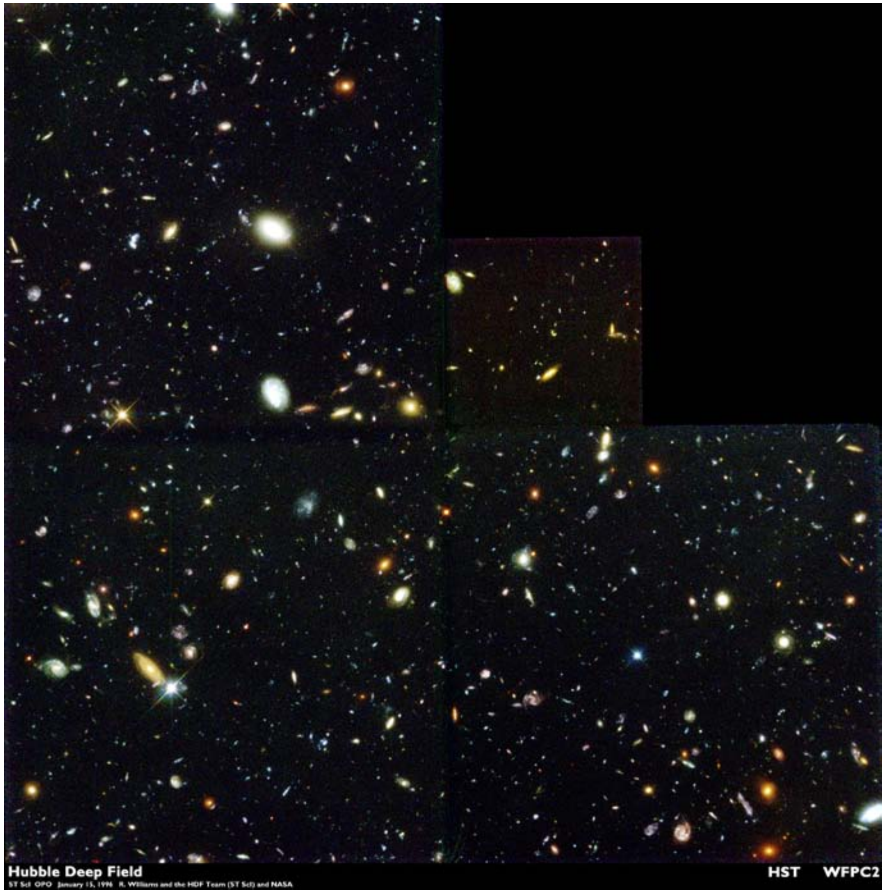
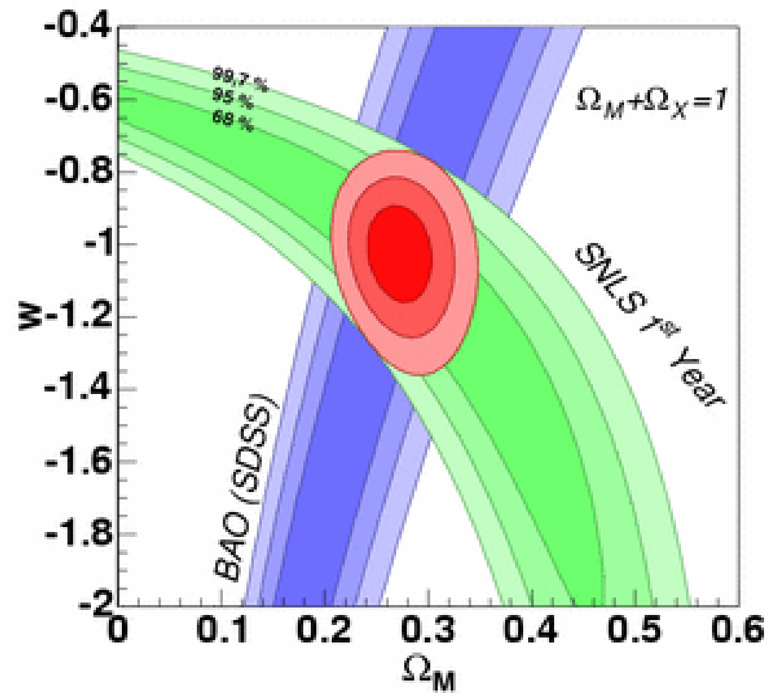
Les grands télescopes du futur au sol et dans l'espace

Citius, Altius, Fortius

CITIUS : plus vite

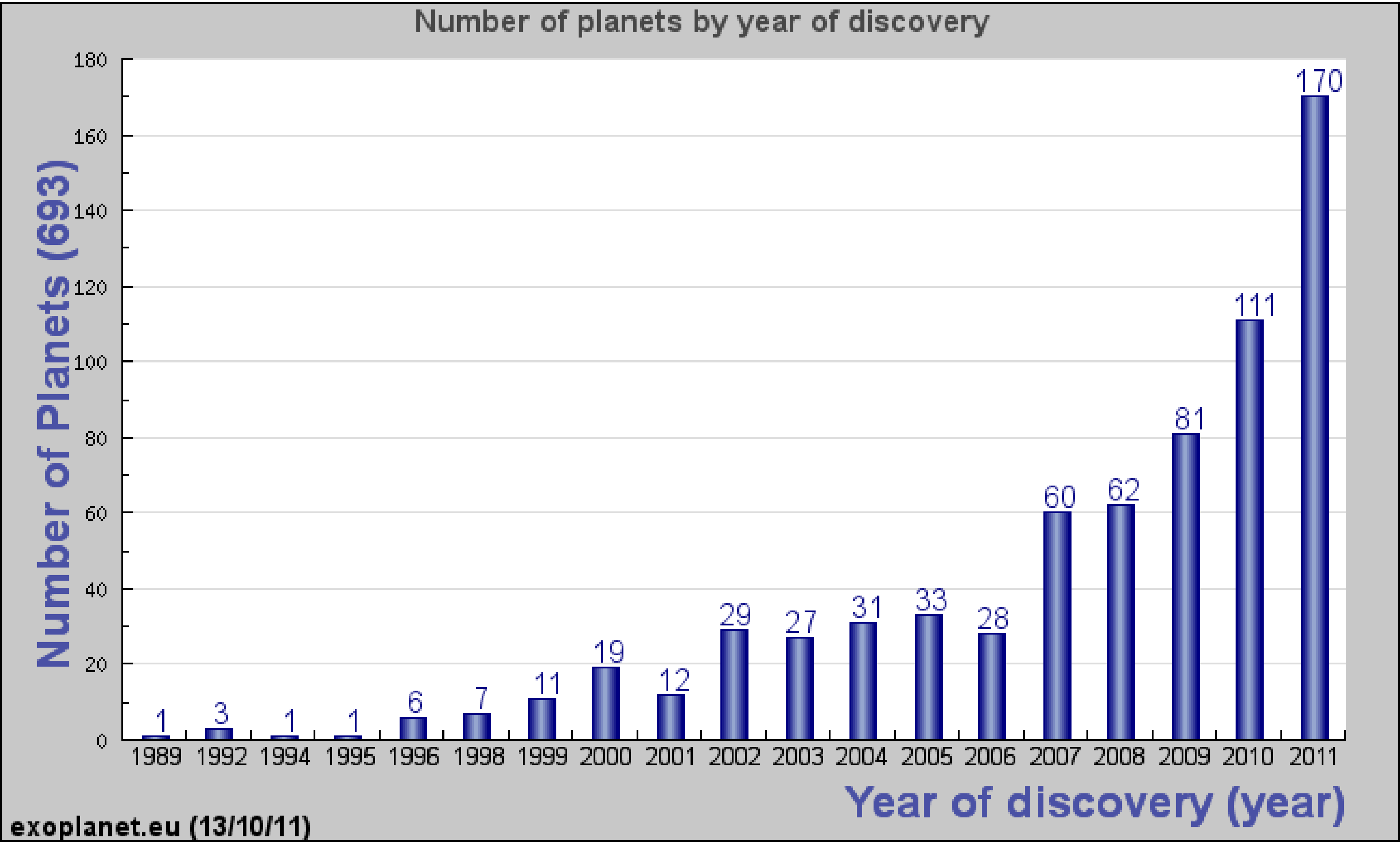


l'approche statistique pour connaître l'évolution des galaxies



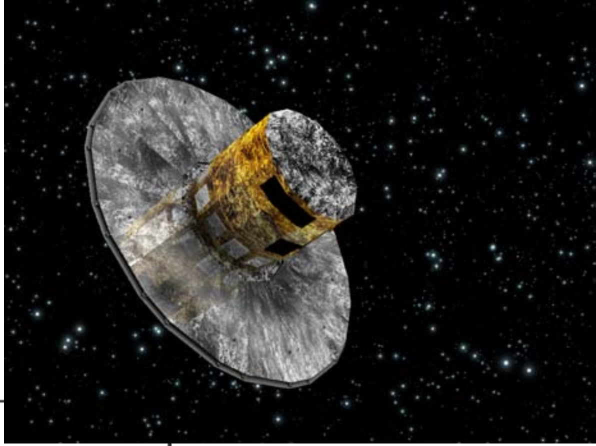
Couvrir de très grandes surfaces pour les études de cosmologie

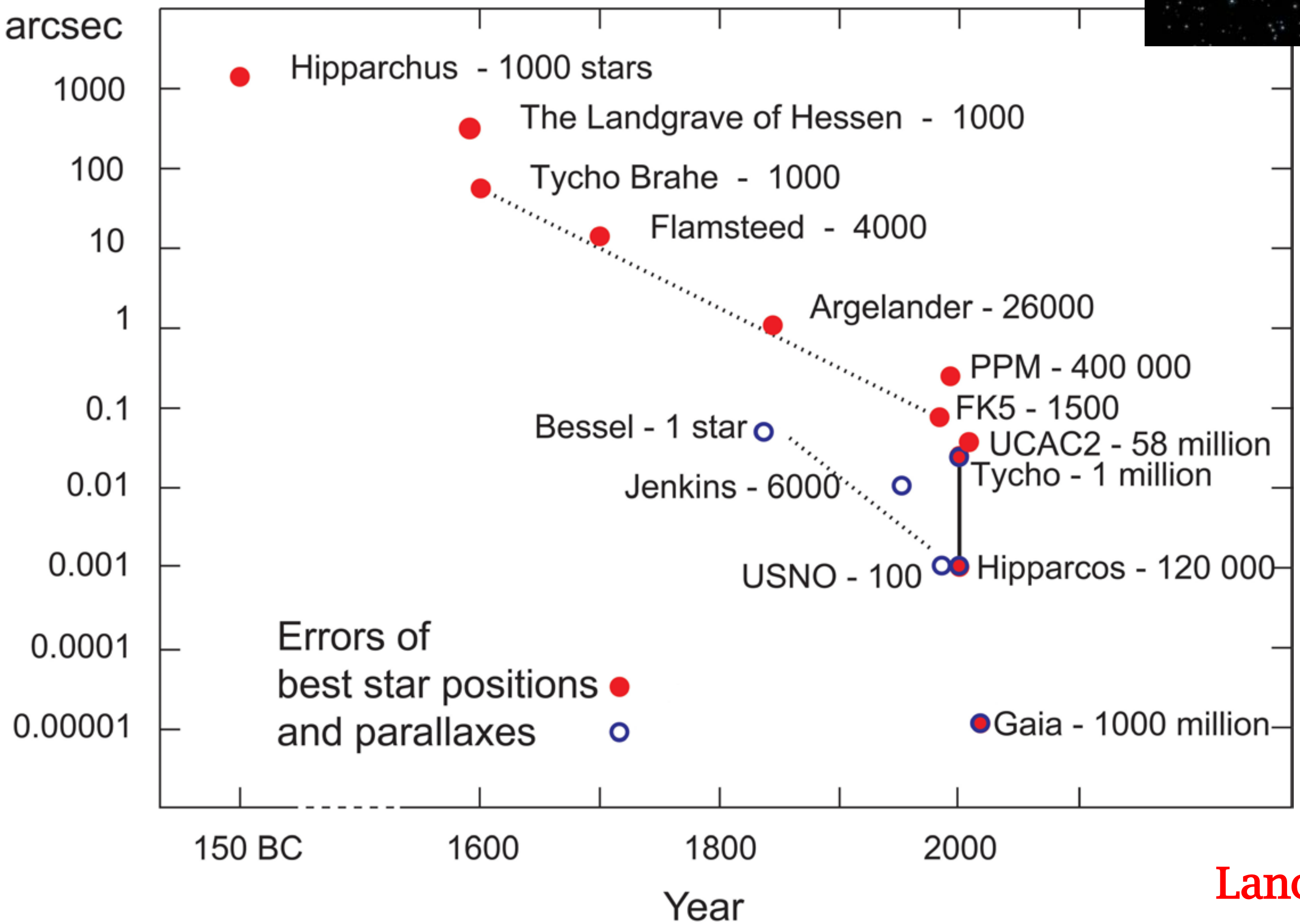
Années	Nombre de. Sources X connues	En utilisant
1960	0	(or 1 if the Sun is counted)
1962	1	expériences fusées
1965	10	expériences fusées
1970	60	fusées et ballons
1974	160	3e catalogue Uhuru
1980	680	Amnuel et al. (1982) Catalog
1984	840	HEAO A-1 Catalogue
1990	8,000	Einstein & EXOSAT
2000	220,000	ROSAT
2007	550,000	XMM-Newton & Chandra
2010	> 1,000,000	XMM et Chandra



Number of planets by year of discovery
Number of Planets (693)
0
20
40
60
80
100
120
140
160
180
1
3
1
1
6
7
11
19
12
29
27
31
33
28
60
62
81
111
170
1989
1992
1994
1995
1996
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Year of discovery (year)
exoplanet.eu (13/10/11)

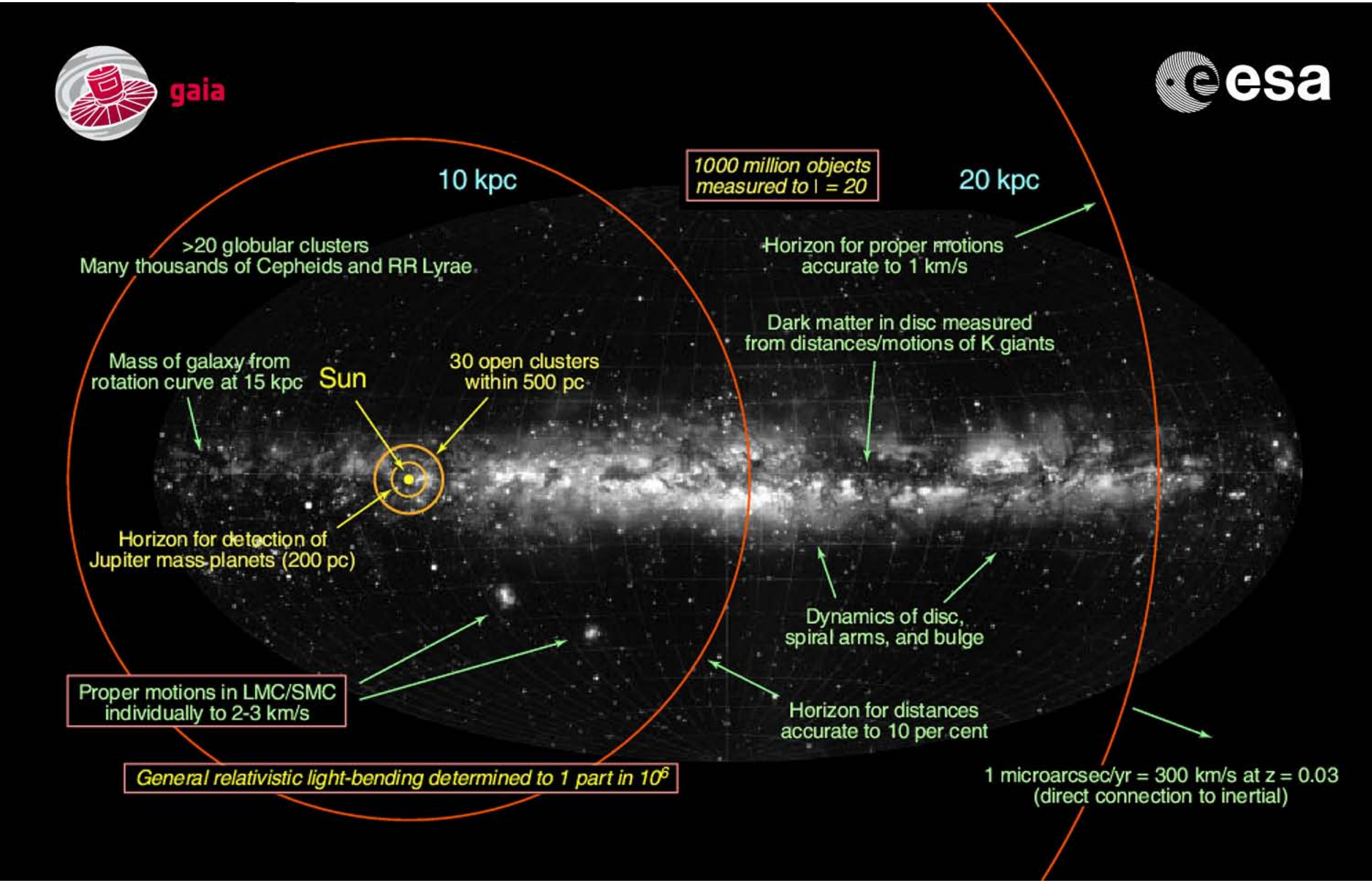
GAIA : le census complet de la voie lactée





