
Le projet E-ELT (European Extremely Large Telescope)

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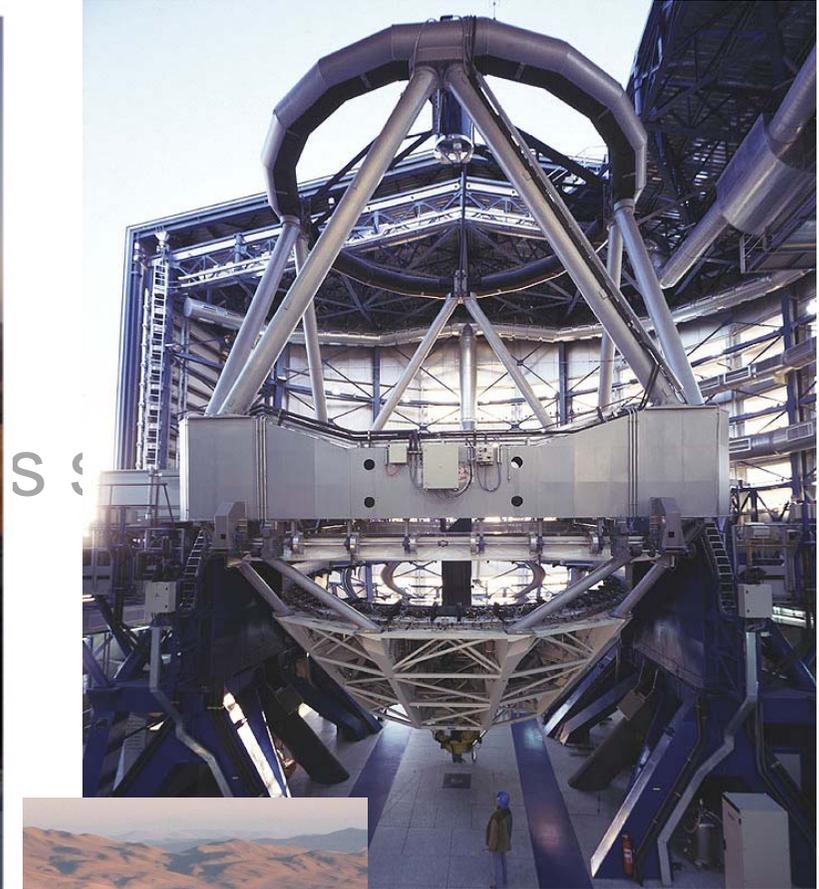
Plan de l'exposé

- Les projets d'ELT
 - L'E-ELT
 - Les projets américains
- Exemples de programmes scientifiques
 - Exoplanètes
 - Expansion de l'Univers
 - Evolution des galaxies
- Conclusions

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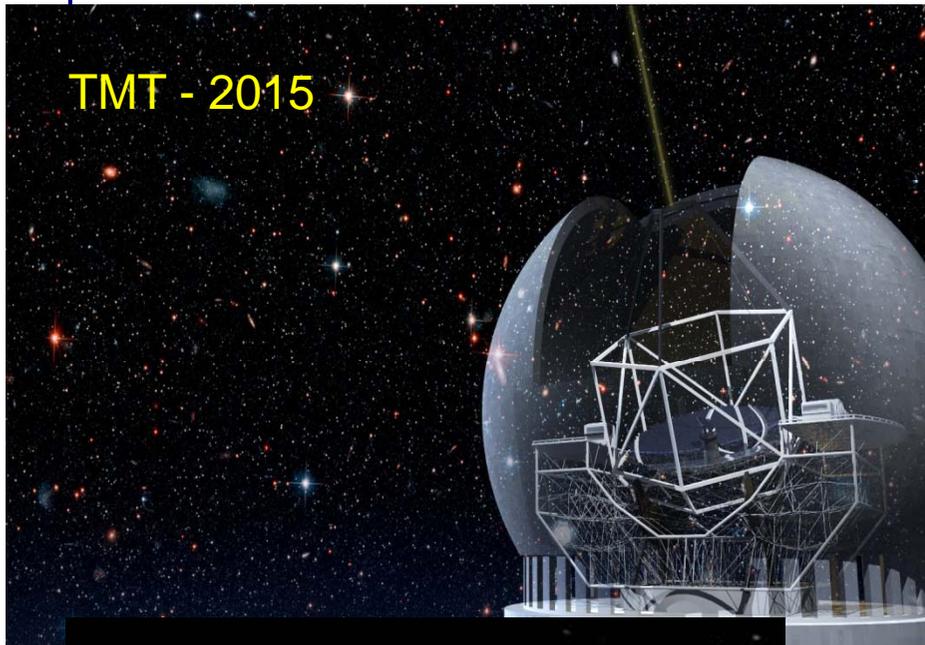
Télescopes: Etat de l'art



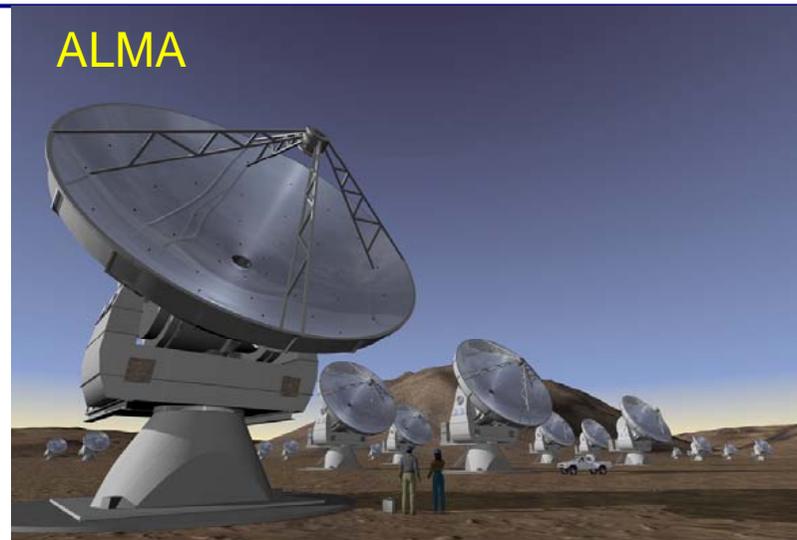
The VLT Array on the Paranal Mountain

Pourquoi un ELT ?

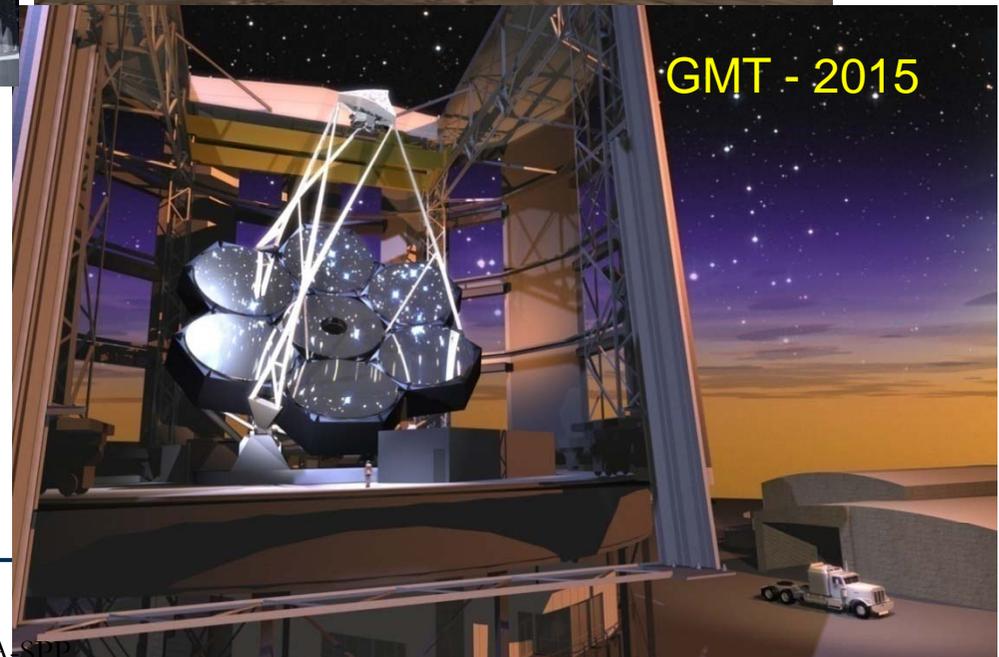
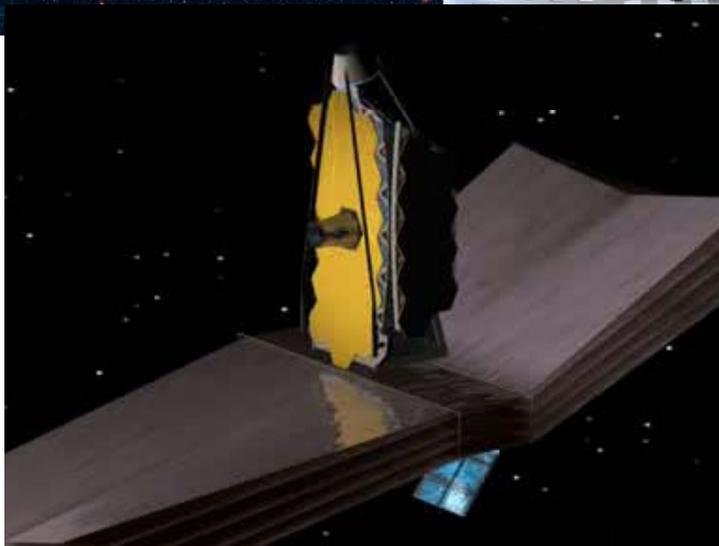
TMT - 2015



