Performance comparison between JWST/MIRI+NIRCam & VLT/SPHERE for exoplanet detection

Charles Hanot, Olivier Absil, Jean Surdej

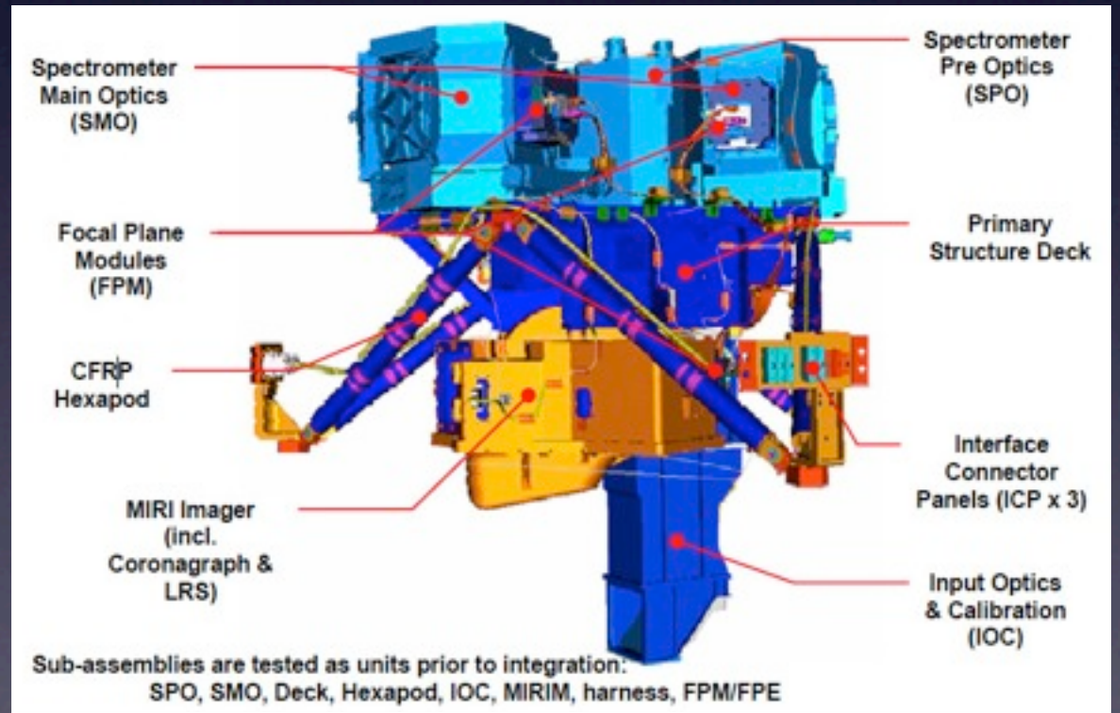
ARC meeting, 11February 2010

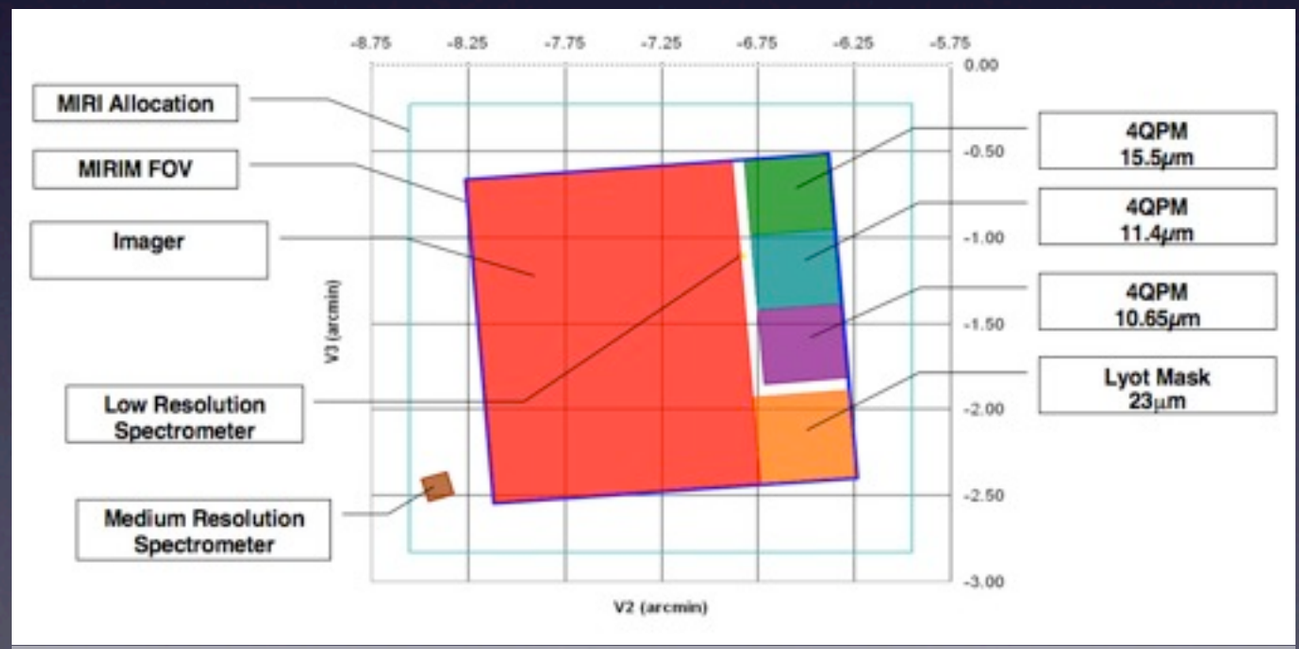
James Webb Space Telescope (JWST)

