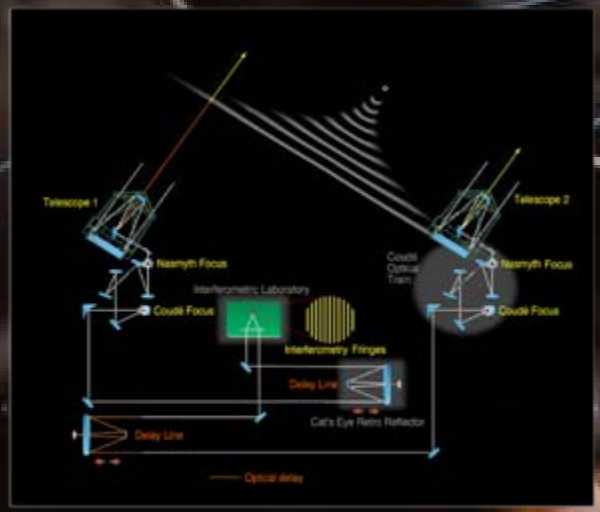
Extrasolar planets

Detection with astrometry



The VLT Interferometer (schematic)

D. Queloz,
Observatoire de l'Université de Genève

Extrasolars planets key themes

planetary formation

- from orbital characteristics
- from mass distribution
- from host star characteristics

physics of planets

- from atmospheric features
- from planet radius
- from planet photometry

Astrometry : required precision

$$\alpha[mas] \approx \frac{M_p[Jup]}{D[pc]} \left(\frac{P[yr]}{M_\star[Sun]} \right)^{2/3}$$

Binary stars :

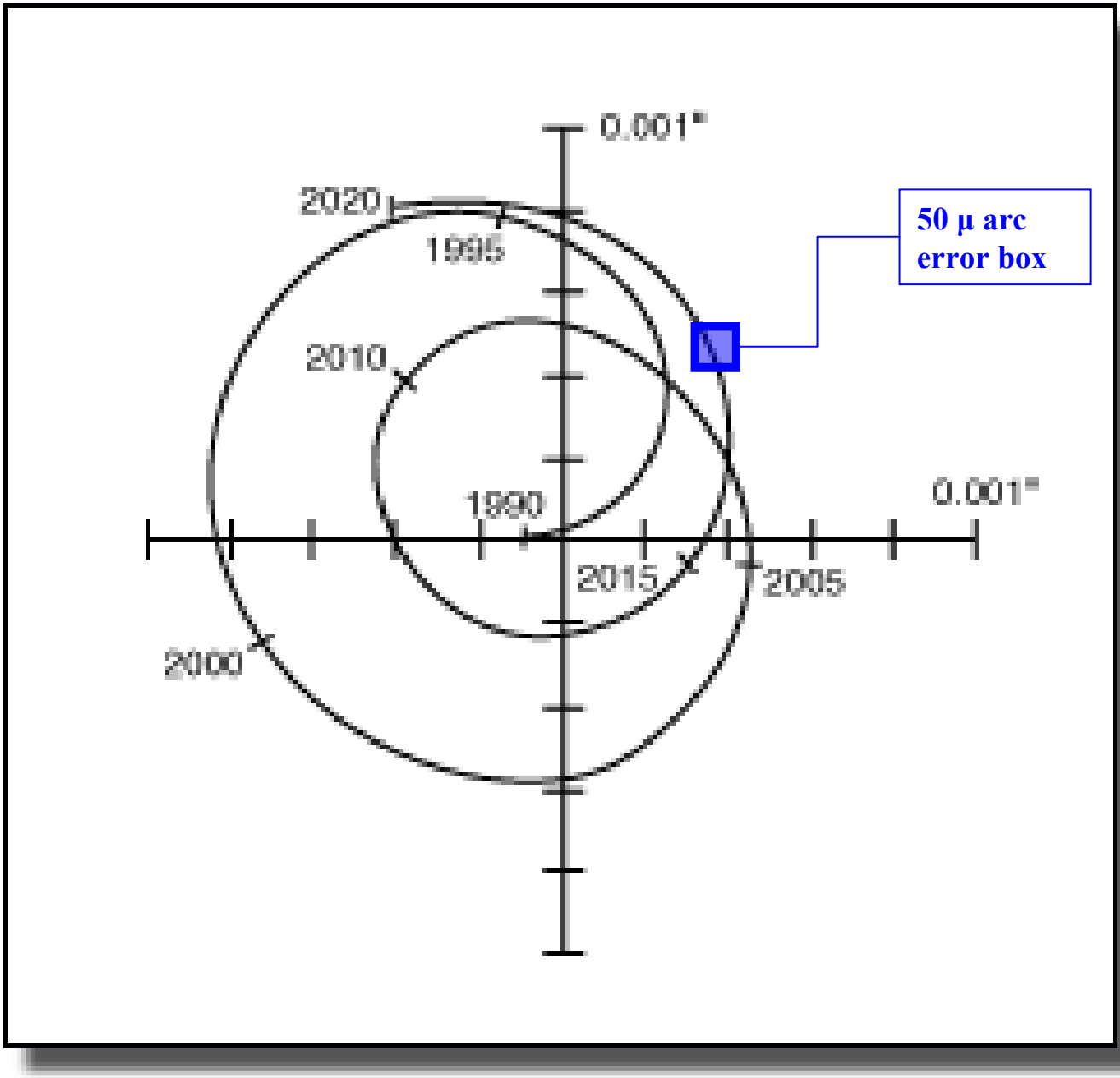
A M6V dwarf (100 M_{jup}) orbiting a G dwarf @ 20pc with P=1yr

α = 5mas

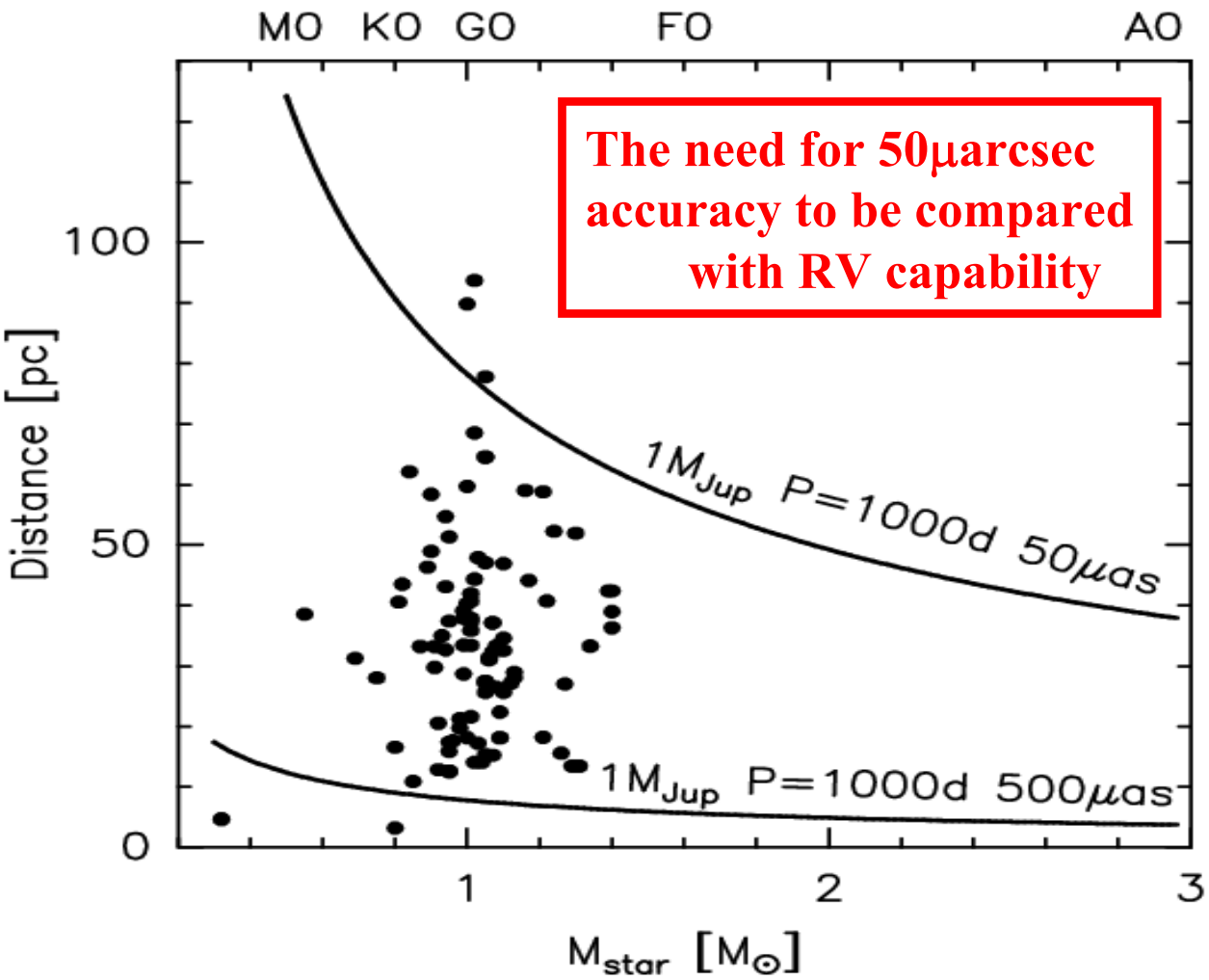
Extrasolar planet :