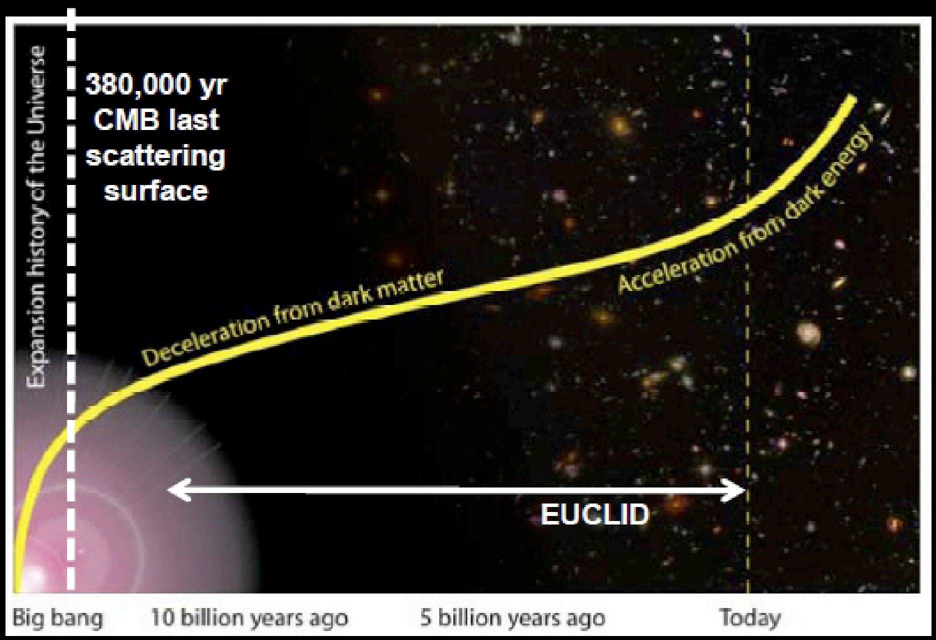
Angle de
10 μarcsec
≈
2 cm sur la lune

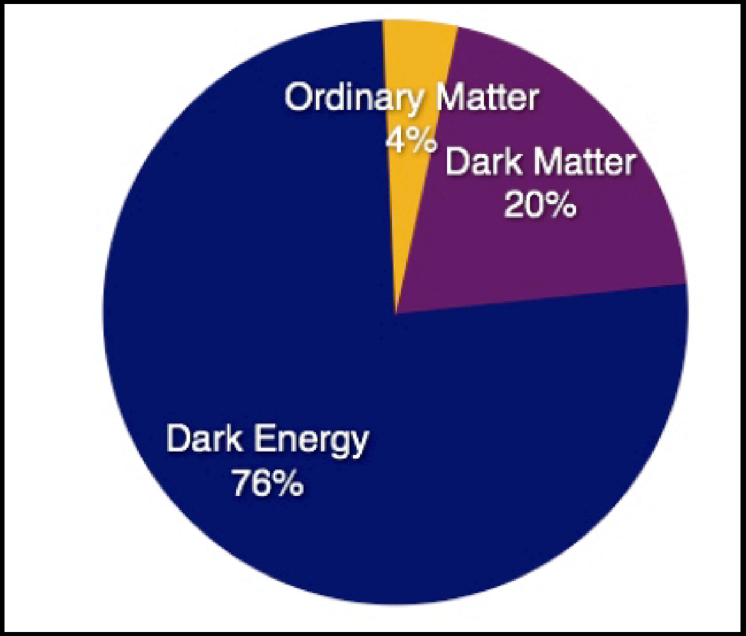
Lancement : 2013

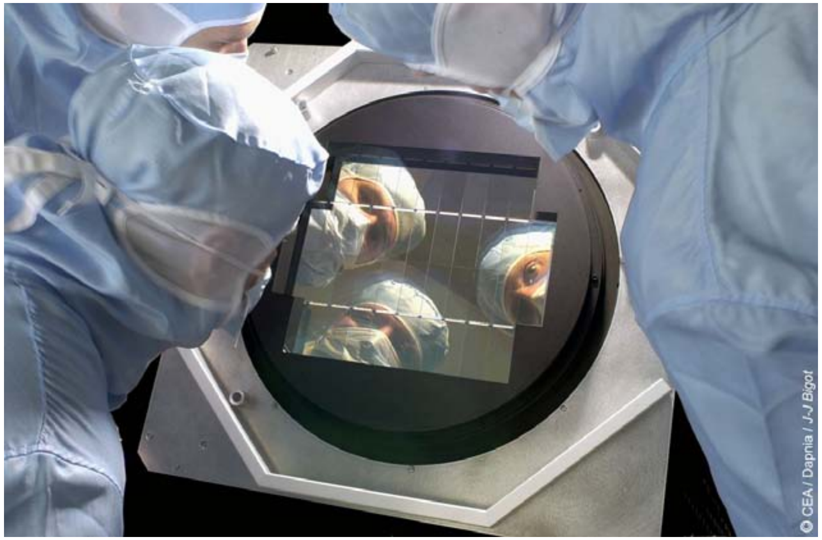

gaia
esa
10 kpc
1000 million objects measured to I = 20
20 kpc
>20 globular clusters
Many thousands of Cepheids and RR Lyrae
Horizon for proper motions accurate to 1 km/s
Dark matter in disc measured from distances/motions of K giants
Mass of galaxy from rotation curve at 15 kpc
Sun
30 open clusters within 500 pc
Horizon for detection of Jupiter mass planets (200 pc)
Dynamics of disc, spiral arms, and bulge
Proper motions in LMC/SMC individually to 2-3 km/s
Horizon for distances accurate to 10 per cent
General relativistic light-bending determined to 1 part in 10^6
1 microarcsec/yr = 300 km/s at z = 0.03
(direct connection to inertial)

Outstanding questions in cosmology

- the nature of the Dark Energy
- the nature of the Dark Matter
- the initial conditions (Inflation Physics)
- modifications to Gravity







CFHT

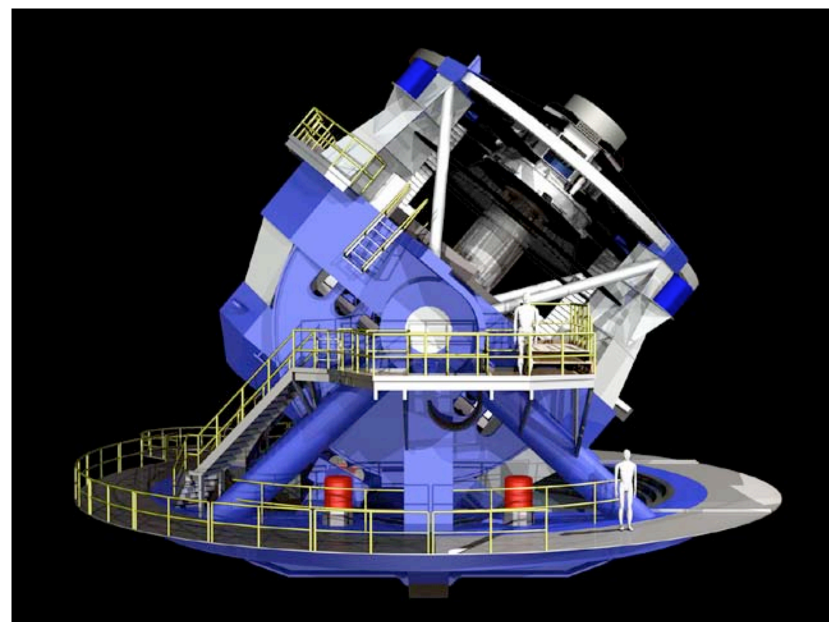
Diam 4 m

360 Mpx

LSST

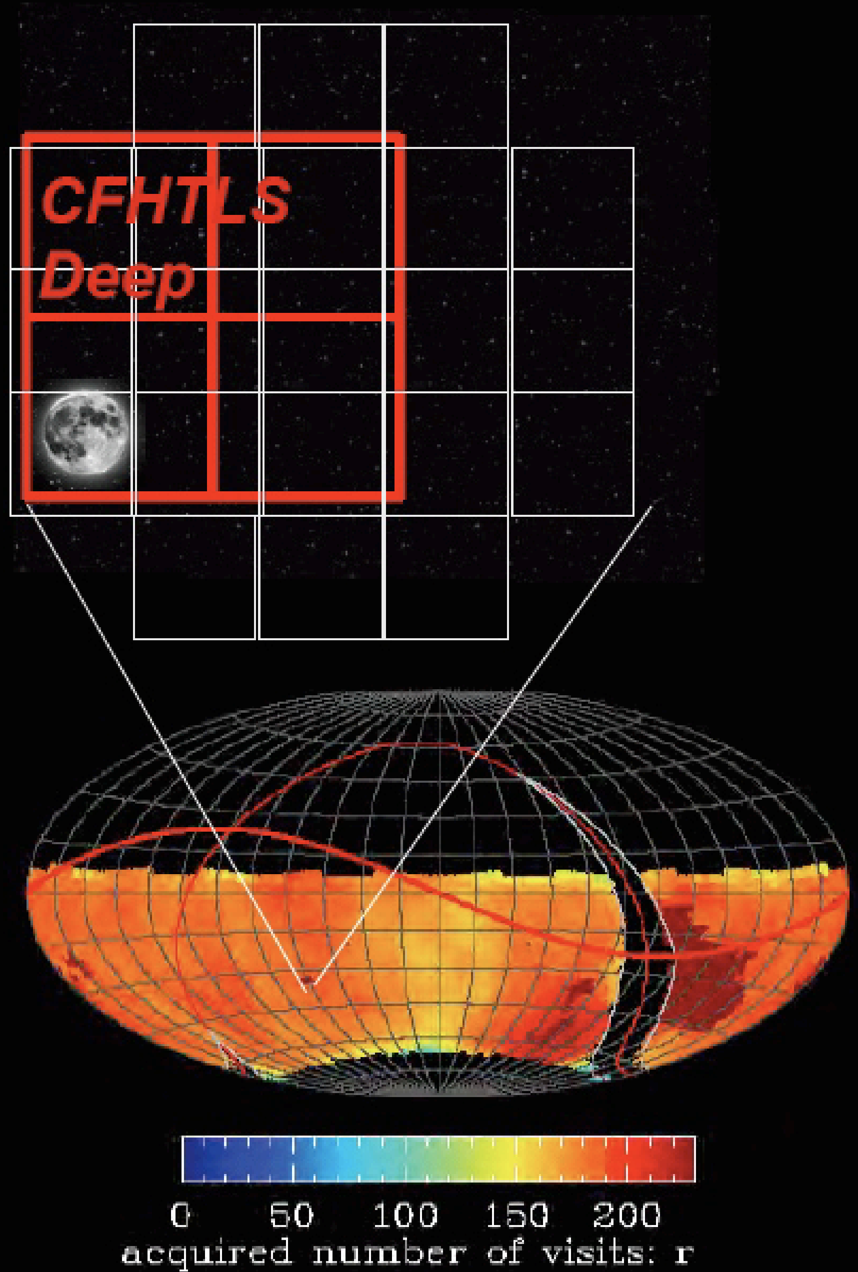
Diam 8 m

3 000 Mpx



CFHTLS Deep:

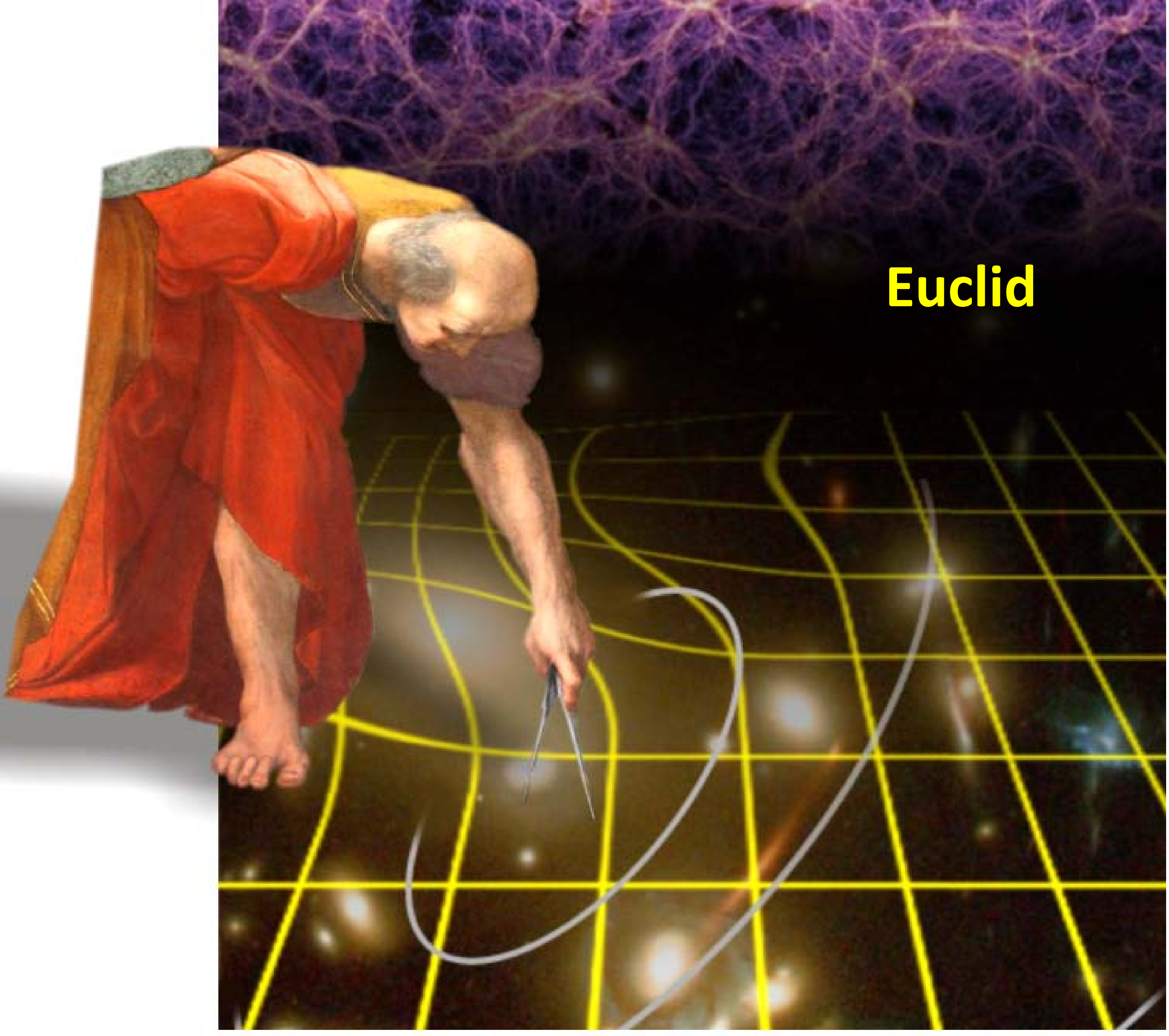
- 4 sq deg
- 5 filters, grizy
- 5 year survey
- few day cadence
- depth ~ 27 mag
- resolution ~0.9”

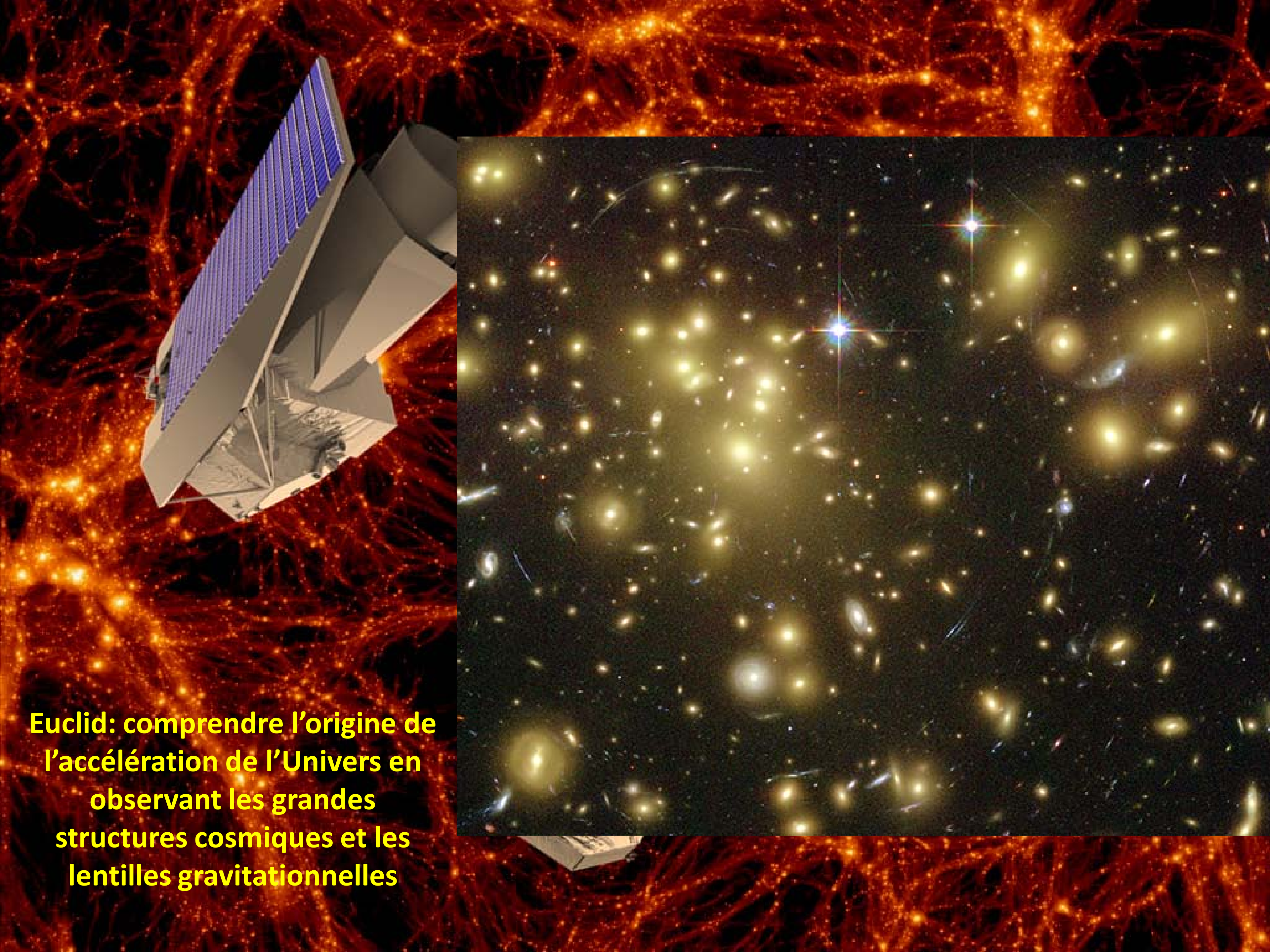


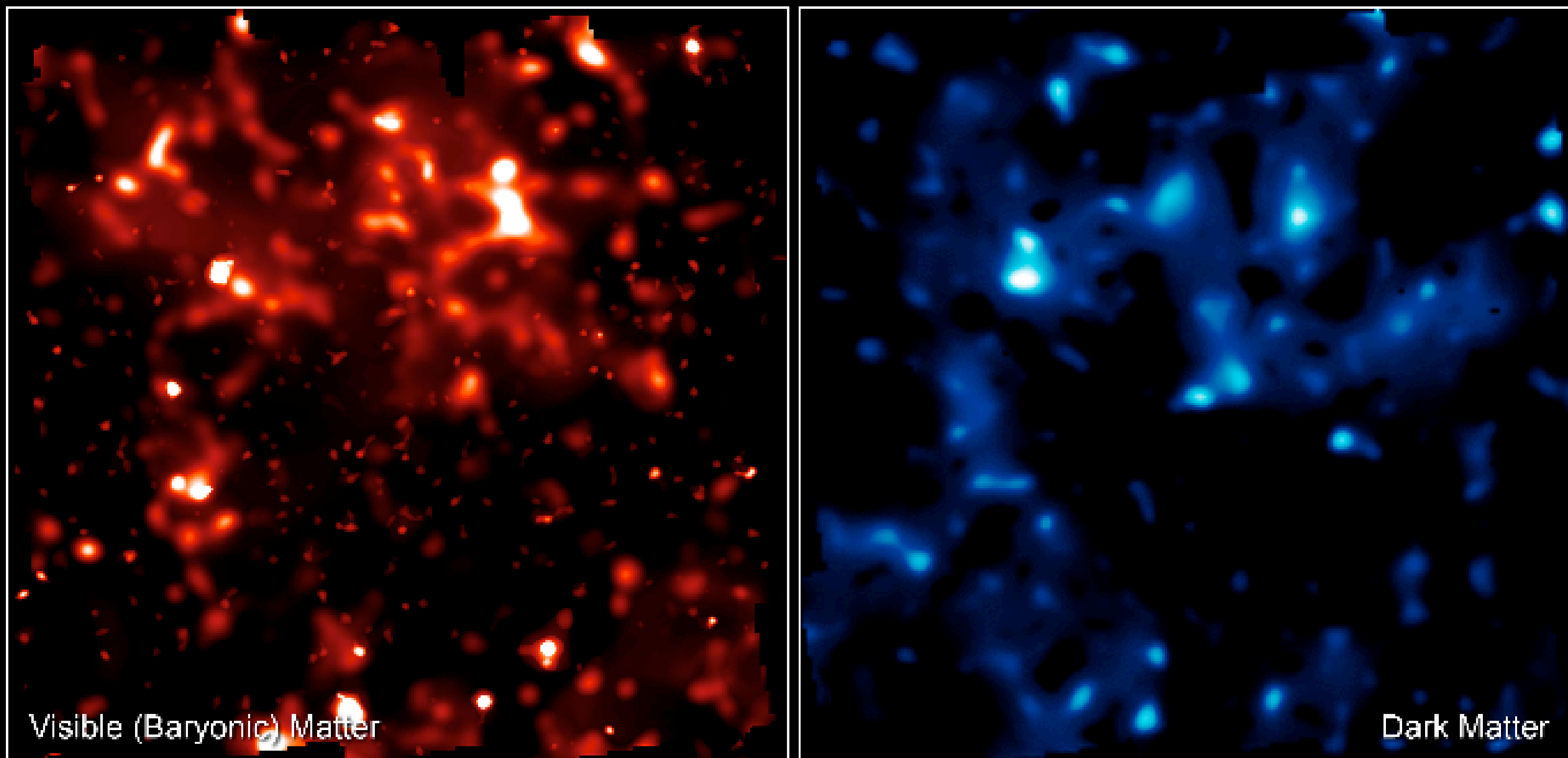
LSST:

- 4x**5000** sq deg
- 6 filters, ugrizy
- 5x**2** year survey
- few day cadence
- depth ~ 27 mag
- resolution **0.4**-1.0”

x100 in volume, billions of galaxies


Euclid


Euclid: comprendre l’origine de
l’accélération de l’Univers en
observant les grandes
structures cosmiques et les
lentilles gravitationnelles



Distribution of Visible and Dark Matter • Cosmic Evolution Survey

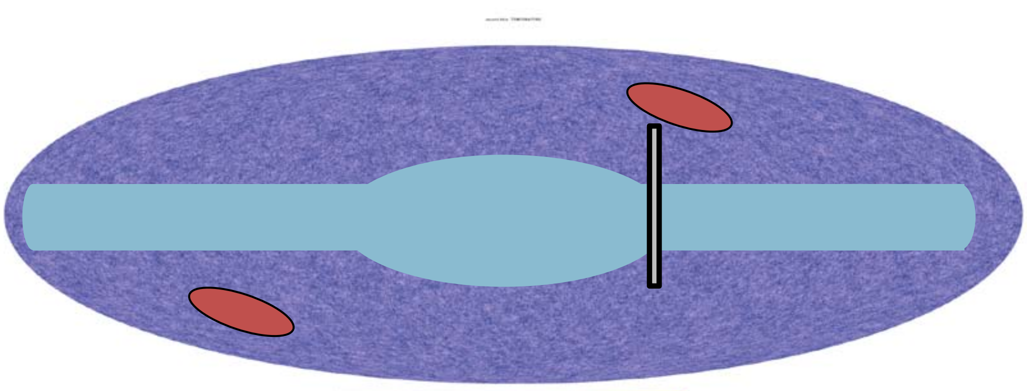
Hubble Space Telescope • Advanced Camera for Surveys

NASA, ESA, and R. Massey (California Institute of Technology)

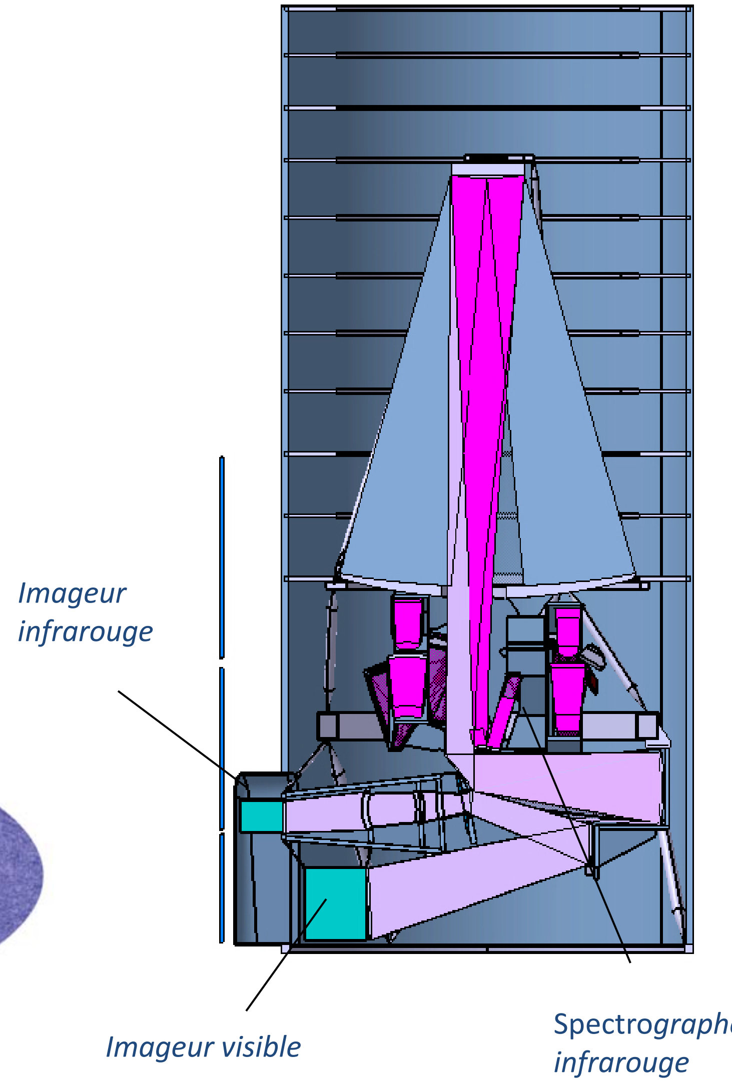
STScI-PRC07-01b

La mission Euclid de l'ESA

- Lancement 2019 depuis la base de Kourou par une fusée Soyuz
- 6 années d'observation
- Télescope de 1,2 mètre de diamètre
- Instruments:
    - Une caméra visible géante (36 CCD)de haute précision pour les lentilles gravitationnelles
    - Une caméra infrarouge géante (16 détecteurs) pour l'imagerie et la spectroscopie des galaxies



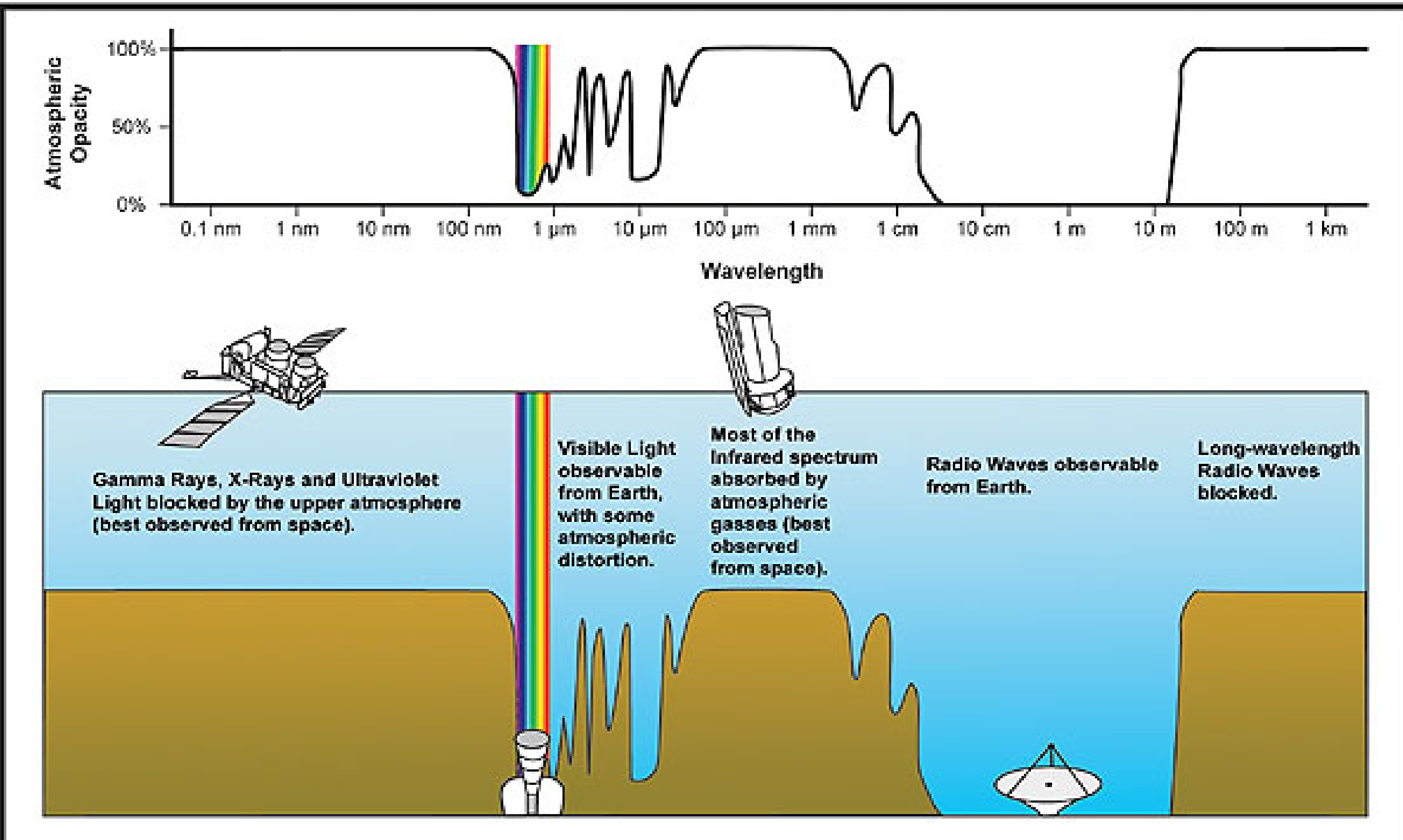
Euclid



ALTIUS : Plus haut

Les montagnes

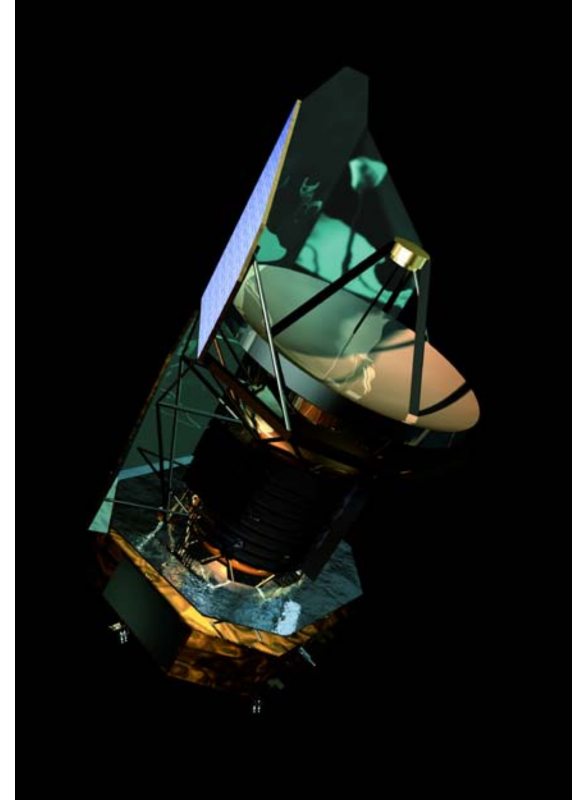
L'espace



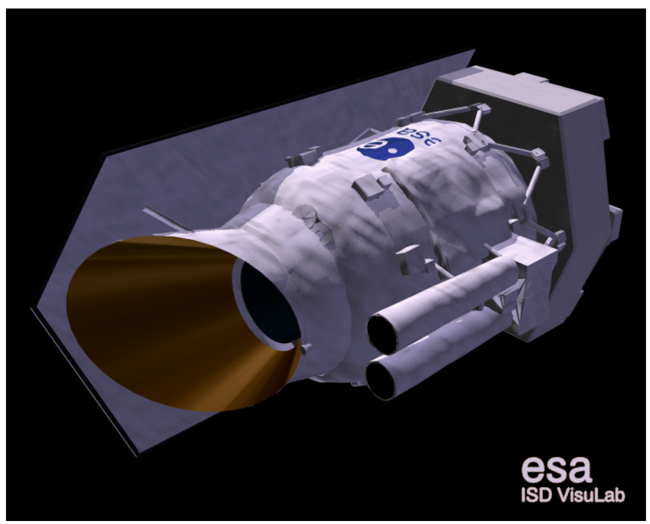
Atmospheric Opacity
100%
50%
0%
0.1 nm
1 nm
10 nm
100 nm
1 µm
10 µm
100 µm
1 mm
1 cm
10 cm
1 m
10 m
100 m
1 km
Wavelength
Gamma Rays, X-Rays and Ultraviolet Light blocked by the upper atmosphere (best observed from space).
Visible Light observable from Earth, with some atmospheric distortion.
Most of the infrared spectrum absorbed by atmospheric gasses (best observed from space).
Radio Waves observable from Earth.
Long-wavelength Radio Waves blocked.

La lignée des
observatoires spatiaux en infrarouge

SPITZER
2002
USA
Télescope 80 cm
2 - 200 µm

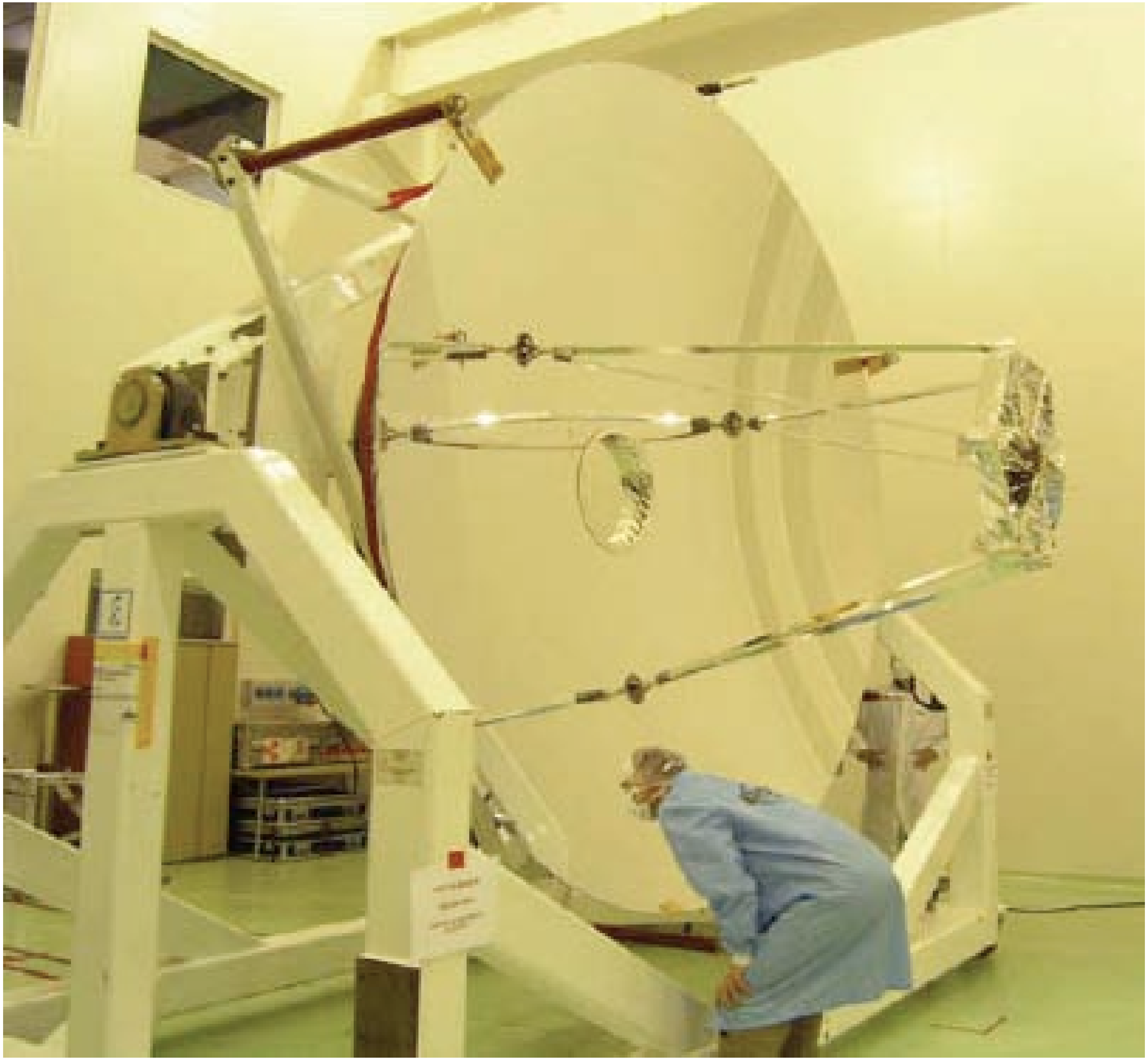


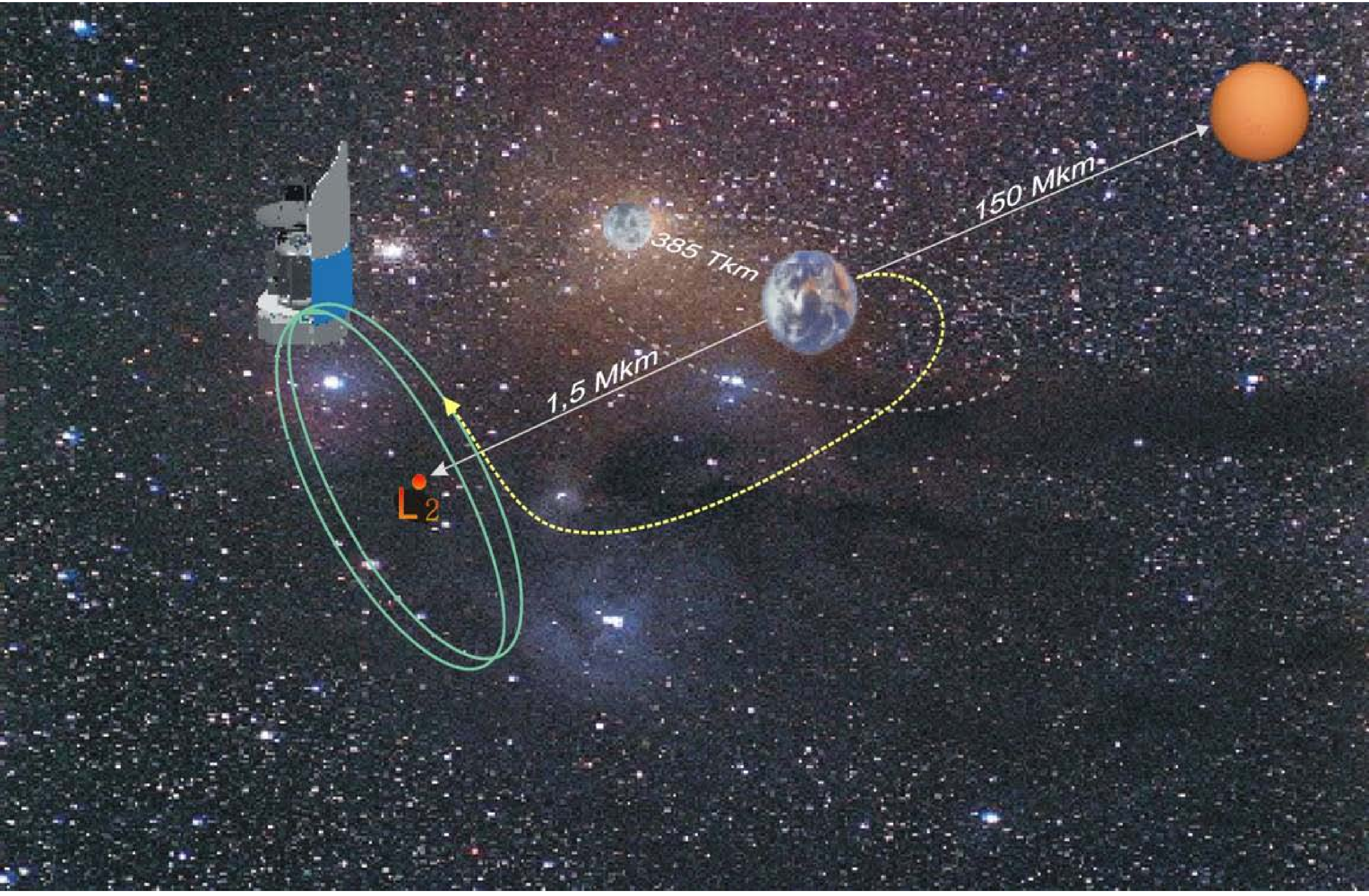
IRAS
1983
USA, UK, NL
Télescope 60 cm
Mode défilant
10 - 100 µm