ALMA



GMT - 2015



June 8, 2009

CEA-STA

VLT: collaboration avec l'industrie

Schott



Zeiss

SOIMI

Linde

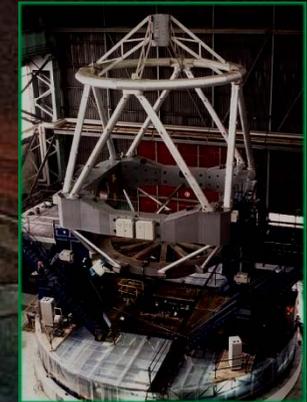
Cegelec

Fokker
TNO/TPD

Ansaldo AES



REOSC



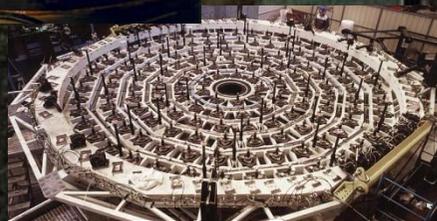
AMOS



GIAT

Dornier

Skanska



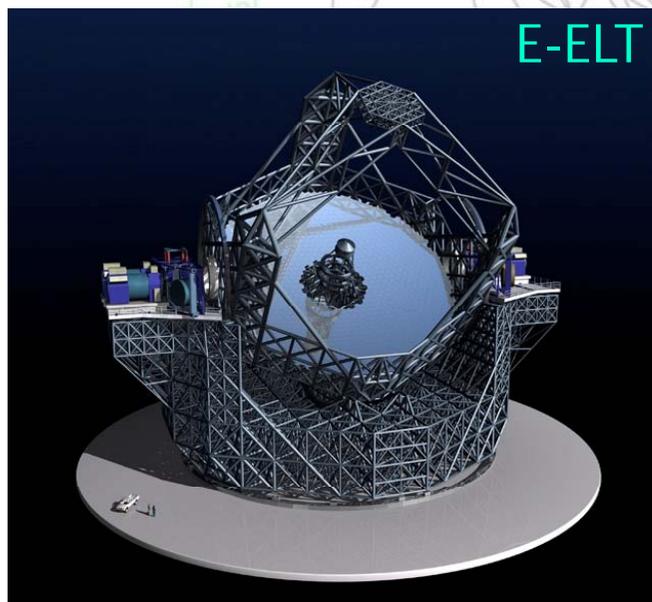
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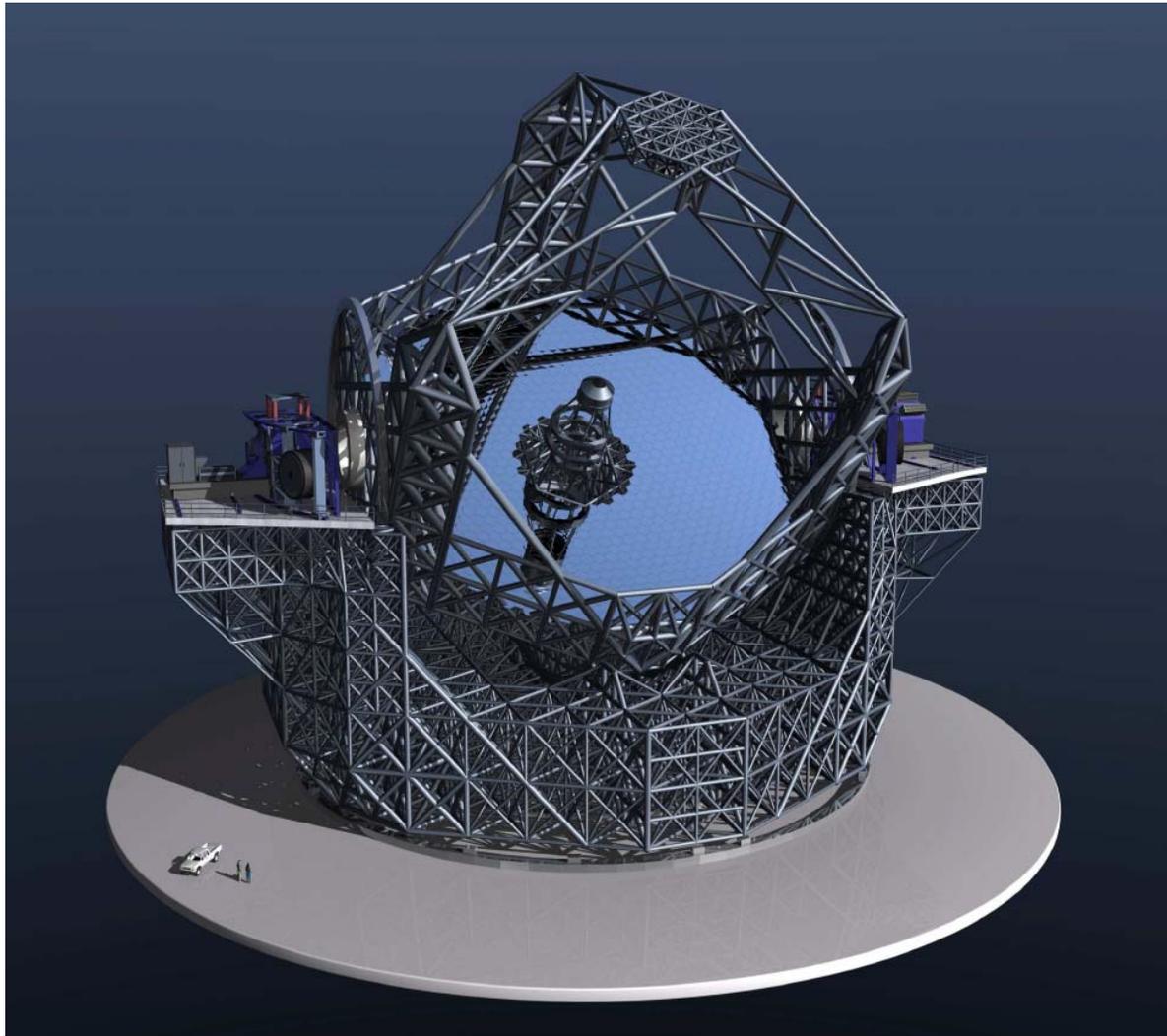
ESO



- 13 états membres
- ~ 700 personnes
- 5 sites (D & Chili)
- 120 M€/an
- VLT (1999)
- ALMA (2012)
 - ESO + US + Japon
- E-ELT (2017)



The European Extremely Large Telescope



E-ELT design
November 2006

M1 42m segmenté
M2 6m monolithique, actif
M4, M5 adaptatif

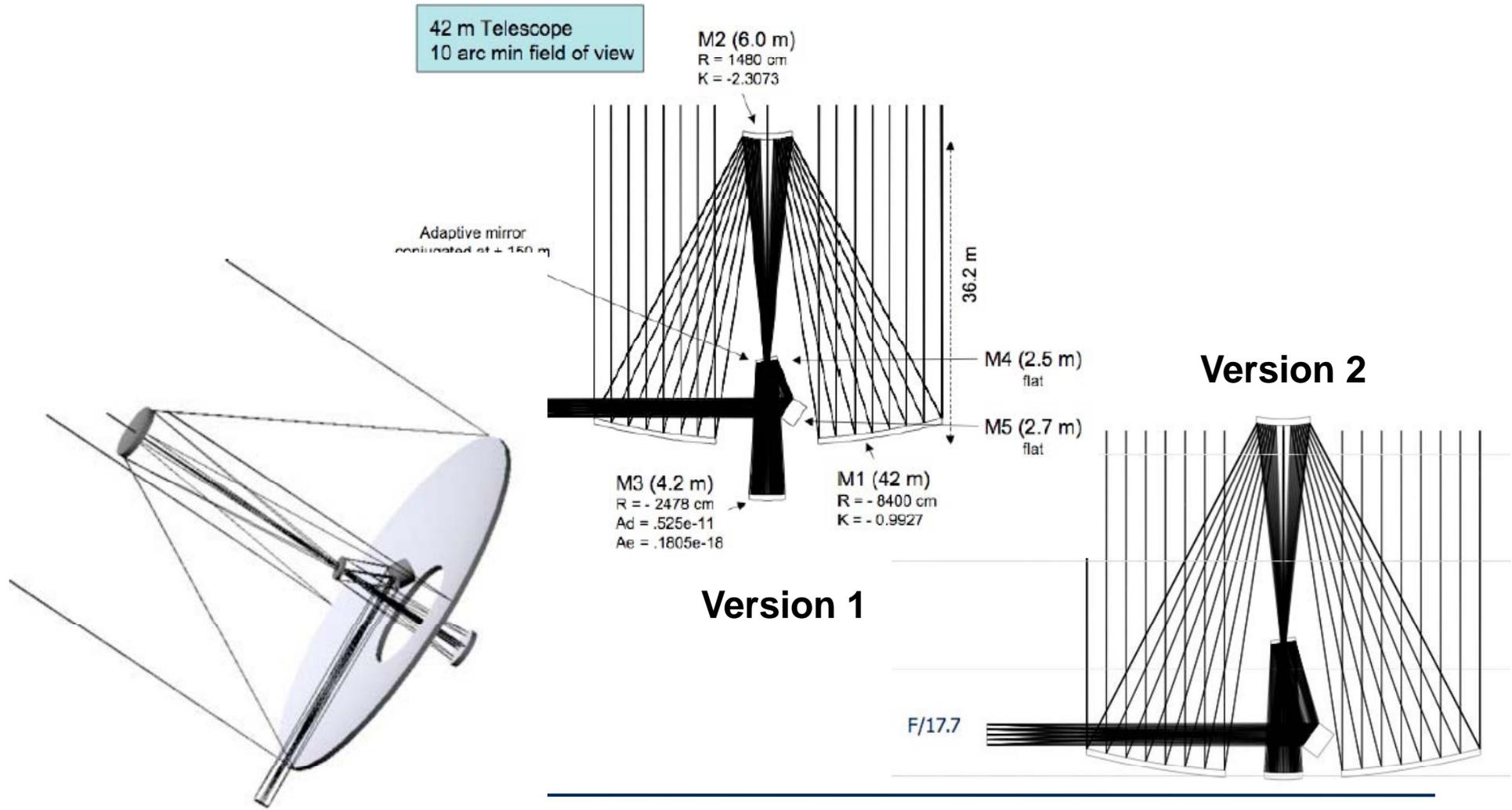
1300 m² de verre (M1)

