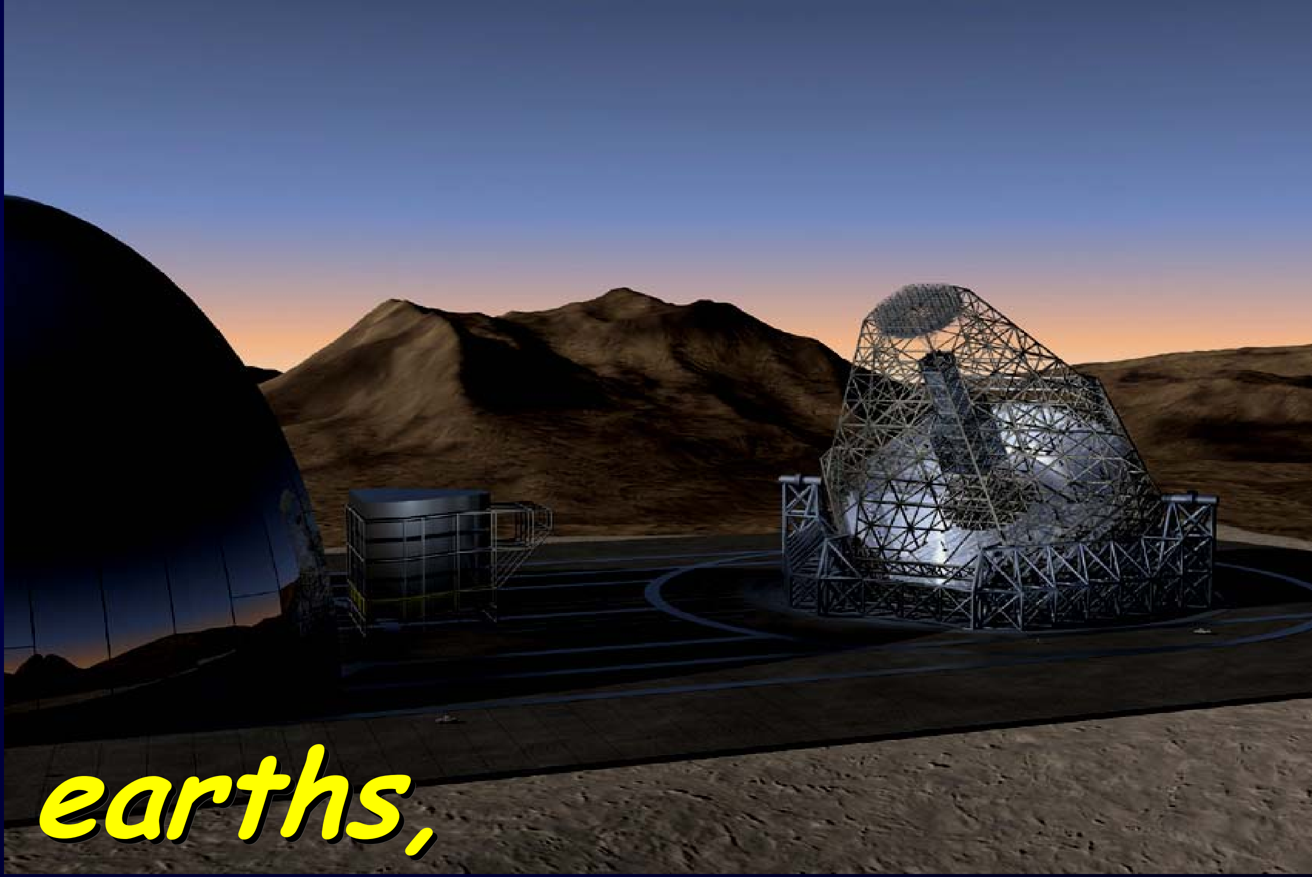


Down to earths,

with OWL

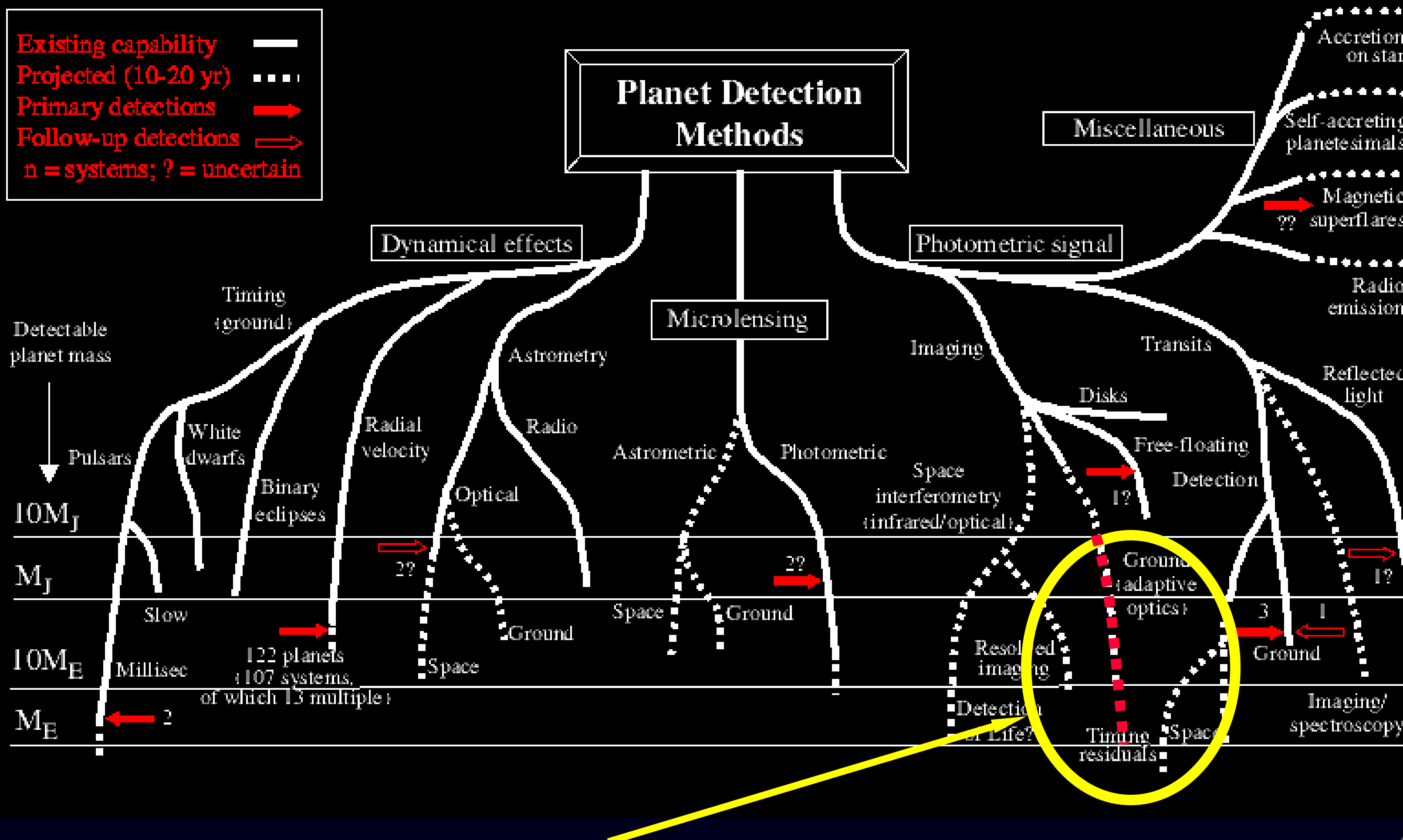
Olivier Hainaut, Roberto Gilmozzi

European Southern Observatory

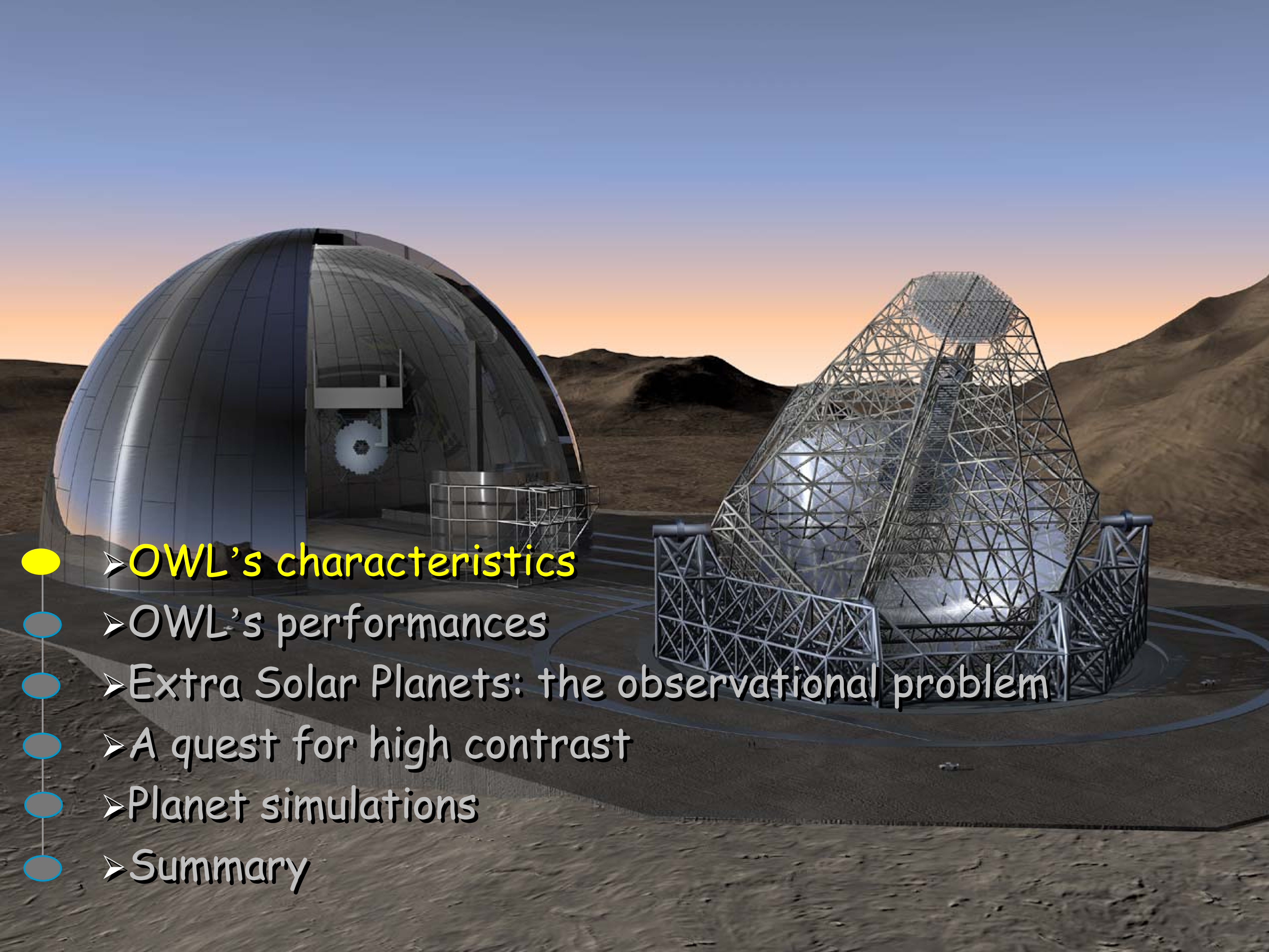
Planet Detection Methods

Michael Perryman, Rep. Prog. Phys., 2000, 63, 1209 (updated May 2004)