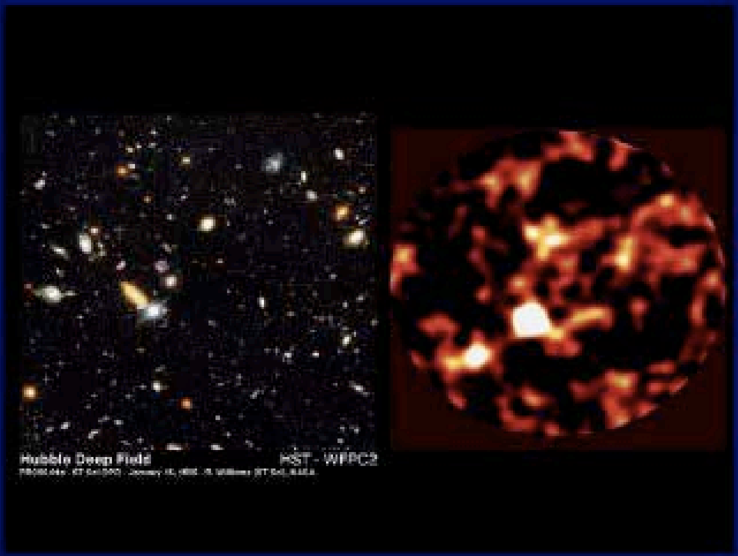
HERSCHEL
2009
Europe
Télescope 3,5 m
Mode pointé
60 - 600 µm

ISO
1995
Europe
Télescope 63 cm
Mode pointé
3 - 200 µm

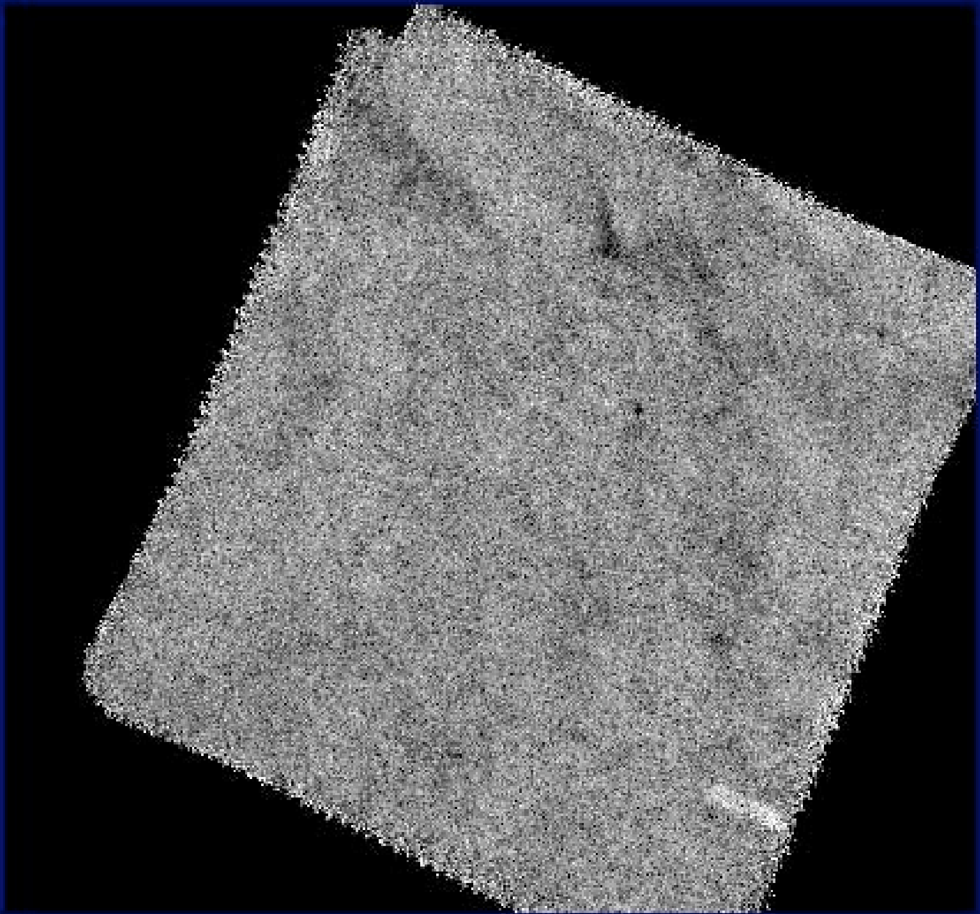



150 Mkm
385 Tkm
1,5 Mkm
L2

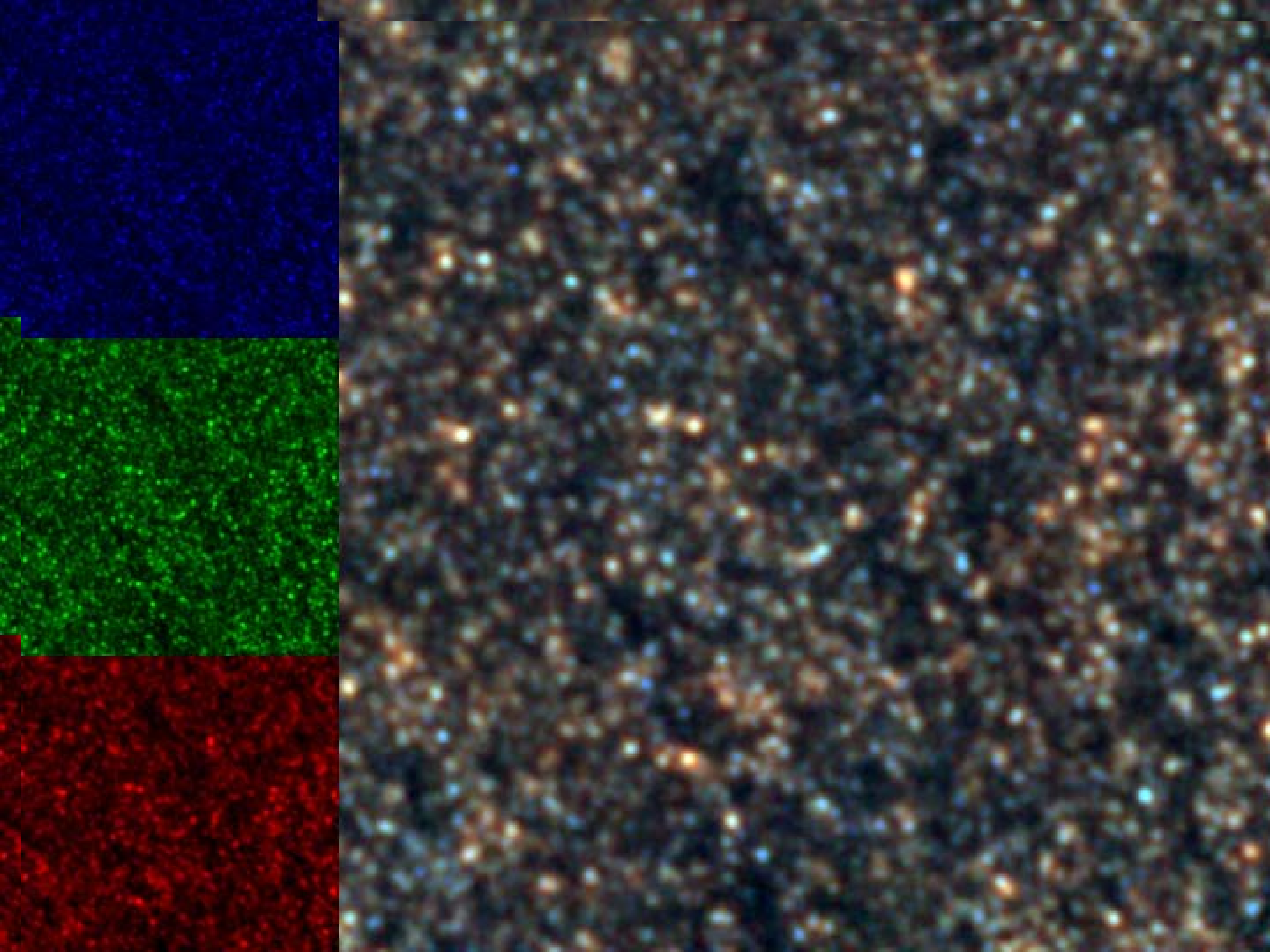
Ten Years in Submm Astronomy



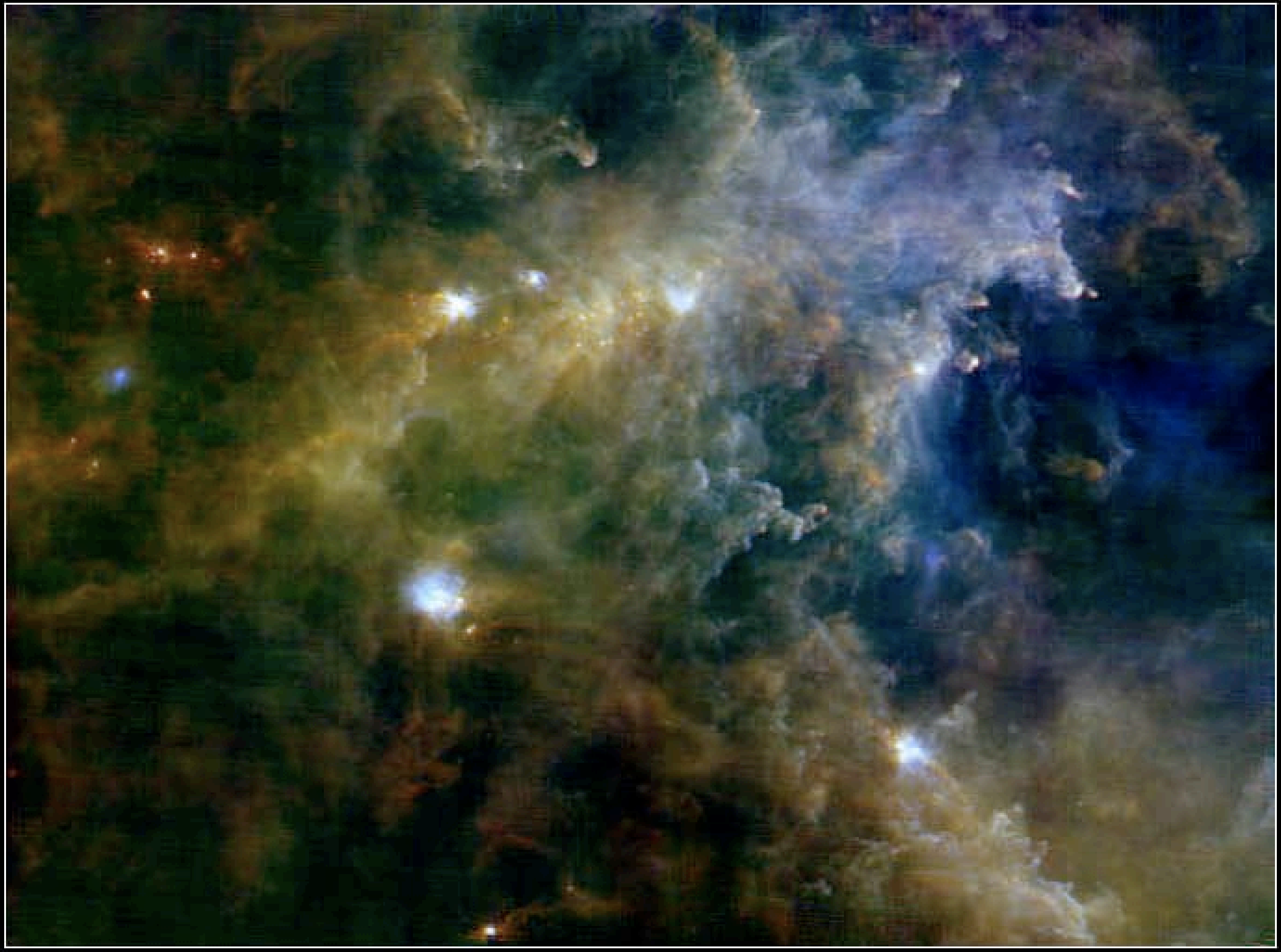
1998: SCUBA observations of the HDF – five sources after 20 nights



