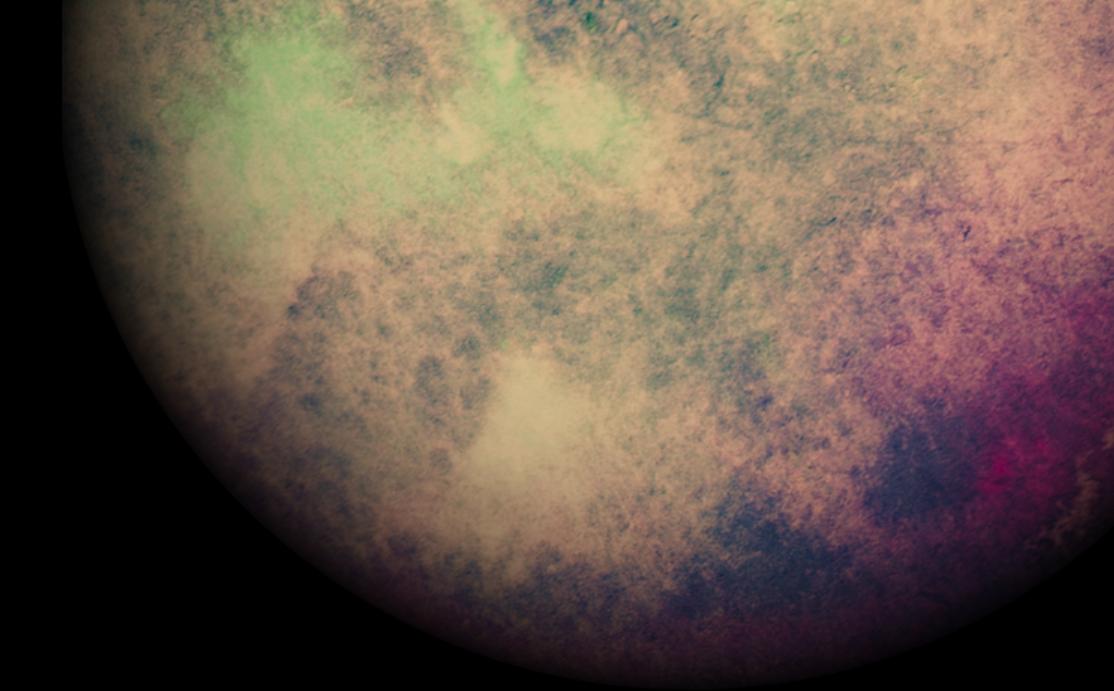


... but our  
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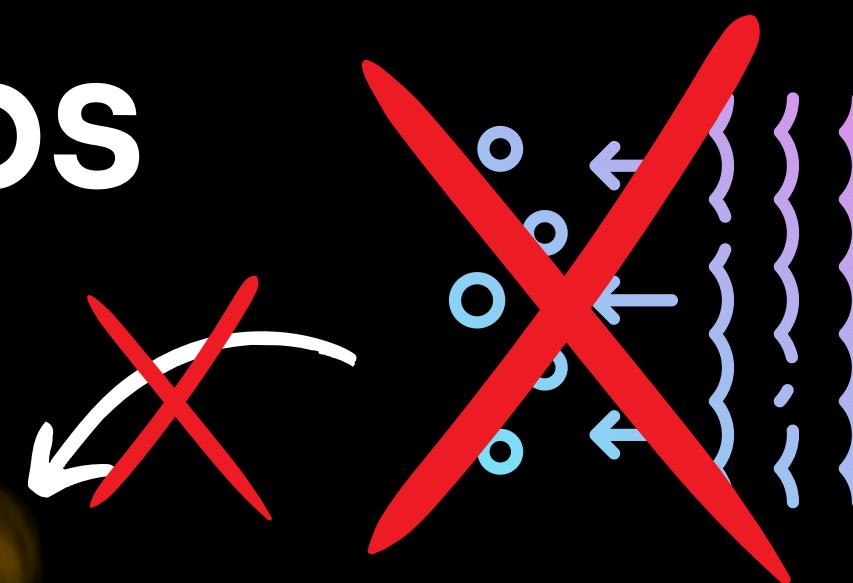