- Infrared-optimized 6.5 m telescope
- Detection of first galaxies
- Stars forming planetary systems

JWST/ MIRI

- Mid-InfraRed Instrument (5-27µm)
- Imager + Spectrograph
- Equiped with coronagraphs for high dynamic imaging



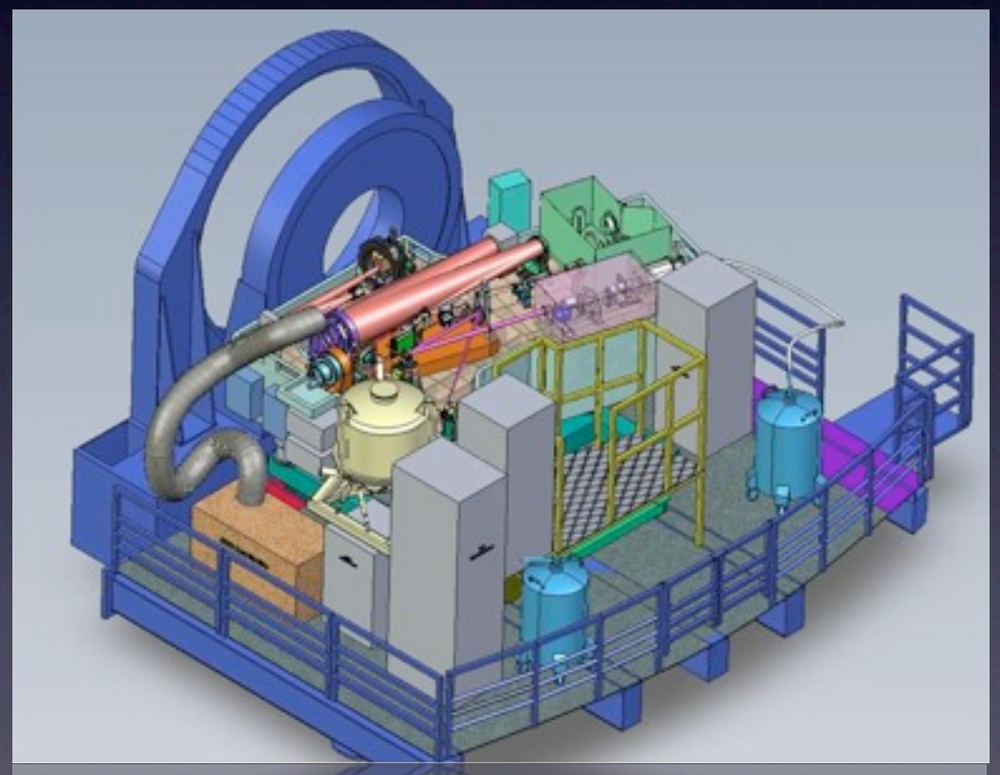


JWST/ NIRCam

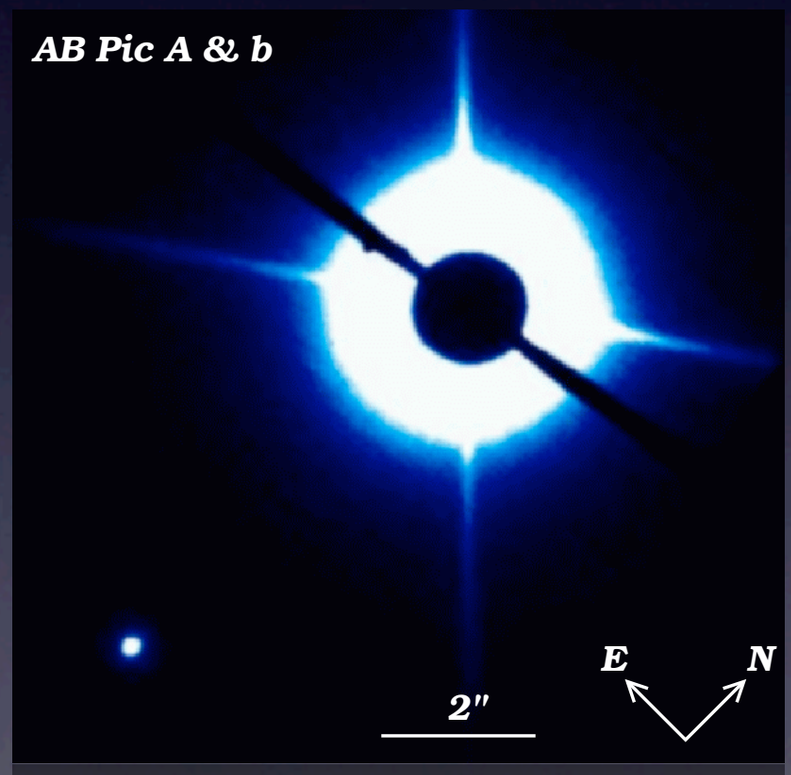
- Near InfraRed Camera (0.6-2.3µm + 2.4-5 µm)
- Imager
- Equipped with coronagraphs for high dynamic imaging

VLT/SPHERE

- Extreme adaptive optics (XAO)
- Coronagraphs (1.4-2.4µm)
- Spectral differential imaging



Chauvin et al. 2005



Context and goals

MIRI GTO: short program proposal

- Well defined, well focused
- Immediate scientific return

Main goals

- Directly detect the smallest possible planets at 5-50 AU from main sequence stars
- Unveil new population of planets
- Follow-up: constrain theoretical cooling models

Why M stars?

Most abundant stellar type

Planetary systems not well known

- Planet formation/migration similar to Sun-like stars?

Currently a hot topic

- RV and transit surveys starting
- Prospects for super-Earths in habitable zones

Low luminosity

- Fainter planets can be imaged at a given contrast

Why young main sequence stars?

"Main sequence"

