利用高分辨率光谱研究系外行星大气

天体丰度与星系演化研究团组
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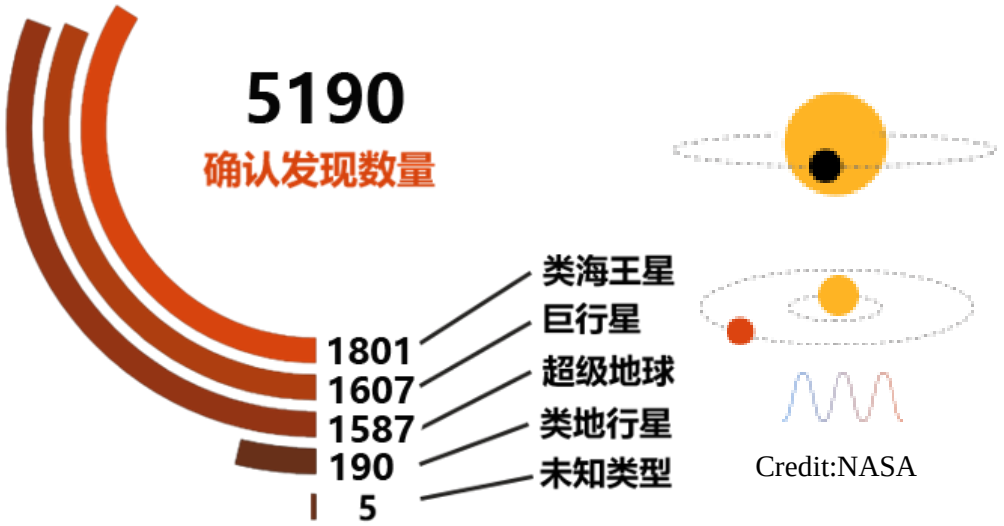
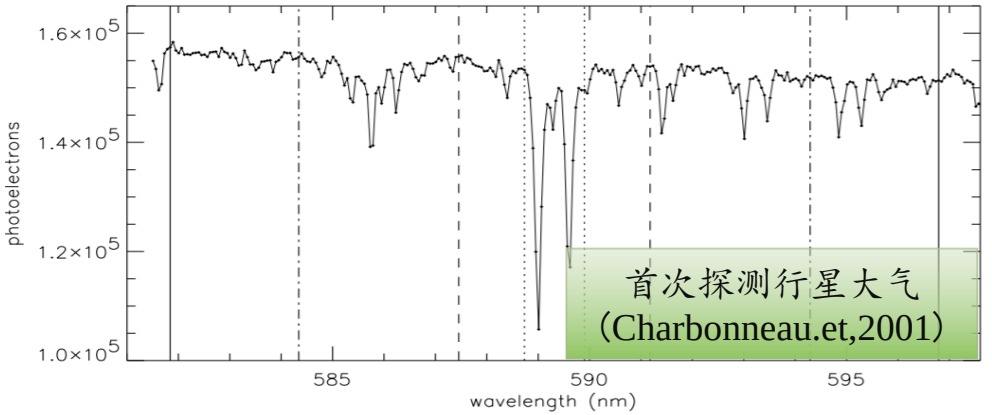
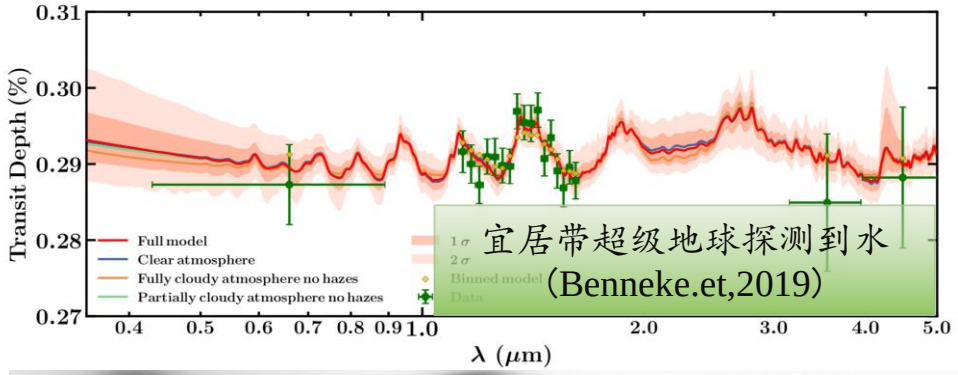
- 高分辨率光谱探测优势及原理
- 实际探测结果及分析