Calendrier:
2007-2009 Phase B
2010-2017 Construction

Coût ~ 1000 M€

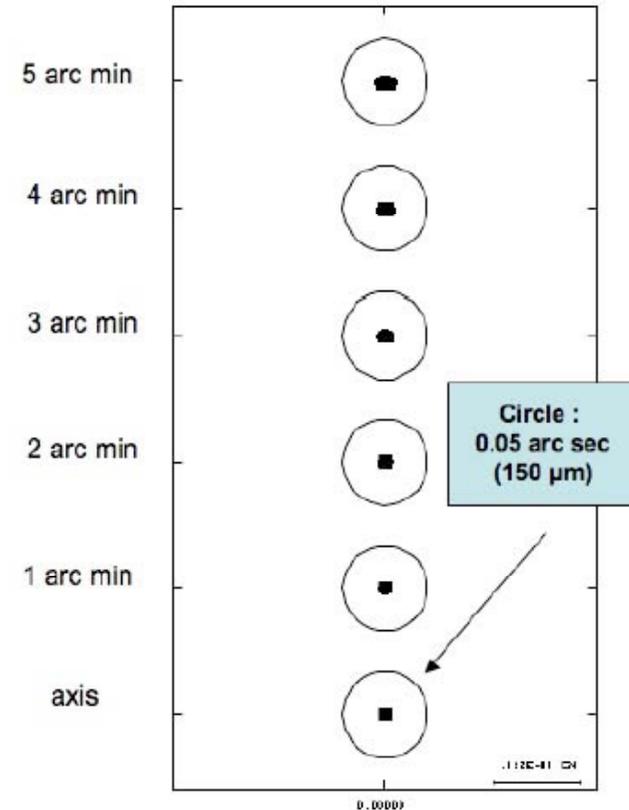
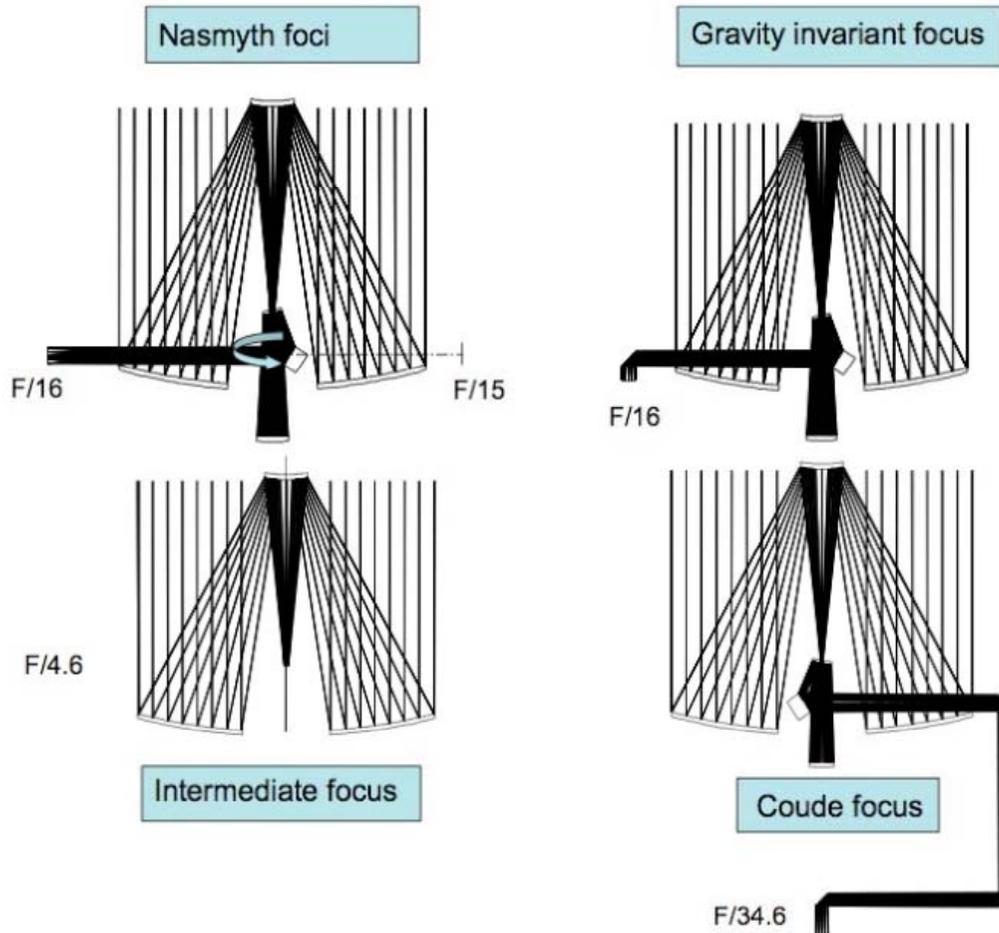
Décision 2010

Le Télescope



Le Télescope

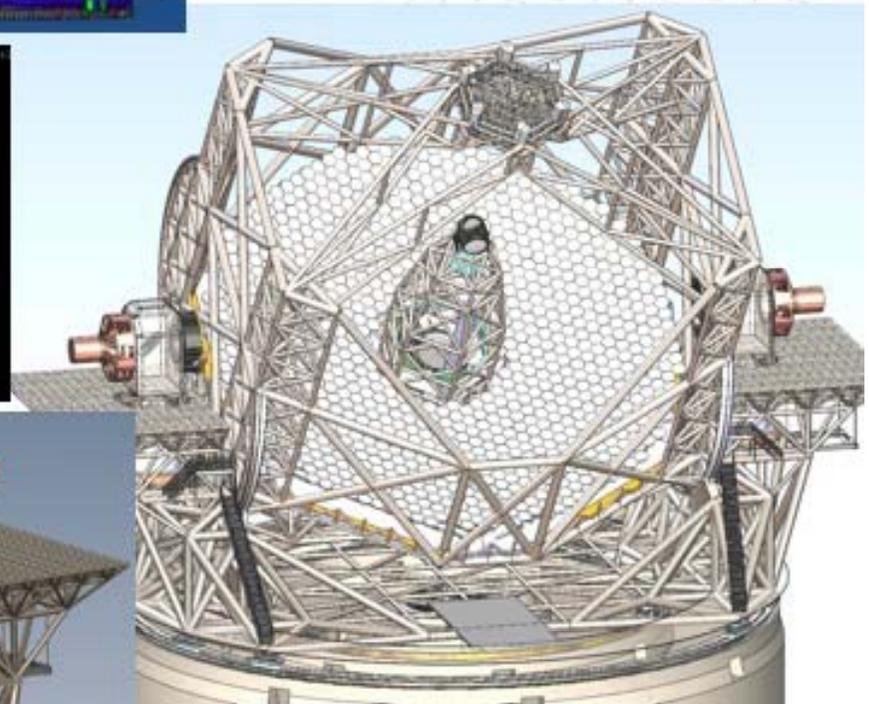
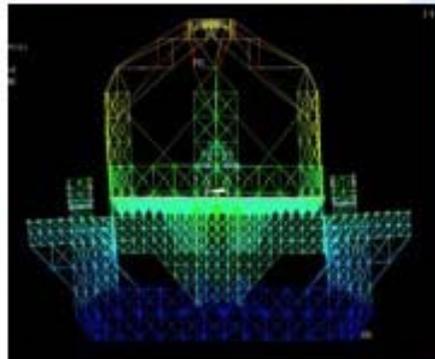
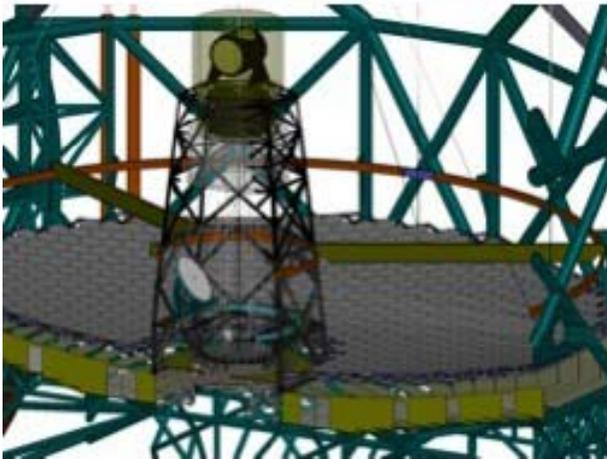
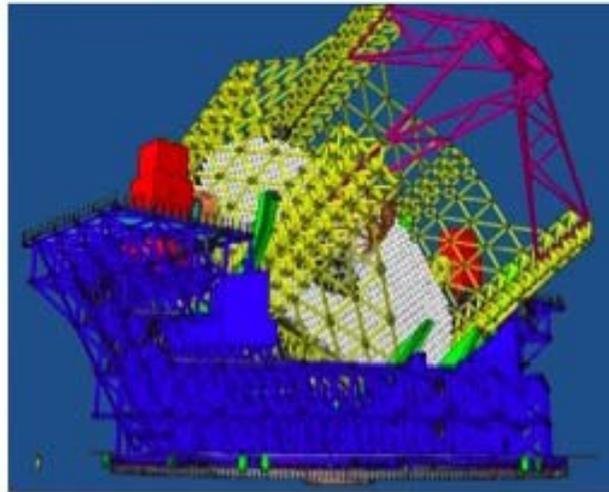
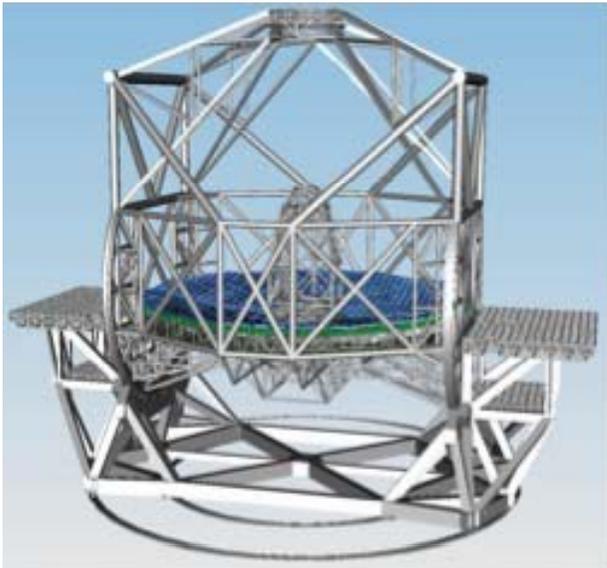
Foyers



The telescope image quality.

TELESCOPE MOUNT

- Two cradle solution
- **Two industrial contracts concluded**
- **FEED ongoing**
- Confirm cost and schedule
- Excellent stiffness ($\geq 3\text{Hz}$)



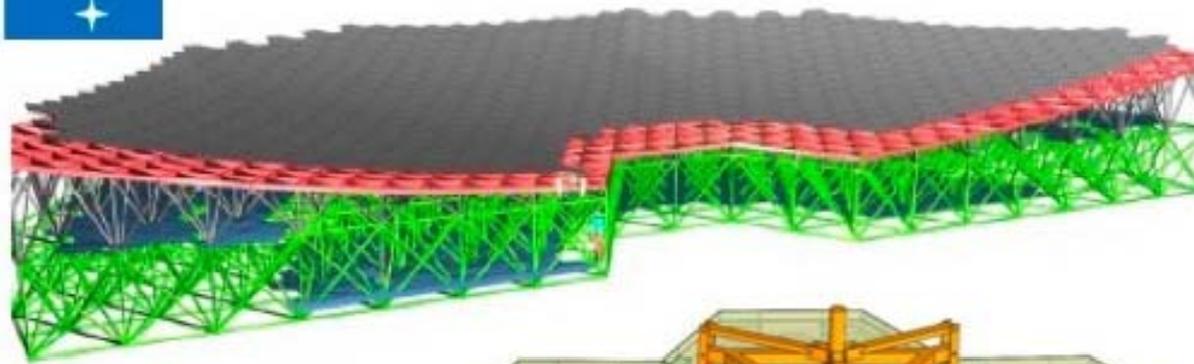
Azimuth track



Altitude cradle

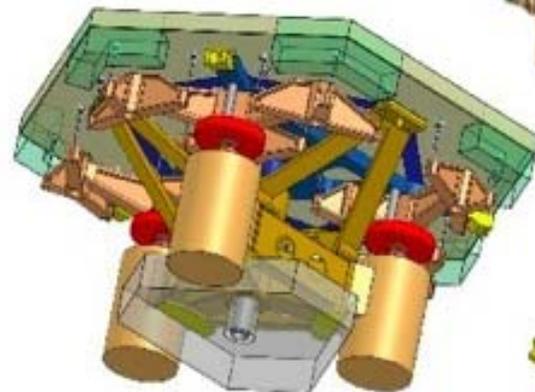
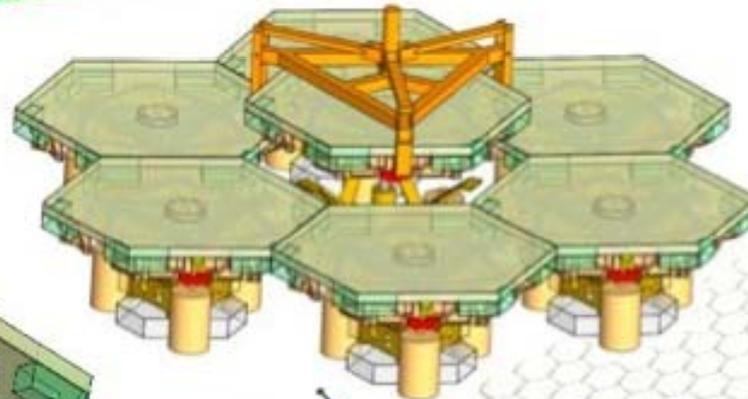