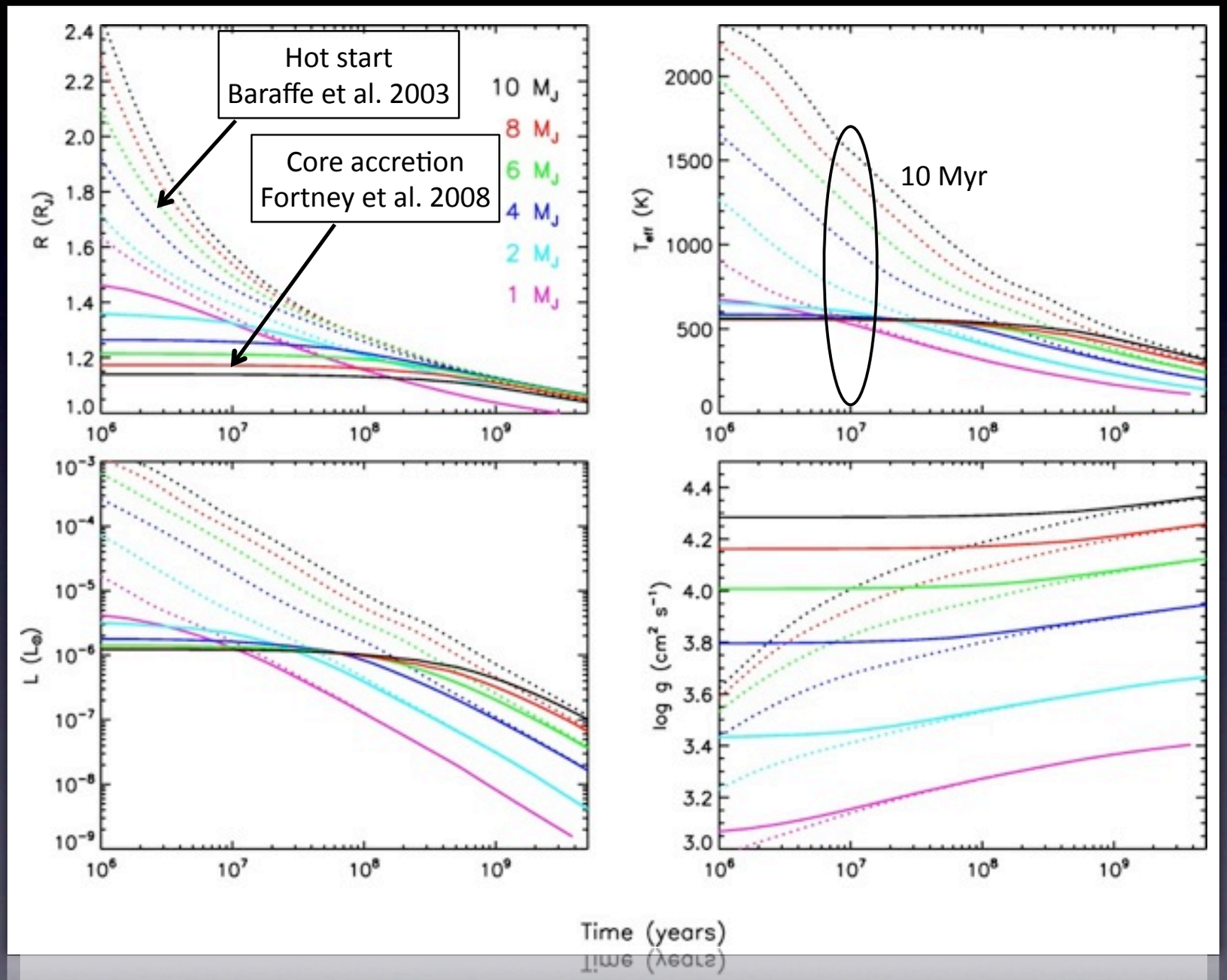
- Thick disks have disappeared
- Planetary systems mostly formed

"Young"

- Planets are still warm and luminous → easier
  - Cooling models poorly constrained
- Moving groups and associations
  - Nearby (typically 20 – 50 pc)
  - Ages relatively well defined

Evolutionary models

Fortney et al. 2008



Scientific return

Detection at 11.4 μm

- Age known → planet temperature and mass from models
- First statistics of low-mass planets

Follow-up with MIRI

- 15.5 μm: model-independent temperature estimation
- 10.65 μm: search for ammonia

