Compared sensitivity of VLT, JWST and ELT for direct exoplanet detection in nearby stellar moving groups

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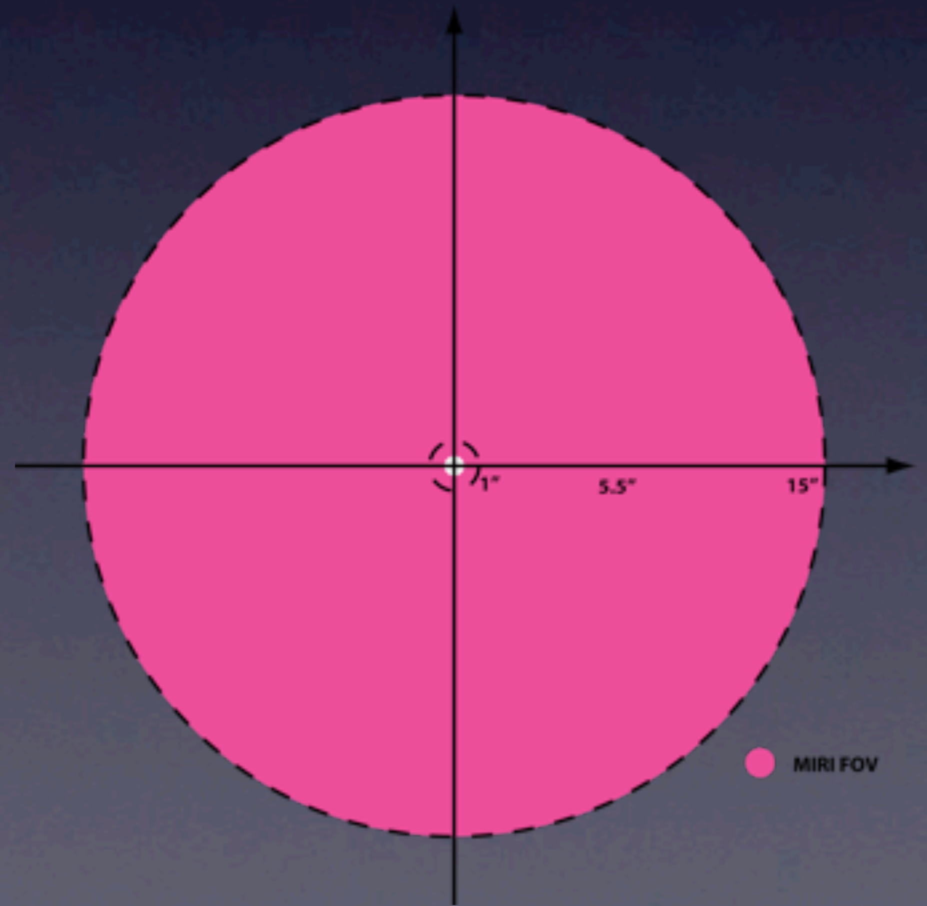
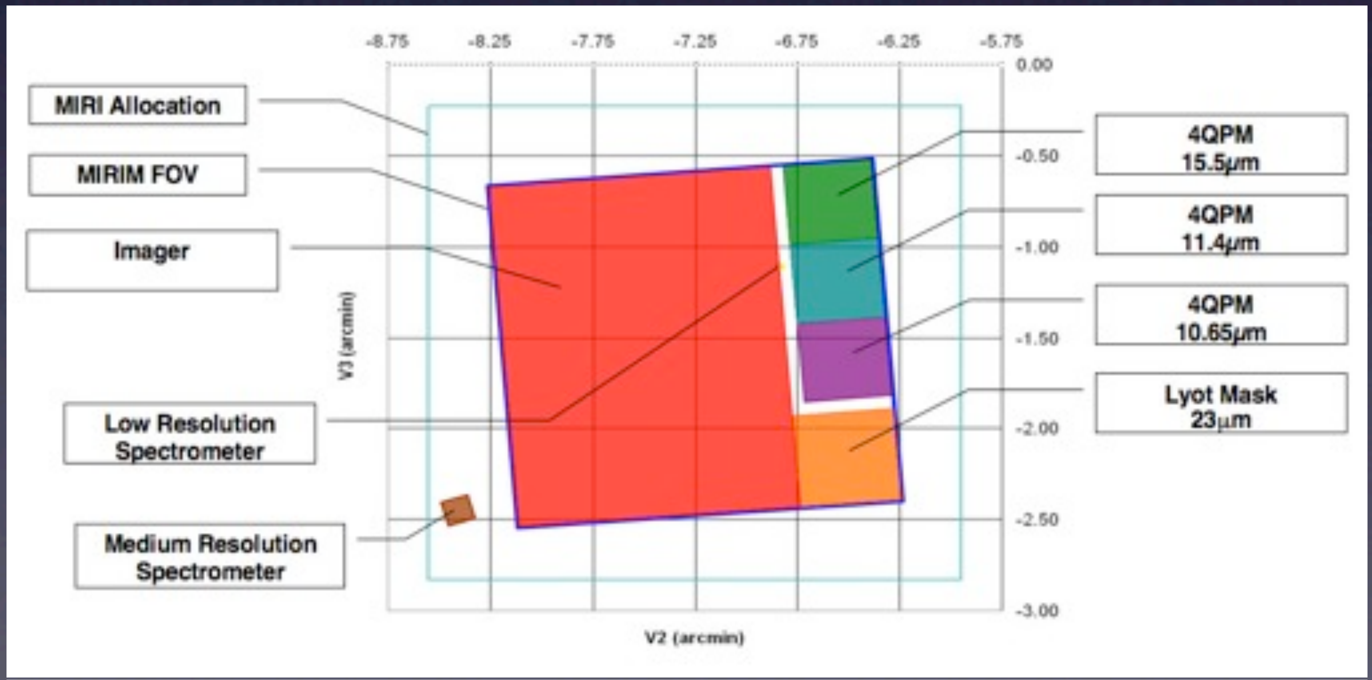
JWST & ELTs: an ideal combination, 13-16 April 2010

JWST/ MIRI

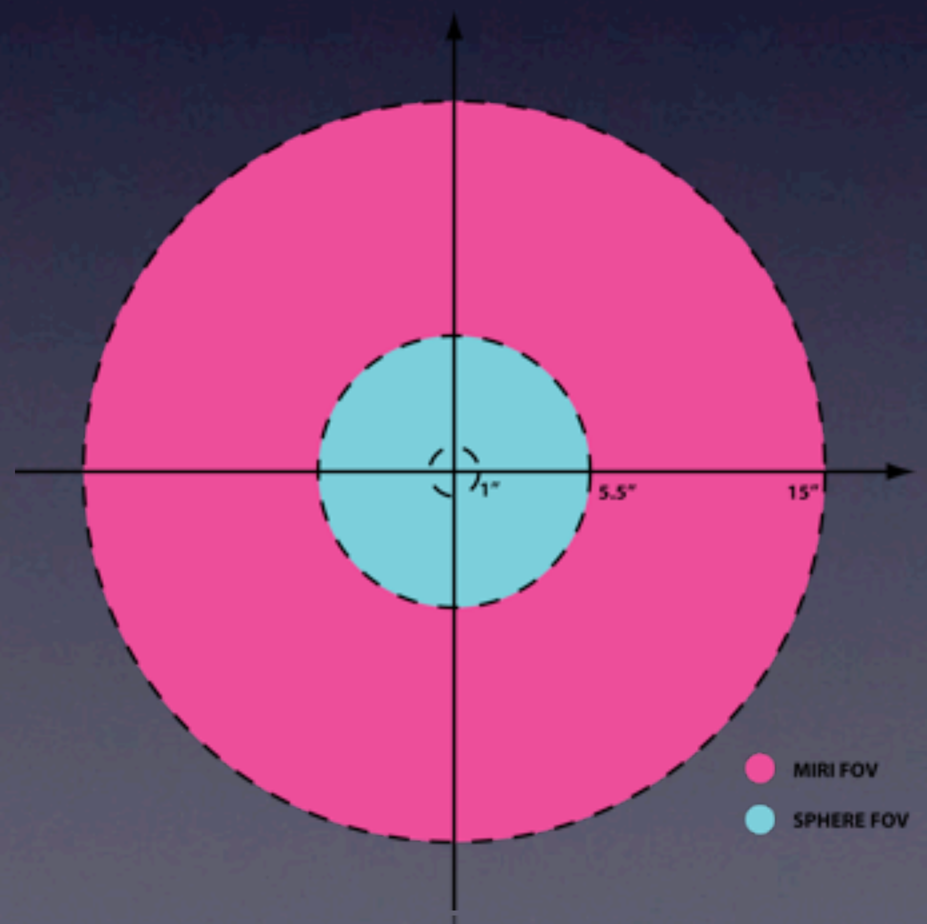
- Mid-InfraRed Instrument (5-27μm)
- FQPM Coronagraph. @ 11.4μm
- λ/D ≈ 0.36”
- FOV ≈ 15”