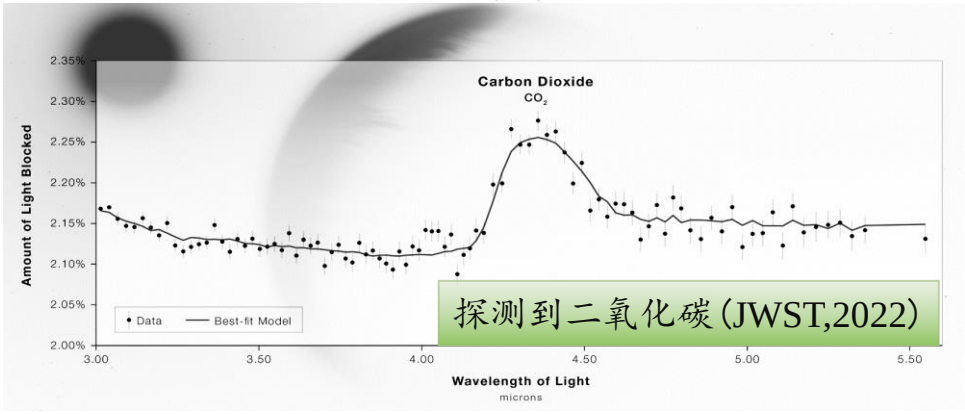
背景

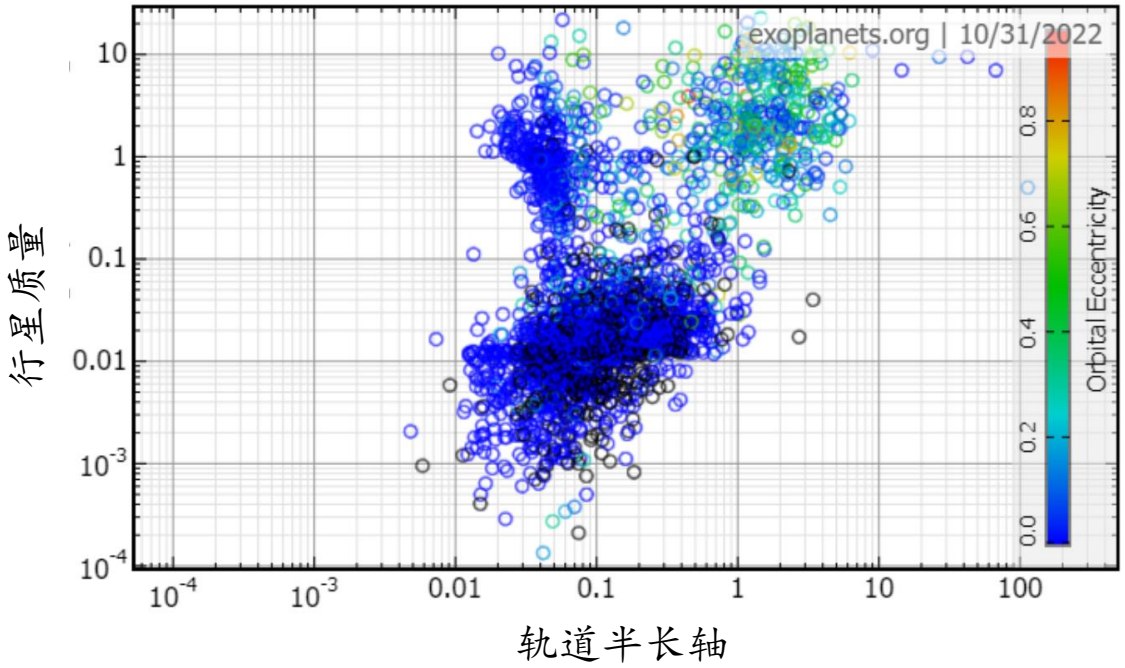


Credit:NASA

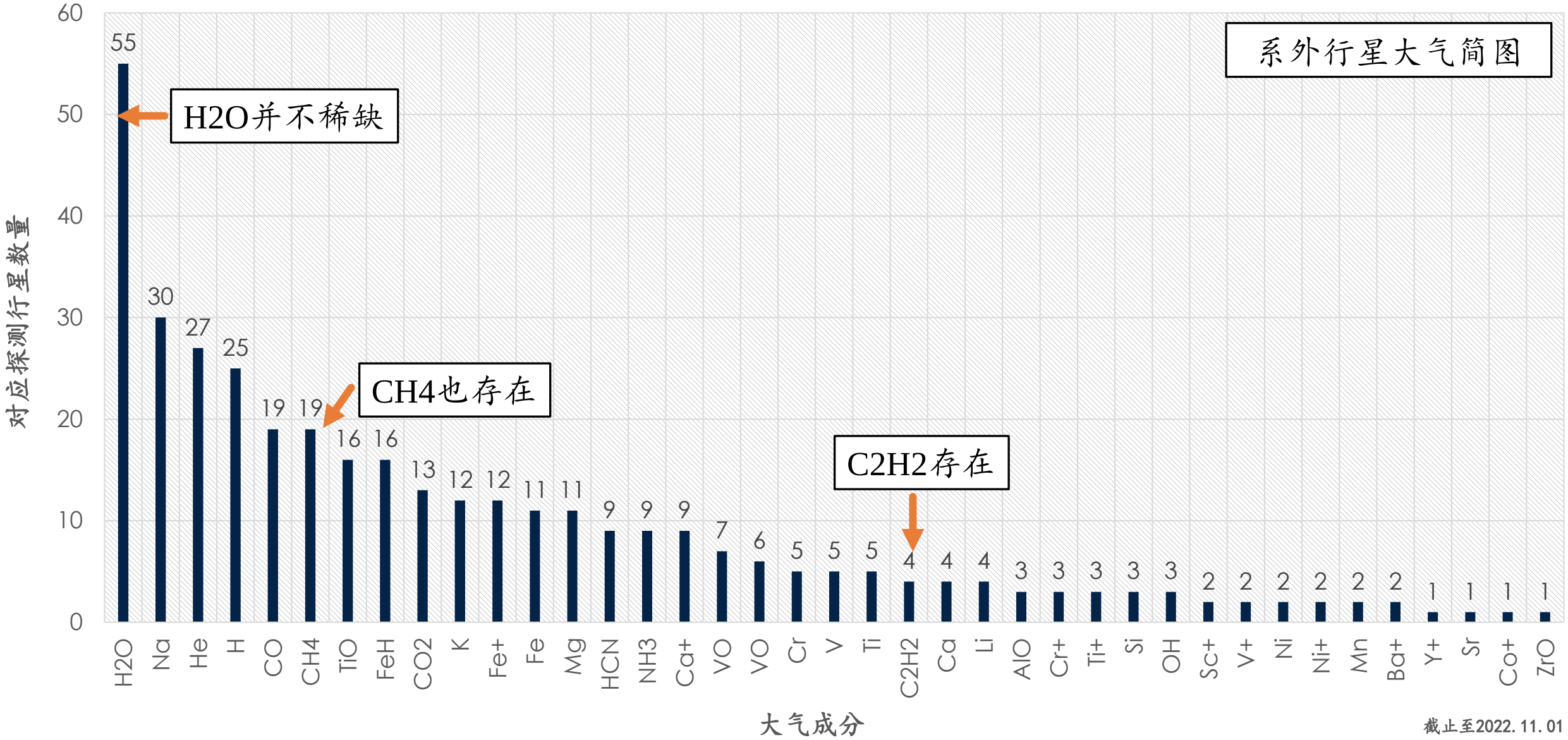






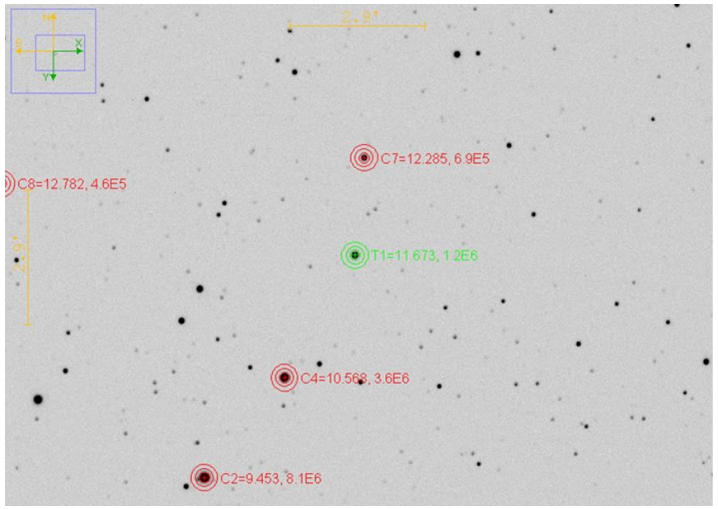


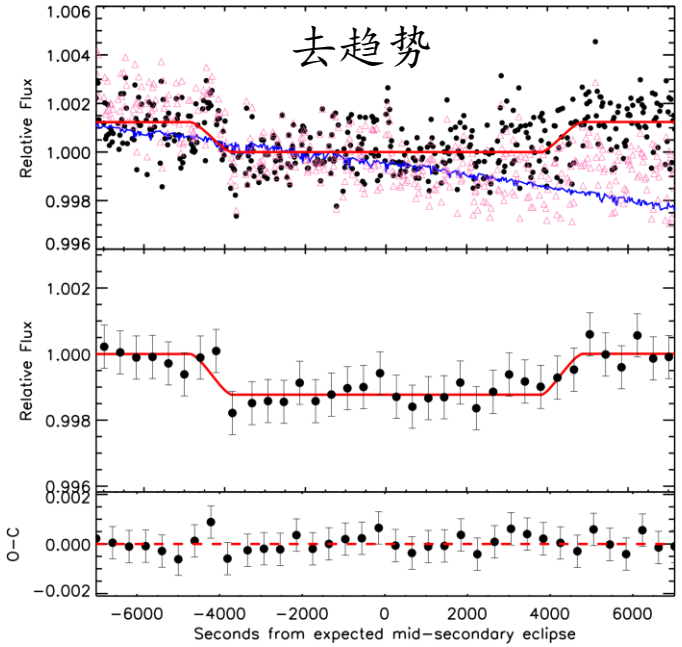
背景


系外行星大气简图
H2O并不稀缺
CH4也存在
C2H2存在
对应探测行星数量
大气成分
截止至2022. 11. 01
0
10
20
30
40
50
60
H2O 55
Na 30
He 27
H 25
CO 19
CH4 19
TiO 16
FeH 16
CO2 13
K 12
Fe+ 12
Fe 11
Mg 11
HCN 9
NH3 9
Ca+ 9
VO 7
VO 6
Cr 5
V 5
Ti 5
C2H2 4
Ca 4
Li 4
AlO 3
Cr+ 3
Ti+ 3
Si 3
OH 3
Sc+ 2
V+ 2
Ni 2
Ni+ 2
Mn 2
Ba+ 2
Y+ 1
Sr 1
Co+ 1
ZrO 1