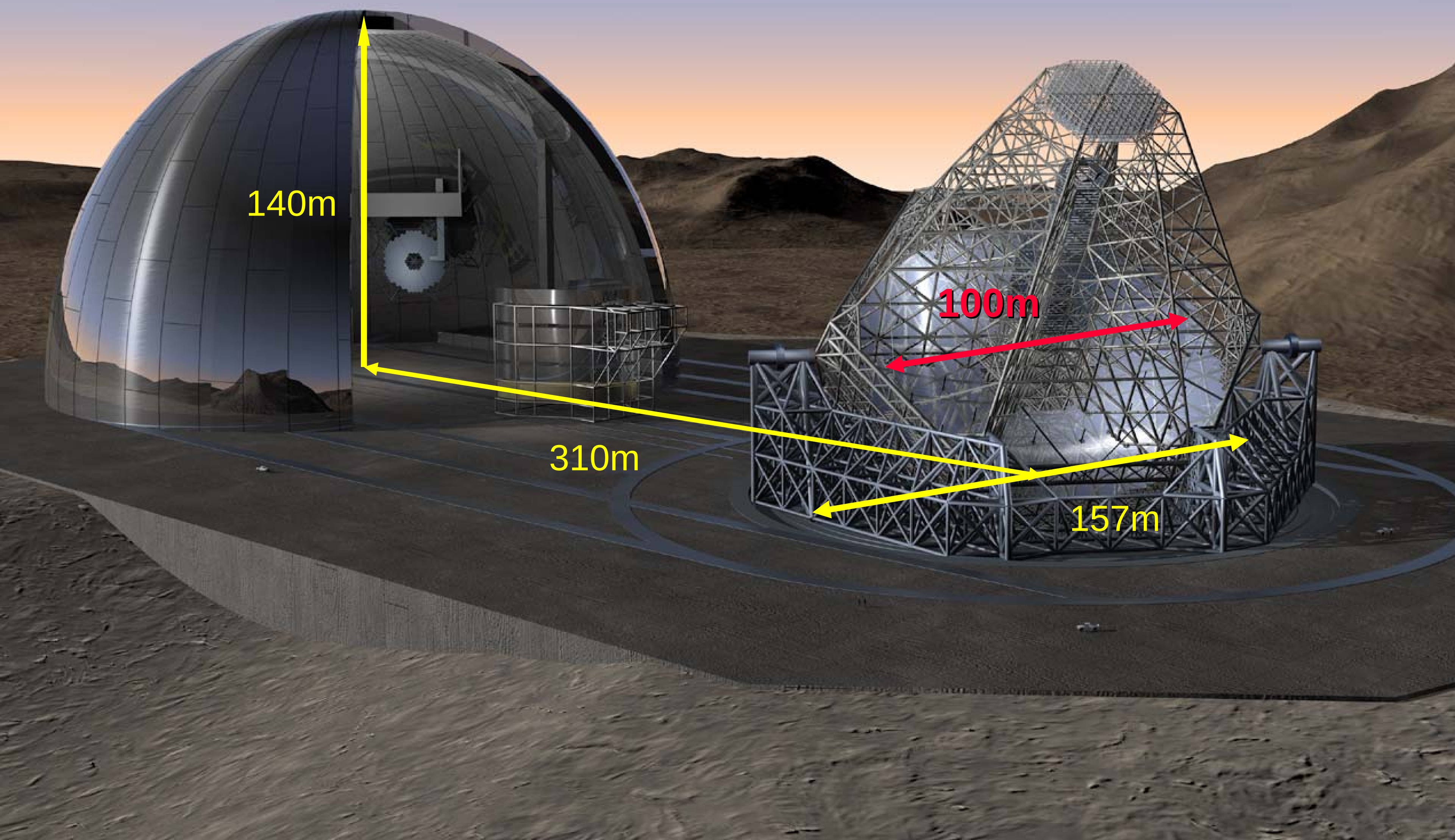
[corrections or suggestions please to michael.perryman@esa.int]



This talk: ground, adaptive optics, projected (10-20yrs)

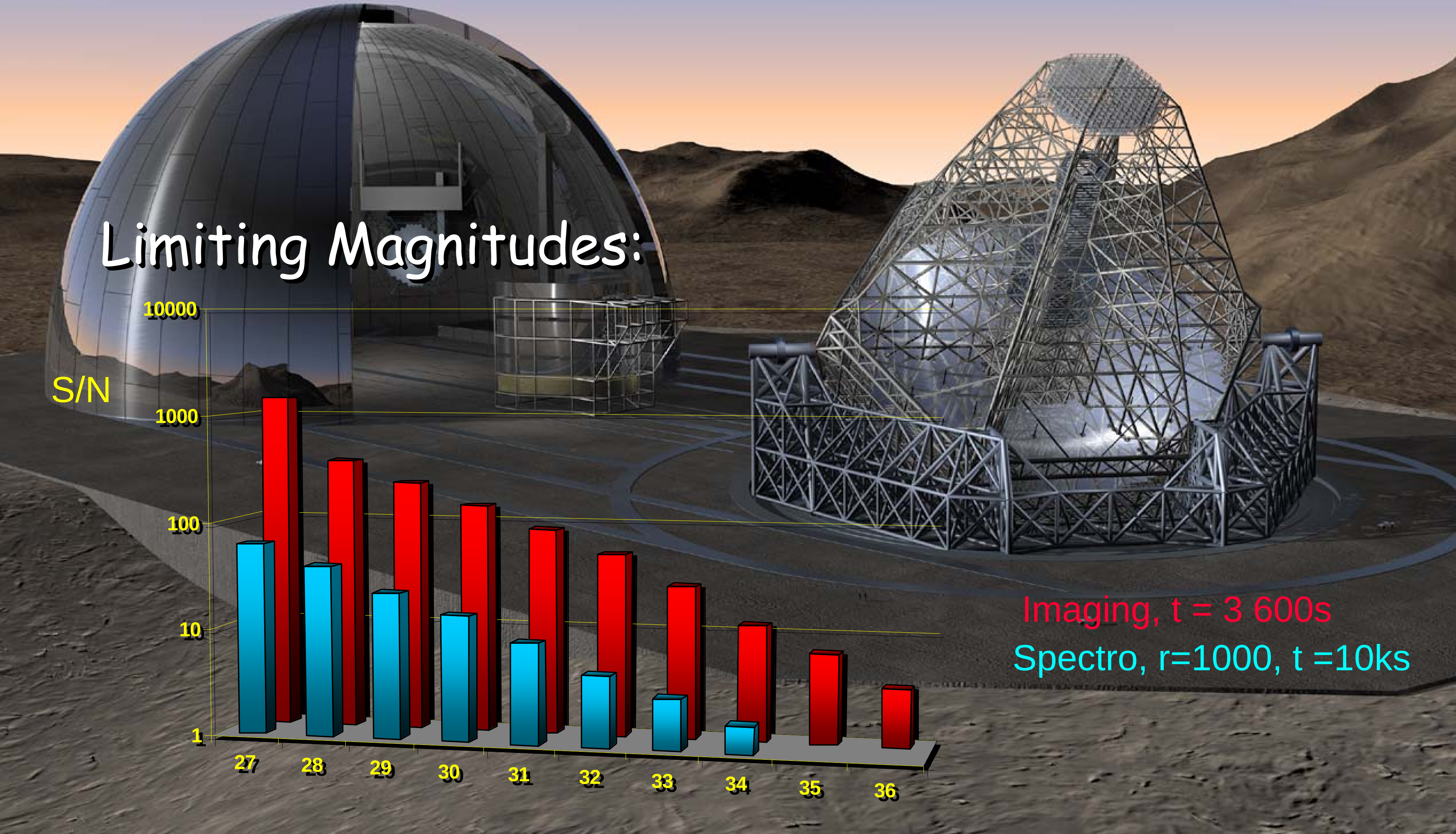

➢OWL's characteristics
➢OWL's performances
➢Extra Solar Planets: the observational problem
➢A quest for high contrast
➢Planet simulations
➢Summary

OWL's characteristics

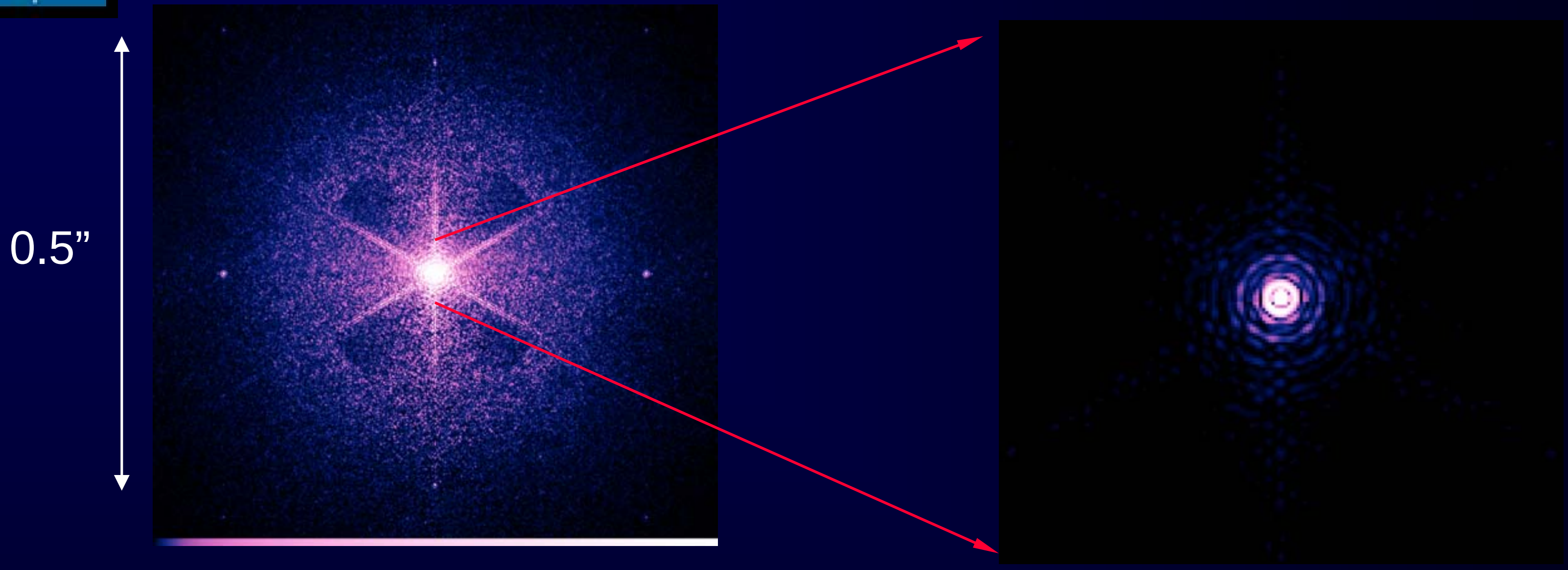


OWL's performances

Limiting Magnitudes:

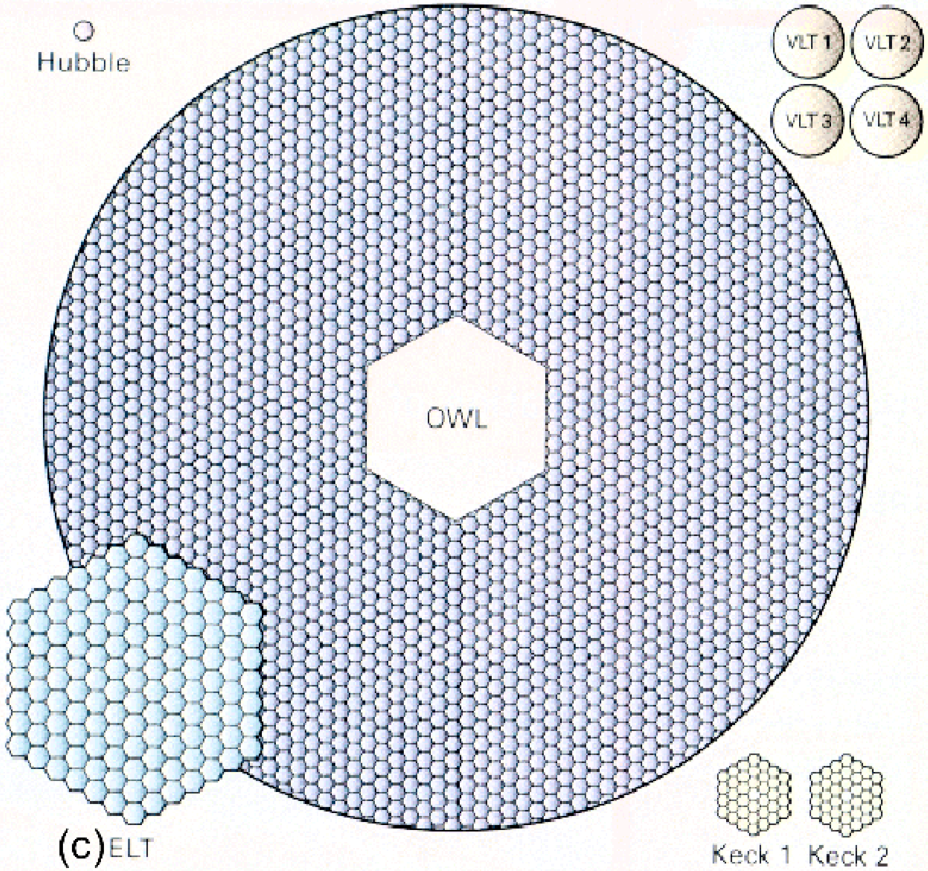


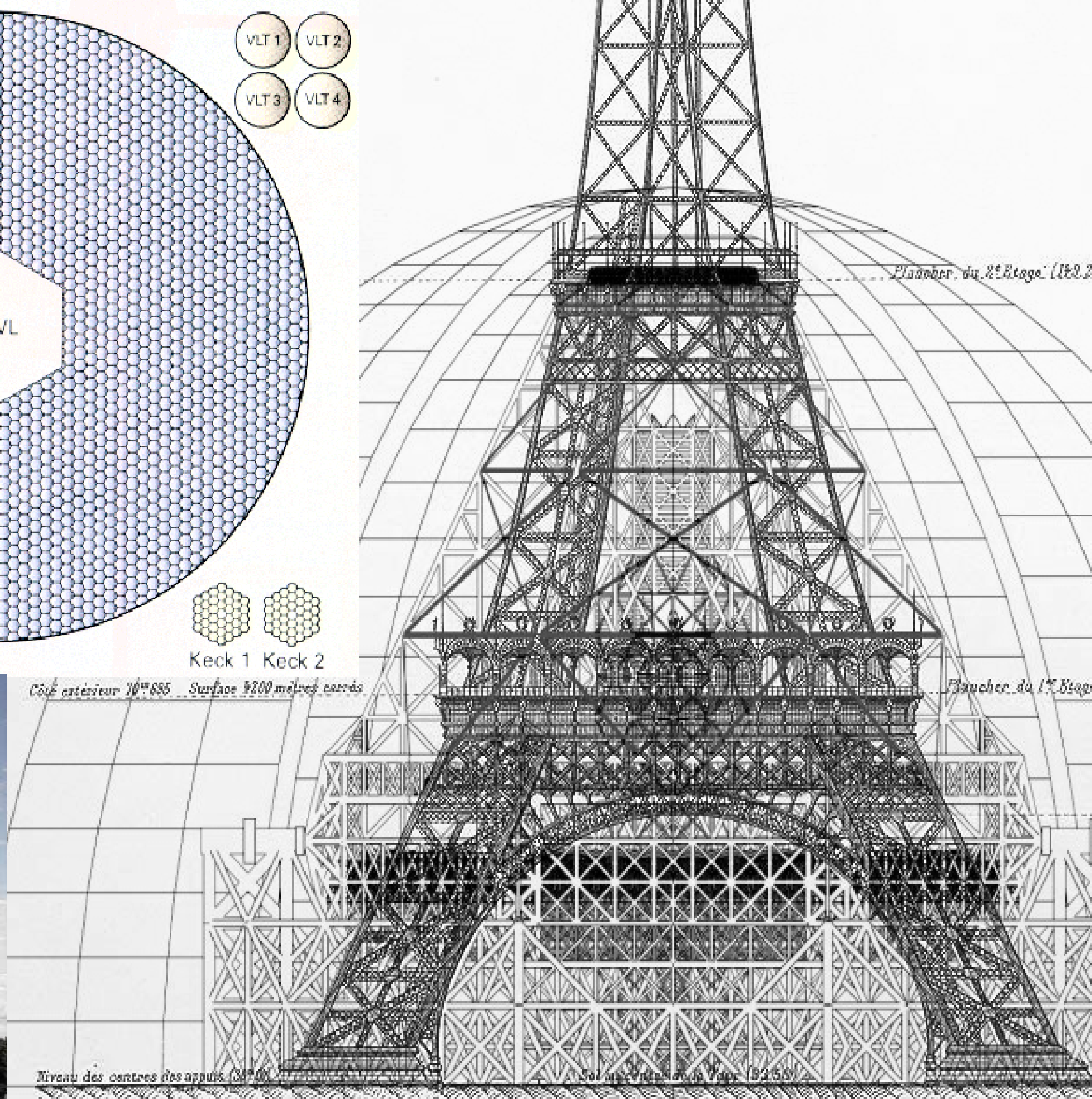
Diffraction limited resolution

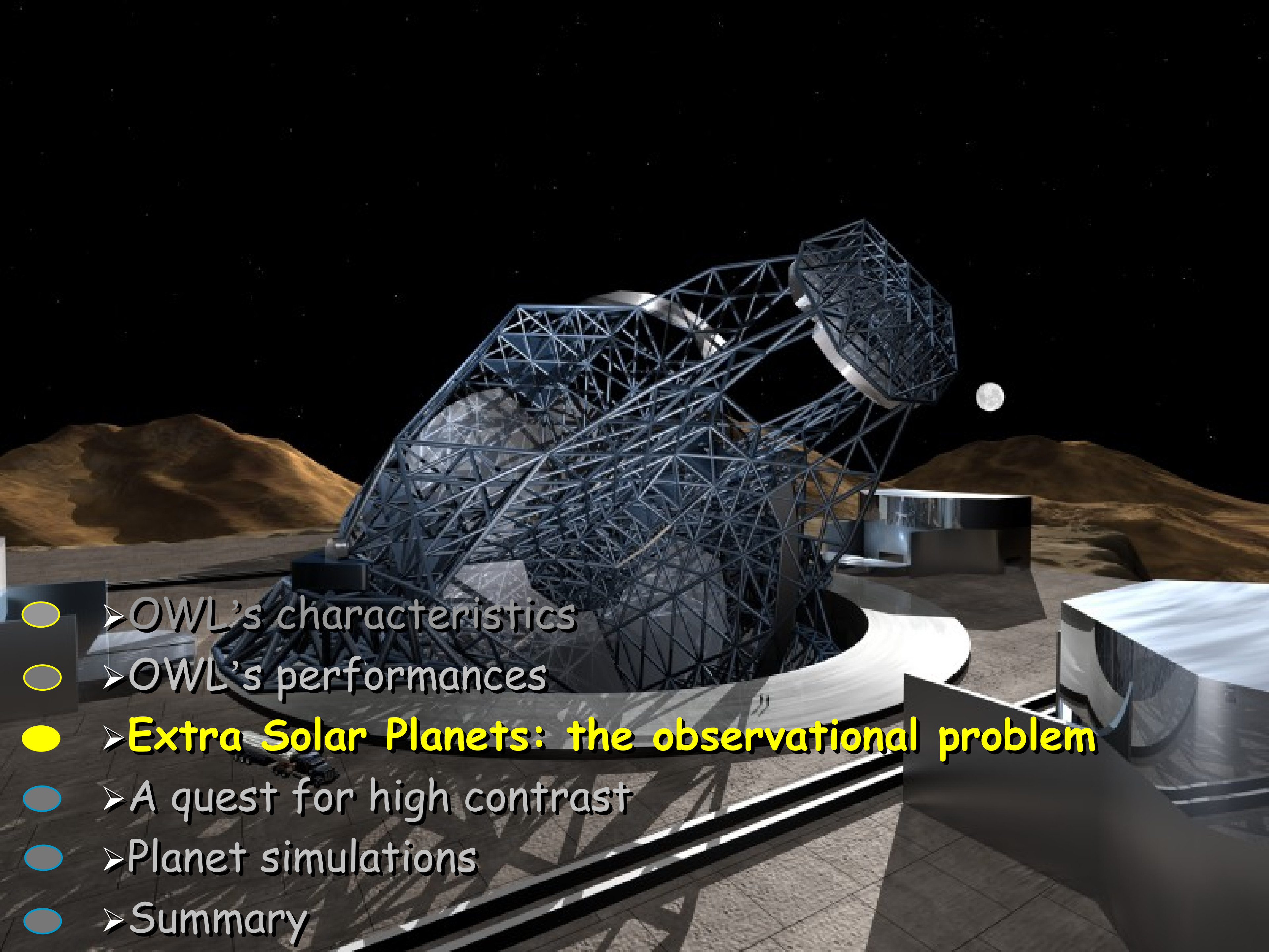


Band	B	V	R	J	H	K	N	
Resolution λ/D	0.9	1.1	1.3	2.6	3.4	4.5	23	mArcsec

Full AO: 1 mas at V *i.e.* 40 × HST


Hubble
VLT 1
VLT 2
VLT 3
VLT 4
OWL
(c) ELT
Keck 1
Keck 2





➢OWL's characteristics
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Extra-Solar Planets

- Magnitude, Separation:

Contrast $10^{\sim 8\text{-}9}$

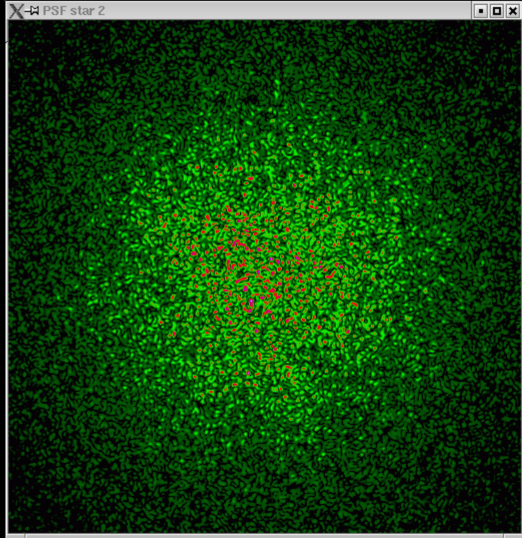
Star Dist [pc]	HotJup 0.2AU	Earth 1AU	Jupiter 5AU	Star
10	Mag.= 18.6 Sep.= 0.020"	27.4 0.100	25.6 0.500	4.8
25	20.6 0.008	29.4 0.040	27.6 0.200	6.8
50	22.1 0.004	30.9 0.020	29.1 0.100	8.3
100	23.6 0.002	32.4 0.010	30.6 0.050	9.8

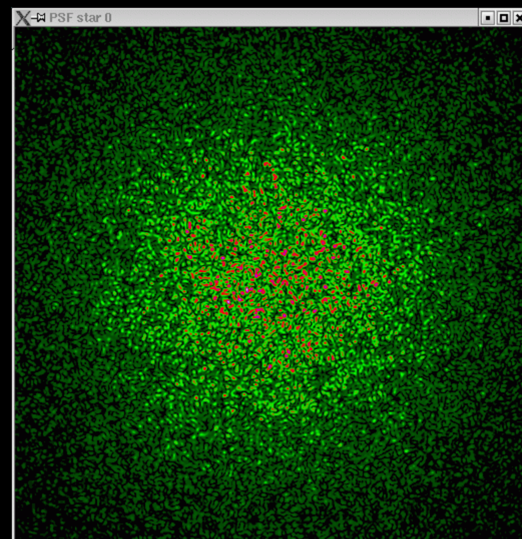
- Planet near star = point source + Point Source
  ← max benefit of λ/d

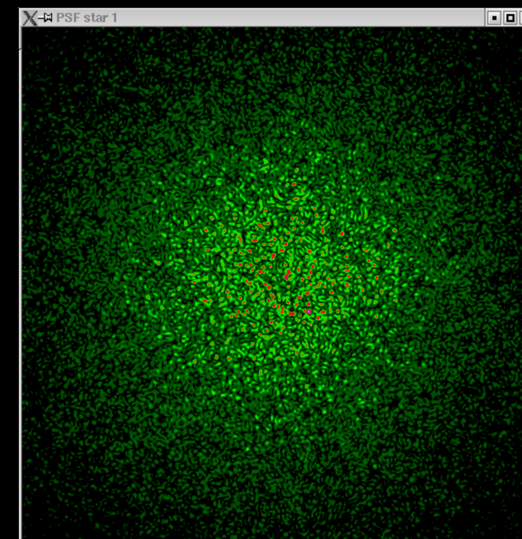
Quest for high-contrast imaging

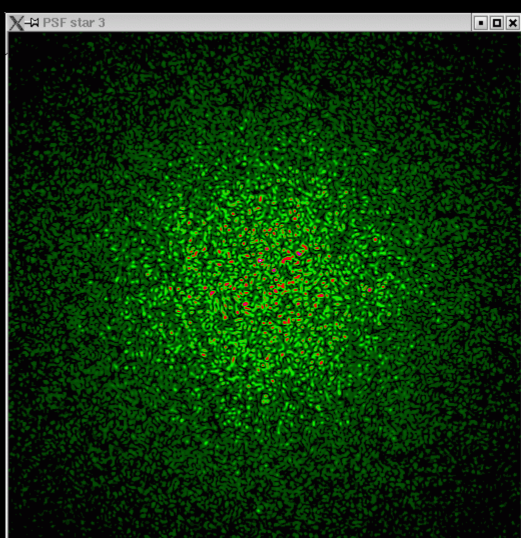
- Coronography
- Nulling interferometry
- Multi-Conjugated Active Optics
- eXtreme Active Optics
- Simultaneous Differential Imaging

