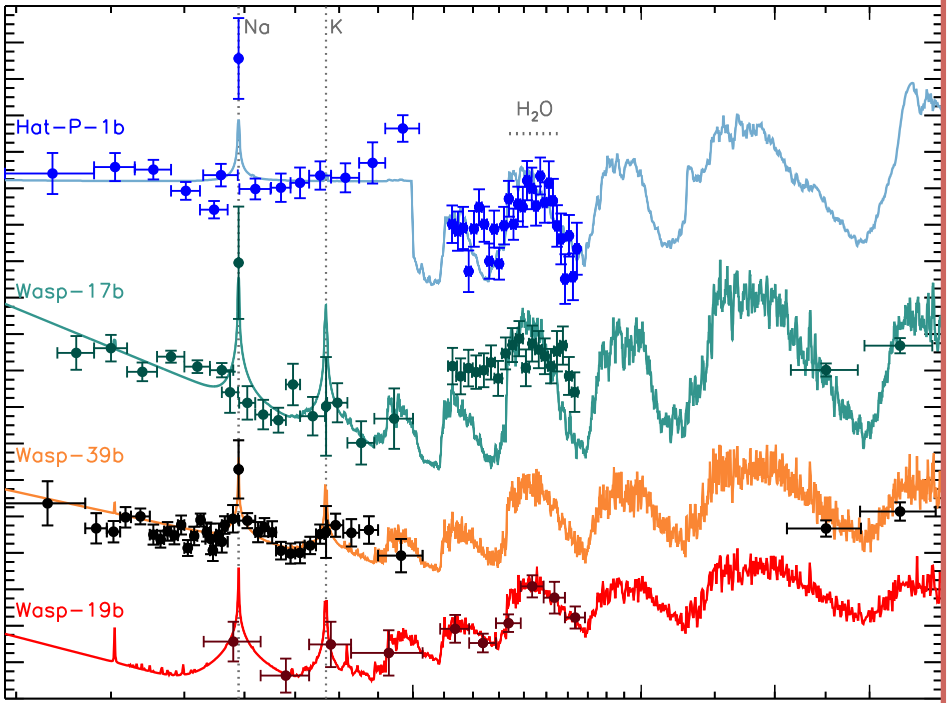
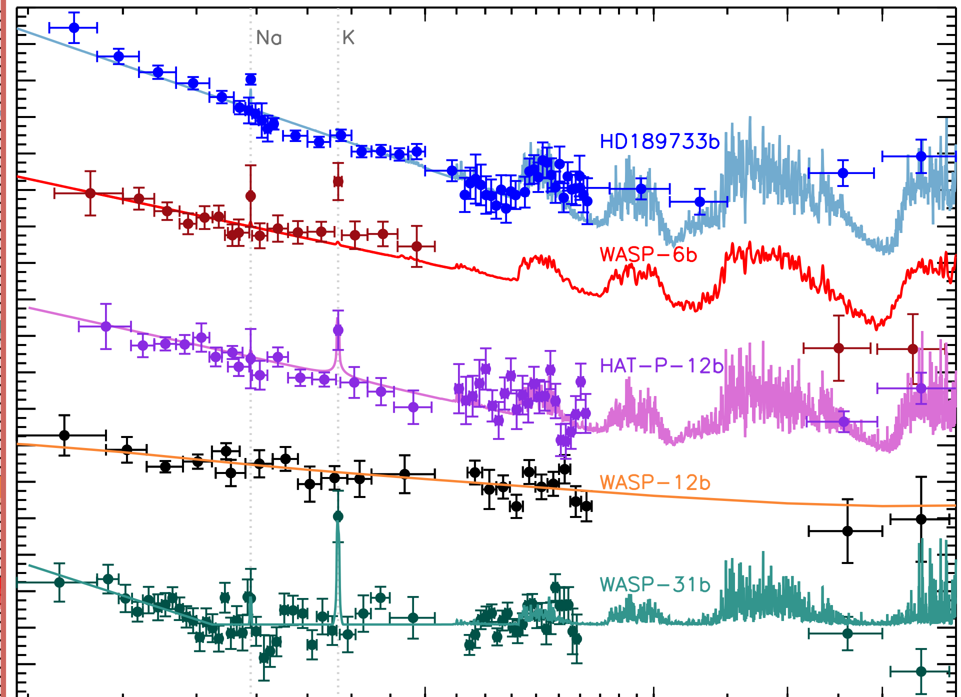
Transmission spectral properties of cloud condensates in hot Jupiter atmospheres