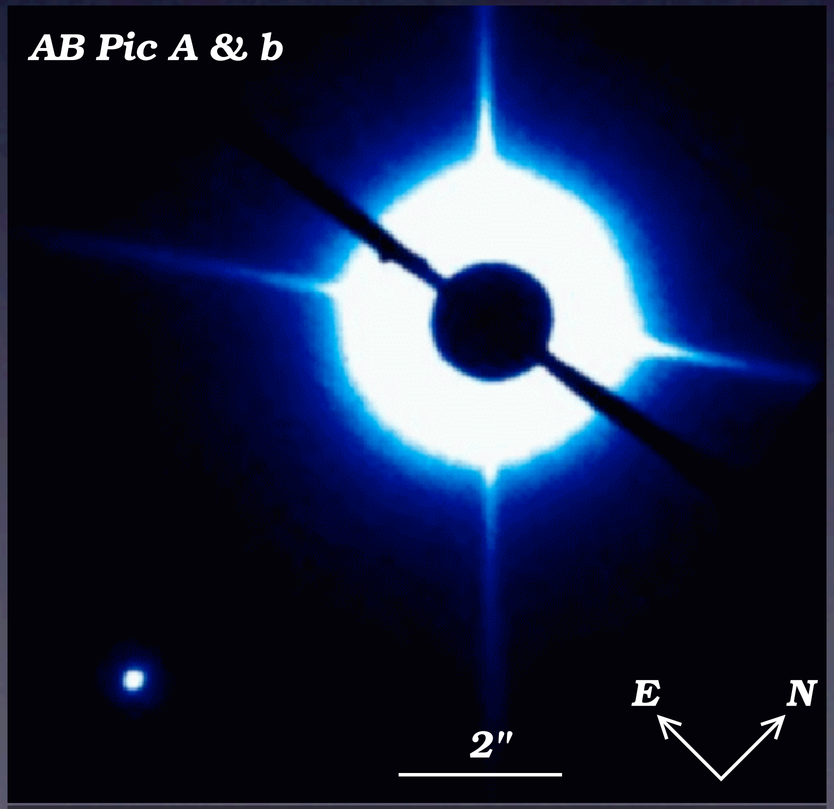


VLT/SPHERE

- Extreme adaptive optics (XAO)
- FQPM Coronagraphs @ 1.6μm
- $\lambda/D \approx 40$ mas
- FOV ≈ 5.5”