2009: Herschel – 15000 sources after 16 hours



Rosette Molecular Cloud

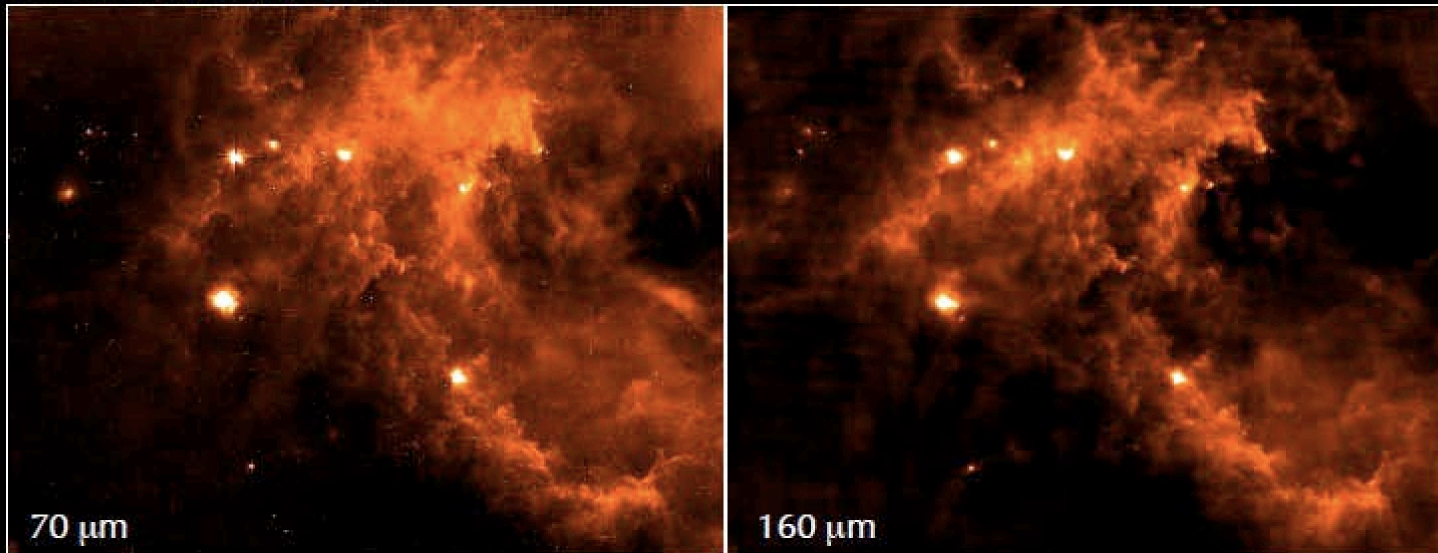


HOBYS - SPIRE consortium

PACS+SPIRE 70, 160, 250 μm

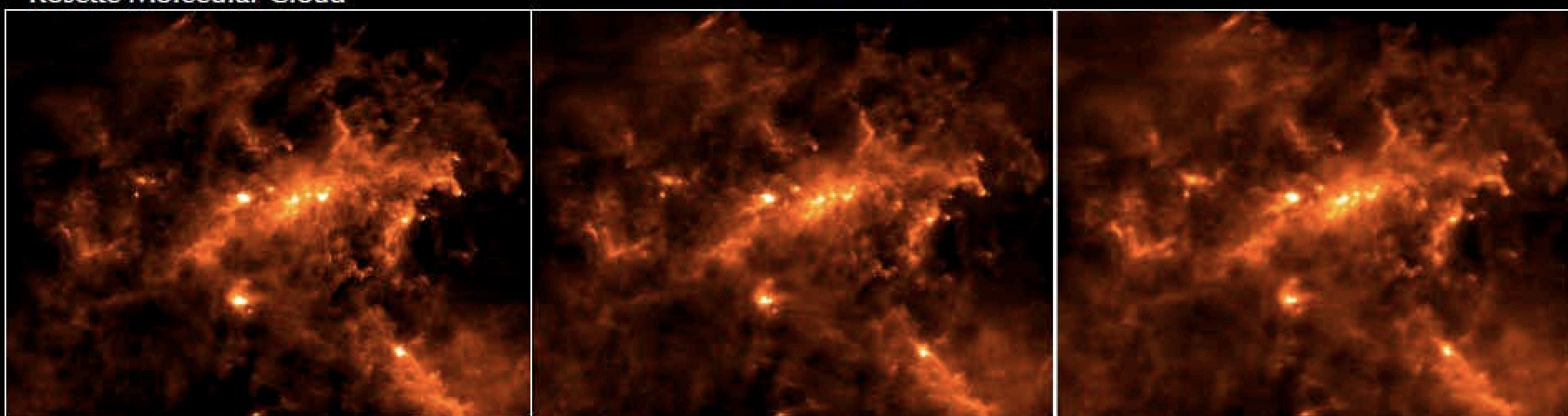
Rosette Molecular Cloud

Herschel/PACS



Rosette Molecular Cloud

Herschel/SPIRE



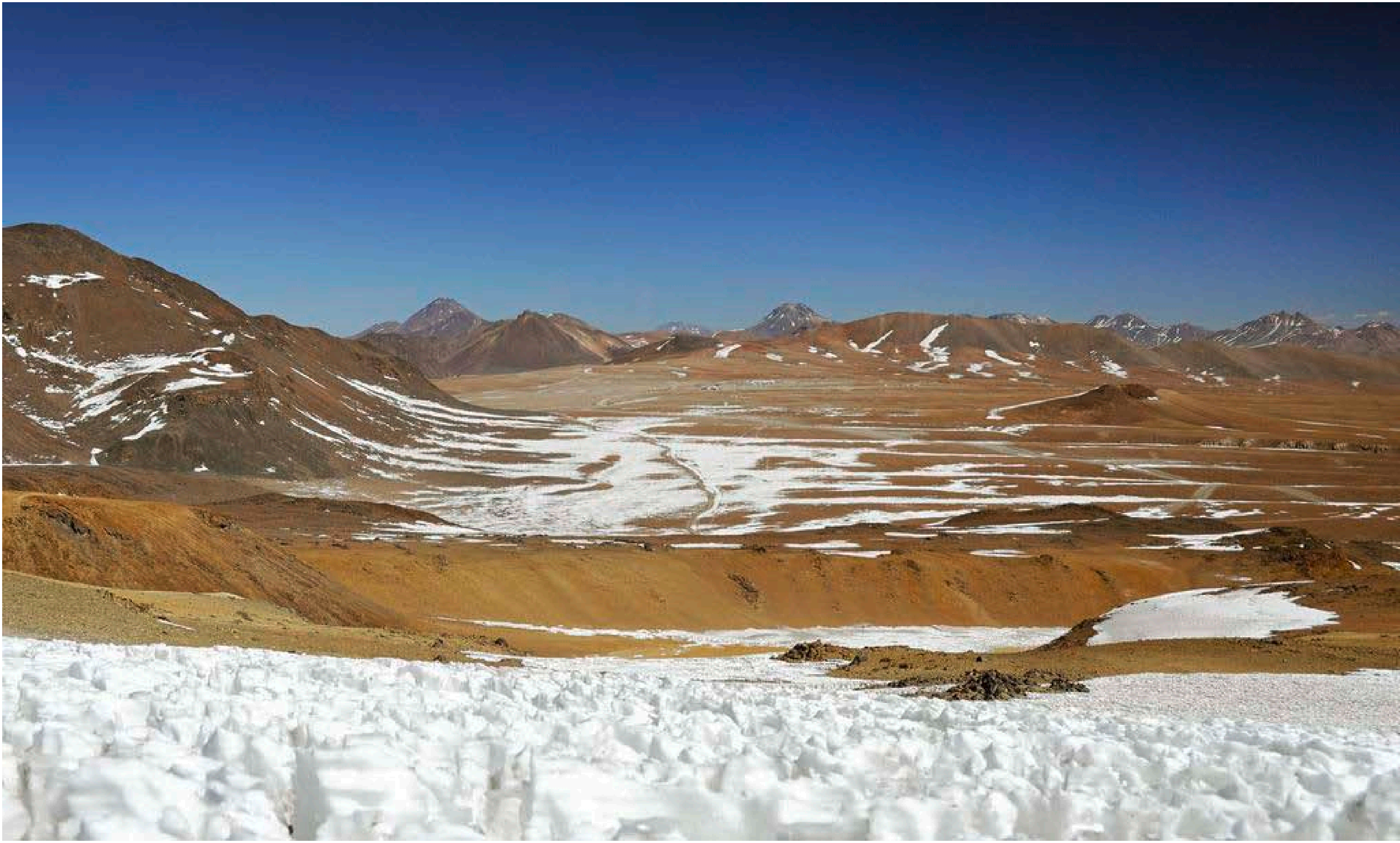
250 μm 350 μm 500 μm

ALMA : le plus grand interféromètre radio (mm)

54 antennes de 12 m + 12 de 7 m

Base maximum : 14 km

Partenariat Europe, USA, Canada, Japon, Taiwan, Chili




SCHEUERLE
Otto


Lore
967

http://www.eso.org/public/outreach/eso1137n.html

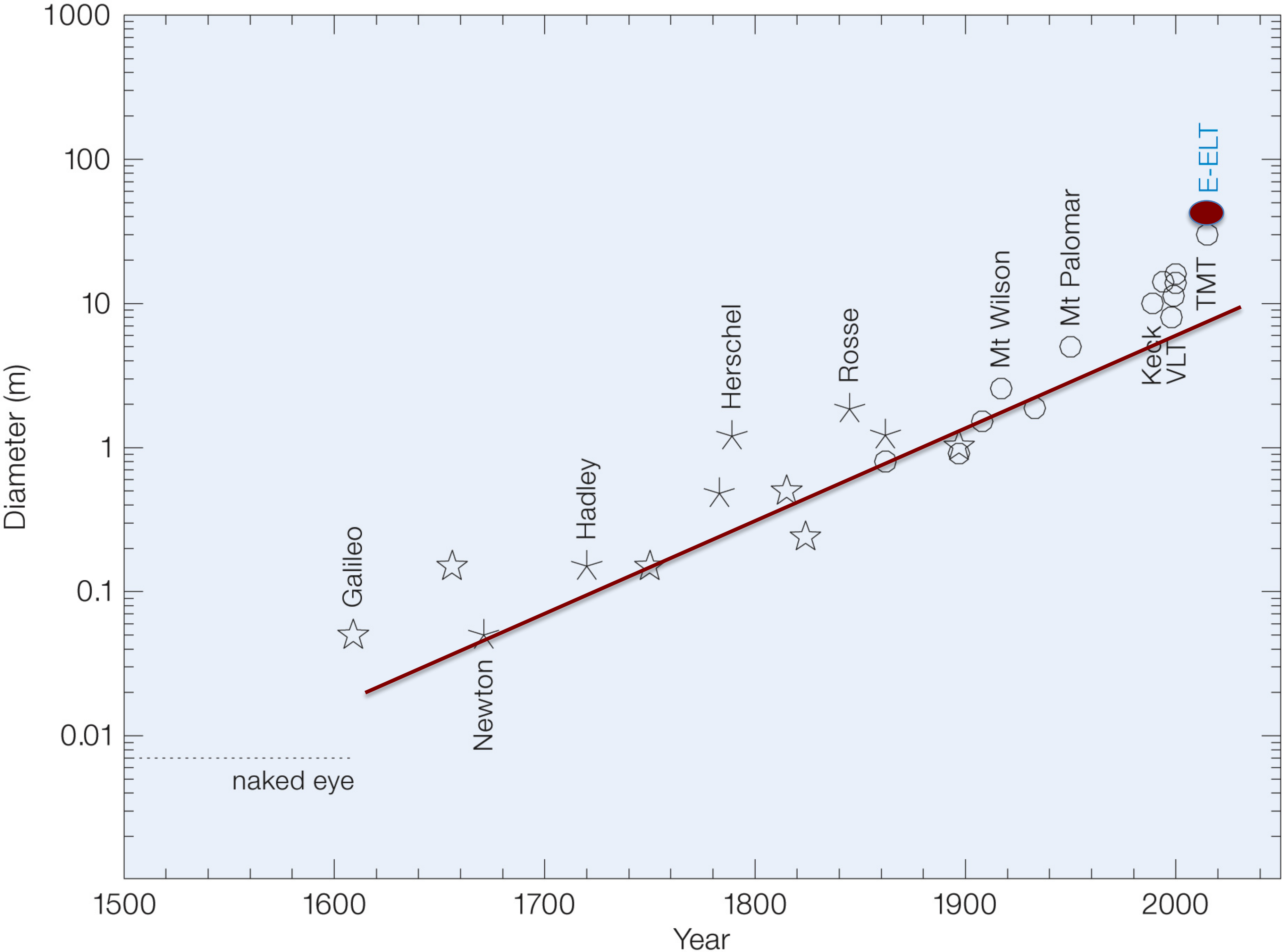
Fortius : plus fort

au sens astronomique :

plus sensible

donc

plus grand


1000
100
10
1
0.1
0.01
Diameter (m)
1500
1600
1700
1800
1900
2000
Year
Galileo
Newton
Hadley
Herschel
Rosse
Mt Wilson
Mt Palomar
Keck
VLT
TMT
E-ELT
naked eye



1991

Cerro Paranal

In the middle of the Atacama desert

Northen Chile

1994

The VLT platform is ready

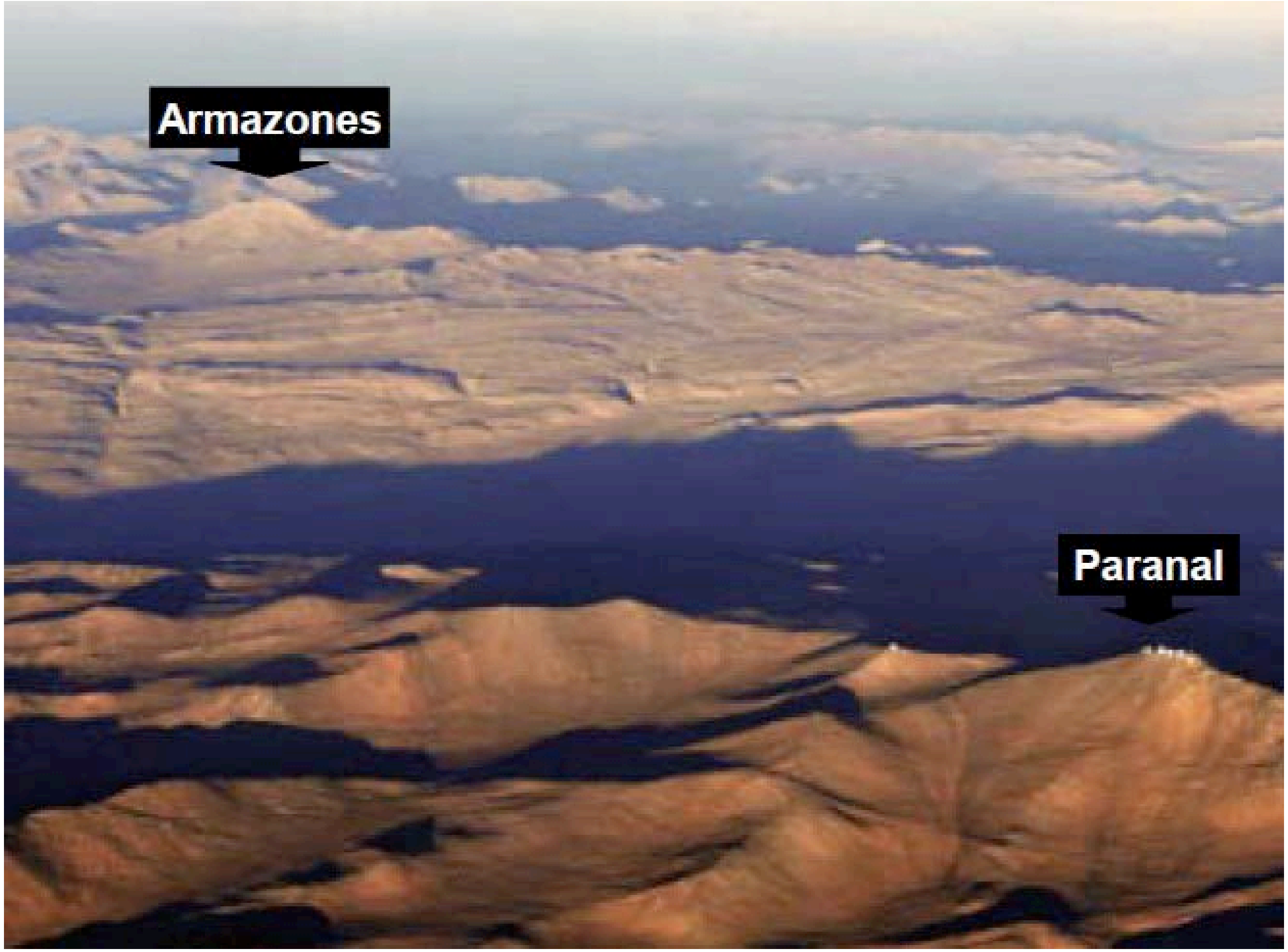
1999

Construction of the 4 telescopes and enclosures is ongoing

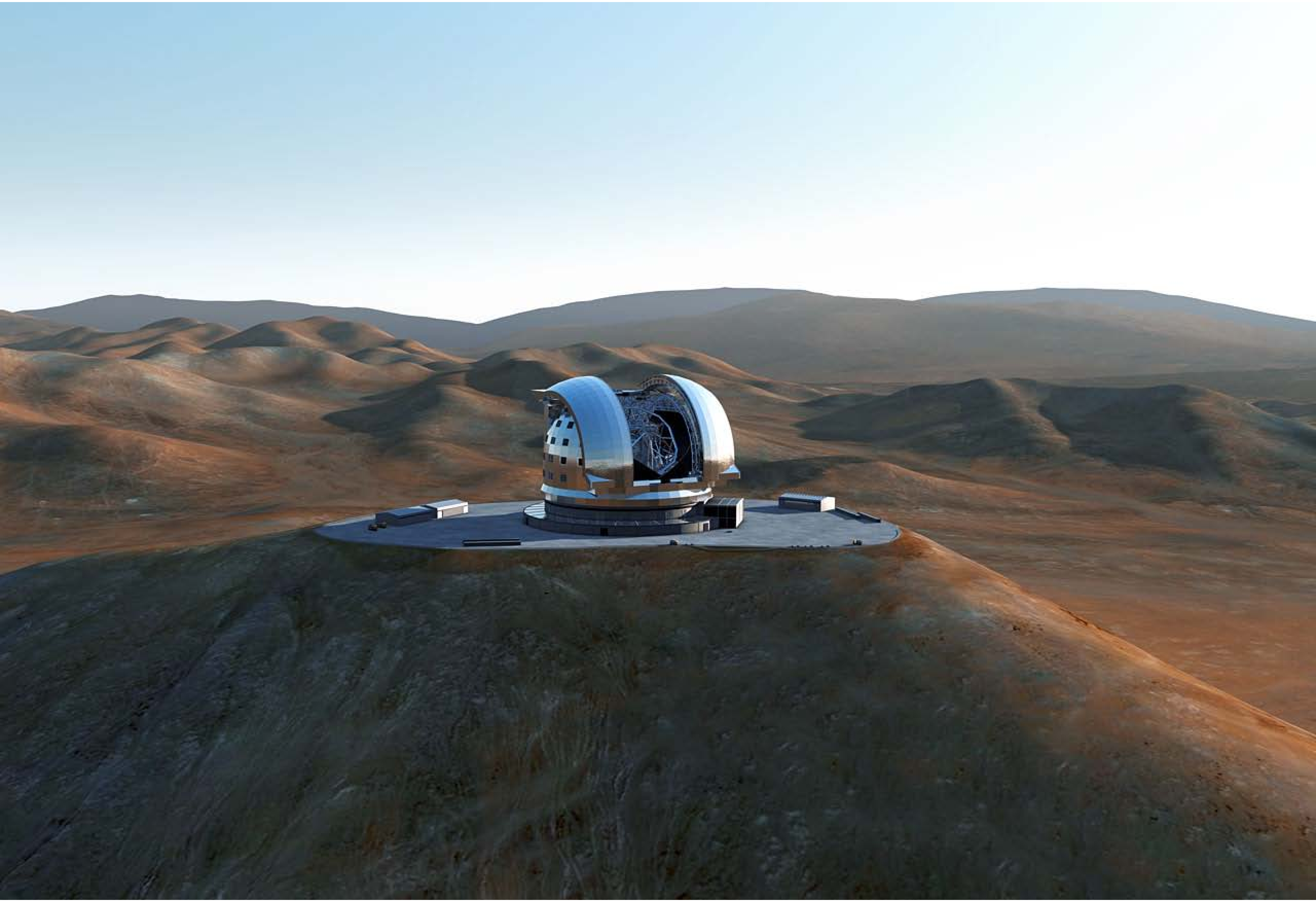
2008 : almost final configuration, 4 UT, 4 AT, VST