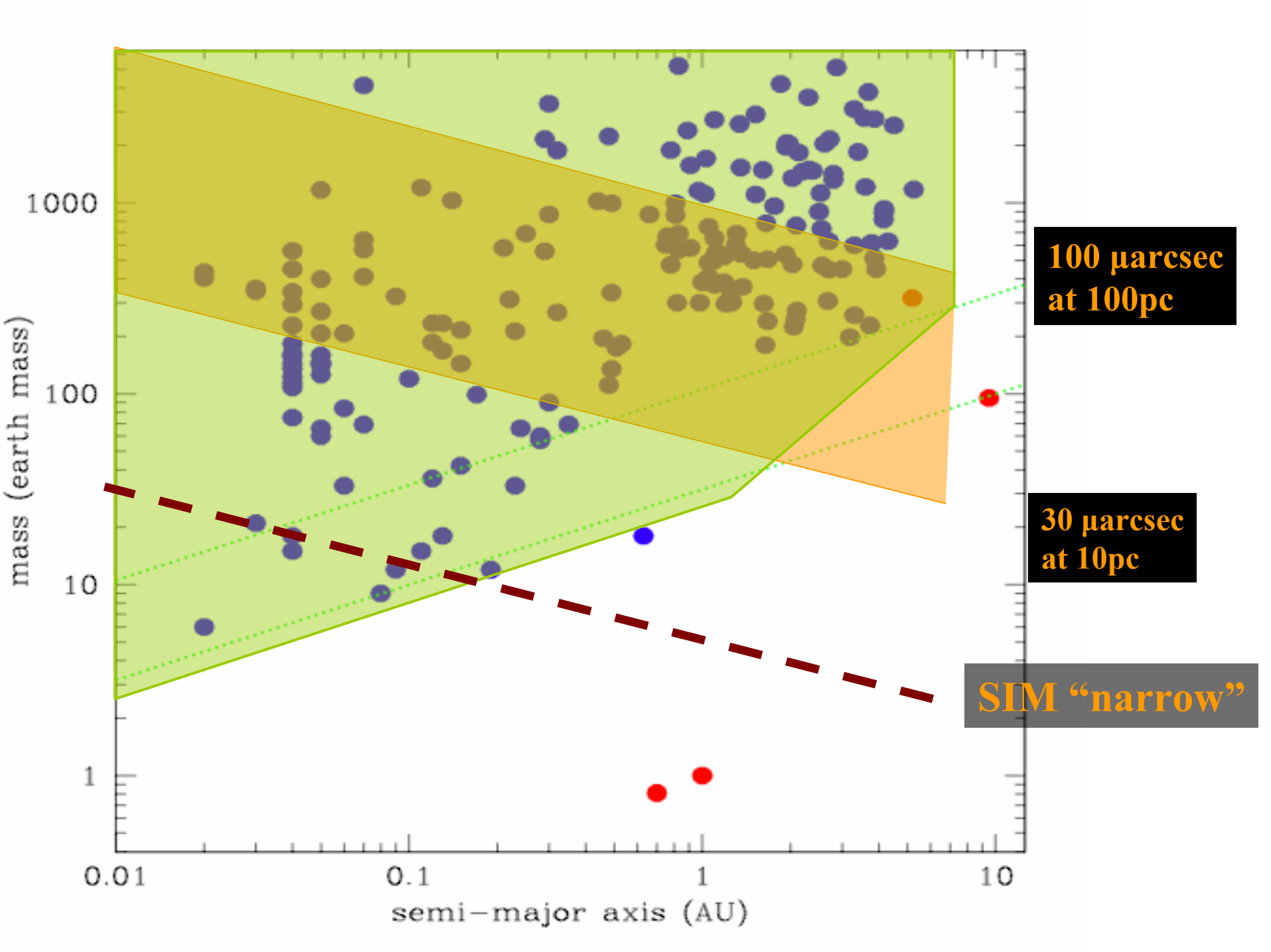
A Jupiter mass planet orbiting a G dwarf @ 20pc with P=1yr

α = 50 μarcsec



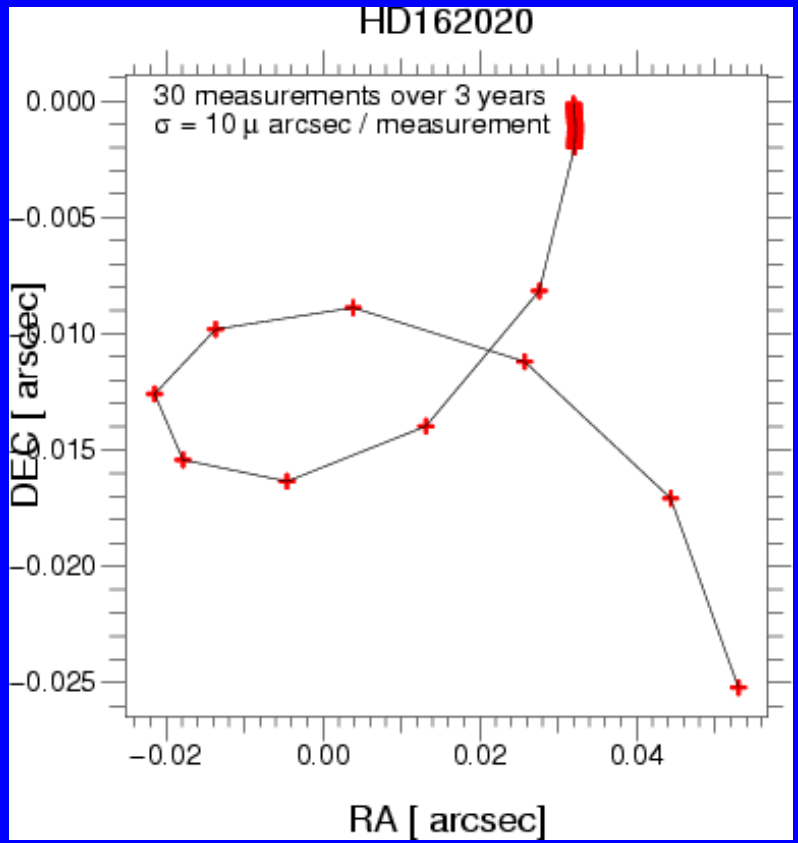
Astrometric displacement of the Sun due to Jupiter as seen from 10 parsecs.

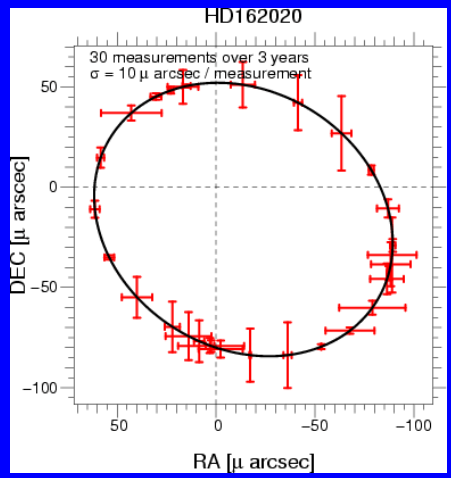

MO
KO
GO
FO
AO
100
50
0
Distance [pc]
1
2
3
M_{star} [$M_\odot$]
$1M_{Jup}$ P=1000d 50μas
$1M_{Jup}$ P=1000d 500μas
The need for 50μarcsec accuracy to be compared with RV capability


1000
100
10
1
mass (earth mass)
0.01
0.1
1
10
semi−major axis (AU)
100 µarcsec
at 100pc
30 µarcsec
at 10pc
SIM “narrow”

Astrometric motion equations

$$\begin{aligned} \xi = &\quad \alpha\cos(\delta) &+\mu_\alpha\cos(\delta)\ (t-t_0)+ &\quad R(t)\,P_\alpha(t)\pi + Y_{orb} \\ \eta = &\quad \delta &+\mu_\delta\ (t-t_0)+ &\quad R(t)\,P_\delta(t)\pi + X_{orb} \end{aligned}$$