Hannah Wakeford
University of Exeter
Supervisor: D.K. Sing

UNIVERSITY OF EXETER

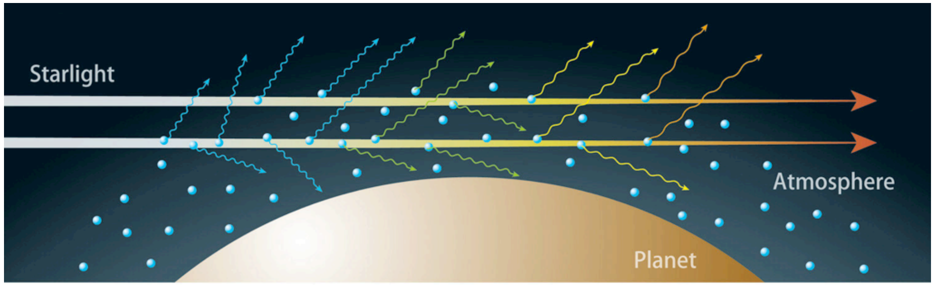
Observations of Exoplanet atmospheres

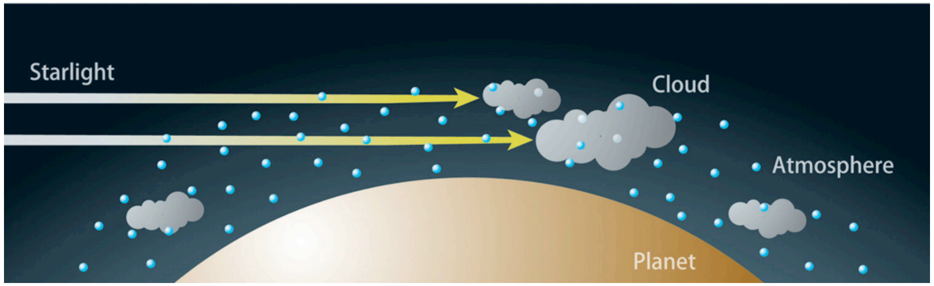




Clear ?

Cloudy ?





