Exoplanet Characterization Observatory

EChO
The Exoplanet Characterization Observatory

Vincent Coudé du Foresto (LESIA, Paris Observatory)
for the EChO team :

G. Tinetti (UCL, UK), J.-P. Beaulieu (IAP, France), T. Henning (MPIA, Germany), M. Meyer (ETH, Switzerland), G. Micela (INAF, Italy), I. Ribas (IEEC, Spain), D. Stam (SRON, Netherlands), M. Swain (JPL, USA)

(present here) P.O. Lagage, E. Palle

Krause O. (MPIA), Ollivier M. (IAS), Pace E. (Un. Firenze), Swinyard B. (UCL-RAL) · Aylward A. (UCL), van Boekel R. (MPIA), Coradini A. (INAF), Encrenaz T. (LESIA, Obs. Paris), Snellen I. (Un. Leiden), Zapatero-Osorio M. R. (CAB) · Bouwman J. (MPIA), Cho J. Y-K. (QMUL), Coud ´e du Foresto V. (LESIA), Guillot T. (Obs. Nice), Lopez-Morales M. (IEEC), Mueller-Wodarg I. (Imperial College), Palle E. (IAC), [illegible] (Un. Bordeaux), Sozzetti A. (INAF), Ade P.A.R. (Cardiff), Achilleos N. (UCL), Adriani A. (INAF), Agnor C. [illegible] C. (MPIA), Allende Prieto C. (IAC), Bakos G. (Princeton), Barber R. J. (UCL), Barlow M. (UCL), Bernath P. (Un. York), B ´ezard B. (LESIA), Bord ´e P. (IAS), Brown L.R. (JPL), [illegible] (UCL), Decin L. (IvS), De Kok R. (SRON), Demangeon O. (IAS), Deroo P. (JPL), Doel P. (UCL), Drossart P. (LESIA), Fletcher L.N. (Oxford), Focardi M. (Un. Firenze), Forget F. (LMD), Fossey S. (UCL), Fouqu ´e P. (Obs-MIP), Frith J. (UH), Galand M. (Imperial College), Gaulme P. (IAS), Gonza ´lez Herna ´ndez J.I. (IAC), Grasset O. (Un. Nantes), Grassi D. (INAF), Grenfell J. L. (TUB), Griffin M. J. [illegible] na), Guio P. (UCL), Hainaut O. (ESO), Hargreaves R. (Un. York), Ha[illegible] (ETH), Heyrovsky D. (CU Prague), Hueso R. (EHU Bilbao), Irwin P. (Oxford), Kaltenegger L. (MPIA), Kervella P. (Paris Obs.), Kipping D. (CfA), Koskinen T.T. (UoA), Kova ´cs G. (Konkoy Obs.), La Barbera A. (INAF/IASFP), Lammer H. (Un. Graz), Lellouch E. (LESIA), Leto G. (INAF/ OACt), Lopez [illegible] s. Geneve) Maggio A. [illegible] (CAB), Maxted P. (Un. Keele), Miller S. (UCL), Molinari S. (Un. Firenze), Montes D. (UCM), Moro-Martin A. (CAB), Moses J.I. (SSI), Mousis [illegible] A), Pascale E. (Cardiff), Pezzuto S. (IFSI-INAF), Pinfield D. (UH), Poretti E. (INAF/OAMi), Prinja R. (UCL), Prisinzano L. (INAF-OAPa), Rees J.M. (LESIA), Reiners [illegible] (EHU Bilbao), Sanz Forcada J. (CAB), Sasselov D. (CfA), Savini G. (UCL), [illegible] (UCL), Strazzulla G. (INAF/OACt), Tennyson J. (UCL), Tessenyi M. (UCL), Vasisht G. (JPL), Vinatier S. (LESIA), Viti S. (UCL), Waldmann I. (UCL), White G.J. (OU-RAL), Widemann T. (LESIA), Wordsworth R. (LMD), Yelle R. (UoA), Yung Y. (Caltech), Yurchenko S.N. (UCL)

50 YEARS 1962–2012

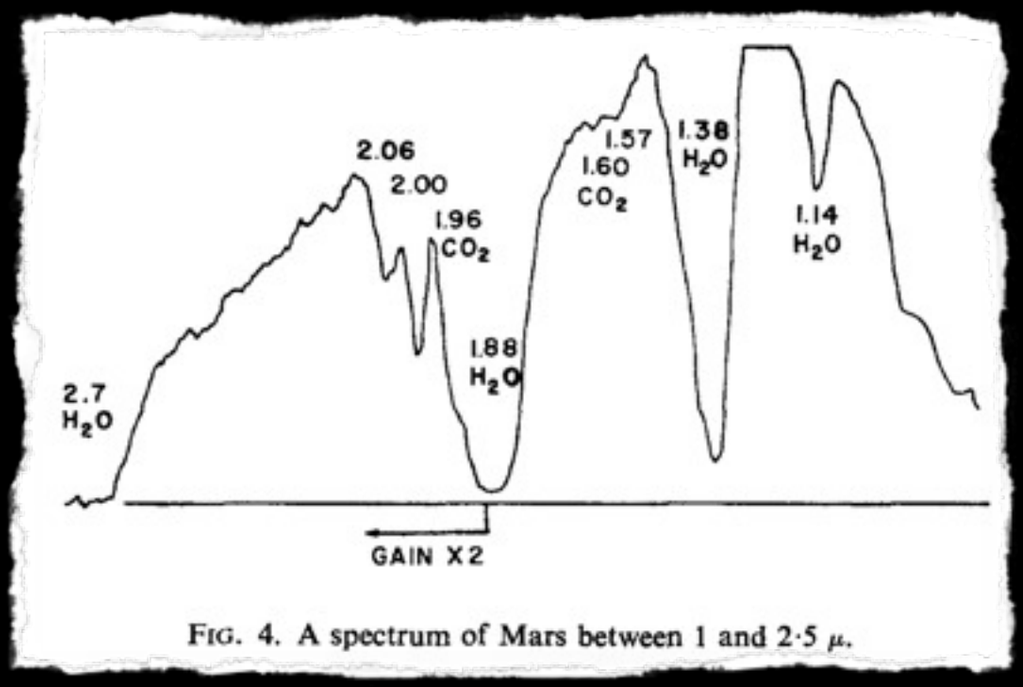


FIG. 4. A spectrum of Mars between 1 and 2·5 μ.

Sinton 1963

1962 data

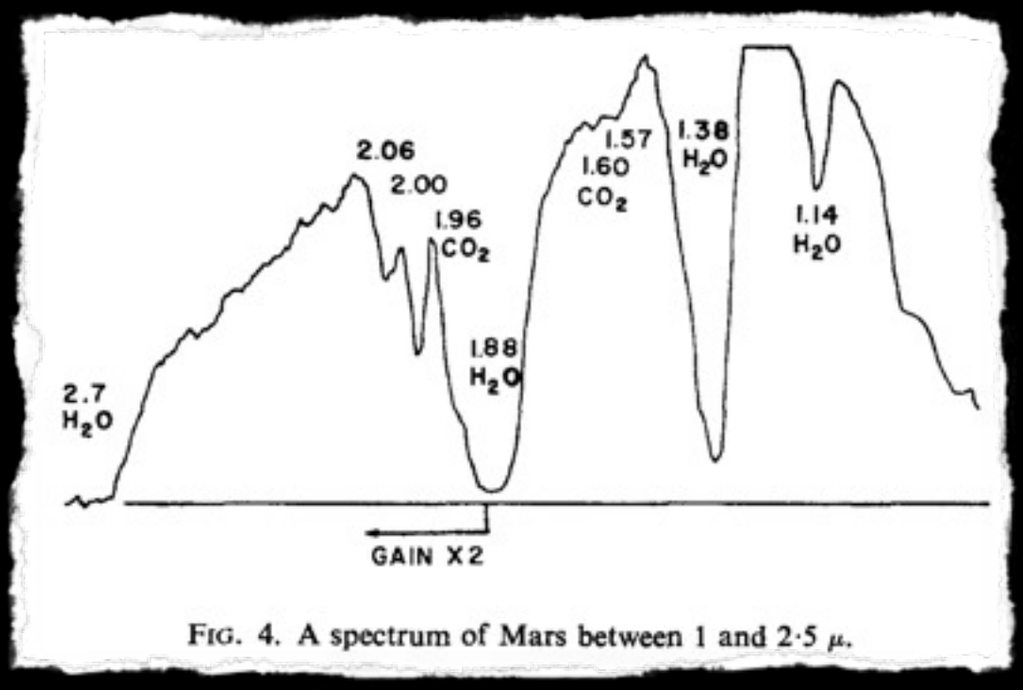
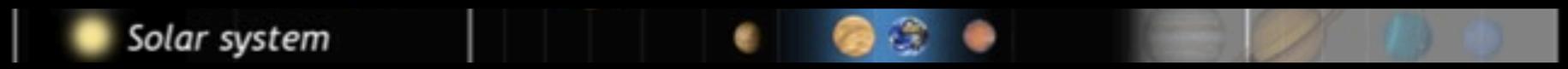


FIG. 4. A spectrum of Mars between 1 and 2·5 μ.

Sinton 1963

1962 data



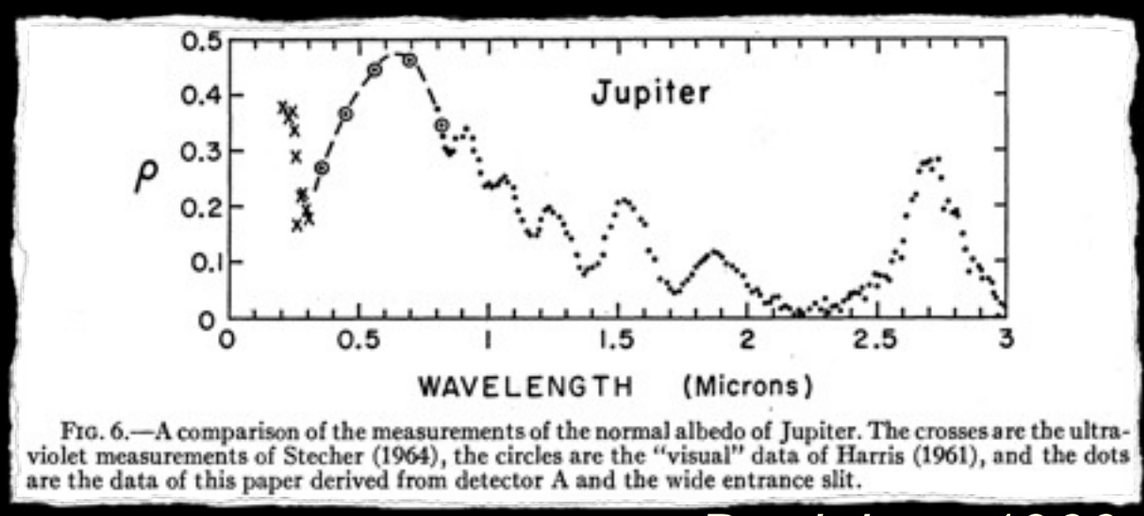


FIG. 6.—A comparison of the measurements of the normal albedo of Jupiter. The crosses are the ultraviolet measurements of Stecher (1964), the circles are the "visual" data of Harris (1961), and the dots are the data of this paper derived from detector A and the wide entrance slit.

Danielson 1966

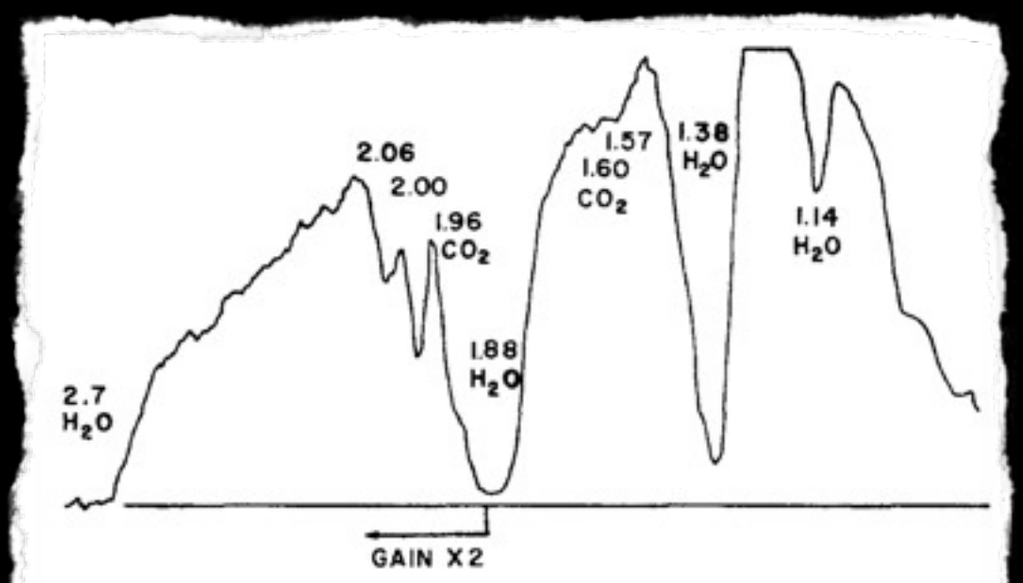


FIG. 4. A spectrum of Mars between 1 and 2·5 μ.

Sinton 1963

1962 data

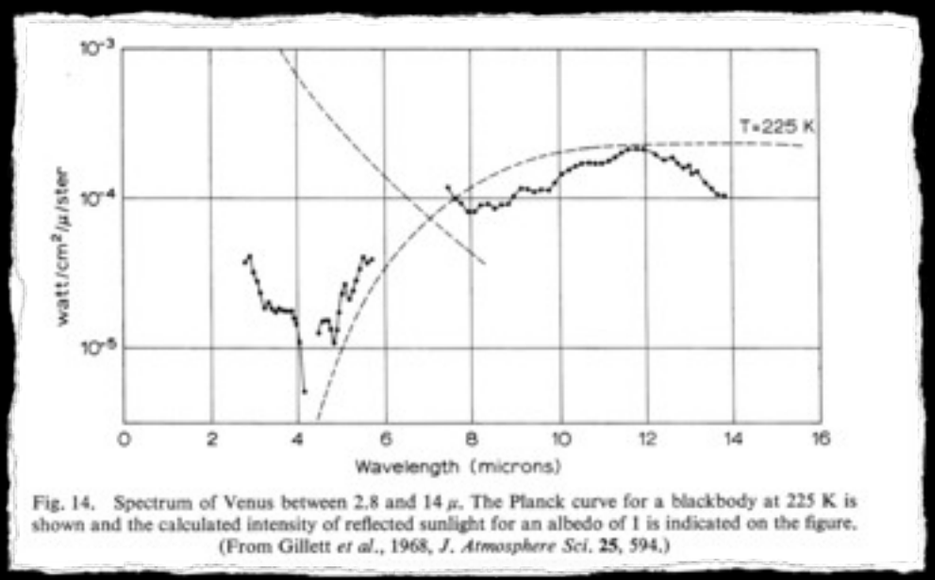


Fig. 14. Spectrum of Venus between 2.8 and 14 μ. The Planck curve for a blackbody at 225 K is shown and the calculated intensity of reflected sunlight for an albedo of 1 is indicated on the figure. (From Gillett *et al.*, 1968, *J. Atmosphere Sci.* **25**, 594.)

Gillett 1968

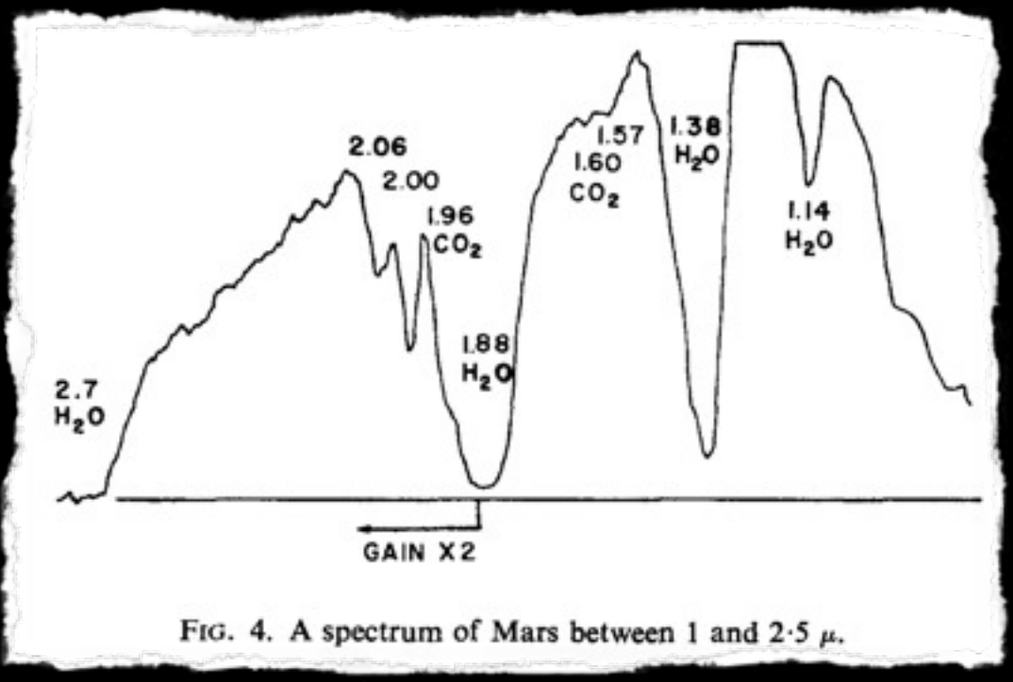


FIG. 4. A spectrum of Mars between 1 and 2·5 μ.