It rains out on the  
nightside because  
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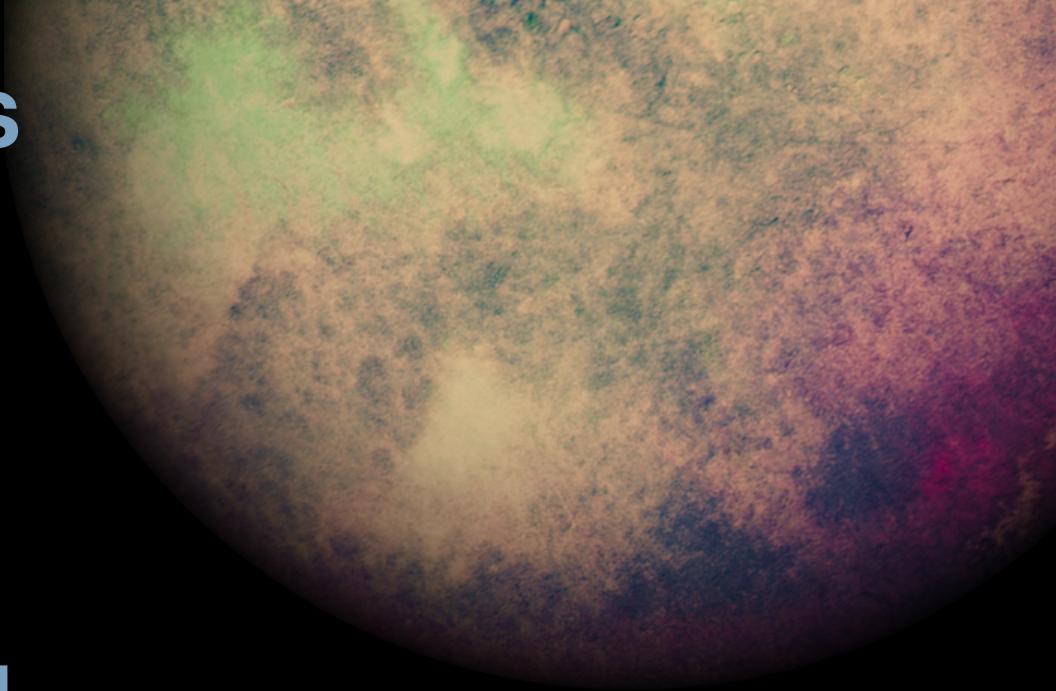
WASP-121 b  
( $T = 2,360$  K)



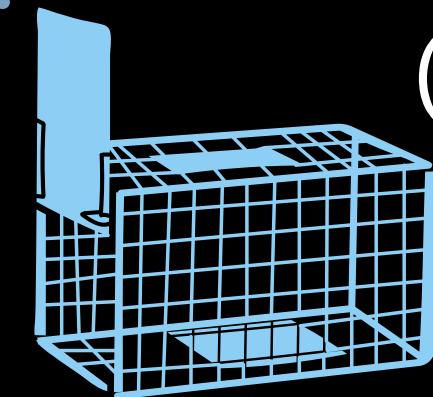
# Cold-traps



Evaporation fails because it is too cold and titanium remains trapped on the nightside.



WASP-121 b  
( $T = 2,360\text{ K}$ )