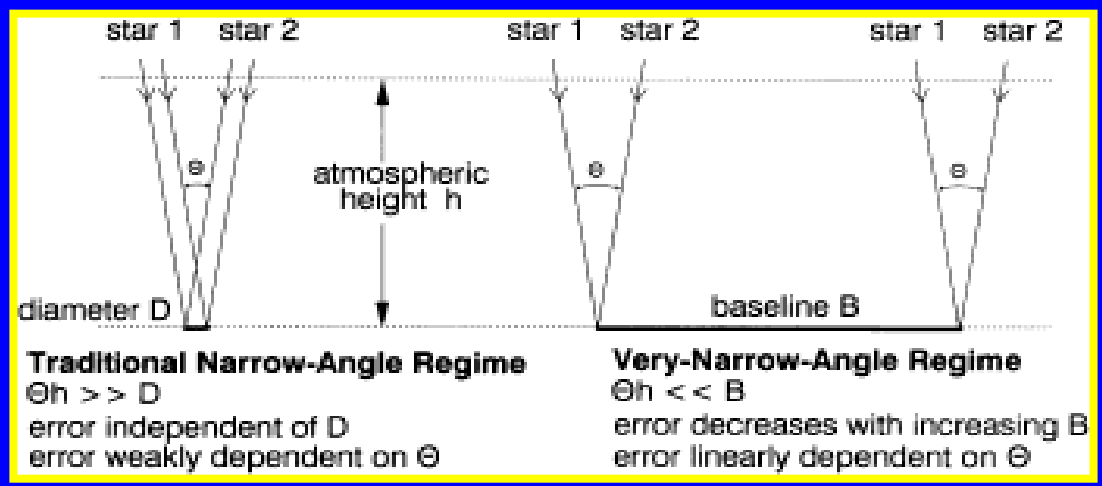
Below the milli-arcsec precision

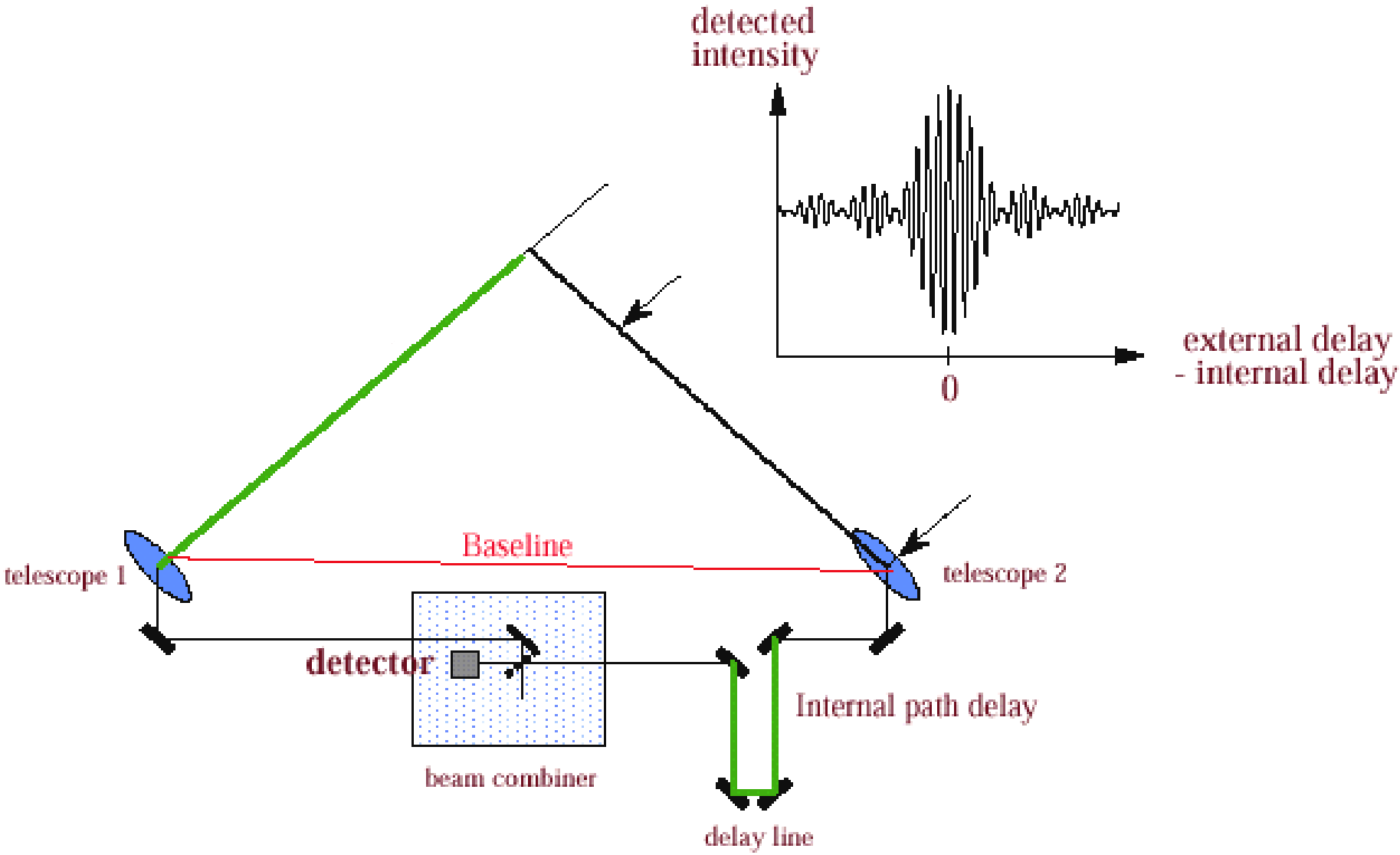
Main ground limitations:

The atmosphere and its turbulence

Solution : Very Narrow angle astrometry

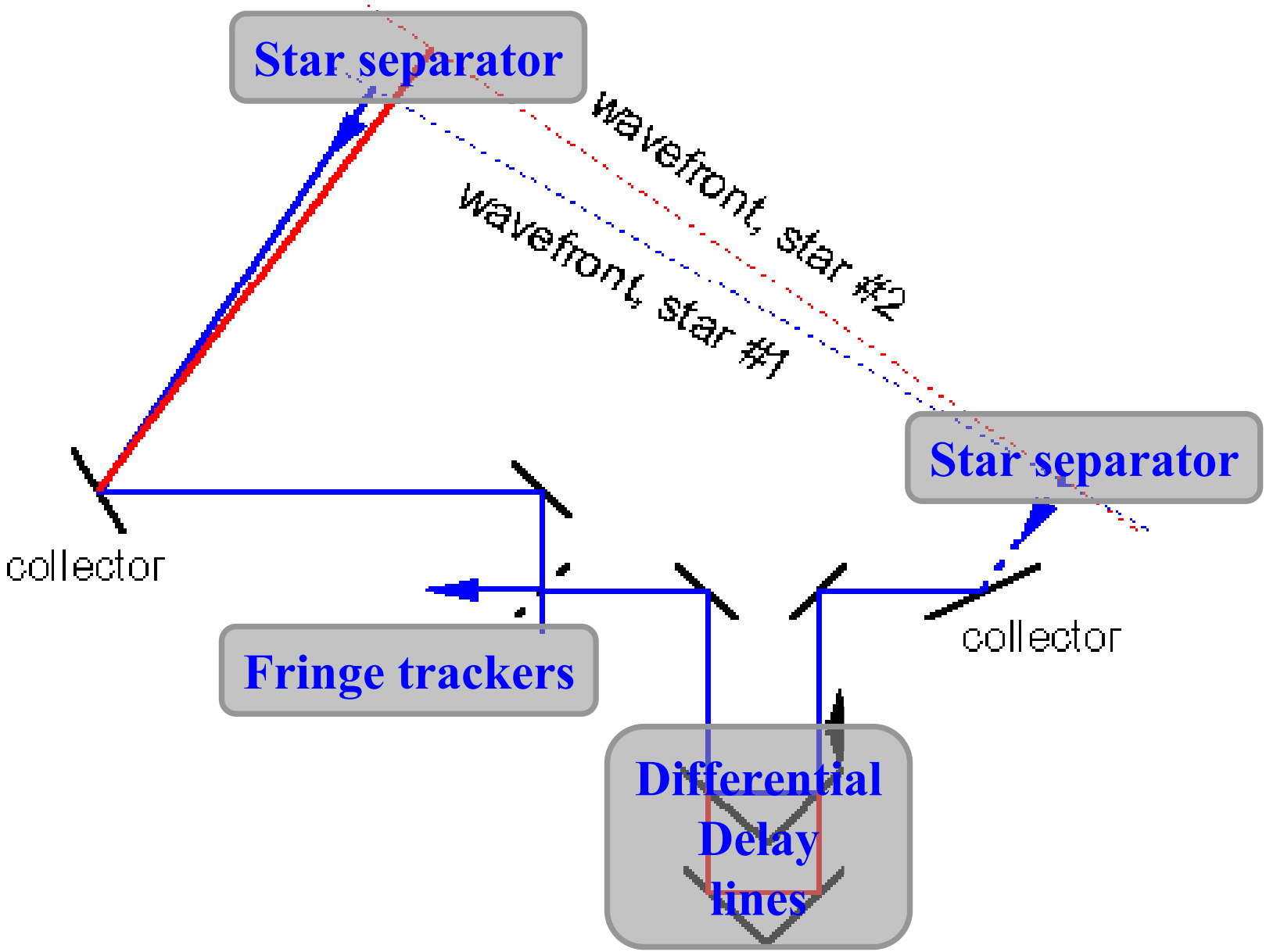
- small $\Delta\theta$ well within the isoplanetic angle (<30arcsec)
- Small $\Delta\theta$ => small refraction angles
- IR observations=> small refraction angles and slower atmospheric effects
- Interferometers with long baselines are more efficient



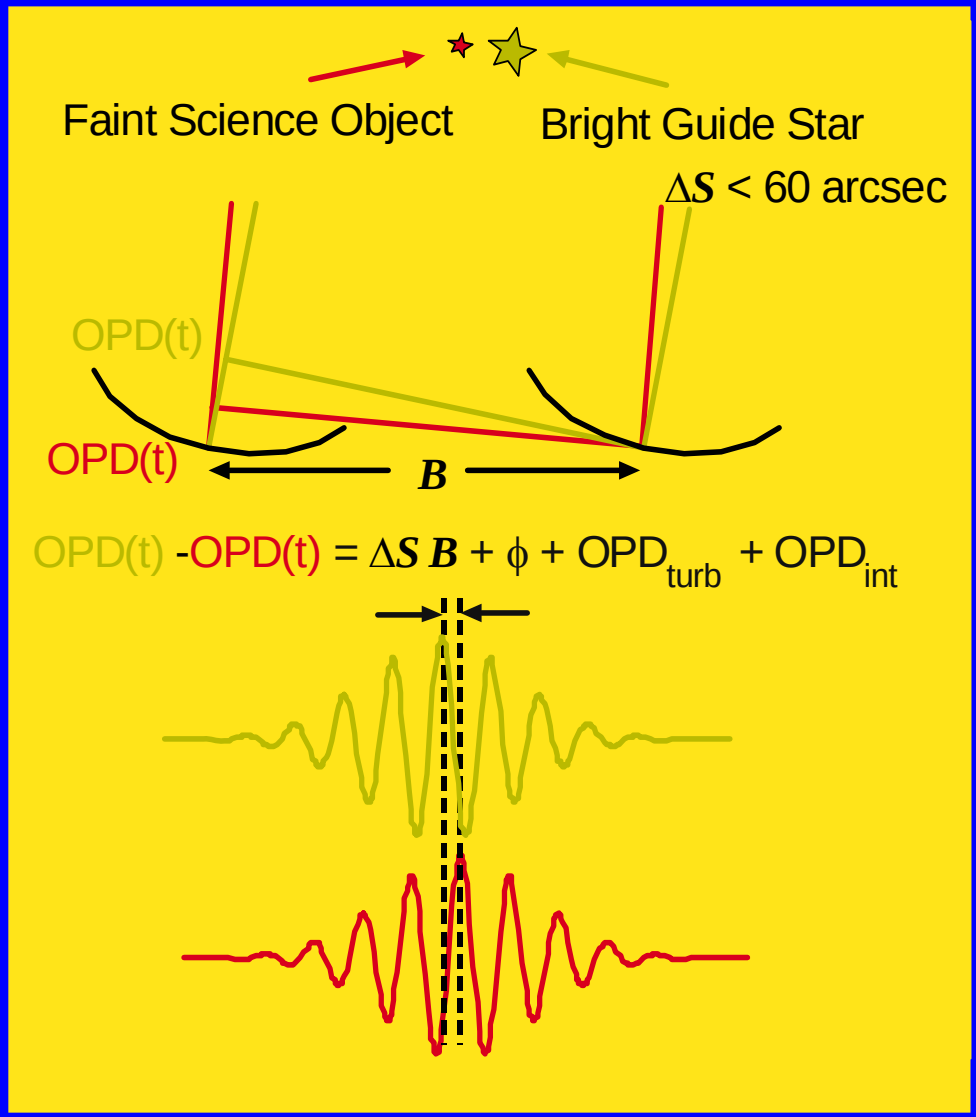


The peak of the interference pattern occurs when the internal path delay equals the external path delay