THE M1 MIRROR

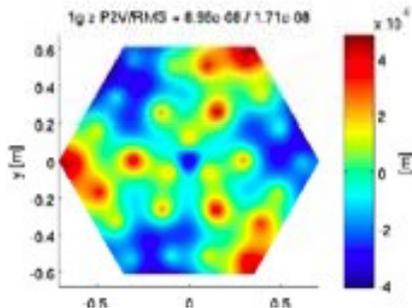
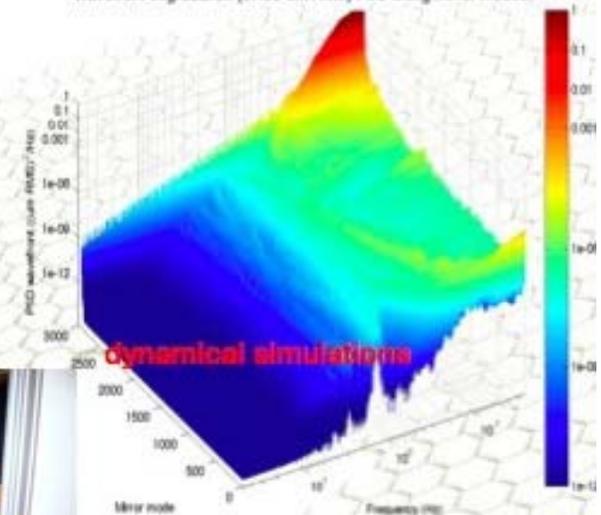


Segment dimensions:
1428.64 mm - 1414.00 mm
(1387.29 - 1427.13 @pupil)
central thickness: 50 mm
gap: 4 mm
bevel 2: mm (goal 1.5)

1148 segments:
984 mirror +
1 spare/family



Wavefront degradation (0.496 um RMS) PSD along mirror modes

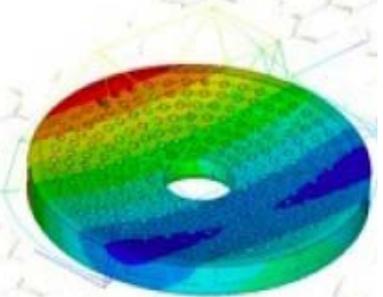
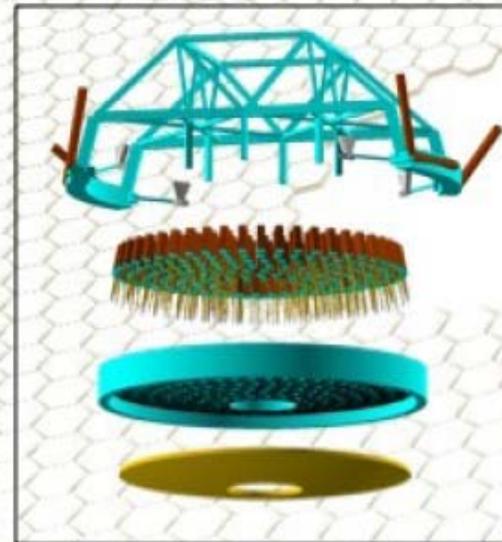
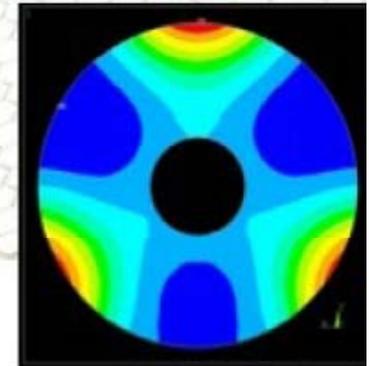
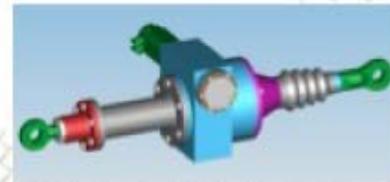
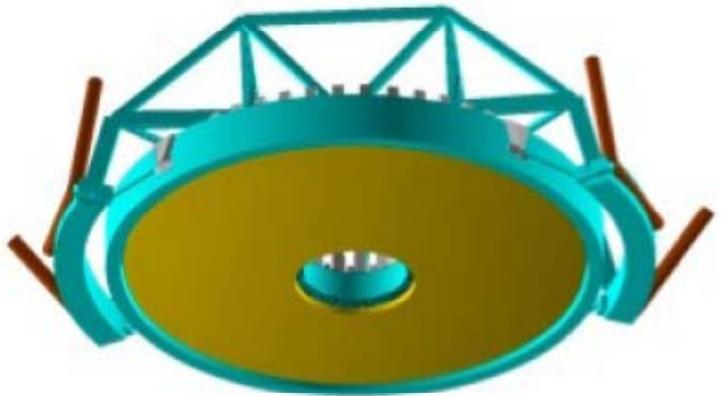
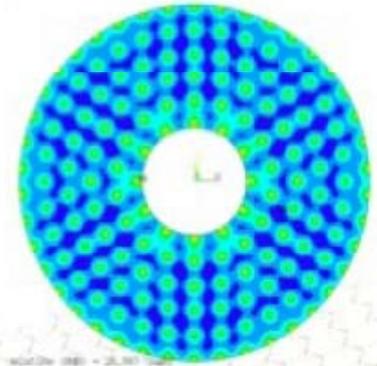
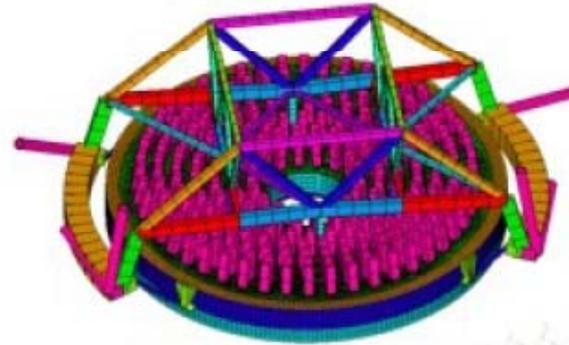


2 x 7 prototype segments being produced by two independent contractors. Production processes being developed under contract to ESO



THE M2 UNIT

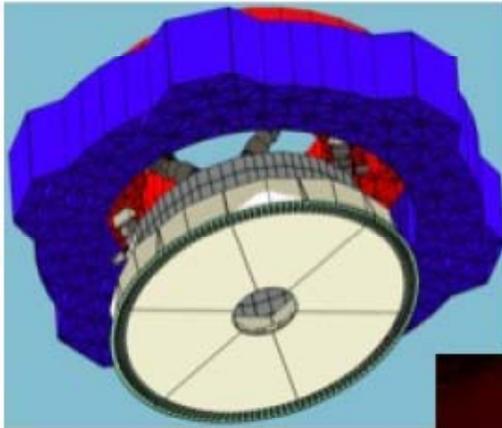
M2 cell design contract ongoing



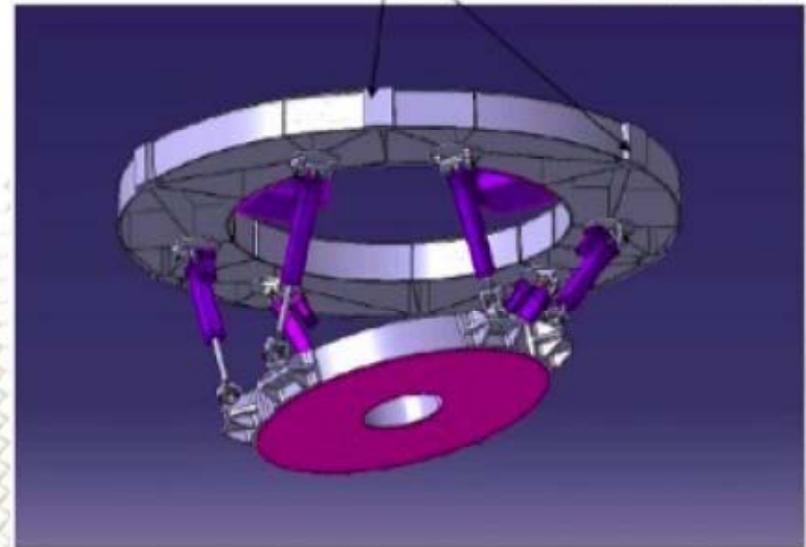


THE M4 ADAPTIVE MIRROR

Two industrial studies will deliver working prototypes



Two contracts running to PDR

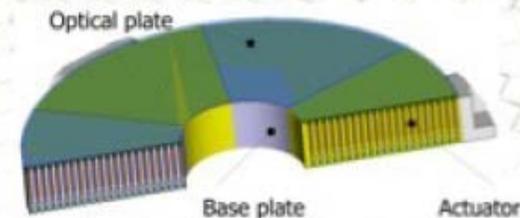


CAD view of the M4 mounting structure holding the 6 feet and the mirror

Specs:

- diameter 2.6 m
- less than 10 tons
- fitting error < 145 nm RMS for median seeing

Either voice coil 30-mm pitch or piezo 20-mm pitch, resulting in 6000-10000 actuators

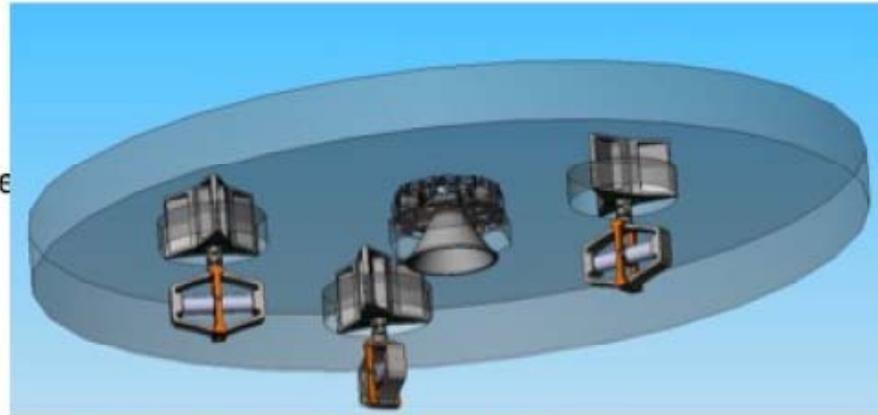




THE M5 FIELD-STABILIZATION MIRROR

M5 field stabilisation unit

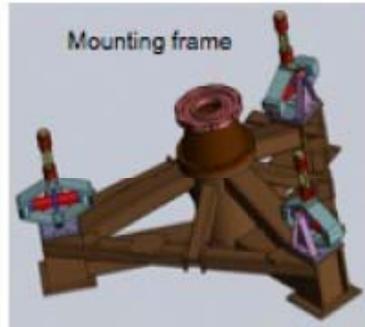
Deliverable of industrial electromechanical study: scale prototype