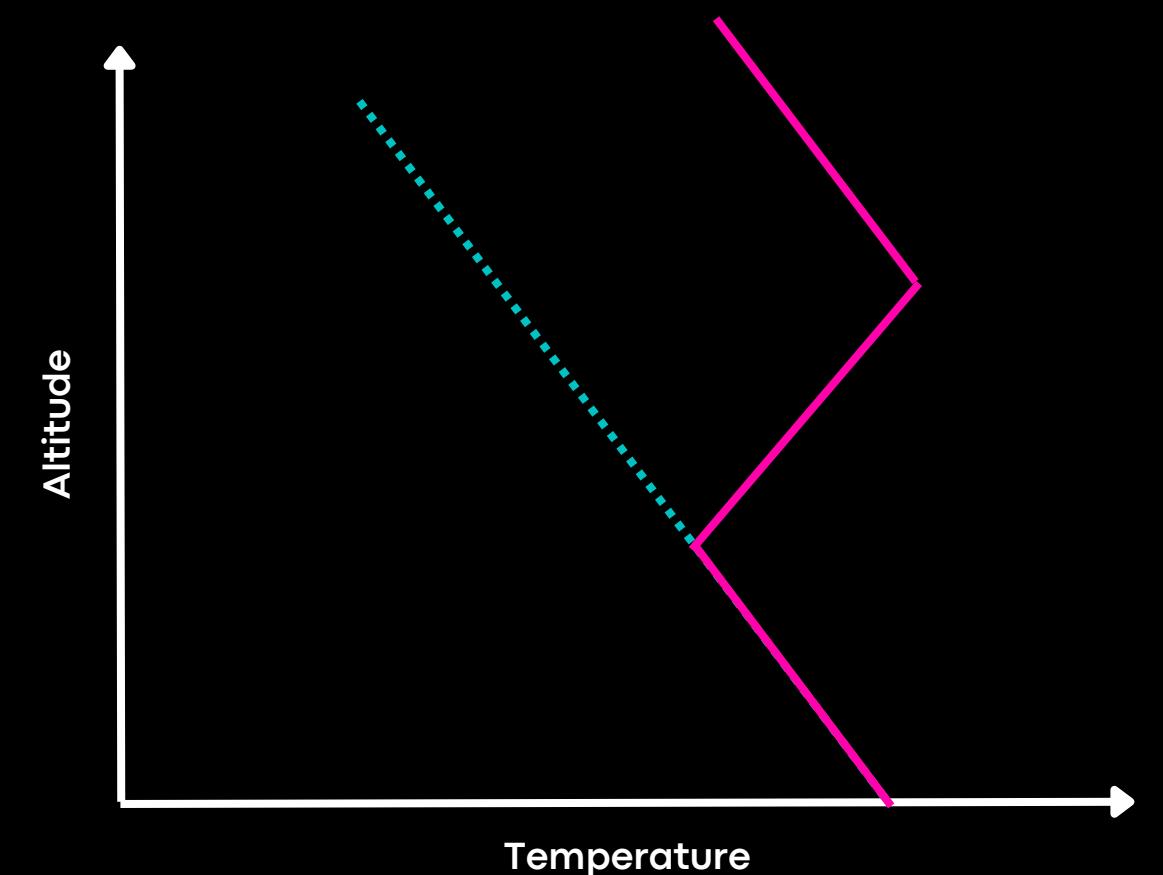
... but our observations say no.