Astrometry with an Interferometer



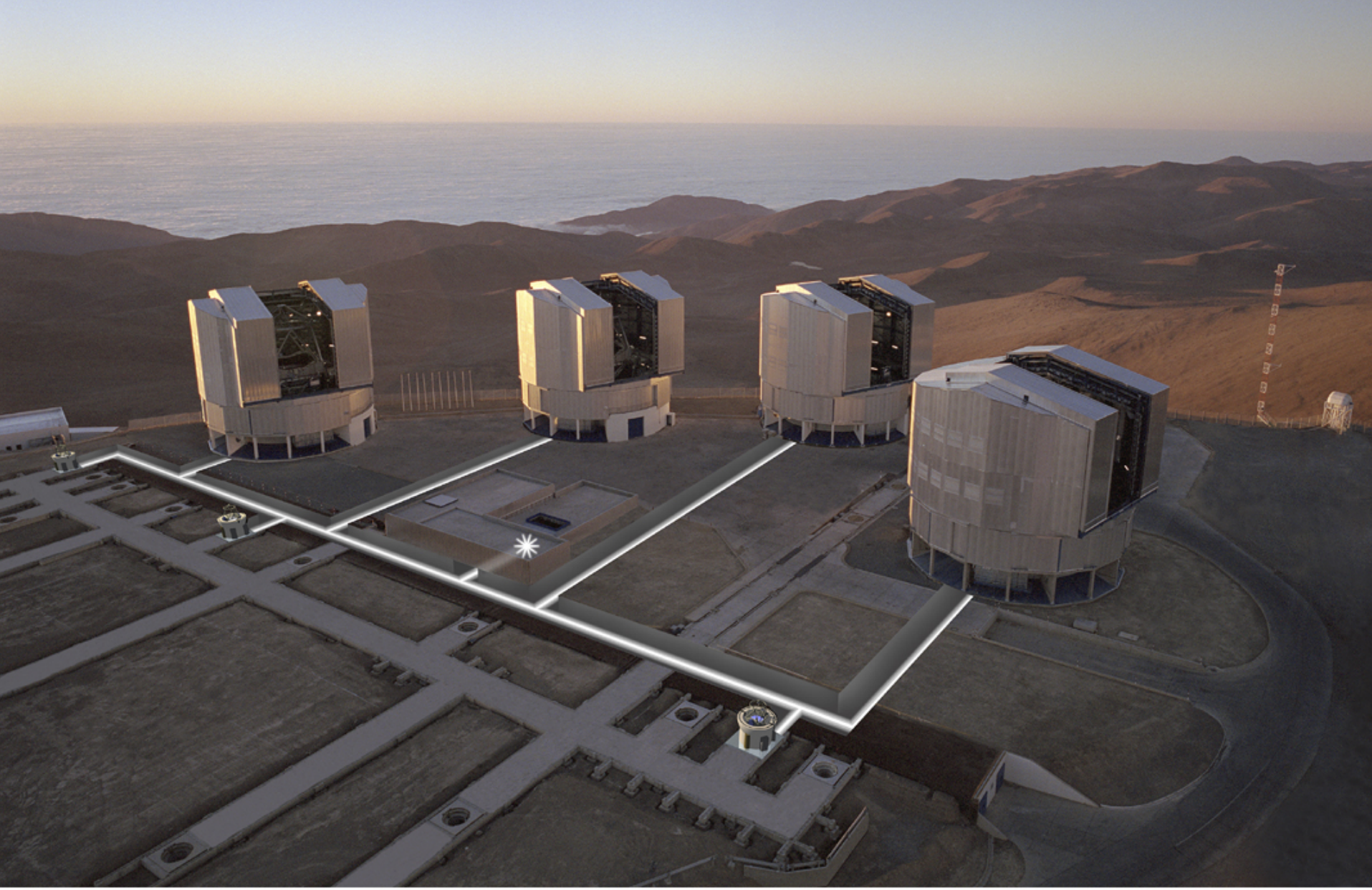
$\Delta OPD = \Delta S \bullet B + \phi + OPD_{turb} + OPD_{int}$



20 μarcsec = $1 \bullet 10^{-10}$ rad
$\Delta S \bullet B$ is 10 nm with 100m

OPD_{turb} averages to zero but it needs integration time…

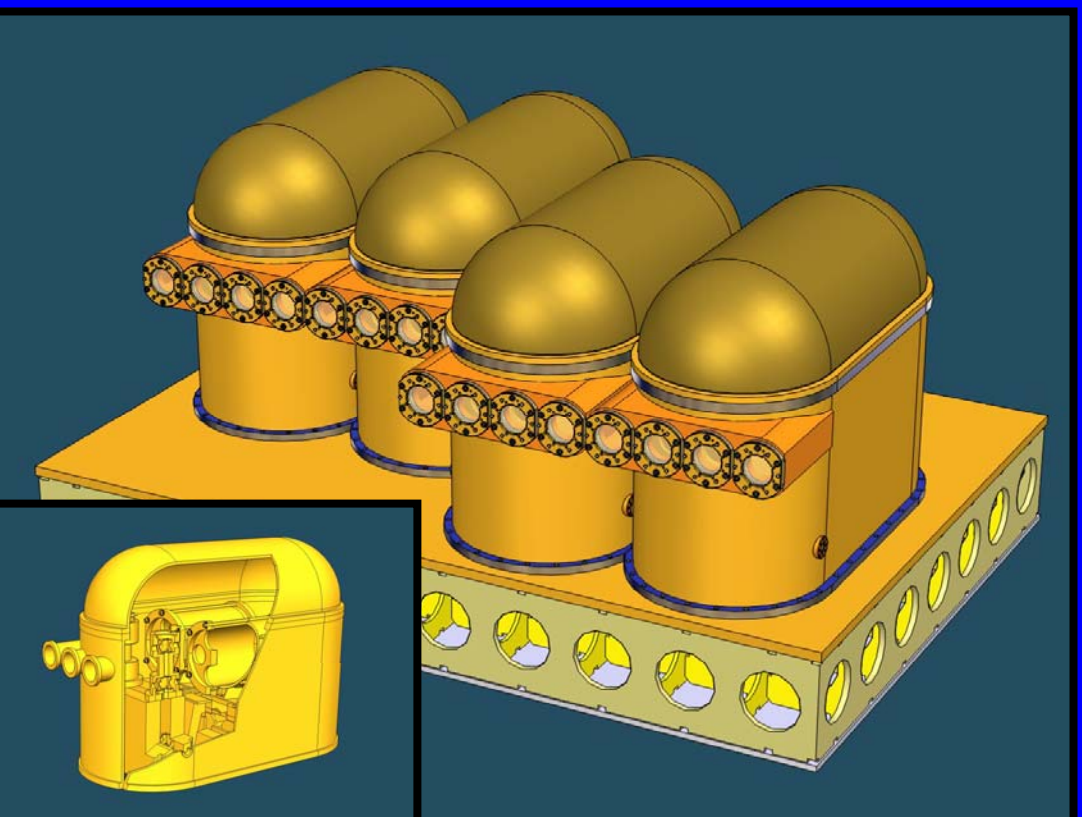
OPD_{int} needs to be measured

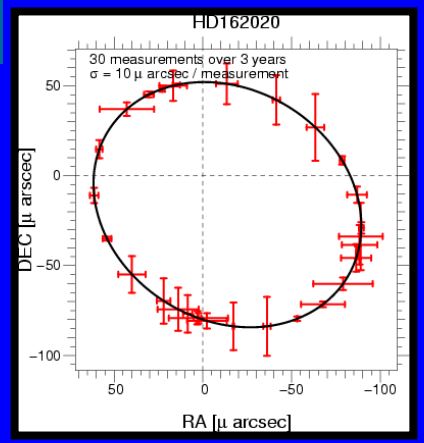


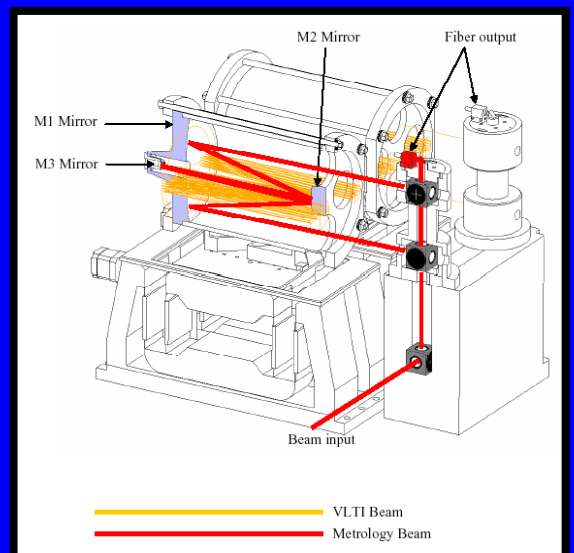
Aerial View of Paranal Observing Platform with VLTI Light Paths

ESO PR Photo 10f/01 (18 March 2001)

PRIMA DDL & AOS Project





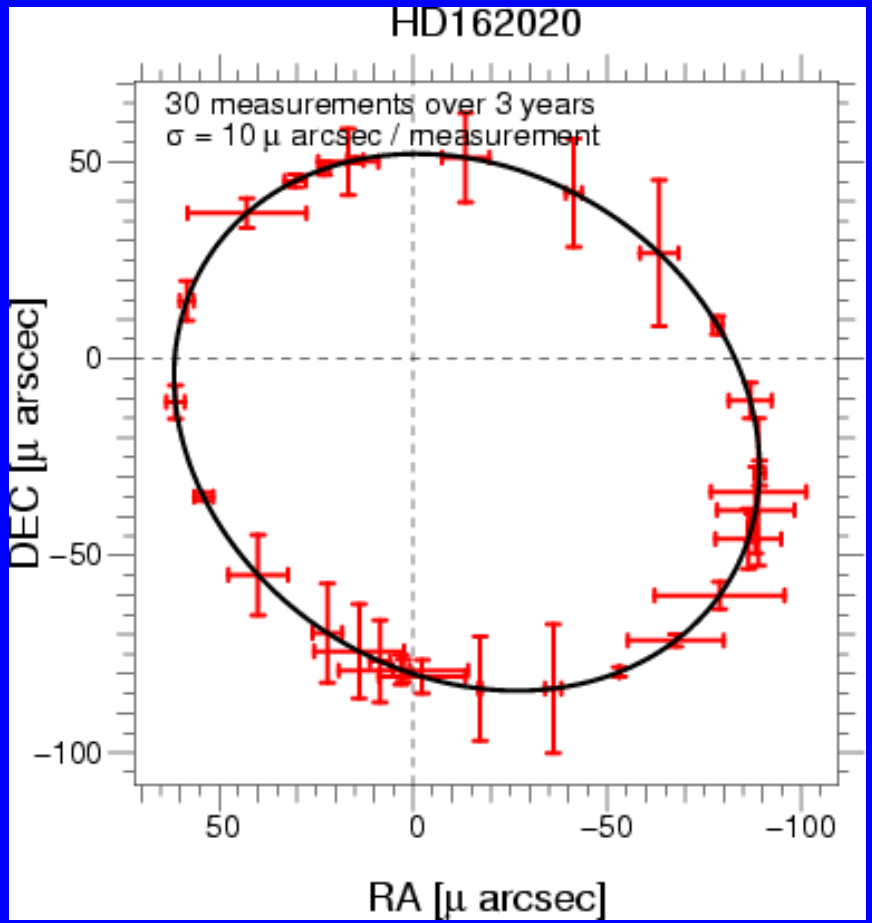


Extra-Solar Planet search with PRIma (ESPRI)