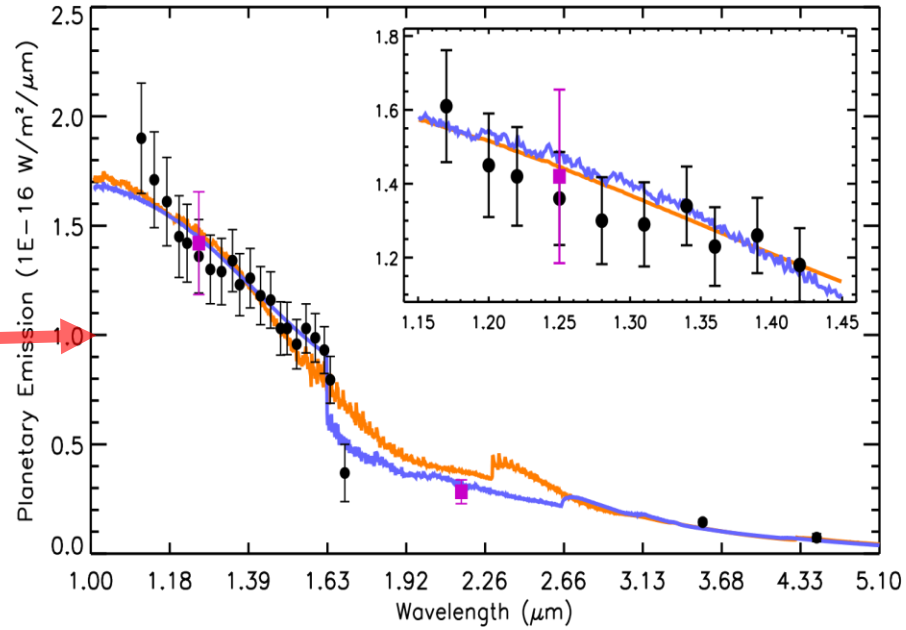
传统方法

测光



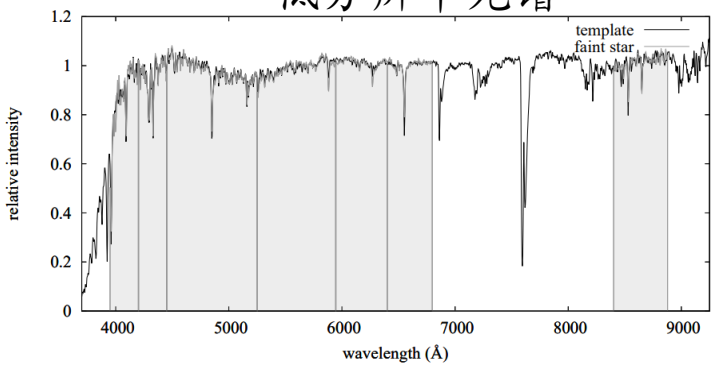


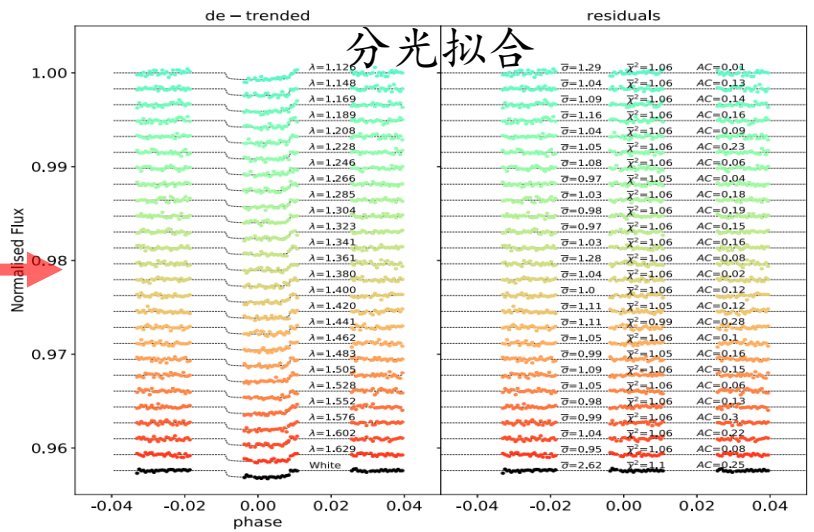
模型拟合



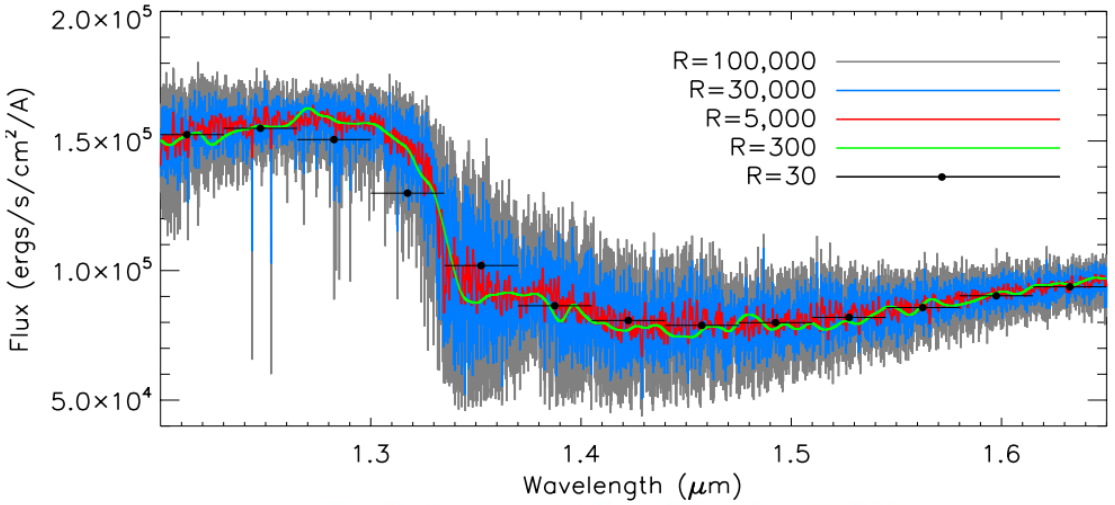
Credit:石亚卿

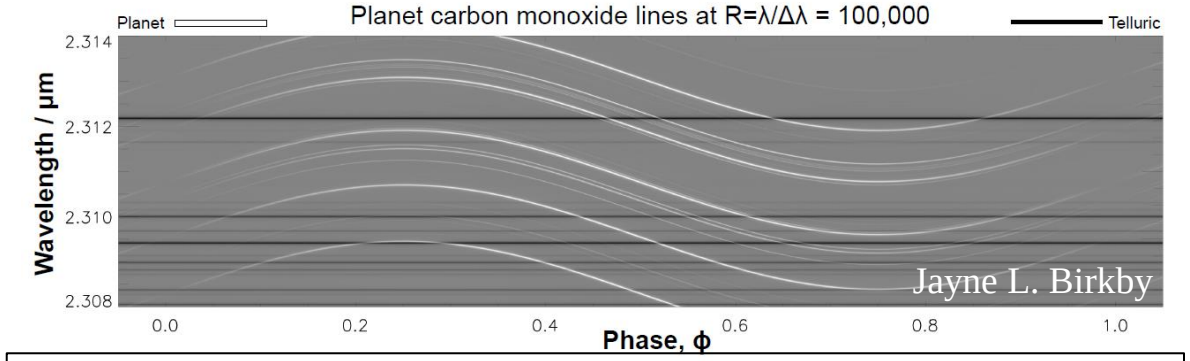
低分辨率光谱





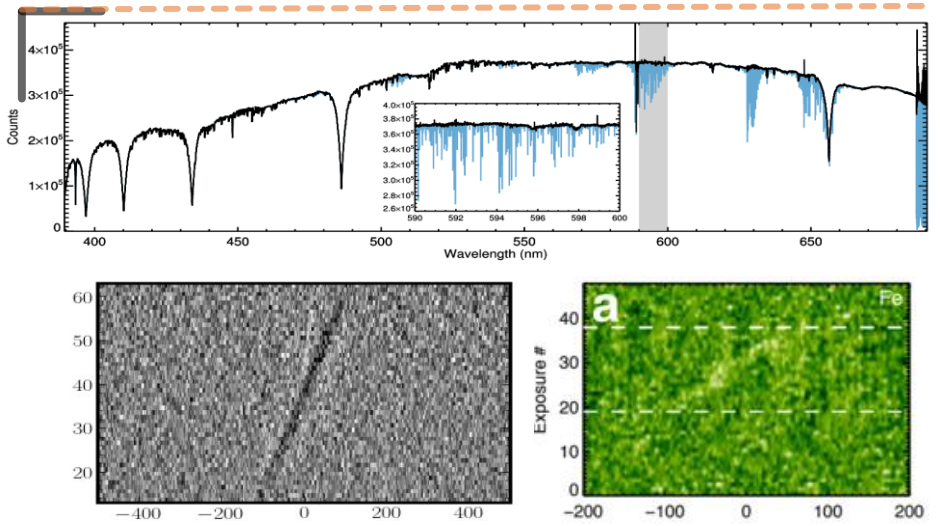
高分辨率光谱的优势



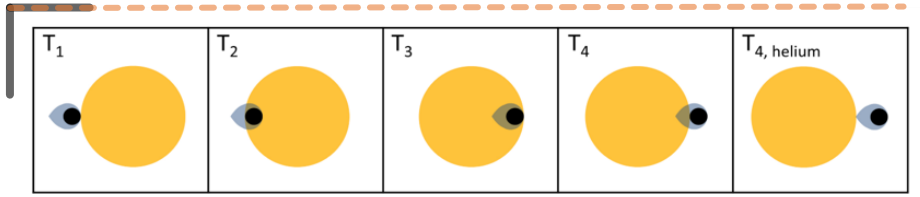


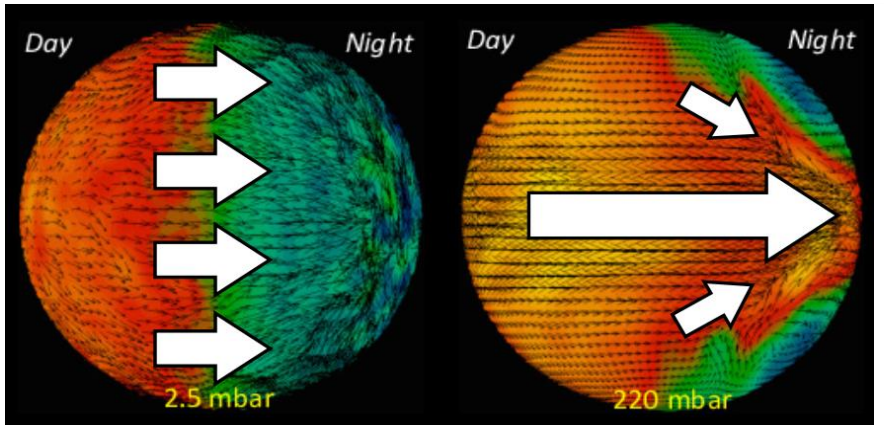
- 行星和恒星信号速度空间分开，探测更暗弱的信号.
- 可分辨谱线越多，通过CCF，探测置信度高.
- 可研究大气运动和加热冷却过程.