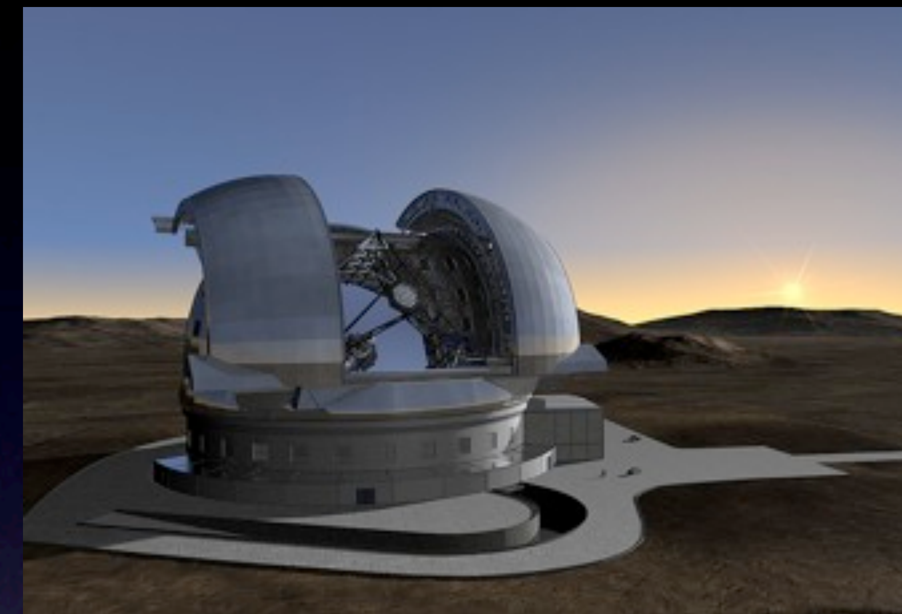


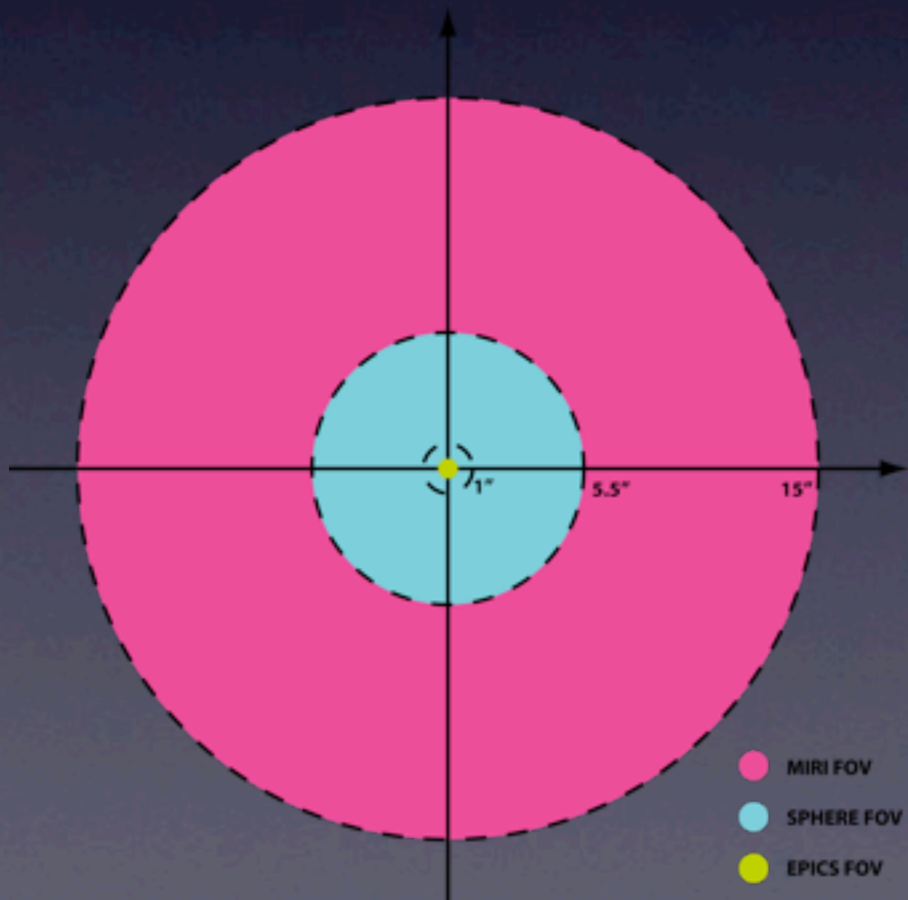
Chauvin et al. 2005

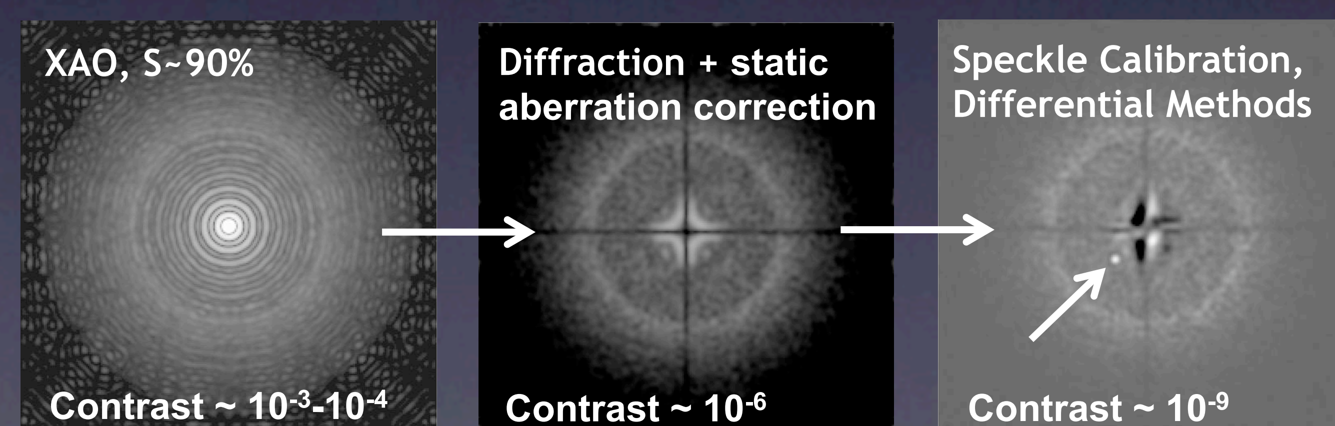


E-ELT/EPICS

- Vis-NIR imager and spectrograph
- Extreme adaptive optics (XAO)
- Coronagraphs (0.95-1.65μm)
- $\lambda/D \approx 8$ mas
- FOV $\approx$ 0.4”







Kasper 09

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 M-type 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

- For a given contrast, fainter planets can be imaged

Why young main sequence stars?

"Main sequence"

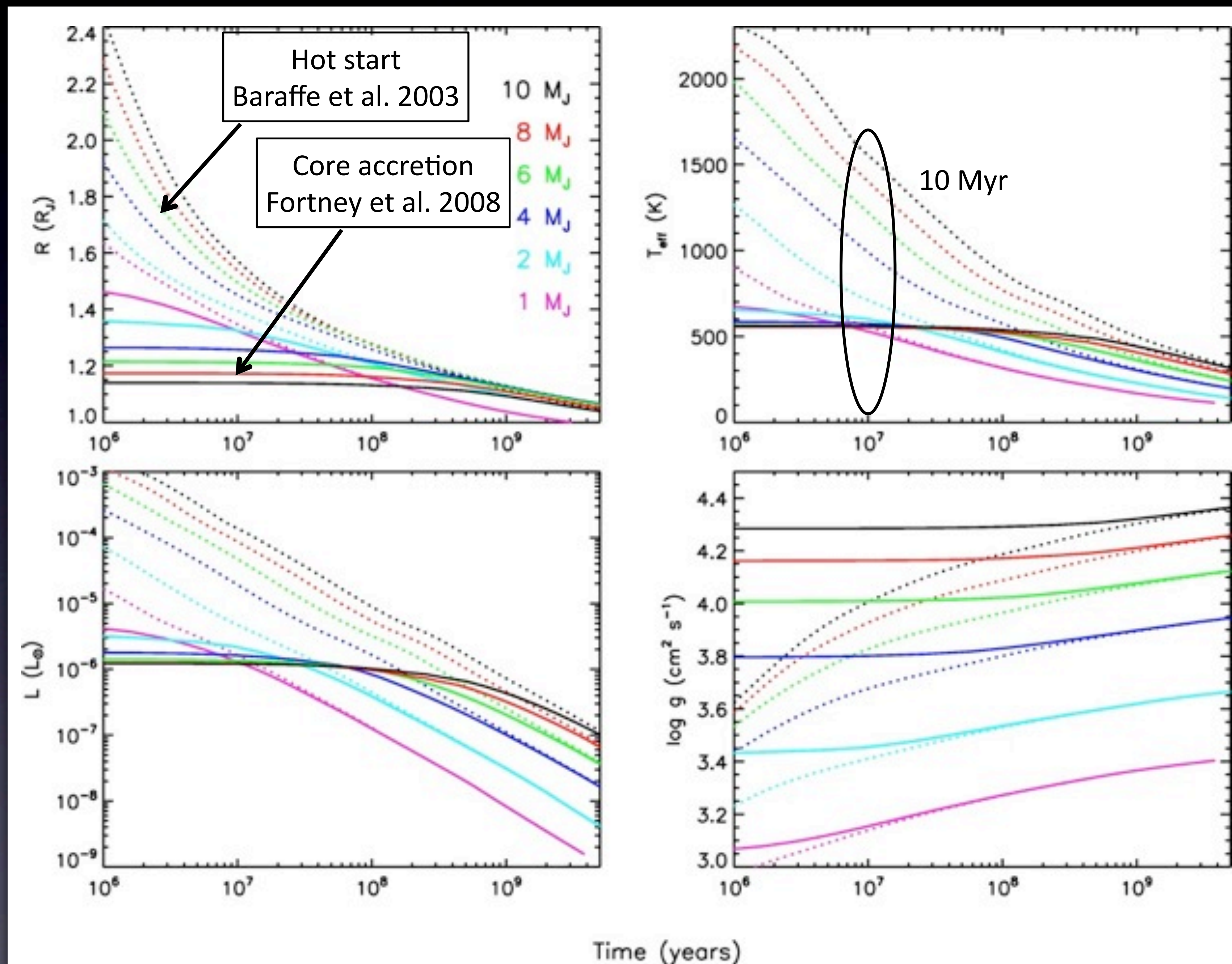
- Thick disks have disappeared
- Planetary systems mostly formed