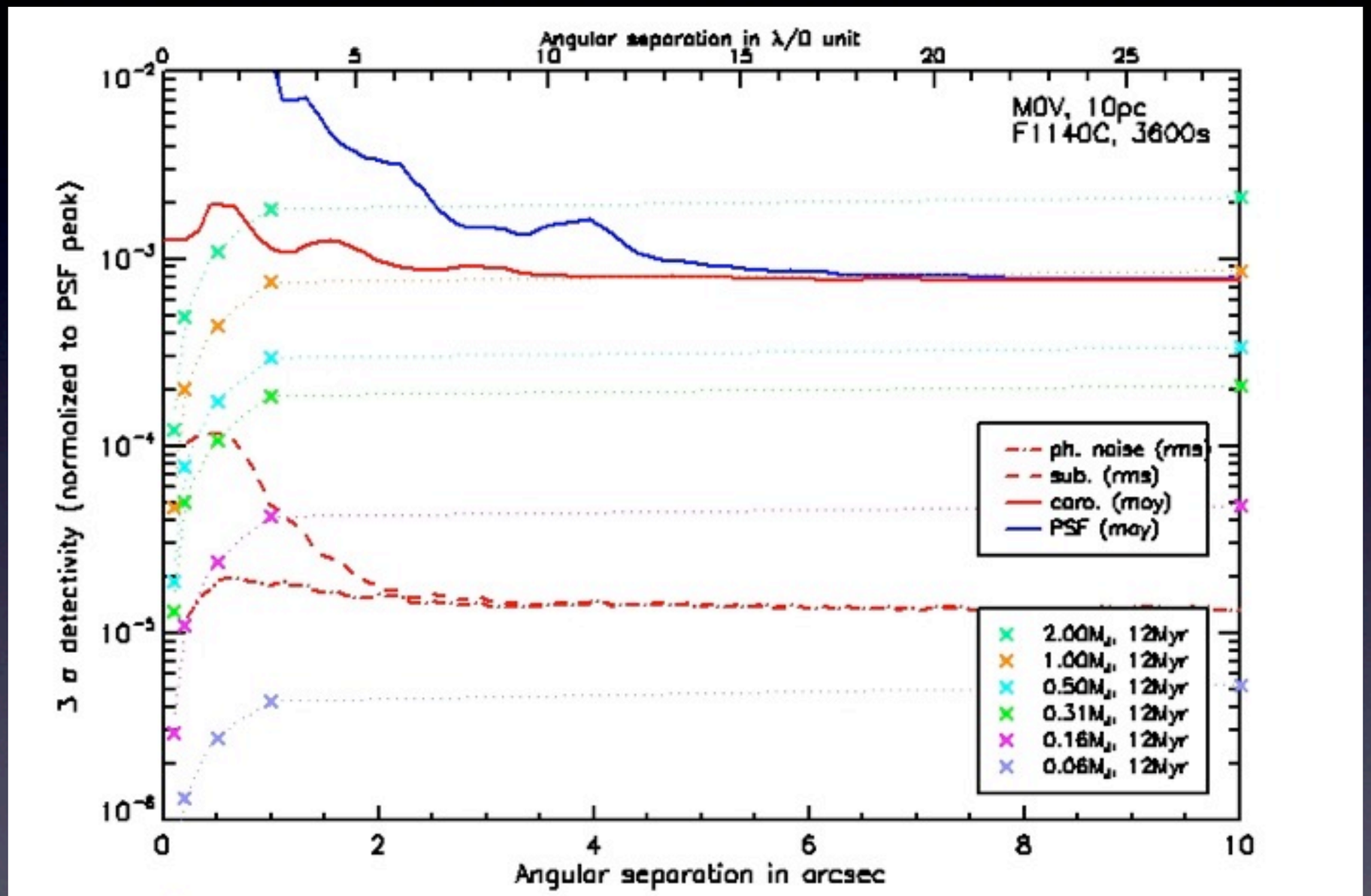
Follow-up with NIRCam at 4.6 μm

- More constraints on theoretical models

Astrometric follow-up → dynamical mass determination for close planets (< 5 AU)