Le futur : l'European Extremely Large télescope

Diamètre 39 m



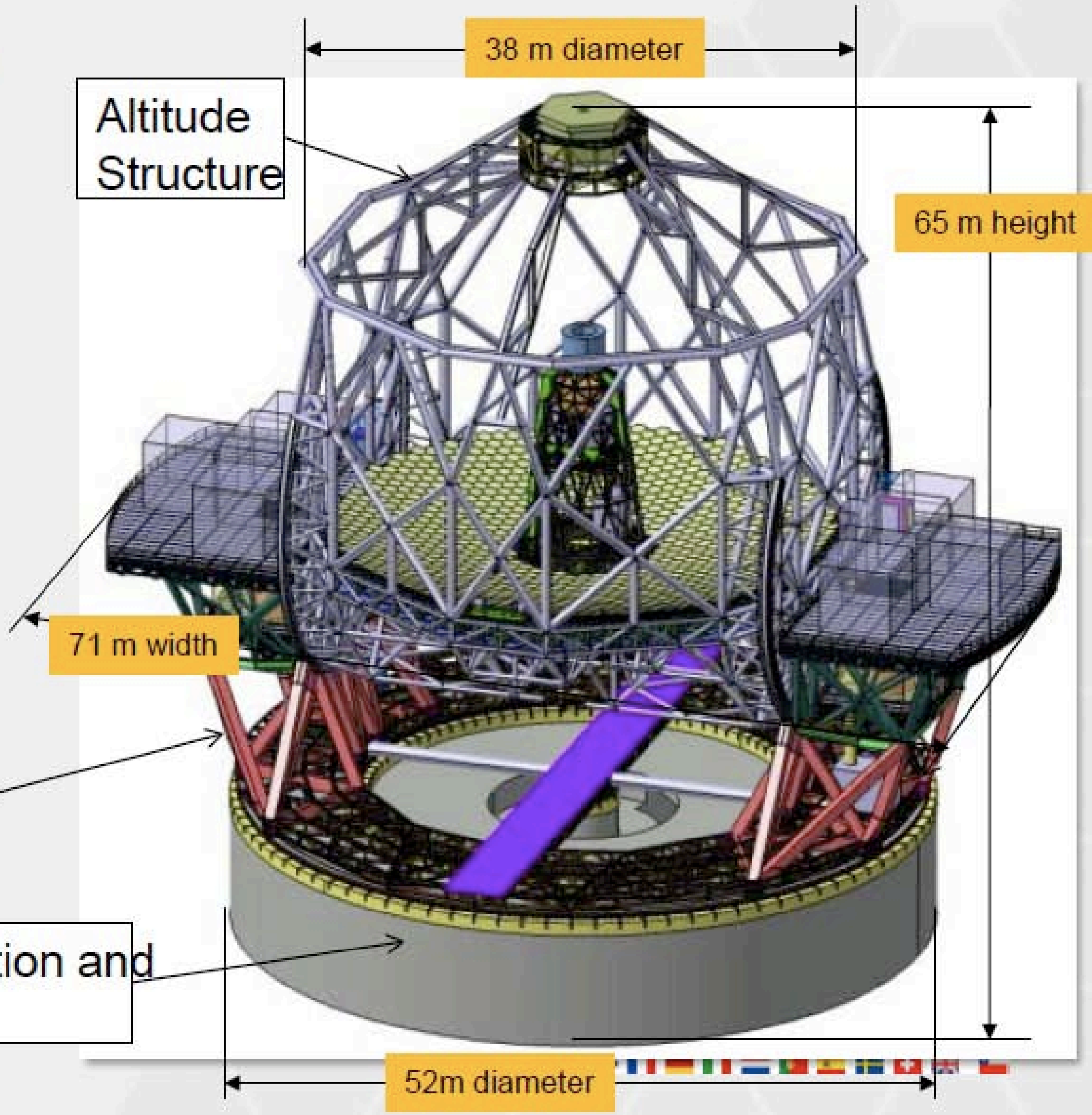
Décision
Mi 2012

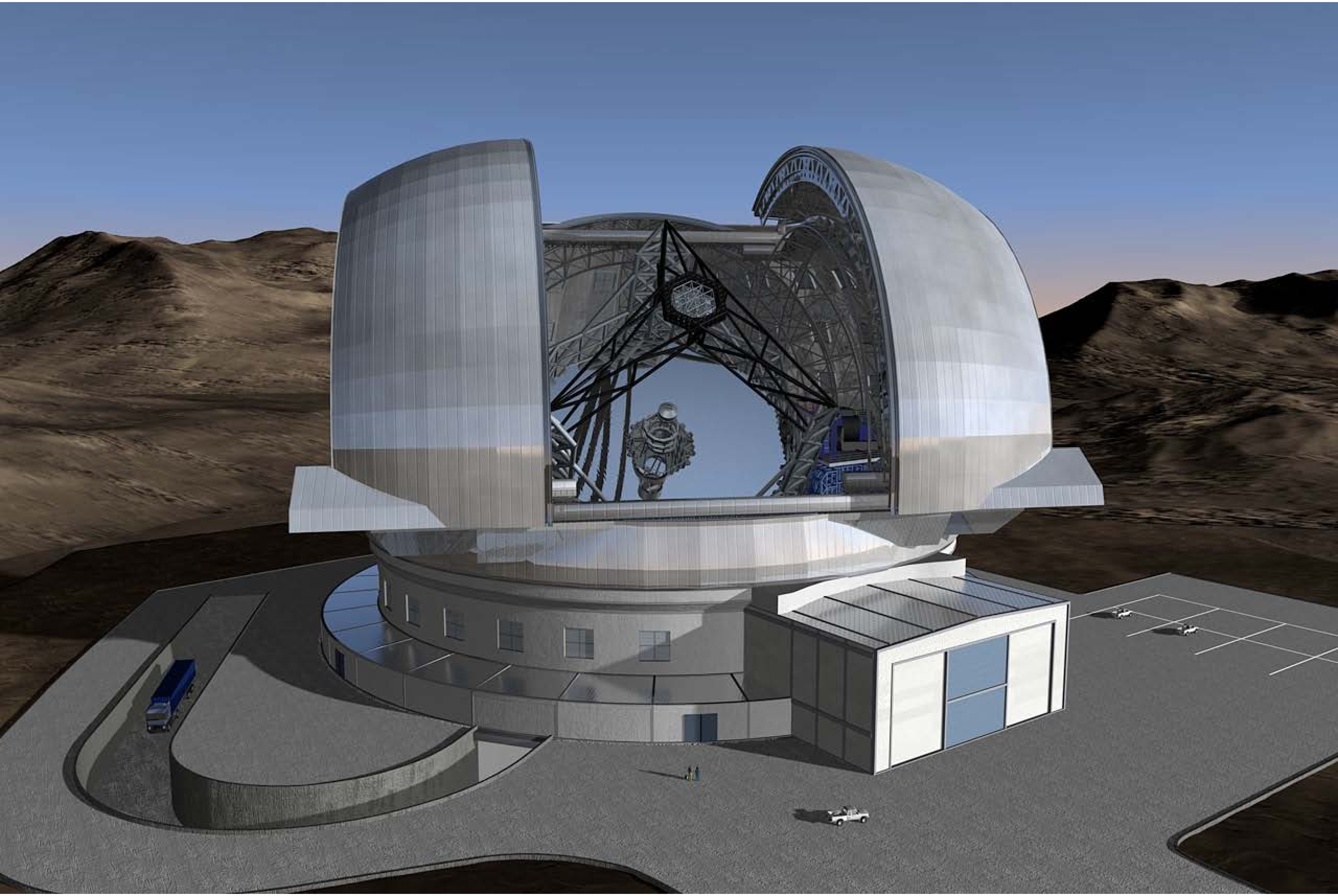


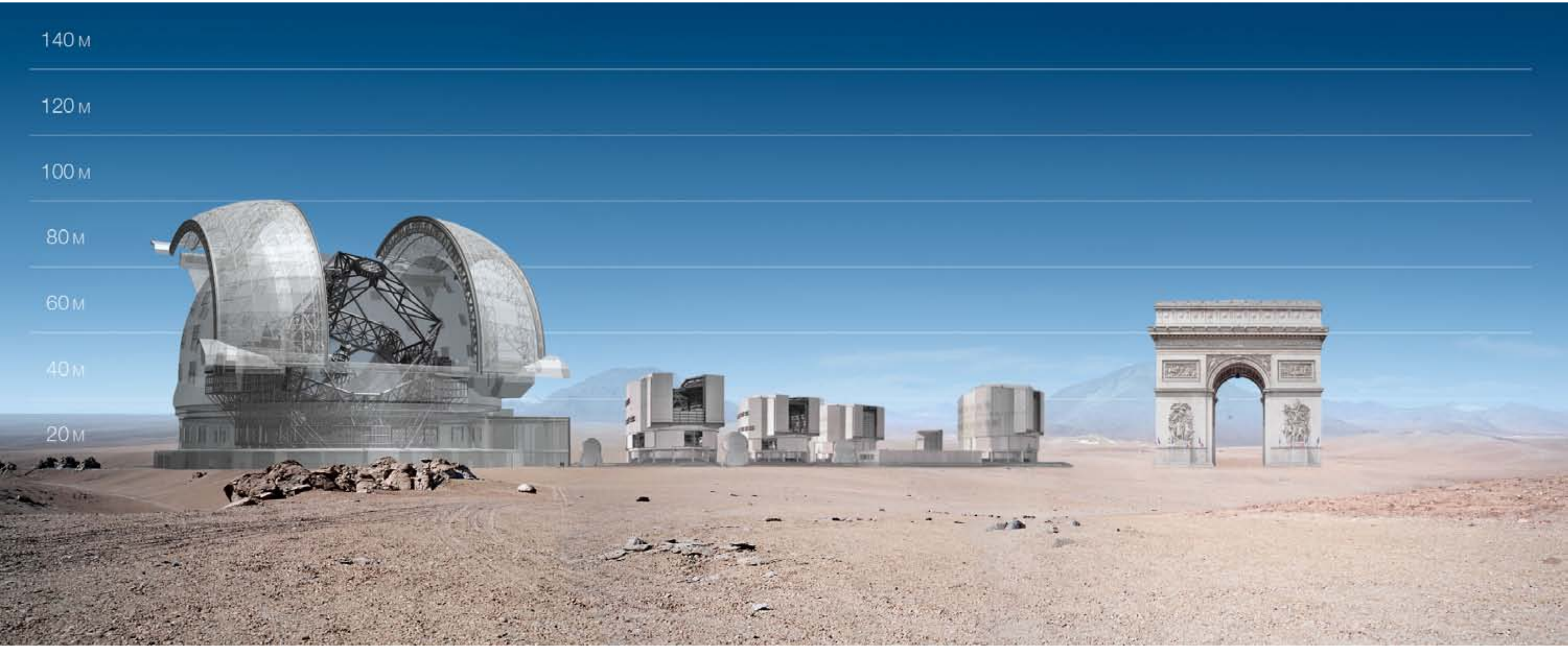
Main Structure Design

General Overview

The Main Structure is about 2500 tons of steel moving 700tons of opto-mechanics and electronics around two perpendicular axes (azimuth and altitude) supported on hydrostatic bearings and driven by electrical direct drive motors with a precision of 0.3 arcsec under the maximum wind disturbance.

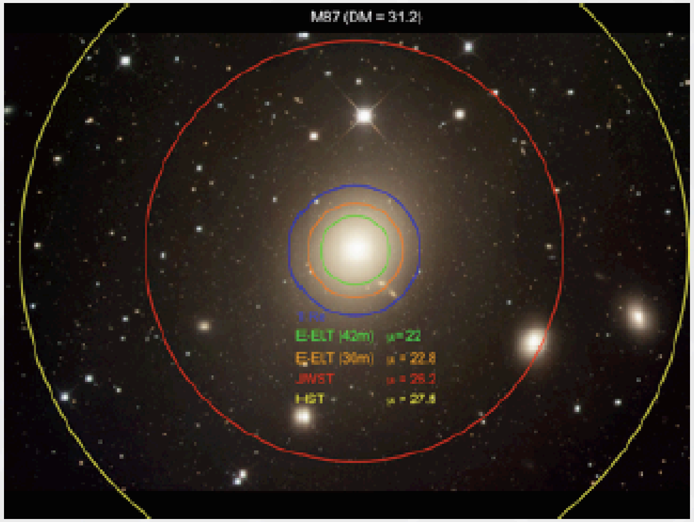


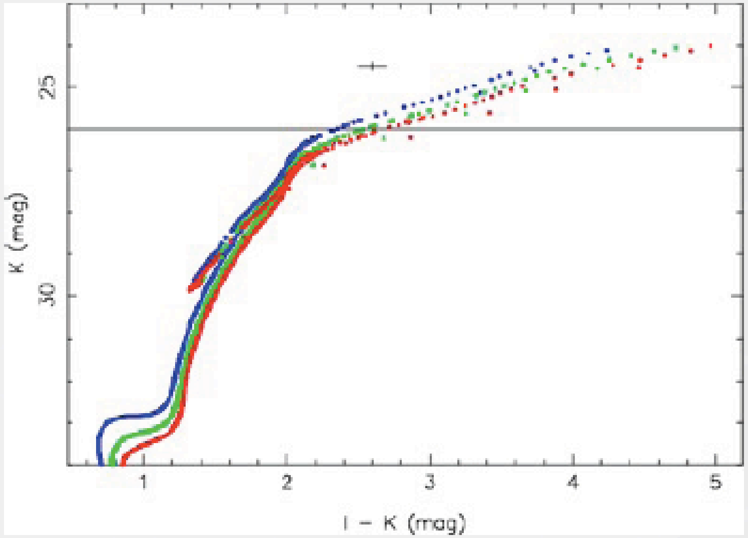


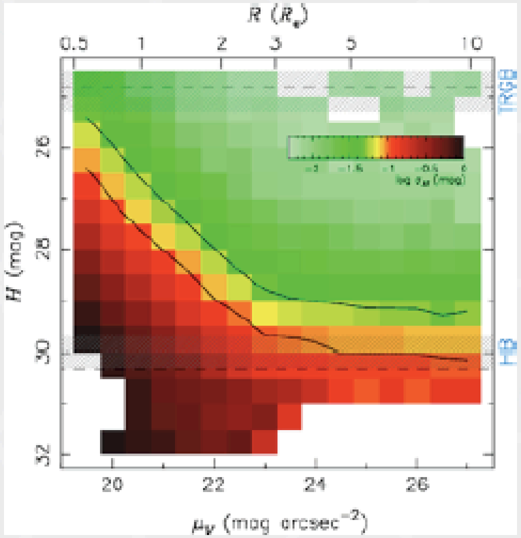

140 м
120 м
100 м
80 м
60 м
40 м
20 м

Key Science Cases
Resolved Stellar Populations

- “Near-field” cosmology - star formation and assembly history of galaxies
- Colour-magnitude diagrams of the stellar populations inside 1 R_{eff} of nearby Ellipticals (out to 20Mpc)
- Precision photometry in crowded fields (this case scales with D^3)

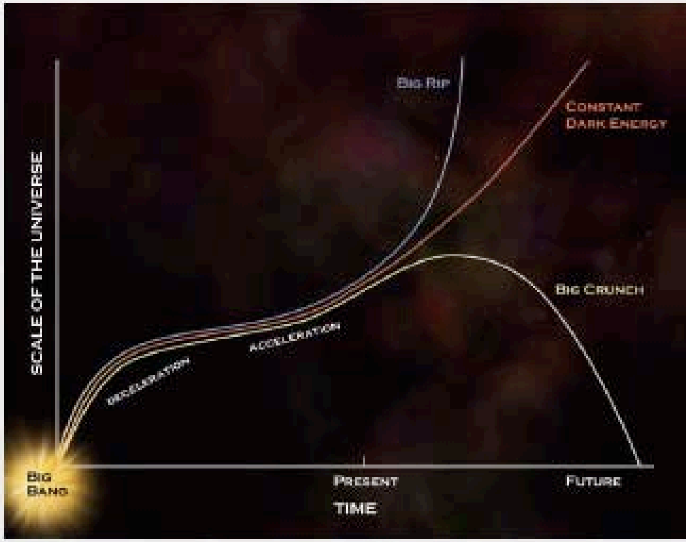


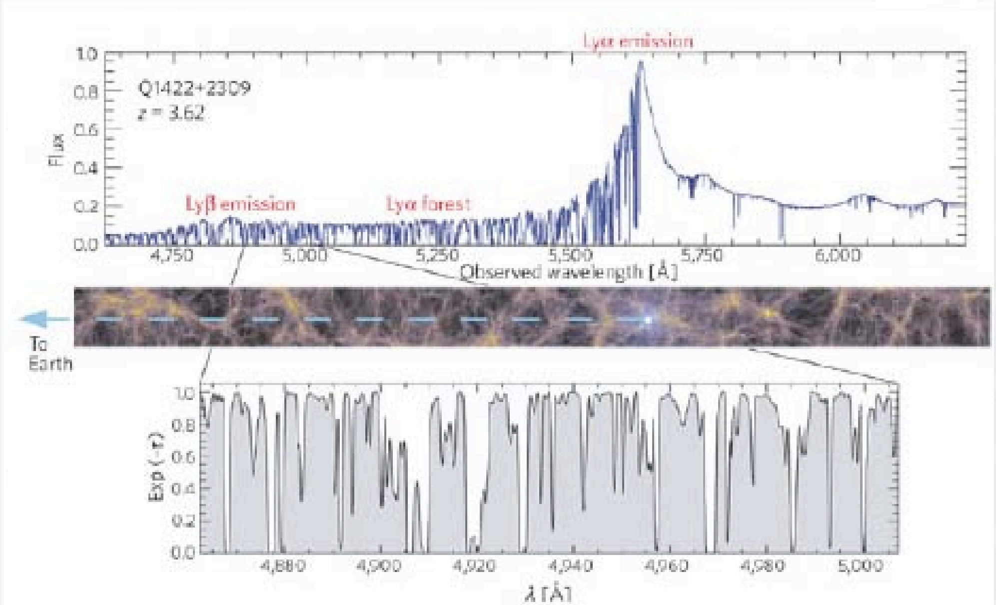




Key Science Cases
Expansion of the Universe

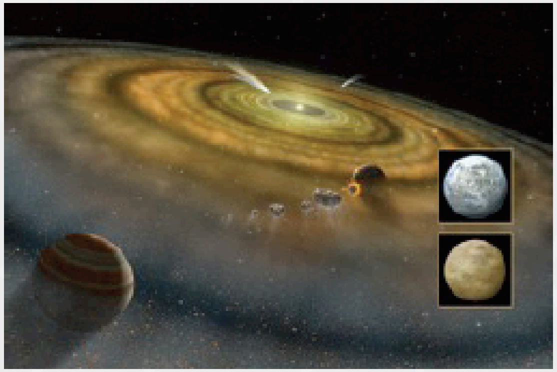
- Direct dynamical measurement of the expansion of the Universe
- High requirements on instrument stability / repeatability
- Photon starved case, just feasible at 40m (requires t=4000h with gain in $t \propto D^2$)

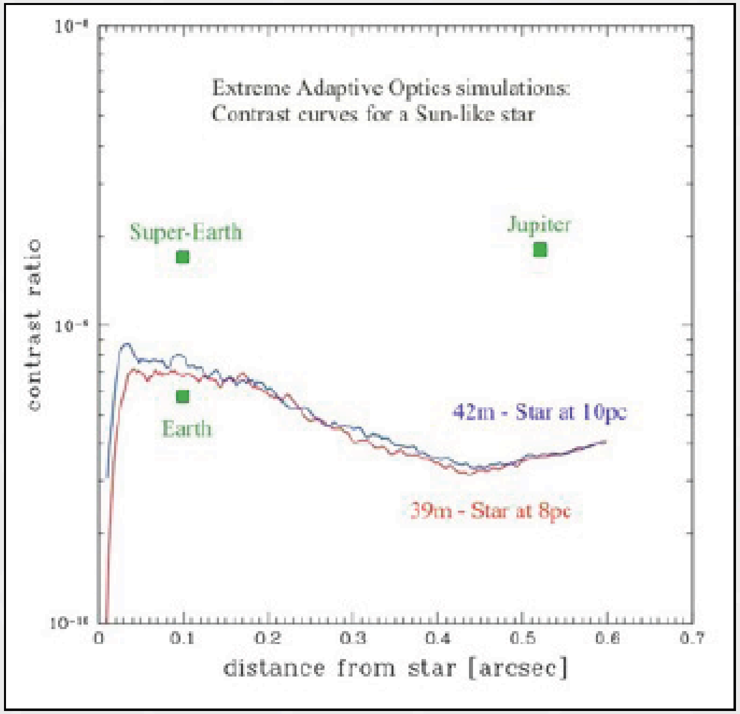




Key Science Cases Exoplanets

- Detecting of Earth-mass exoplanets by radial velocity method
- Characterisation of atmospheres of transiting exoplanets
- Direct imaging and characterisation of rocky exoplanets in habitable zones (this case scales with D^{6+})