"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

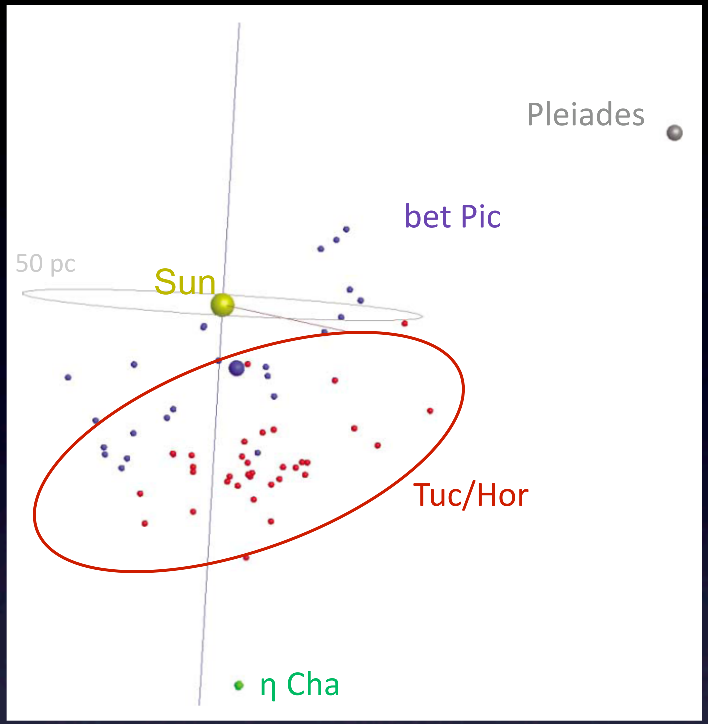
Follow-up with other instruments

- More constraints on theoretical models

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

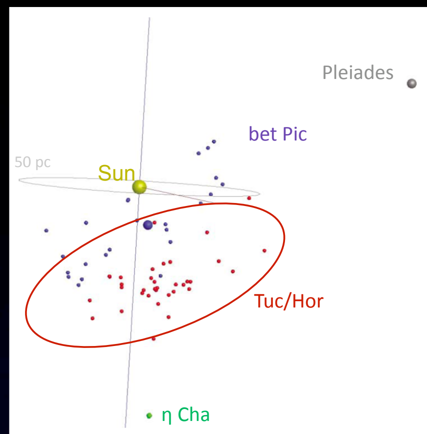
Simulations

Simulations



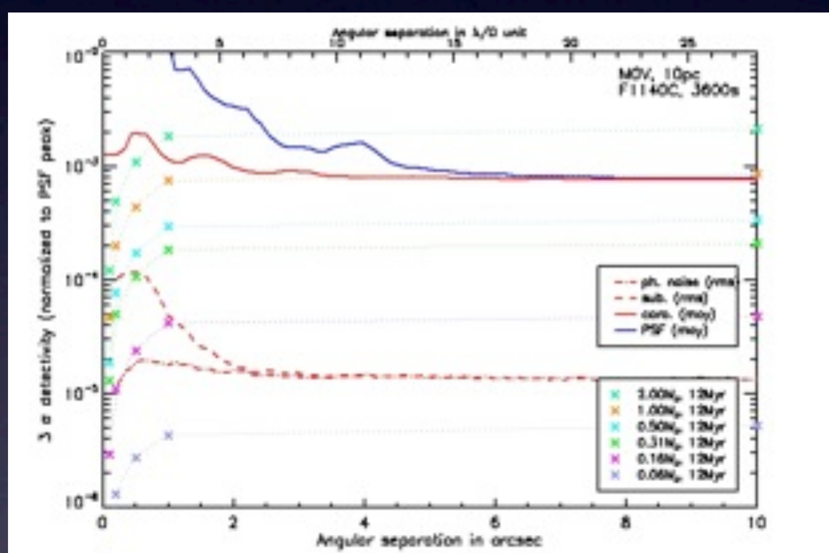
1. Age, distance and magnitude

Simulations



MIRI

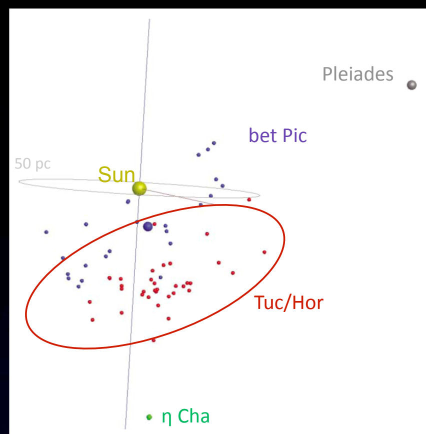
M0V,10pc, 12 Myr, 1h



1. Age, distance and magnitude

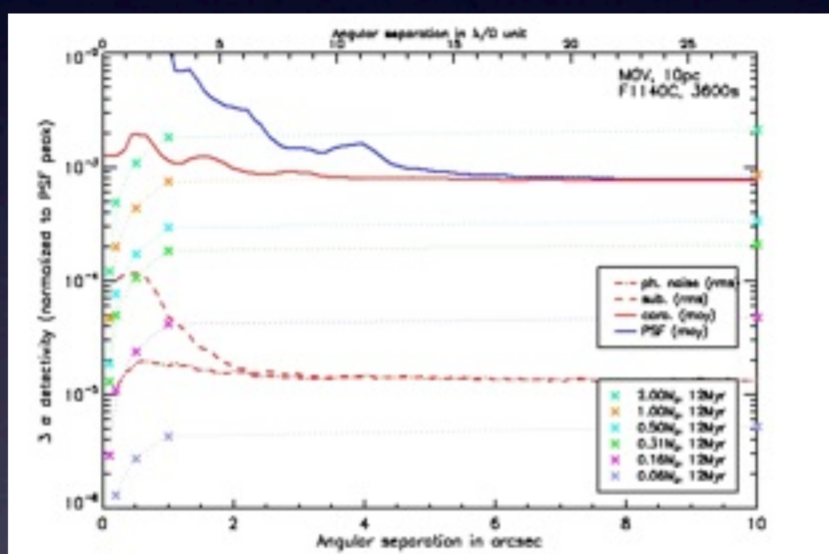
2. Coro. profile ⇒ contrast

Simulations



MIRI

M0V,10pc, 12 Myr, 1h

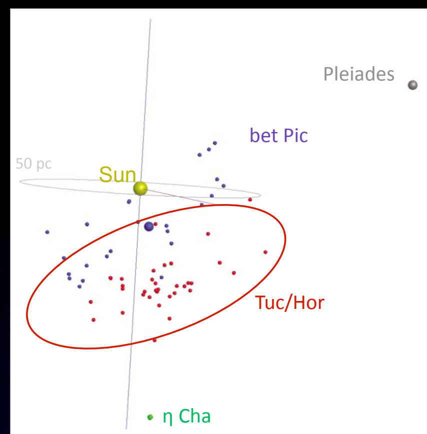


1. Age, distance and magnitude

2. Coro. profile ⇒ contrast

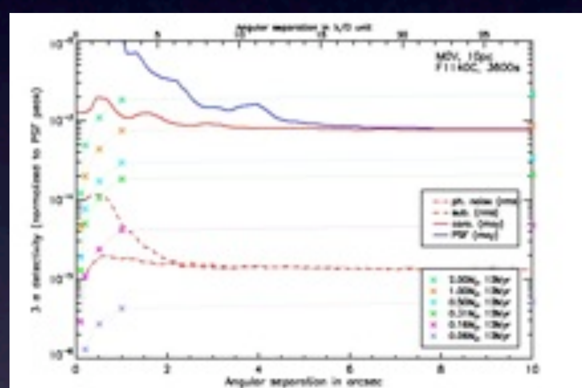
3. ⇒ Companion magnitude