Sinton 1963

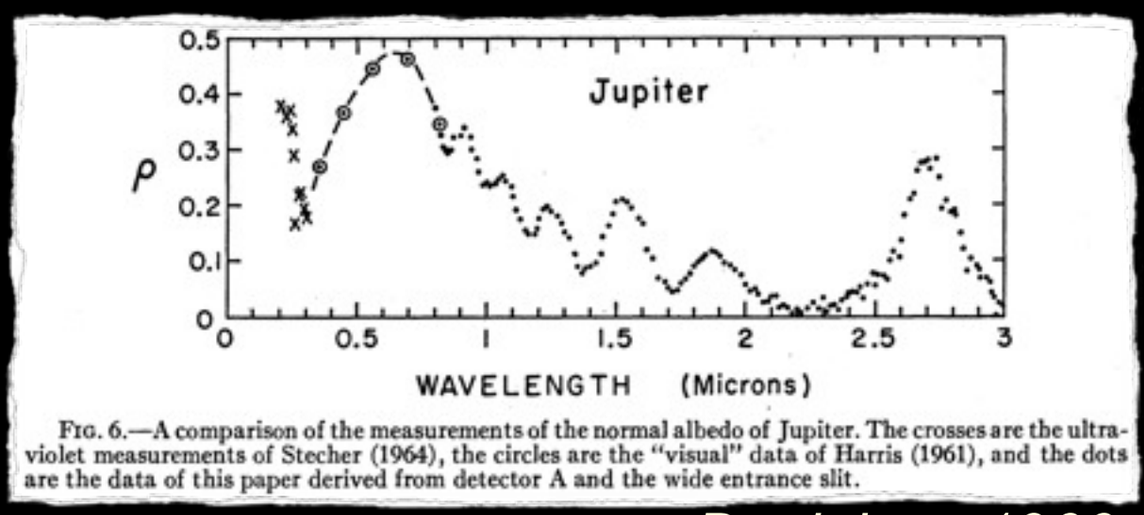
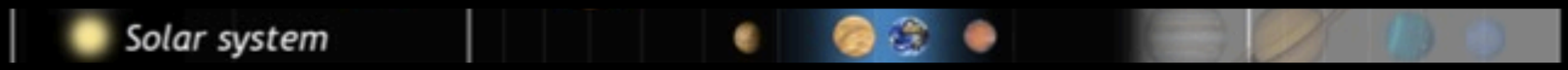
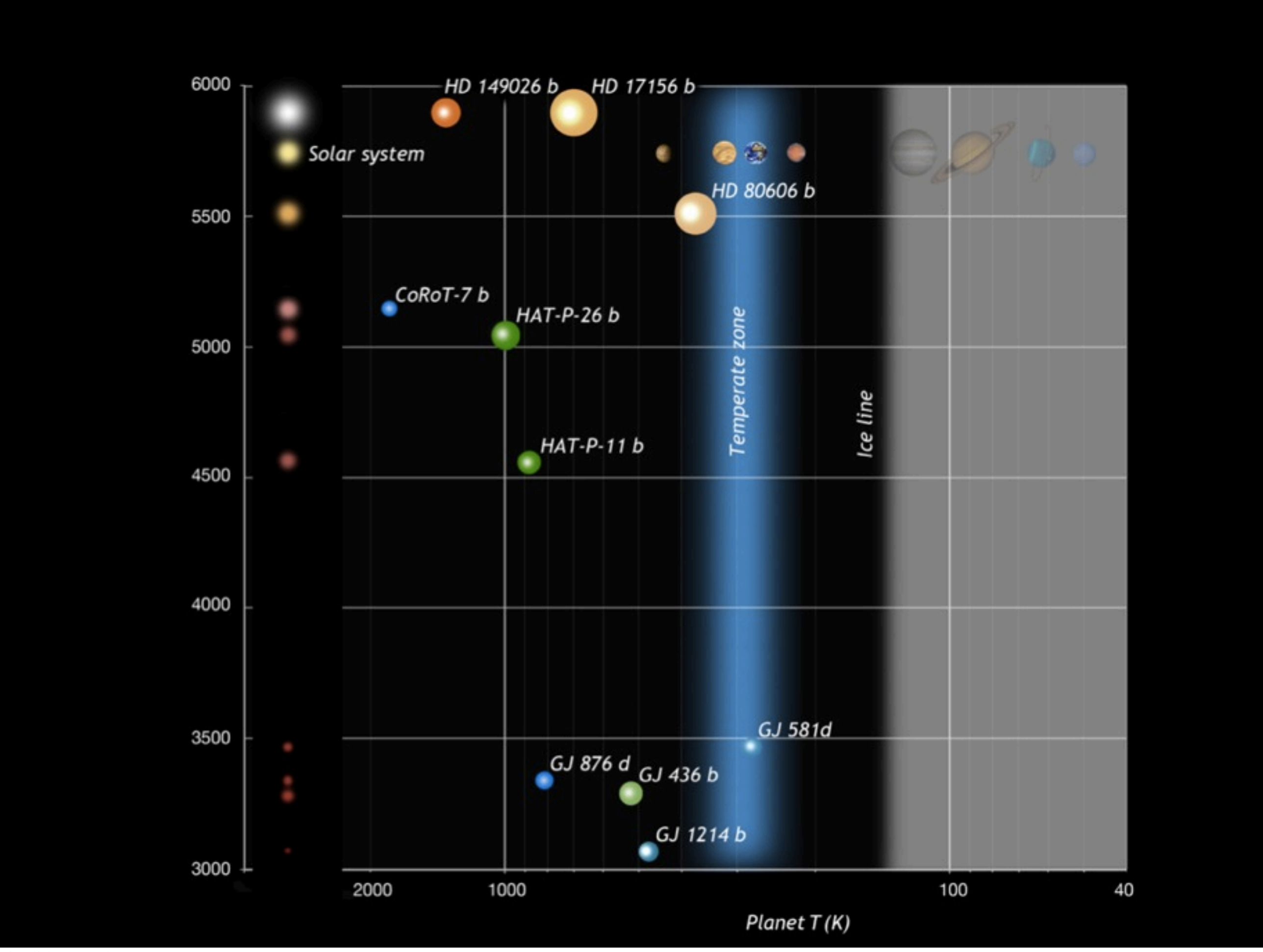


FIG. 6.—A comparison of the measurements of the normal albedo of Jupiter. The crosses are the ultraviolet measurements of Stecher (1964), the circles are the "visual" data of Harris (1961), and the dots are the data of this paper derived from detector A and the wide entrance slit.

Danielson 1966

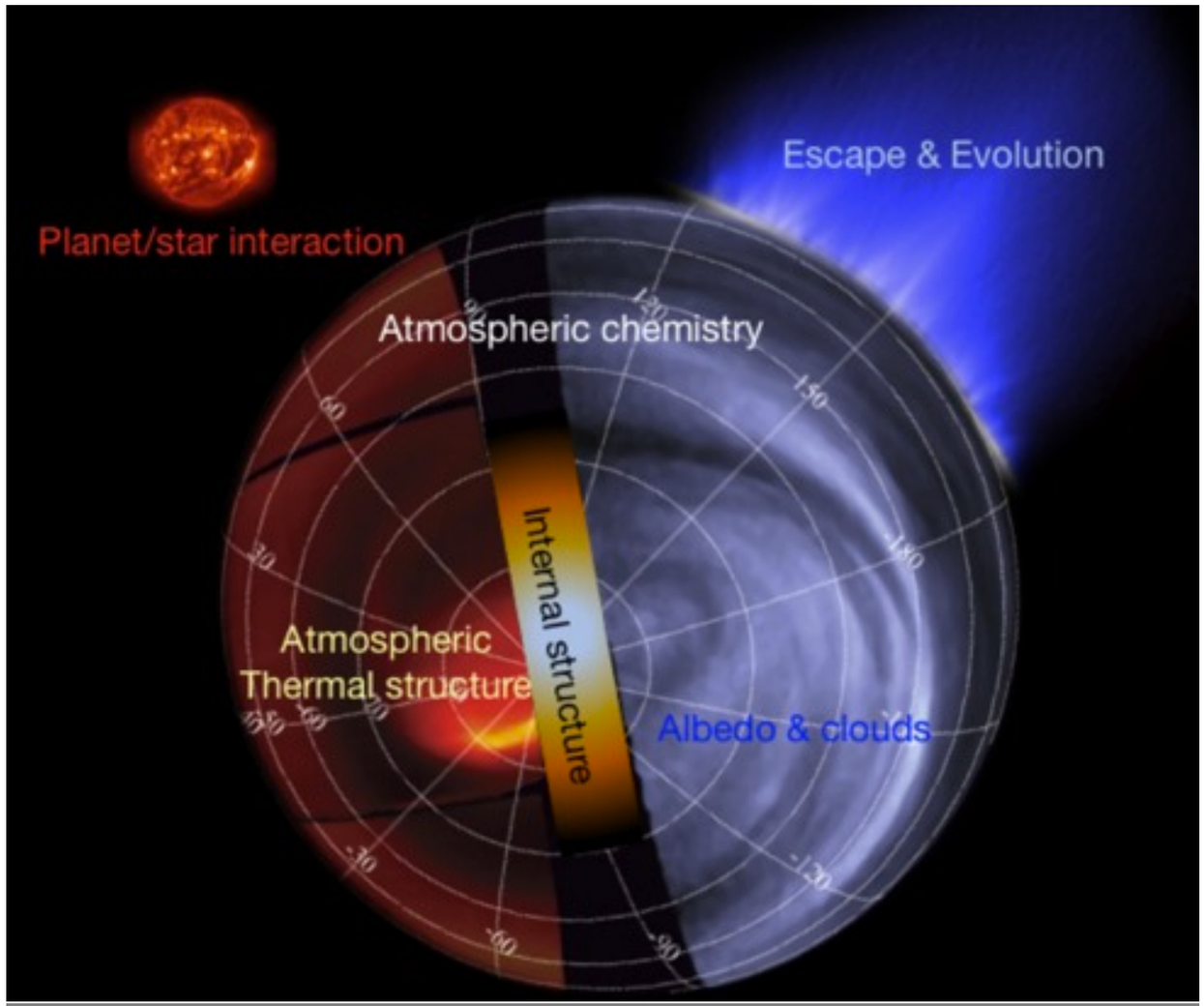
1962 data


Solar system


6000
5500
5000
4500
4000
3500
3000
2000
1000
100
40
Planet T (K)
HD 149026 b
HD 17156 b
Solar system
HD 80606 b
CoRoT-7 b
HAT-P-26 b
HAT-P-11 b
Temperate zone
Ice line
GJ 581d
GJ 876 d
GJ 436 b
GJ 1214 b

Exoplanet Characterization Observatory

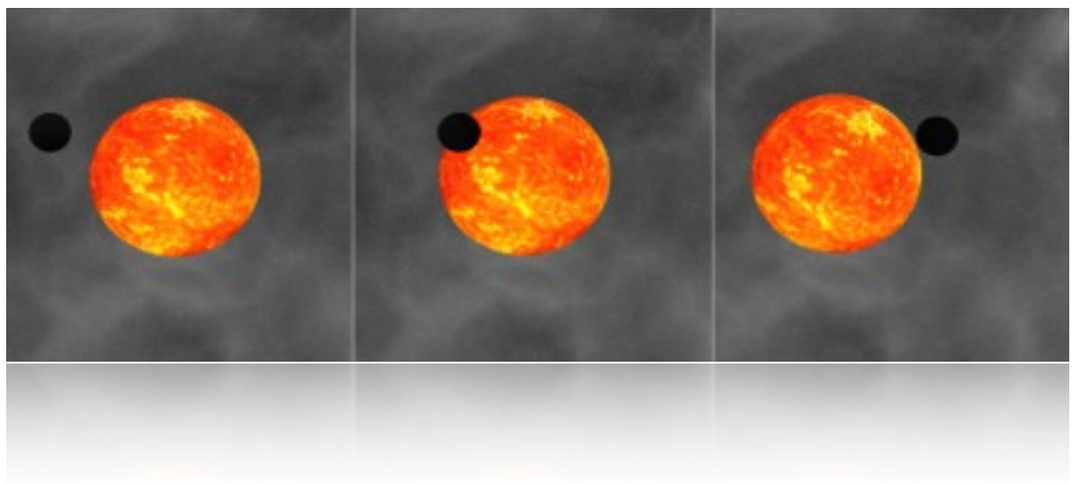
EChO's objectives



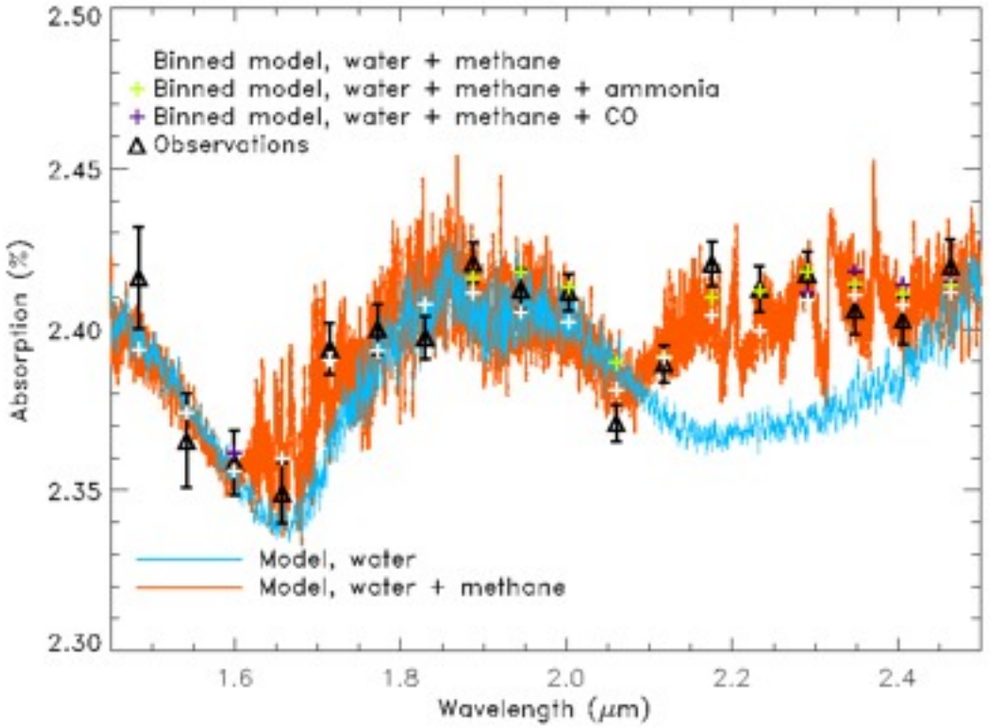
- Study the physics and chemistry of the atmospheres of a *representative sample* of *known exoplanetary systems* found around *nearby stars* :
  - Statistically significant (~100 planets)
  - From hot Jupiters to planets closest in mass and temperature to Earth
  - With temporal and spatial resolution in the best cases

Exoplanet Characterization Observatory

Primary transit



HD189733b, terminator

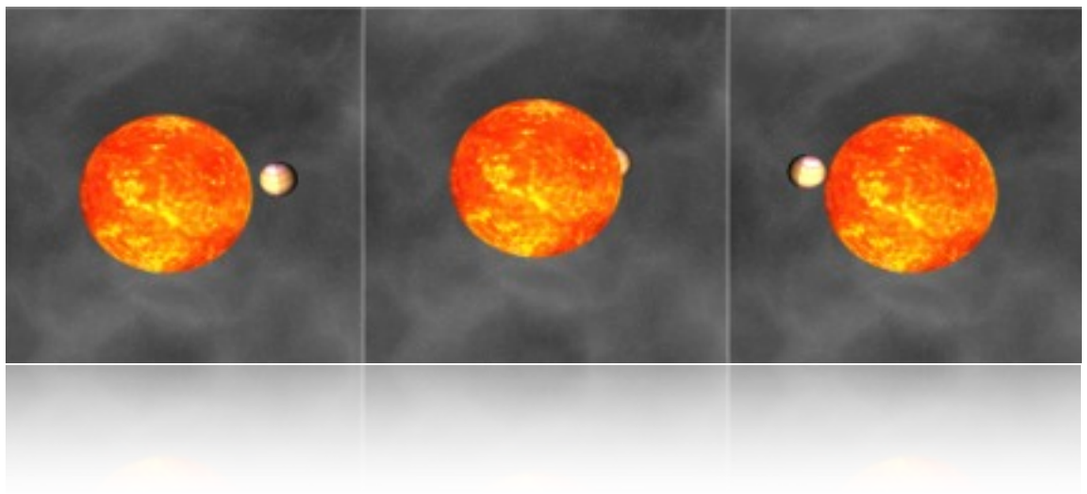


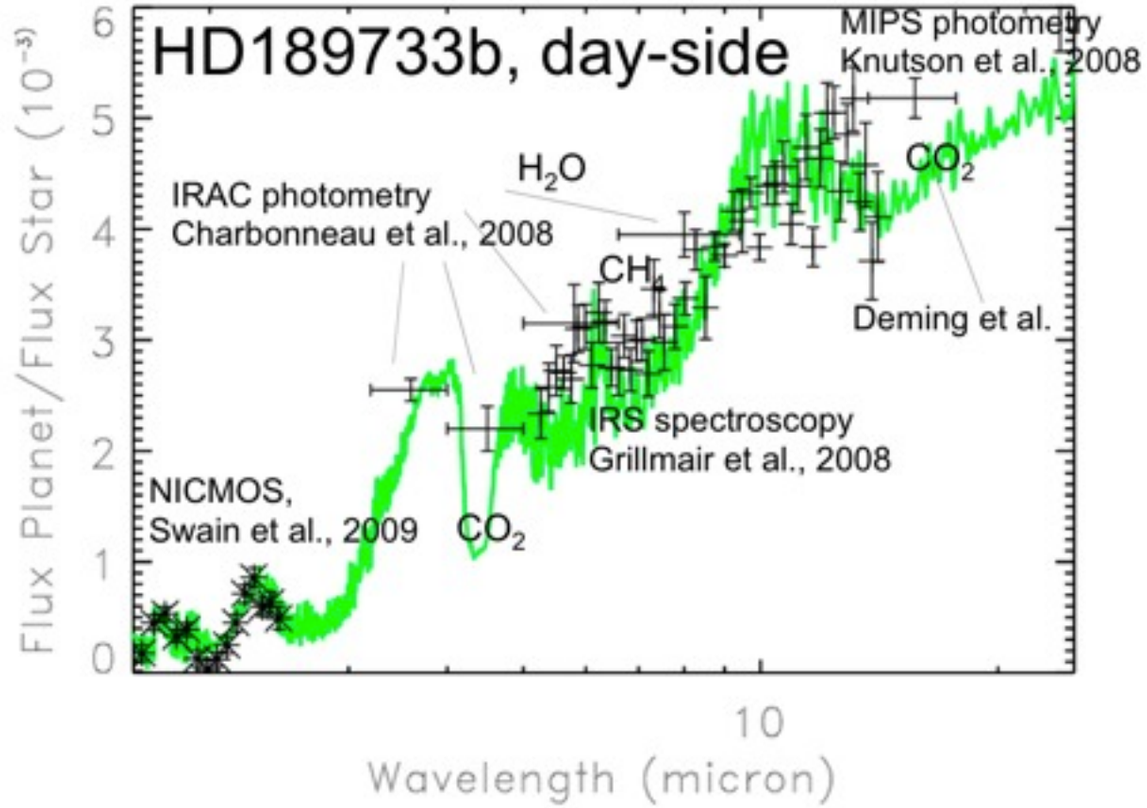
Swain, Vasisht, Tinetti, Nature, 2008

- Transmission spectroscopy
- Probes the high altitude atmosphere at the terminator
- Signal proportional to the scale height (T and molecular weight dependent)

