EUCLID microlensing planet hunting

Jean-Philippe Beaulieu,
Institut d'Astrophysique de paris,

In collaboration with E. Kerins, M. Penny, N. Rattenbury, M. Zapatero, V. Batista,
A. Cassan, P. Tisserand, P. Fouqué, C. Coutures, J.B. Marquette, F. Mogavero and the
EUCLID Science Working Group on exoplanets

EUCLID : Understand the origin of the Universe's accelerating expansion

Science requirement

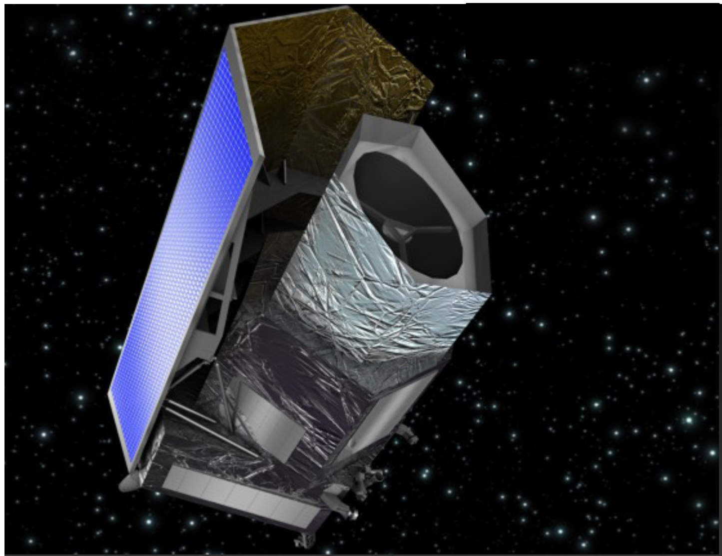
Properties and nature of dark energy, dark matter, gravity

Distinguish effects by:

- Using at least 2 independent but complementary probes (5 probes total)

- Tracking their observational signatures on
  the geometry of the universe:
  Weak Lensing (WL) Galaxy Clustering (GC)

- Cosmic history of structure formation:
  WL, Redshift Space Distortion (RSD), Clusters of Galaxies (CL)
- Controling systematic residuals to an unprecedented level of accuracy.



A brief history of EUCLID

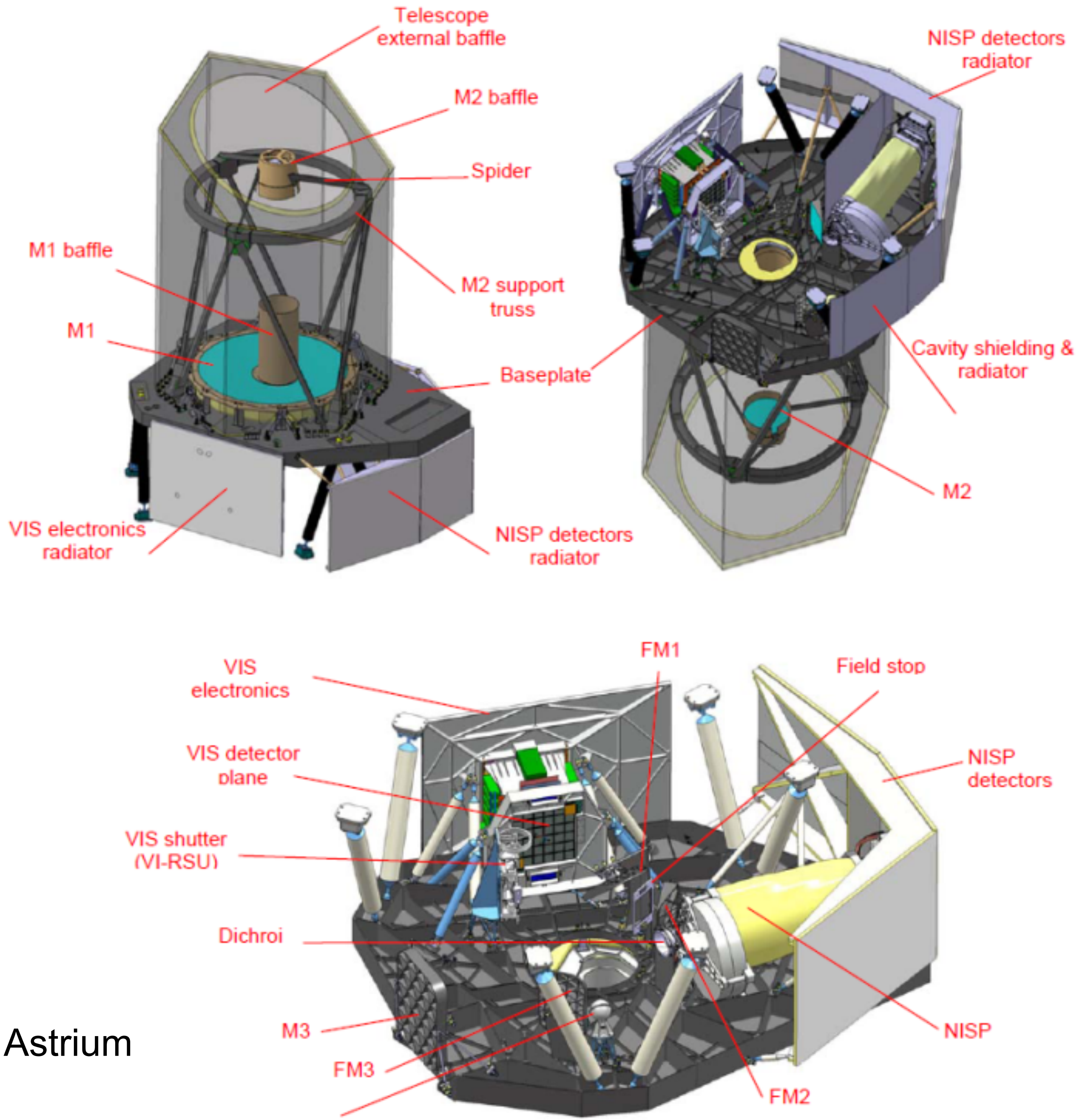
- DUNE mission (wide field imager in VIS) proposed to ESA in 2007

  DUNE had already a 3 month legacy program to do a microlensing survey.

- SPACE mission (IR and spectroscopy) proposed to ESA in 2007.

→ Merging of DUNE and SPACE in EUCLID.

- Final selection of EUCLID in 2010, adoption in 2013.



Astrium

Euclid

télescope & instruments

- Stabilisation:
- Pointing error of 25 mas over 600 sec

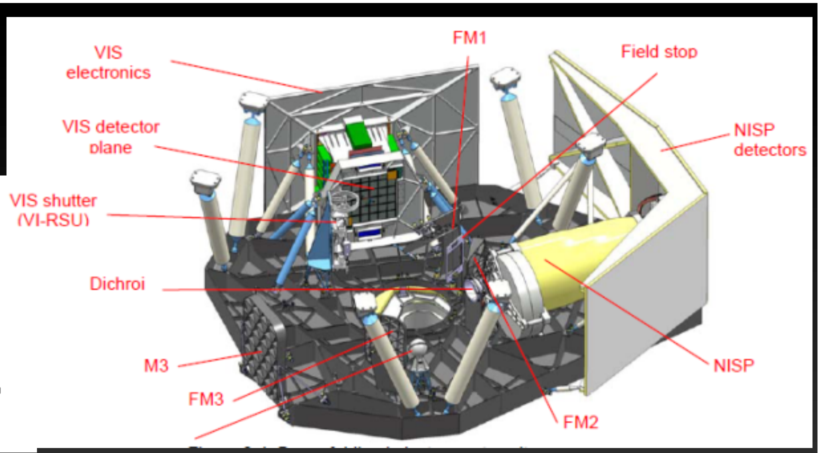
e

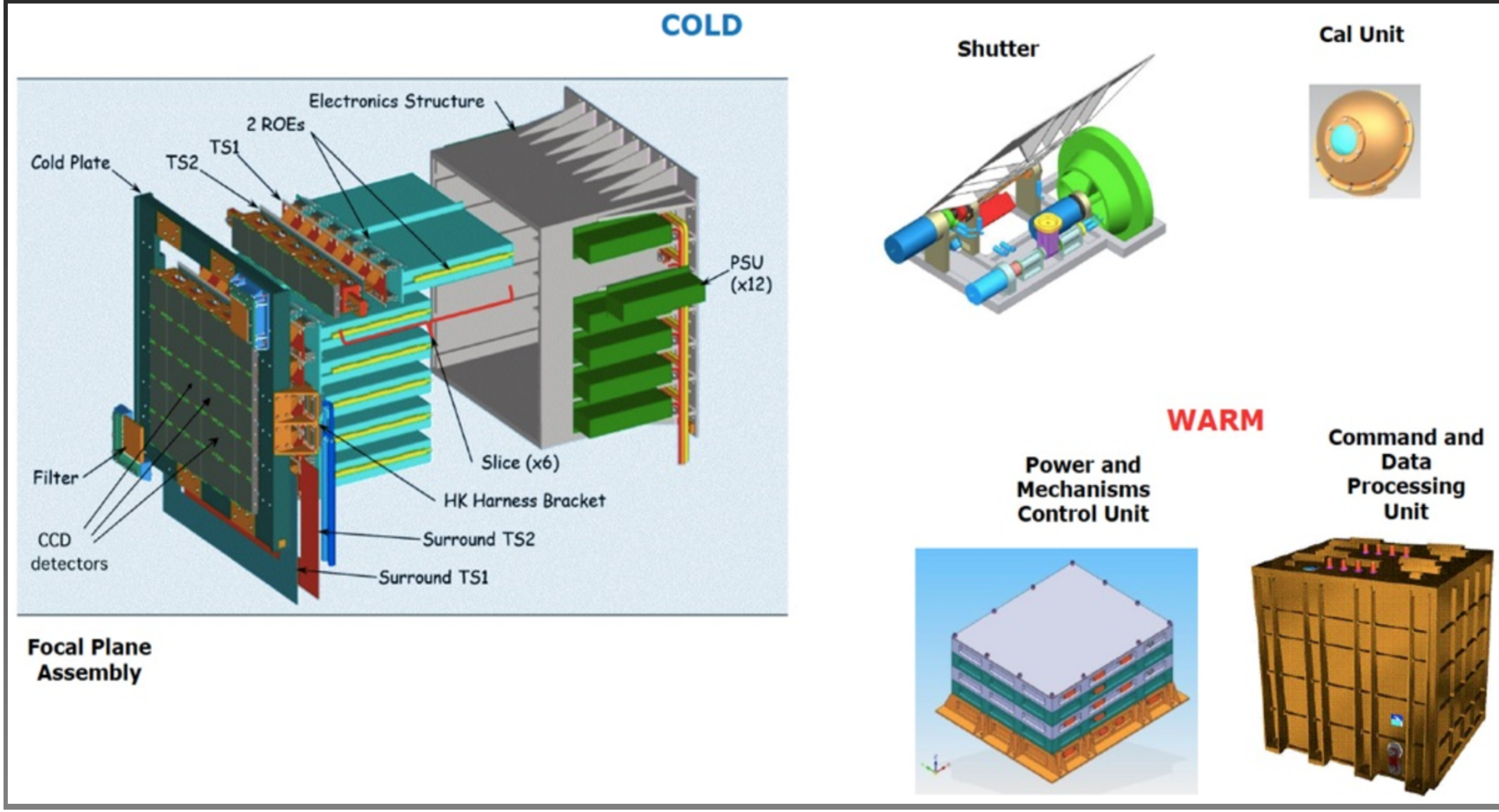
- FoV:

Common optical and IR field of view of 0.54 deg^2

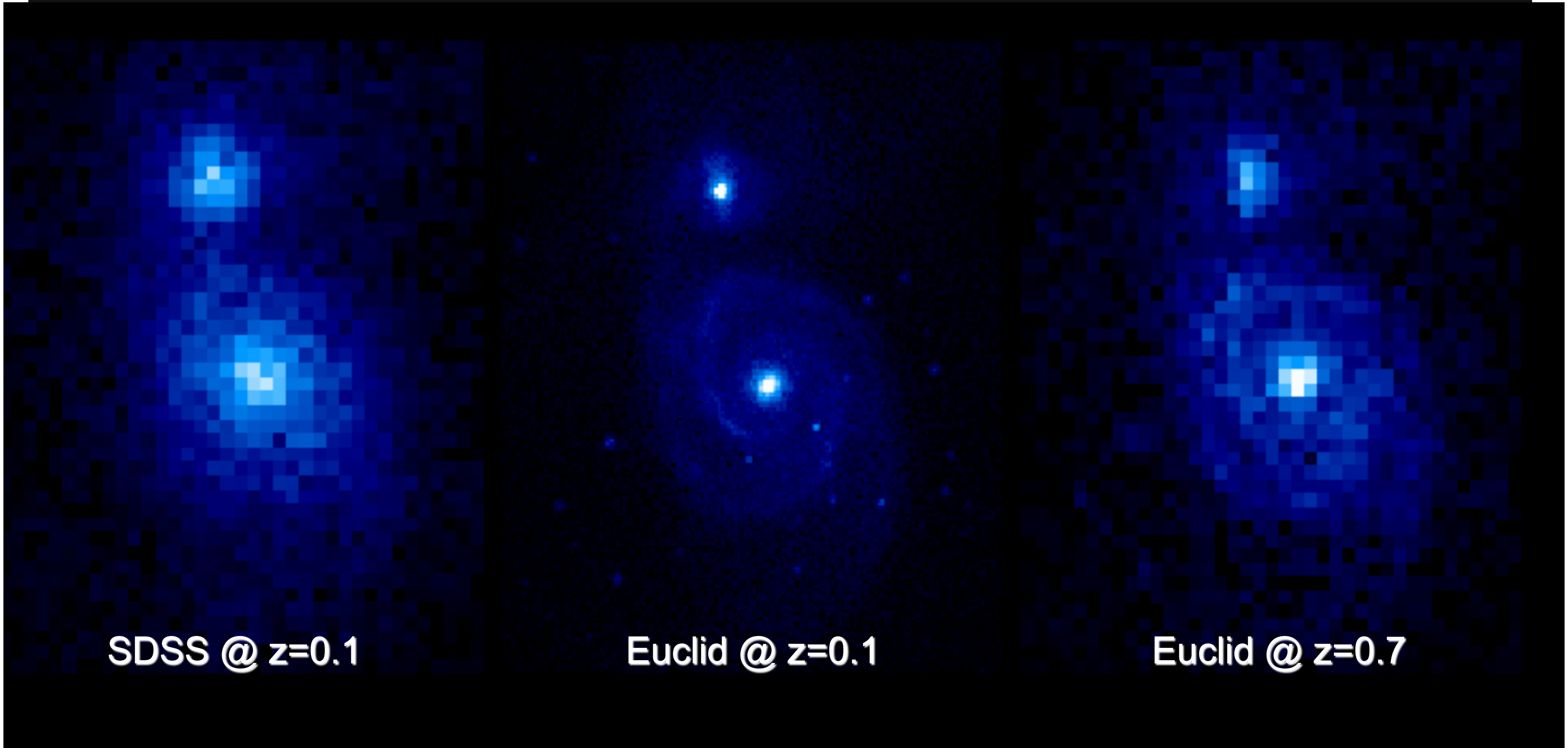
L'instrument VIS

- large area imager – a 'shape measurement machine'
- 36 4kx4k CCDs with 12 micron pixels
- 0.1 arcsec pixels on sky
- bandpass 550-900 nm – narrow band channel
- limiting magnitude for wide survey of magAB = 24.5 for 10σ (extended)
- data volume – 520Gbit/day



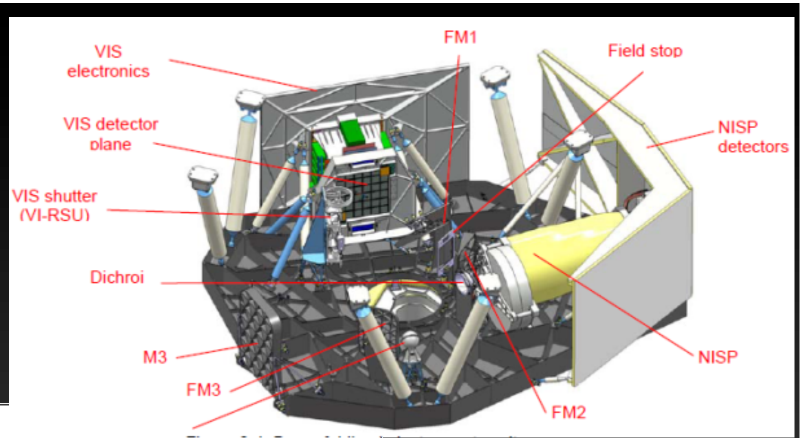


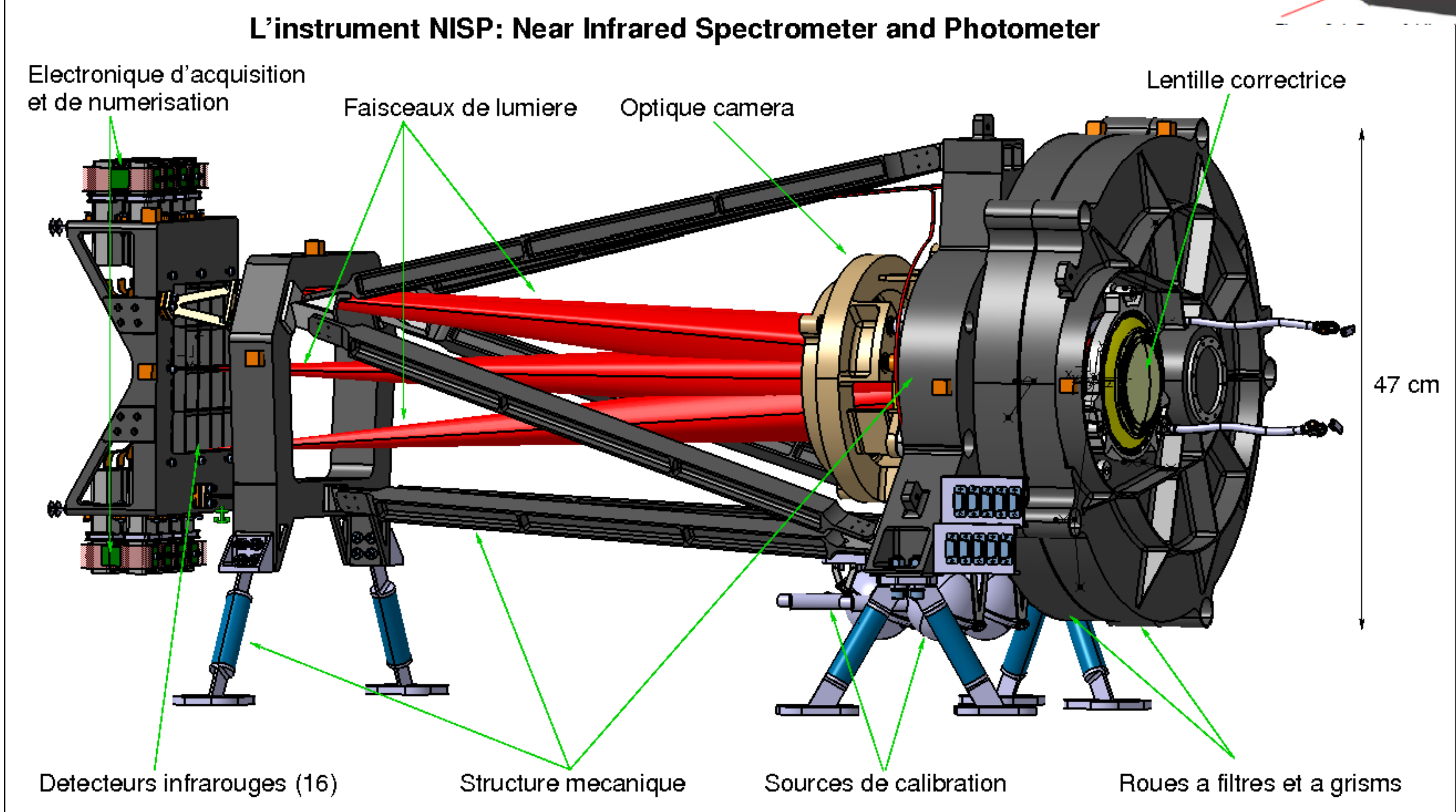
Simulation of M51 in the visible



Euclid will have the same resolution at z~1 than the SDSS at z~0.05, but it will be 3 magnitude deeper

L'instrument NISP





- 16 détecteurs NIR 2kx2k H2RG - 0.3 arcsec/pixel
- 4 Grisms (2 B, 2 R, tournés de 90 deg.) ; 3 filtres NIR: Y, J H - Télémétrie= 180 Gbit/j

Euclid baseline, launch 2020

Ground based Photometry and Spectroscopy (photo-z)

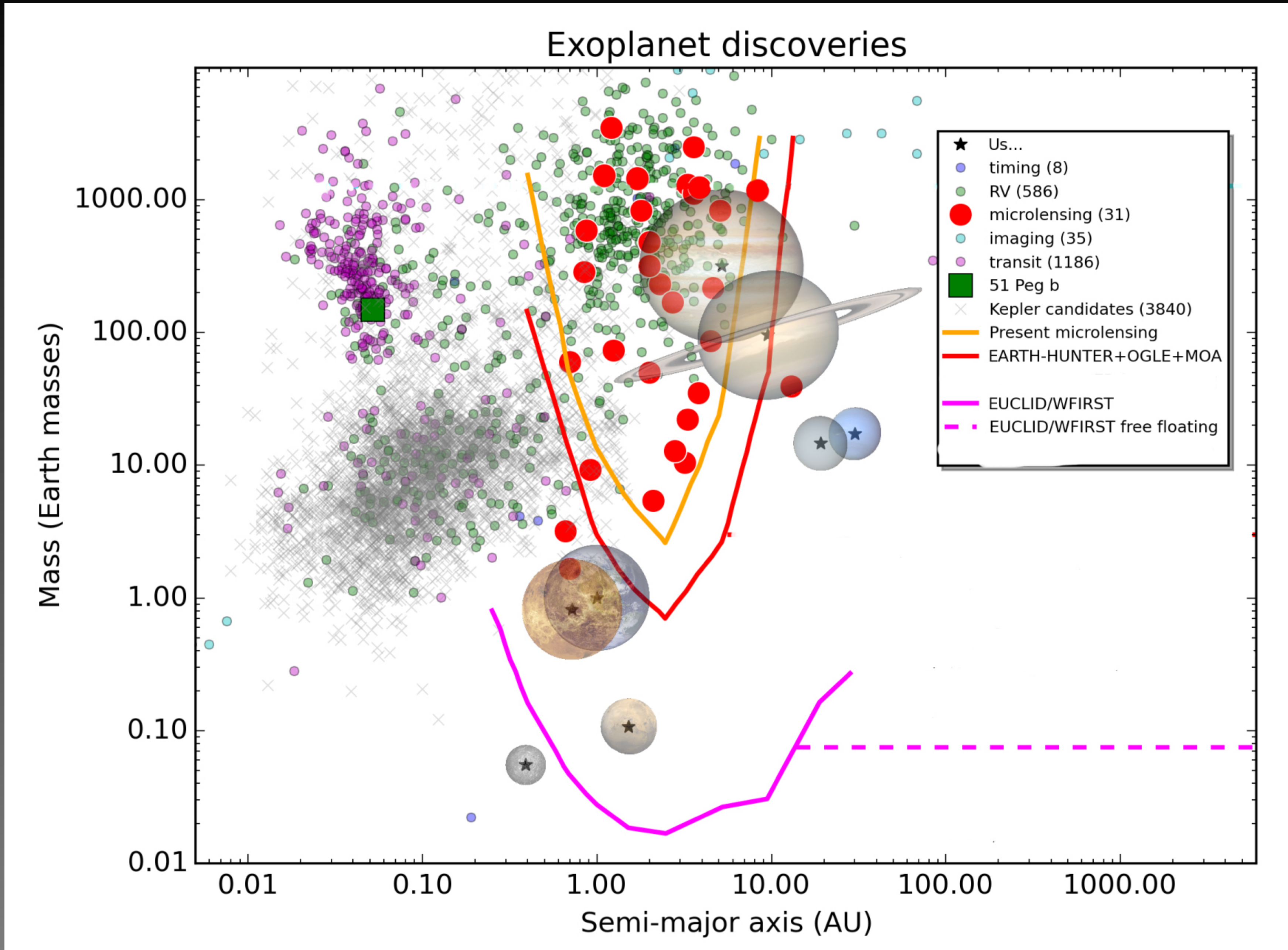
SURVEYS **In ~6 years**

	Area (deg2)	Description
Wide Survey	**15,000 deg^2**	Step and stare with 4 dither pointings per step.
Deep Survey	**40 deg^2**	In at least 2 patches of > 10 deg^2 2 magnitudes deeper than wide survey

PAYLOAD

Telescope	1.2 m Korsch, 3 mirror anastigmat, f=24.5 m				
Instrument	VIS	NISP			
Field-of-View	0.787×0.709 deg^2	0.763×0.722 deg^2			
Capability	Visual Imaging	NIR Imaging Photometry			NIR Spectroscopy
Wavelength range	550– 900 nm	Y (920-1146nm),	J (1146-1372 nm)	H (1372-2000nm)	1100-2000 nm
Sensitivity	24.5 mag 10σ extended source	24 mag 5σ point source	24 mag 5σ point source	24 mag 5σ point source	3 10^{-16} erg cm-2 s-1 3.5σ unresolved line flux
	Shapes + Photo-z of n = 1.5 x10^9 galaxies			z of n=2.5x10^7 galaxies	

Legacy science, microlensing survey, Supernovae, milky way to be decided
After the PDR (mid-late 2015)