大气成分

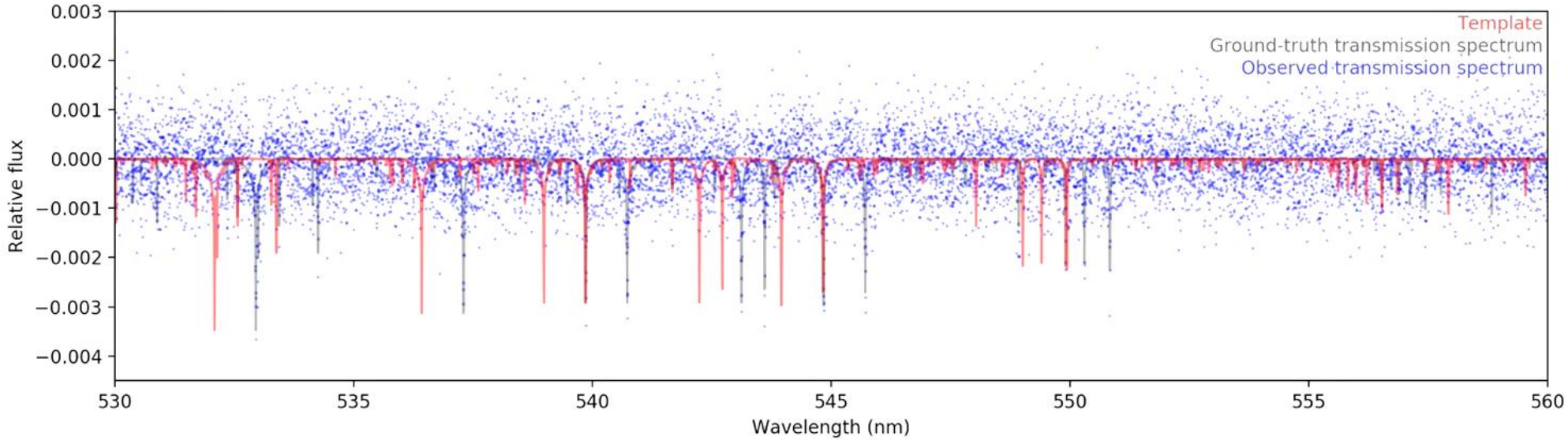


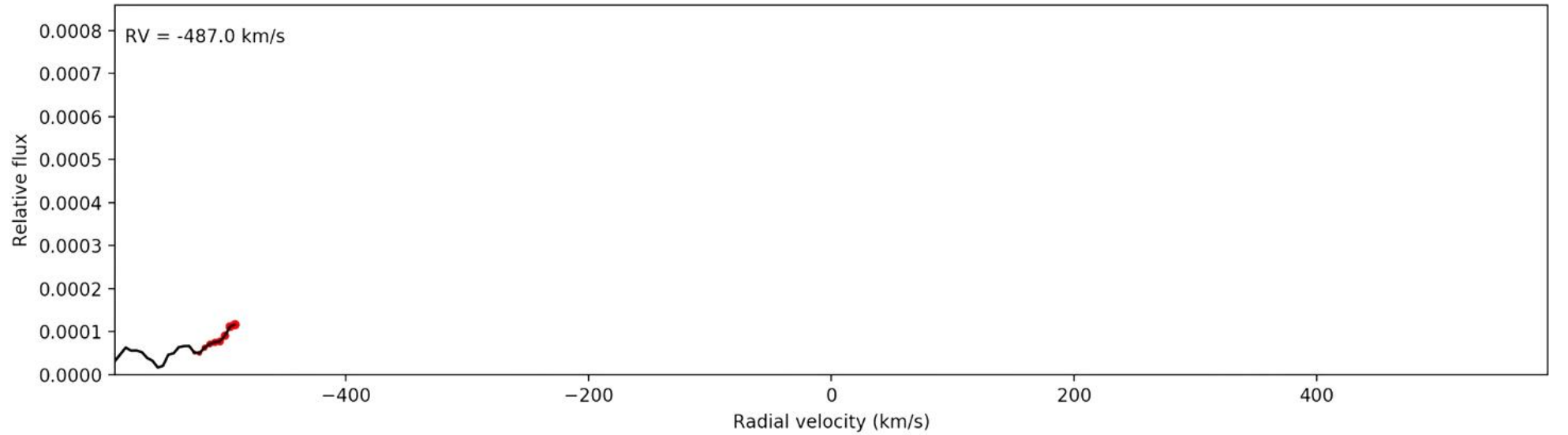
大气运动



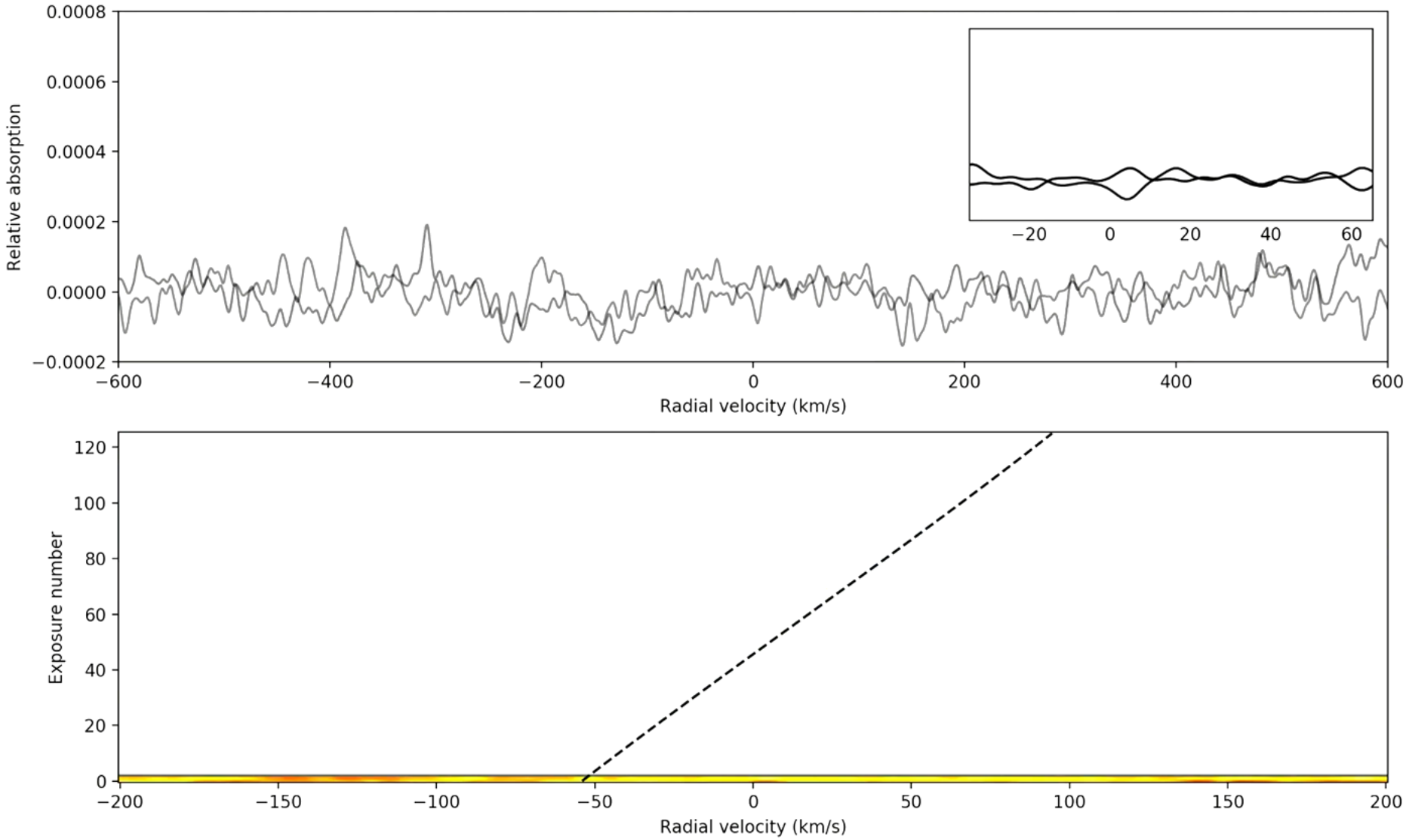


原理

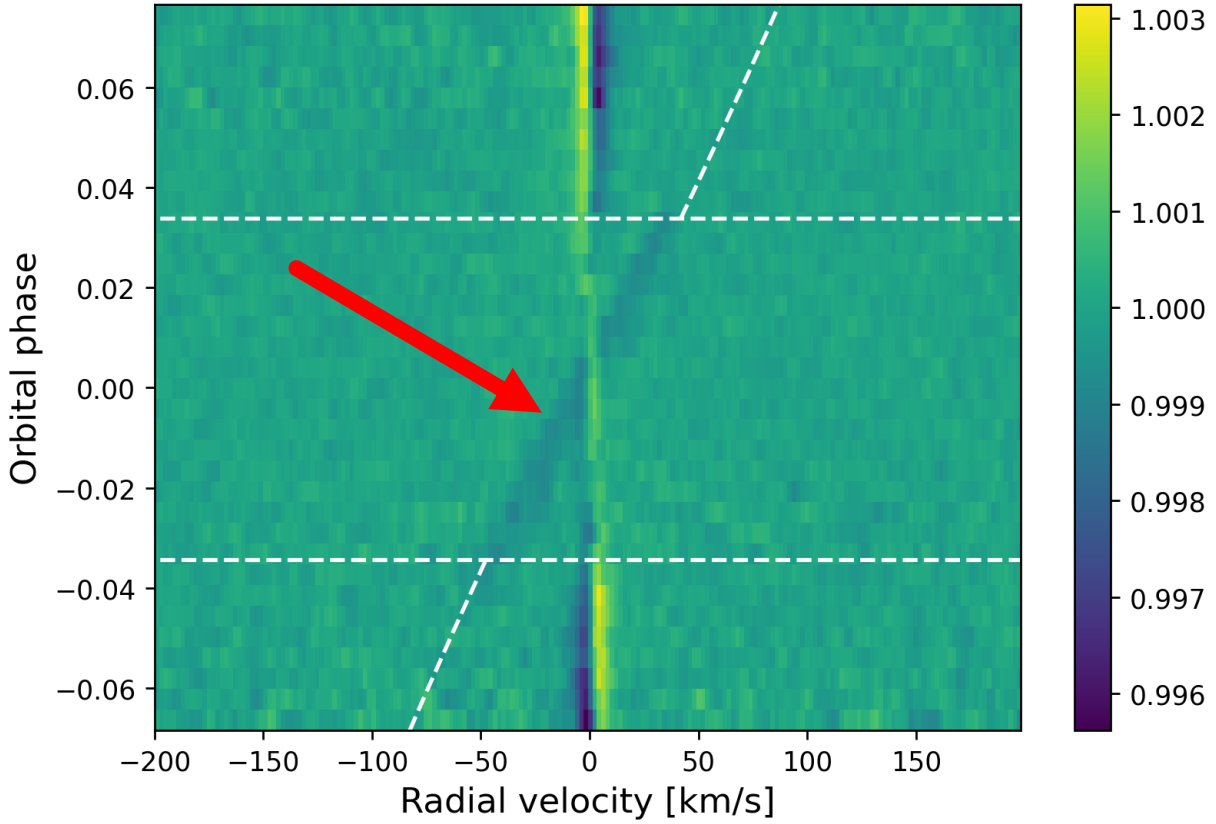

Template
Ground-truth transmission spectrum
Observed transmission spectrum
Relative flux
0.003
0.002
0.001
0.000
−0.001
−0.002
−0.003
−0.004
530
535
540
545
550
555
560
Wavelength (nm)

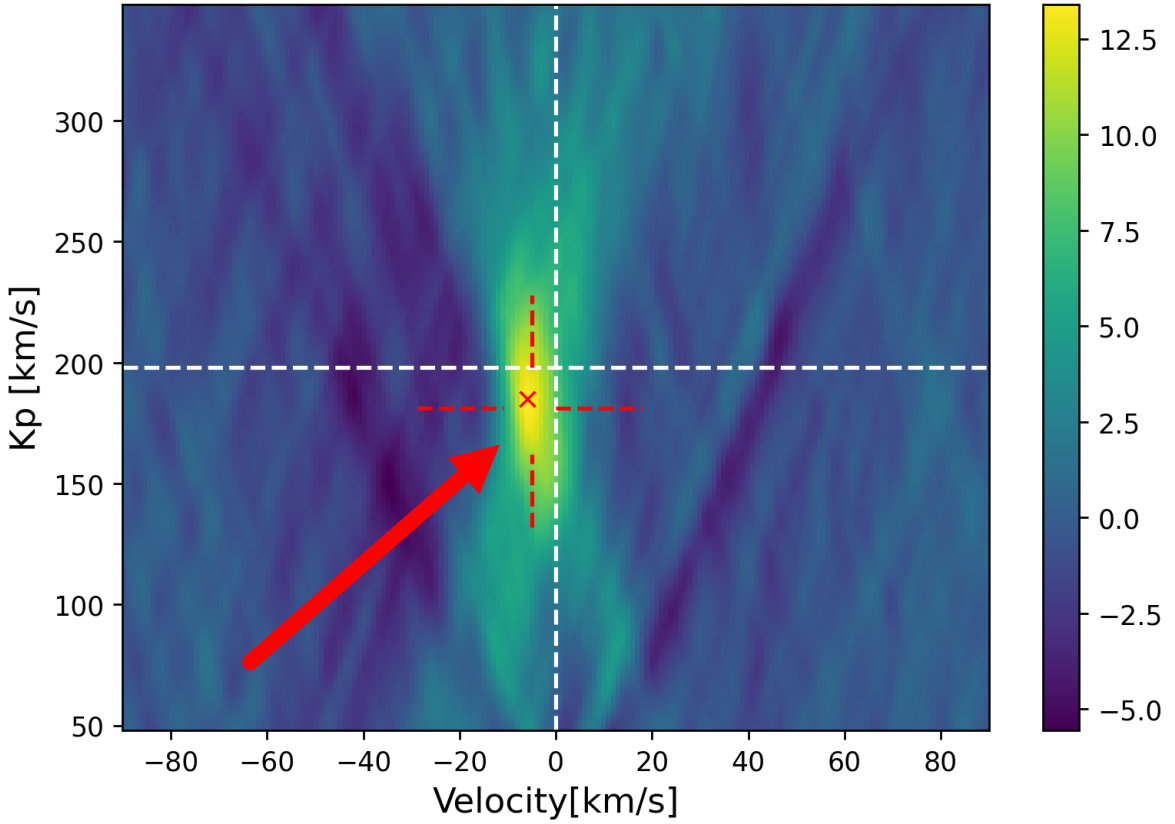

RV = -487.0 km/s
Relative flux
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0.0000
−400
−200
0
200
400
Radial velocity (km/s)

原理


0.0008
0.0006
0.0004
0.0002
0.0000
−0.0002
Relative absorption
−600
−400
−200
0
200
400
600
Radial velocity (km/s)
−20
0
20
40
60
120
100
80
60
40
20
0
Exposure number
−200
−150
−100
−50
0
50
100
150
200
Radial velocity (km/s)

预期结果


Orbital phase
0.06
0.04
0.02
0.00
−0.02
−0.04
−0.06
−200
−150
−100
−50
0
50
100
150
Radial velocity [km/s]
1.003
1.002
1.001
1.000
0.999
0.998
0.997
0.996