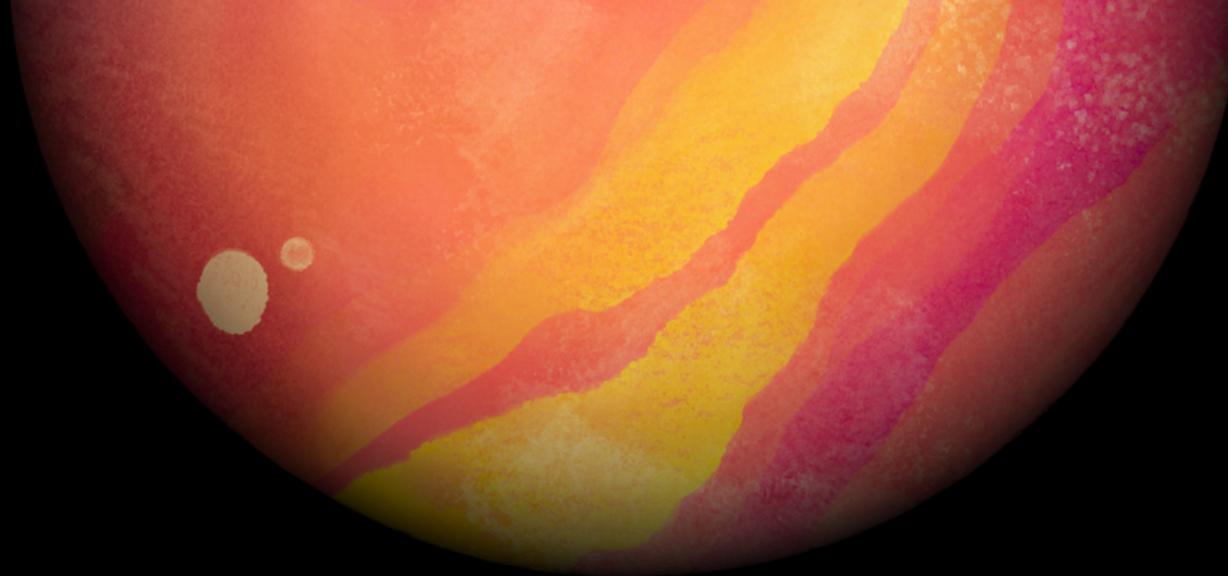
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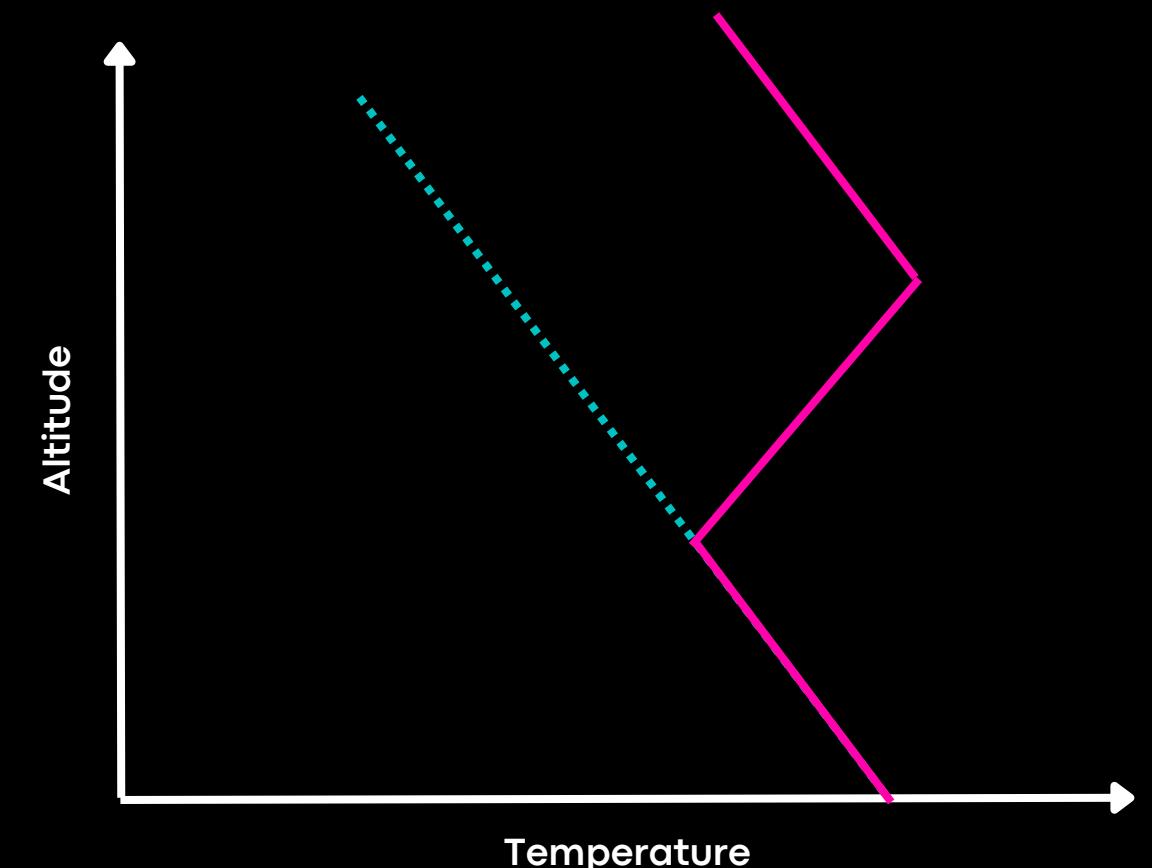
WASP-189 b