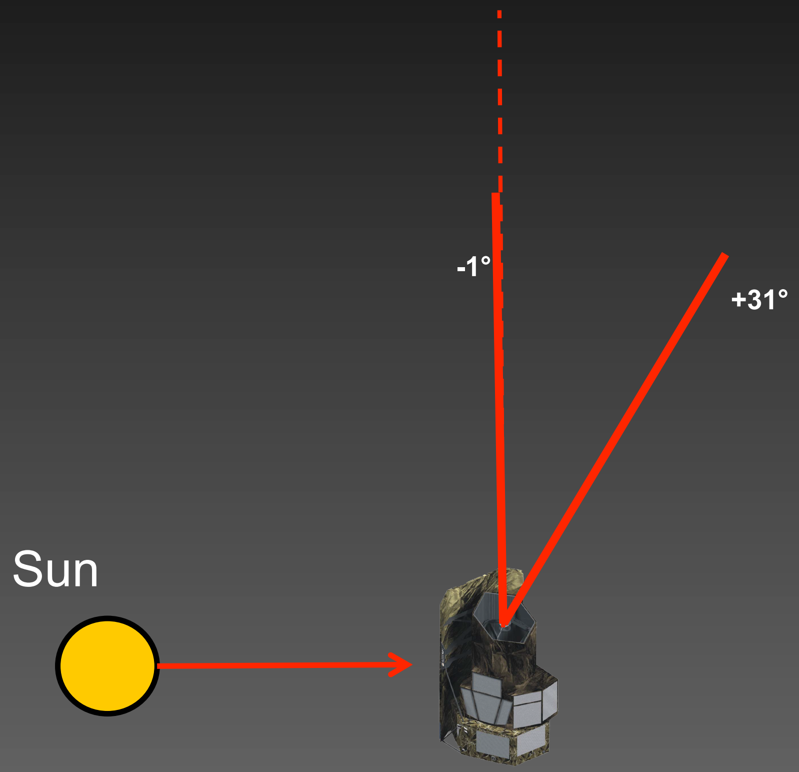

Exoplanet discoveries
Mass (Earth masses)
1000.00
100.00
10.00
1.00
0.10
0.01
0.01
0.10
1.00
10.00
100.00
1000.00
Semi-major axis (AU)
Us...
timing (8)
RV (586)
microlensing (31)
imaging (35)
transit (1186)
51 Peg b
Kepler candidates (3840)
Present microlensing
EARTH-HUNTER+OGLE+MOA
EUCLID/WFIRST
EUCLID/WFIRST free floating

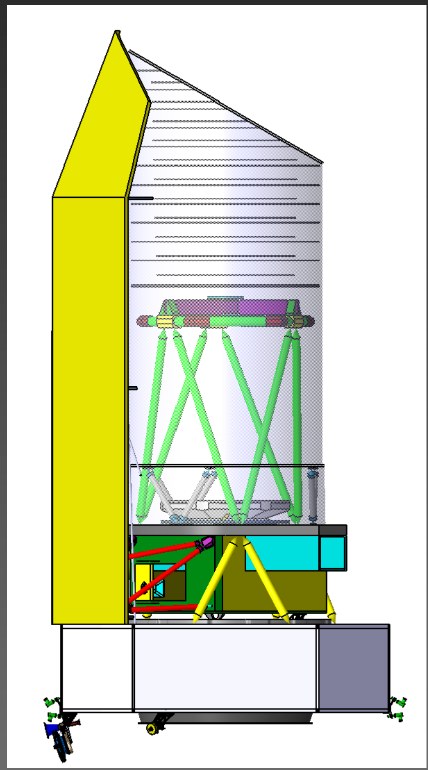
Status of the microlensing program on board EUCLID

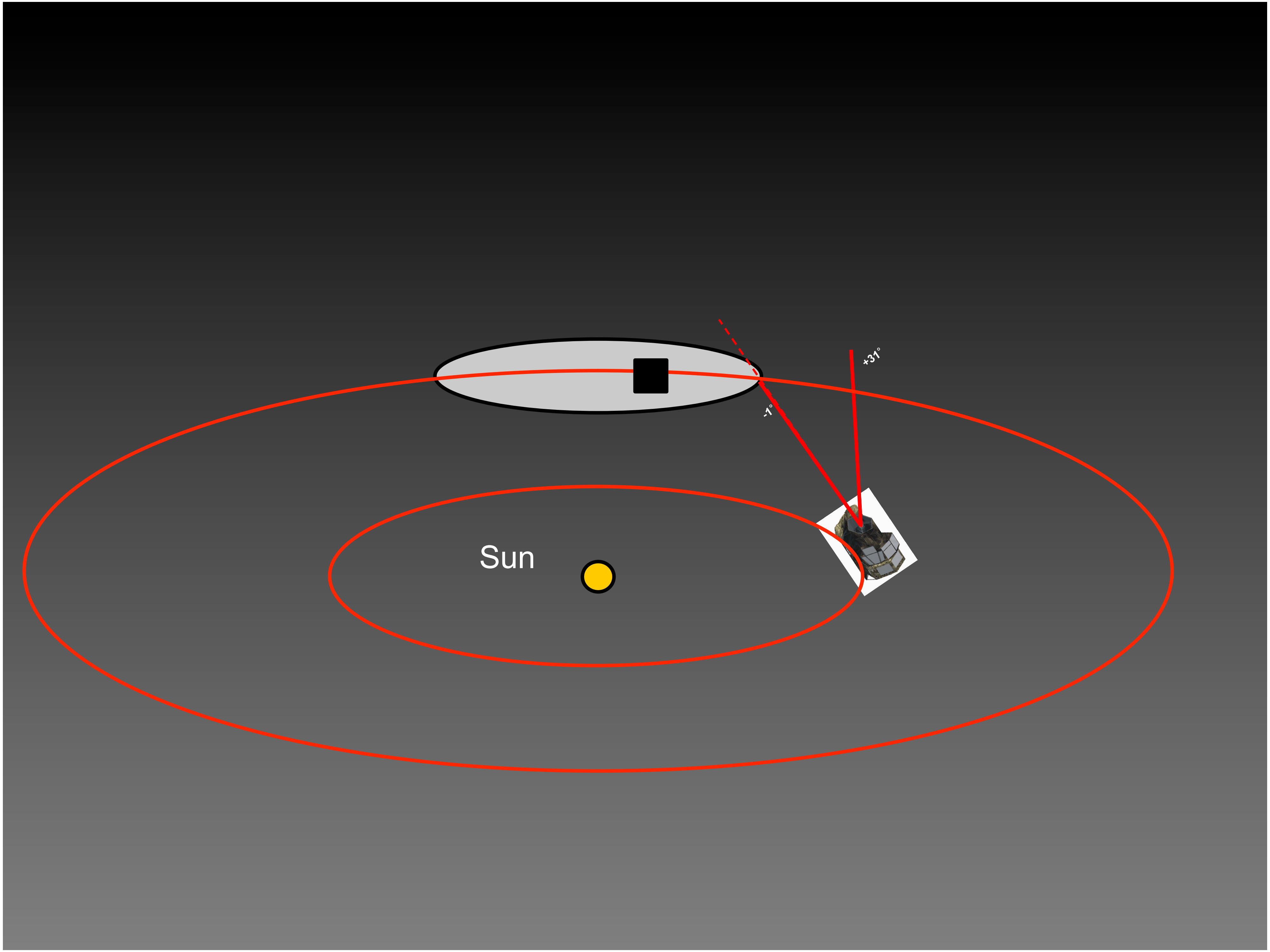
Being Legacy Science, we cannot set requirements.
Only Cosmic Shear and BAO can.

We have to wait the end of the mission PDR, mid-late 2015
to implement the Legacy surveys