Exoplanet Characterization Observatory

Secondary transit

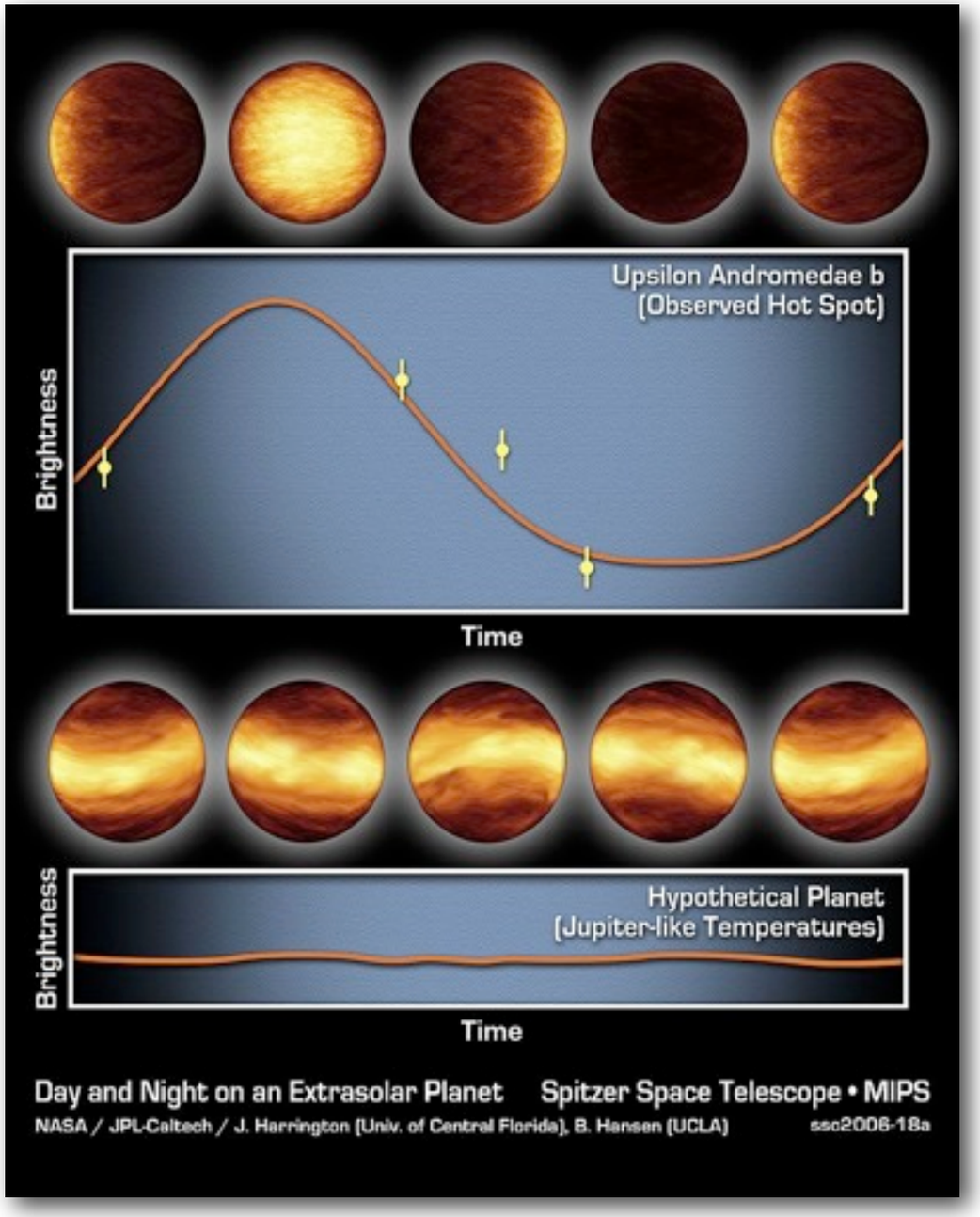




- Day side spectrum
- Thermal emission (modulated by molecular features) in the IR:
  - Depends on vertical T gradient
  - Probes higher P levels
- Reflected light in VIS dominated by scattering, clouds

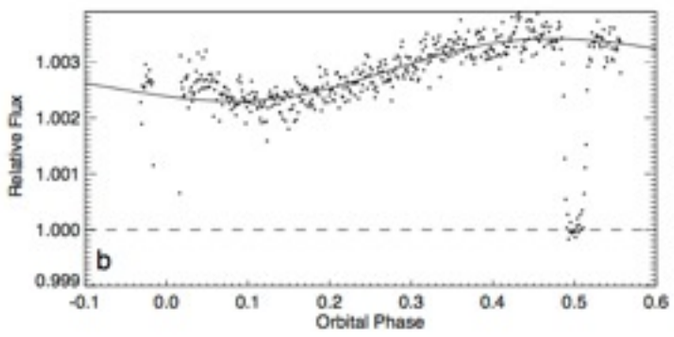
Exoplanet Characterization Observatory

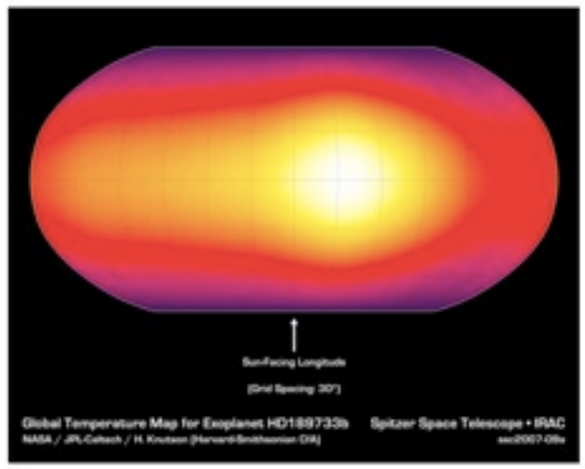
Phase variations



Ups And
(Harrington et al. 2006)

- Can be performed on non-transiting planets
- Needs long-term stability : can be done only from space
- Provides info on day/night redistribution of absorbed stellar energy and atmosphere dynamics

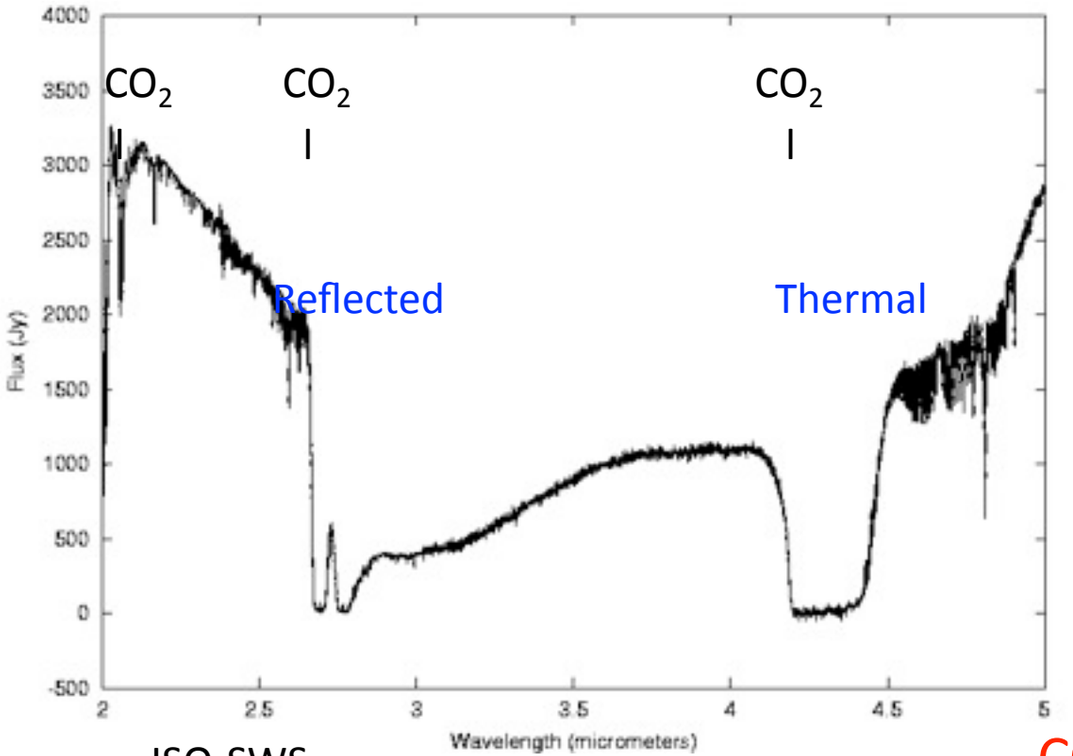




HD189733b
(Knutsen et al. 2007)

Spectral coverage needed

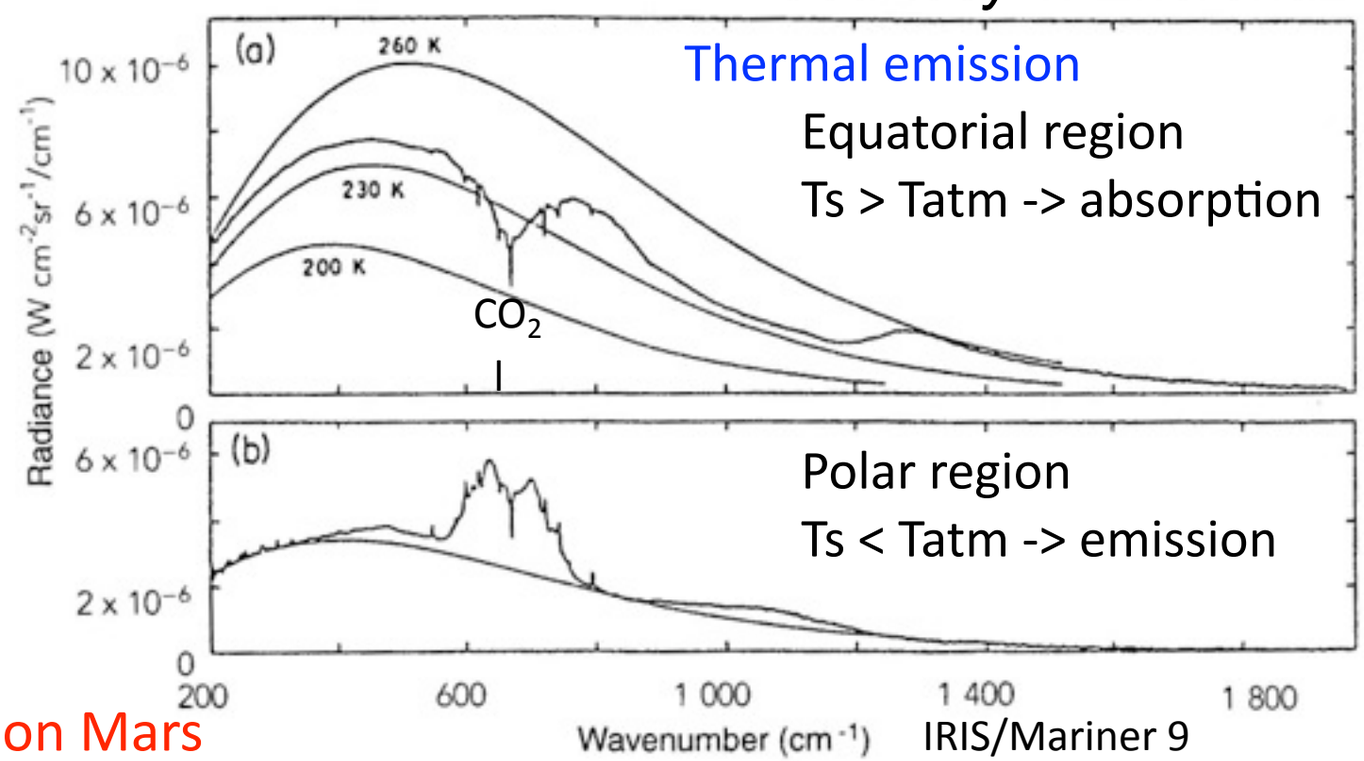
- Simultaneous visible to thermal IR spectrum essential to :
  - Monitor stellar magnetic activity during observation
  - Resolve the temperature / composition ambiguity in emission spectrum (by using bands of different intensities for a given molecule)



ISO-SWS

CO_2 on Mars

Courtesy T. Encrenaz



IRIS/Mariner 9

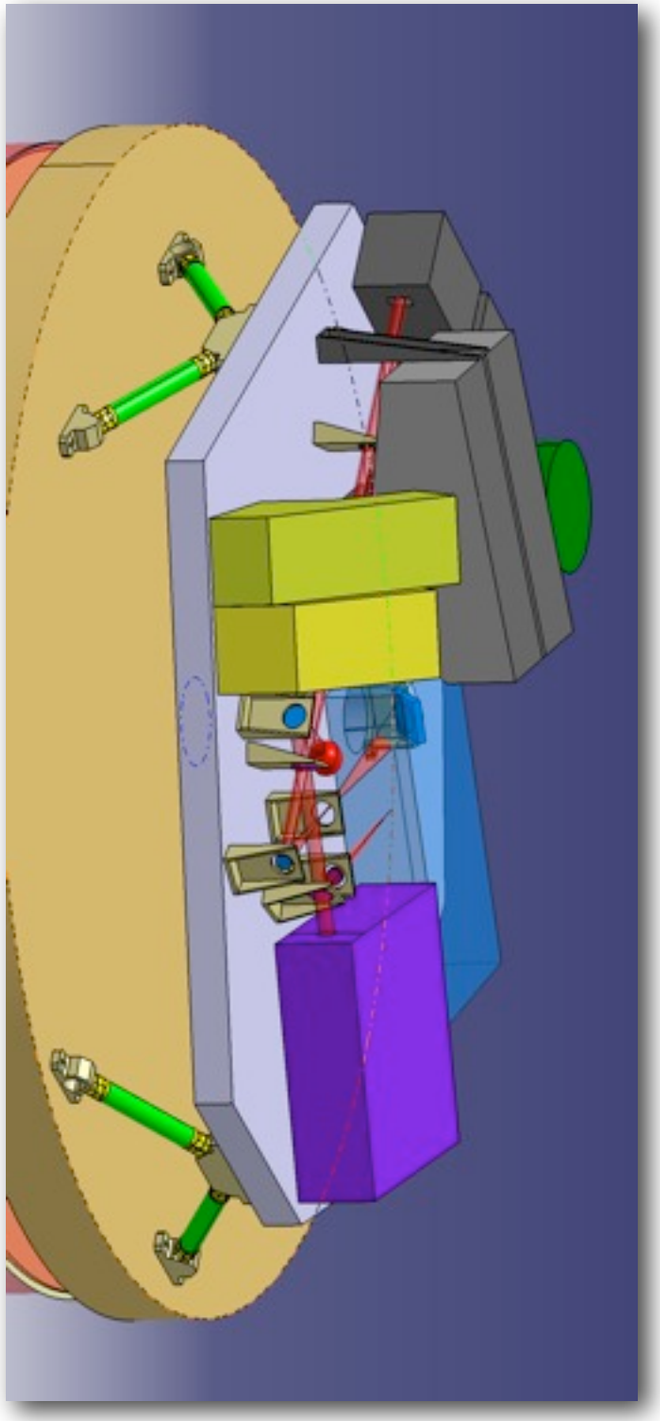
Exoplanet Characterization Observatory

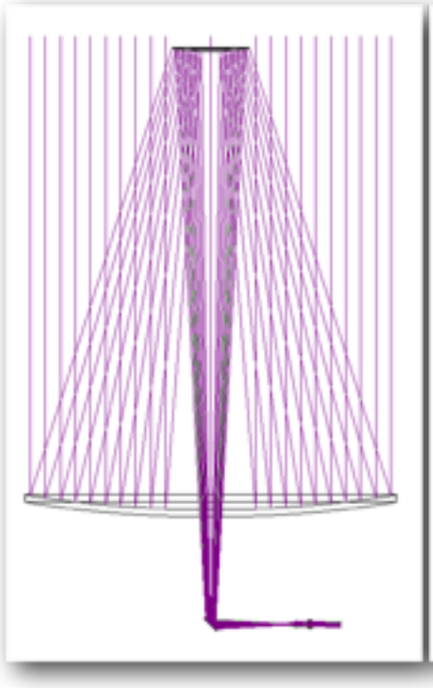
Mission concept

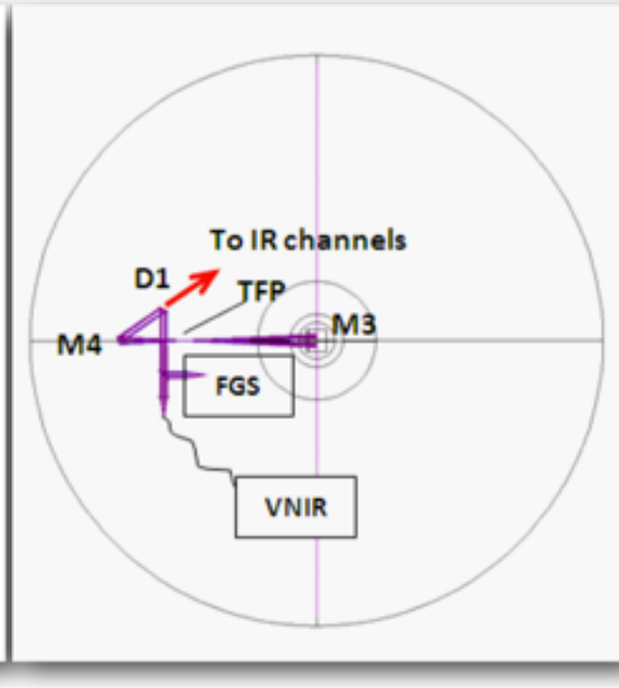
- 1.26m telescope, passively cooled to 38K
- Optimized for photometric stability at the level of ~10^{-4} or better over several hours
- A single science instrument:
  - 0.4 to 16μm spectrometer
- Soyouz launch from Kourou
- Grand halo orbit around Lagrange point L2
- Mission nominal duration 5 years