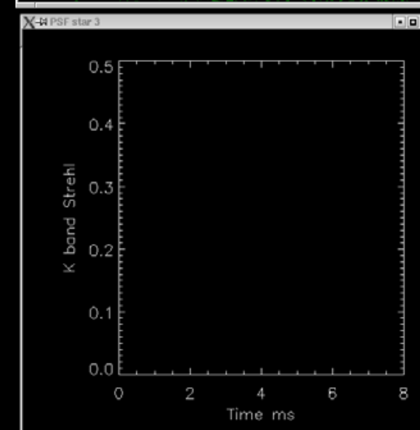
MCAO simulation

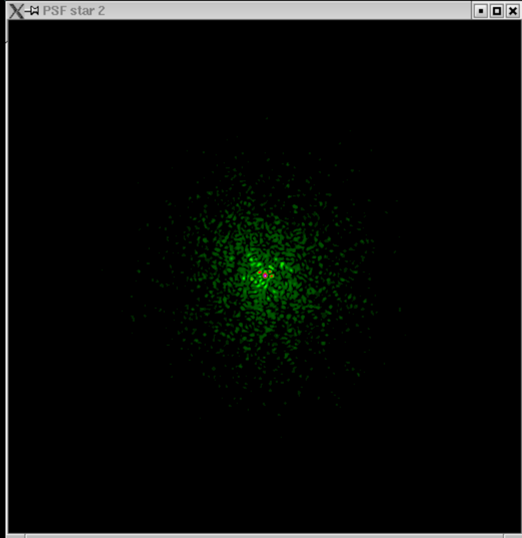


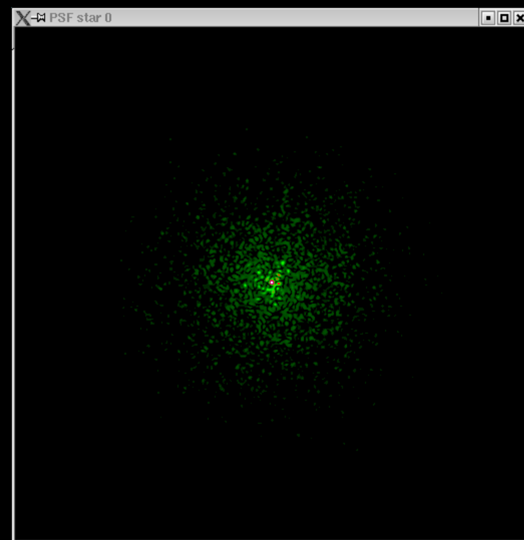


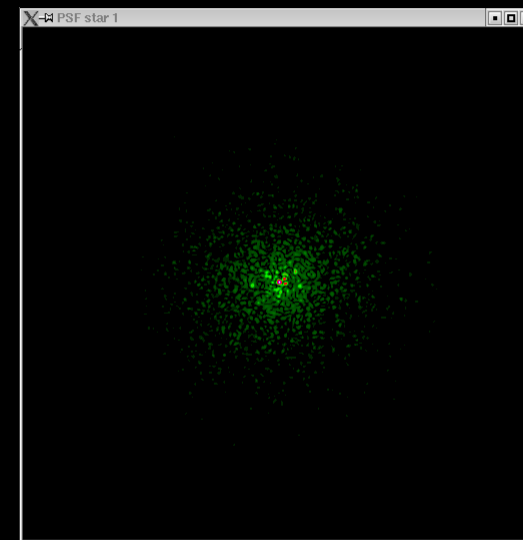


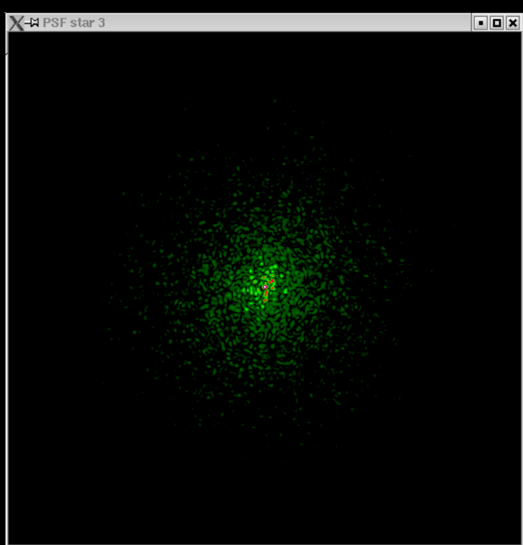


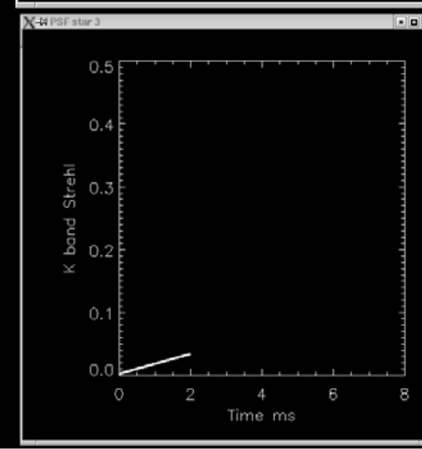


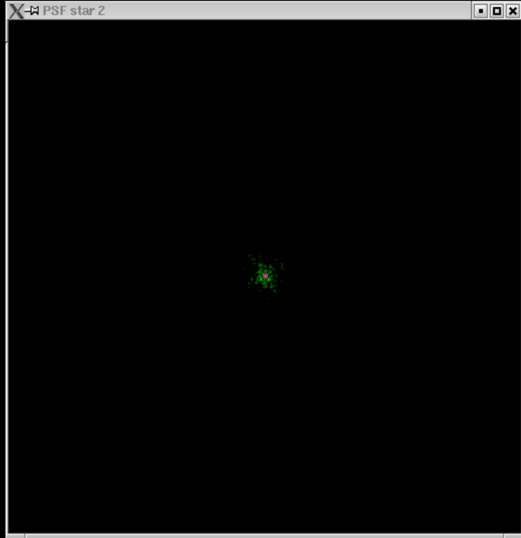

PSF star 2

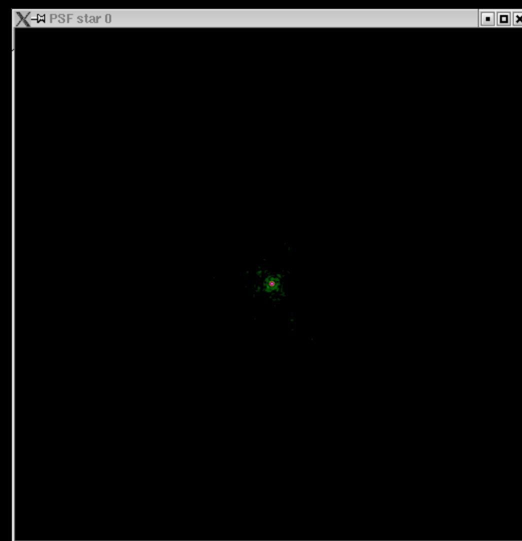

PSF star 0

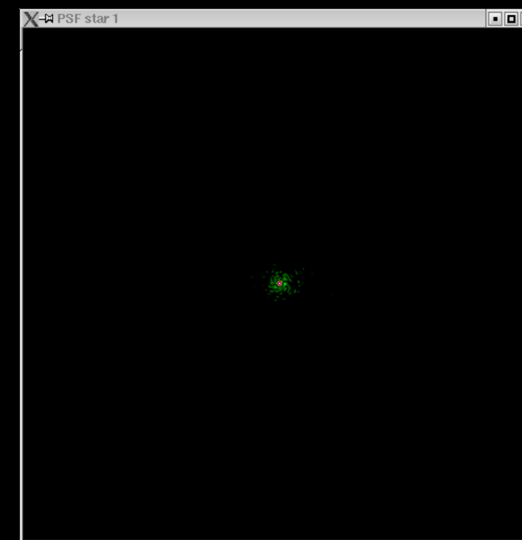

PSF star 1

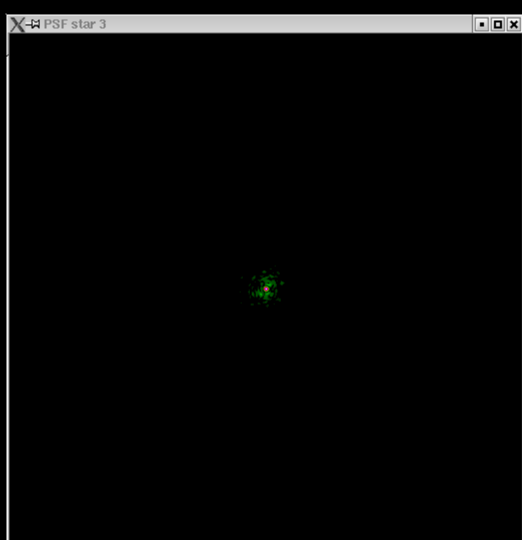

PSF star 3

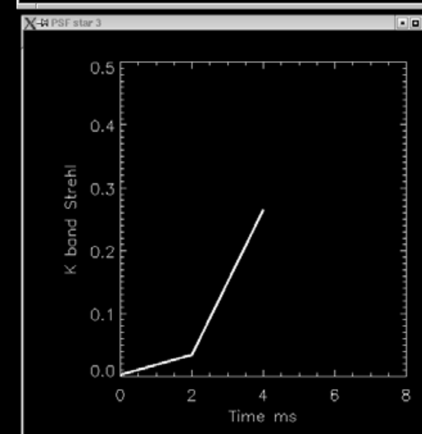

0.5
0.4
0.3
0.2
0.1
0.0
K band Strehl
0
2
4
6
8
Time ms

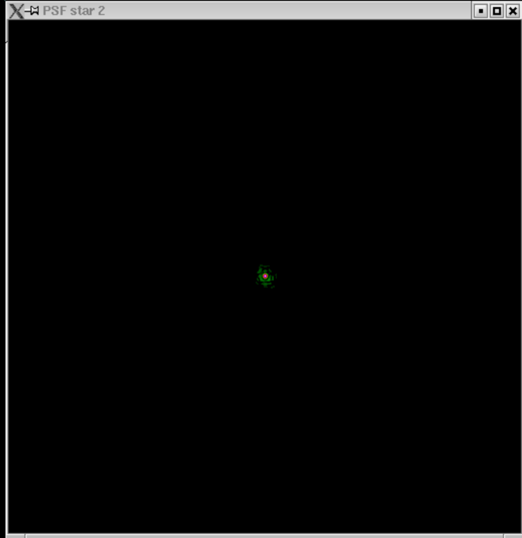

PSF star 2

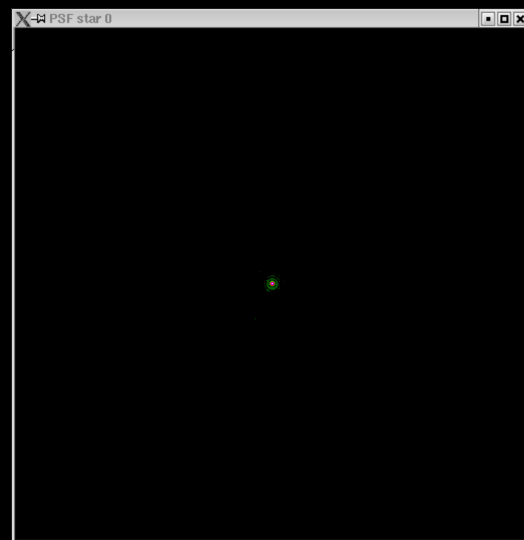

PSF star 0

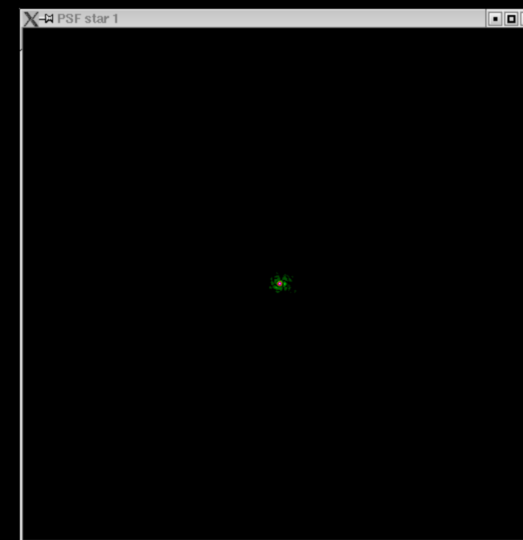

PSF star 1

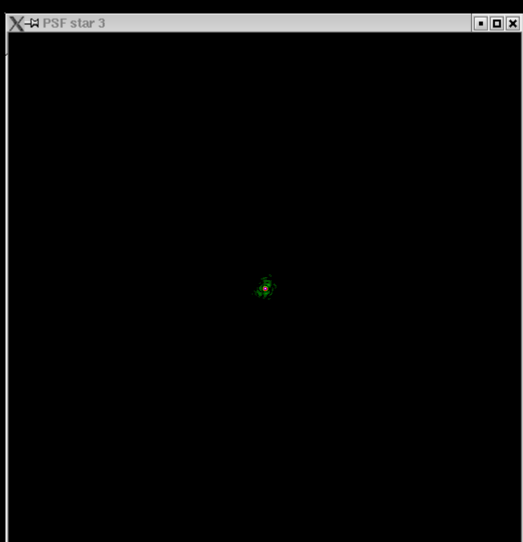

PSF star 3

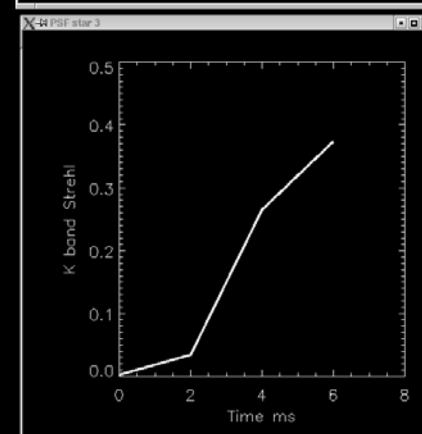

PSF star 3
0.5
0.4
0.3
0.2
0.1
0.0
K band Strehl
0
2
4