Backside with support elements and actuators



M5 actuator breadboard

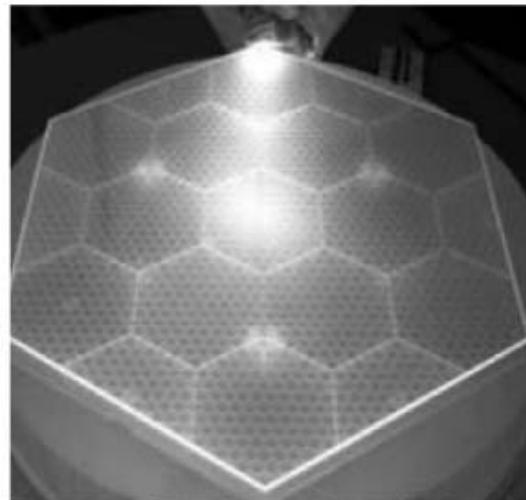


Mounting frame

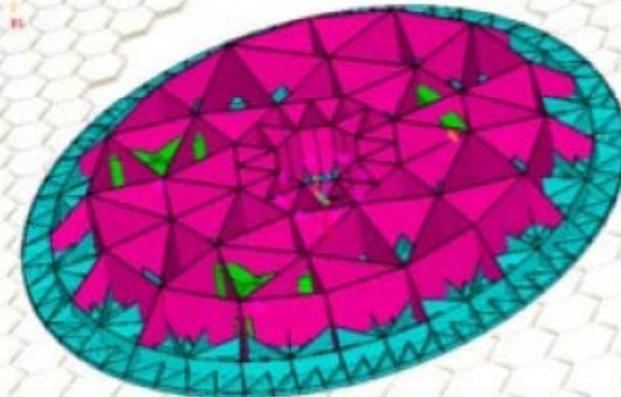
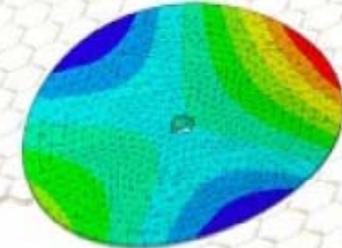
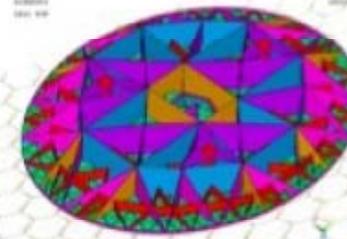
M5 mirror

Flat, 3x2.4m ultra-lightweight mirror goal: 40 kg/m²

Example: ASMD mirror (1.4 m - JWST study)



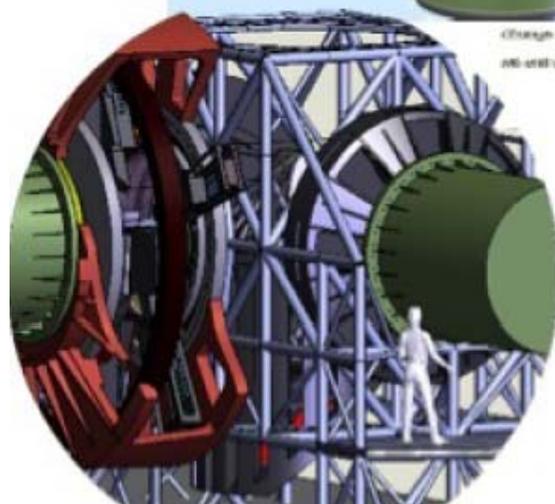
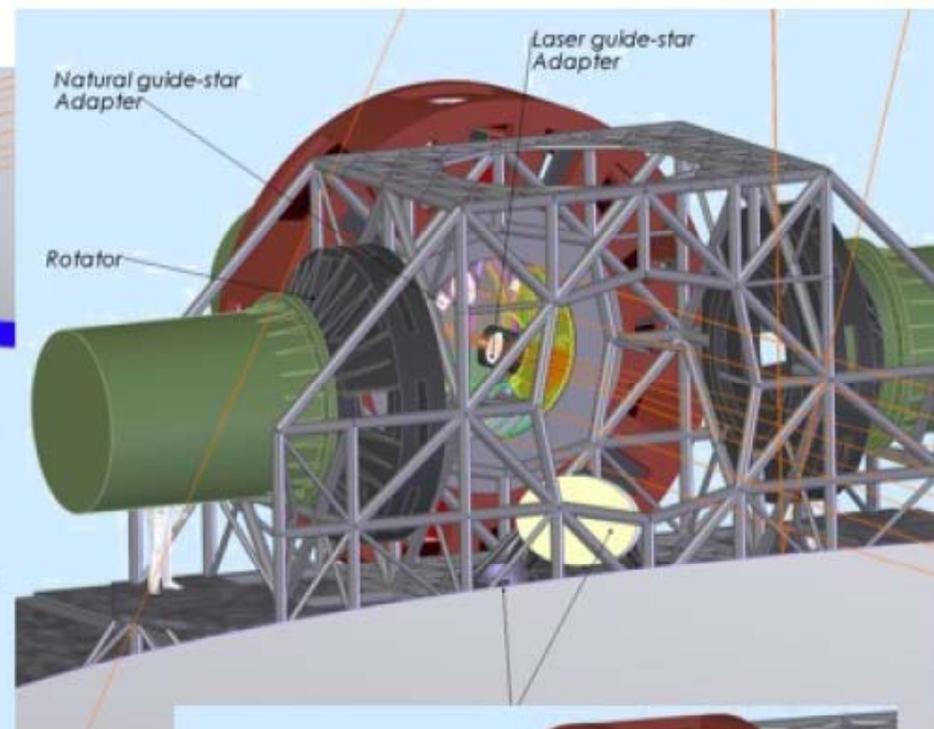
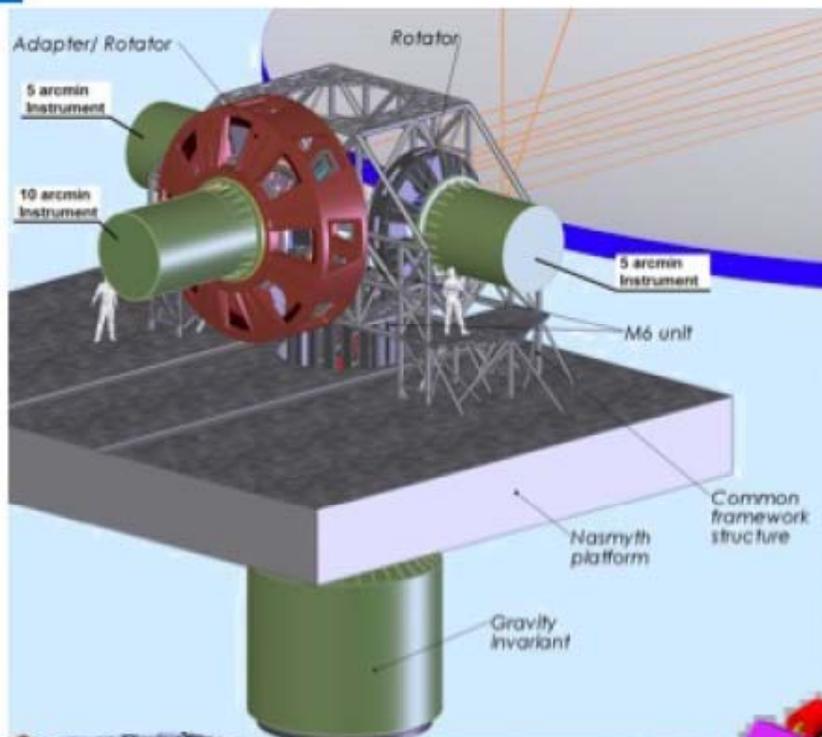
Example: ASMD mirror Lightweight ULE (JWST)



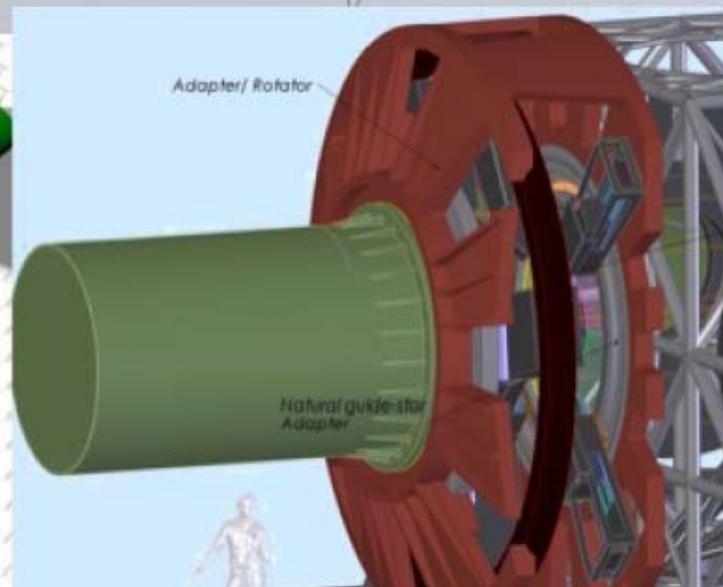
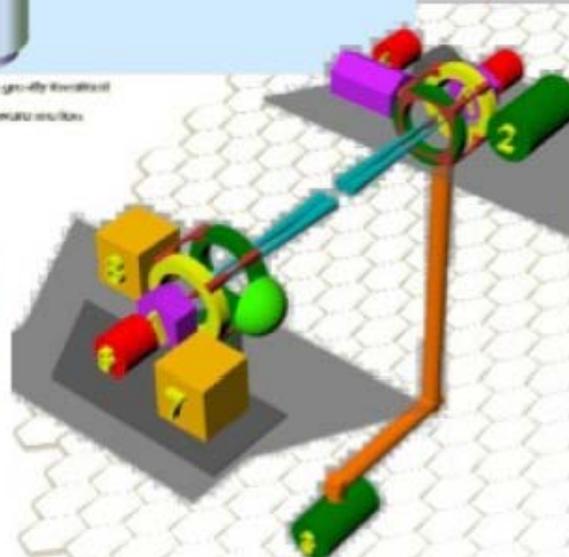
Alternative SiC design (67 kg/m²) design