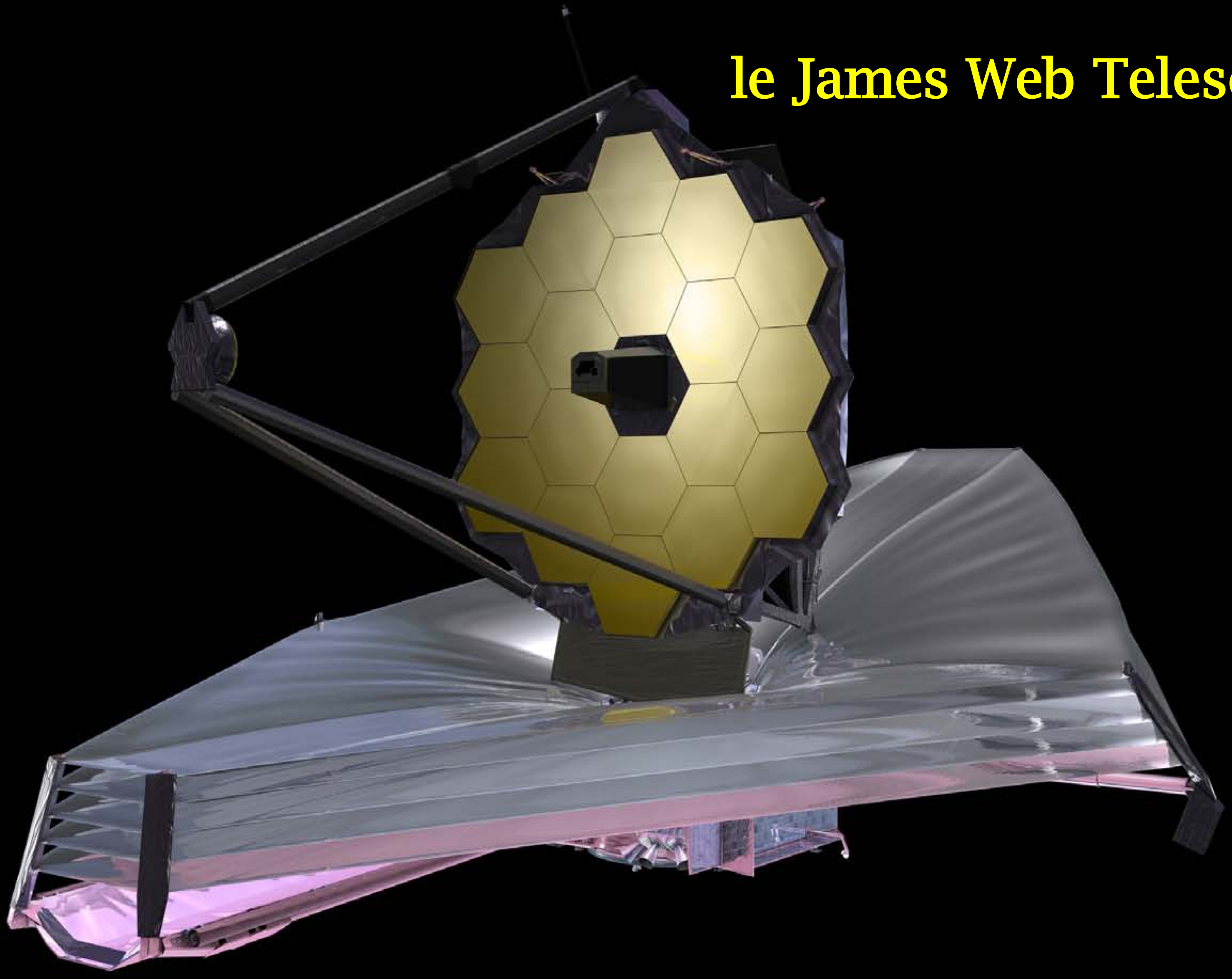


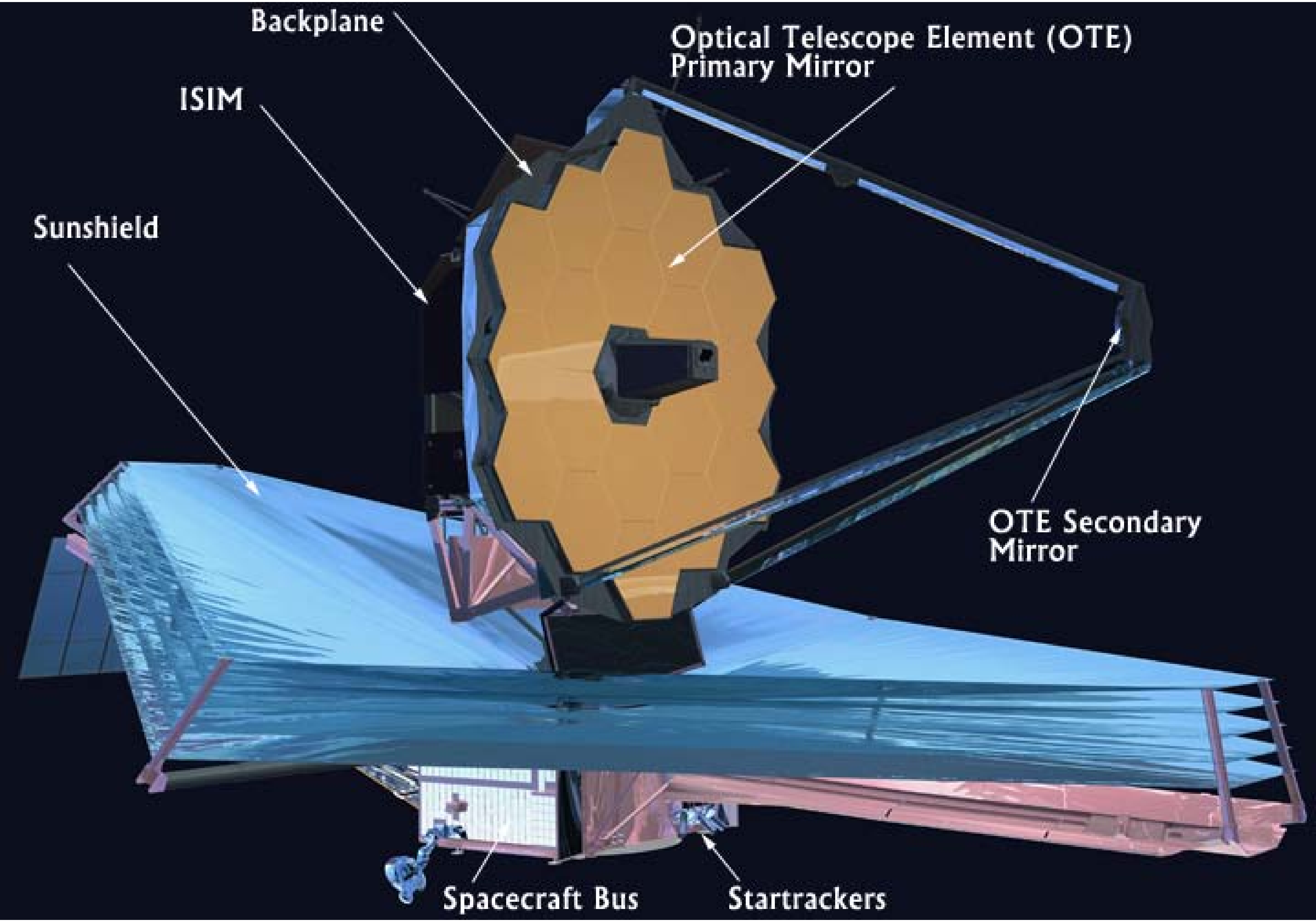


E-ELT sees	<6pc	<8pc 39m	<10pc 42m
F stars	1	1	5
G stars (Sun/Earth)	2	6	13
K stars	8	16	25
M stars	29	45	72

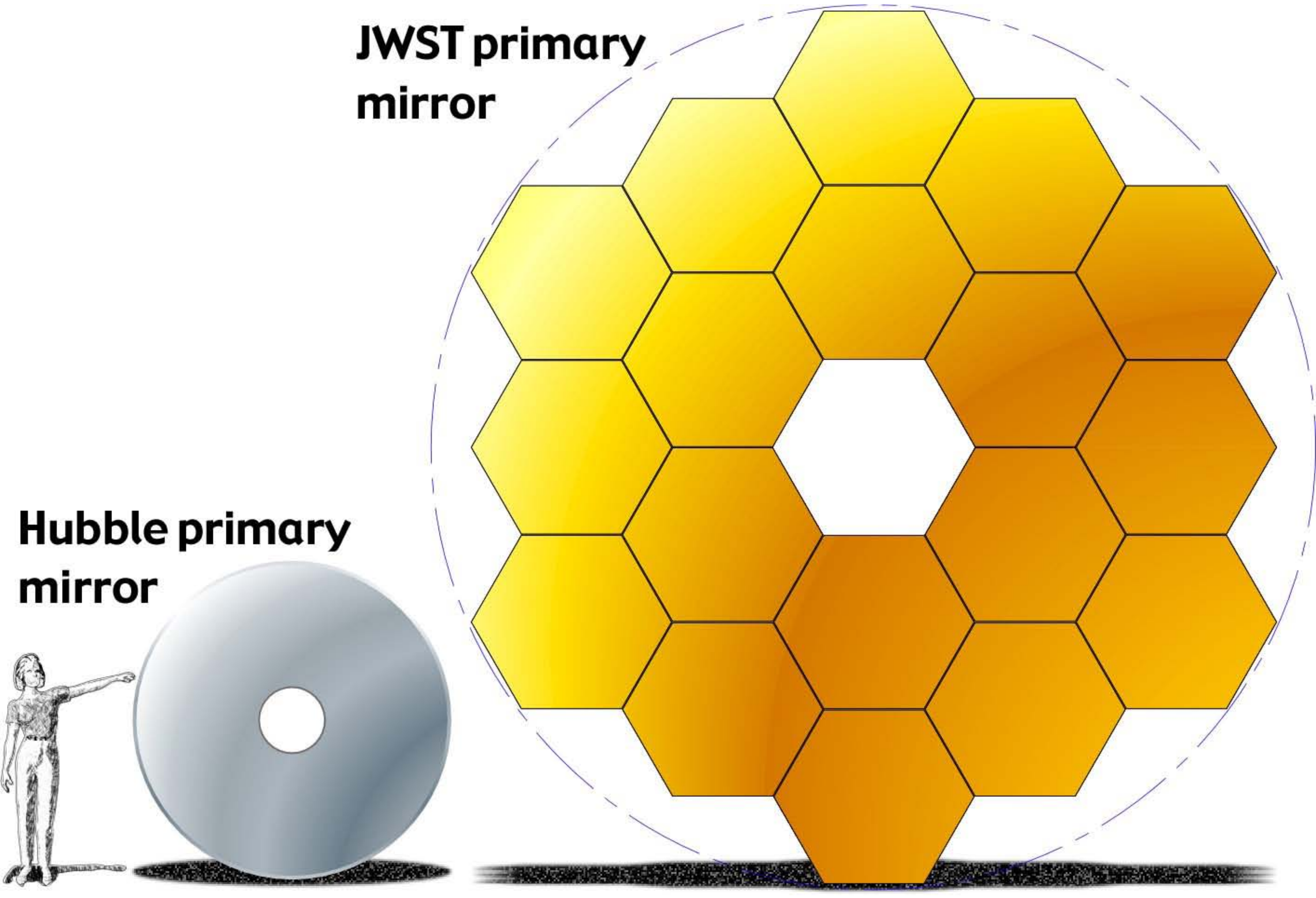
Le successeur du Hubble Space Telescope :

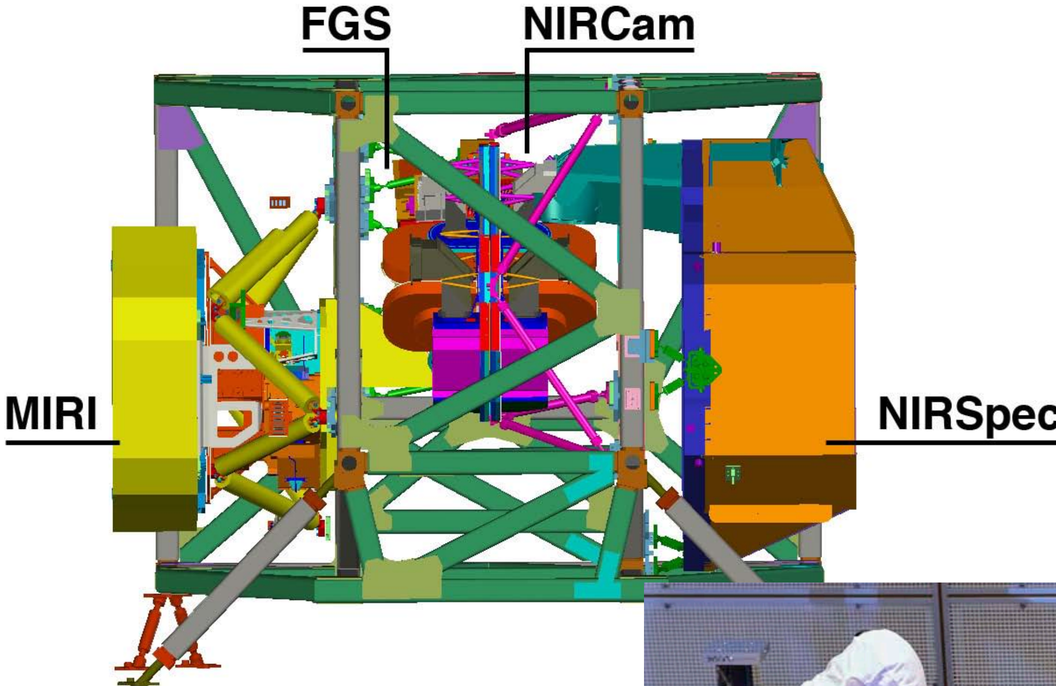
le James Web Telescope



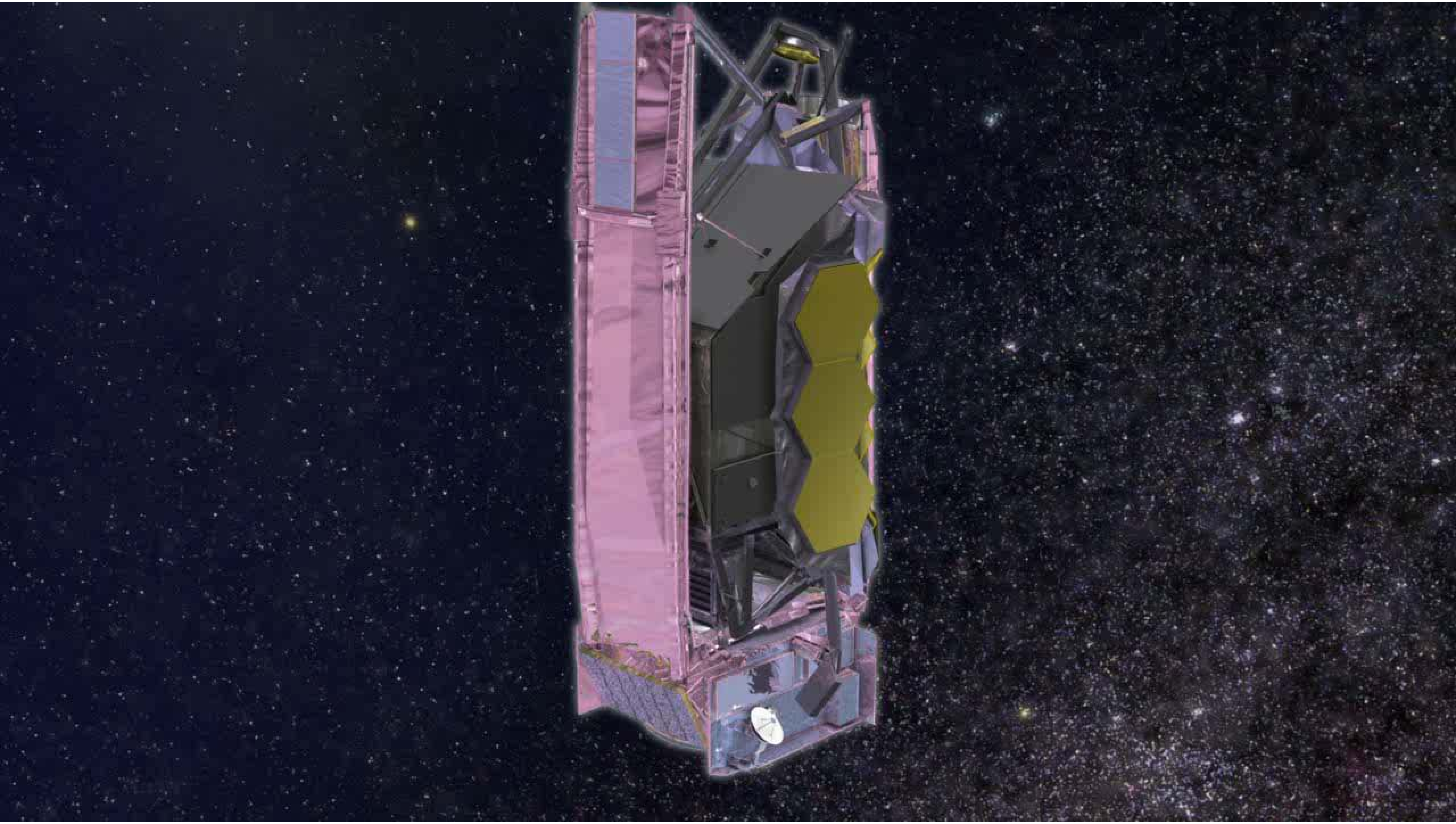


Backplane
Optical Telescope Element (OTE)
Primary Mirror
ISIM
Sunshield
OTE Secondary
Mirror
Spacecraft Bus
Startrackers


JWST primary mirror
Hubble primary mirror


FGS
NIRCam
MIRI
NIRSpec


CE
NIRSpec
+V1
ASTRIUM
ASTRIUM
NIRSPEC



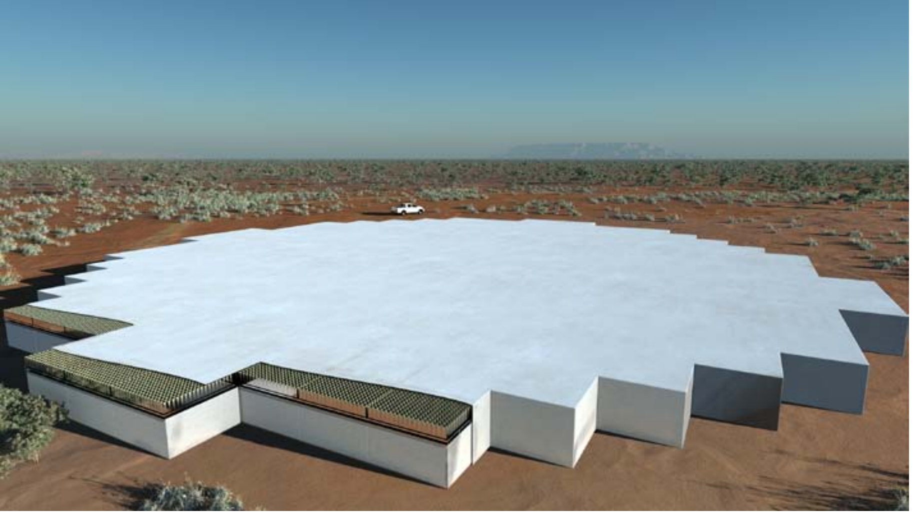
SKA

SQUARE KILOMETRE ARRAY

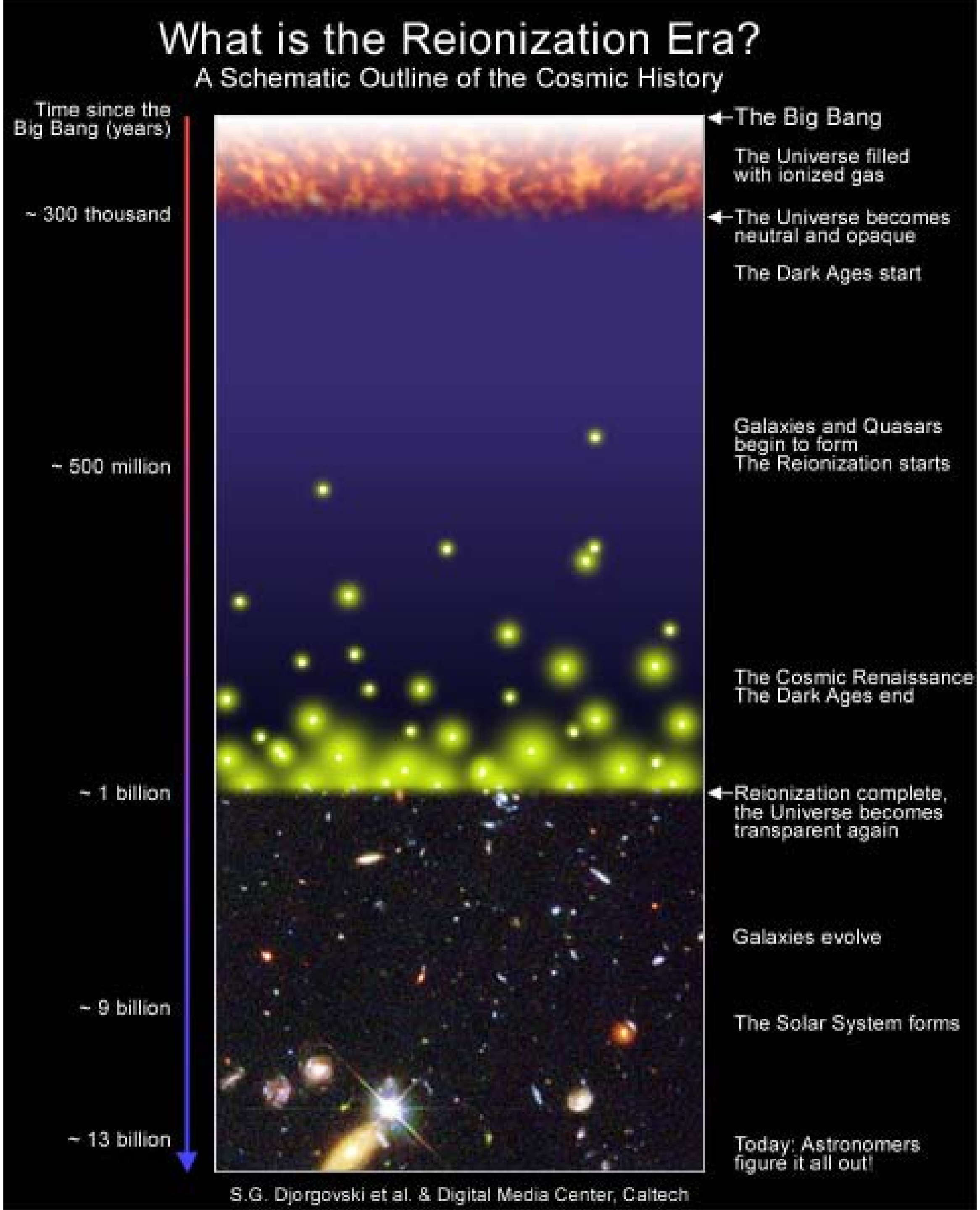
www.skatelescope.org

The Square Kilometre Array

SWINBURNE ASTRONOMY PRODUCTIONS



PARAMETER	SPECIFICATION
FREQUENCY RANGE	70 MHz TO 10 GHz
SENSITIVITY AREA / SYSTEM TEMP	5 000 M^2/K (400 μJy IN 1 MINUTE) BETWEEN 70 AND 300 MHz
SURVEY FIGURE-OF-MERIT	$4\times10^{7} – 2\times10^{10}$ m^4K^{-2} deg^2 DEPENDING ON SENSOR TECHNOLOGY AND FREQUENCY
FIELD-OF-VIEW	200 SQUARE DEGREES BETWEEN 70 AND 300 MHz 1-200 SQUARE DEGREES BETWEEN 0.3 AND 1 GHz 1 SQUARE DEGREE MAXIMUM BETWEEN 1 AND 10 GHz
ANGULAR RESOLUTION	<0.1 ARCSECOND
INSTANTANEOUS BANDWIDTH	BAND CENTRE ± 50%
SPECTRAL (FREQUENCY) CHANNELS	16 384 PER BAND PER BASELINE
CALIBRATED POLARISATION PURITY	10 000:1
SYNTHESISED IMAGE DYNAMIC RANGE	>1 000 000
IMAGING PROCESSOR COMPUTATION	$10^{\sim17}$ OPERATIONS/SECOND
FINAL PROCESSED DATA OUTPUT	10 GB/SECOND