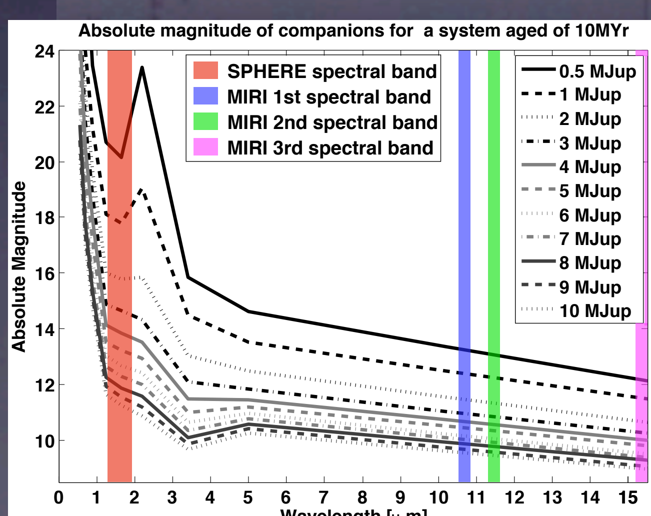
Simulations



MIRI

M0V,10pc, 12 Myr, 1h





1. Age, distance and magnitude
2. Coro. profile ⇒ contrast
3. ⇒ Companion magnitude
4. Evol. model ⇒ mass

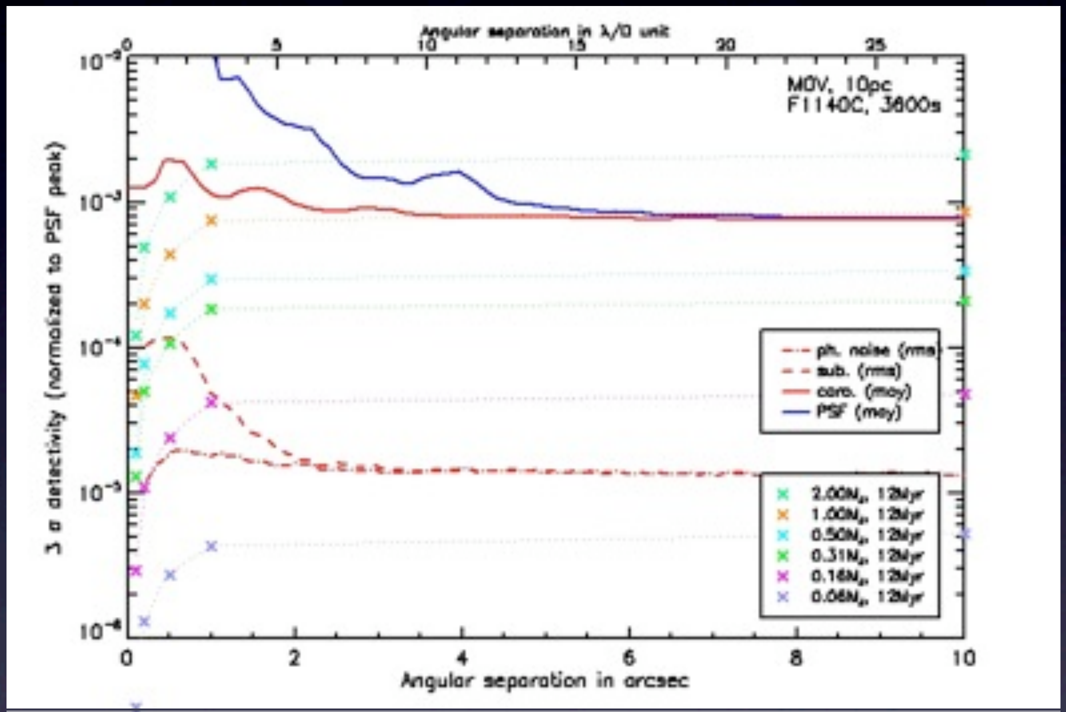
Simulations & assumptions

MIRI

- Reference subtraction

MIRI

M0V,10pc, 12 Myr, 1h



Courtesy A. Boccaletti

Simulations & assumptions

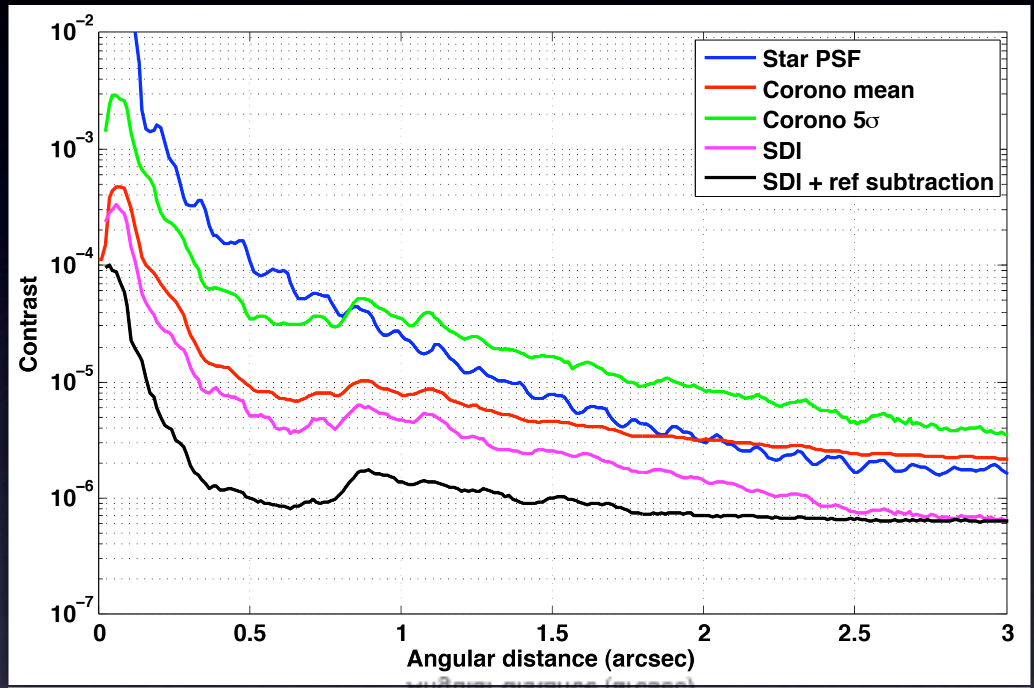
MIRI

- Reference subtraction

SPHERE

- Reference subtraction
- Ref subtraction + SDI

SPHERE G0V, 24pc, 12 Myr, 1h



Courtesy A. Boccaletti

Simulations & assumptions

MIRI

- Reference subtraction

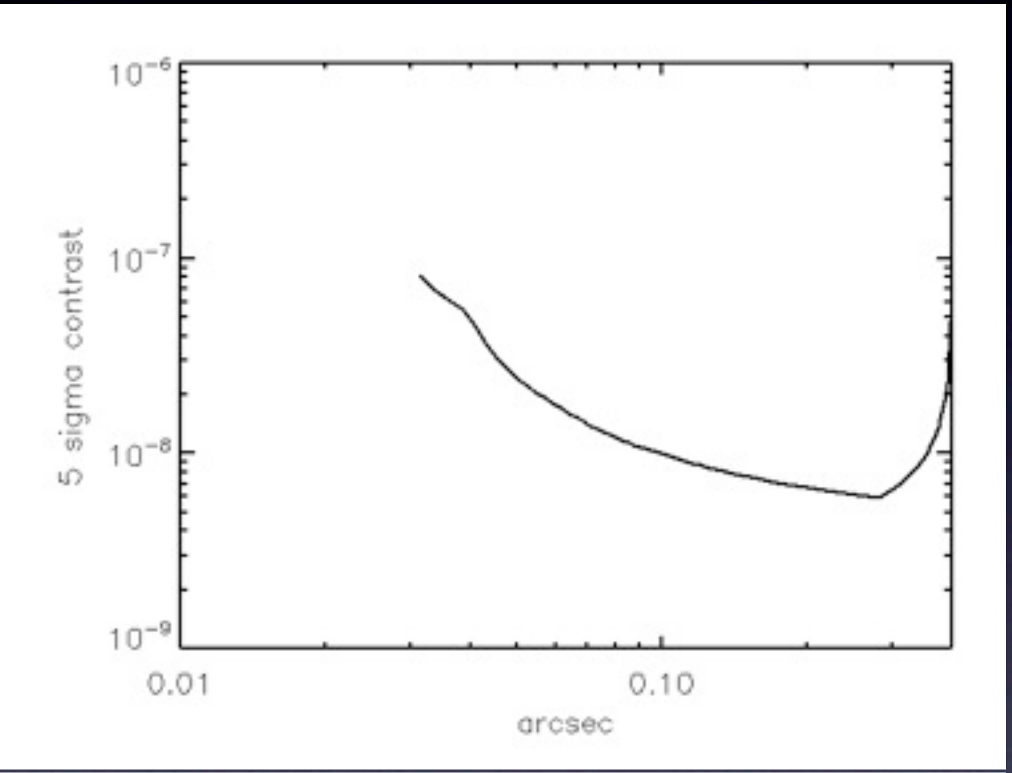
SPHERE

- Reference subtraction
- Ref subtraction + SDI

EPICS

- Ref subtraction + SDI + Pol.