Wakeford & Sing, 2015, A&A, 573, A122

Cloud Condensates

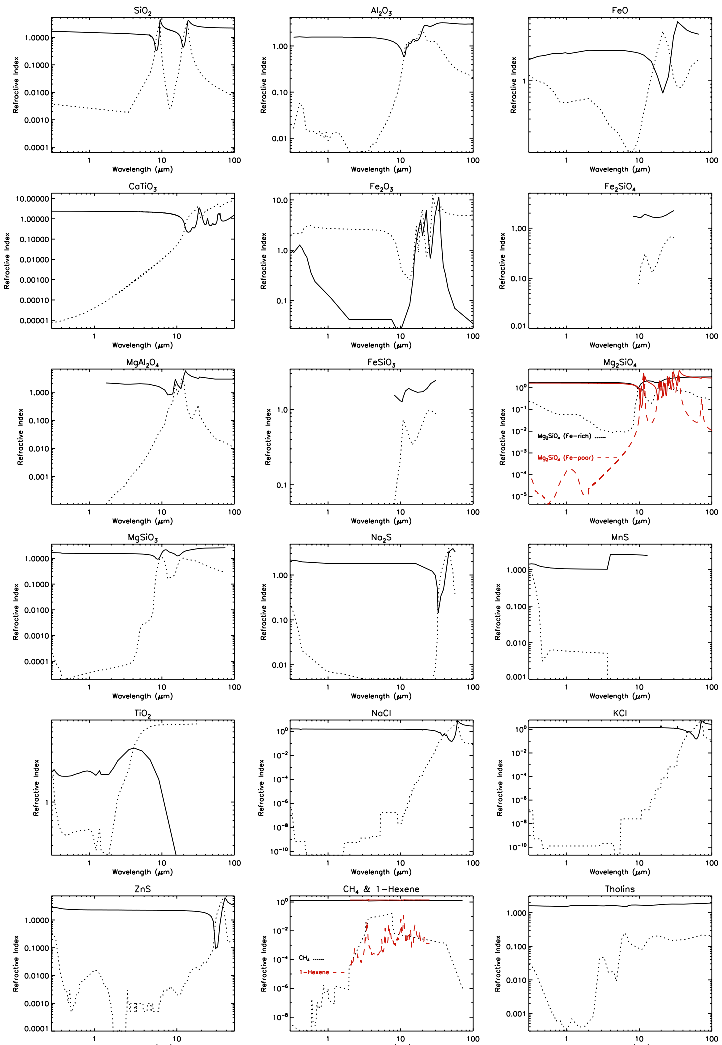


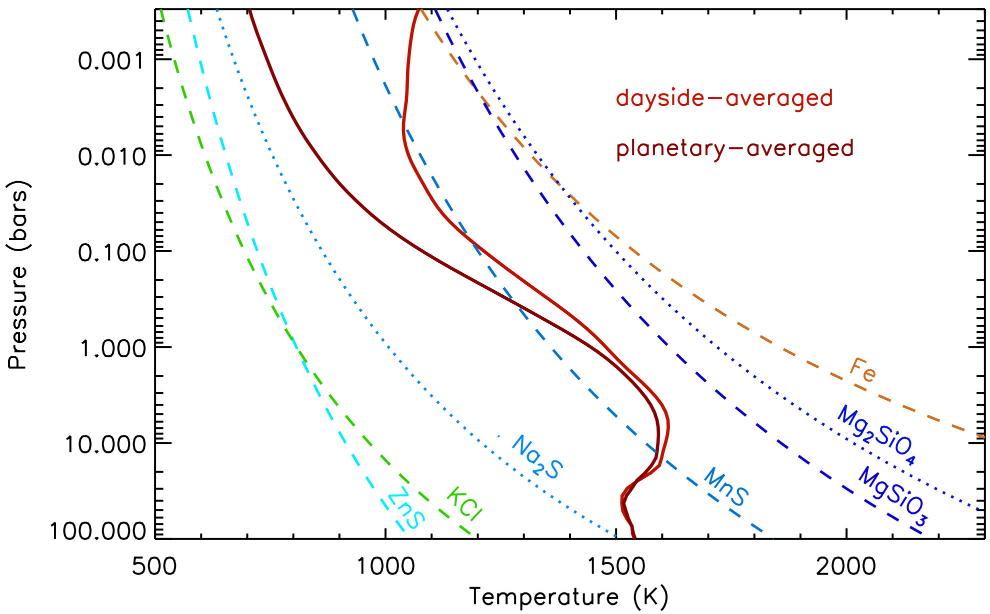
Table 1: Table of references for n and k index for a number of condensates expected to form clouds in the upper atmosphere of hot Jupiters.

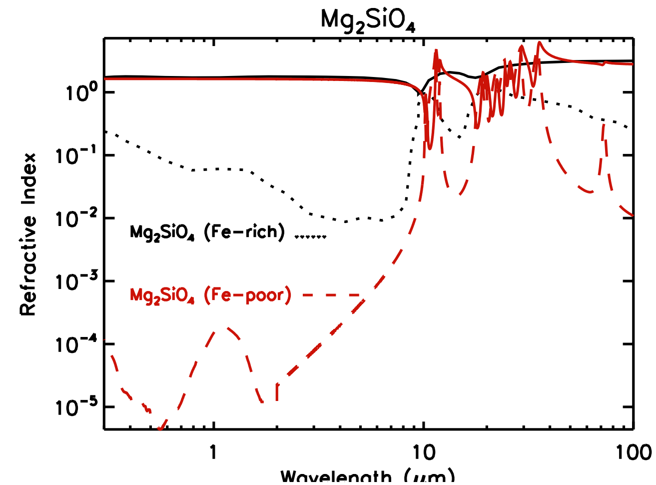
Condensate	Reference n, k index	λ Range (μm)	Condensation Temperature[+] (K)	Molecular Weight
SiO_2	Palik (1998)	0.04 - 11	1725	60.08
	Andersen et al. (2006)	7 - 28	-	-
	M. Meinecke (2005)*	6.6 - 10000	-	-
Al_2O_3	Koike et al. (1995)	0.3 - 150	1677[1]	101.96
FeO	Begemann et al. (1995)	10 - 100	1650[4]	71.79
	Andersen et al. (2006)	15 - 40	-	-
$CaTiO_3$	Posch et al. (2003)	2 - 155	1582[1]	135.94
Fe_2O_3	M. Meinecke (2005)*	0.1 - 987	1566	159.68
Fe_2SiO_4	Day (1981)	8.2 - 35	1443[4]	203.77
$MgAl_2O_4$	M. Meinecke (2005)*	1.6 - 270	1397[1]	142.26
$FeSiO_3$	Day (1981)	8.2 - 35	1366[4]	131.92
Mg_2SiO_4 (Fe–rich)	Henning et al. (2005)	0.2 - 445	1354[1]	140.63
Mg_2SiO_4 (Fe–poor)	Zeidler et al. (2011)	0.19 - 800	1354[1]	140.63
$MgSiO_3$	Egan & Hilgeman (1975)	0.1 - 0.4	1316[1]	100.33
	Dorschner et al. (1995)	0.5 - 80	-	-
Na_2S	Morley et al. (2012)	0.03 - 73	1176	78.04
MnS	Huffman & Wild (1967)	0.1 - 3	1139[2]	87.00
TiO_2	Kangarloo (2010a)	0.3 - 1.2	1125[2]	79.86
	Kangarloo (2010b)	1.3 - 30	-	-
NaCl	Palik (1998)	0.04 - 1000	825[3]	58.44
KCl	Palik (1998)	0.02 - 200	740[3]	74.55
ZnS	Querry (1987)	0.2 - 167	700[5]	97.45
CH_4	Martonchik & Orton (1994)	0.02 - 72	~80	16.04
C_6H_{12}	Anderson (2000)	2.0 - 25	68	84.1
Titan Tholins	Khare et al. (1984)	0.01 - 0.2	≤90	~50.0
	-	1.1 - 1000	-	-
	Ramirez et al. (2002)	0.2 - 1	-	-