Illustrative result with MIRI

M0V,10pc, 12 Myr, 1h

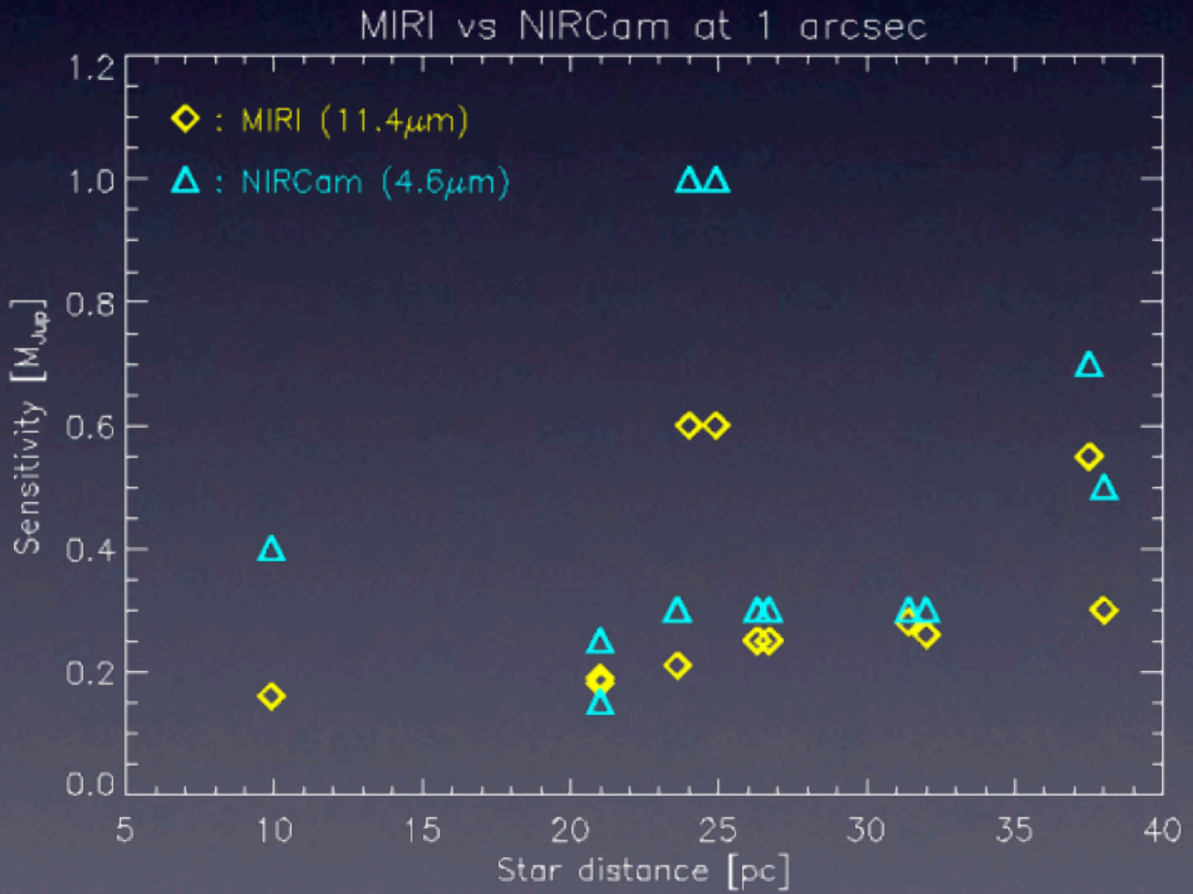


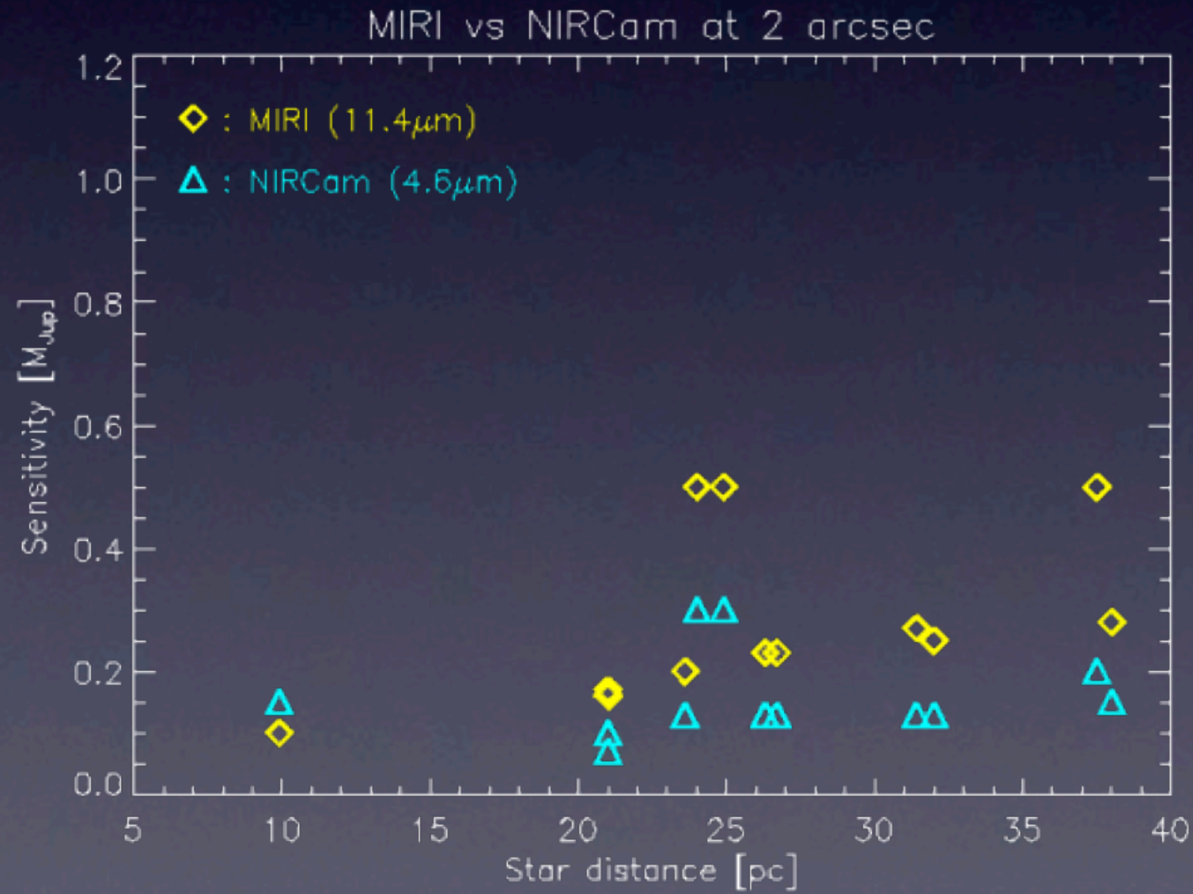
Sample and sensitivity

					0.2”		0.5”		1.0”		2.0”	
Name	Dist (pc)	Age (Myr)	Sp type	V	a AU	**M Mjup**	a AU	**M Mjup**	a AU	**M Mjup**	a AU	**M Mjup**
AU Mic	9.9	12	M1Ve	8.8	2	**0.50**	5	**0.30**	10	**0.16**	25	**0.10**
TWA 8A	21.0	8	M3Ve	12.2	4	**0.40**	11	**0.25**	21	**0.19**	53	**0.16**