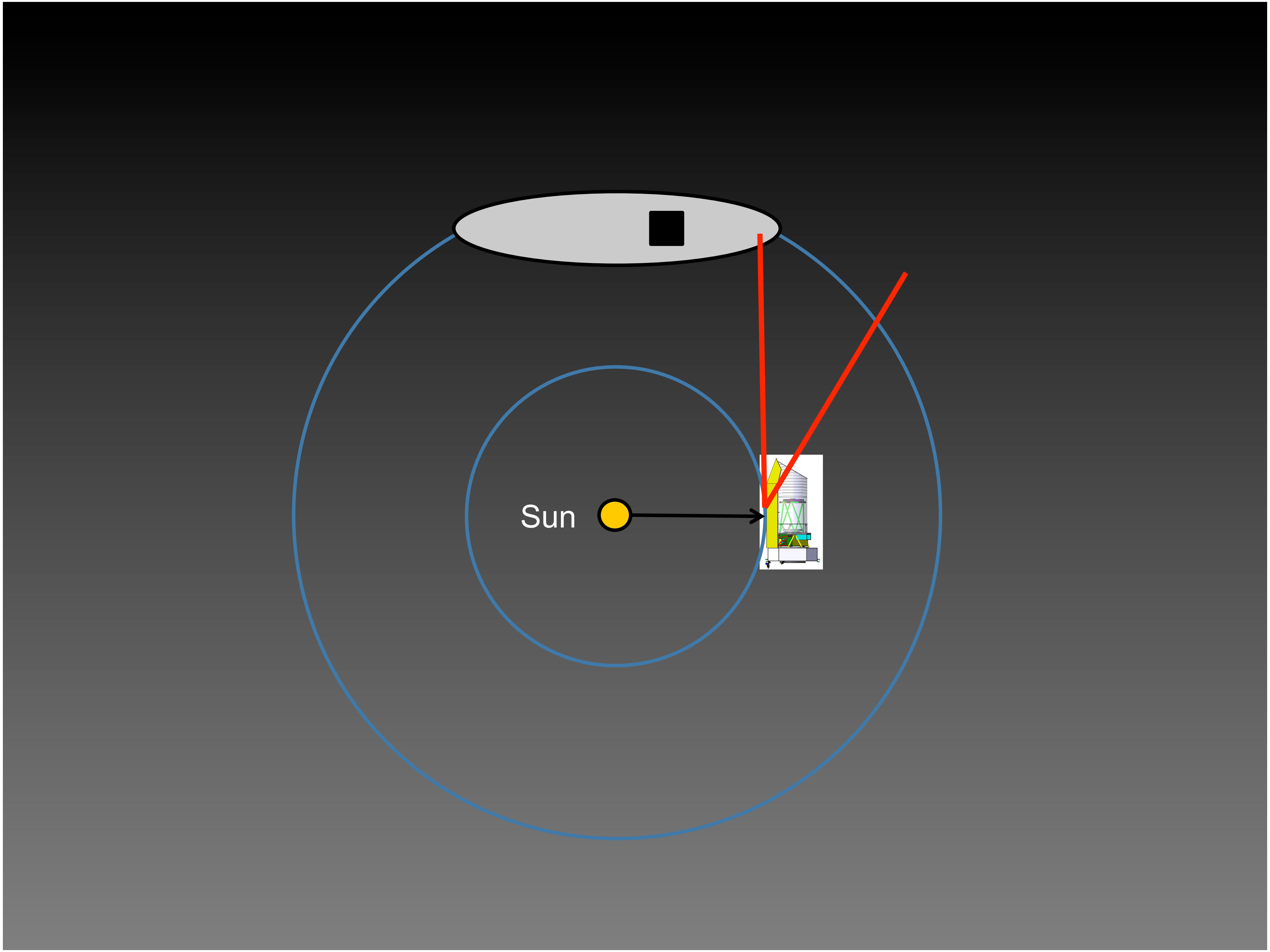
Sun avoidance angle, a limitation

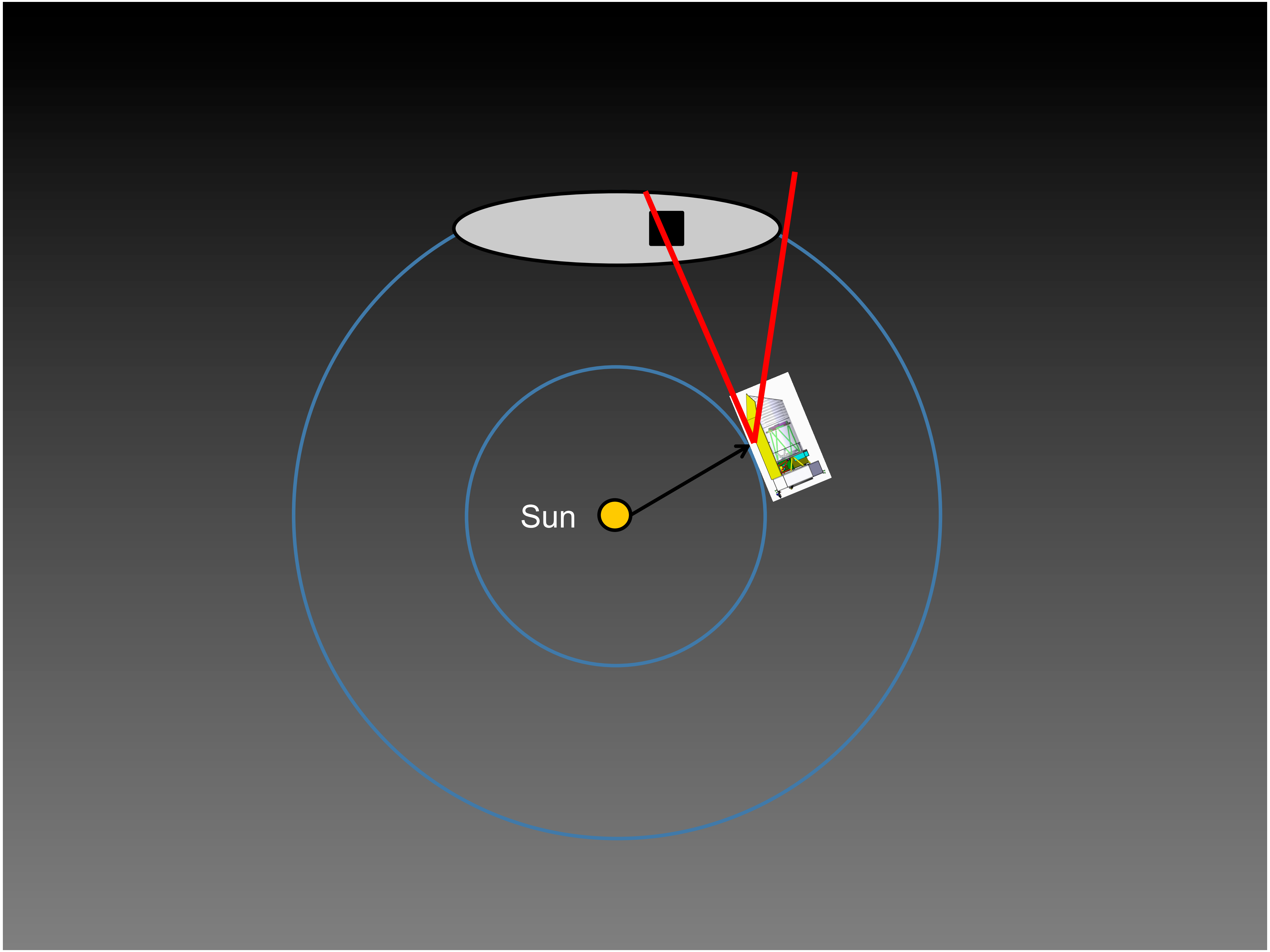


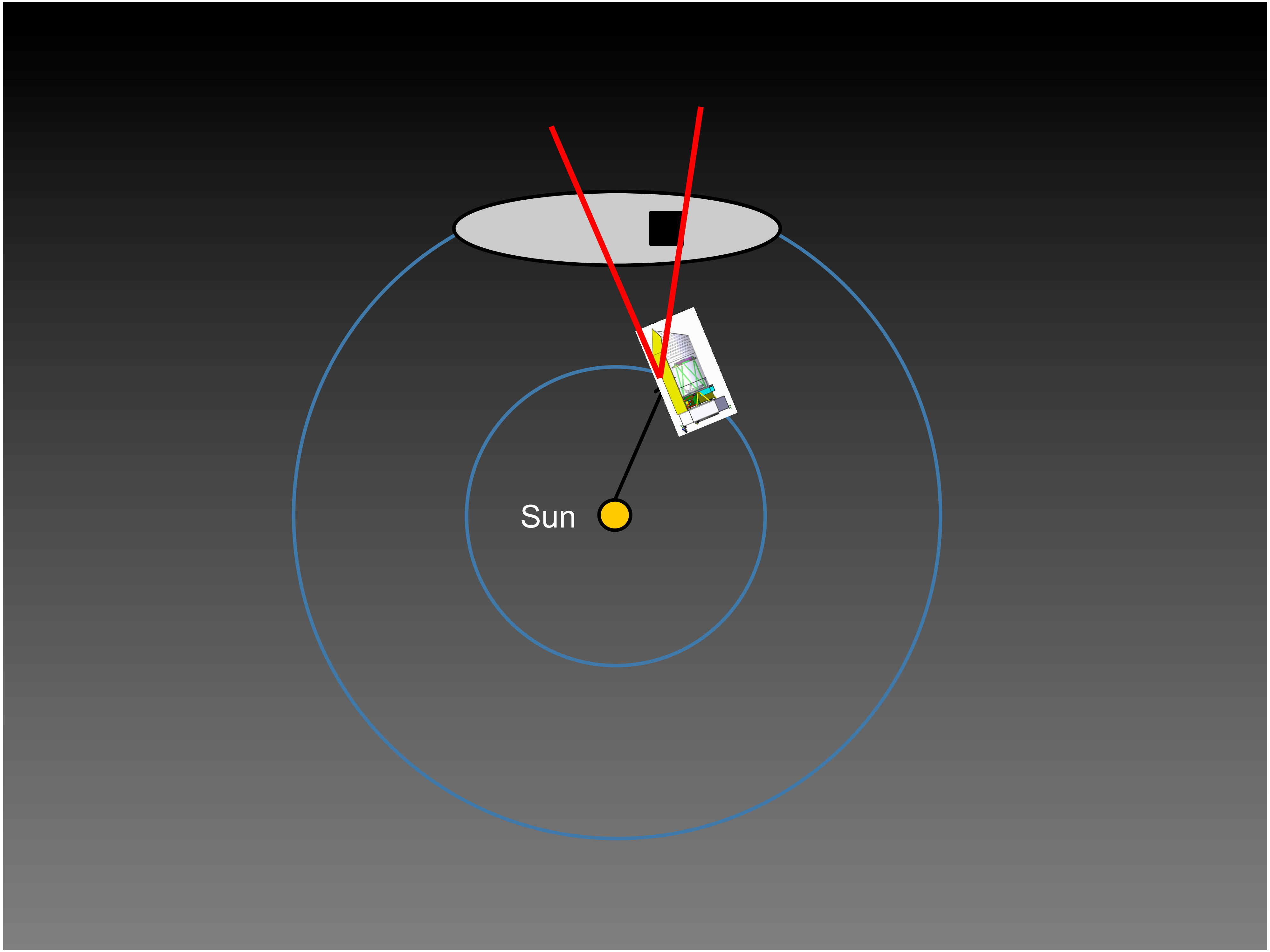


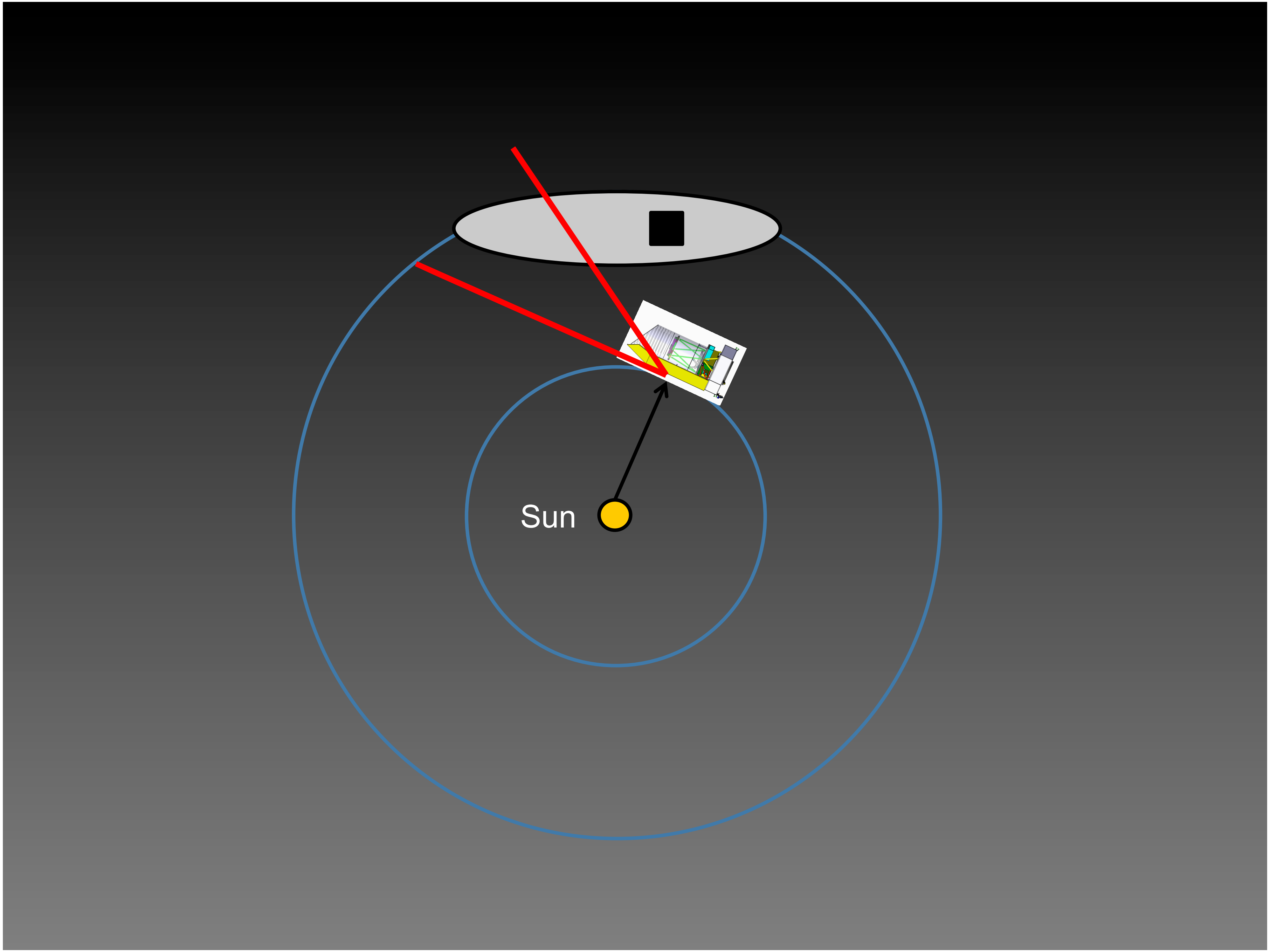


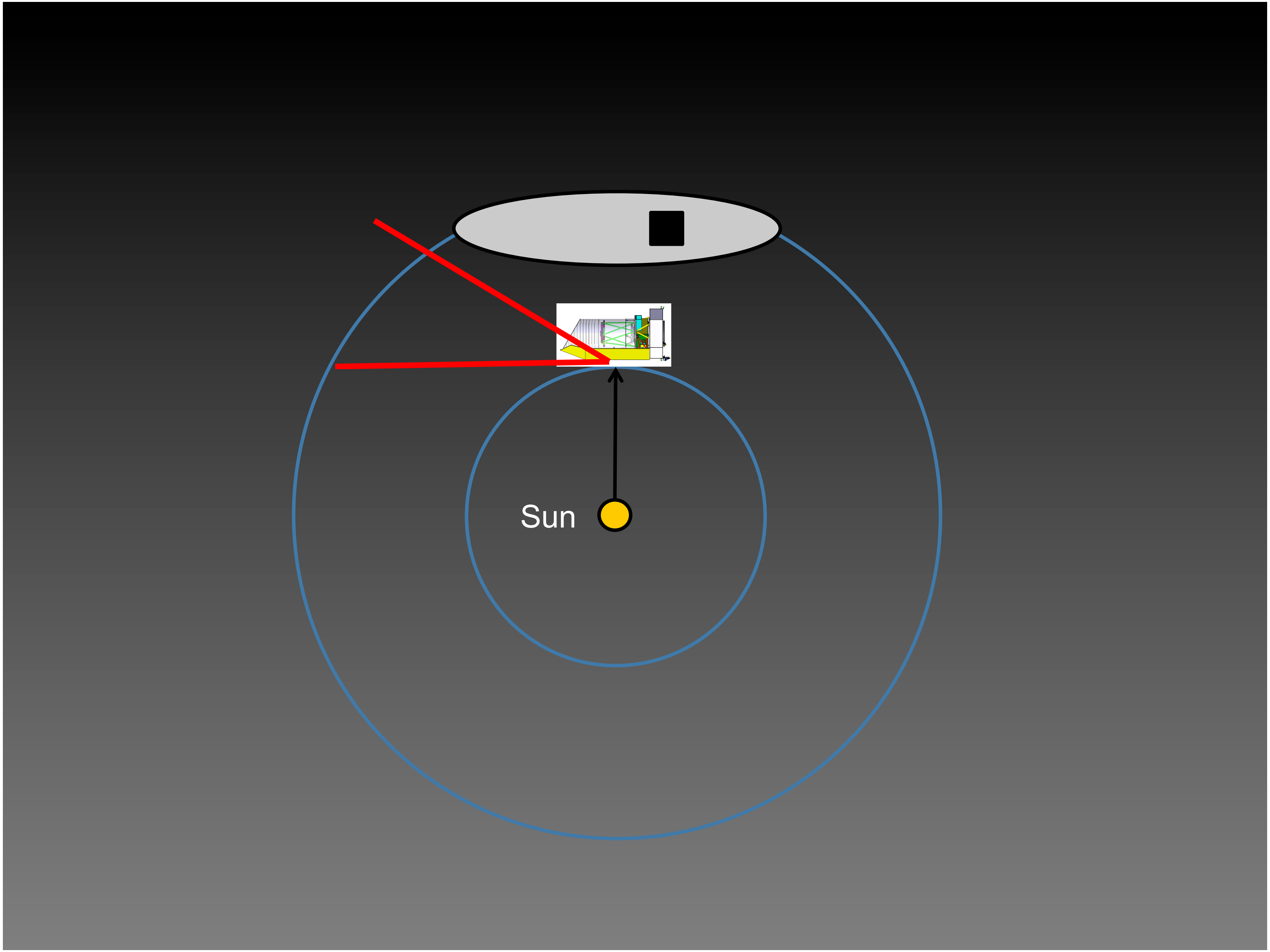
Sun
-1°
+31°

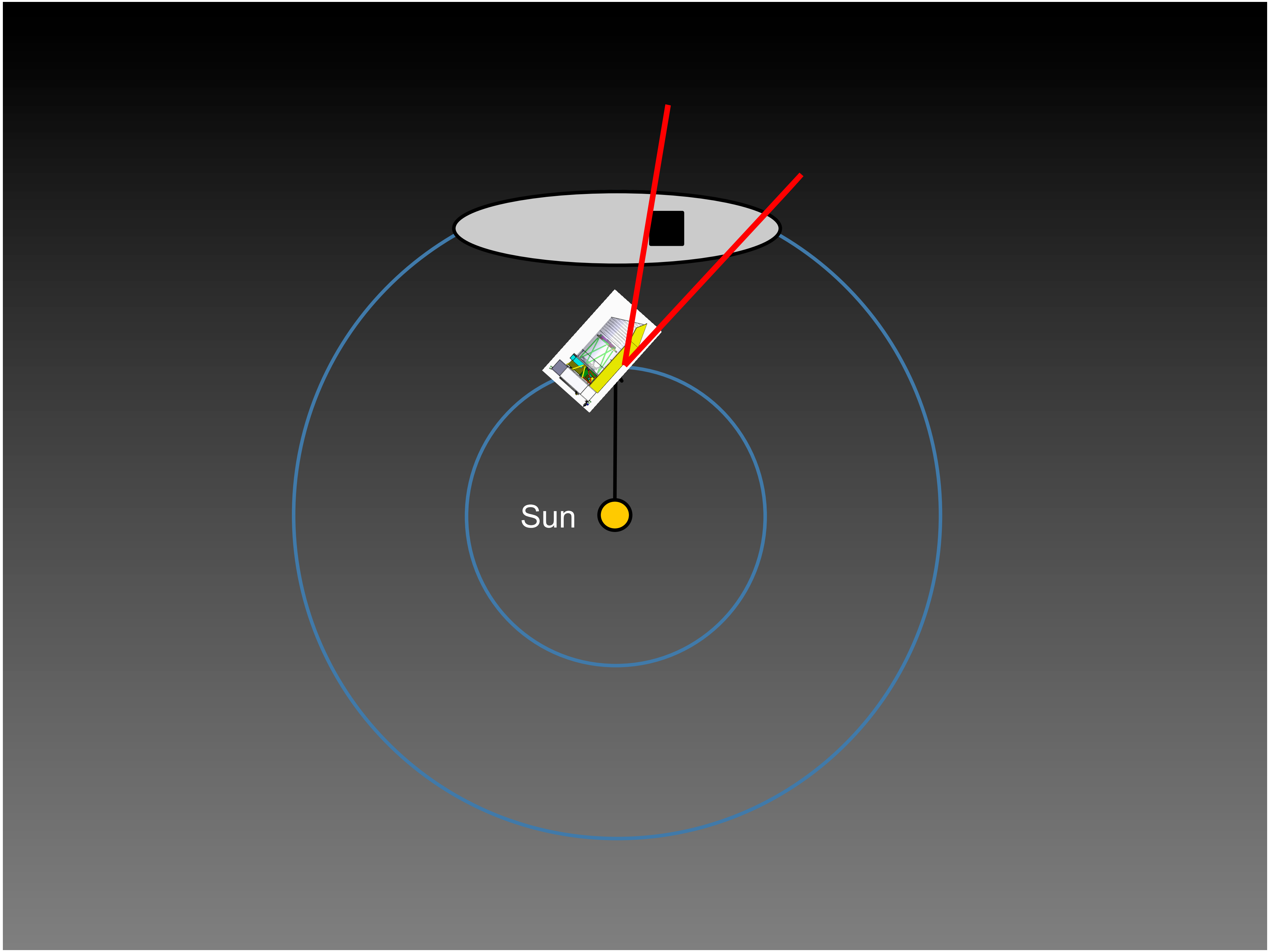

Sun

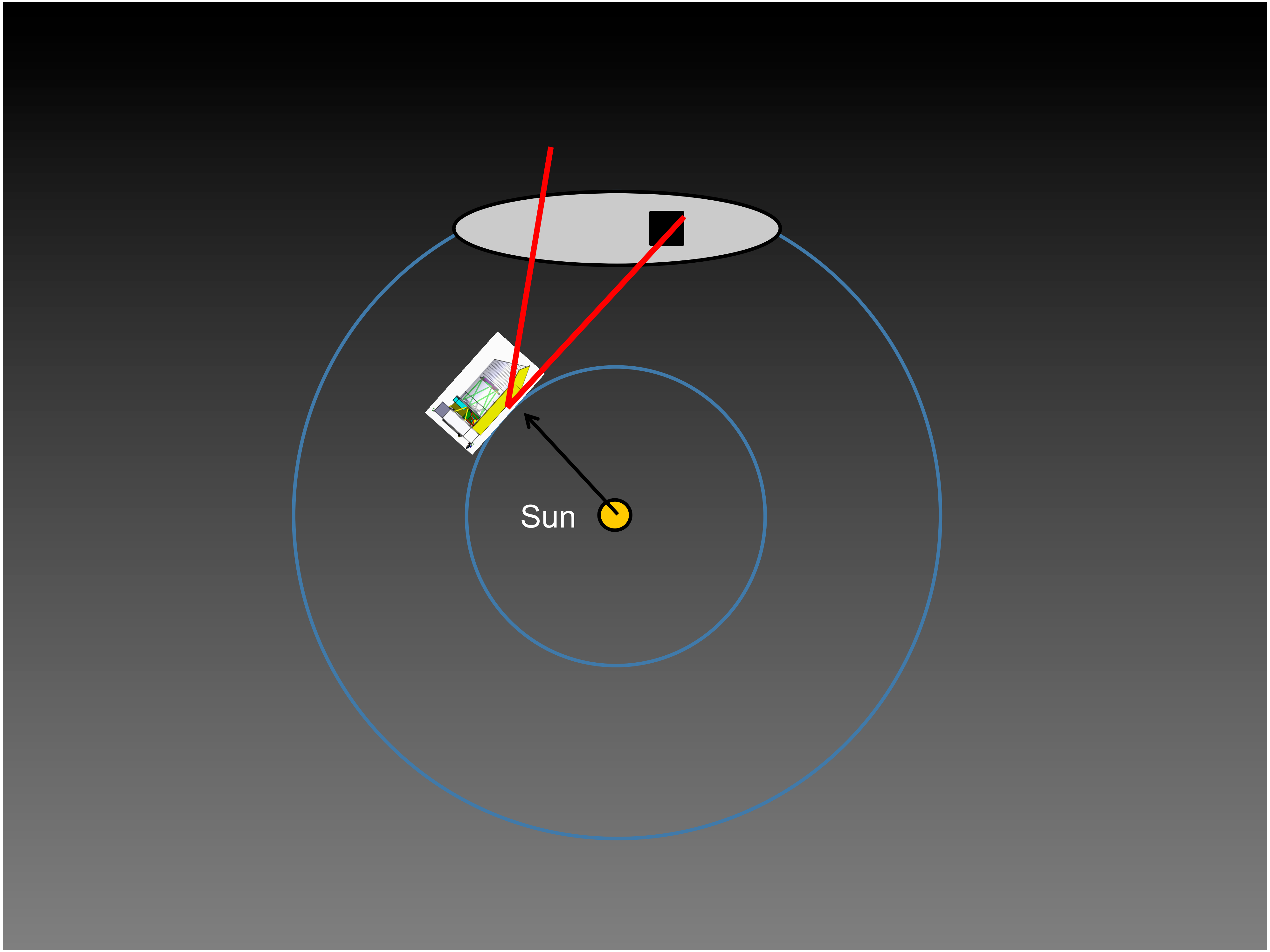

Sun

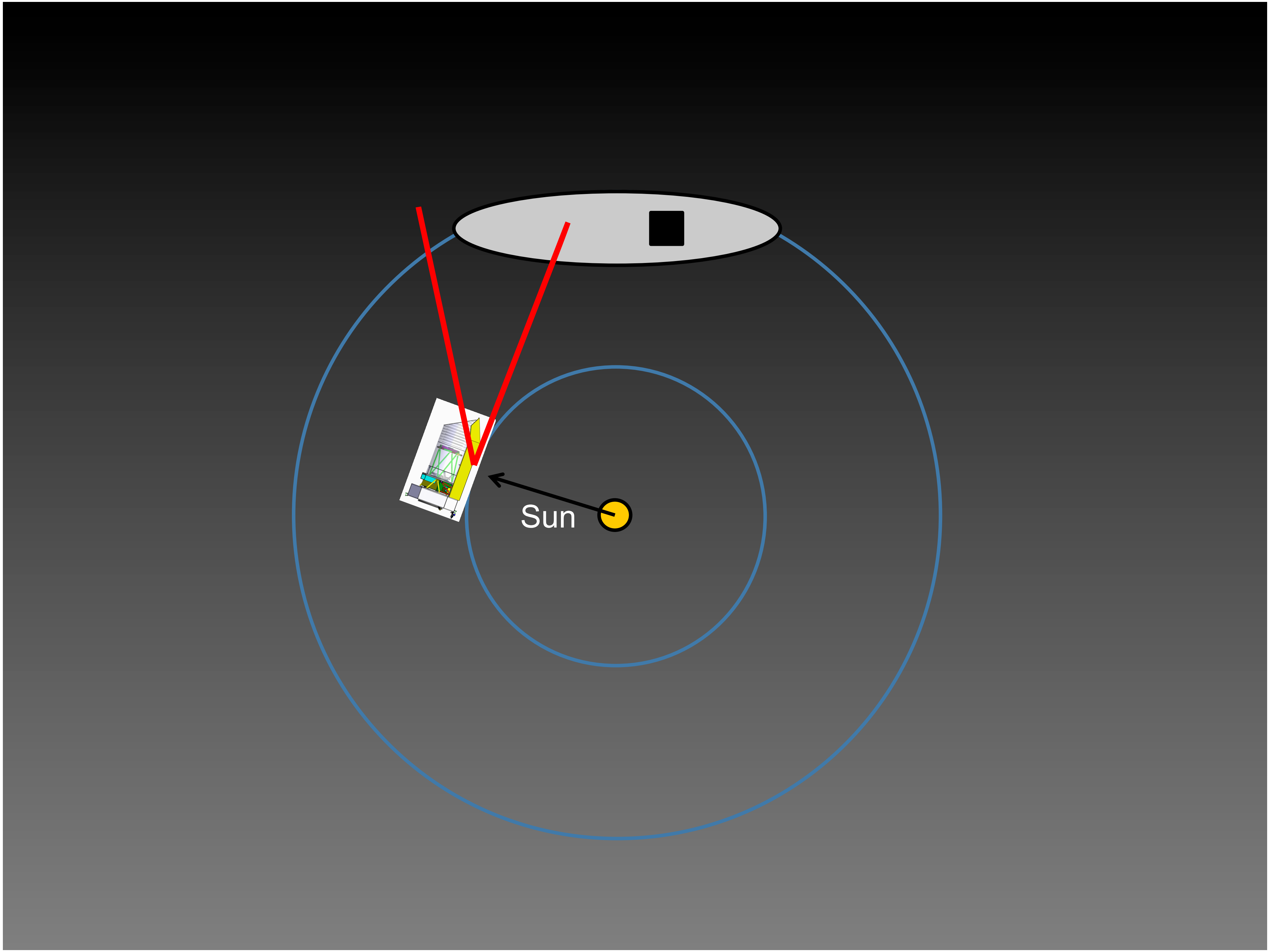

Sun


Sun


Sun


Sun


Sun


Sun

Operation angle from -1 deg to +31 deg.

We can observe for about a month, twice a year.

EUCLID has no contigency for weight : we cannot extend the shielding.

→ Maximum observation : 2 months/year

Waiting for EUCLID PRELIMINARY DESIGN REVIEW IN 2015

Final value of operation angle. 31 deg ? More ?

Pointing, repointing efficiencies : do we save time on the DE survey ?

Can we do the needed multiple pointings for a microlensing survey ?

What will be the data rate of EUCLID ?

We have a pretty good idea already of what the answers will be,
but we do need to get the final numbers !