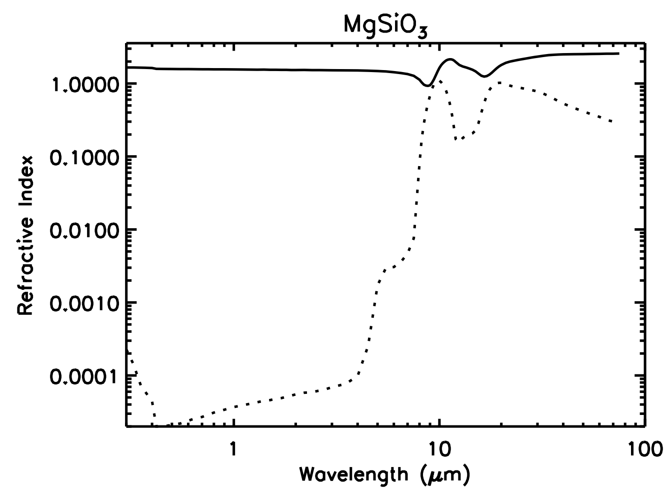
* http://www.astro.uni-jena.de/Laboratory/OCDB/oxsul.html; + at 10^{-3} bar
[1] Lodders (2003), [2] Grossman (1972), [3] Burrows & Sharp (1999), [4] Ebel & Grossman (2000)
[5] Morley et al. (2012)