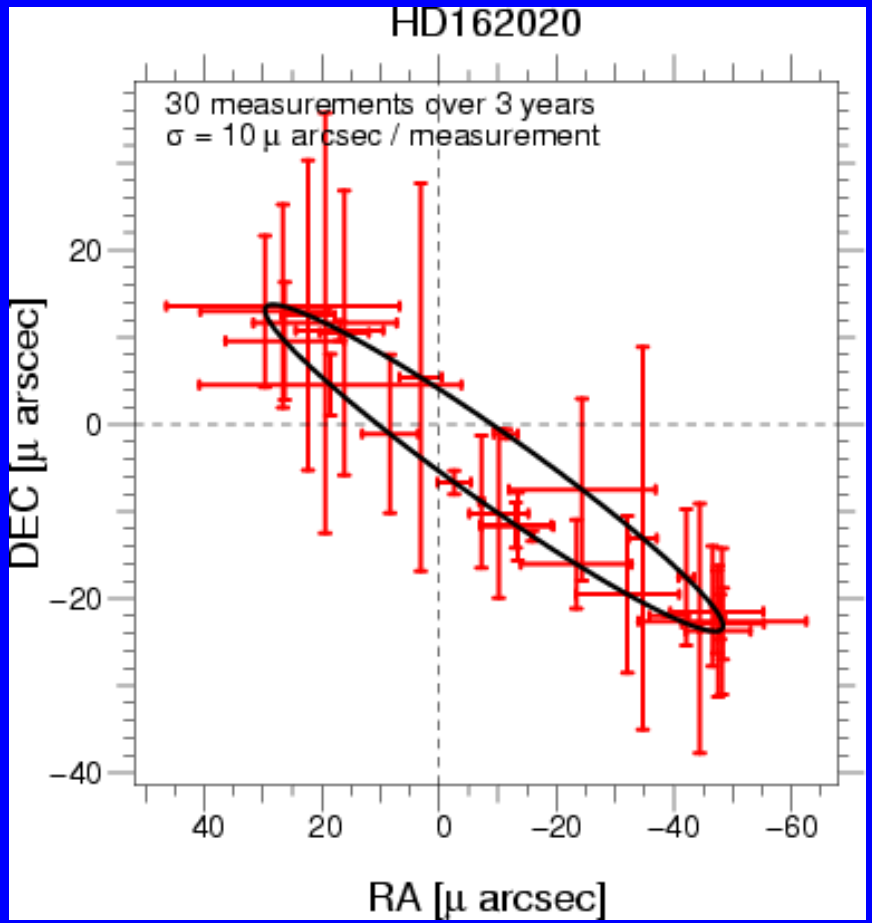
Carry out extra-solar planet searches on nearby stars, using accurate astrometric measurements.
Start of the program in Oct 2008

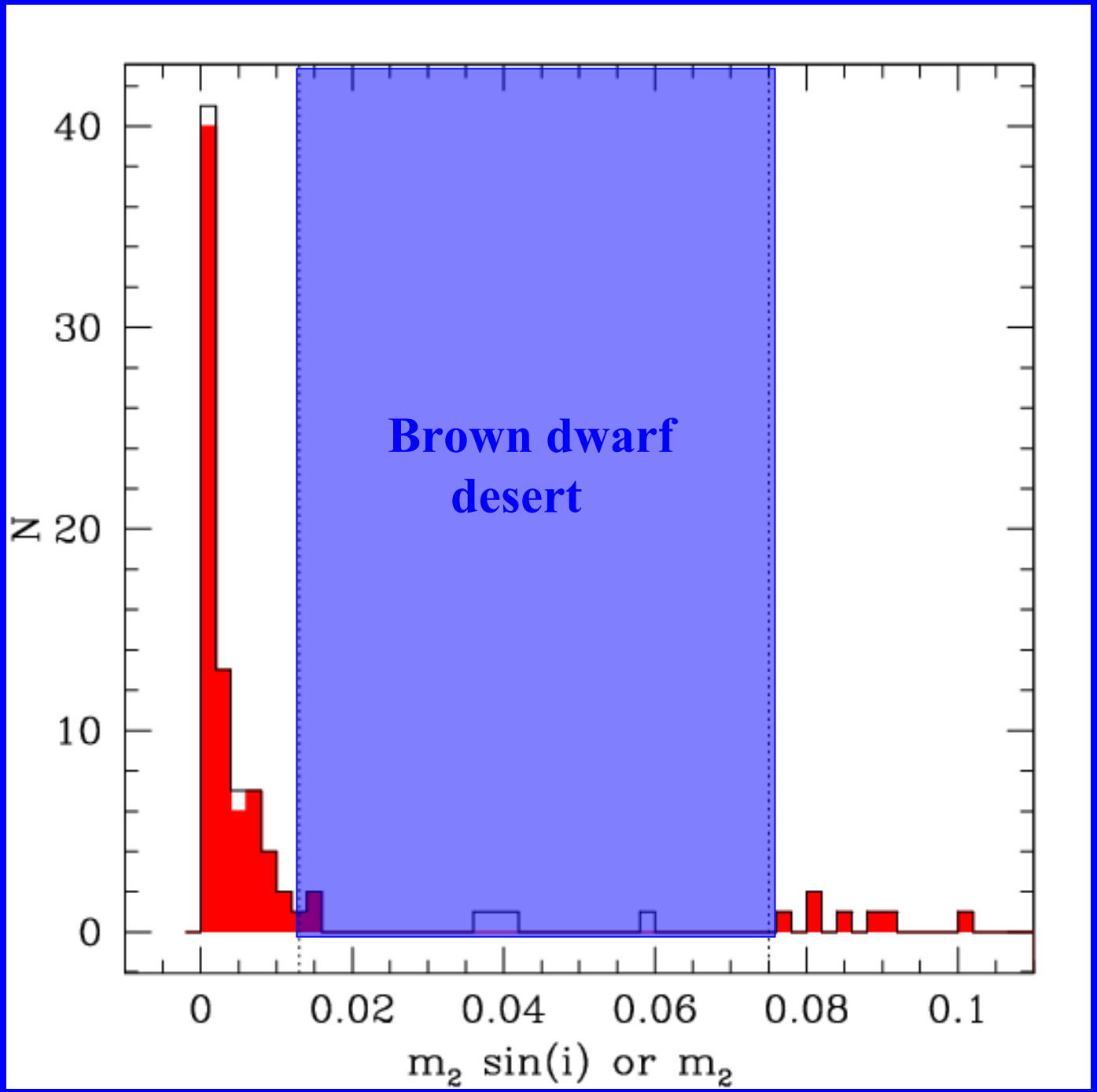
- Mass measurements of known systems
- Multiple systems inclinations
- Search on "other stars not RV suitable"
  - active stars
  - massive stars
- Search on "nearby stars"