6
8
Time ms


PSF star 2

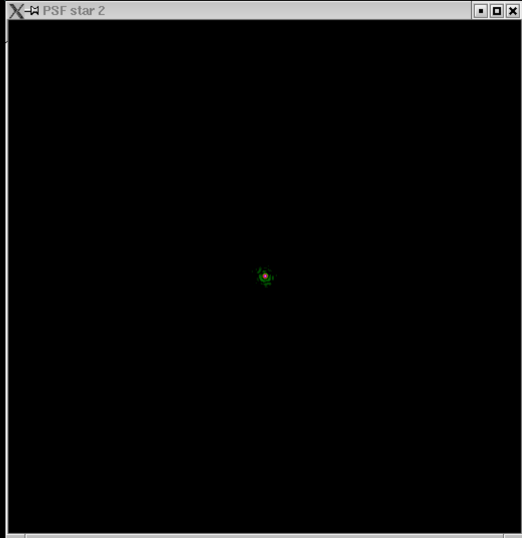

PSF star 0

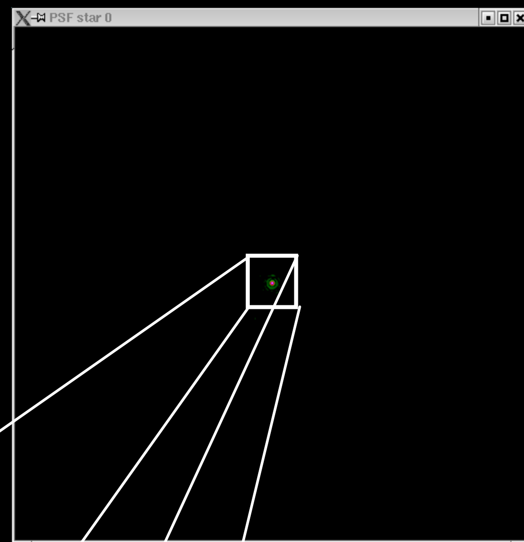

PSF star 1

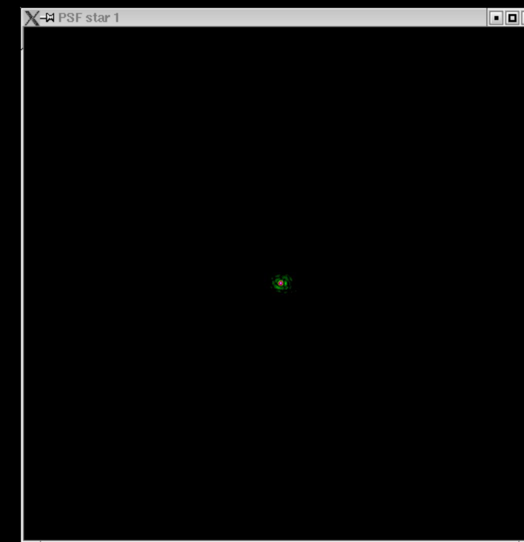

PSF star 3

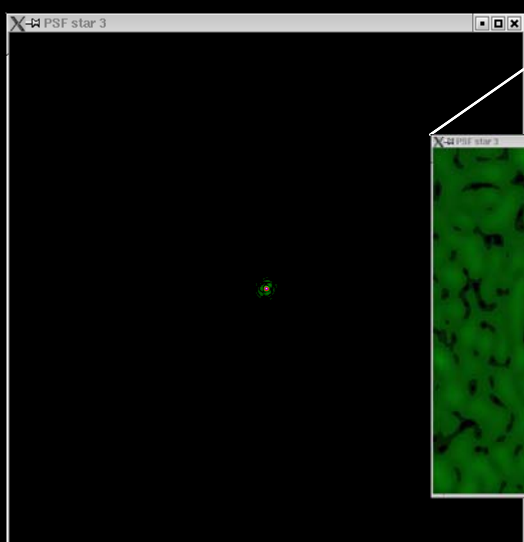

PSF star 3
0.5
0.4
0.3
0.2
0.1
0.0
K band Strehl
0
2
4
6
8
Time ms

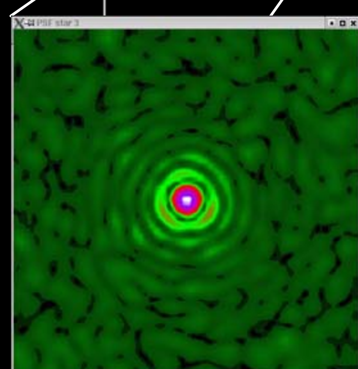
Total FOV: 2' (diameter)
100m telescope, K-Band
FWHM: ~5mas, Sr ~ 30-40%
2 DMs (8k - 9k actuators)
3 NGSs (100x100 Shack-Hartmann)



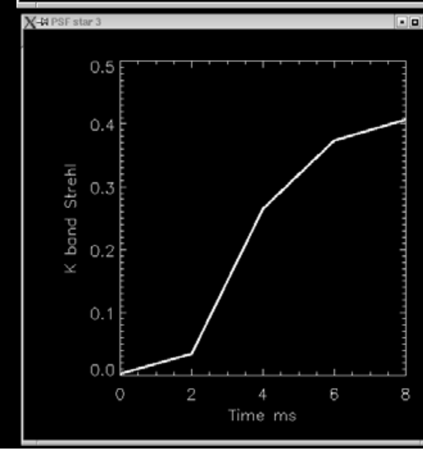




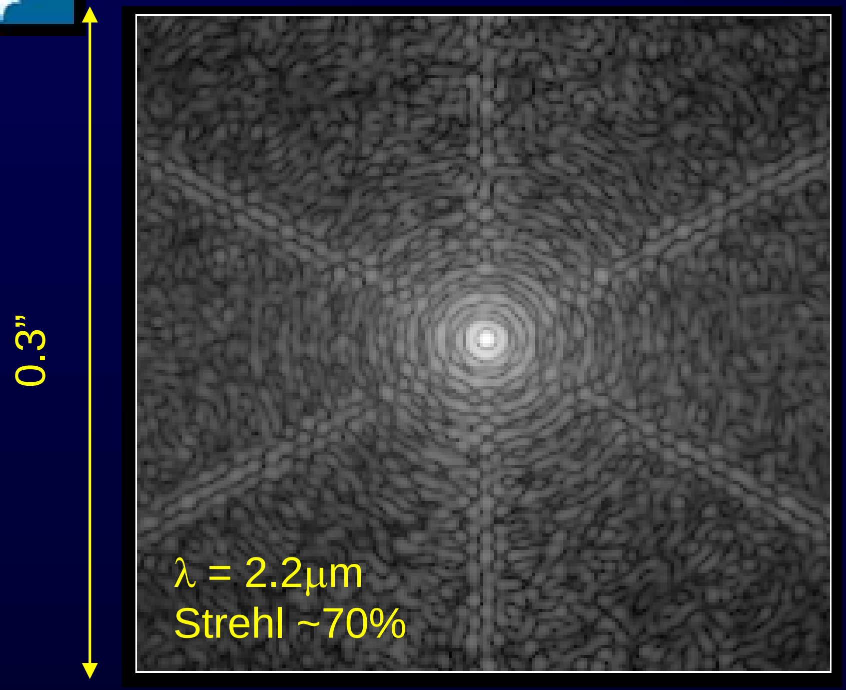




Sqrt stretch



XAO simulations for OWL



- 125 sub-apertures across pupil (80 cm sub-apertures, 11198 actuators active on DM)
- Each sub-aperture is 4x4 pixels, i.e. 500x500 WFS CCD
- Bright NGS on-axis
- 1 kHz frame-rate, ~1 sec of real-life PSF
- 4 ms coherence time
- 0.5" seeing (at 0.5 um)
- OWL pupil + cophasing errors included