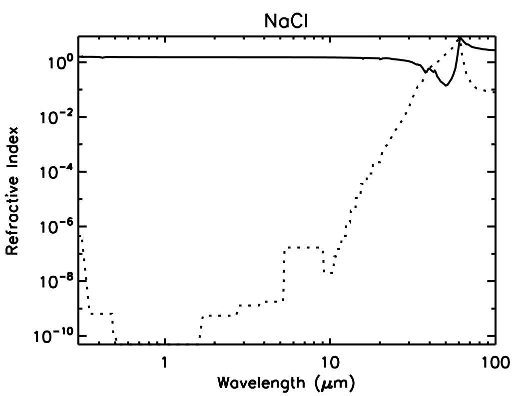
Wakeford & Sing, 2015, A&A, 573, A122

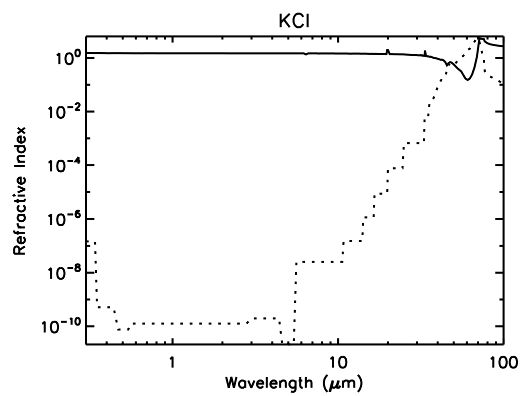
Cloud Condensates





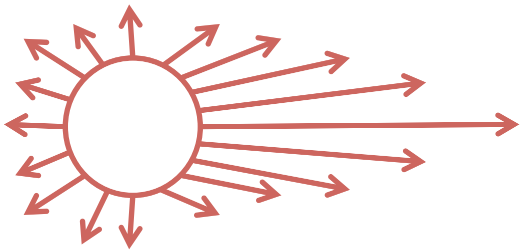