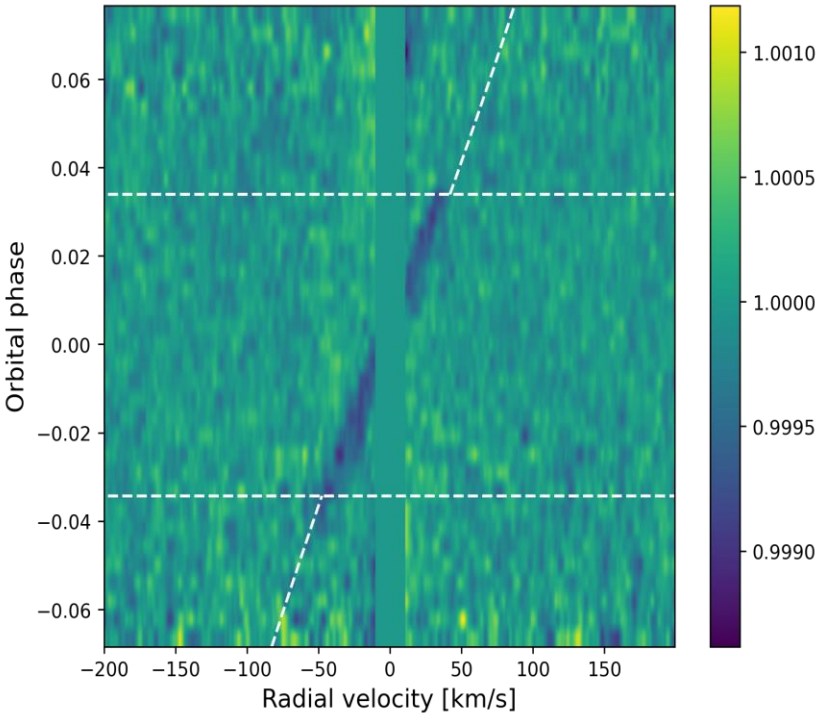

Kp [km/s]
300
250
200
150
100
50
−80
−60
−40
−20
0
20
40
60
80
Velocity[km/s]
12.5
10.0
7.5
5.0
2.5
0.0
−2.5
−5.0

WASP-76b

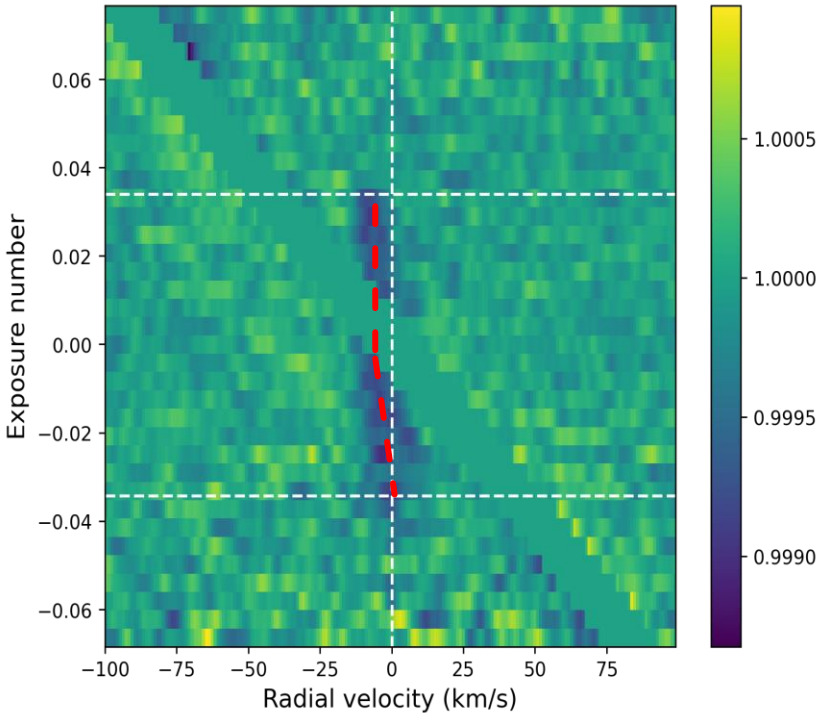
主星有效温度	6278±115K
半径	1.83±0.04R_J
质量	0.92±0.03M_J
平均密度	0.201±0.013
表面平衡温度	2160±40K
已发现大气成分	TiO VO H2O Fe+ Li Na Mg Ca+ K Fe Ti Cr Ni TiO ZrO FeH He Na Li H K OH V Cr Sr Co+
类型	超热木星
特点	探测到大气成分最多的系外行星；边界层处有铁雨降落
参考文献	Ehrenreich, D. et al, 2020, Nature, 580, 597.