M. Le Louarn, Ch. Verinaud,
Adaptive Optics Department
N. Yaitskova,
OWL Group

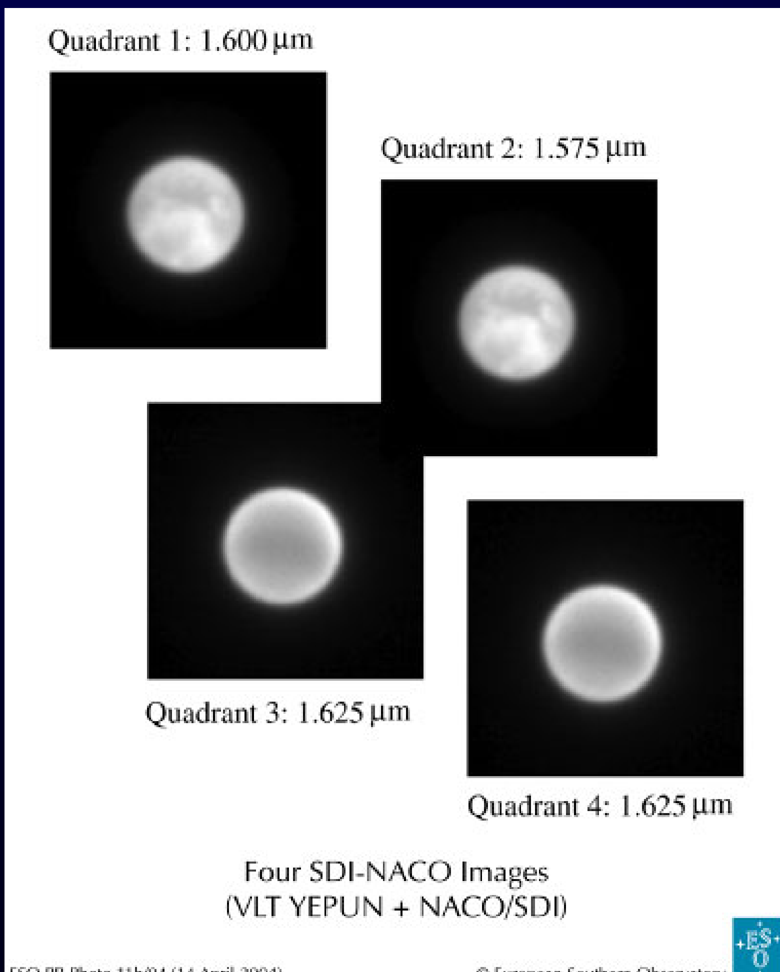
Simultaneous Differential Imaging

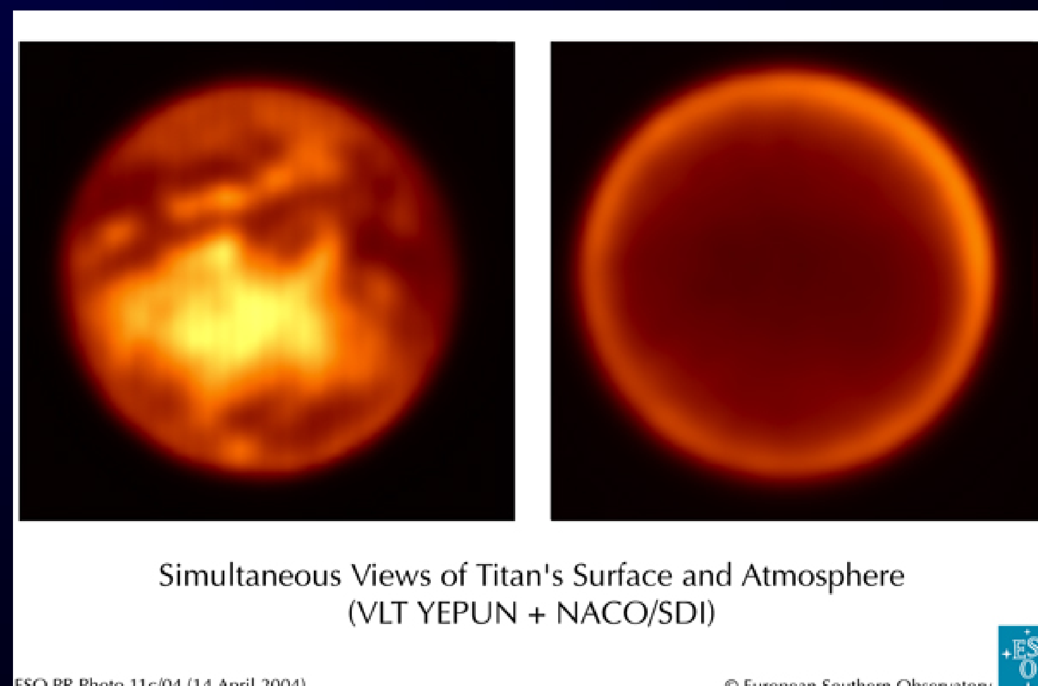
Adaptive Optics

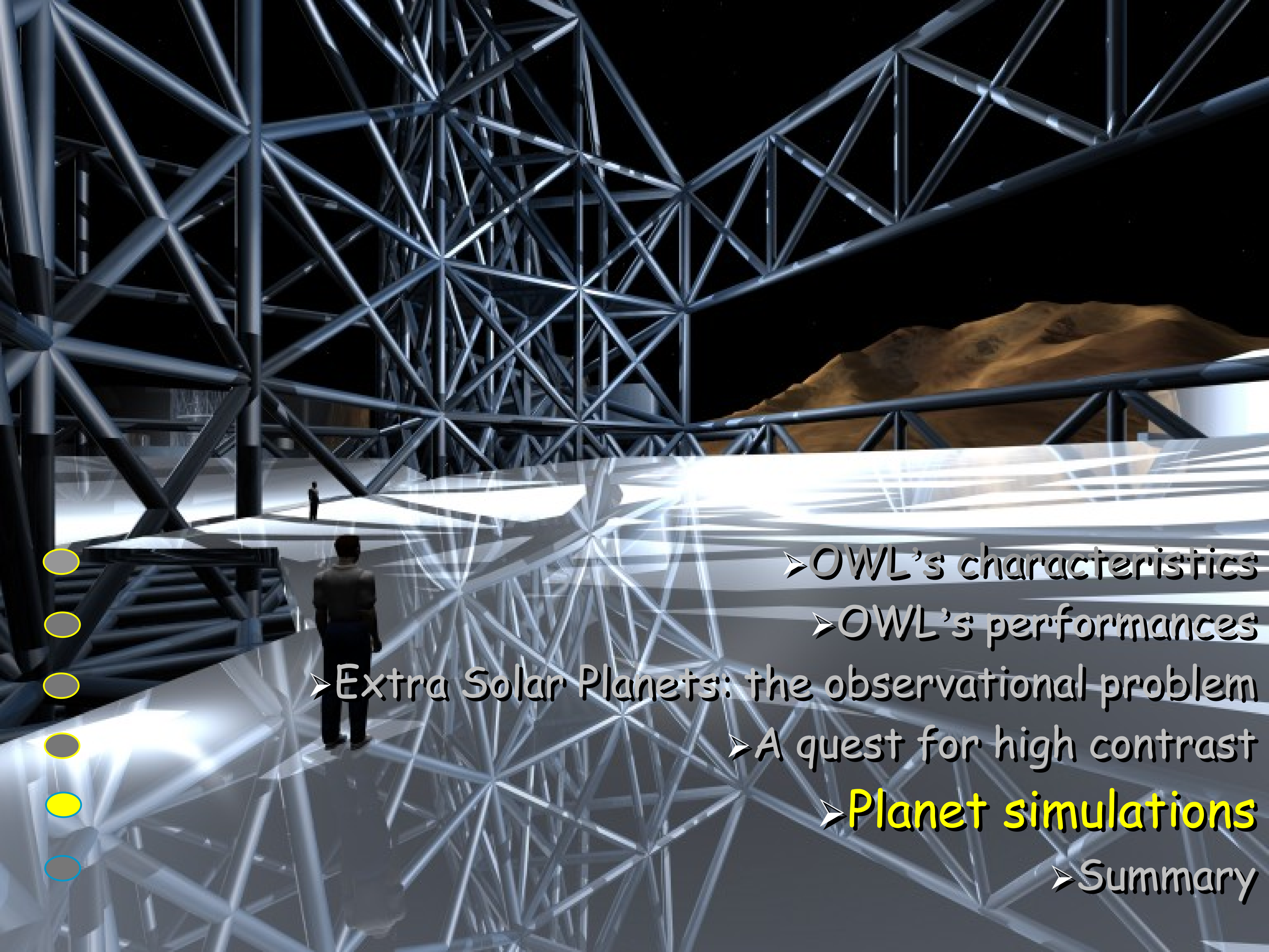
- @ Specific wavelengths
- Cancel the speckles in real time

→Very high contrast (~50k)

- Today on NaCo, VLT UT4



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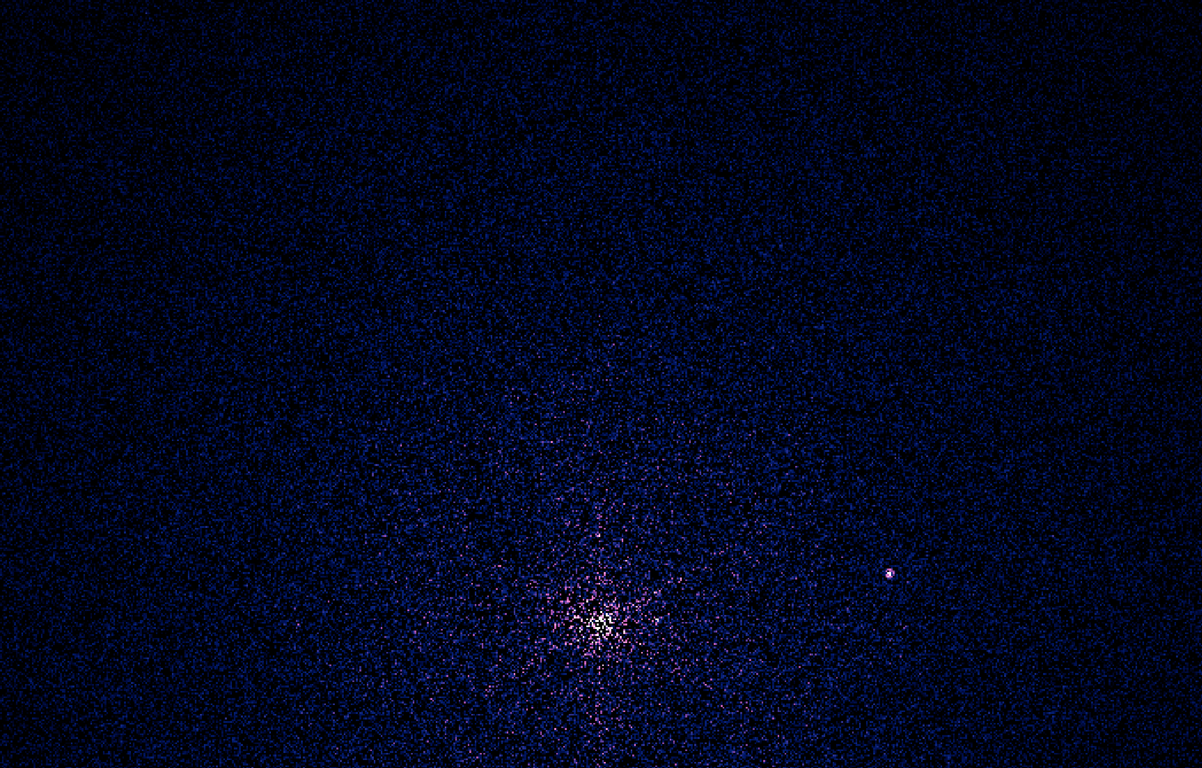
Models