EPICS M0V, 10pc, 12 MYr, 1h



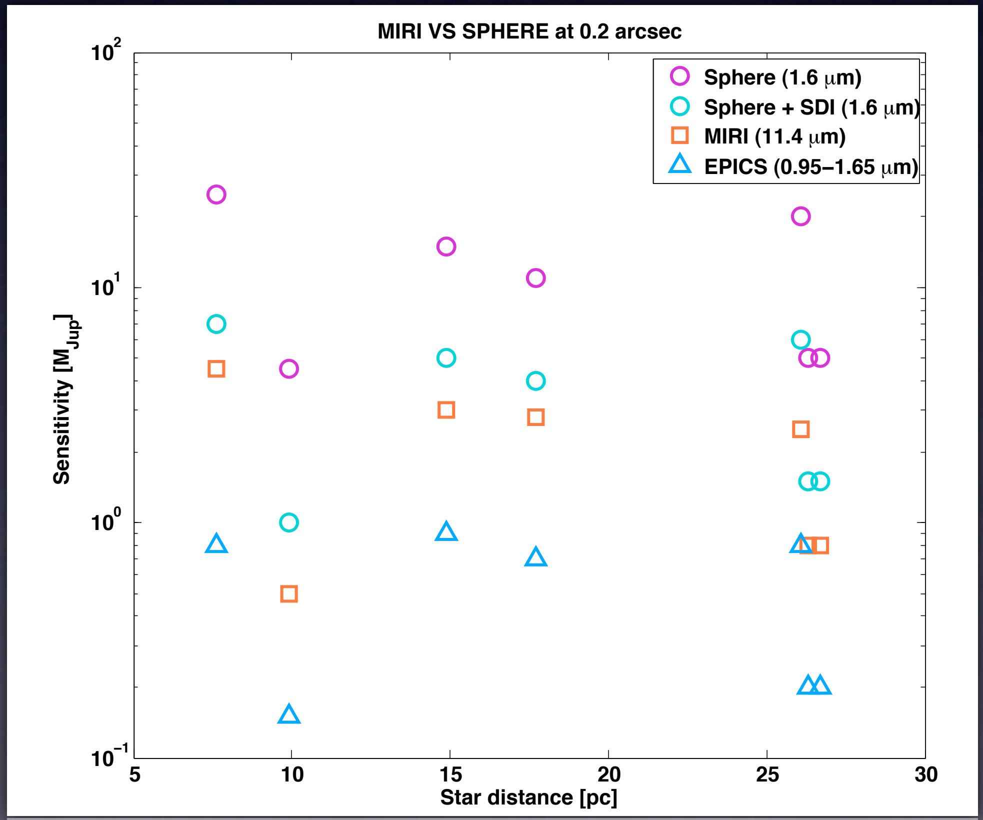
Courtesy C.Verinaud

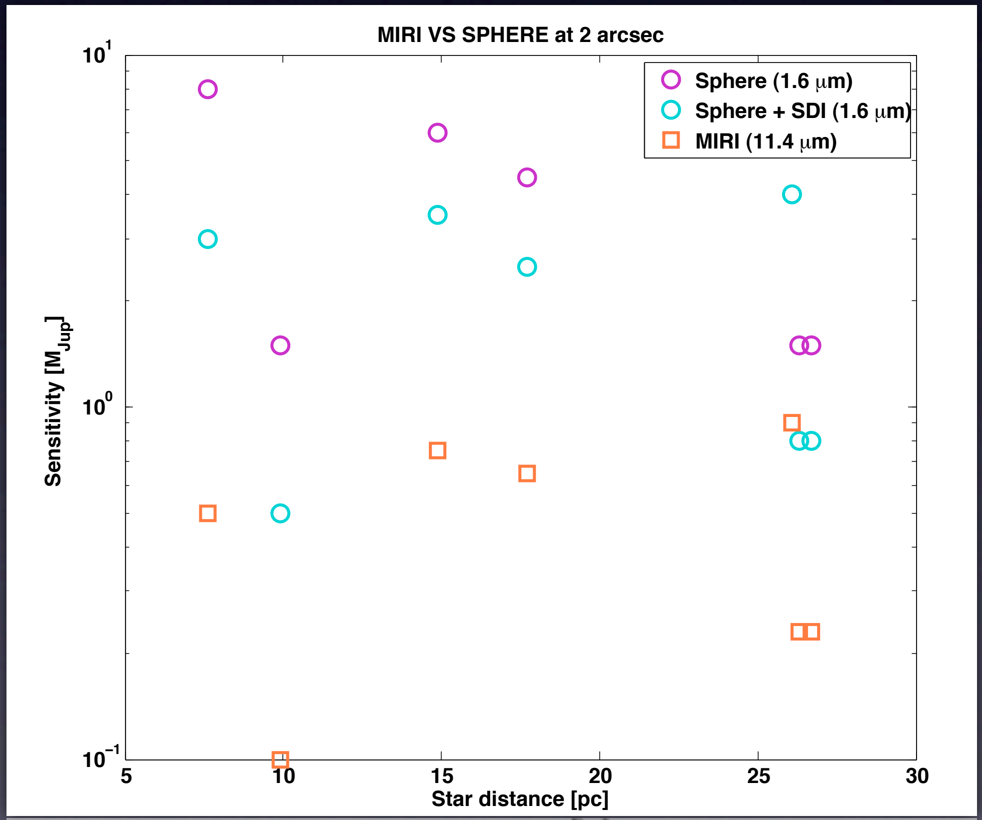
Sample and sensitivity for MIRI

Name	Dist (pc)	Age (Myr)	Sp type	V	0.2" a AU	0.2" M Mjup	0.5" a AU	0.5" M Mjup	1.0" a AU	1.0" M Mjup	2.0" a AU	2.0" 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**