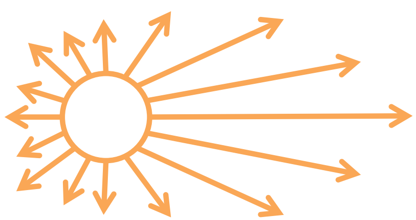


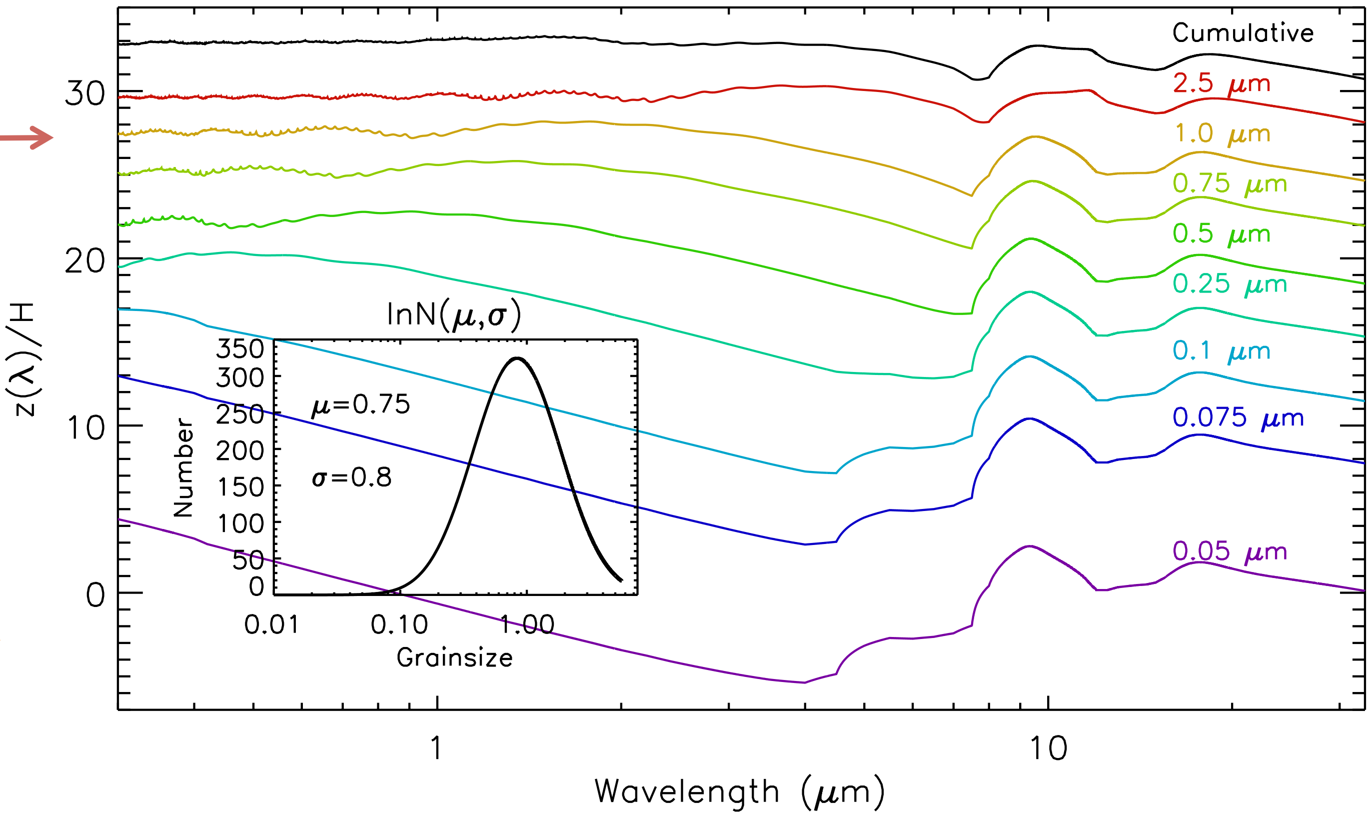


Wakeford & Sing, 2015, A&A, 573, A122

Fitting for cloud particle distributions

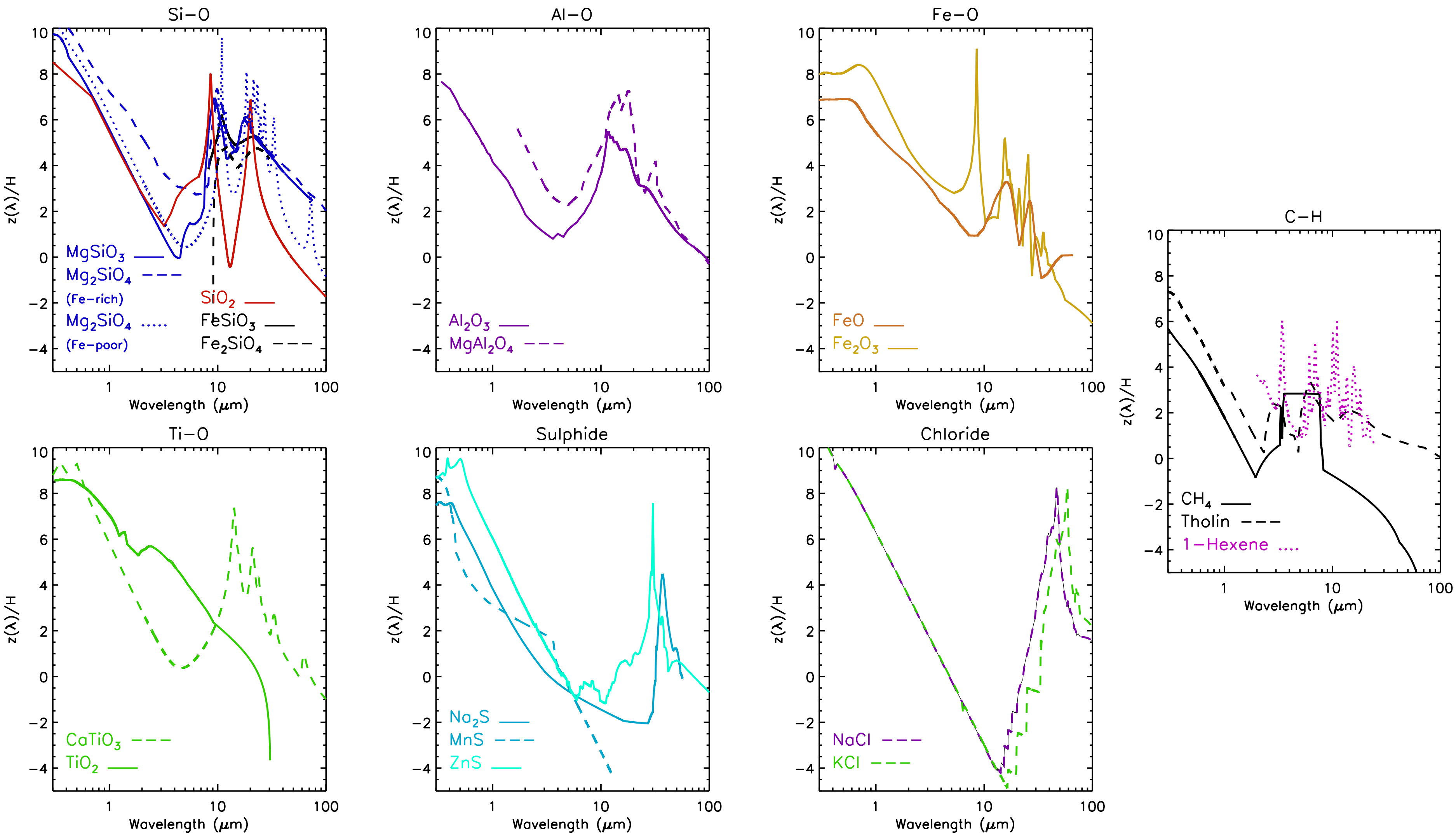