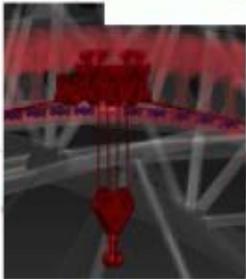
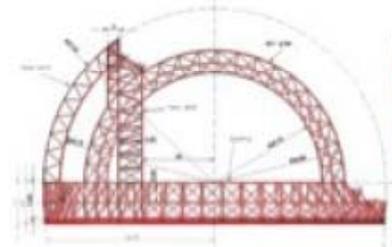
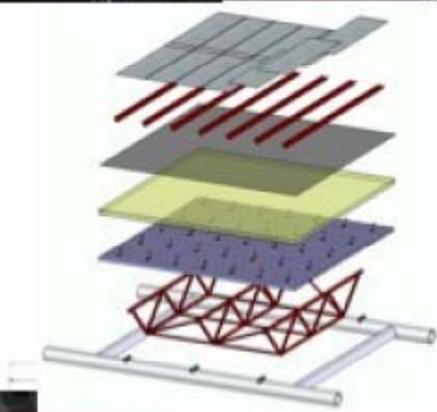
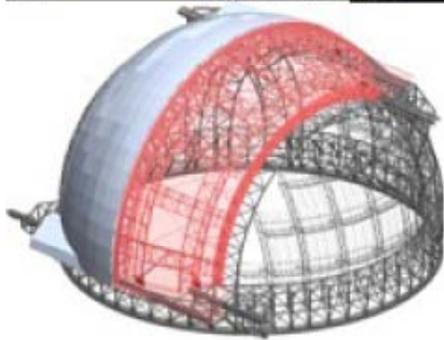
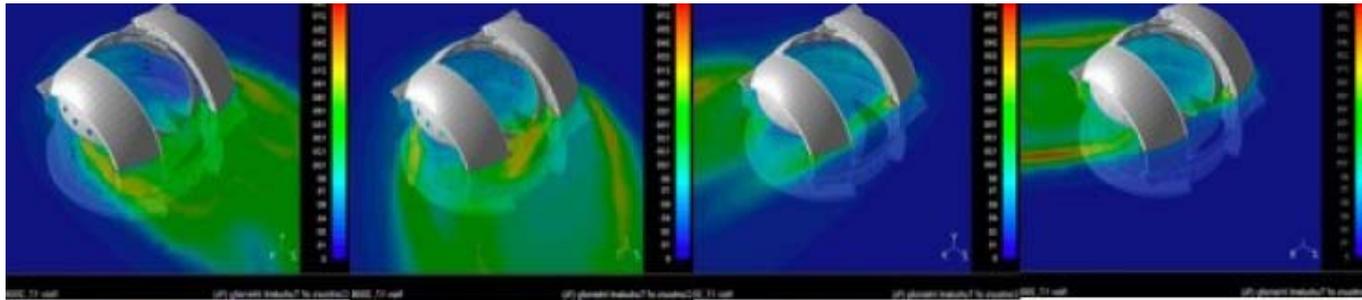
PRE FOCAL STATIONS



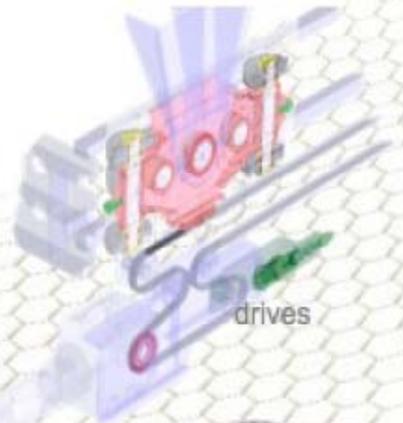
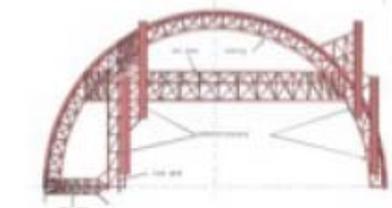
Changes for gravity invariant
M6 unit assembly structure



THE DOME



crane

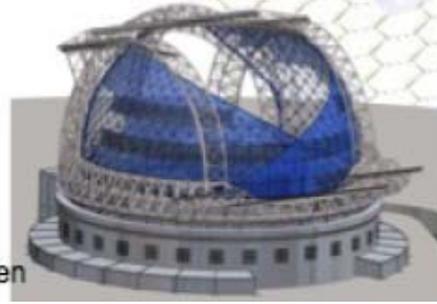


drives

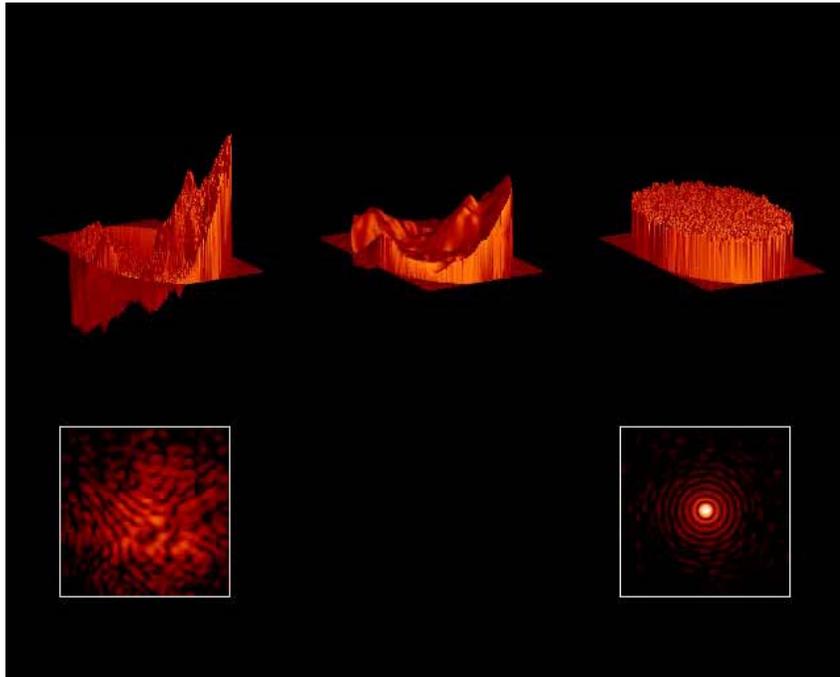
Two preliminary design contracts concluded providing schedule and cost. FEED ongoing



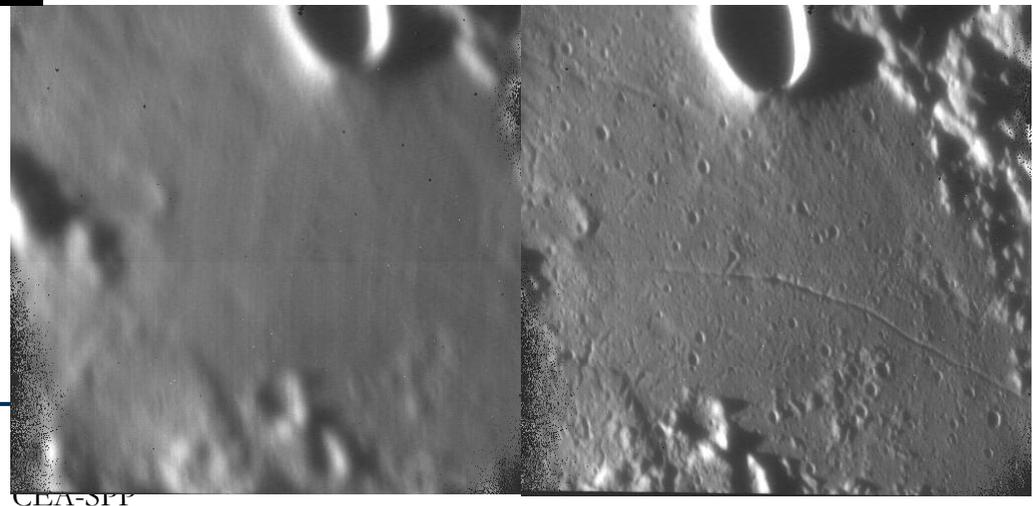
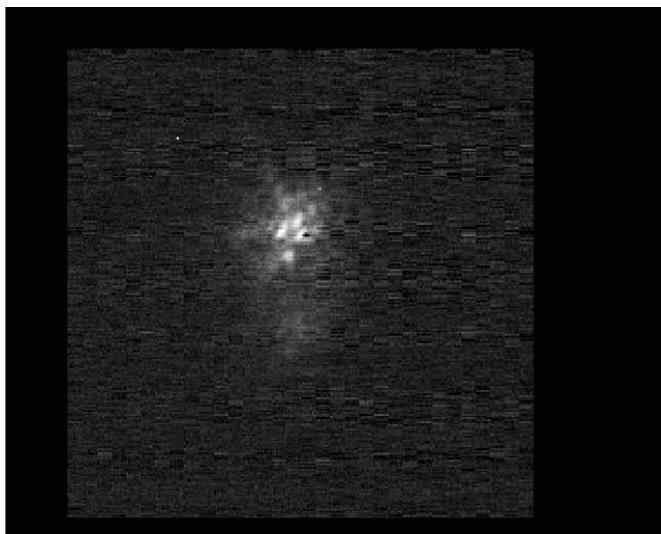
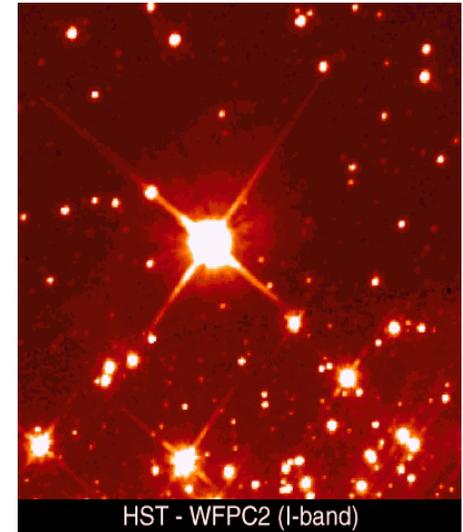
wind screen



Optique Adaptative



- Correction temps réel de la dégradation des images due à la turbulence
- Intégrée au télescope et aux instruments



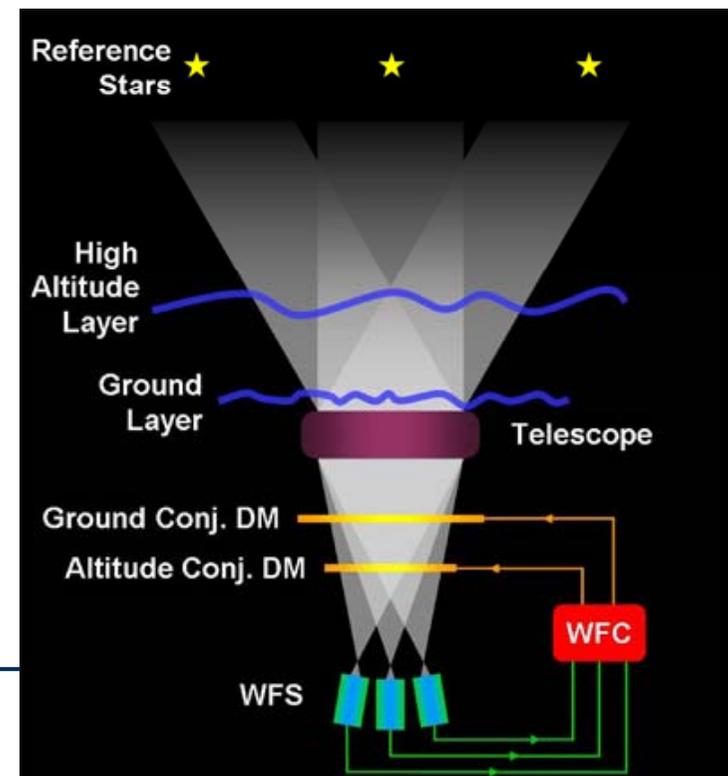
CEA-SPT

Optique Adaptative

- ❑ Etoiles laser pour une couverture complète du ciel
- ❑ Jusqu'à 9 étoiles laser pour une reconstruction tomographique de la turbulence atmosphérique
- ❑ Jusqu'à 2 ou 3 miroirs adaptatifs conjugués à différentes altitudes (couches turbulentes)