MIRI vs SPHERE

Most M stars too faint for SPHERE's AO
SPHERE more sensitive <2AU



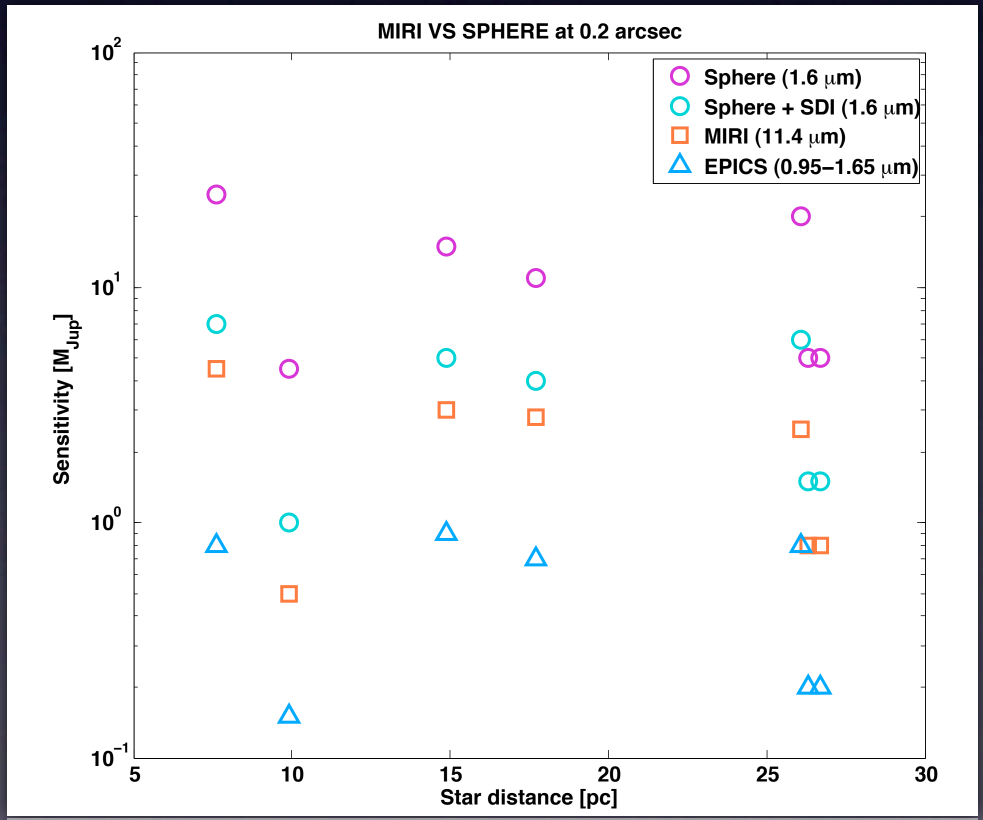


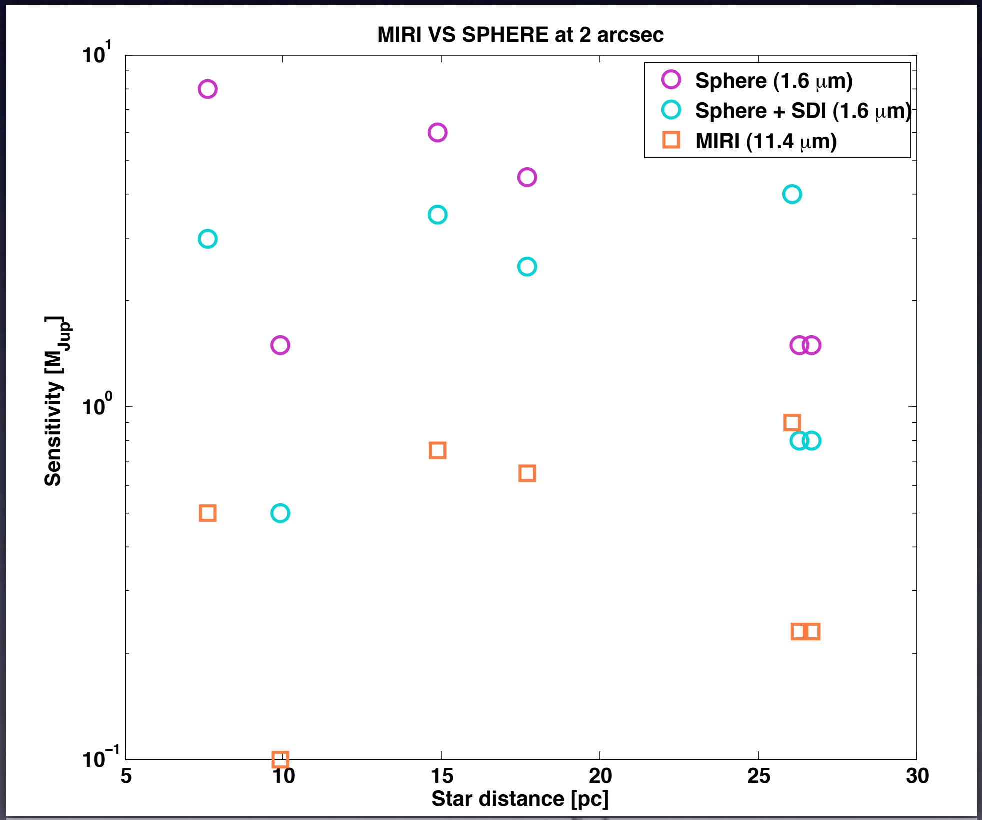
MIRI vs SPHERE vs EPICS

Most M stars too faint for EPICS's AO too

EPICS always more sensitive

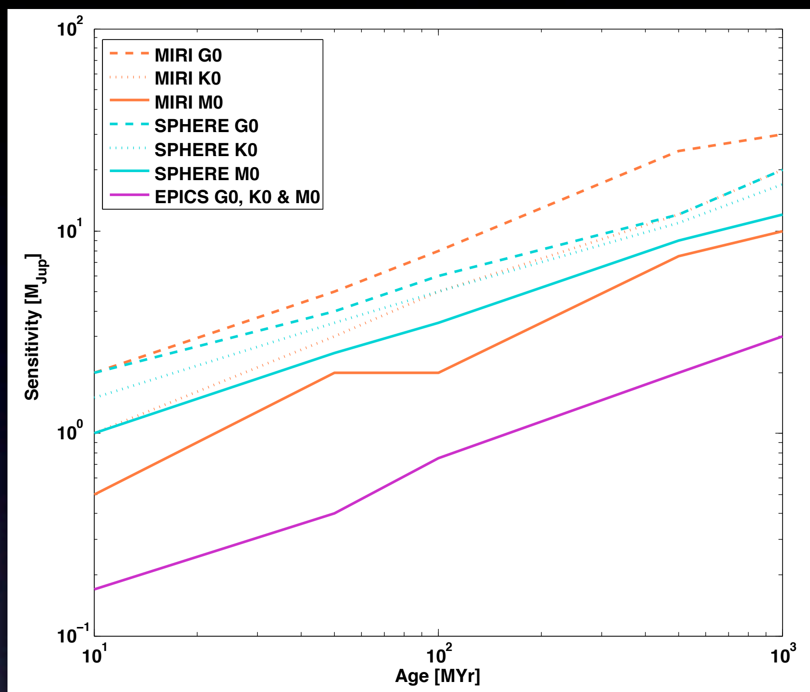
EPICS FOV ≈ MIRI IWA



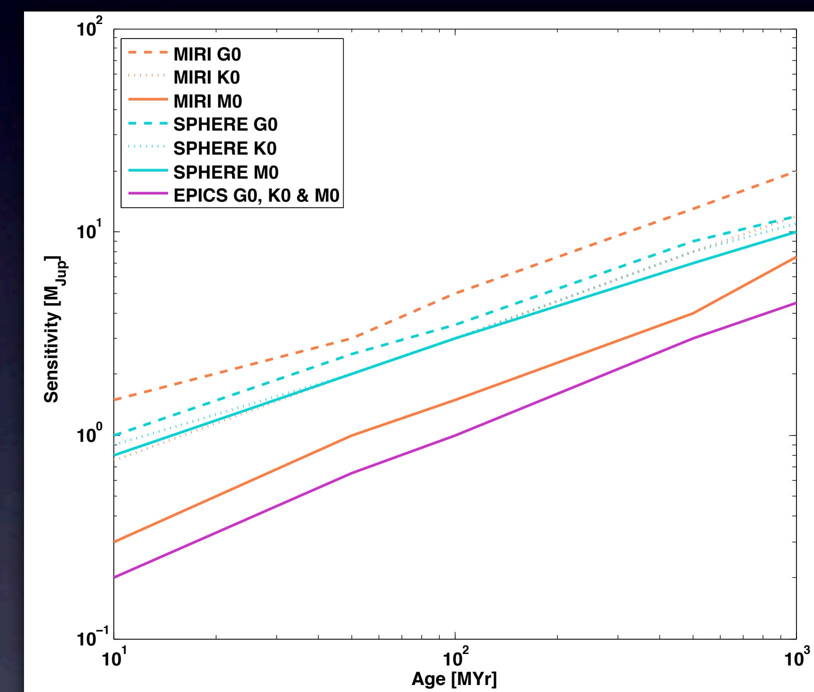


MIRI vs SPHERE vs EPICS

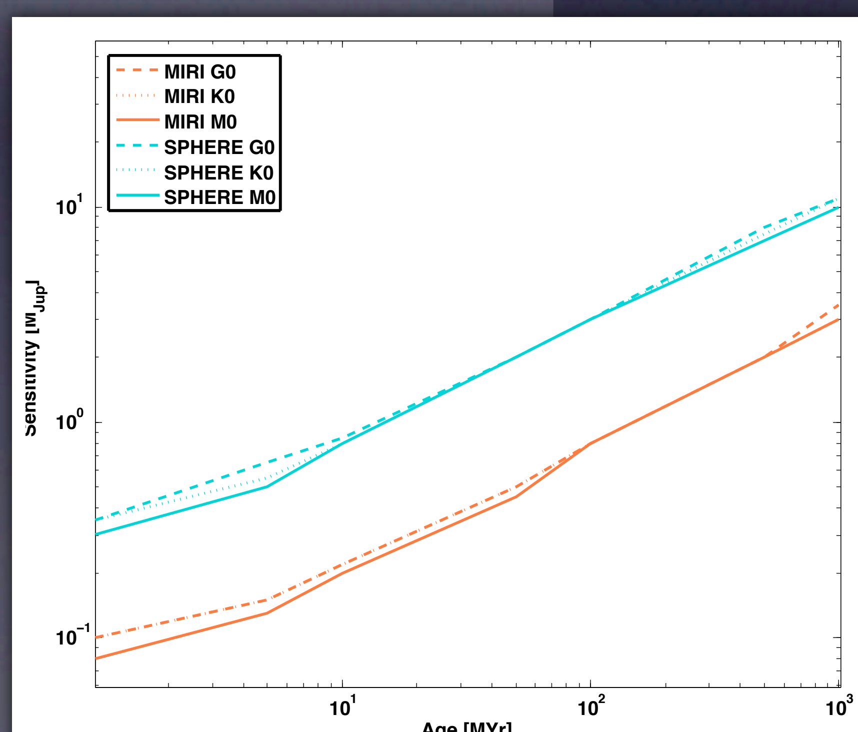
0.2”



0.5”



2”



Conclusions

- MIRI can detect Neptune size planet around M stars