sin i =0.5

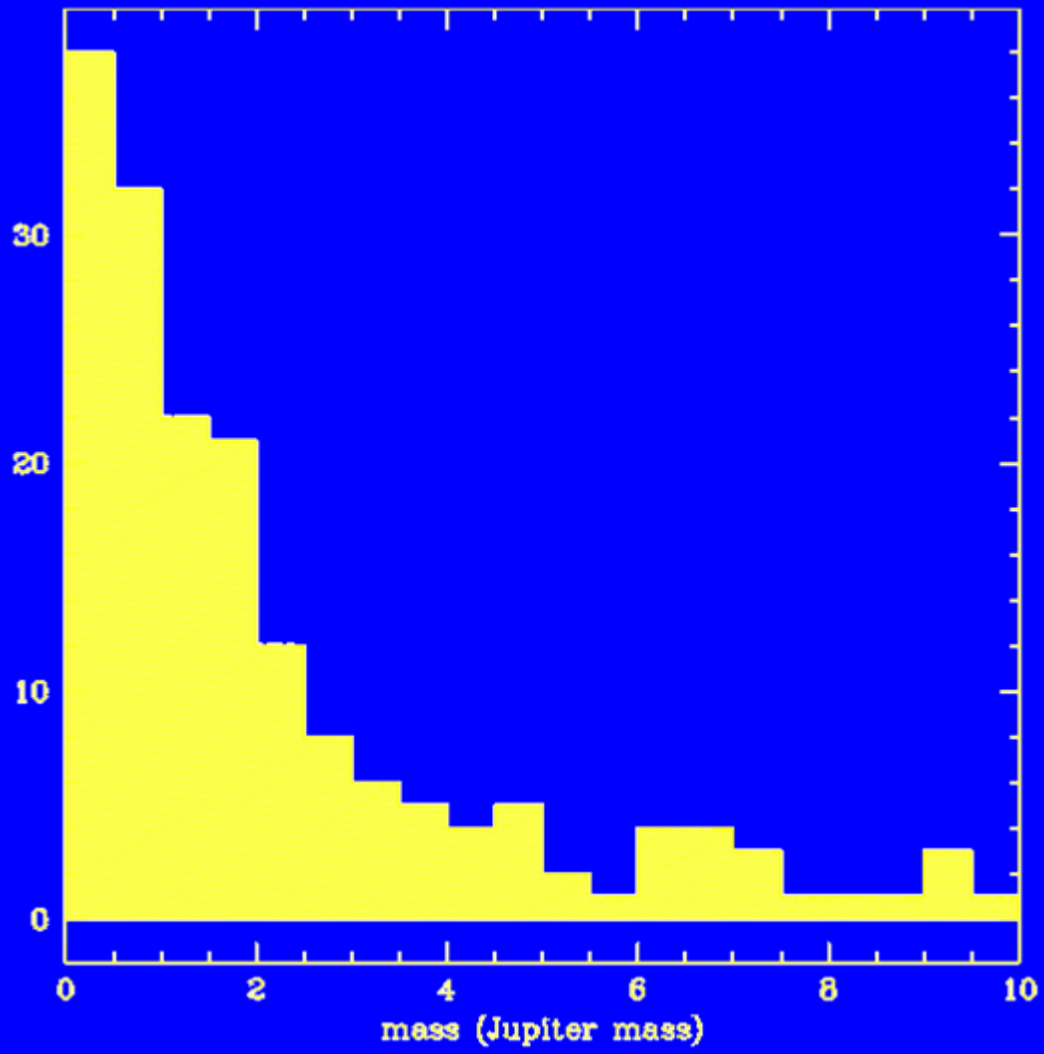


sin i =0.99




Brown dwarf
desert
N
40
30
20
10
0
0
0.02
0.04
0.06
0.08
0.1
m2 sin(i) or m2

Planet Mass Distribution



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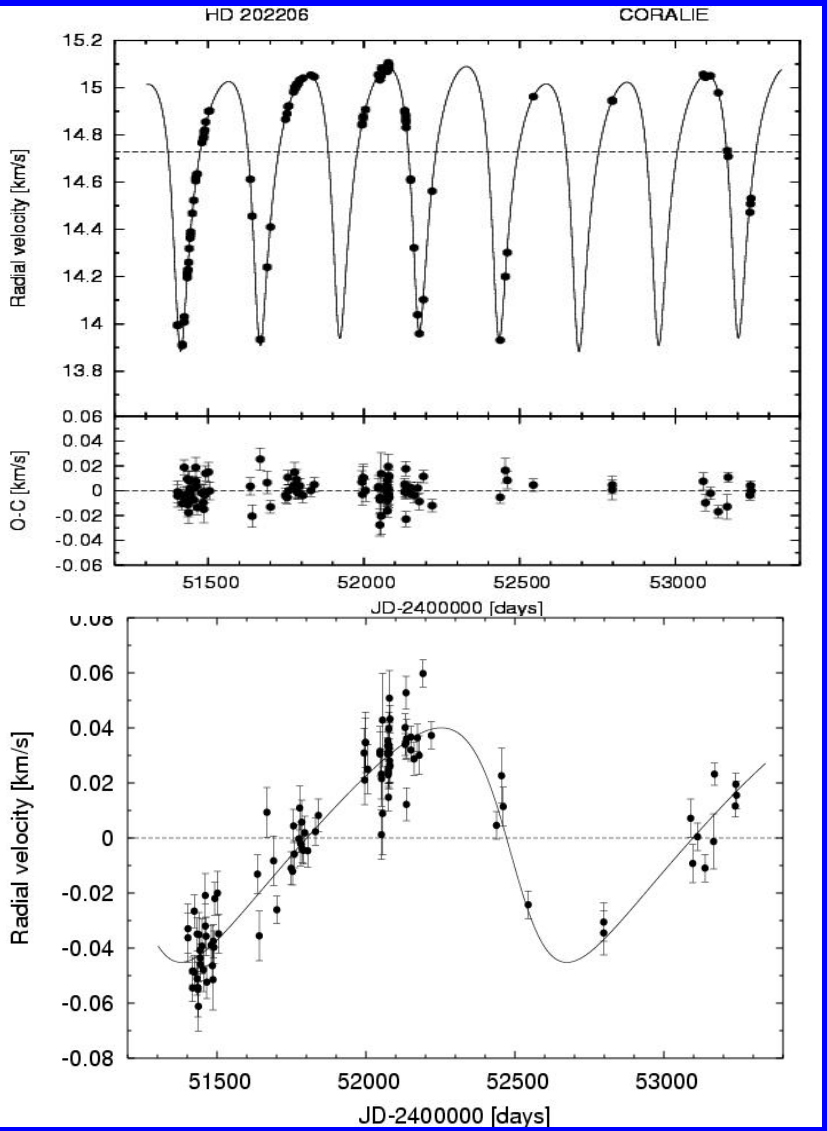
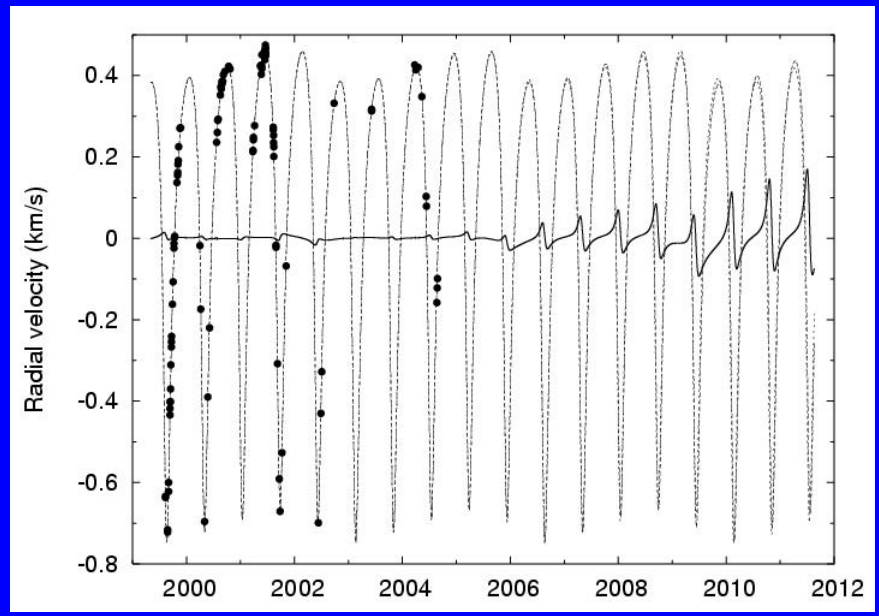
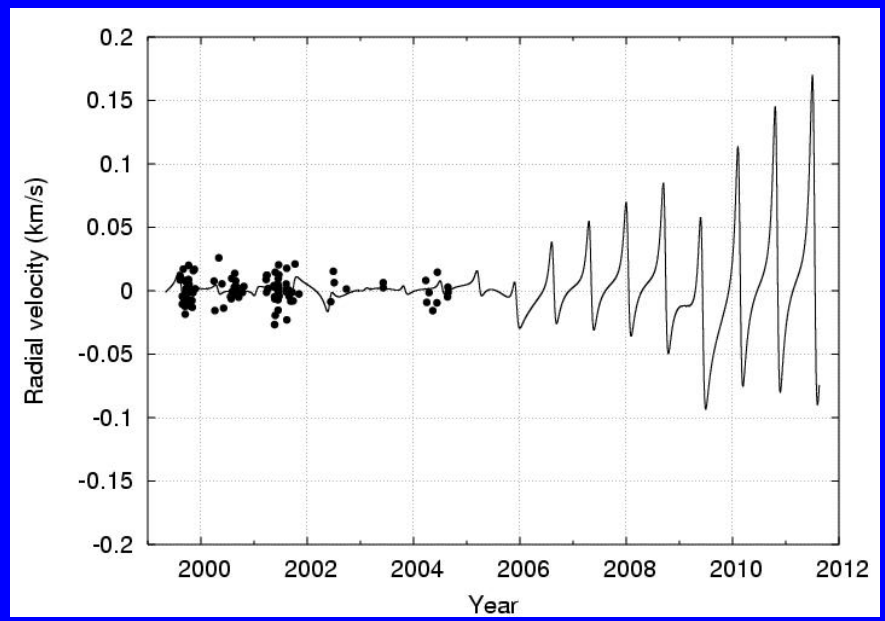
Multi-planetary systems: HD202206







- P1 = 256 d m1=17.5 M_{Jup}
- P2 = 1383.5 d m2= 2.5 M_{Jup}

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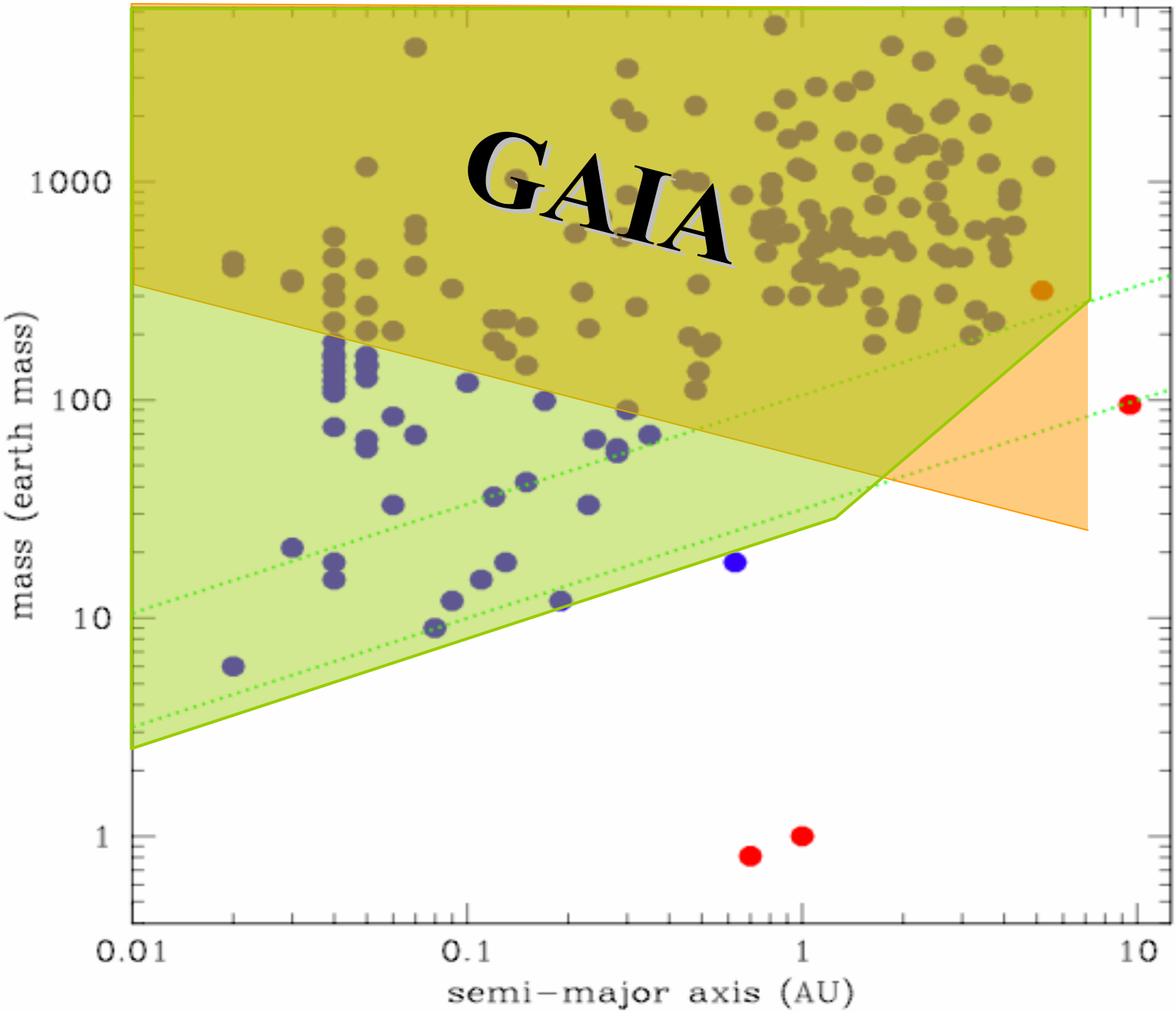
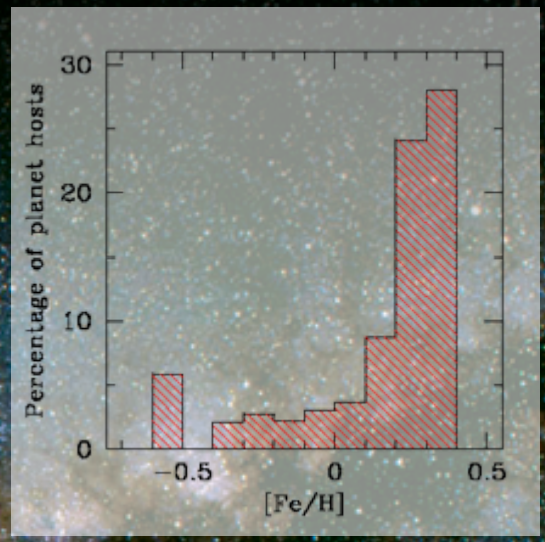