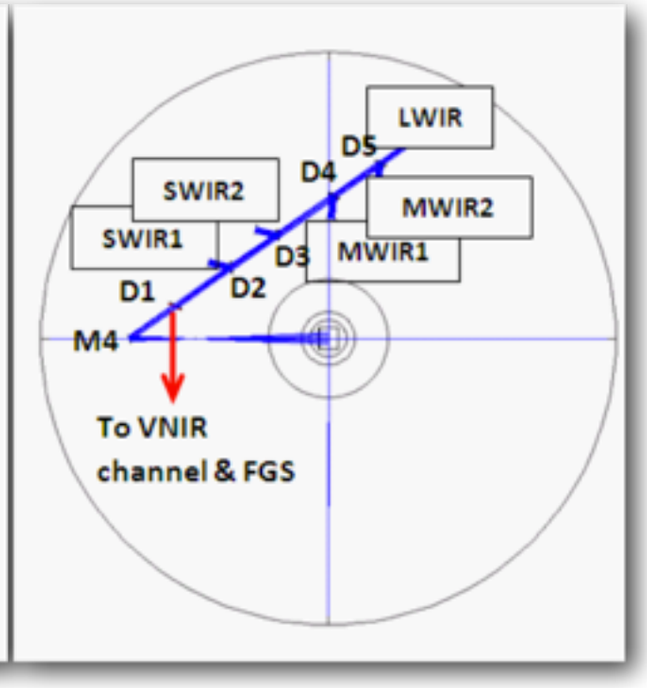
Exoplanet Characterization Observatory

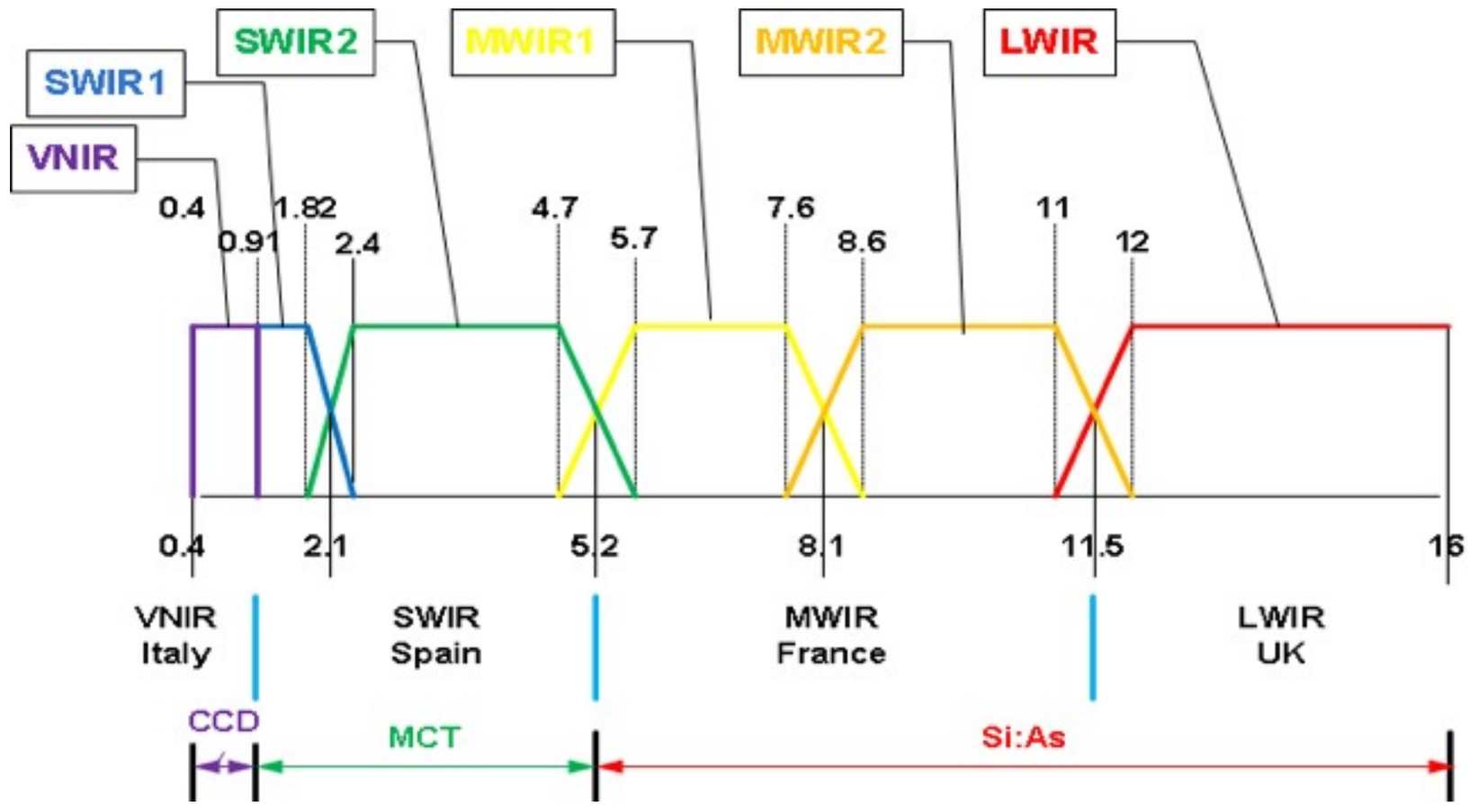
Focal plane spectrometer





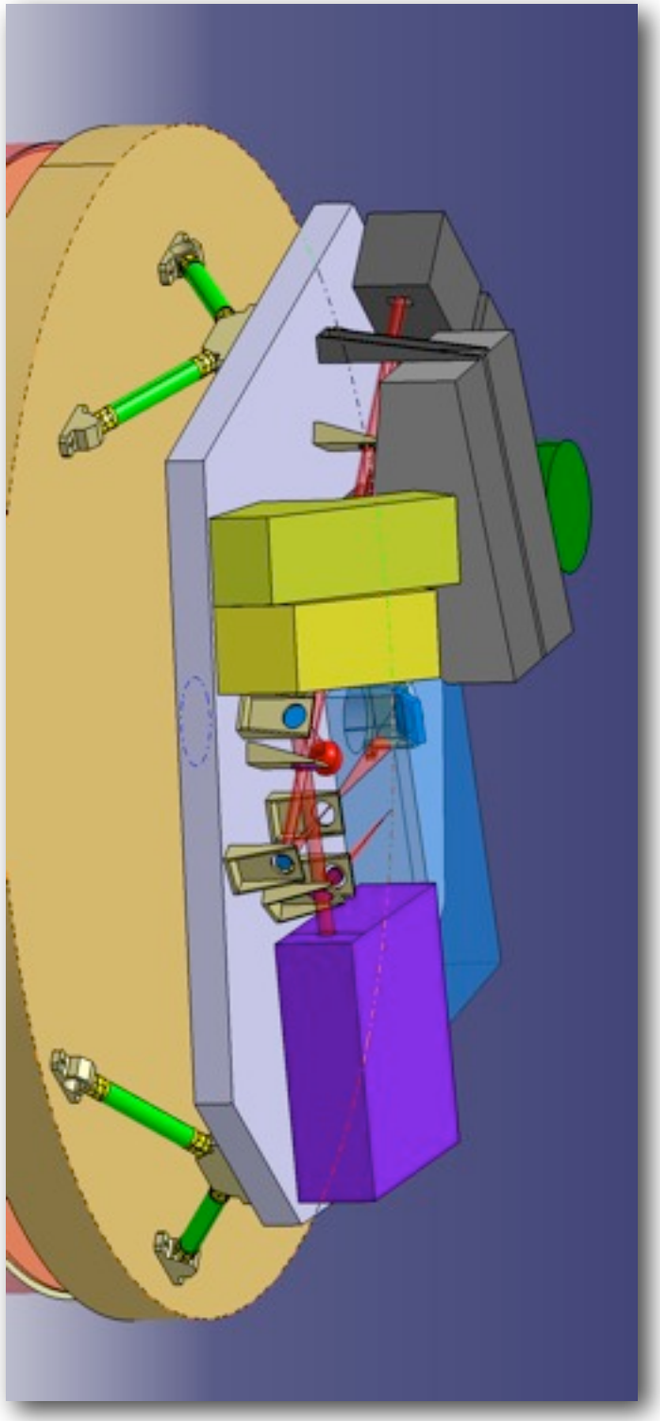


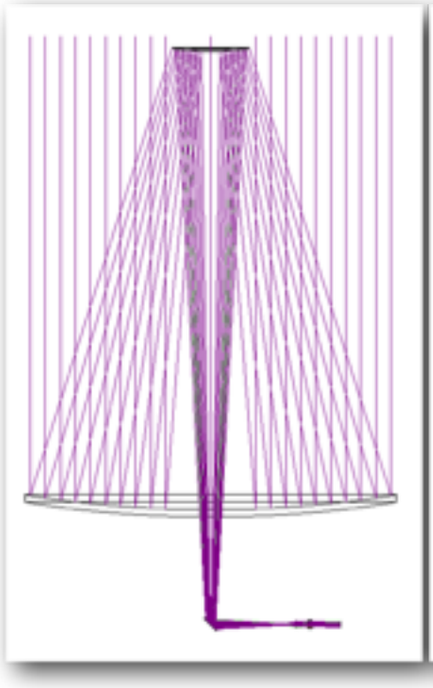


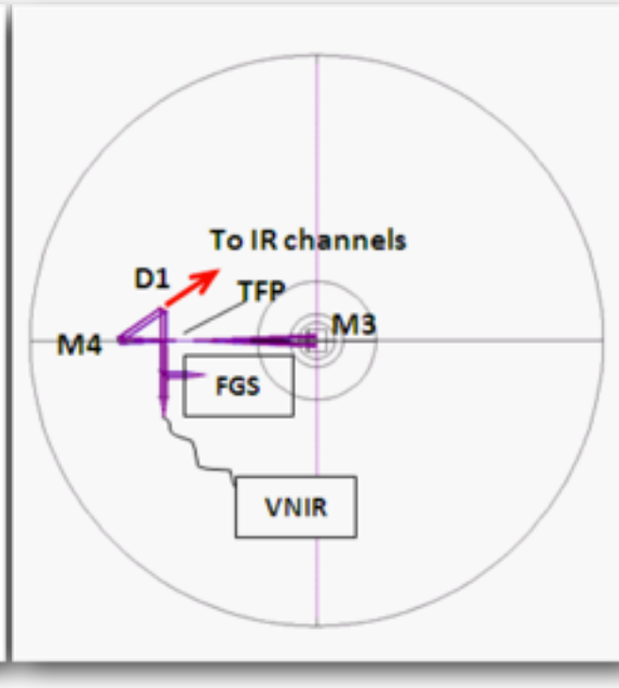


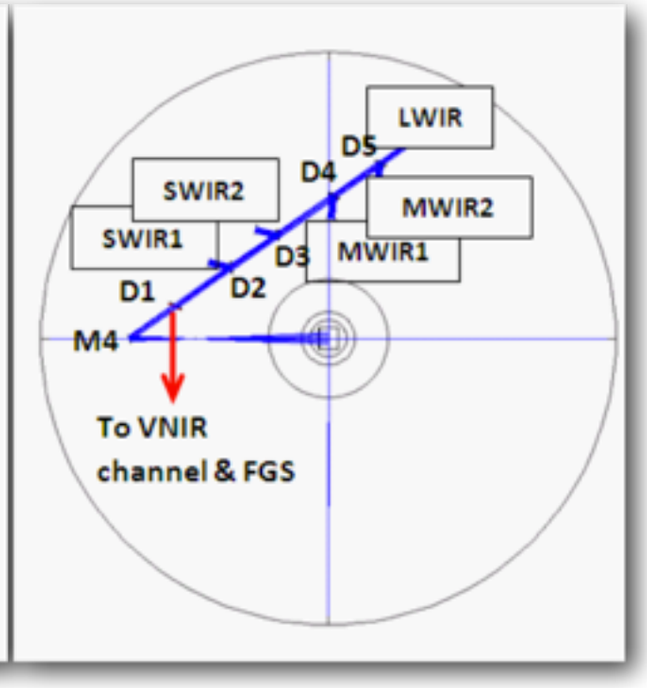
Exoplanet Characterization Observatory

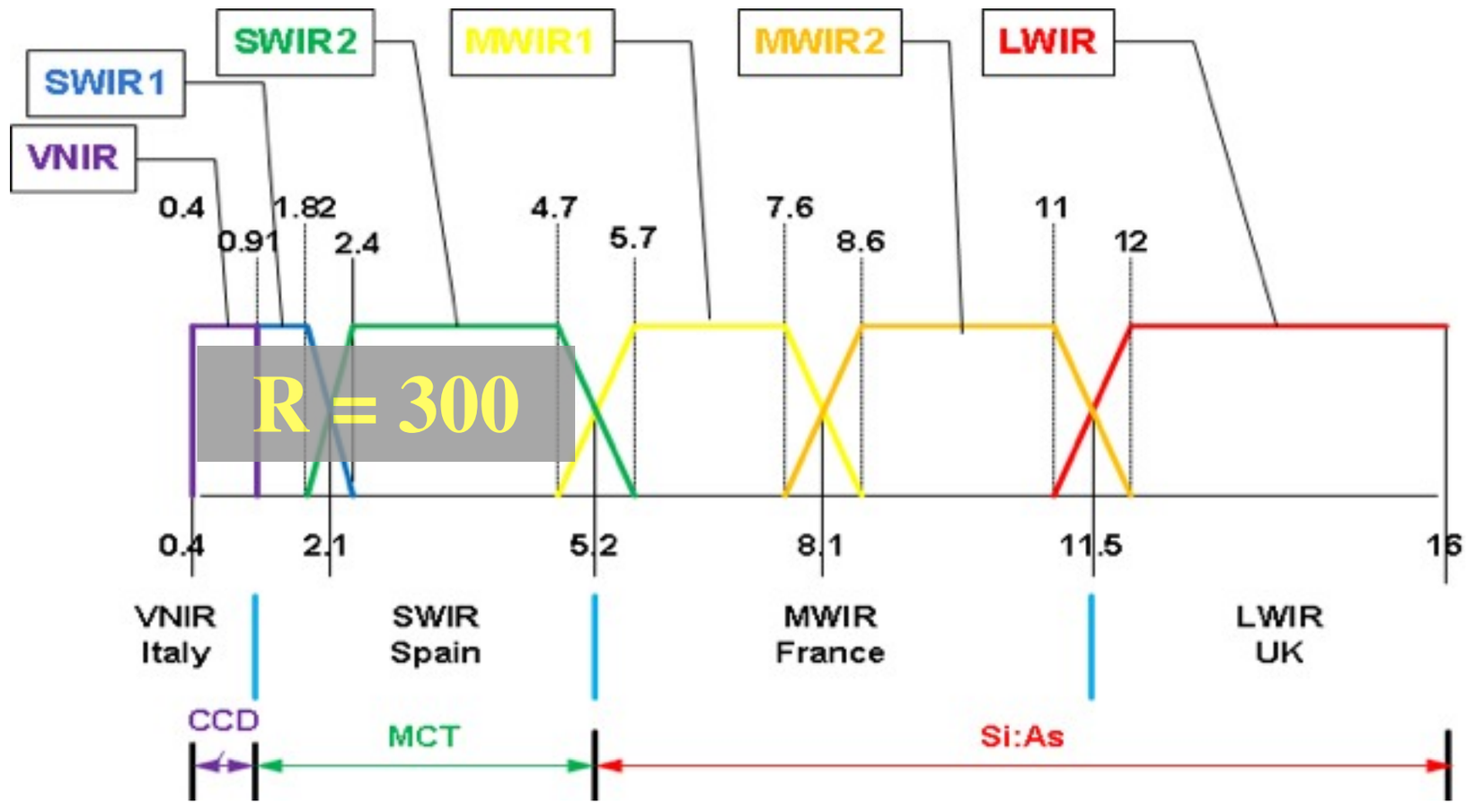
Focal plane spectrometer





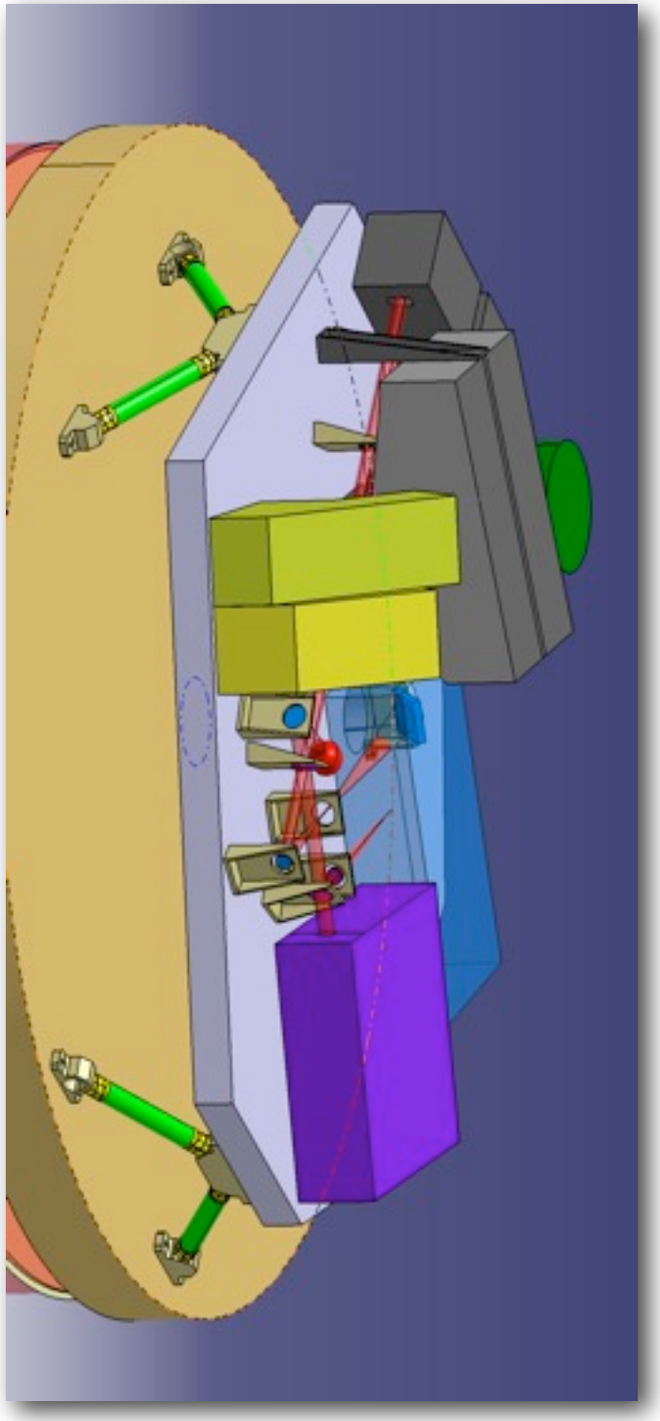


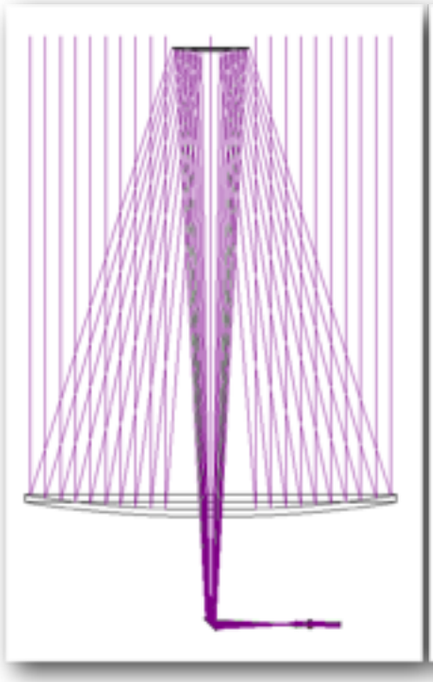


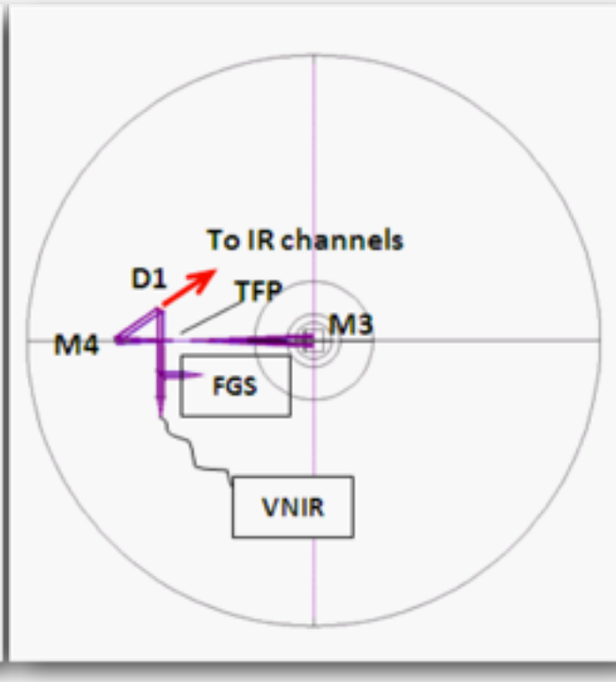


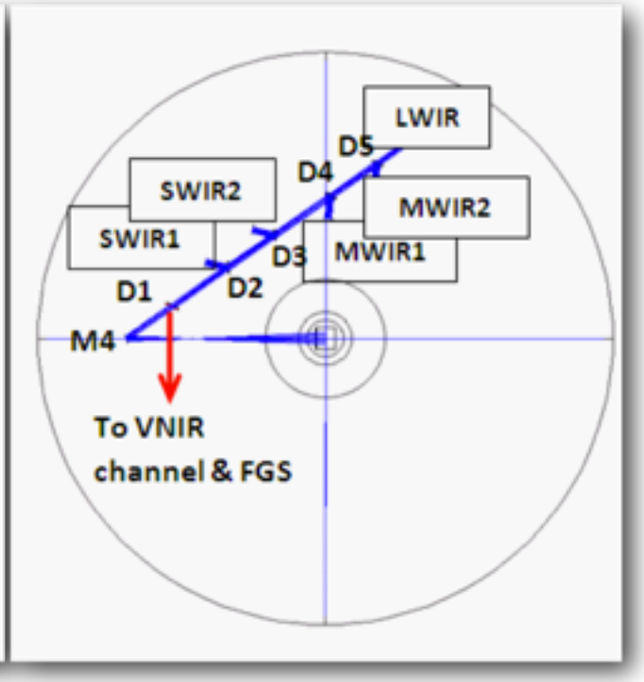
Exoplanet Characterization Observatory

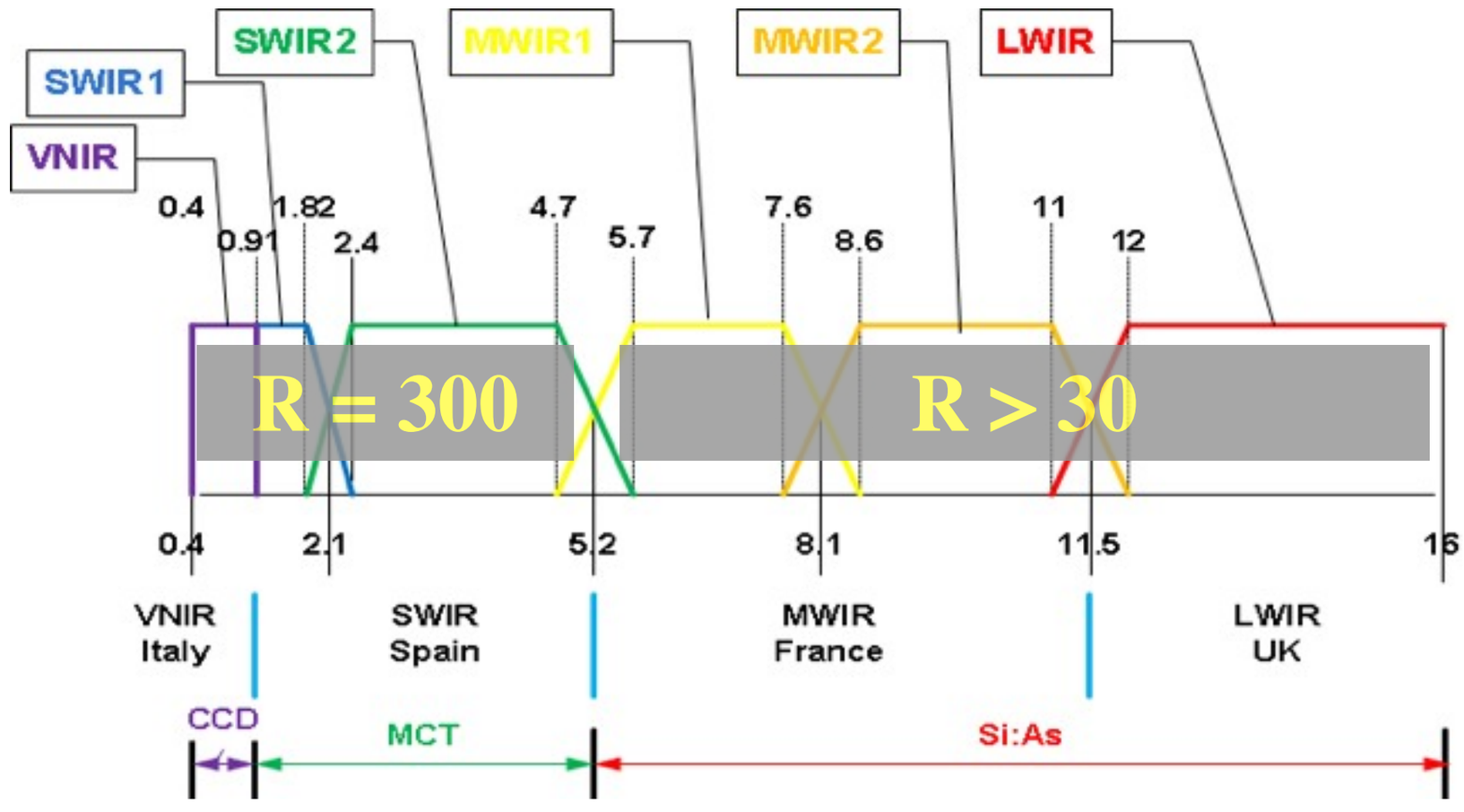