WASP-76b

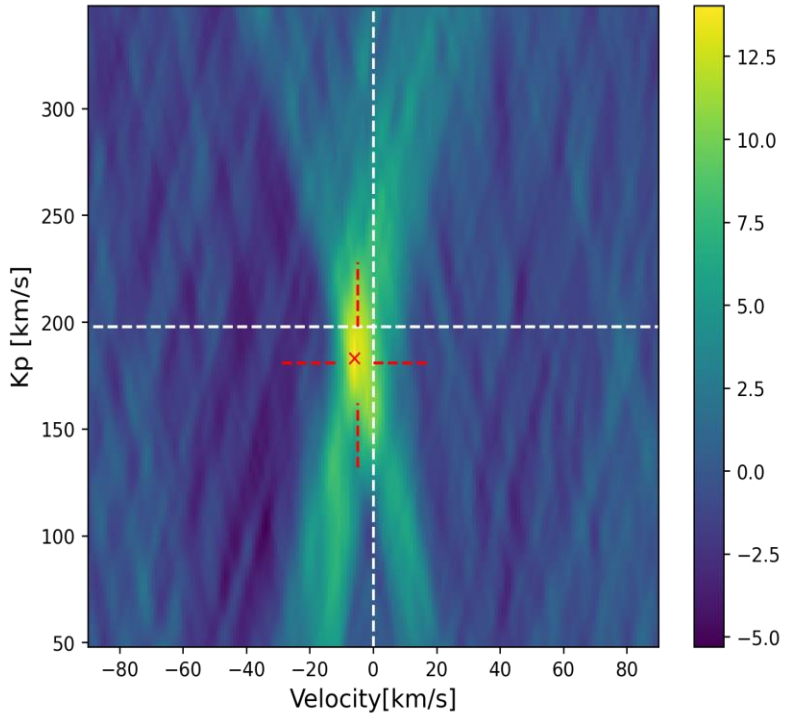
SRF



PRF

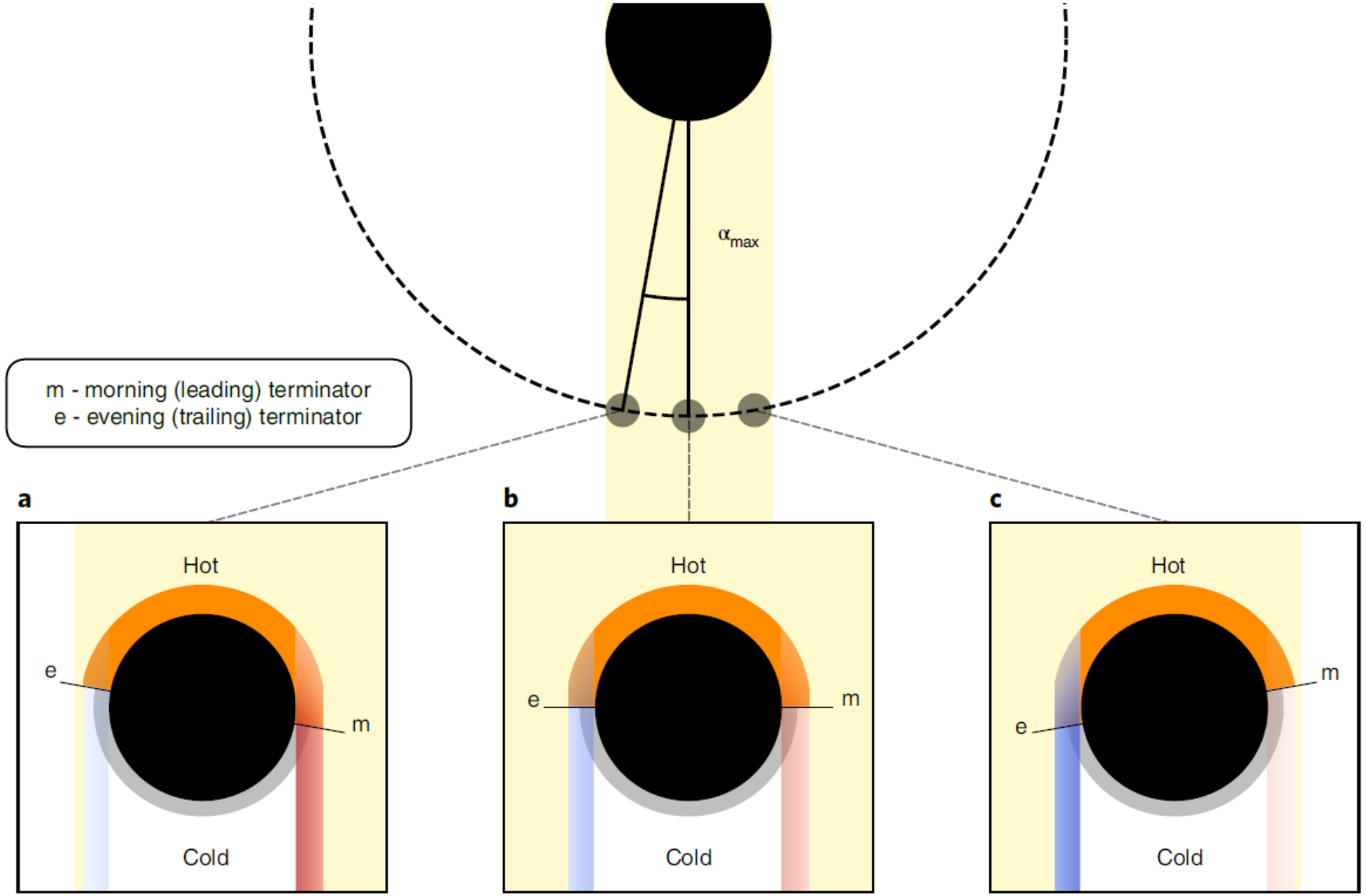


Kp-Vsys



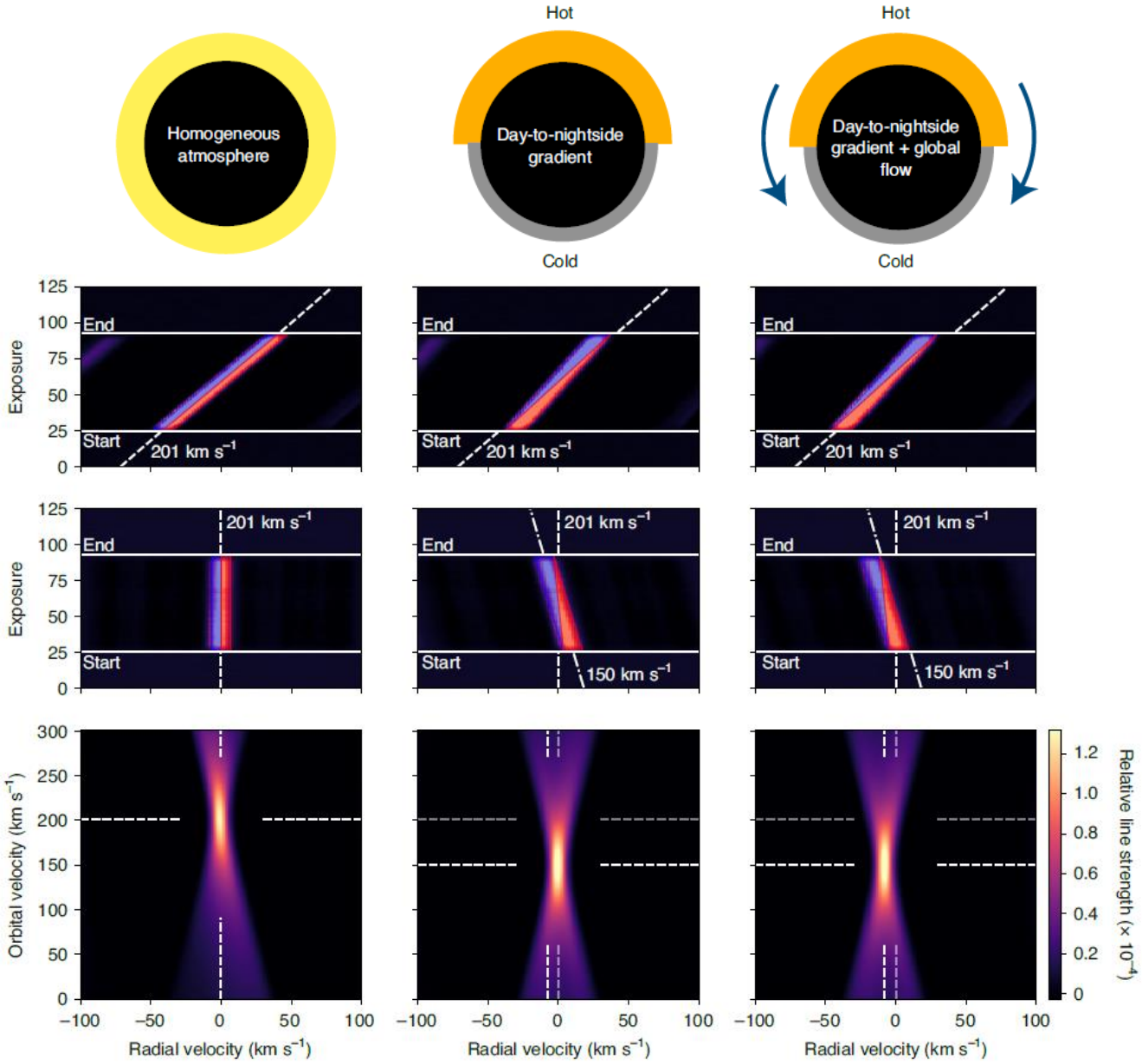
信号不在预计位置？

WASP-76b

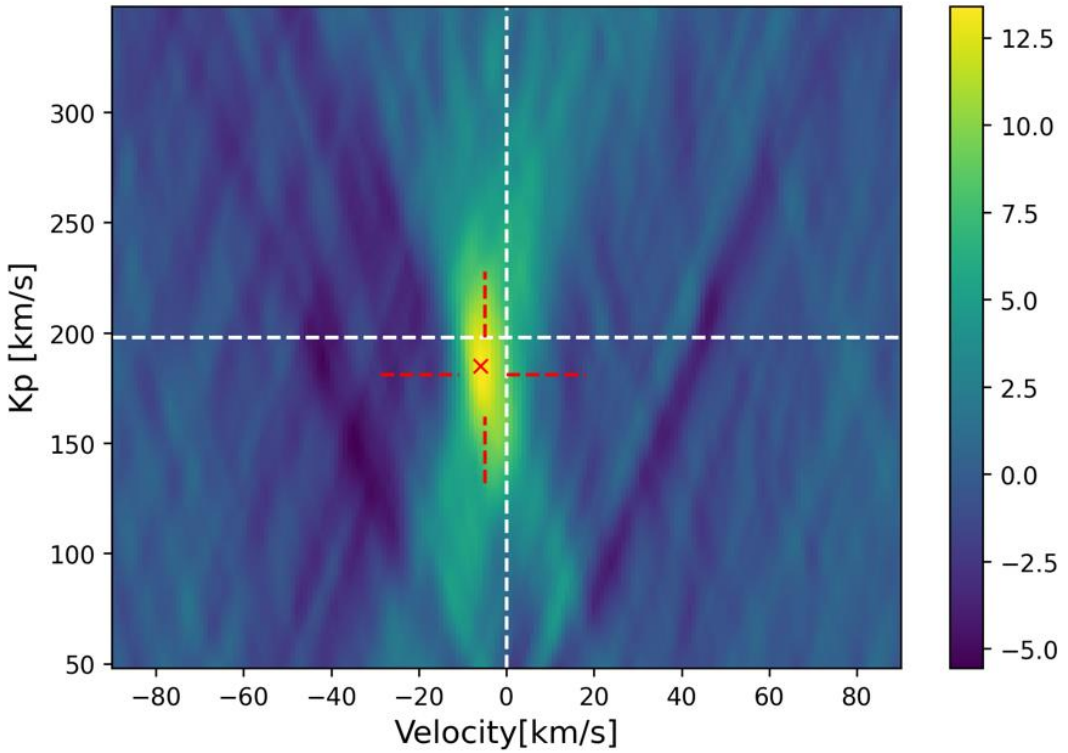


Credit: Bibiana Prinoth

WASP-76b

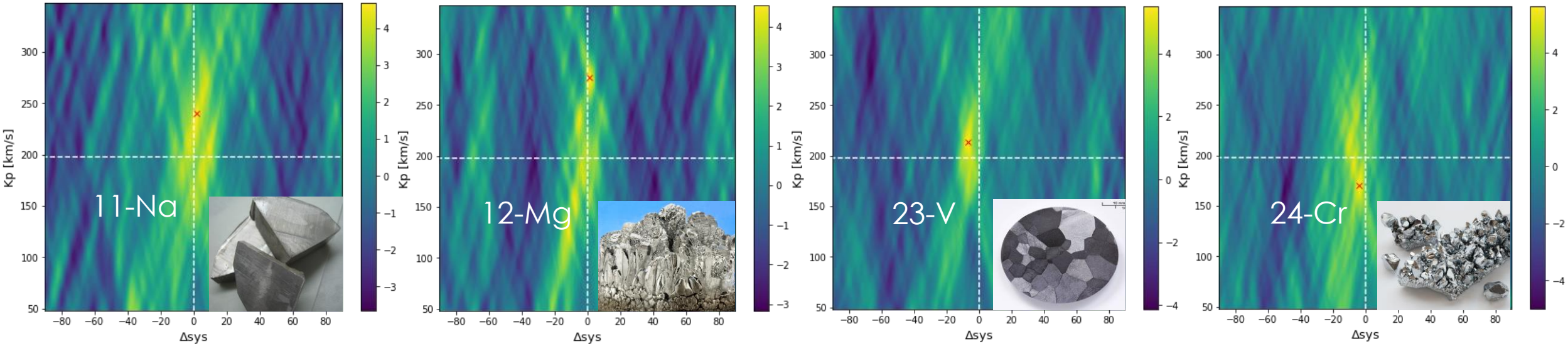


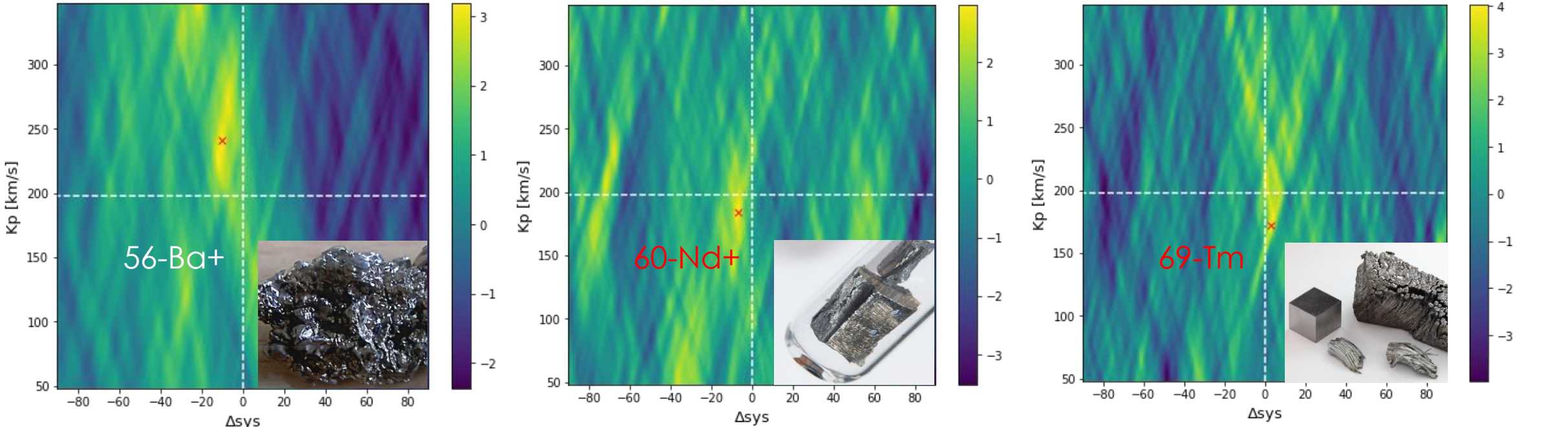
Fe风的存在



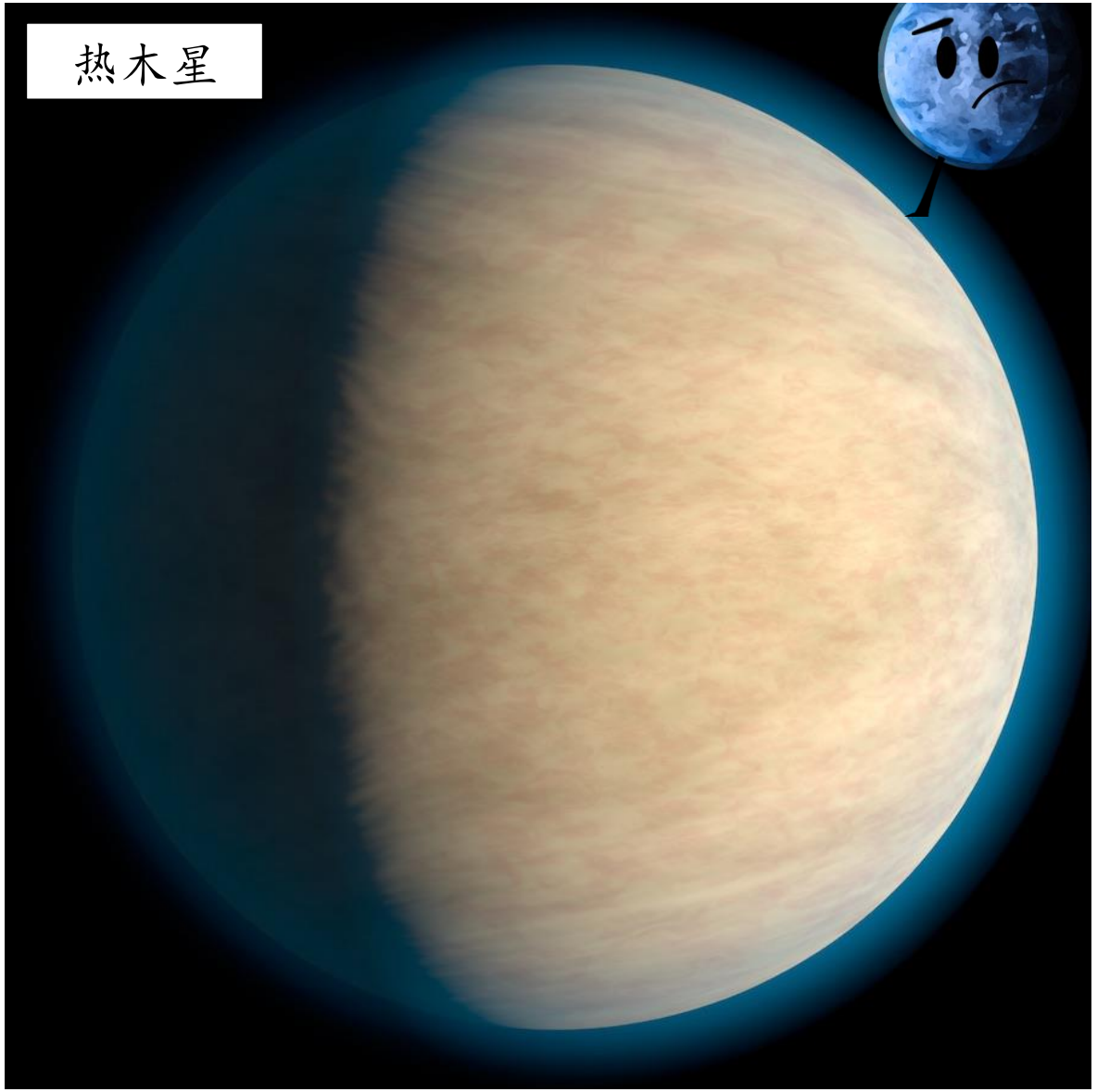