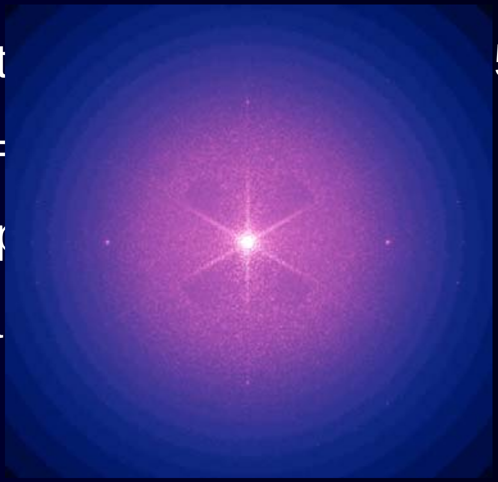


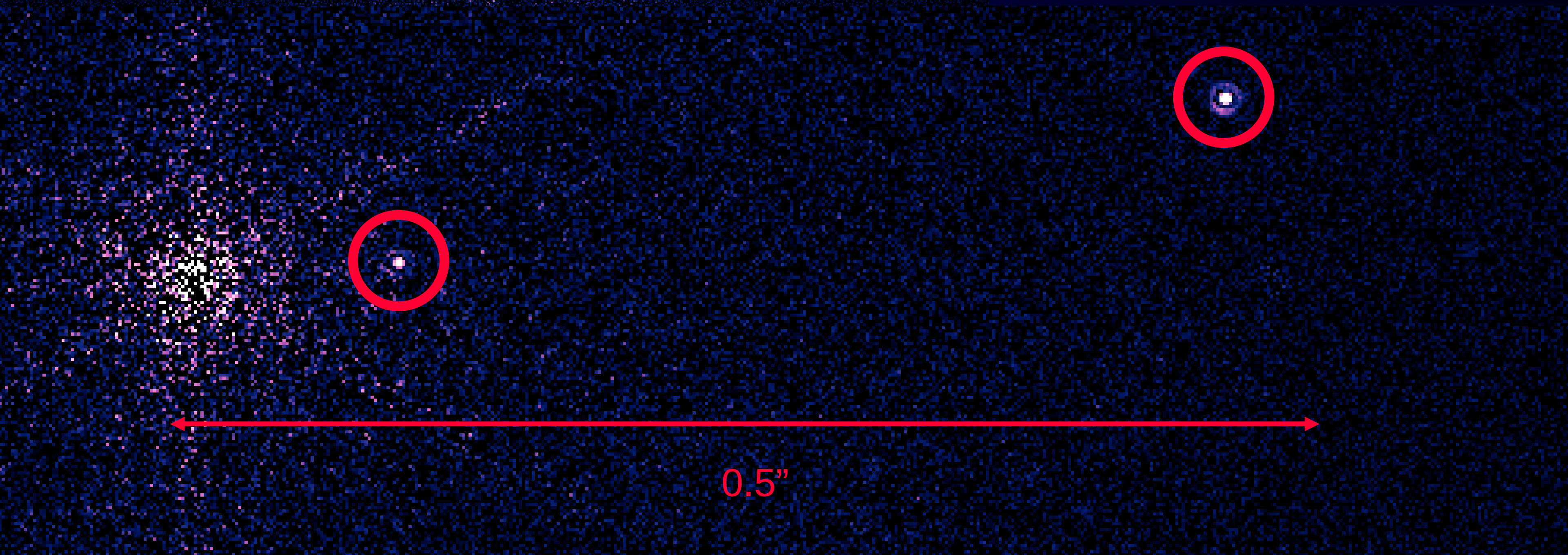
Filt 5

d =

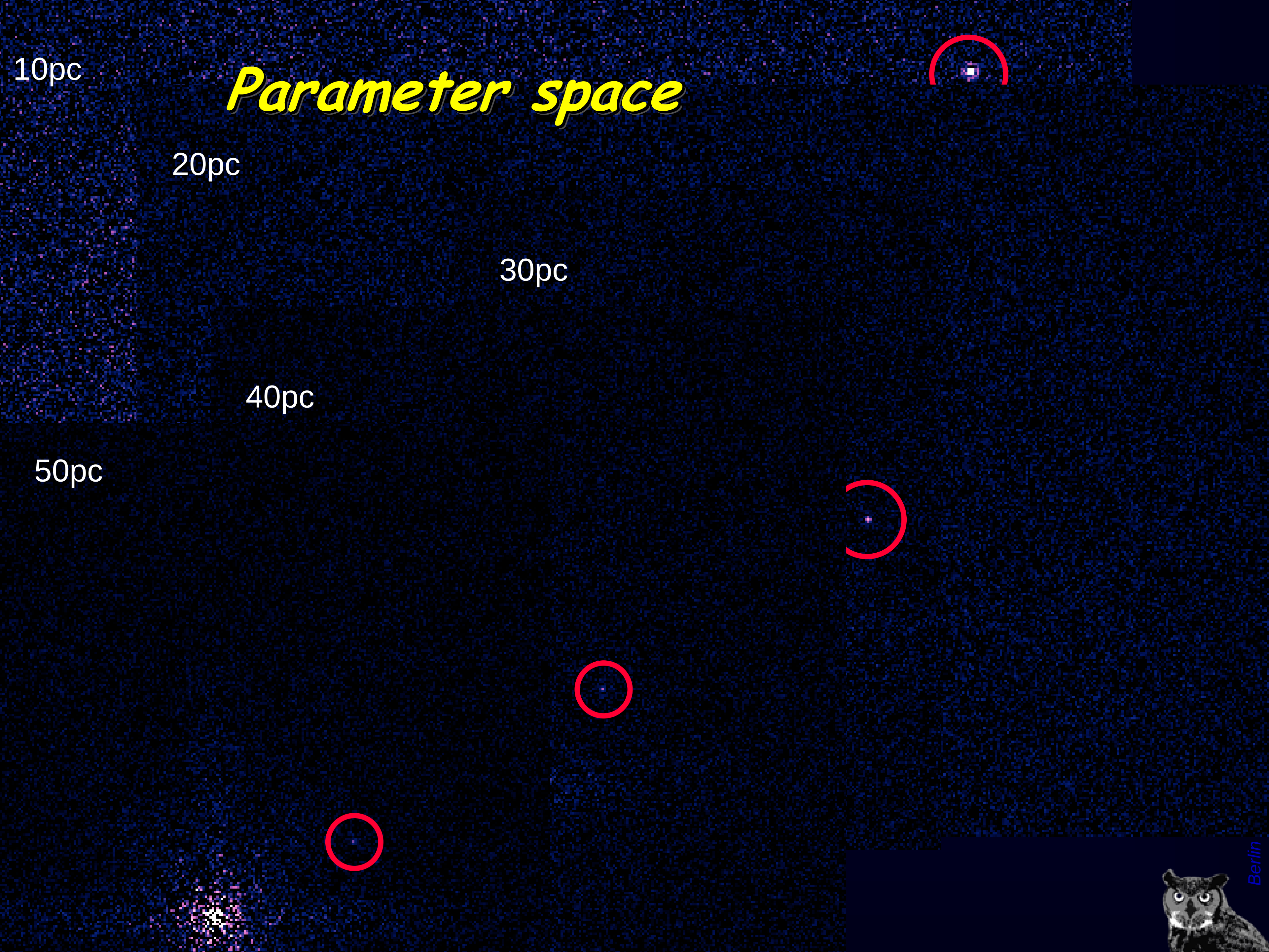
Jup

Ea



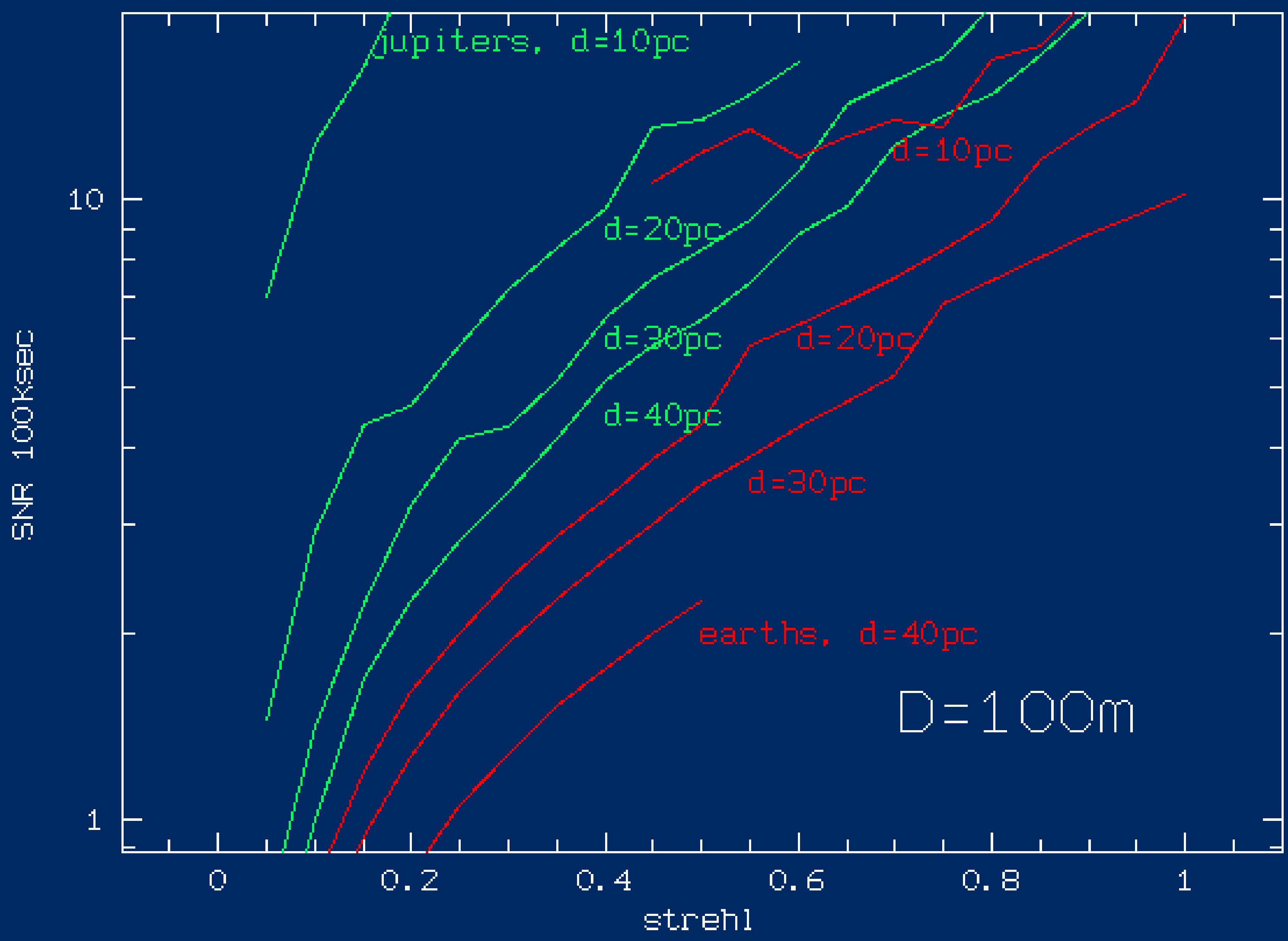


Parameter space

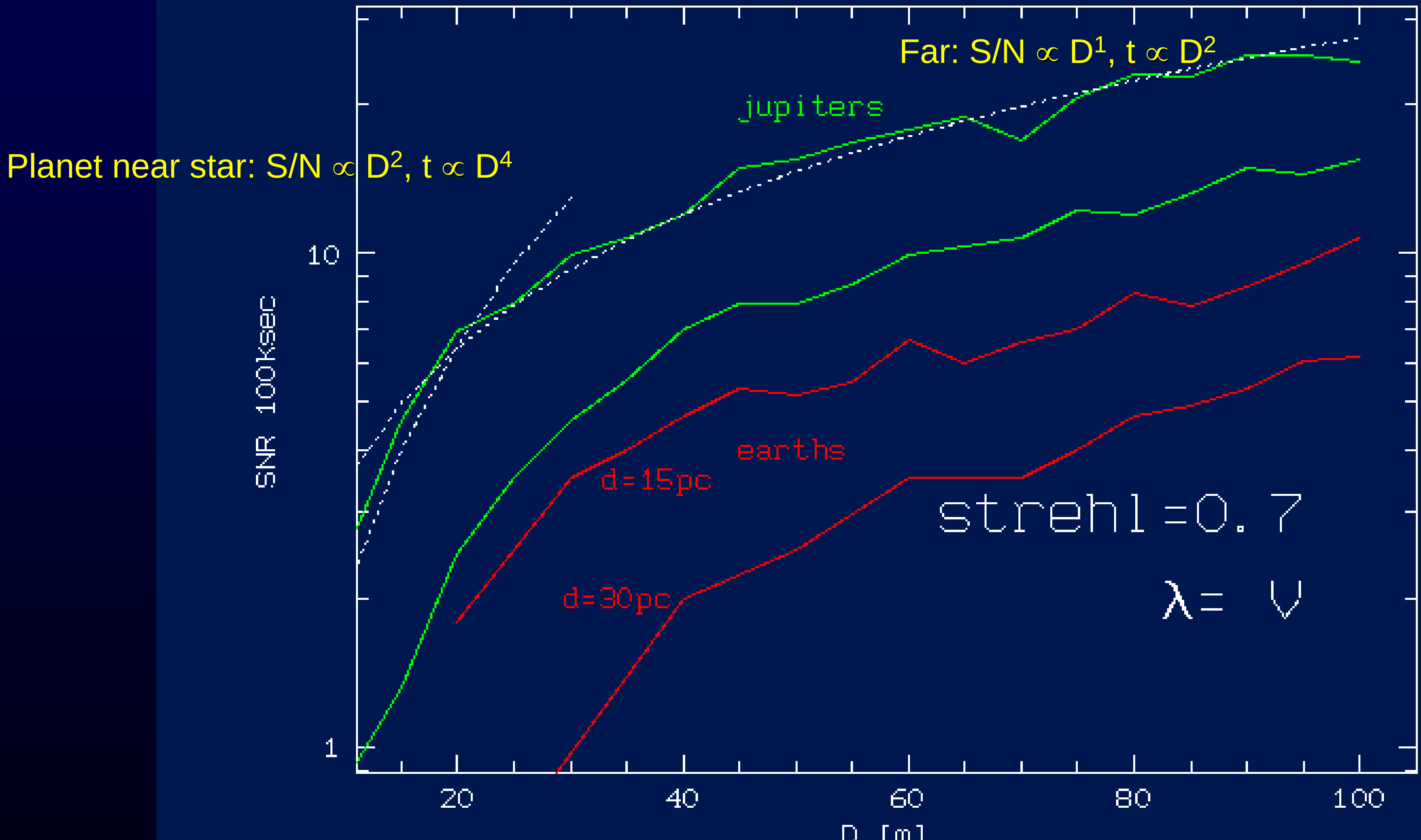


Berlin

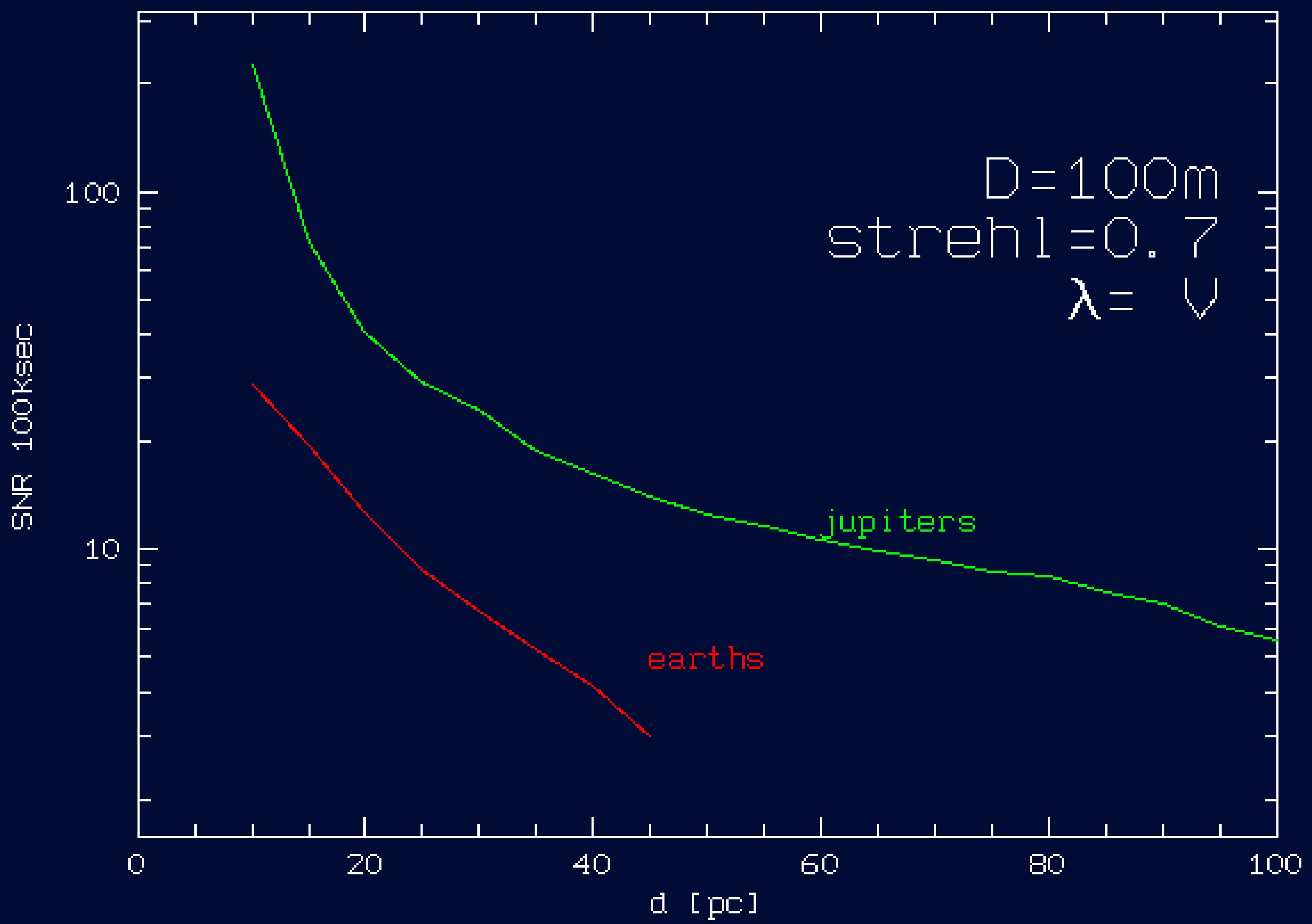
Scan strehl ratio



Scan telescope diameter

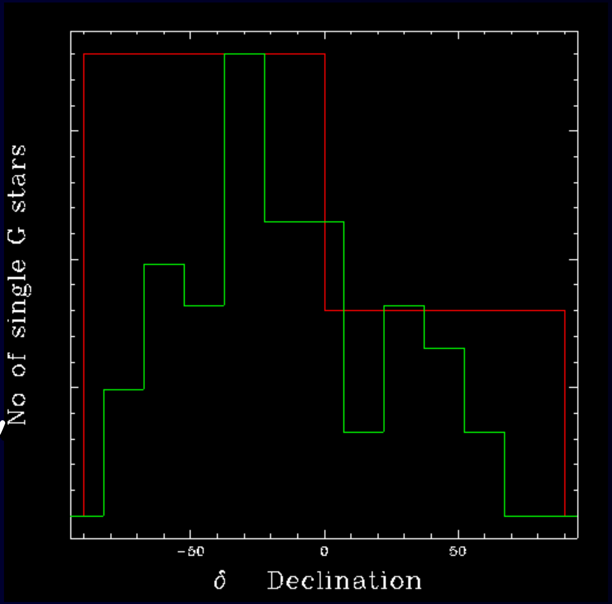


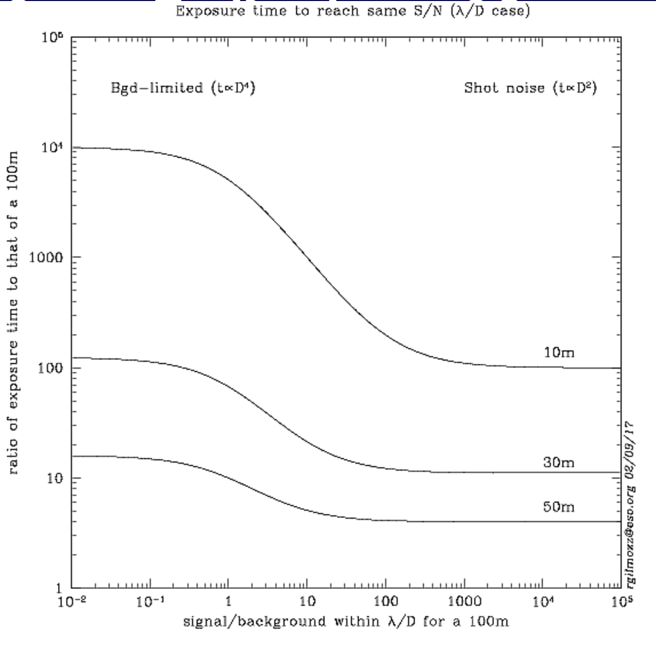
Scan star distance



Dependence in D

- Separation ∝ D: → Volume ∝ D^3
  Number of observable single G stars,
  λ=1.





Teles… Diame…	Earth 1AU	Jupiter 5AU
30m	24	3070
60m	196	24500
100m	910	114000

- S/N ∝ D^2 --- t ∝ D^4
  → to reach same S/N: $t_{30m} = 120 \times t_{100m}$

Exo-earths: detection comparison

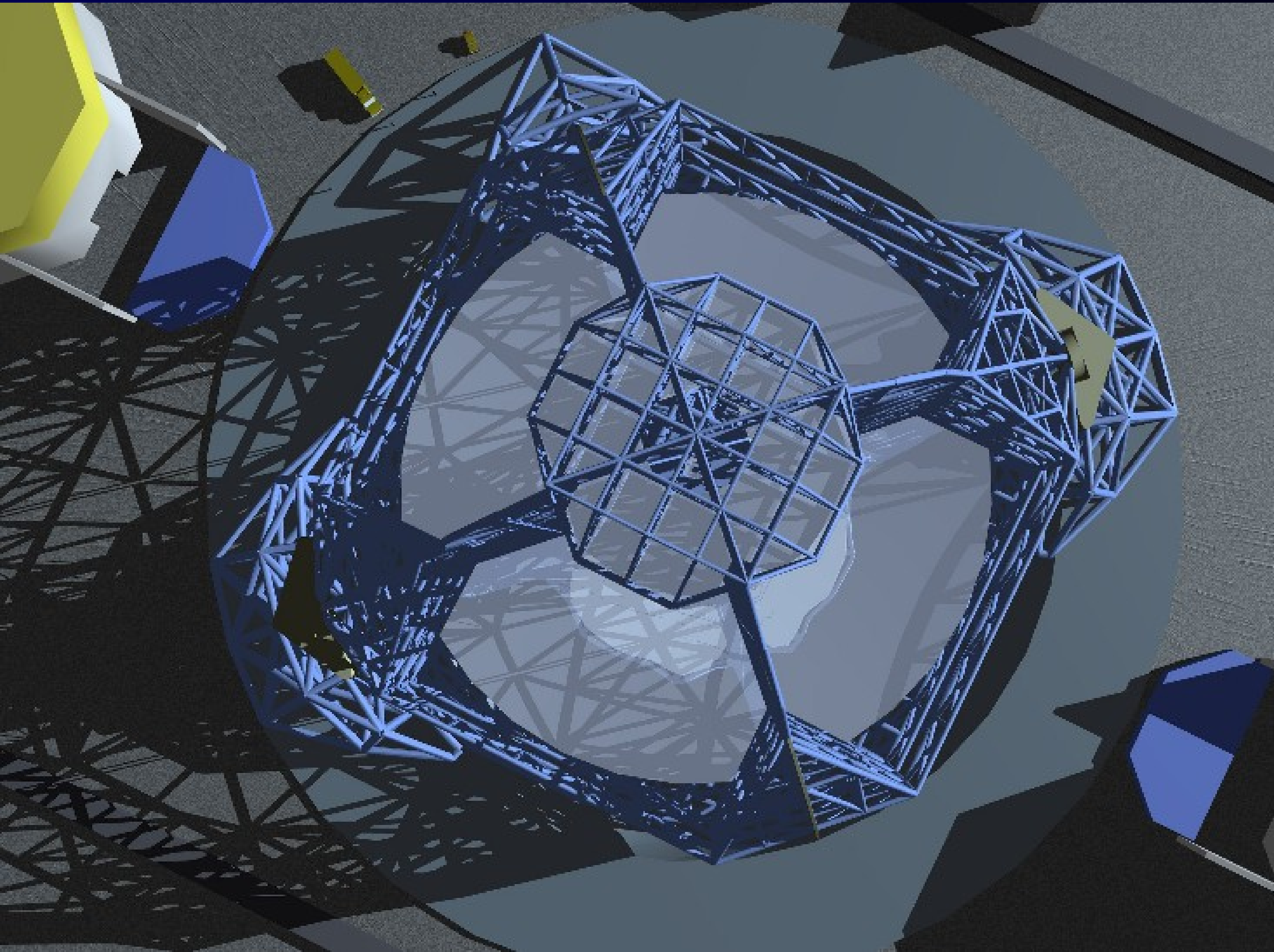
(Angel, 2003)

telescope		wave (μm)	mode	S/N	(earth@10pc, 24h exp)
space interf	4x2m	11	nulling	8.4	Darwin, TPF