Focal plane spectrometer



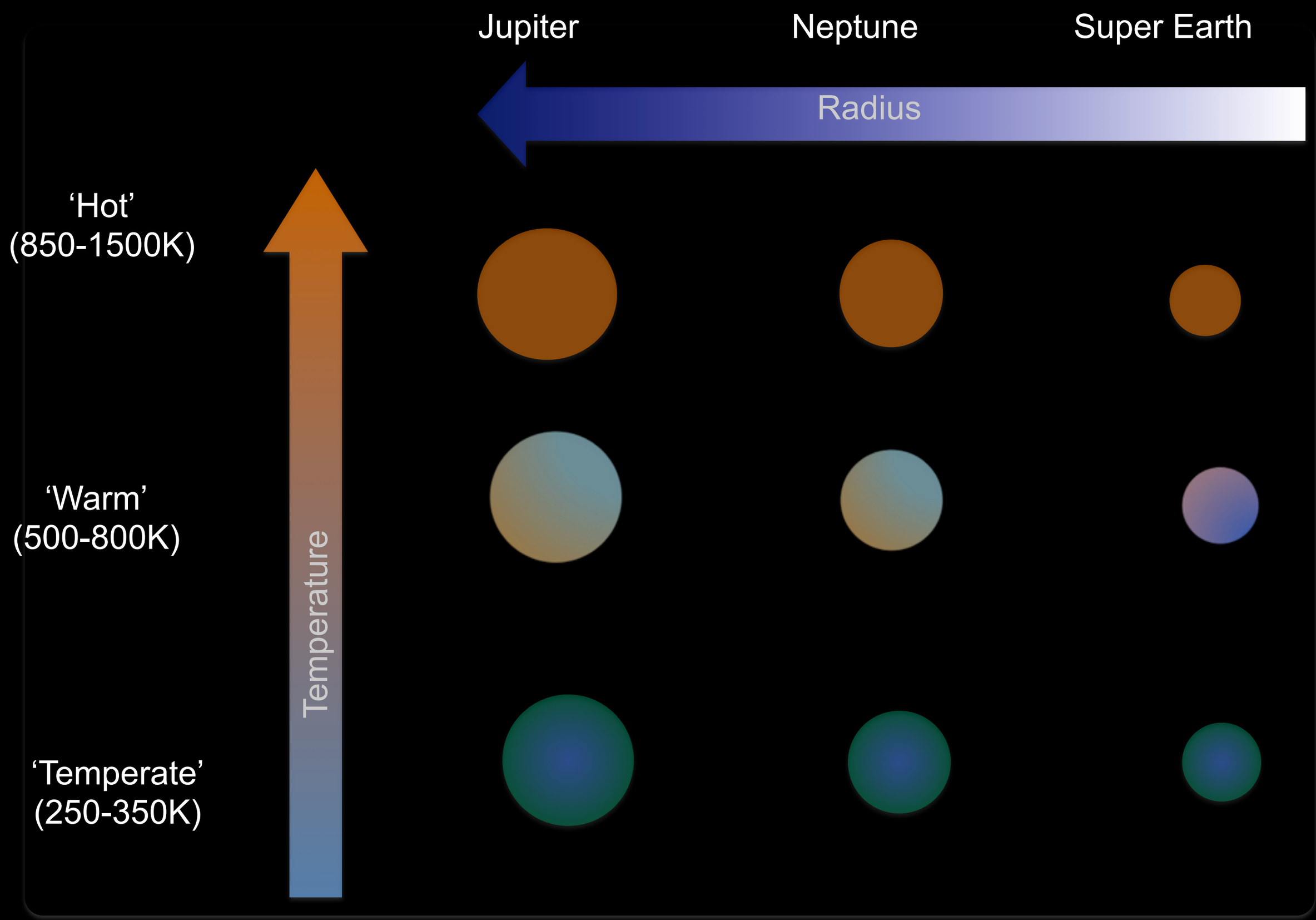








Planets studied by EChO



Planets studied by EChO

Jupiter

Neptune

Super Earth

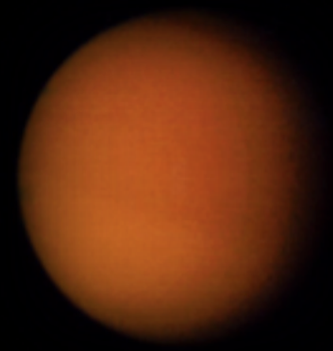
Radius

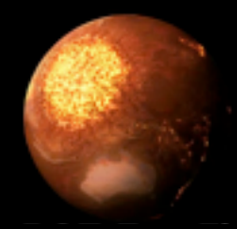
‘Hot’
(850-1500K)

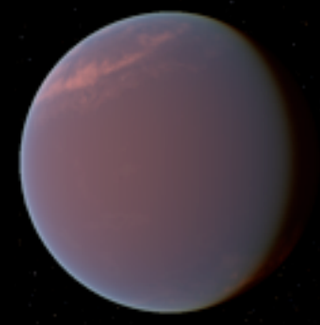
‘Warm’
(500-800K)

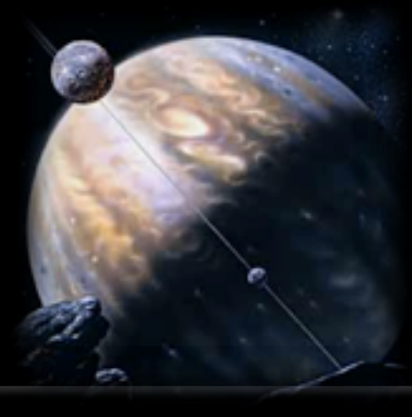
‘Temperate’
(250-350K)

Temperature





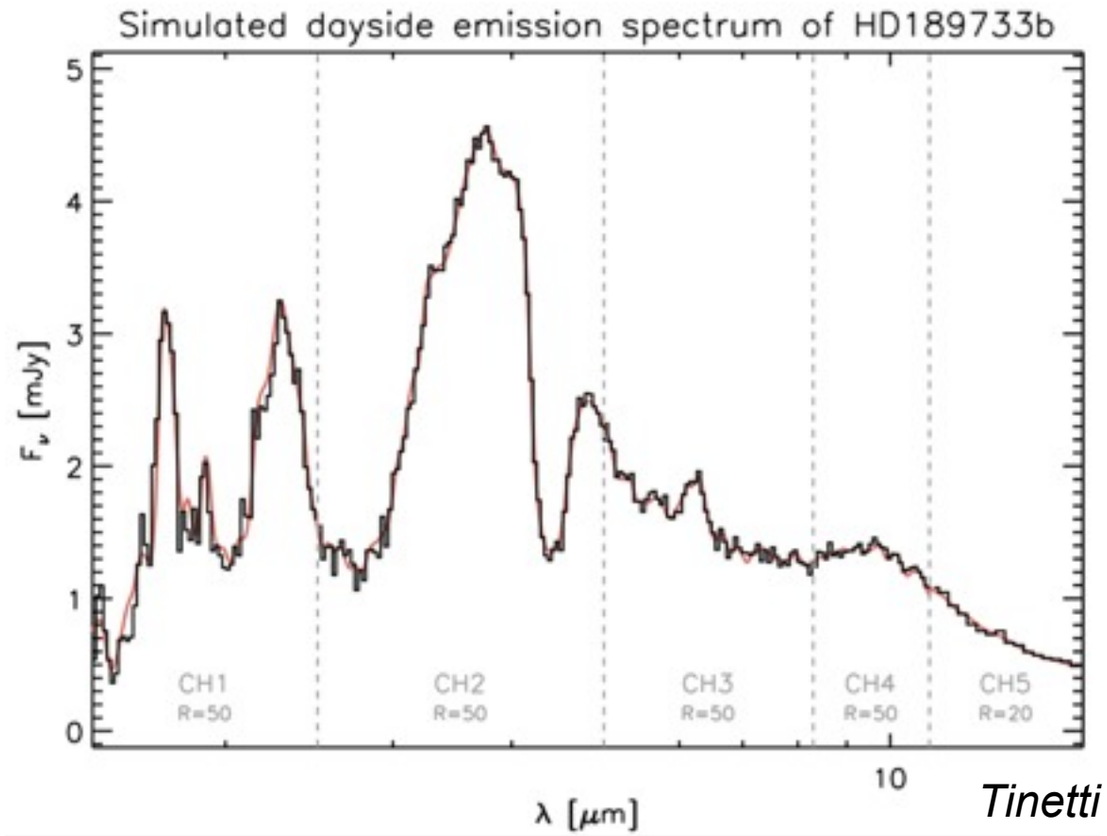




Exoplanet Characterization Observatory

Simulated observation

Hot Jupiter, secondary transit



Tinetti et al. 2012

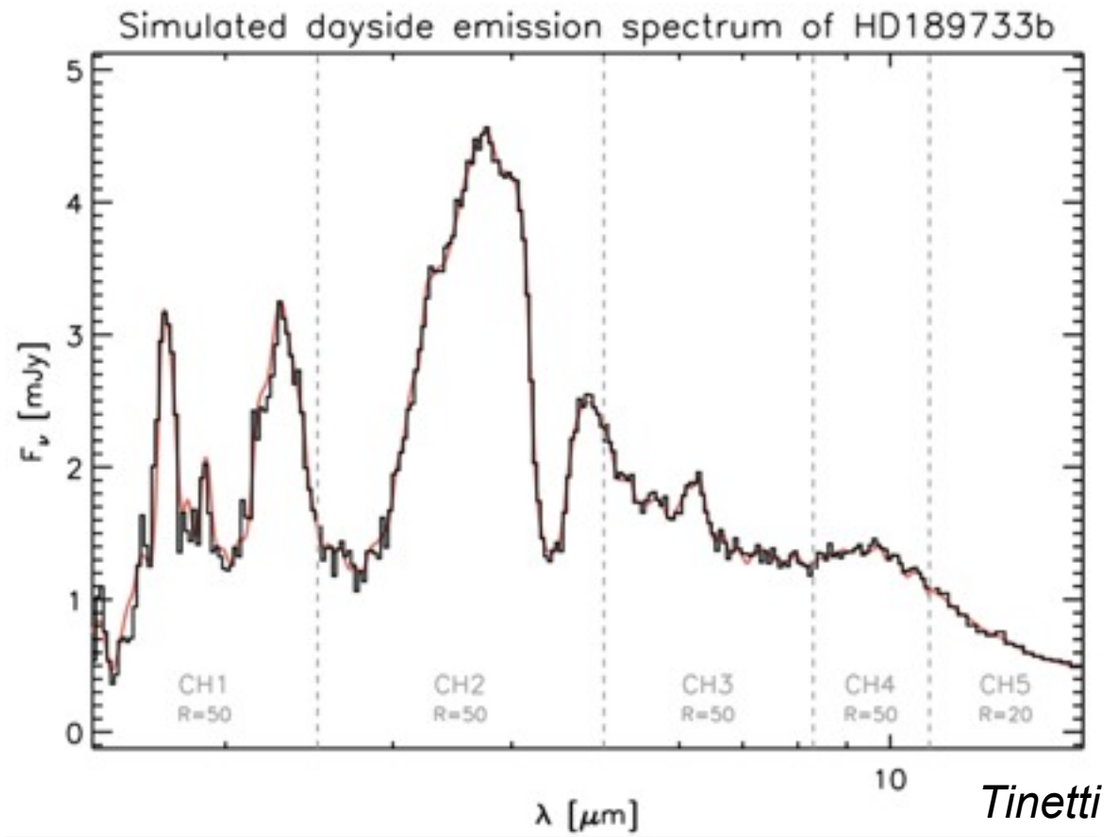
Dayside emission spectrum at
R=50, single transit