TWA 8B	21.0	8	M5	15.2	4	**0.33**	11	**0.23**	21	**0.18**	53	**0.17**
WW PsA	23.6	12	M4	12.2	5	**0.50**	12	**0.30**	24	**0.21**	59	**0.20**
CD-57 1054	26.3	12	M0/1	10.0	5	**0.80**	13	**0.50**	26	**0.25**	66	**0.23**
V1005 Ori	26.7	12	M0.5V	10.1	5	**0.80**	13	**0.50**	27	**0.25**	67	**0.23**
TWA 12	32.0	8	M1Ve	12.9	6	**0.80**	16	**0.45**	32	**0.26**	80	**0.25**
CPD-66 3080B	31.4	12	M3Ve	12.7	6	**0.80**	16	**0.42**	31	**0.28**	79	**0.27**
TWA 7	38.0	8	M2Ve	11.7	8	**0.90**	19	**0.52**	38	**0.30**	95	**0.28**
GJ 4020 A	24.0	50	M0	10.2	5	**2.00**	12	**1.10**	24	**0.60**	60	**0.50**
GJ 9809	24.9	50	M0	10.9	5	**2.00**	12	**1.10**	25	**0.60**	62	**0.50**
CT Tuc	37.5	30	M0Ve	11.5	7	**1.70**	19	**0.95**	37	**0.55**	94	**0.50**

Comparison with NIRCam

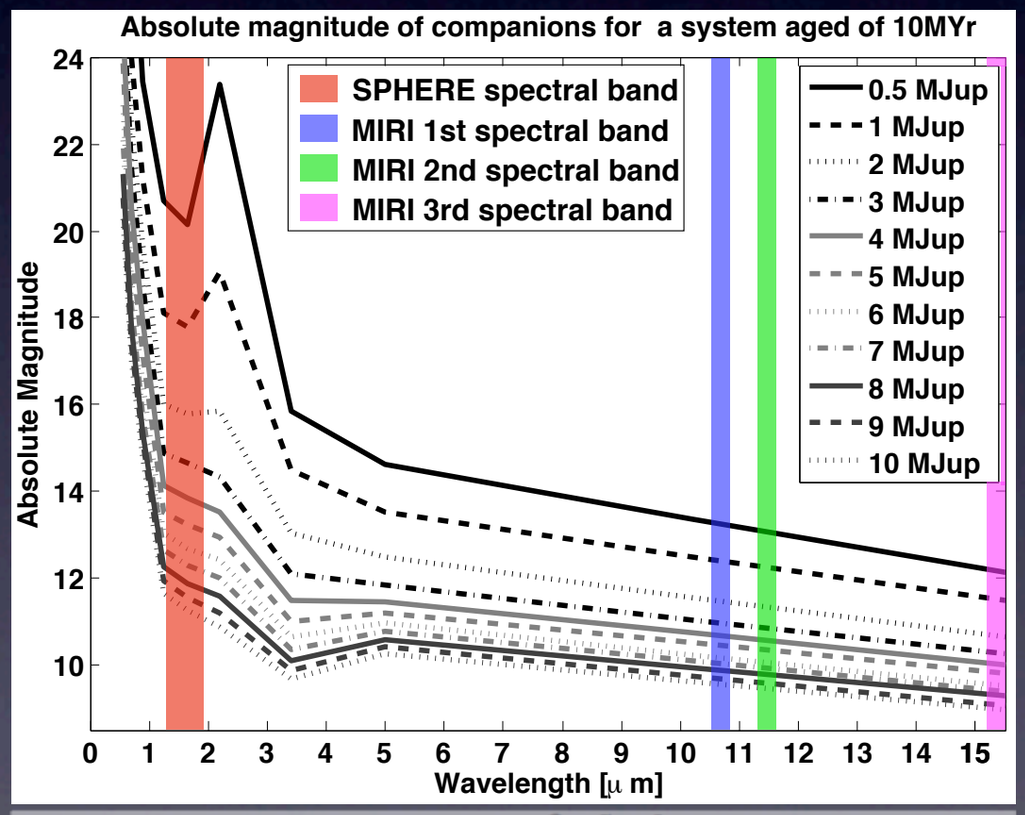
MIRI better than NIRCam for planets <1.5” (~40AU)
Only MIRI can access planets <0.8” (~20AU)