Credit: Bibiana Prinoth

WASP-76b





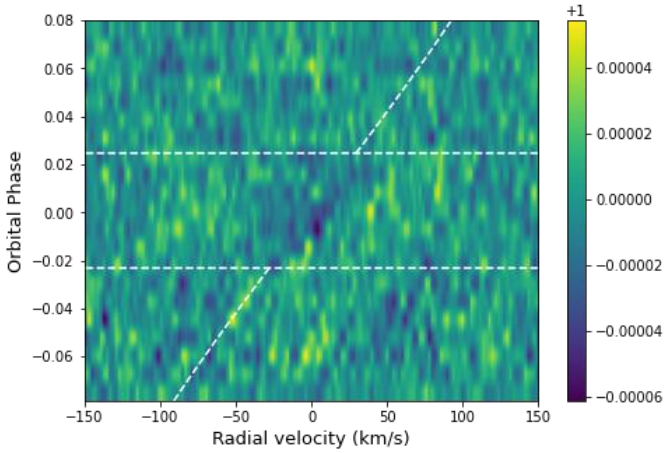
WASP-77Ab/WASP-85Ab

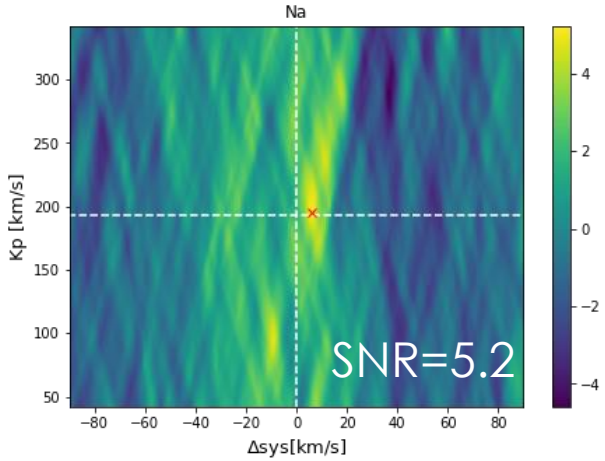


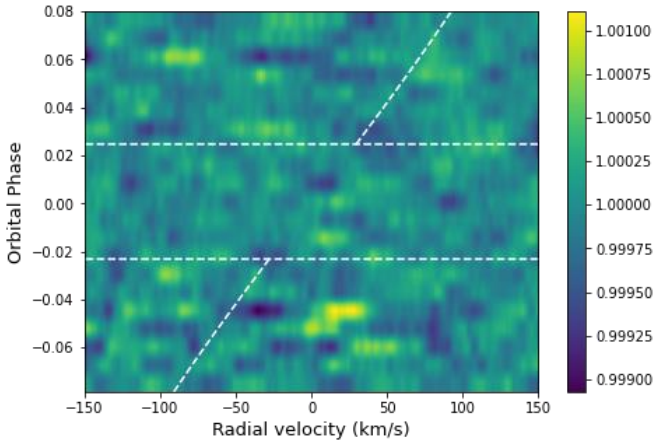
参数	WASP-77Ab	WASP-85Ab
主星有效温度	5605±72K	6112±27K
半径	1.23±0.03R_J	1.24±0.03R_J
质量	1.67±0.06M_J	1.26±0.06M_J
平均密度	1.15±0.05	0.88±0.03
表面平衡温度	1715±26K	1452±6K
已发现大气成分	H20, CO	无
类型	热木星	热木星
特点	共面轨道	共面轨道
参考资料	Nasa Archive	Nasa Archive