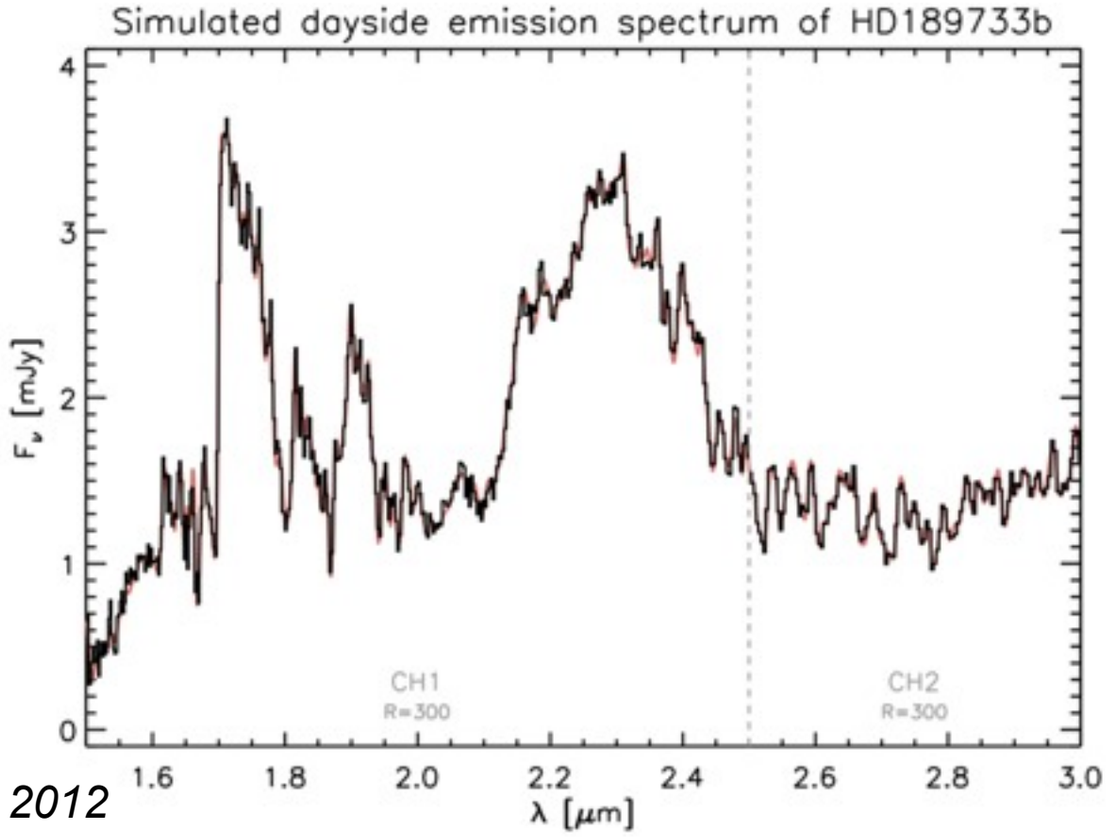
HD189733b

Exoplanet Characterization Observatory

Simulated observation

Hot Jupiter, secondary transit





Tinetti et al. 2012

Dayside emission spectrum at R=50, single transit

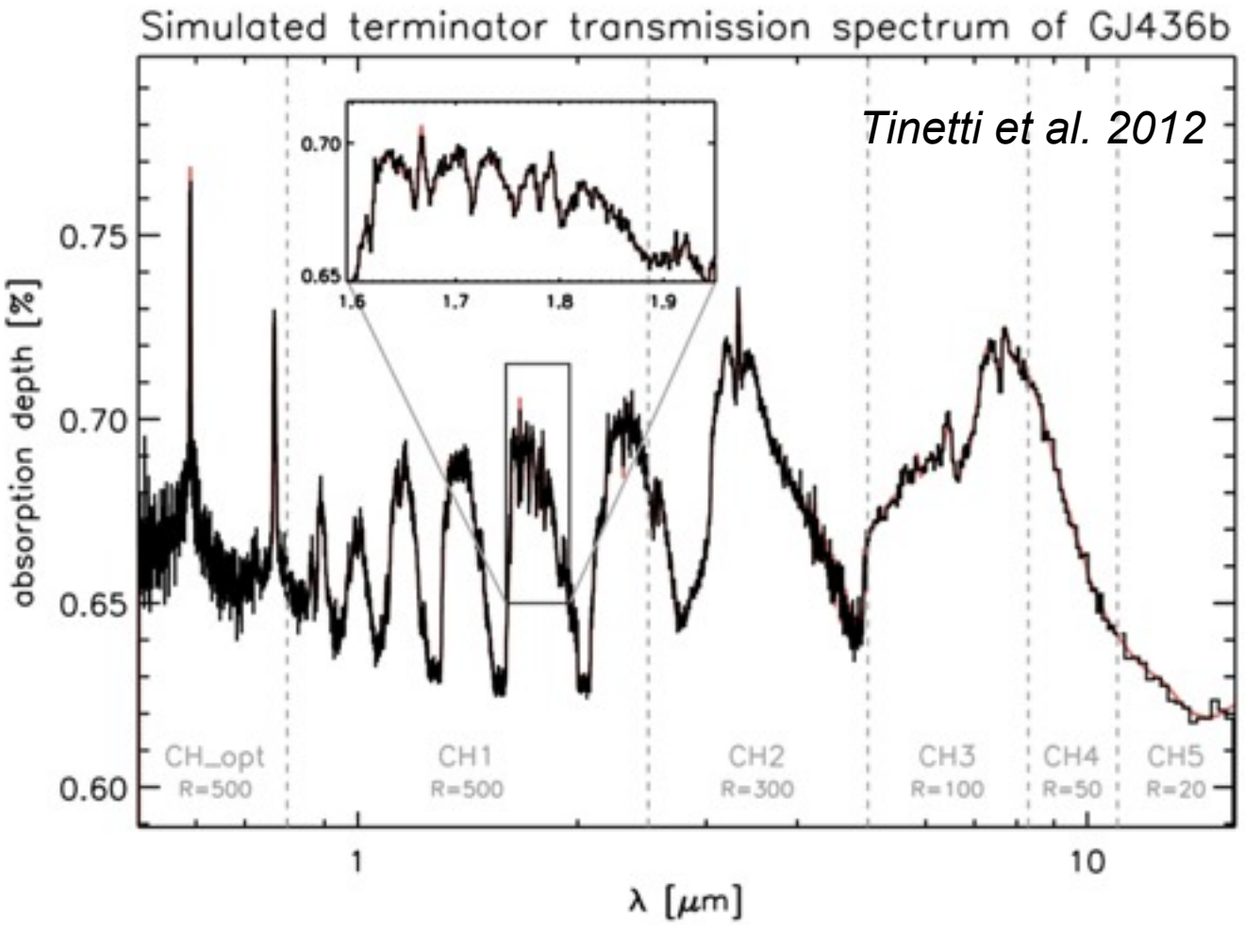
NIR zoom of dayside emission at R=300, averaged over 50 eclipses. Total observing time 192h, can be done over 3.5 months

HD189733b

Exoplanet Characterization Observatory

Simulated observation

Hot Neptune, primary transit



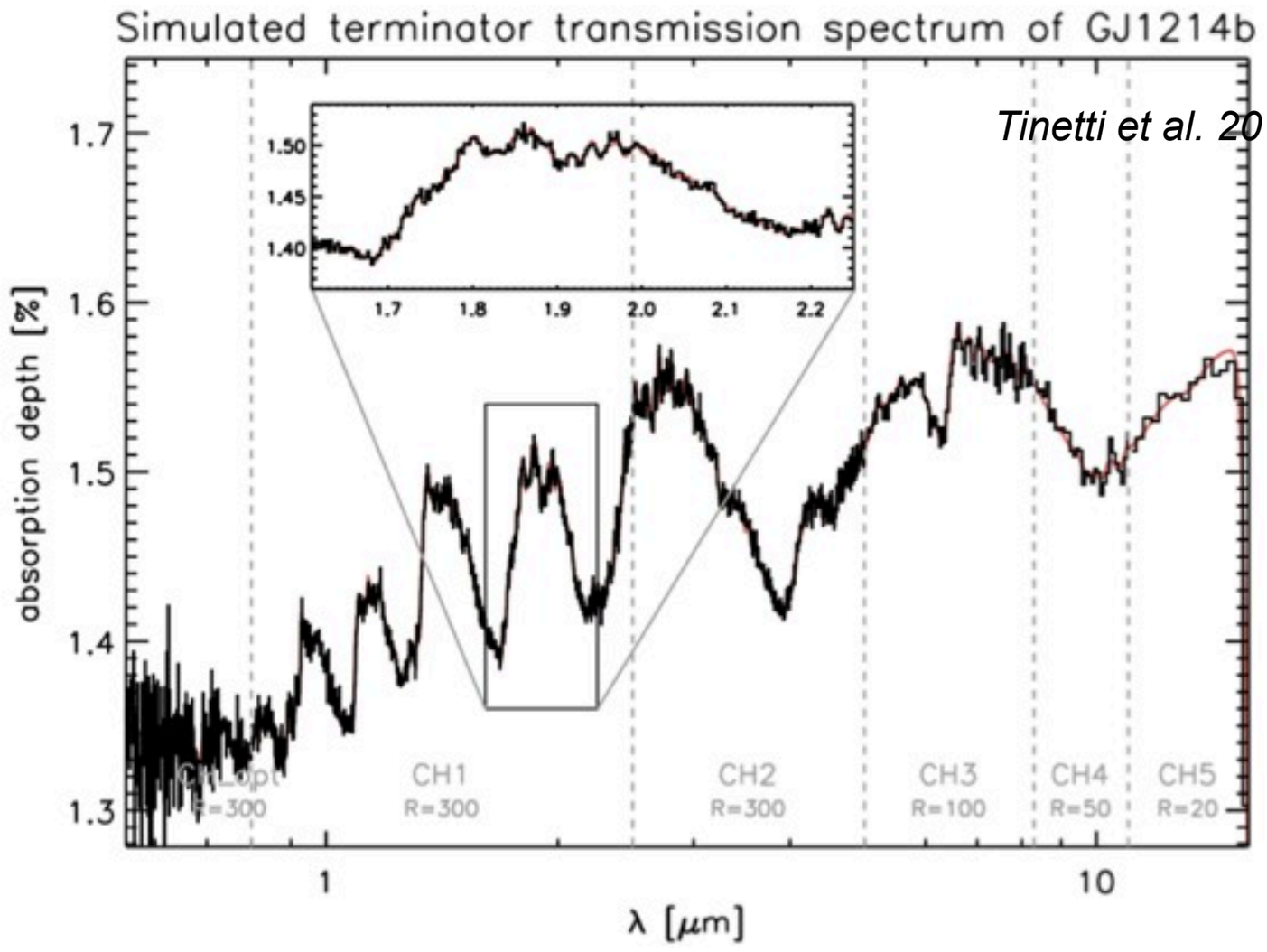
Transmission spectrum at R=300, averaged over 50 transits. Total observing time 144h, can be done over 4 months.

GJ1436b

Exoplanet Characterization Observatory

Simulated observation

Warm super-Earth, primary transit



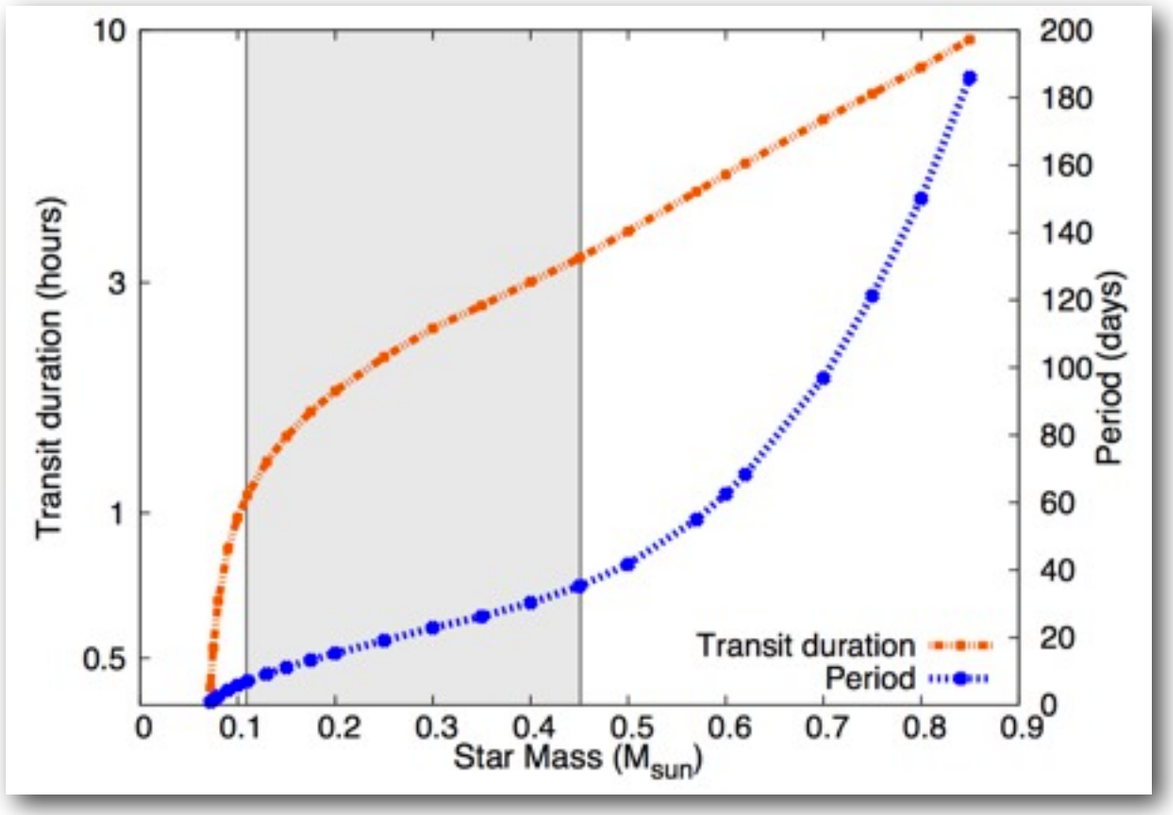
Tinetti et al. 2012

High resolution transmission spectrum of warm Super-Earth GJ1214b, averaged over 300 transits. Total observing time 504h, can be done over 1.3 years.