Plans for EUCLID microlensing

A short VIS, Y, J, H survey during comissioning phase
(get constraints for proper motions)

4 months spread during the 6 years of the prime EUCLID mission

Possibility of microlensing survey during the extended mission 2026+
We can envision some simultaneous EUCLID-WFIRST observations

EUCLID microlensing

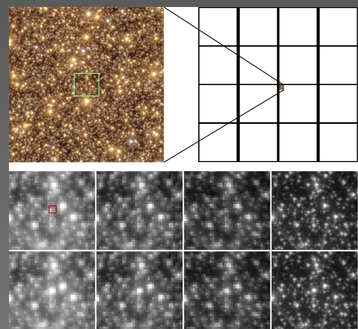
First estimates based on Bennett & Rhie (2002)
Beaulieu et al., 2008 ESA EPRAT white paper

Detailed simulations: *PhD of M. Penny*
Penny M. T., Kerins E., Rattenbury N., Beaulieu J.-P., Robin A. C., Mao S., Batista V., Calchi Novati S., Cassan A., Fouqué P., McDonald I., Marquette J. B., Tisserand P., Zapatero Osorio M. R., 2013, "ExELS: an exoplanet legacy science proposal for the ESA Euclid mission - I. Cold exoplanets"

EUCLID microlensing

	RIZ	*Y*	*J*	*H*
Telescope parameters				
Diameter (m)				1.2
Central blockage (m)				0.4
Slew + settle time (s)				85(285)
Detector parameters				
Instrument	VIS		NISP	
Filter	*RIZ*	*Y*	*J*	*H*
Size (pixels)	24k × 24k		8k × 8k	
Pixel scale (arcsec)	0.1		0.3	
PSF FWHM (arcsec)	0.18	0.3*	0.36*	0.45*
Bias level (e^-)	380†		380†	
Full well depth (e^-)	2^{16}		2^{16}	
Zero-point (ABmag)	25.58⋆	24.25⋆⋆	24.29⋆⋆	24.92⋆⋆
Readout noise (e^-)	4.5	7.5*	7.5*	9.1*
Thermal background (e^- s^{-1})	0	0.26	0.02	0.02
Dark current (e^- s^{-1})	0.00056◇		0.1*	
Systematic error	0.001†		0.001†	
Diffuse background (ABmag $arcsec^{-2}$)	21.5‡	21.3‡	21.3‡	21.4‡
Exposure time (s)	540(270)	90	90	54
Images per stack	1	3(1)	3(1)	5(2)
Readout time (s)	< 85		5†	

- Besançon model
- Microlensing simulator
  3 fields, 270 sec per pointing,
  5x2 months observing



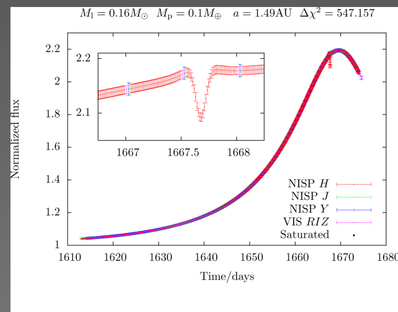
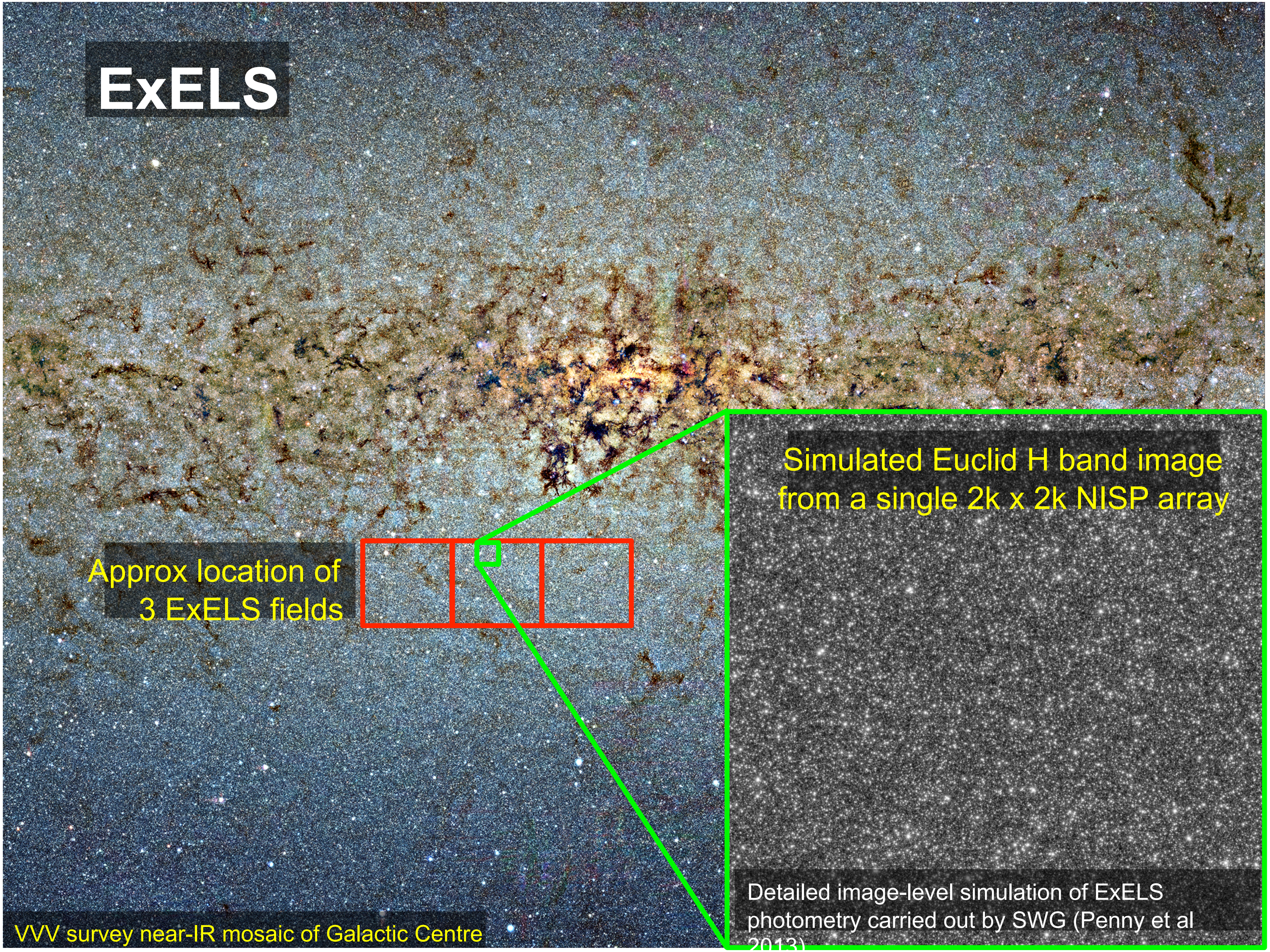
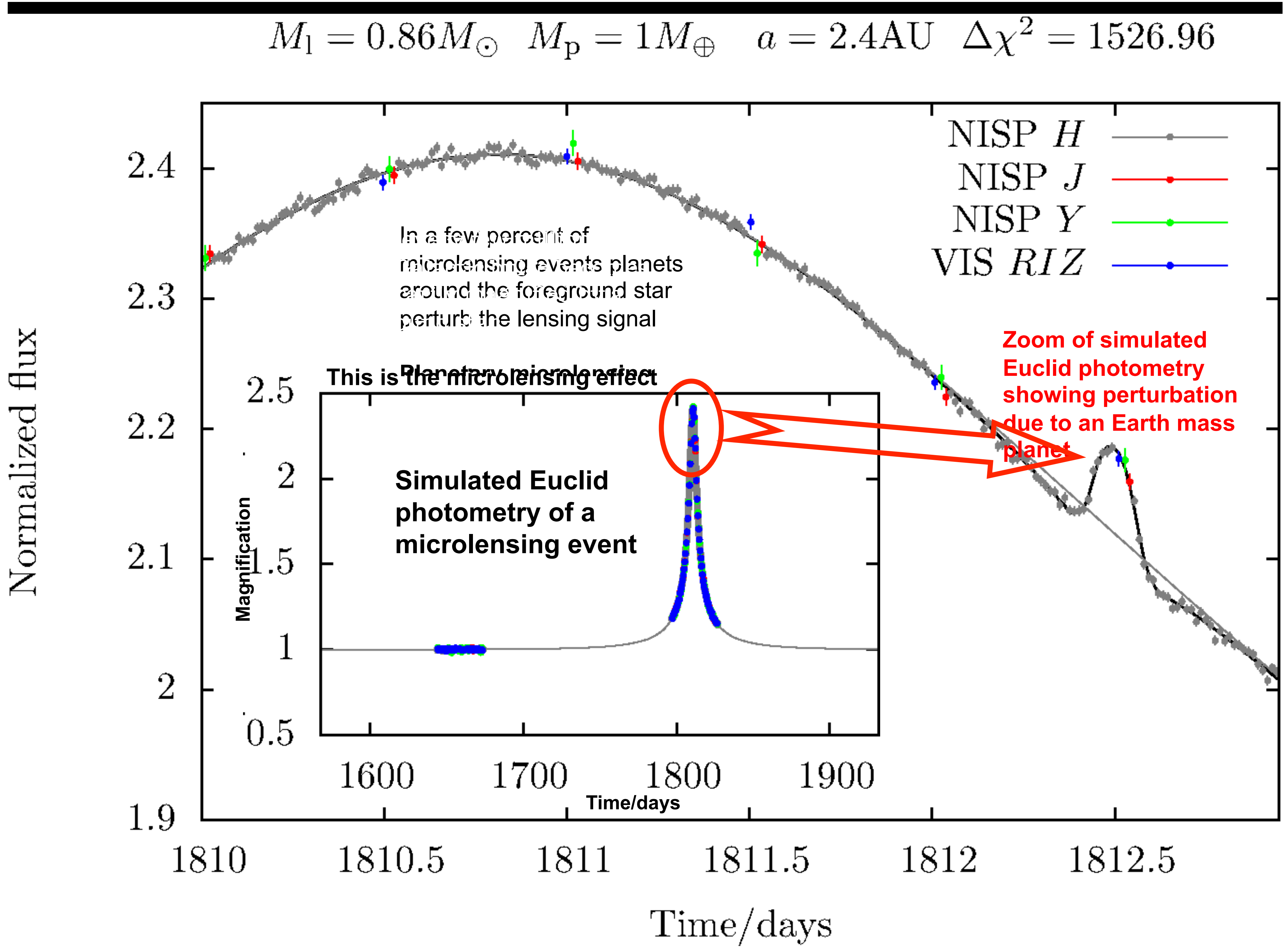


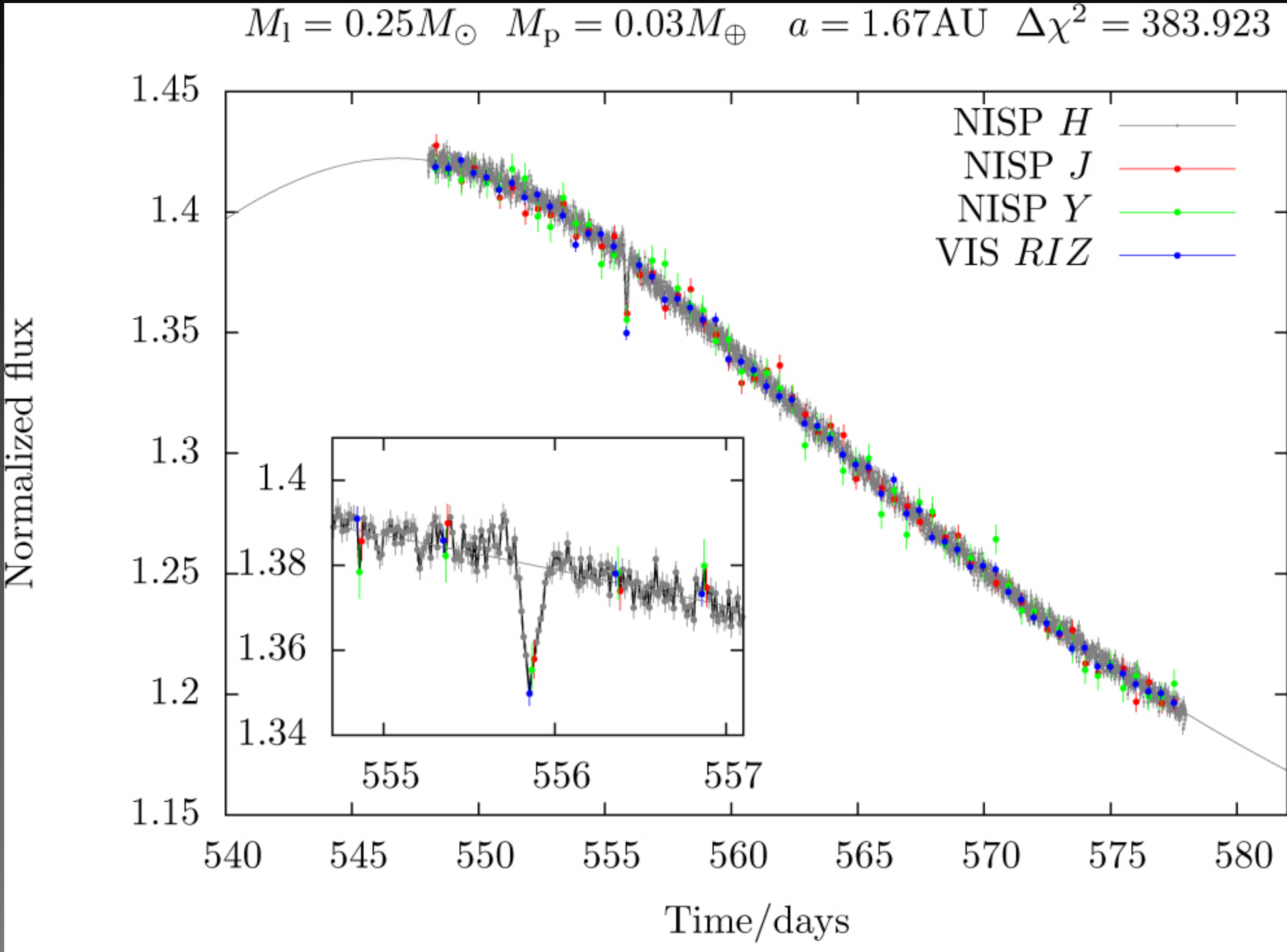
Figure 3. Example lightcurves


ExELS
Approx location of
3 ExELS fields
Simulated Euclid H band image
from a single 2k x 2k NISP array
Detailed image-level simulation of ExELS
photometry carried out by SWG (Penny et al
2013)
VVV survey near-IR mosaic of Galactic Centre