space filled	7m	0.8	coronagr	5.5-34	JWST or HST successor
Antarctic	21m	11	nulling	0.52	GMT
		0.8	coronagr	5.9	
ground	30m	11	nulling	0.34	Celt, GSMT
		0.8	coronagr	4.1	
ground	100m	11	coronagr	4.0	OWL
		0.8	coronagr	46	
Antarctic	100m	11	coronagr	17	BOWL=better OWL
		0.8	coronagr	90	

This paper: S/N = 35 @ strehl=75%

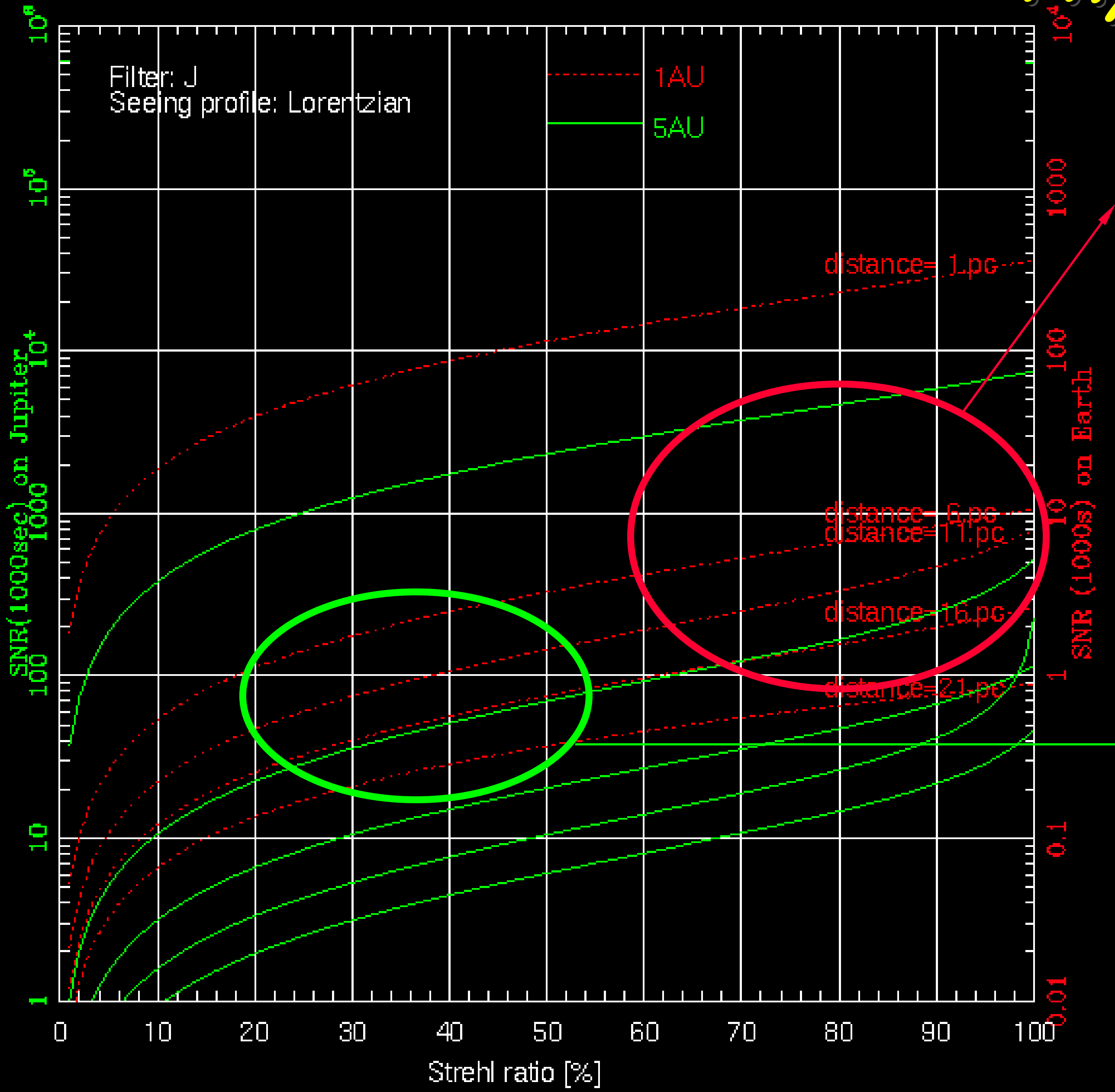
Summary

- Exp.time $\propto D^4$
- Number of objects $\propto D^3$
- With D=100m
  - ⇨ Spectro of jupiters not a problem
  - ⇨ Photometry of earths: d<25pc
    (~60 stars if lat ~ -25°)
  - ⇨ Spectro of earths: d < 15pc , strehl>80%
    (30stars if lat ~ -25°)
- With D=30m
  - ⇨ Photometry of earths @ d < 10pc
    (~8 stars…)



0.6 arcsec

Physical Studies



Earth:

-Photom in 25ks

d < 25pc

-Spectro in 100ks

d < 16pc

➔Strehl > 60%

Jupiter:

-Photometry in 10ks

-Spectro in 100ks

➔ Strehl > 20%