GJ1214b

Exoplanet Characterization Observatory

Observing telluric super-Earths in the temperate zone of M dwarfs

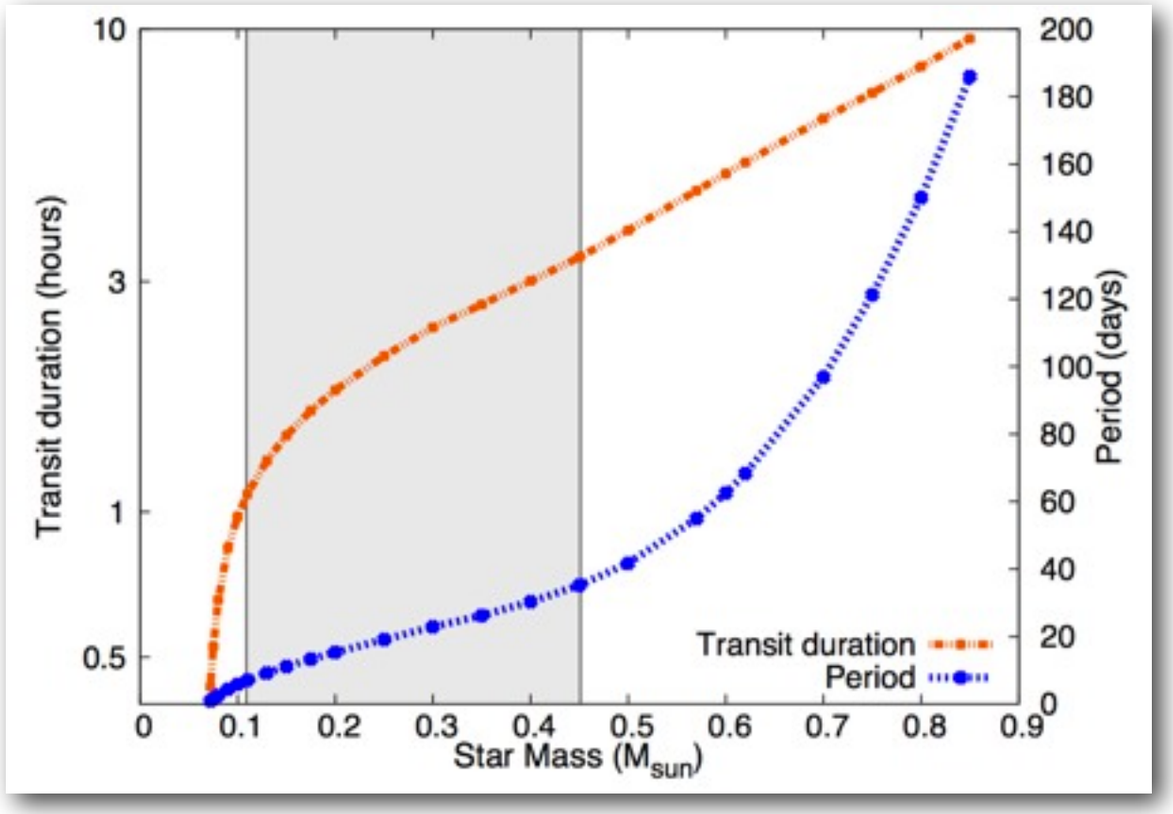


Tessenyi et al. 2011

Transit duration and orbital period in the habitable zone as a function of stellar mass

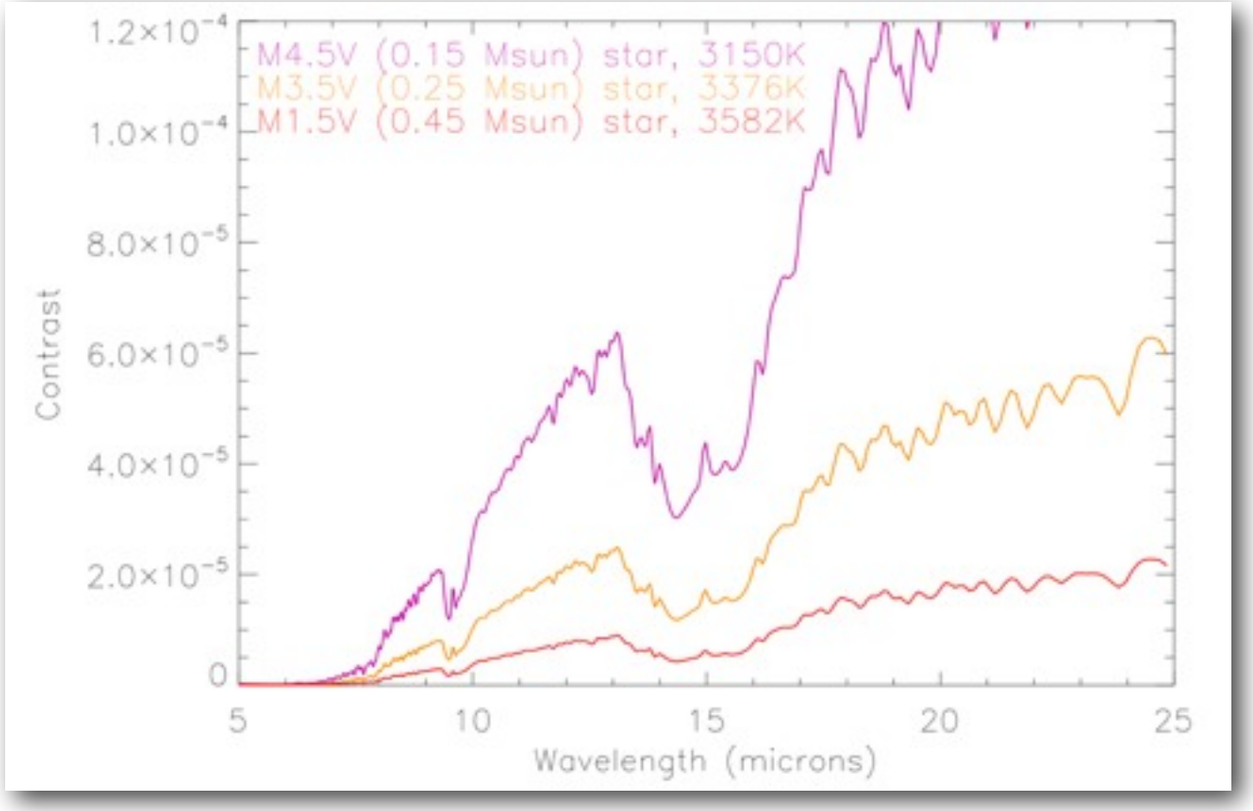
Exoplanet Characterization Observatory

Observing telluric super-Earths in the temperate zone of M dwarfs



Tessenyi et al. 2011

Transit duration and orbital period in the habitable zone as a function of stellar mass



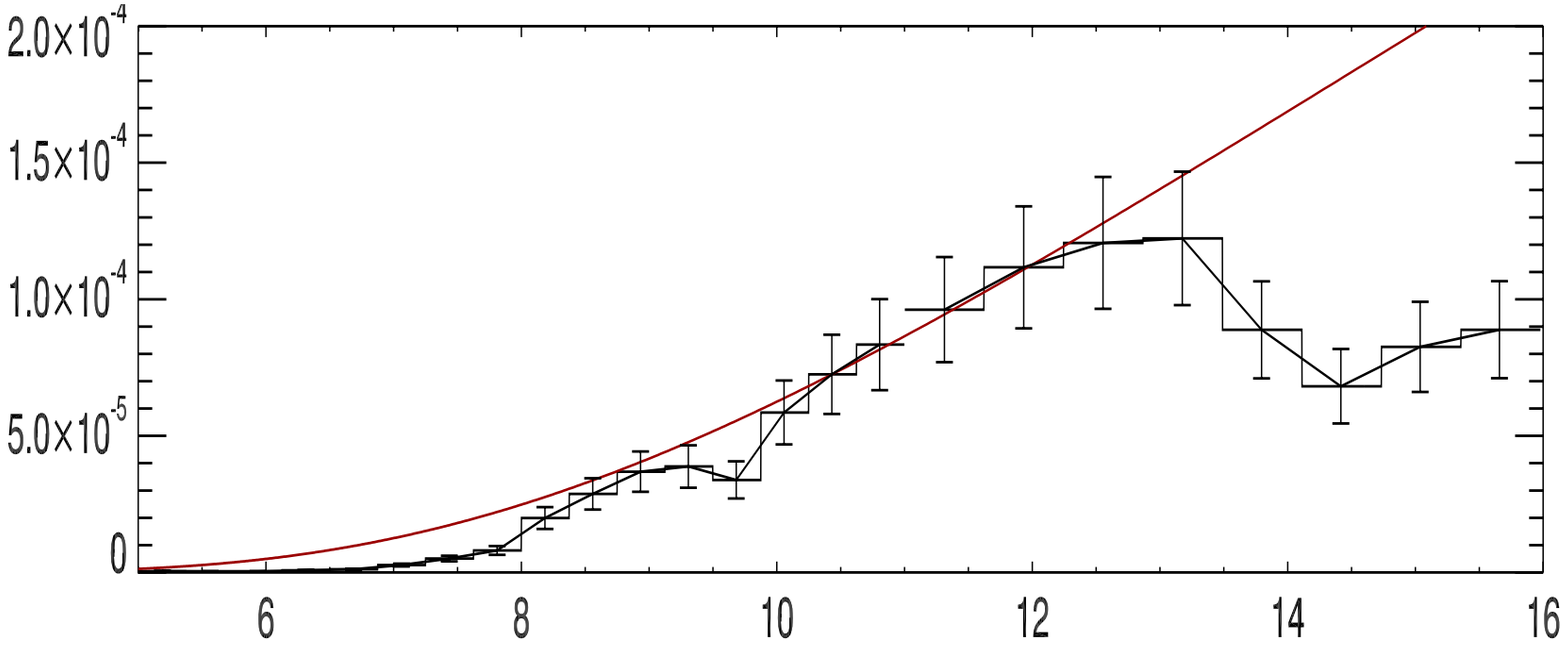
Tessenyi et al. 2011

Planet/star flux contrast for a super-Earth orbiting different M-type stars (M1.5V, M3.5V and M4.5V). In this example the super-Earth is assumed to have an Earth-like atmosphere.

Exoplanet Characterization Observatory

Simulated observation

Temperate super-Earth



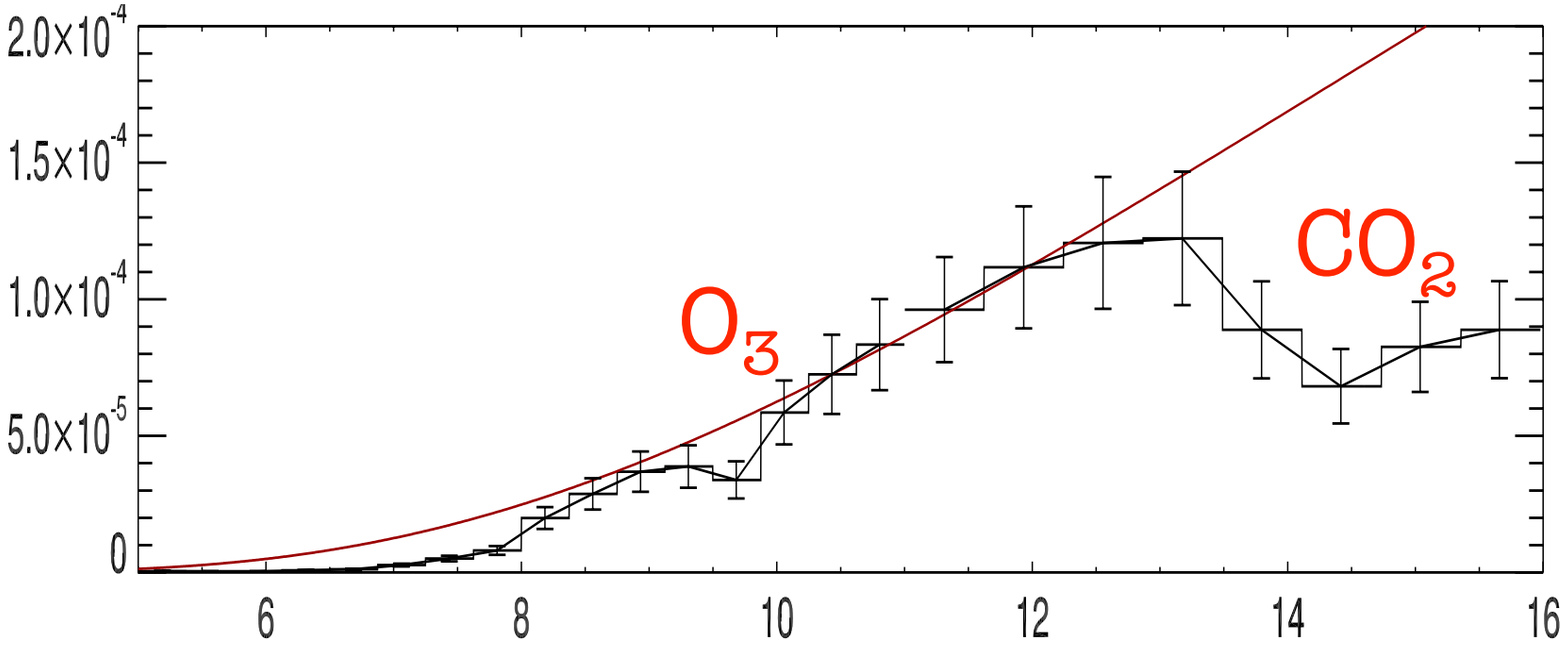
Emission spectrum at R=20 collected in 182 transits of 1.4h each (254h total integration over 5 years)

1.8R_{earth} @ 320K around M5V (3200K)
Earthlike atmosphere

Exoplanet Characterization Observatory

Simulated observation

Temperate super-Earth



Emission spectrum at R=20 collected in 182 transits of 1.4h each (254h total integration over 5 years)

1.8R_{earth} @ 320K around M5V (3200K)
Earthlike atmosphere

Exoplanet Characterization Observatory

Simulated observation

Temperate super-Earth

With Resolution 10, SNR 5, 5-16 µm

Tinetti et al. 2012

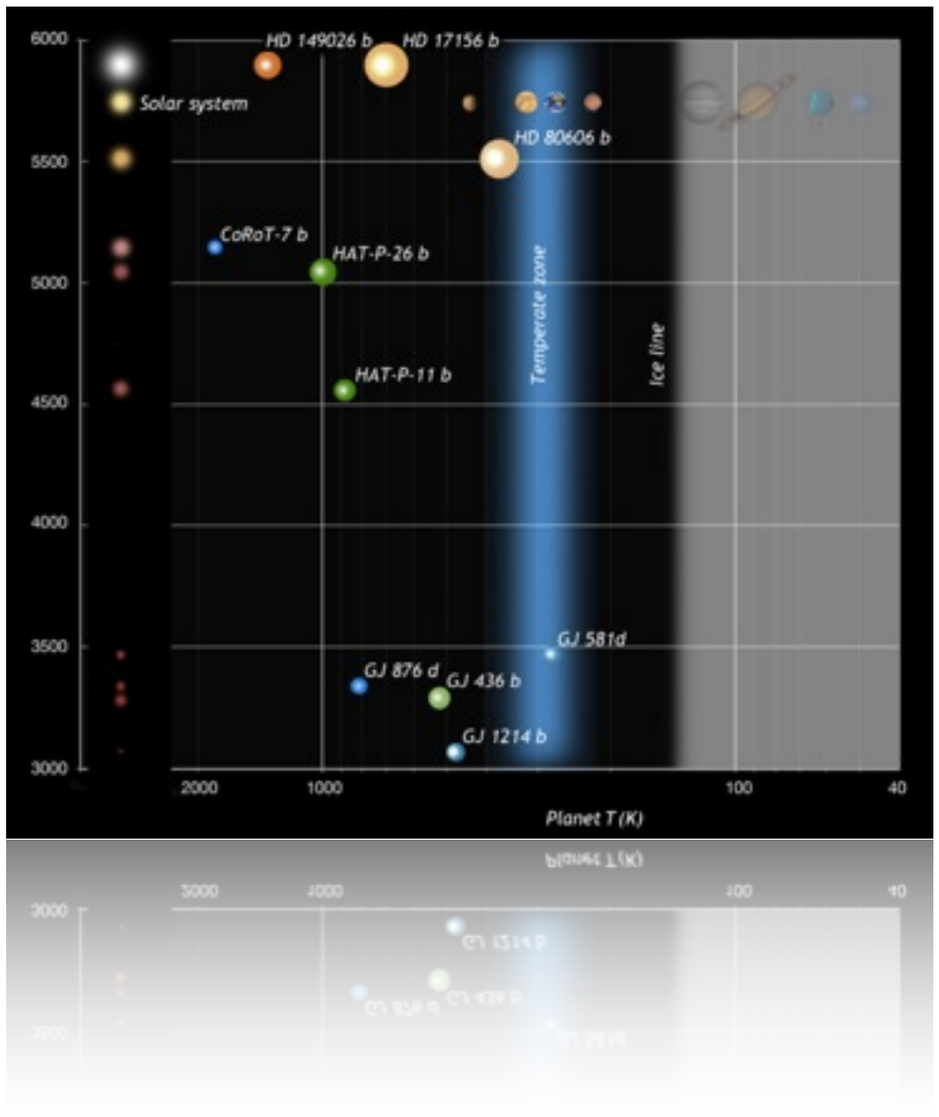
Star type	T (K)	R ($R_\odot$)	Period (days)	contrast (10^{-5})	Magnitudes in K 5	6	7	8	9
M2V	3522	0.38	30.6	0.9	72				
	3475	0.34	26.6	1.2	45	113			
M3V	3436	0.30	23	1.5	32	81			
	3380	0.25	19.3	2	20	52	132		
M4V	3230	0.19	12.7	4		18	46	117	
	3150	0.17	10.7	5.2		12	32	80	208
M5V	3055	0.15	8.7	6.9			19	49	128
	2920	0.13	6.7	9.8			12	29	76

Table 5: Integration times (number of transits) for a habitable-zone (320 K) Super-Earth (1.6 $R_\odot$) in secondary transit