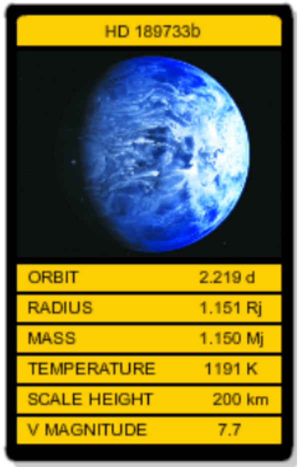
Wakeford & Sing, 2015, A&A, 573, A122

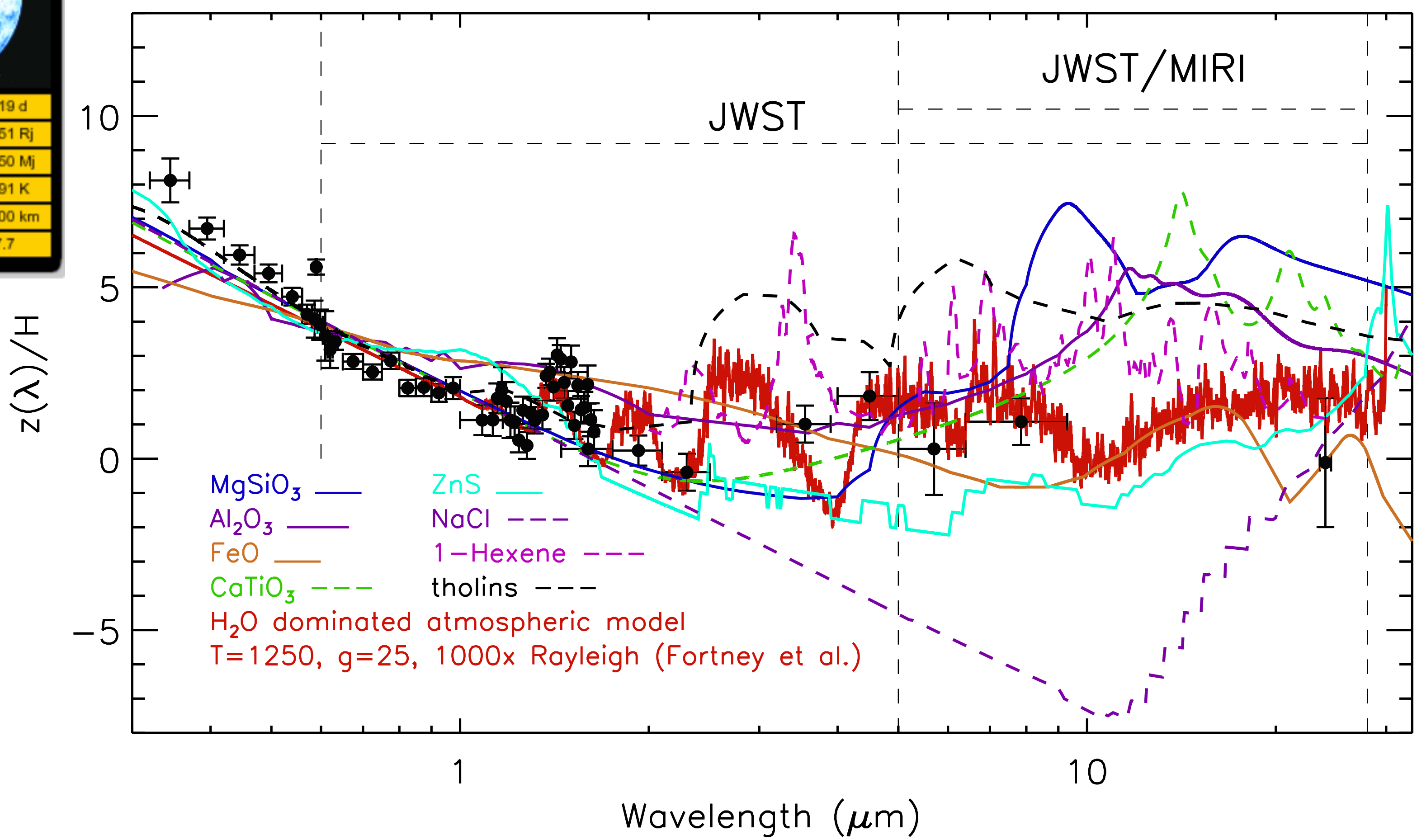
Transmission Spectra of cloud condensates