What is the Reionization Era?
A Schematic Outline of the Cosmic History
Time since the Big Bang (years)
~ 300 thousand
~ 500 million
~ 1 billion
~ 9 billion
~ 13 billion
The Big Bang
The Universe filled with ionized gas
The Universe becomes neutral and opaque
The Dark Ages start
Galaxies and Quasars begin to form
The Reionization starts
The Cosmic Renaissance
The Dark Ages end
Reionization complete, the Universe becomes transparent again
Galaxies evolve
The Solar System forms
Today: Astronomers figure it all out!
S.G. Djorgovski et al. & Digital Media Center, Caltech

Founding Board : Australie, Chine, France, Allemagne, Italie, Pays-Bas, Nouvelle Zélande, Afrique du Sud, et Royaume-uni

Phase préparatoire jusqu'en 2012

Sélection du site (Afrique du sud ou Australie) en 2012

Pre-Construction phase	2013 – 2015
Construction phase 1	2016 – 2019
Construction phase 2	2018 – 2023
Science operation phase 1	2020
Science operation phase 2	2024

Le calculateur central de SKA aura la même puissance de calcul qu'un milliard de PCs.

La fibre optique utilisée pour SKA est assez grande pour faire 2 fois le tour de la terre

Les antennes de SKA vont générer un flux de données 100 fois plus important que le trafic internet actuel au niveau mondial

Où encore de remplir 15 millions d'Ipods 64 GB par jour.

Les antennes de SKA seront suffisamment sensible pour détecter un radar d'aéroport sur une exoplanete à 50 années lumières de distance

Situation à l'ESO

VLT et VLTI : installation progressive des instruments de seconde génération

ALMA :	early science	septembre2011
	configuration complète	≈ fin 2013
E-ELT :	décision	mi 2012
	construction	une dizaine d'année

Situation à l’ESA

<u>Missions L</u> *(coût ESA ≈ 1 000 M€)*

3 candidats présentés en février 2011 en partenariat avec la NASA

IXO, LISA, EJSM-Laplace

Suite au retrait probable de la NASA sur ces 3 missions, l’ESA à décidé d’étudier des missions plus petites, et purement ESA

IXO	>>>	ATHENA Advanced telescope for High Energy Astrophysics
LISA	>>>	NGO (New Gravitationnal Wave Observatory)
EJSM	>>>	JUICE (Jupiter Icy Moon Explorer)

Décision sur les missions L en février 2012

Situation à l’ESA

<u>Missions M</u> *(coût ESA ≈ 500 M€)*

M1	approuvée	Solar Orbiter
M2	sélectionnée	EUCLID
	approbation finale mi 2012	
M3	en cours de sélection	

Situation à l'ESA

Missions M3

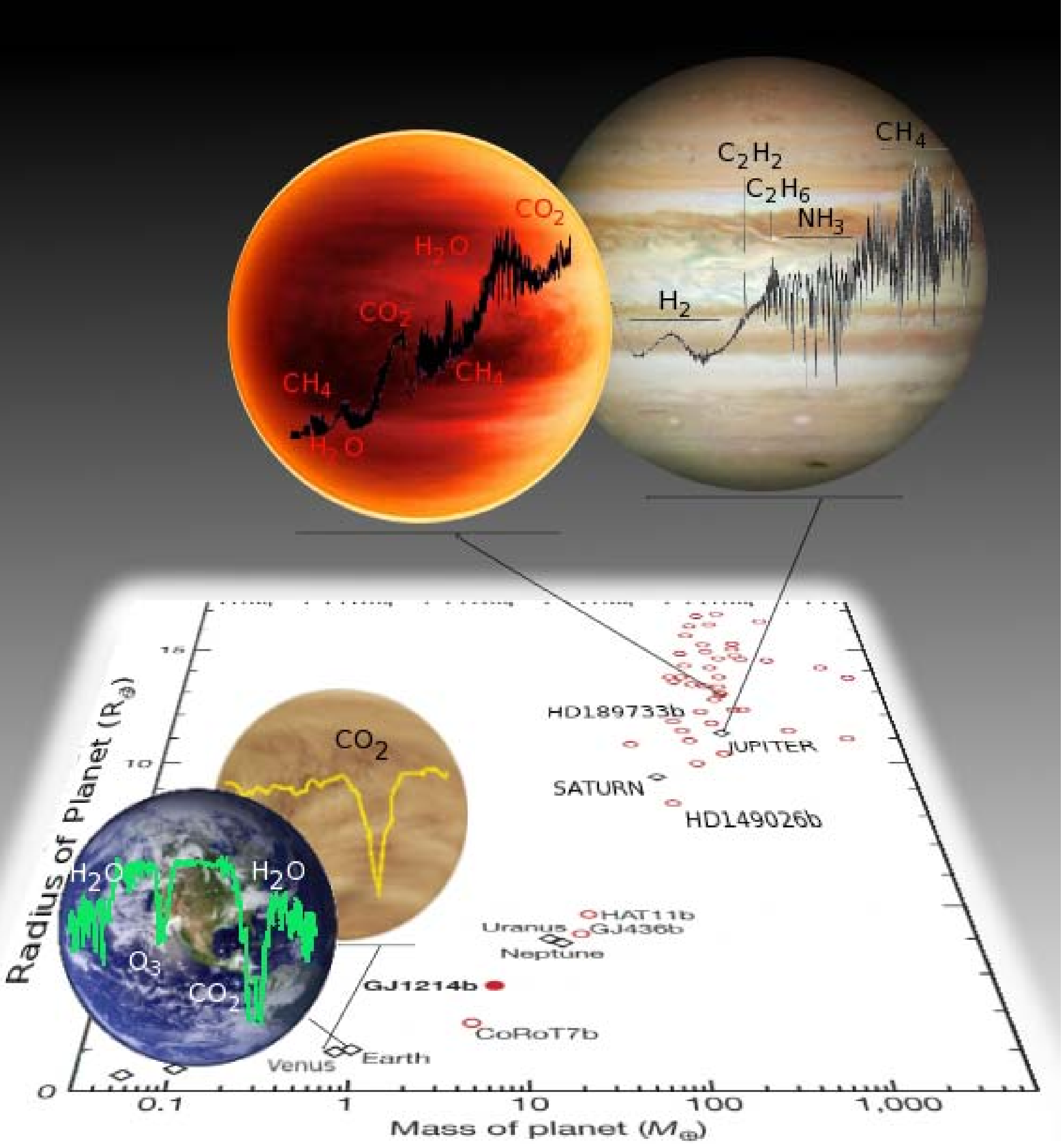
EChO (Exoplanet Characterisation Observatory)

STE-QUEST (Space-Time Explorer and Quantum Equivalence Principle Space Test)

MarcoPolo-R (to return a sample of material from a primitive near-Earth asteroid)

LOFT (Large Observatory For X-ray Timing)

Phase 0 (concept study)		avril 2011 – juin 2013
Down selection	4 >> 2 (?)	juin 2013
Selection M3		mi 2015



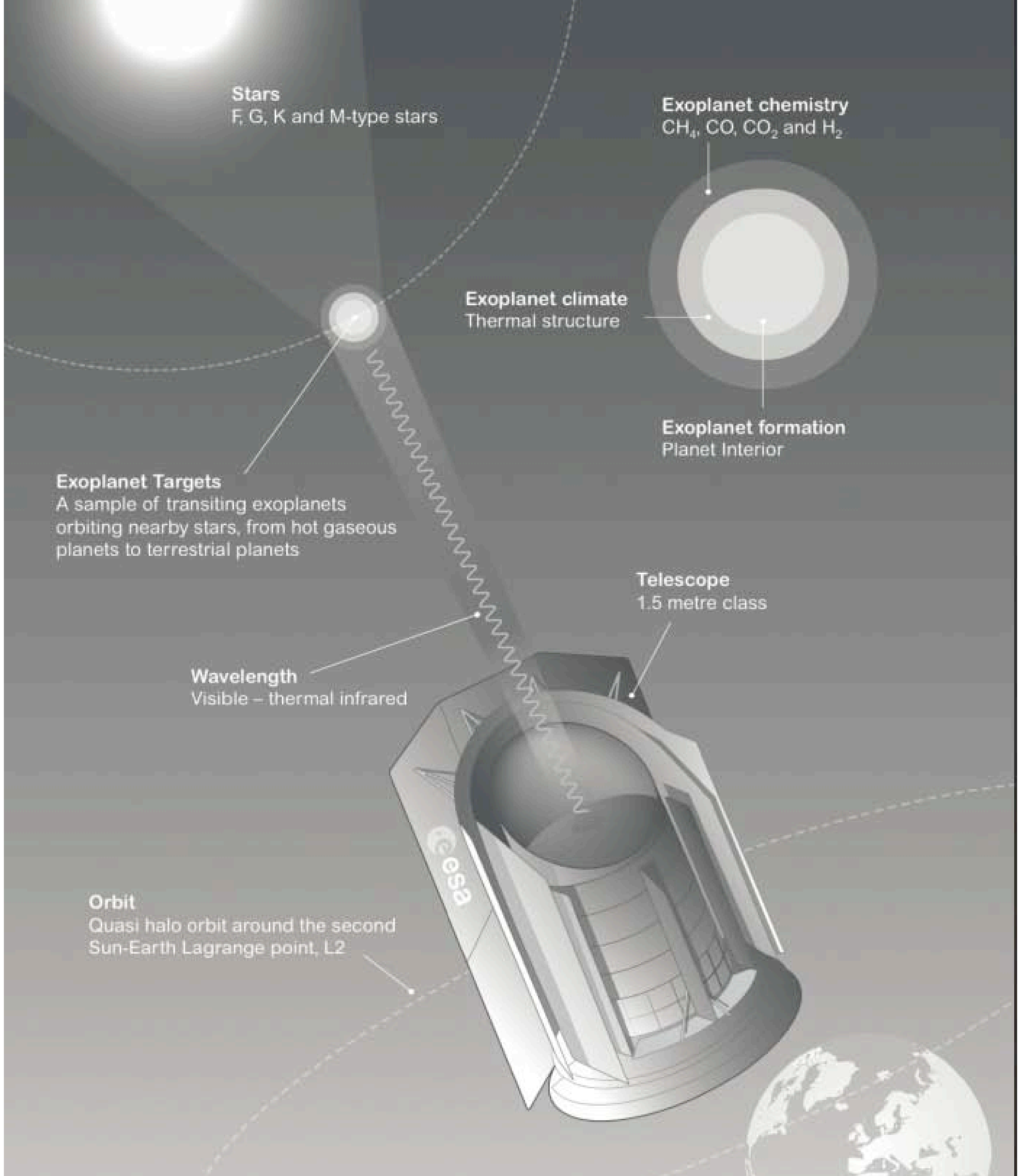
ECHO

trouver des exoplanètes ne suffit pas,

il faut les caractériser:

Méthode:

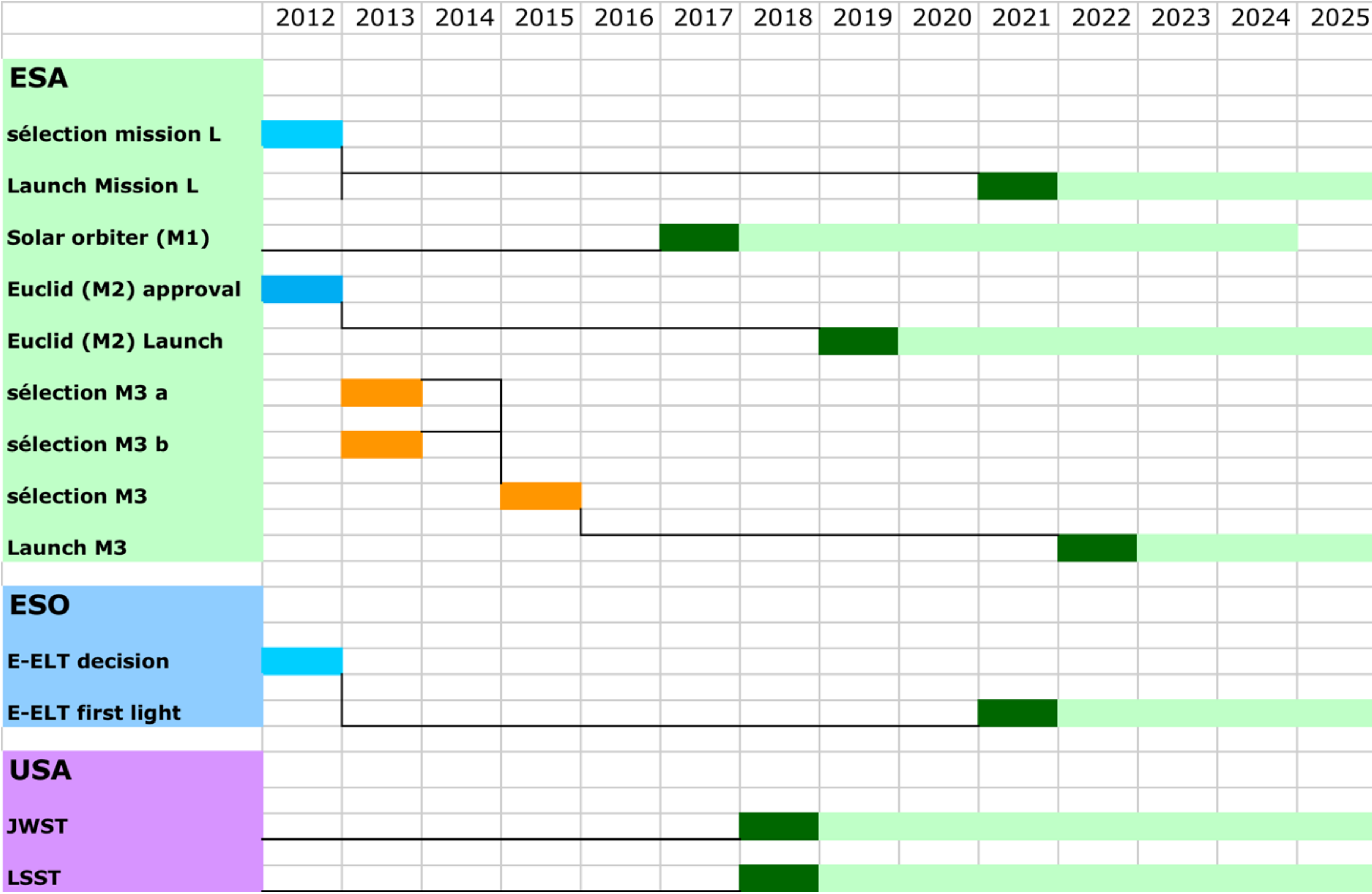
Spectroscopie lors des transits



Exoplanet Characterisation Observatory

Theme
What are the conditions for planet formation and the emergence of life?

Primary goal
To characterise the atmospheres of nearby transiting exoplanets, including temperate super Earths


2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
ESA
sélection mission L
Launch Mission L
Solar orbiter (M1)
Euclid (M2) approval
Euclid (M2) Launch
sélection M3 a
sélection M3 b
sélection M3
Launch M3
ESO
E-ELT decision
E-ELT first light
USA
JWST
LSST

Nom	Coût
LSST	500 M$
Euclid	550 M€ (ESA) + 30% états membres
GAIA	550 M€ (ESA) + 20% états membres
ALMA	1 000 M€ dont 450 M€ coût ESO
E-ELT	1 083 M€ (coût ESO)
SKA	1 500 M€ (target cost)
JWST	8 7000 M$
Lancement Navette	500 M$ (≈ 1 500 M€ pour mission service HST)
Herschel + Planck	1 400 M€

Nom	coût
A 380	250 M€
Rafale	300 M€
Porte avion	3 000 M€
100 km d’autoroute	600 M€
EPR	5 000 M€
ITER	16 000 M€
International Space Station (construction et opération)	115 000 M$

Tout ceci est-il raisonnable ?

Quel prix la société est disposée à payer pour des projets de recherche fondamentale ?

La principale justification de la construction des grands télescopes est l'augmentation du savoir

Mais

L'astronomie à un important retour en dehors de cela

> Le transfert de nouvelle technologies
> le développement de nouvelles capacités dans l'industrie
> un retour en terme d'emploi industriel: 60 - 80% du coût sont des en contrats dans l'industrie

Citation de M. Seznec (president et CEO of Thales Alenia Space) lors de l'inauguration de l'Année internationale de l'Astronomie à l'UNESCO en 2009:

Astronomy projects are challenging projects able to motivate industrial teams

Où est la limite

Acceptable par la société ?

Acceptable sociologiquement par la communauté des astronomes ?

Non sclérosante pour la communauté des astronomes ?

La question reste ouverte