Exoplanet Characterization Observatory

EChO targets

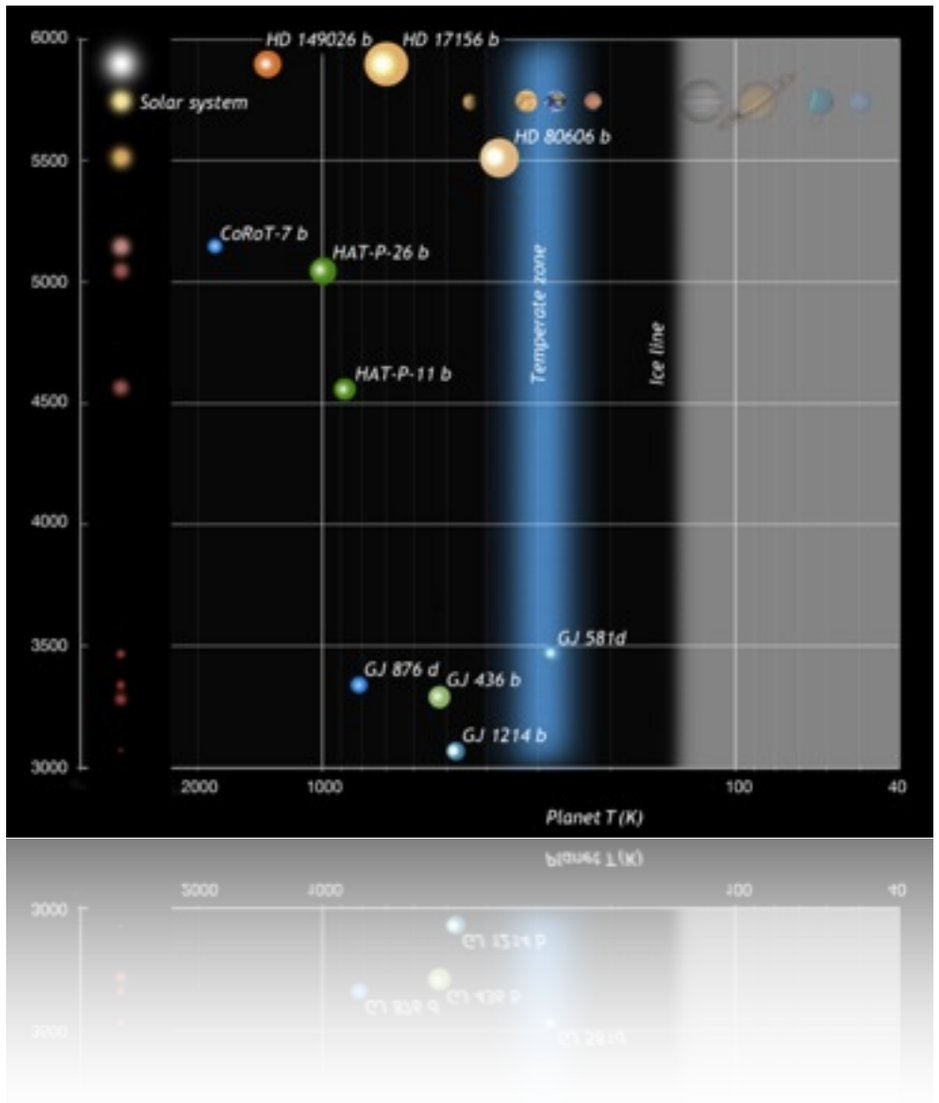
- ~25 good targets already known today… and counting



Exoplanet Characterization Observatory

EChO targets

- ~25 good targets already known today… and counting

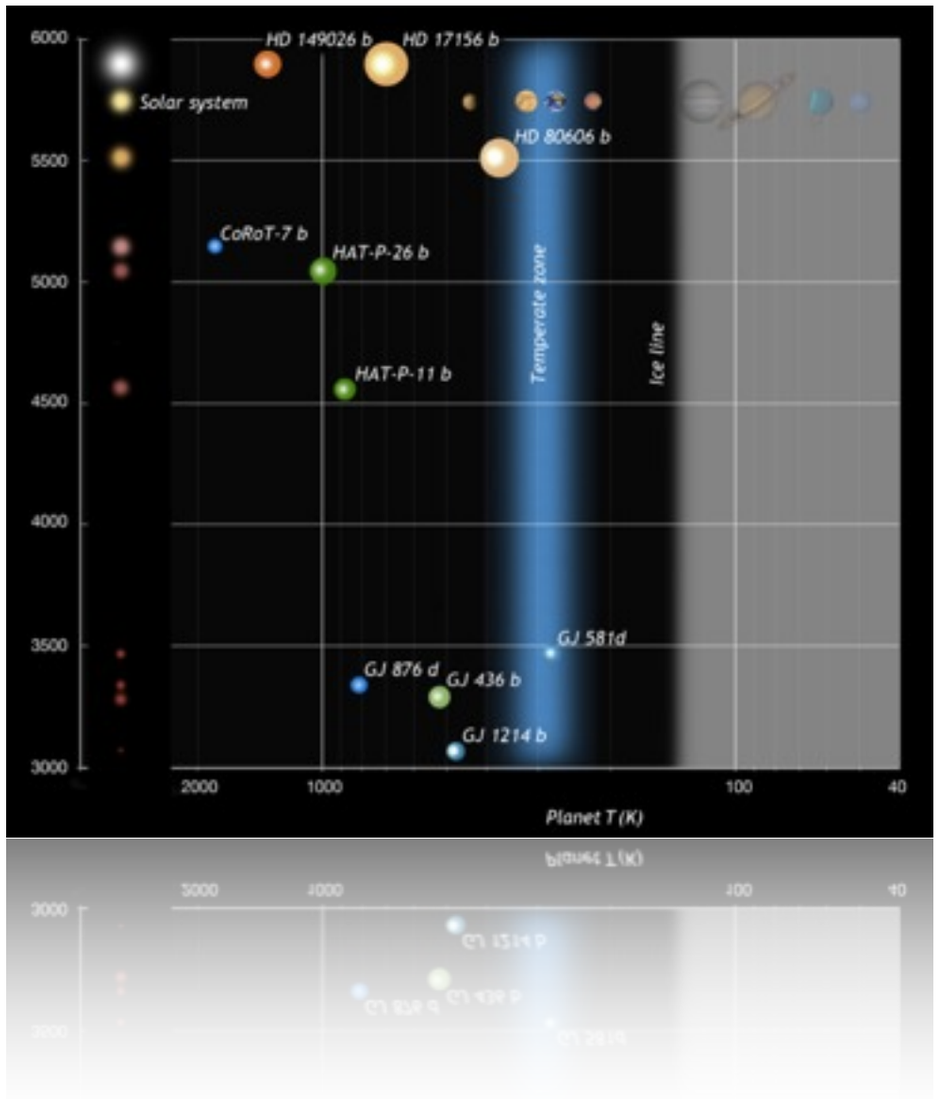


- The rest is to be found by surveys, many on the way particularly for M stars:
  - MEARTH: 2000 late M dwarfs R < 0.33 Rsol, in progress, and APACHE (extension, starting)
  - CARMENES: RV in IR, late M dwarfs, start in 2014
  - 2MASS+WISE+GAIA: hunting for close and late M dwarfs
  - SPIROU : CFHT 2014, monitoring 800 M dwarfs -> 80 planets M<20 ME
  - For Early M : HAT, HARPS, ESPRESSO

Exoplanet Characterization Observatory

EChO targets

- ~25 good targets already known today… and counting



- The rest is to be found by surveys, many on the way particularly for M stars:
  - MEARTH: 2000 late M dwarfs R < 0.33 Rsol, in progress, and APACHE (extension, starting)
  - CARMENES: RV in IR, late M dwarfs, start in 2014
  - 2MASS+WISE+GAIA: hunting for close and late M dwarfs
  - SPIROU : CFHT 2014, monitoring 800 M dwarfs -> 80 planets M<20 ME
  - For Early M : HAT, HARPS, ESPRESSO
  - PLATO : 20 % of sky, VIS, submitted to ESA, 2018 (early M)
  - TESS : all sky, I band, submitted to NASA, 2016 (earlier than M2)

Exoplanet Characterization Observatory

Target statistics

Ribas and Lovis, in prep.

- Super-Earths (< 10 $M_\oplus$):

All	Hot	Warm	Temperate
2-5x M4-M9@K<8	1-2x M4-M9@K<9	1-3x M4-M9@K<9	2-4x M4-M9@K<8
1-3x M2-M3@K<7	1-3x M2-M3@K<8	1-3x M2-M3@K<8	1-2x M2-M3@K<7
6x K7-M1@K<7	2x K7-M1@K<7	3x K7-M1@K<7	1x K7-M1@K<7
4x K0-K5@K<6	4x K0-K5@K<6	-	-
3x G0-G8@K<5	3x G0-G8@K<5	-	-

- Neptunes (10 < M < 30):

All	Hot	Warm
8x K7-M1@K<8	2x K7-M1@K<8	4x K7-M1@K<8
6x K0-K5@K<7	6x K0-K5@K<7	2x K0-K5@K<8
4x G0-G8@K<6	4x G0-G8@K<6	-

- Jupiters (P < 11 days):

Hot
17x K0-K5@K<9
48x G0-G8@K<9
14x F5-F9@K<8

Exoplanet Characterization Observatory

Target statistics

Ribas and Lovis, in prep.

- Super-Earths (< 10 $M_\oplus$):

All	Hot	Warm	Temperate
2-5x M4-M9@K<8	1-2x M4-M9@K<9	1-3x M4-M9@K<9	2-4x M4-M9@K<8
1-3x M2-M3@K<7	1-3x M2-M3@K<8	1-3x M2-M3@K<8	1-2x M2-M3@K<7
6x K7-M1@K<7	2x K7-M1@K<7	3x K7-M1@K<7	1x K7-M1@K<7
4x K0-K5@K<6	4x K0-K5@K<6	-	-
3x G0-G8@K<5	3x G0-G8@K<5	-	-

- Neptunes (10 < M < 30):

All	Hot	Warm
8x K7-M1@K<8	2x K7-M1@K<8	4x K7-M1@K<8
6x K0-K5@K<7	6x K0-K5@K<7	2x K0-K5@K<8
4x G0-G8@K<6	4x G0-G8@K<6	-

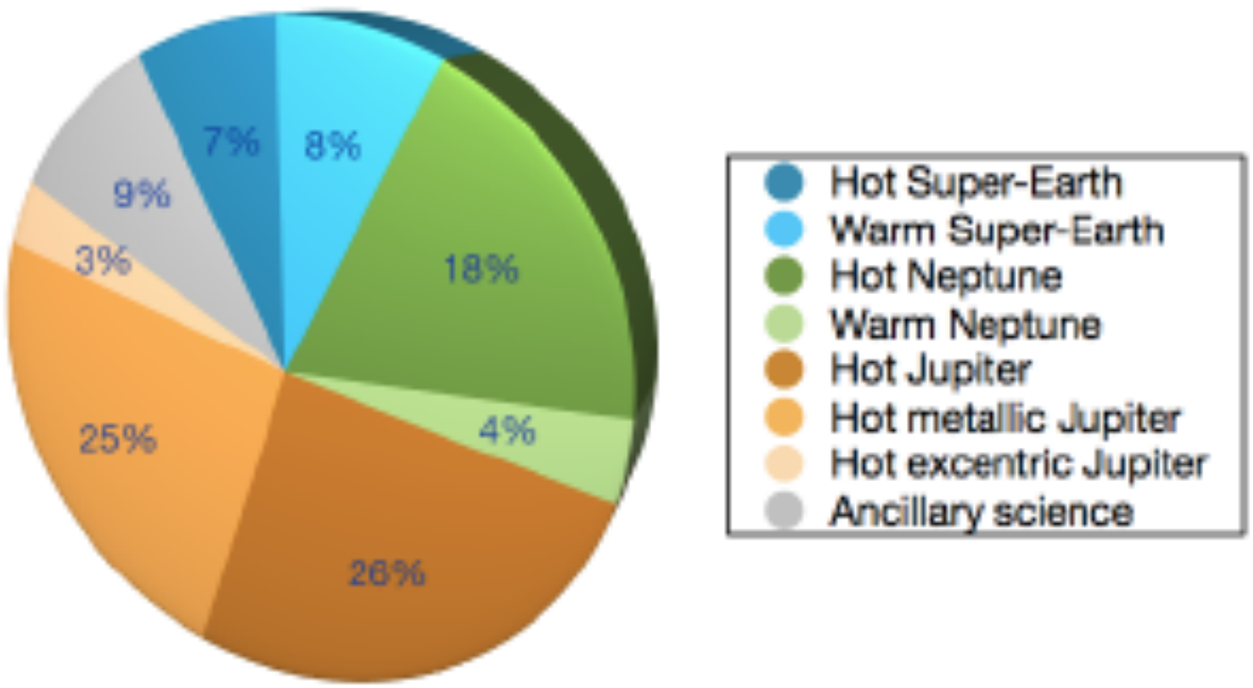
- Jupiters (P < 11 days):

Hot
17x K0-K5@K<9
48x G0-G8@K<9
14x F5-F9@K<8

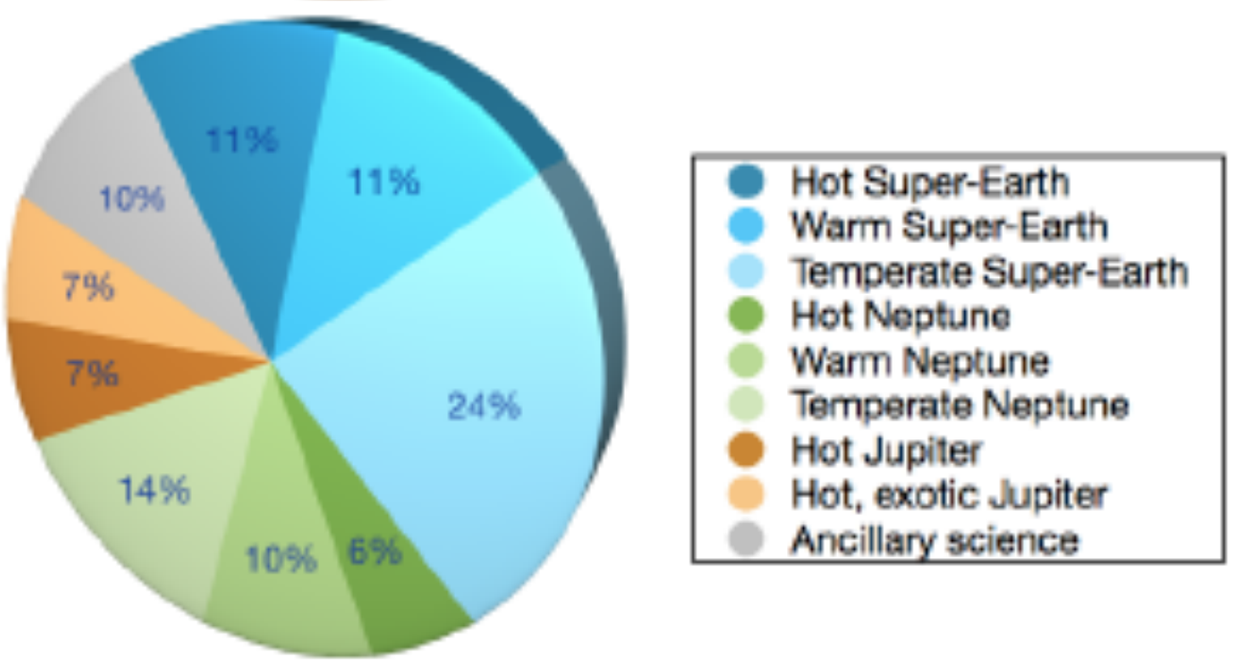
Exoplanet Characterization Observatory

Typical mission profile

Partition of observing time on available sources for EChO if it were launched today (with known sources).



Partition of observing time for EChO in 2020 (with sources known by then)

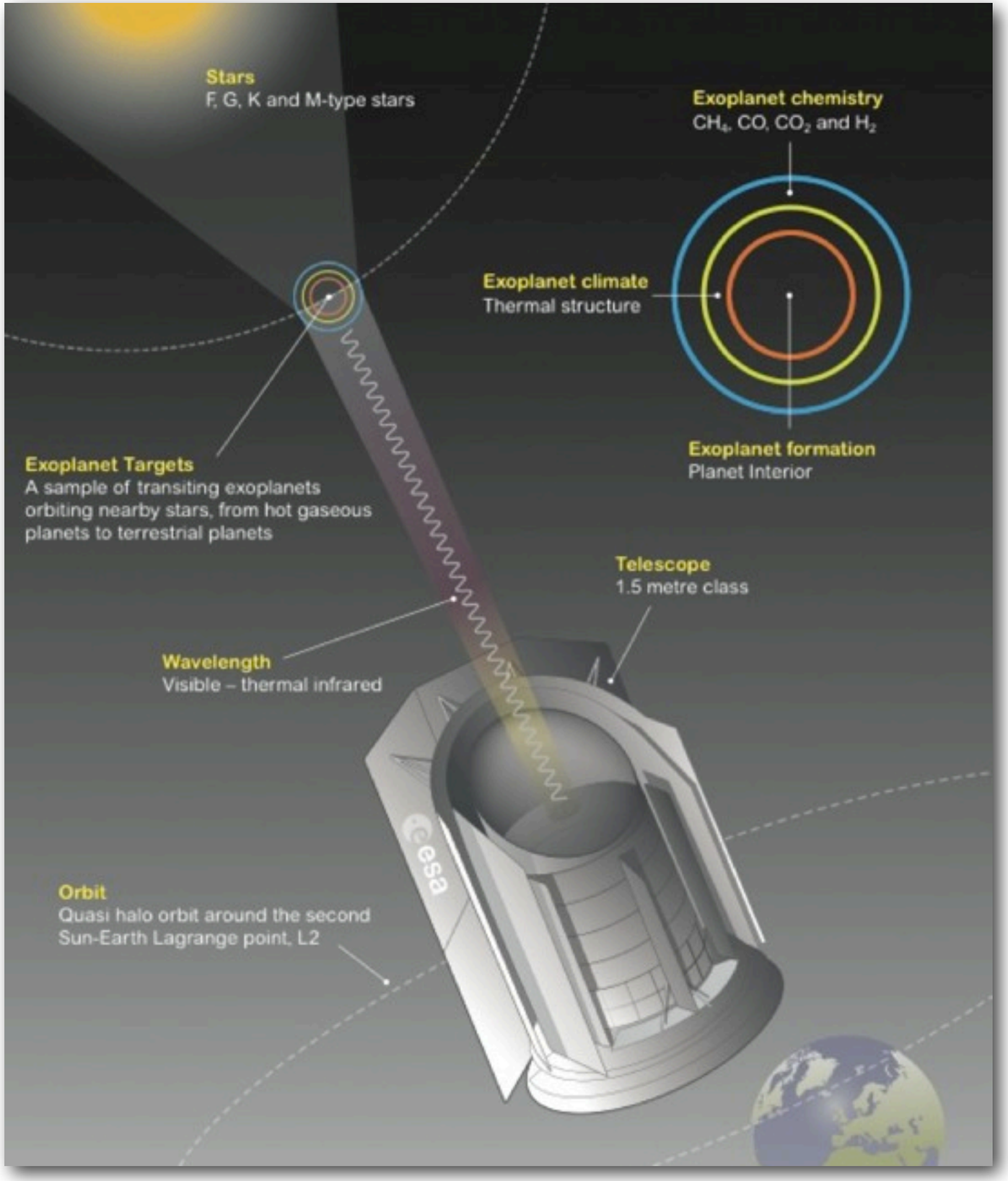


Source : EChO proposal

Exoplanet Characterization Observatory

Want to know more ?

Tinetti et al. :
arXiv:1112.2728



http://echo-spacemission.eu