- Ground based telescopes limited by AO sensitivity
- SPHERE more efficient for brighter targets
- EPICS more sensitive but small FOV
- Performances can improve for longer integrations
- What about advanced subtraction methods?

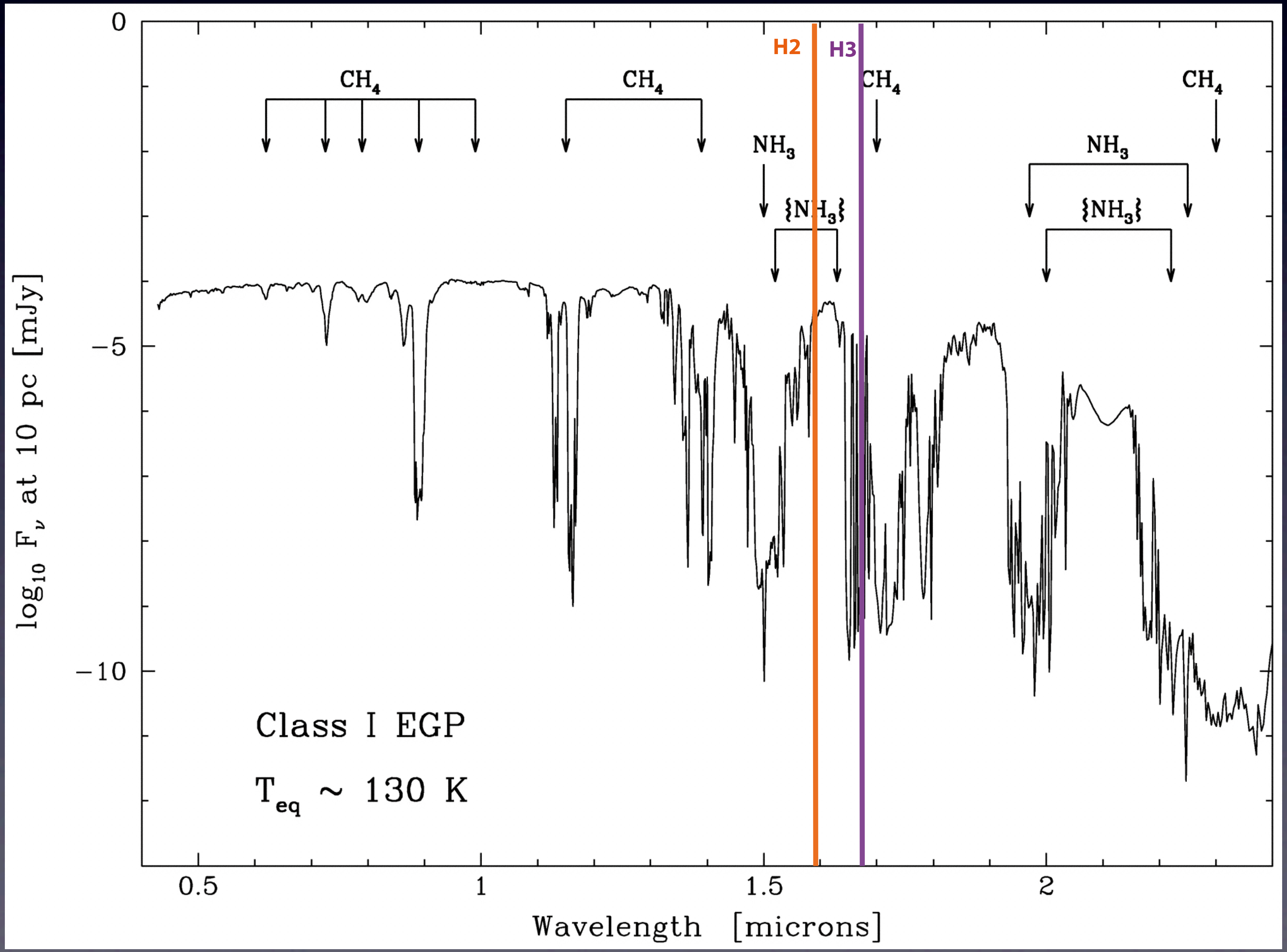
Acknowledgments

- To A. Boccaletti for SPHERE and MIRI simulations
- To C. Verinaud for EPICS simulations

Backup sides

- Cool planets : Teff = 130K
- H2/H3 contrast important

Sudarsky et al. 2003



Backup sides

- Hot planets : Teff = 1000K
- H2/H3 contrast low

Sudarsky et al. 2003