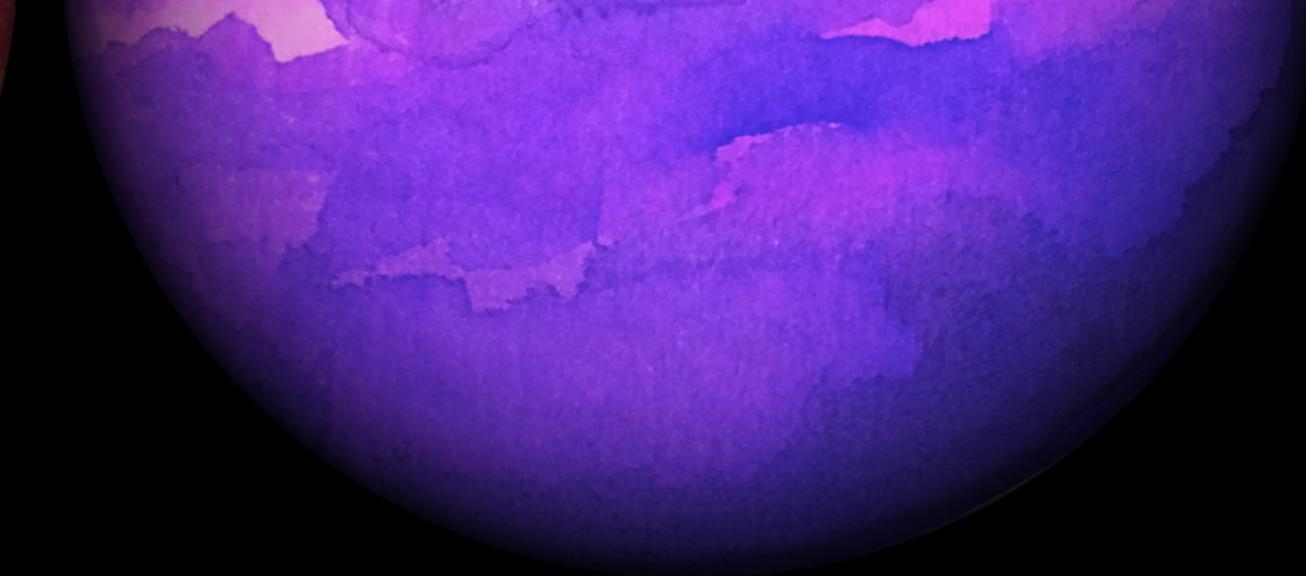
Temperature  
inversions



WASP-189 b



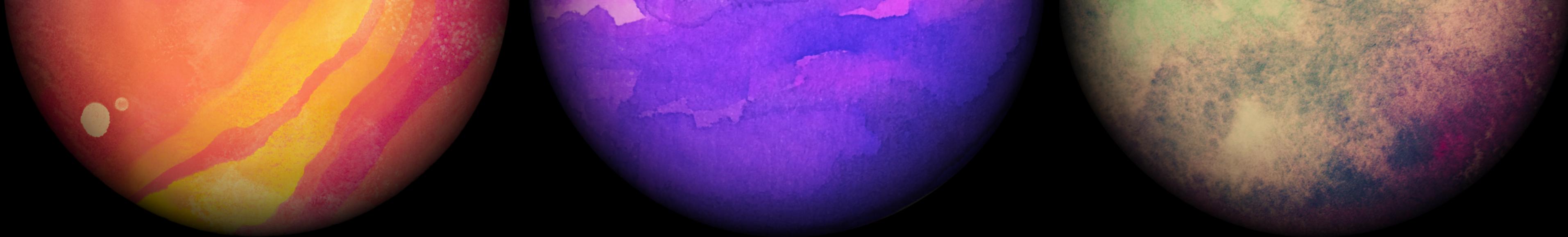
Temperature  
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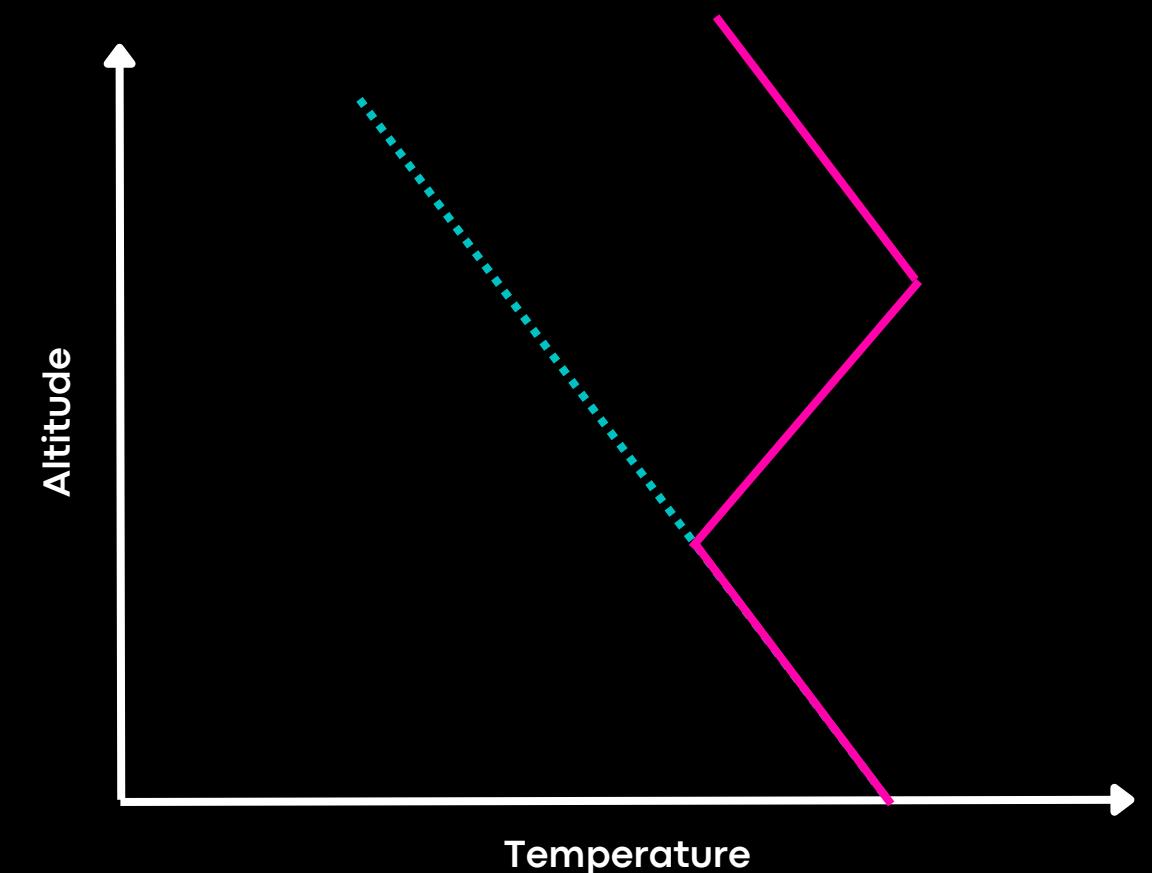
WASP-76 b