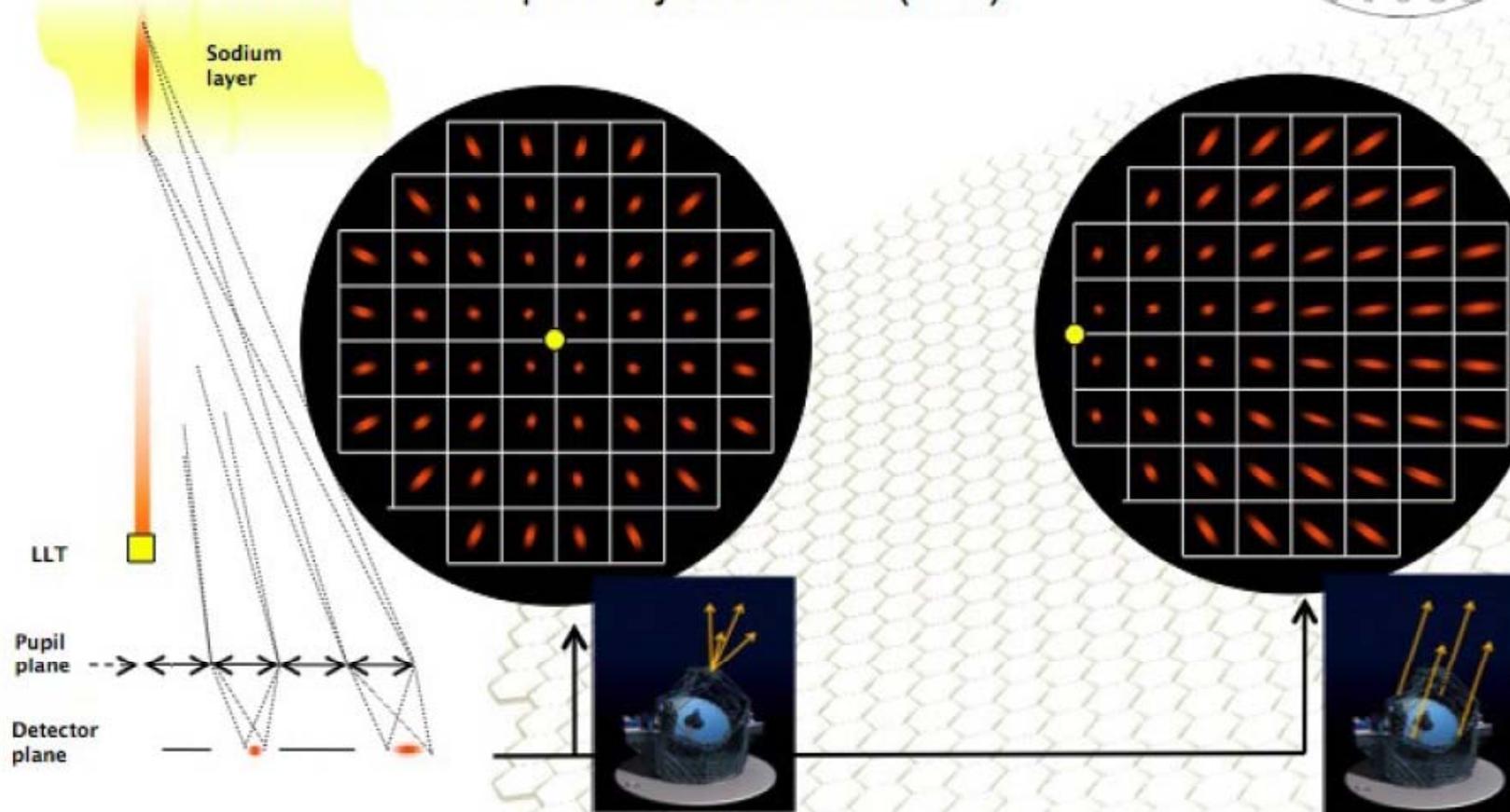
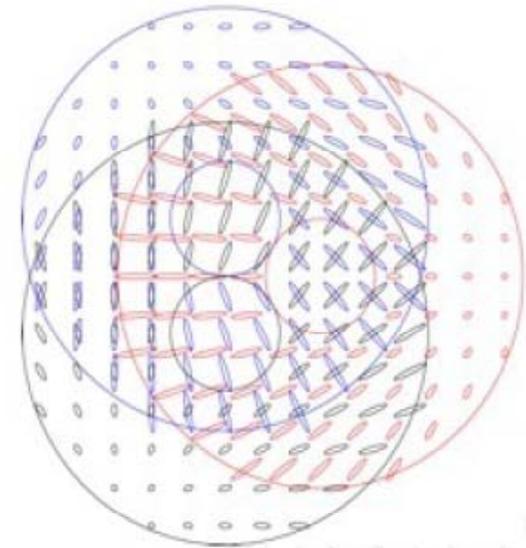
CEA-SPP



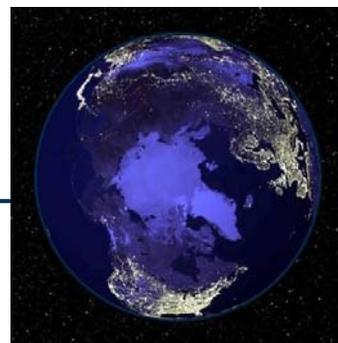
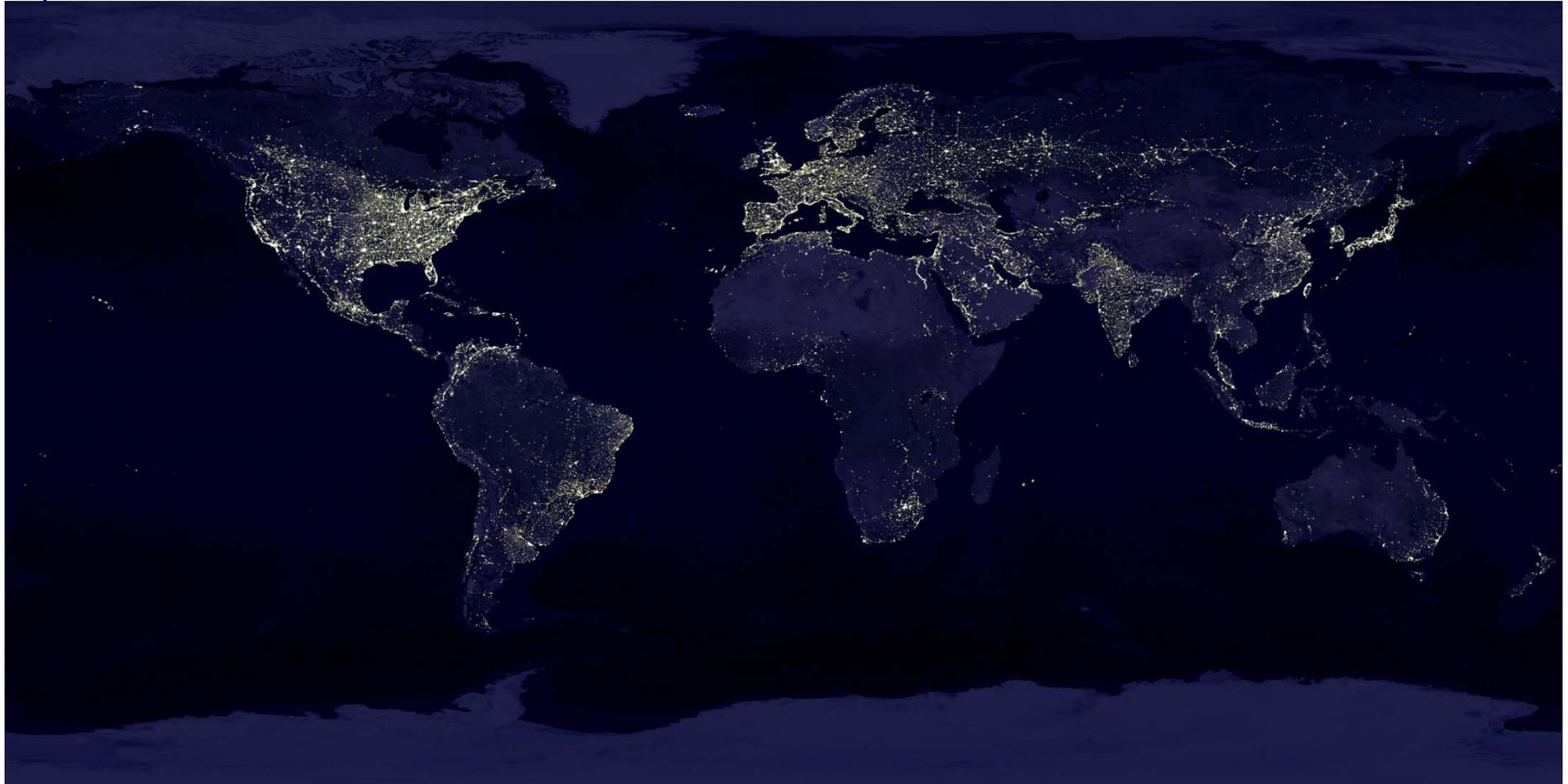


LASERS

- 4 laser stations consisting of:
 - 6 laser units of ~25 W ; 4 required for telescope GLAO
 - 4 Launch telescopes of 40cm (30 cm useful aperture)
 - 4 beam relay units beam steering, field selector and beam diagnostic tools compatible with 2 laser beams
 - 4 TBD-m baffles: probably closed tube (TBC)