Comparison with SPHERE

Most M stars too faint for SPHERE
SPHERE more sensitive <15AU



Name	Mov group	Dist (pc)	Age (Myr)	Sp Type	K_{mag}	N_{mag}	Mass (10AU)	Mass (20AU)
203	β Pic	39.1	12	F2 IV	5.4	5.12	9.5 / **4**	0.75 / **2.5**
2884	Tuc - Hor	41	30	B9 V	4.48	4.2	35 / **8**	7.5 / **5.75**
2885	Tuc - Hor	46	30	A2 V	4.11	4.13	45 / **11**	30 / **5.5**
3003	Tuc - Hor	47	30	A0 V	4.98	4.87	40 / **9**	11 / **5.75**
12894	Tuc - Hor	47.2	30	F2 V	5.45	5.23	25 / **8**	8 / **6**
14082	β Pic	39.4	12	F5 V	5.79	5.83	5.5 / **3.5**	0.3 / **2**
14228	Tuc - Hor	47.5	30	B8 V	4.13	3.8	65 / **11**	22 / **7.5**
16978	Tuc - Hor	47	30	B9 V	4.25	4.13	45 / **11**	15 / **7.5**
17332	AB Dor	32.6	50-70	G0+G5	5.52	5.43	9 / **7**	0.45 / **5.5**
25457	AB Dor	19.2	50-70	F5 V	4.18	4.24	0.5 / **5.5**	0.39 / **6**
29391	β Pic	29.8	12	F0 V	4.54	4.29	9.5 / **3.5**	0.9 / **6.5**
35850	β Pic	26.8	12	F7/8 V	4.93	5.08	3 / **3**	0.15 / **2**
98736	Castor	32	200	G5	6.03	6.47	3/ **-**	0.375 / **-**
146624	β Pic	43.1	12	A0 (V)	4.74	4.59	17 / **6**	2 / **2.5**
164249	β Pic	46.9	12	F5 V	5.91	5.83	10 / **4.5**	3 / **2**
165189	β Pic	43.9	12	A5 V	4.39	4.5	19 / **7**	4 / **4**
172167	Castor	7.75	200	A0 V	0.13	0.1	6/ **-**	1 / **-**
172555	β Pic	29.2	12	A5 IV/V	4.3	4.27	9.5 / **3.5**	0.3 / **2.5**
181296	β Pic	47.7	12	A0 V	5.01	4.87	19 / **7**	8.5 / **2.5**
181327	β Pic	50.6	12	F5/6 V	5.91	5.84	13 / **5**	5 / **2.5**
195627	Tuc - Hor	27.6	30	F0 V	4.8	4.7	7.5 / **5**	0.33 / **4.25**
199143	β Pic	47.7	12	F8 V	5.81	5.99	12 / **5**	2.5 / **2.5**
207964	Tuc - Hor	46.5	30	F0 IV	4.9	4.8	35 / **7**	3 / **4.25**
210027	Castor	11.75	200	F5 V	2.56	2.85	3/ **-**	0.5 / **-**
217343	AB Dor	32.1	50-70	G3 V	5.94	5.89	6 / **6**	0.3 / **5**
224392	Tuc - Hor	49	30	A1 V	4.82	4.77	50 / **9**	6 / **4.25**
GJ 226.2	Castor	25	200	K8 V	6.67	6.65	3/ **-**	0.375 / **-**
GJ 466	Castor	39.87	200	M0 V	7.18	6.96	7.5/ **-**	1 / **-**
GJ 842.2	Castor	21	200	M0.5	6.73	6.86	0.45/ **-**	0.25 / **-**