Wakeford & Sing, 2015, A&A, 573, A122

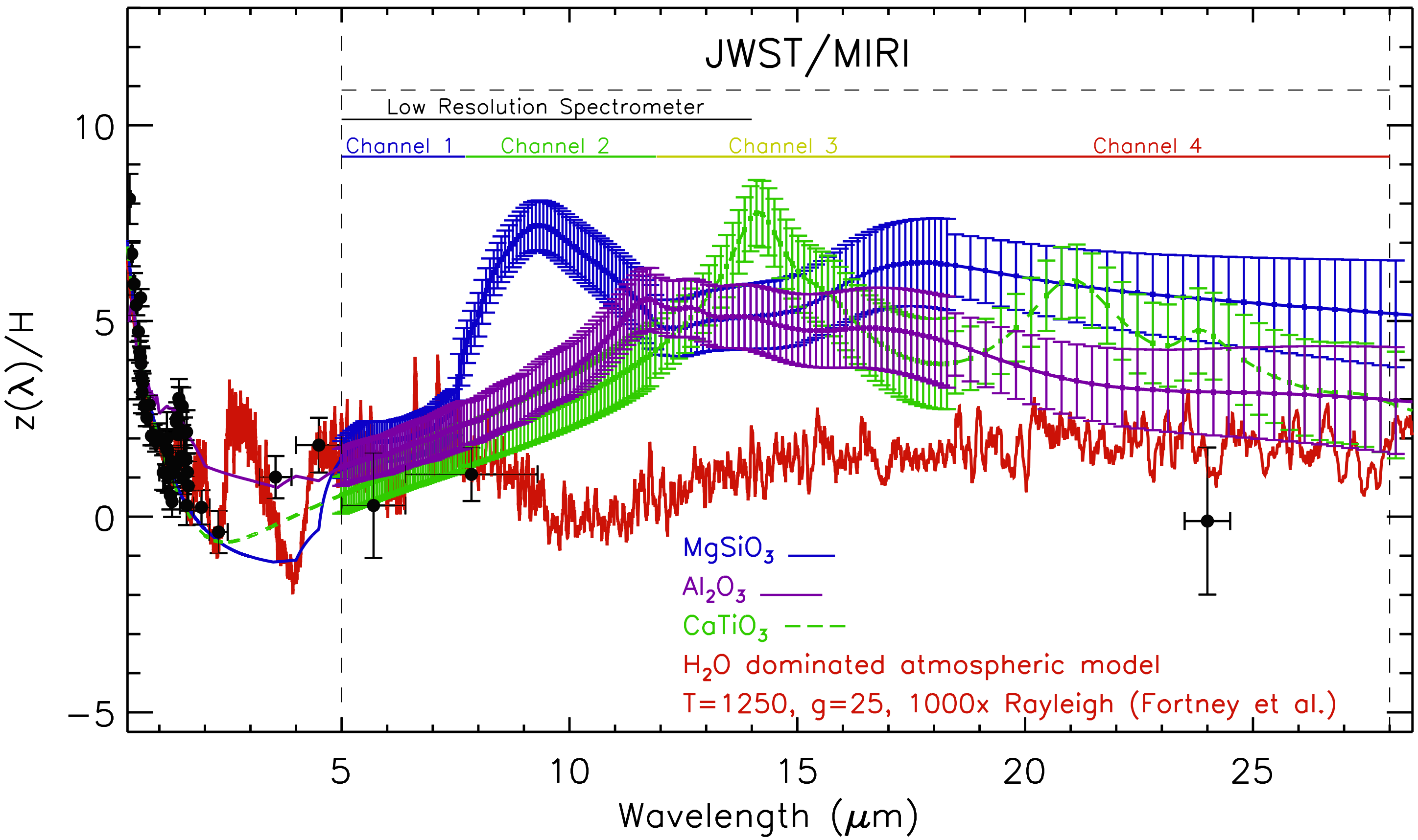
Transmission Spectral Signatures





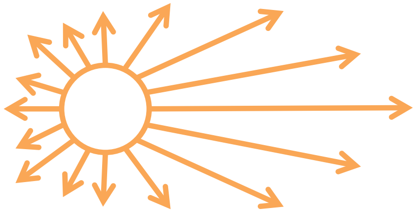
Wakeford & Sing, 2015, A&A, 573, A122

JWST



Wakeford & Sing, 2015, A&A, 573, A122

Summary



- Condensate transmission spectra can be approximated using the largest particle size in a distribution
- Absorption features are dominated by vibrational modes of the major di-atomic bond in the condensate
- As a result on observational distinction can be made between species generated photochemically or through condensation

- Rayleigh scattering in the optical can be used as a diagnostic for particle size and condensates to be observed in the IR
- JWST MIRI will have 50x sensitivity and 7x angular resolution of Spitzer

What's Next?

NPP Fellow
working with Avi Mandell