GAIA
1000
100
10
1
mass (earth mass)
0.01
0.1
1
10
semi−major axis (AU)

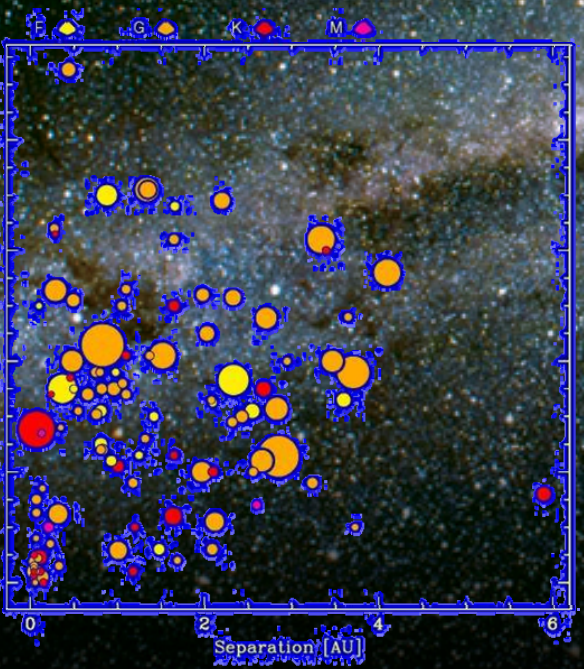
GAIA

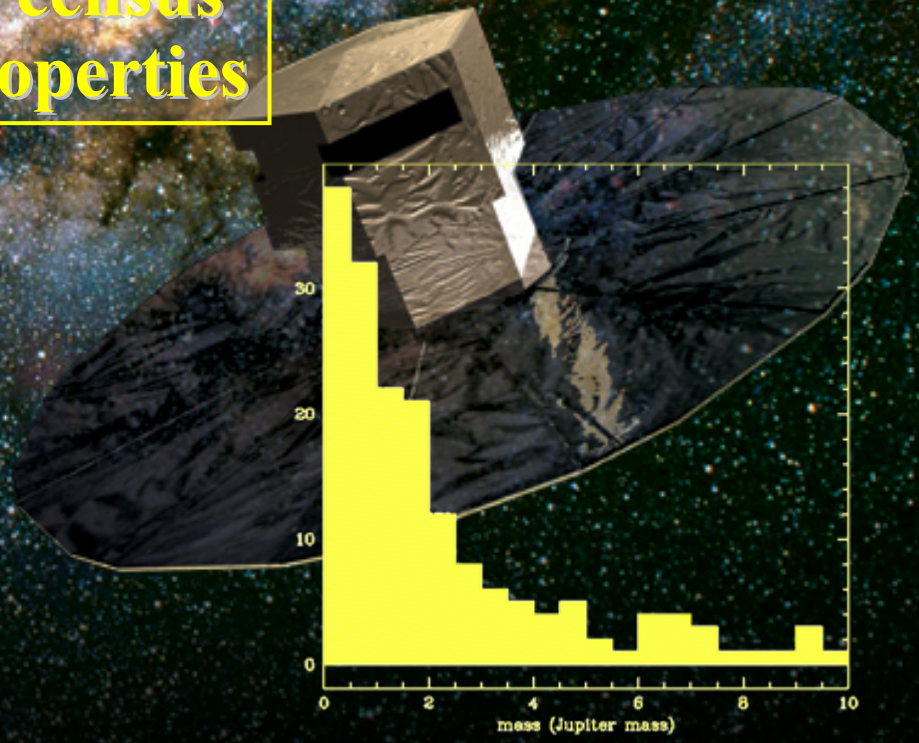
$$\sqrt{60^2 + 40^2}/\sqrt{11} \approx 20 \mu arcsec$$

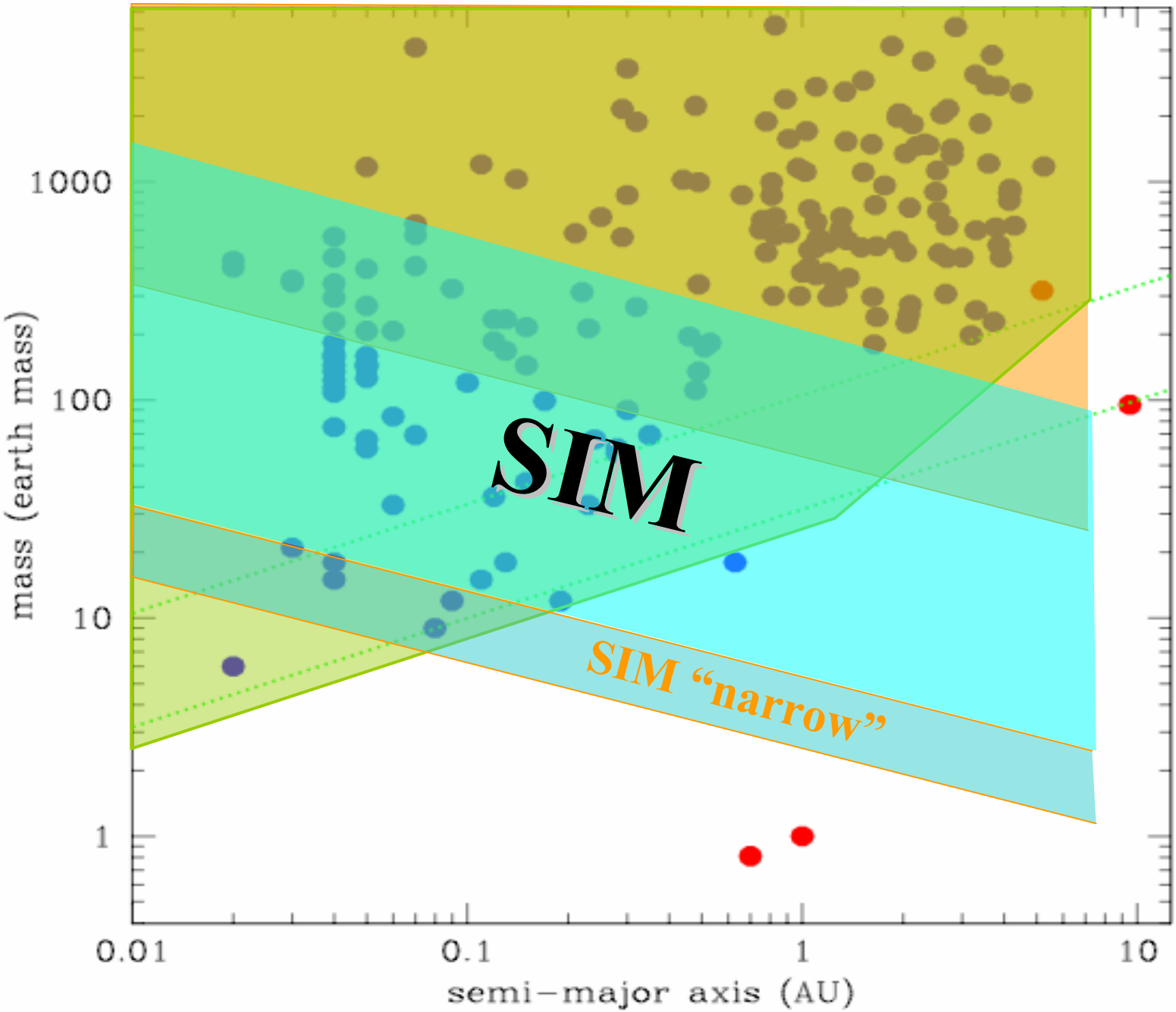
About 5000 planets expected on stars inside 200 pc with 10 > mv >15