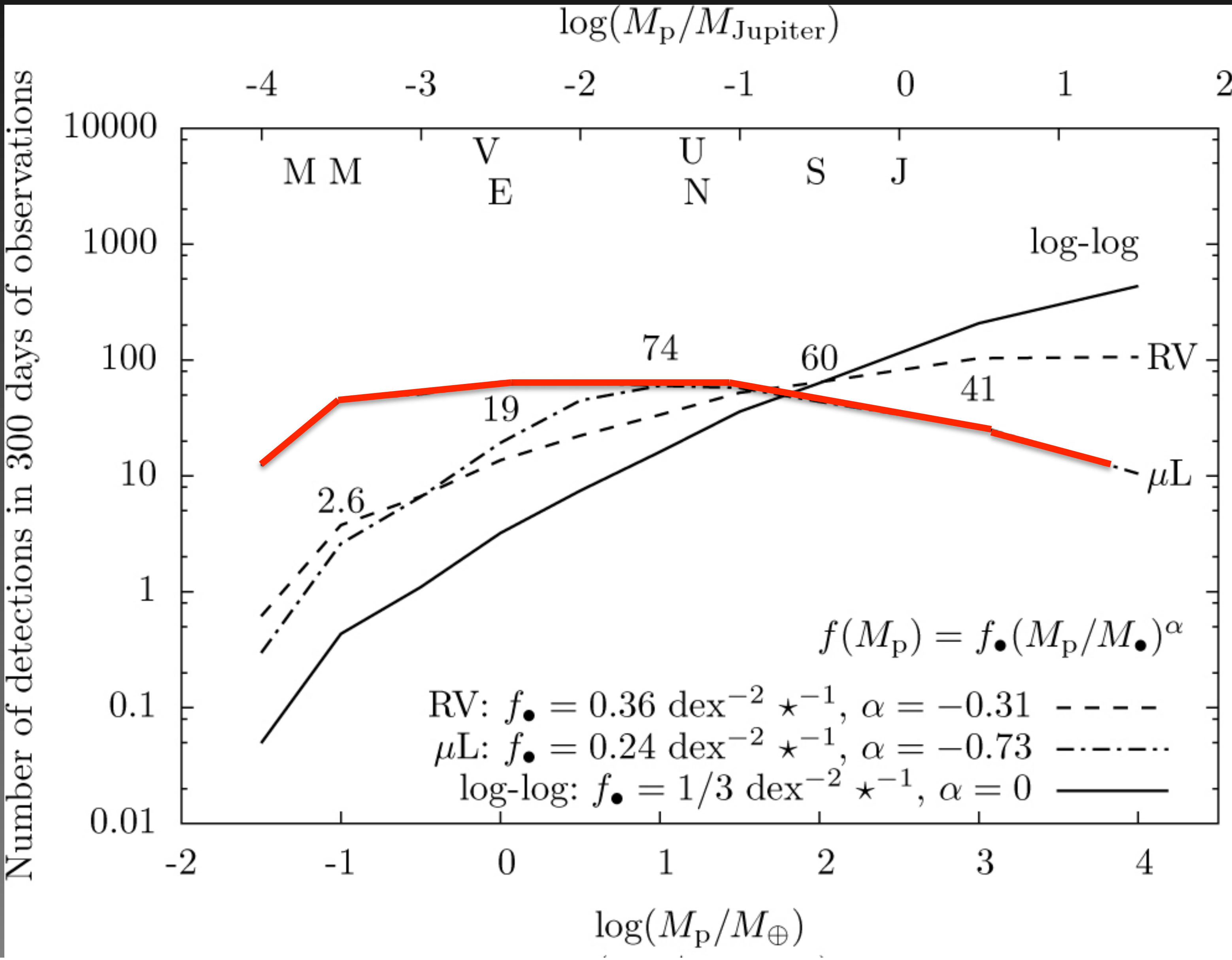
$M_l = 0.86 M_\odot$ $M_p = 1 M_\oplus$ $a = 2.4$AU $\Delta\chi^2 = 1526.96$
Normalized flux
Time/days
NISP H
NISP J
NISP Y
VIS RIZ
In a few percent of microlensing events planets around the foreground star perturb the lensing signal
This is the microlensing effect
Planetary microlensing
Simulated Euclid photometry of a microlensing event
Magnification
Time/days
Zoom of simulated Euclid photometry showing perturbation due to an Earth mass planet

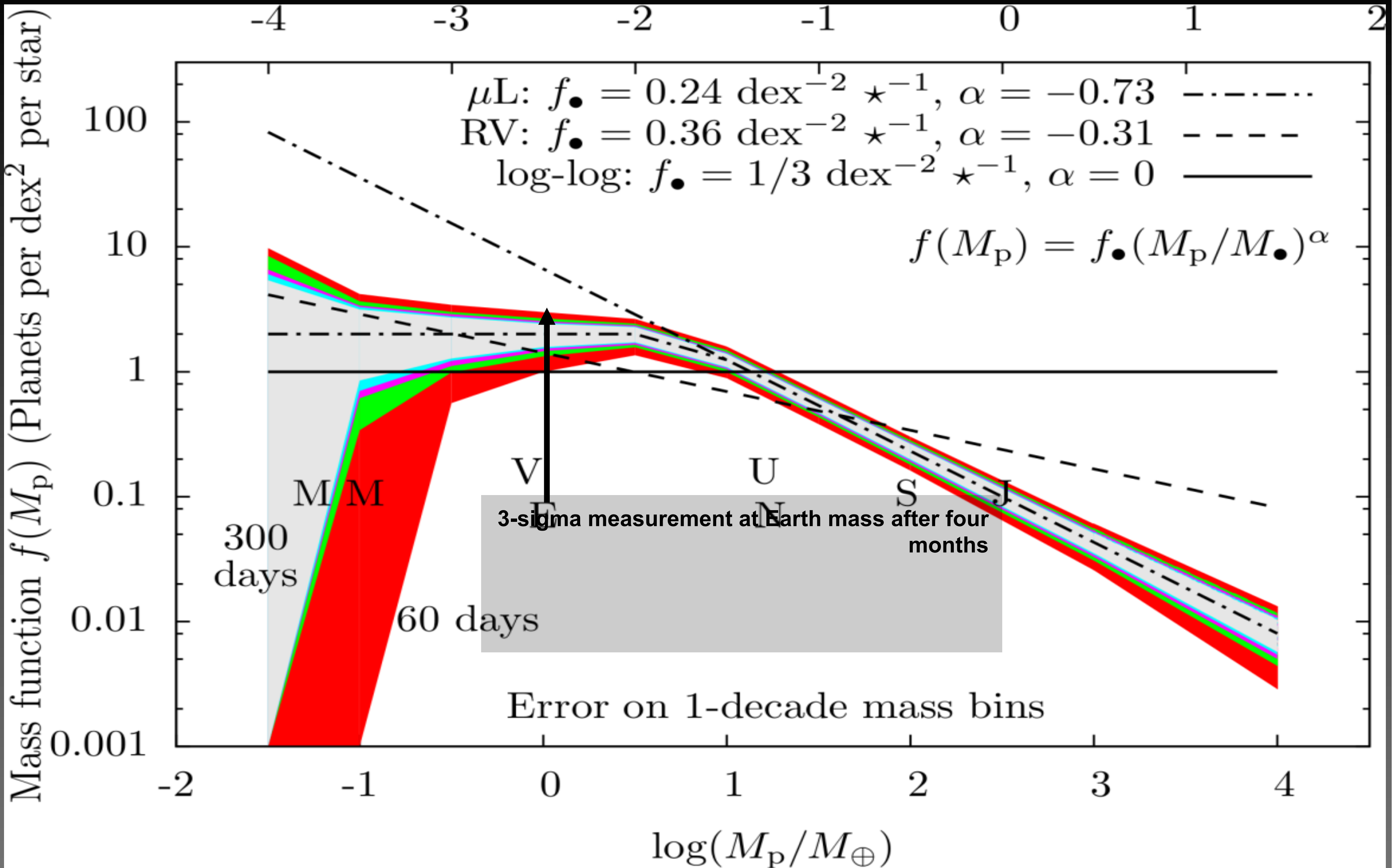
EUCLID will detect very low mass planets



(d)