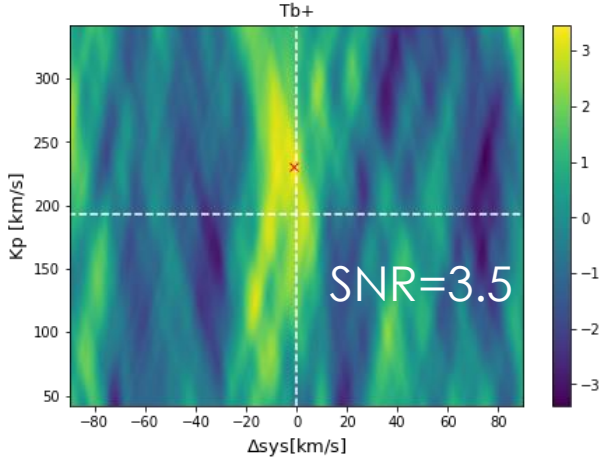
WASP-77Ab/WASP-85Ab

WASP-77Ab

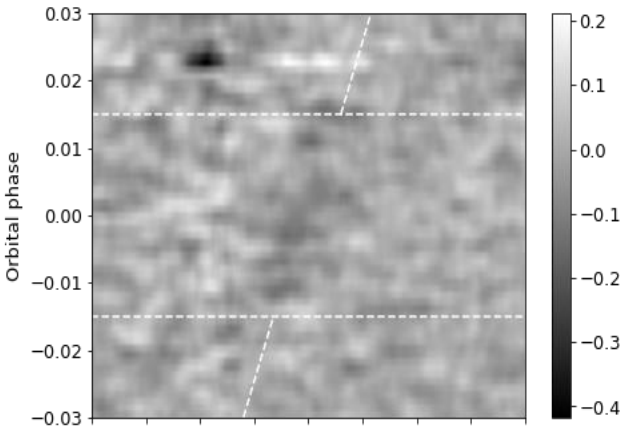


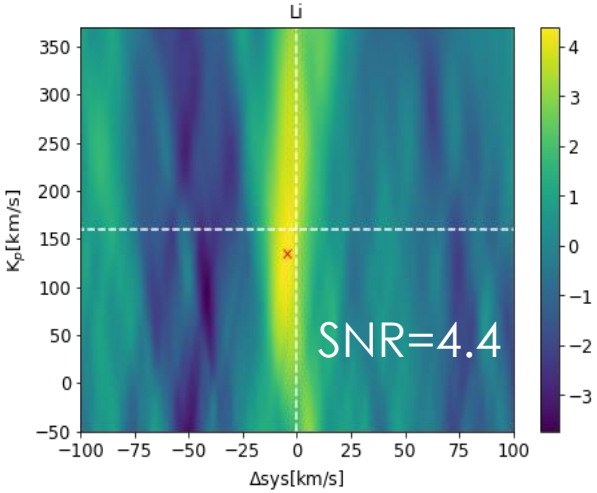




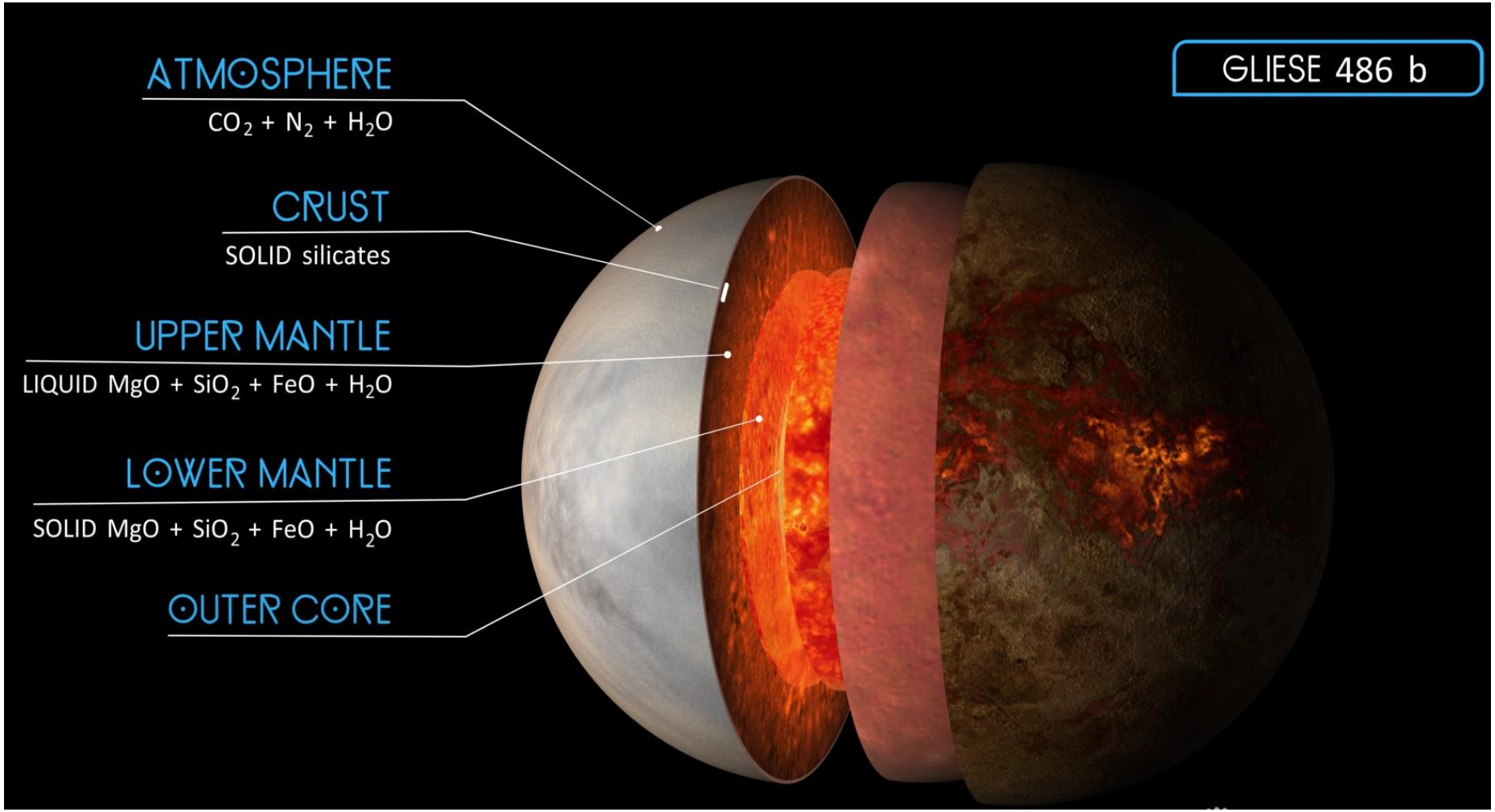


WASP-85Ab



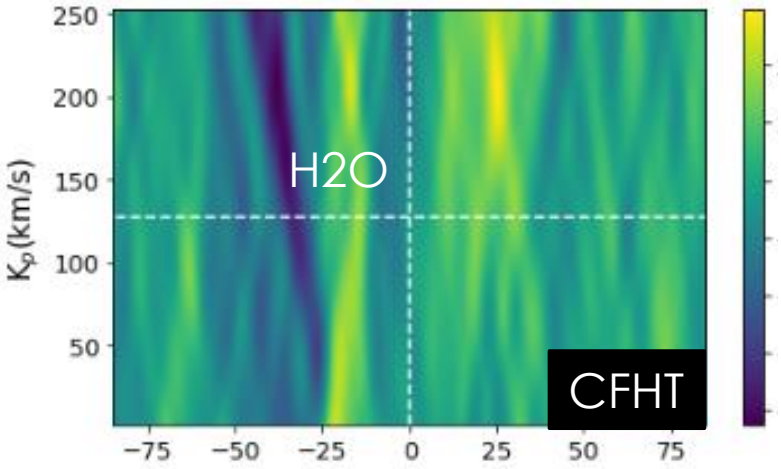


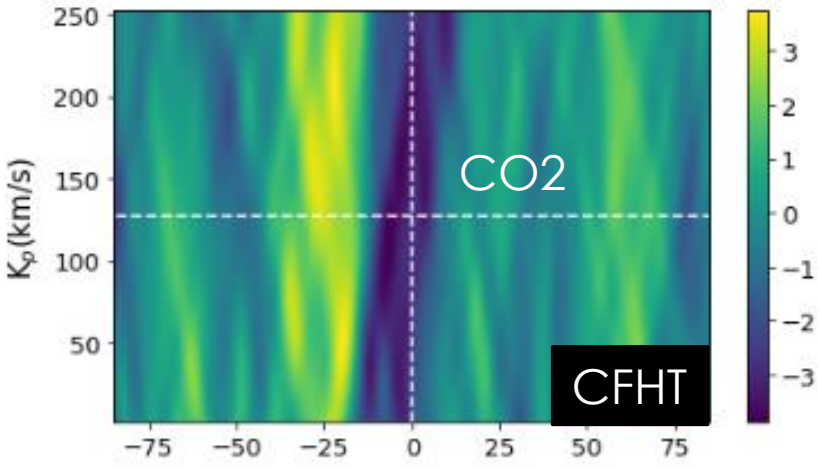
GJ-0486b

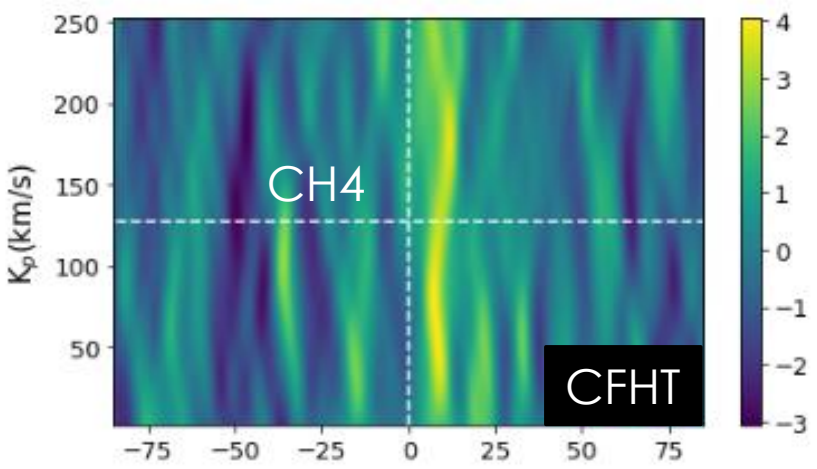


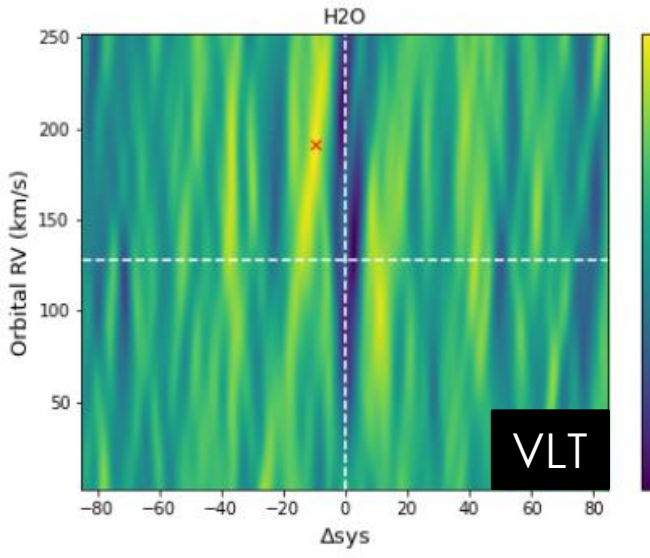
主星有效温度	3340±54K
半径	1.31±0.06R⊕
质量	2.82±0.11M⊕
平均密度	7.0±1.2
表面平衡温度	701±13K
已发现成分	无
类型	超级地球

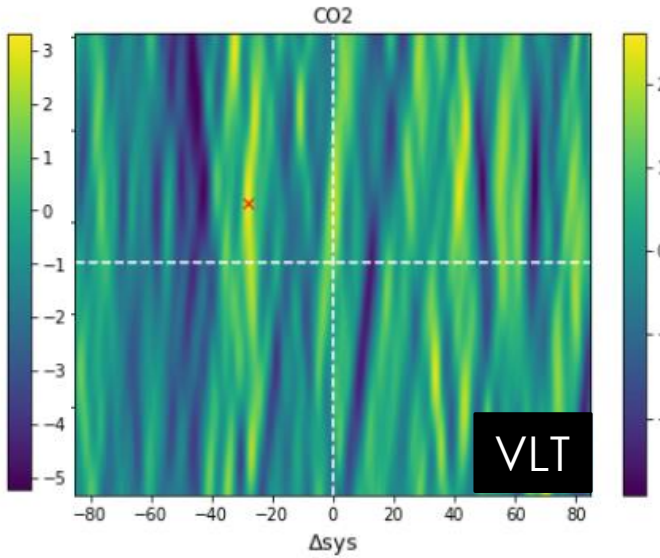
GJ-0486b

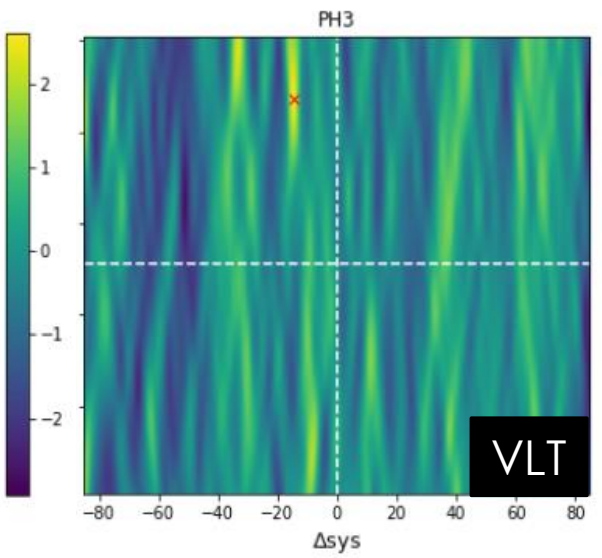

H2O
CFHT
K_p(km/s)

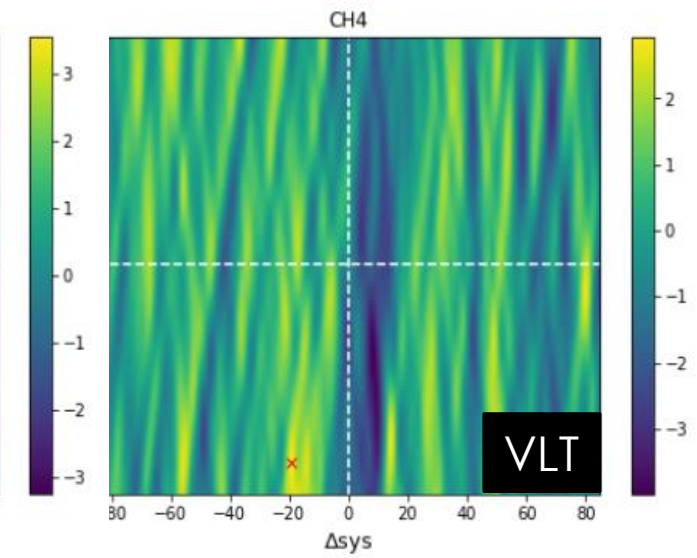

CO2
CFHT
K_p(km/s)


CH4
CFHT
K_p(km/s)


H2O
VLT
Orbital RV (km/s)
Δsys


CO2
VLT
Δsys


PH3
VLT
Δsys


CH4
VLT
Δsys


感谢聆听，请多指教