A statistical census of planet properties

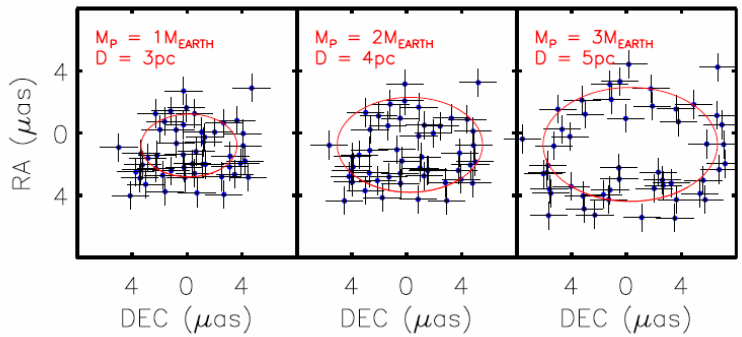


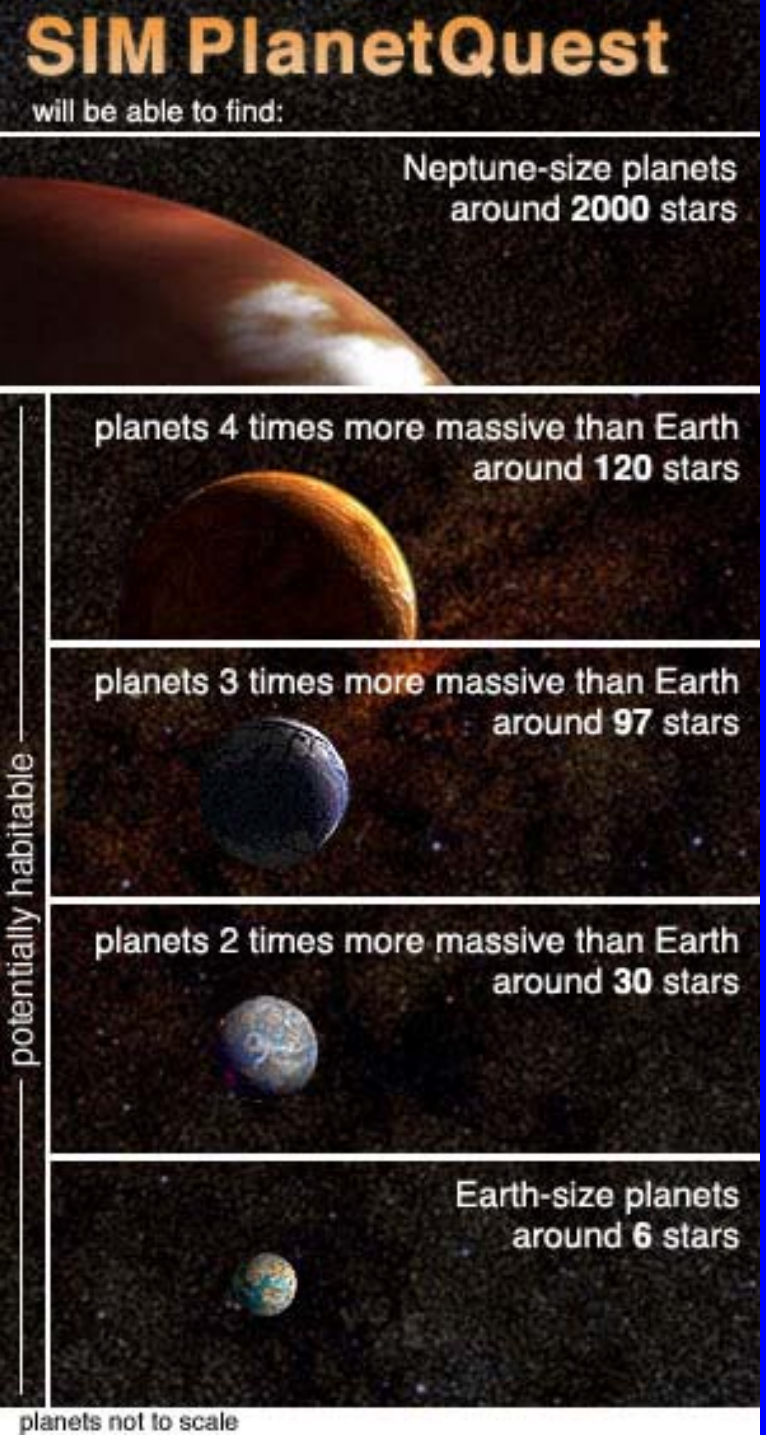



1000
100
10
1
mass (earth mass)
0.01
0.1
1
10
semi−major axis (AU)
SIM
SIM “narrow”

SIM planet survey

Scenario	Target Brightness	Observation Period	Requirement
Planet-Finding	6 mag	Single visit, 1000 s/visit	1.12 μas
Legacy Narrow Angle	10 mag	Single visit, 1000 s/visit	1.48 μas
Narrow Angle (faint)	13 mag	Single visit, 1000 s/visit	3.24 μas
Grid Stars	10.6 mag	5 year mission accuracy	3.47 μas
Legacy Wide Angle	18 mag	5 year mission accuracy	5.38 μas
Wide Angle	19 mag	Single visit, 2000 s	41 μas
2000 Decadal Review			*Floor*
Narrow Angle			3 μas
Wide Angle			10 μas





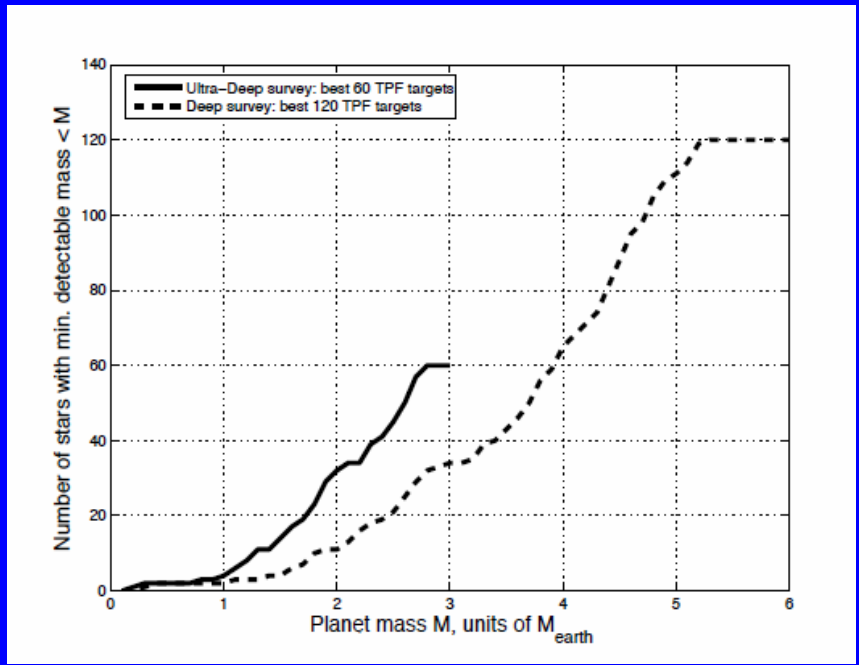
EPIcS

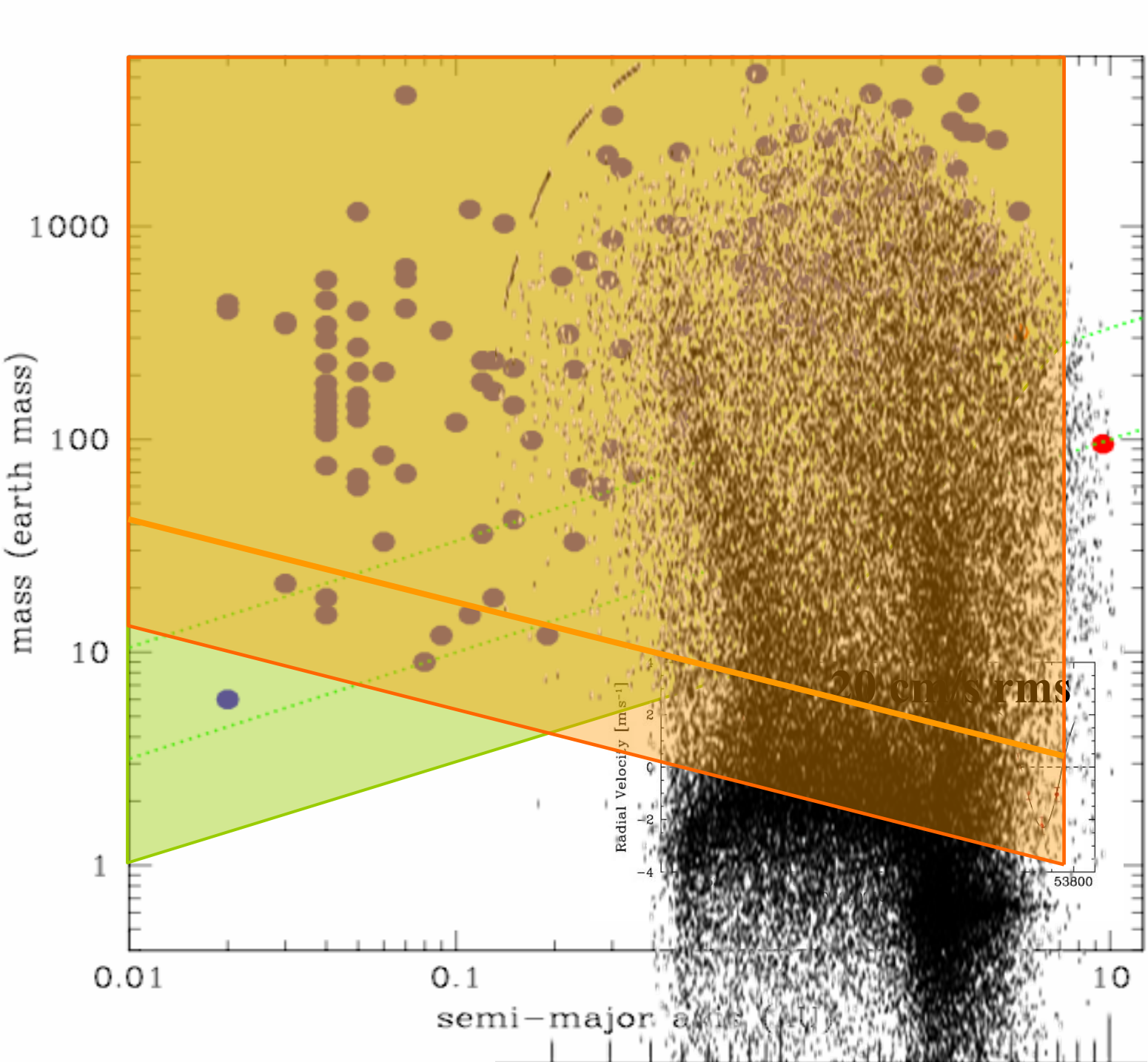
Wide survey

2000 stars at 5 μarcsec

Narrow angle survey (1 μarcsec):

- ***ultra deep* 60 stars, 200 meas./star**
- ***deep survey* 120 stars, 100 meas./star**




1000
100
10
1
mass (earth mass)
0.01
0.1
10
semi−major a
20 cm/s rms
Radial Velocity [m s^{-1}]
2
0
−2
−4
53800