Condensation  
& evaporation



WASP-189 b



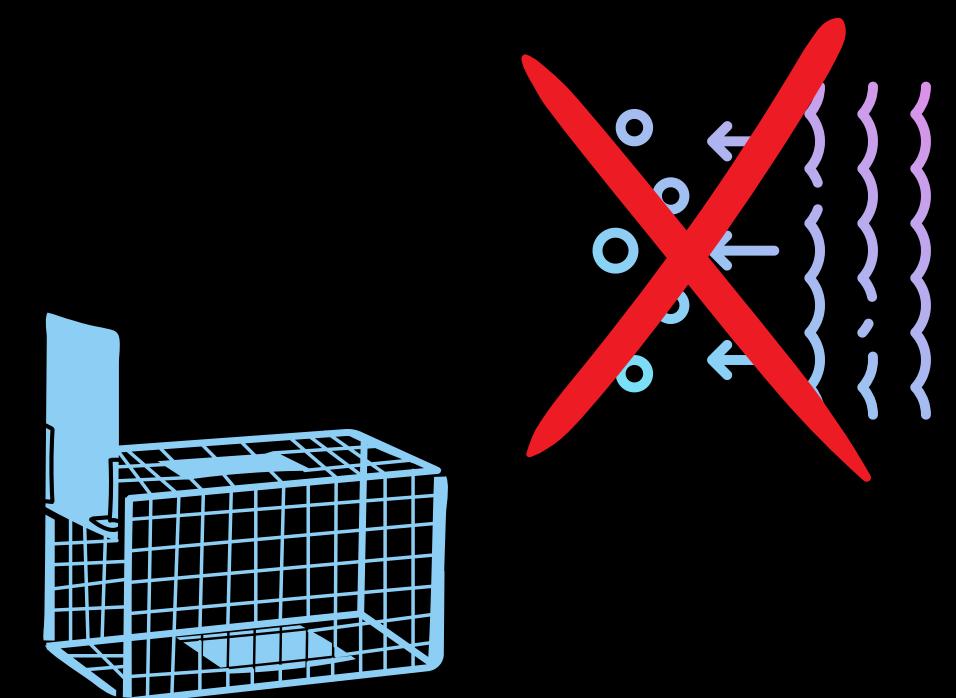
Temperature  
inversions

WASP-76 b



Condensation  
& evaporation

WASP-121 b



Cold traps

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