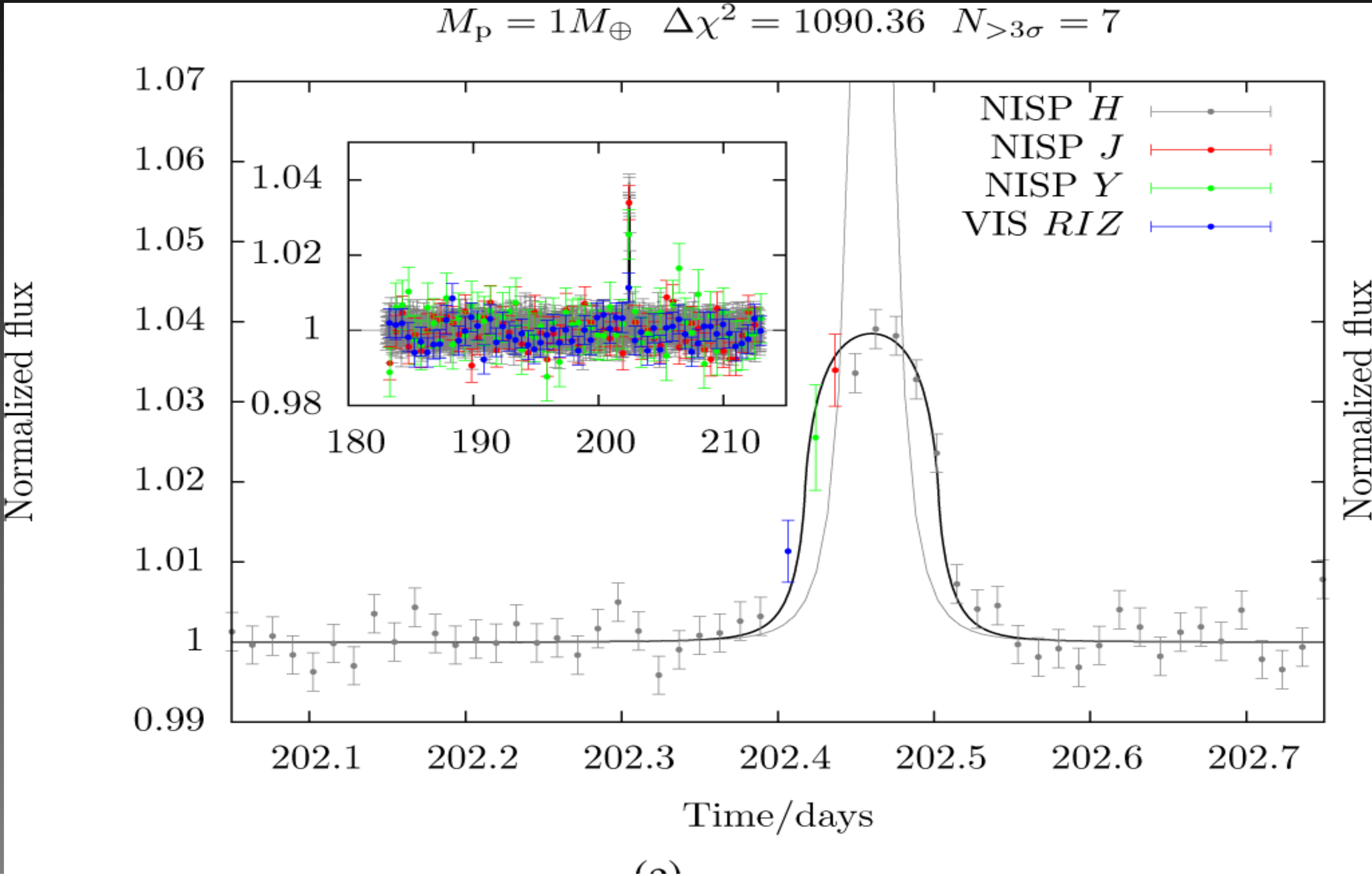
EUCLID's planet catch



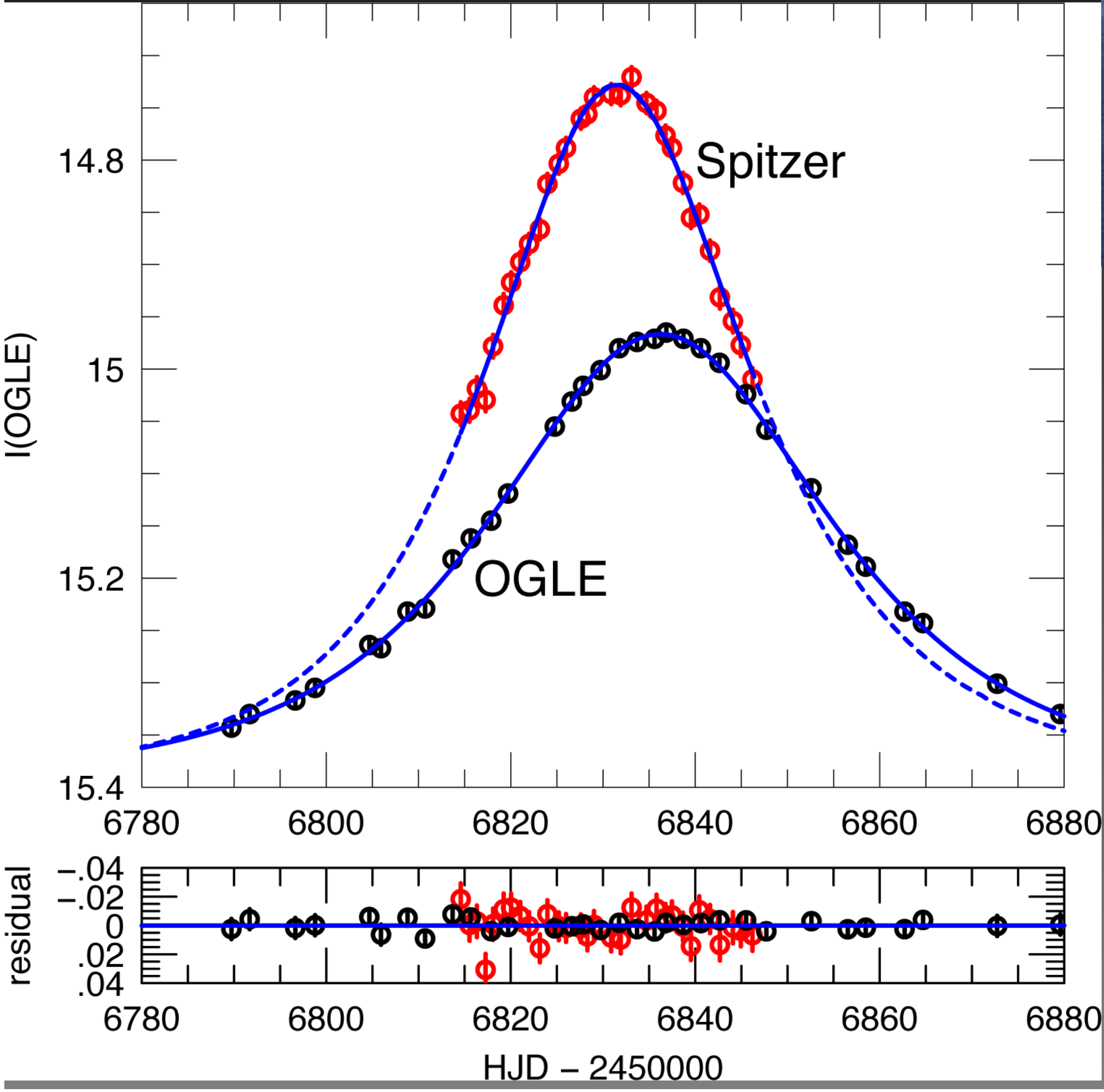


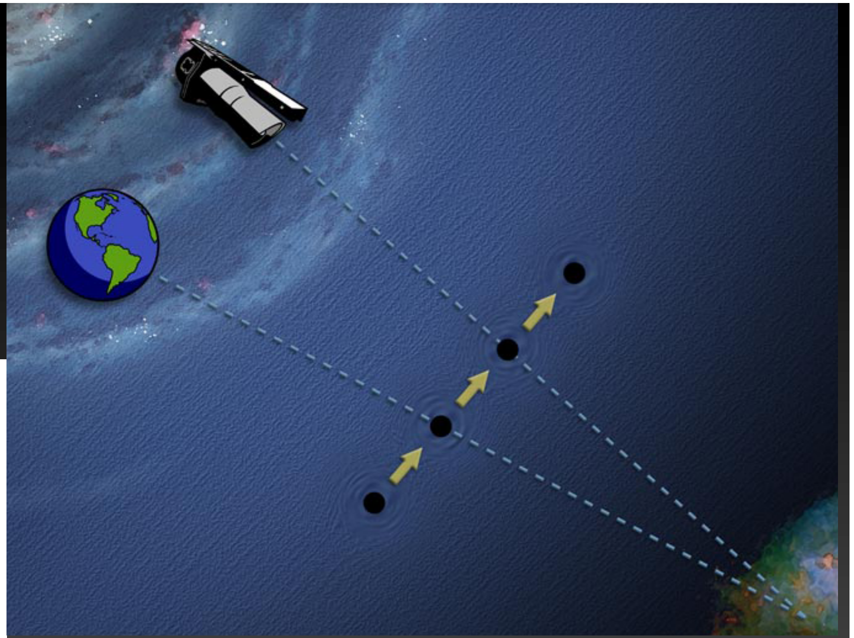
Abundance measurement sensitivity versus
planet mass for different extrapolations of measured
exoplanet mass functions and survey lifetimes

Free floating planets



Parallax Ground-Space





Spitzer at 1 AU from us

We can measure the mass
And distance of the lens.

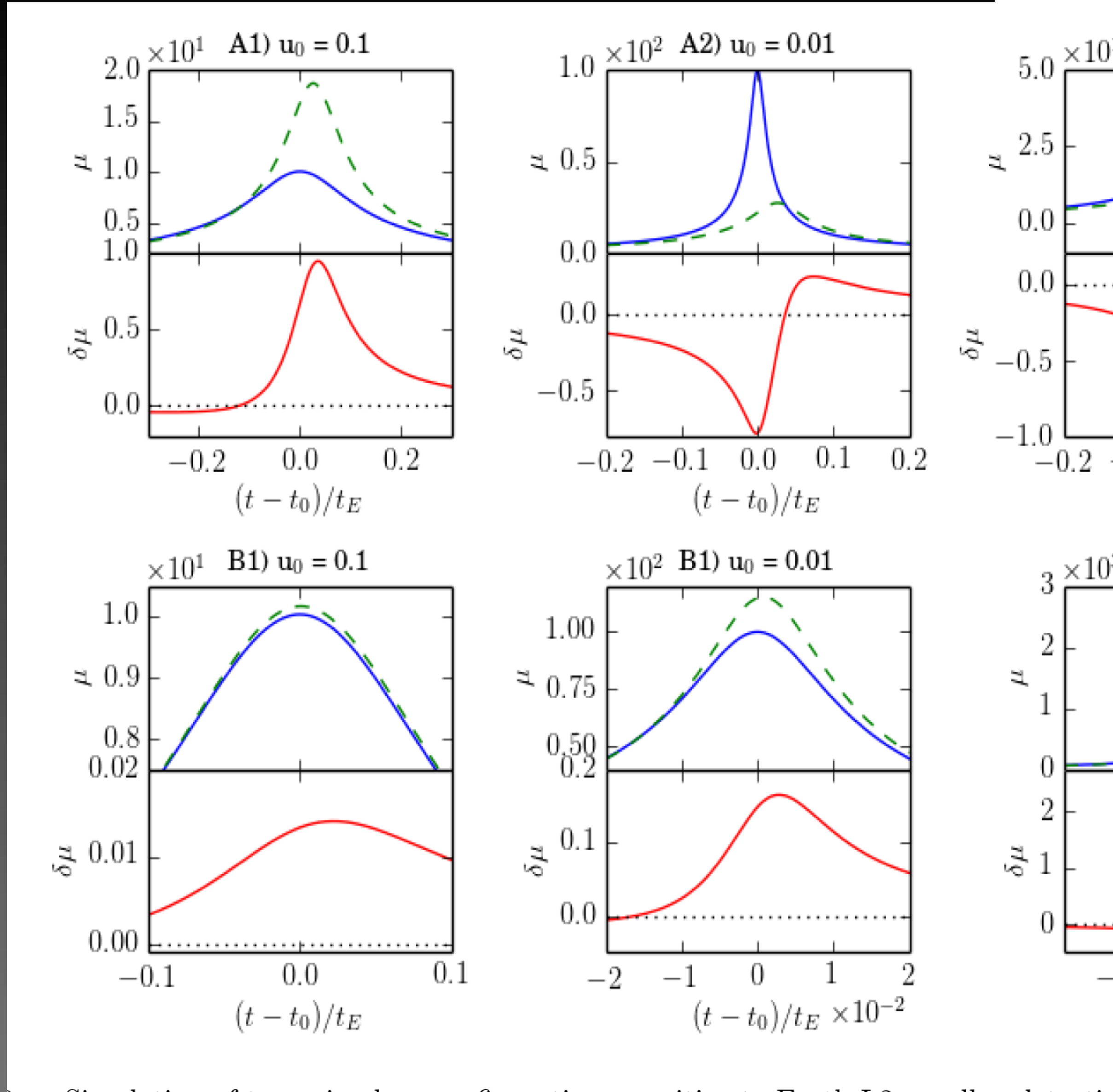
Yee et al., 2014, astroph
Jennifer's talk

Ground-space parallax (EUCLID + ground)

Mogavero & Beaulieu, 2015, in prep

Jupiter at 500 pc

Brown dwarf at 4 kpc



In a significant number of cases, we will get masses directly !

Things to do for late 2015

Work to be done:
- Ground space parallax for EUCLID (in progress)
- Study the effect of ghosts from NISP camera on photometry (not started)
- Study the effect of persistence from IR chips
- Revising strategy, planet catch, in light of PDR
- Study simultaneous EUCLID-WFIRST obs
- Constraints on lens mass & proper motion

Community:
- Need for support from the community

Microlensing program on board the EUCLID Dark Universe Probe

3 fields observed every 17 min in H, every 12 hours in VIS, J, Y.
Mini-survey during commissionning, then 4 months survey

- Measuring cold Earth abundance and mass function

  ~35 planets / month (5 Earth / month, 15 Neptune / month)

- Getting constraints on free floating planets

  ~15 free-floating planets / month

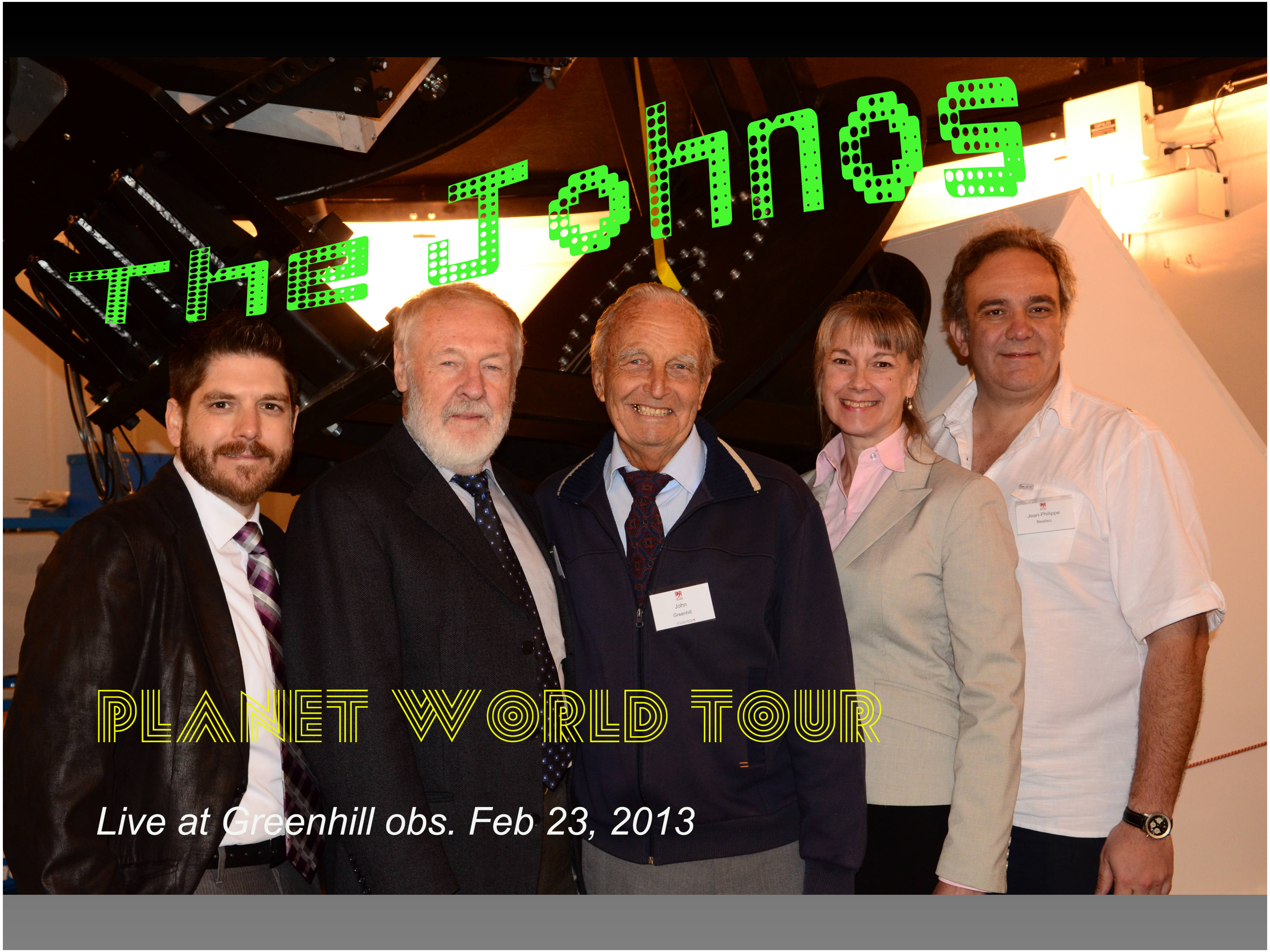
- EUCLID/ML complements parameter space probed by RV and KEPLER

- Currently in Legacy science. Why ?

  The board and ESA are waiting for the PDR of the full mission 2015.

- EUCLID understood the excellent synergy cosmic shear/microlensing requirements already in 2007…

- Possibility of simultaneous EUCLID-WFIRST in the extended mission 2026+


The Johnos
PLANET WORLD TOUR
Live at Greenhill obs. Feb 23, 2013