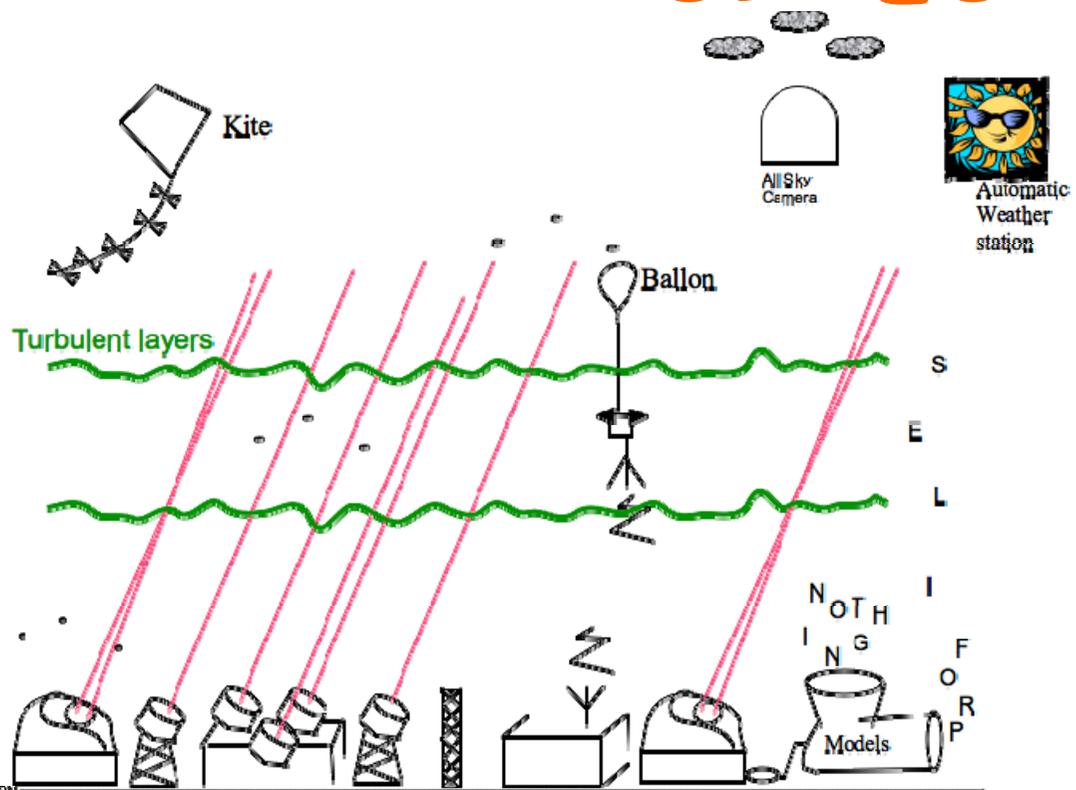


Site

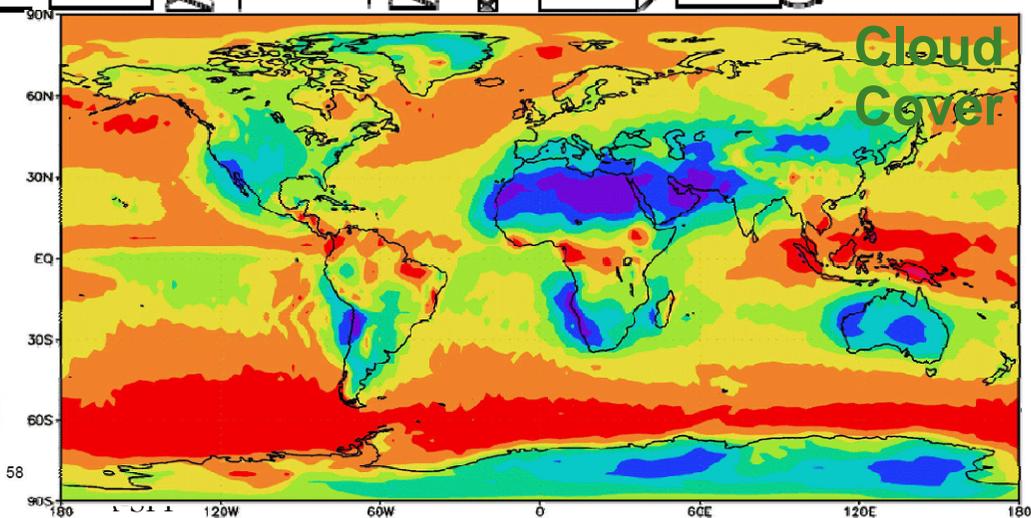




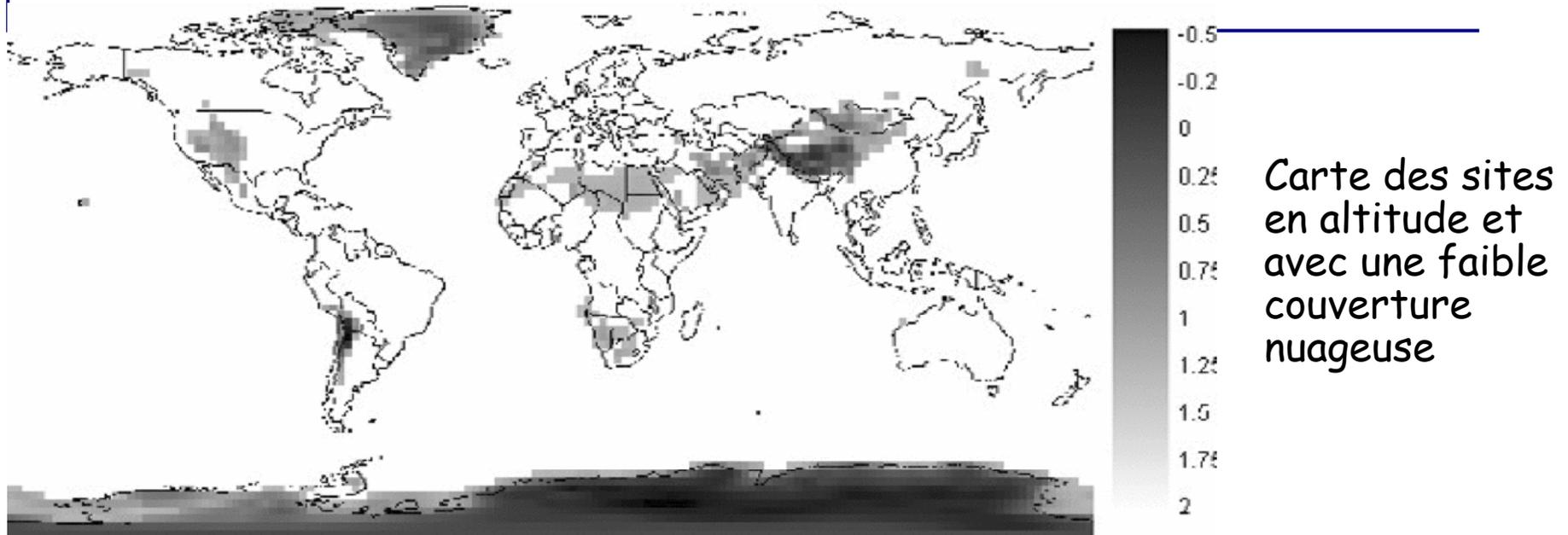
SITES



Chile Site Locations



Site



De très nombreux autres critères de choix:

- Techniques
- Pratiques (accès, logistique, etc.)
- Politiques
- Environnementaux, culturels, ethnologiques, etc.



The 'Pachamama' Ceremony

ESO Press Photo 13b/07 (14 March 2007)

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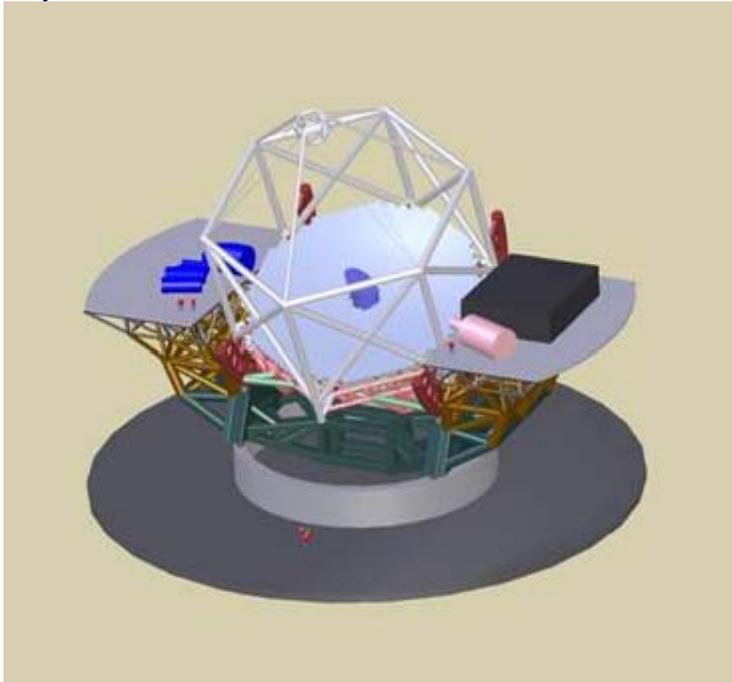




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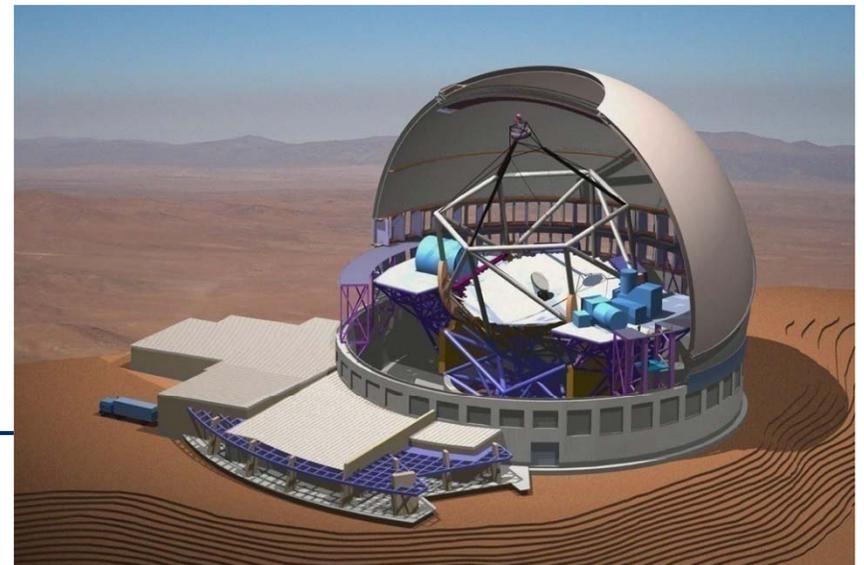
TMT



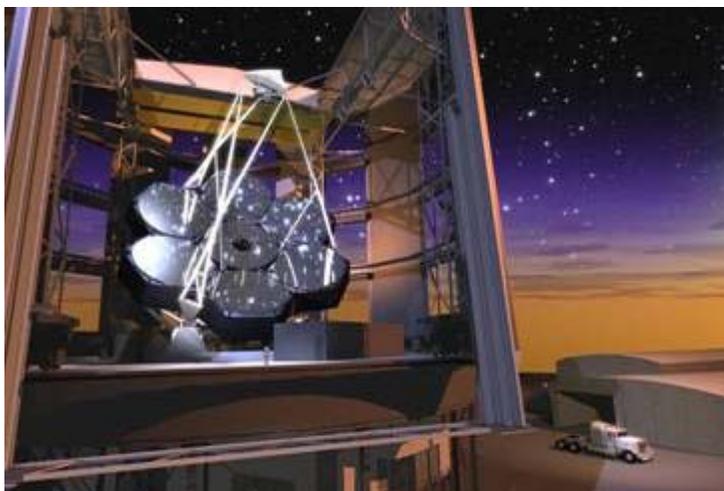
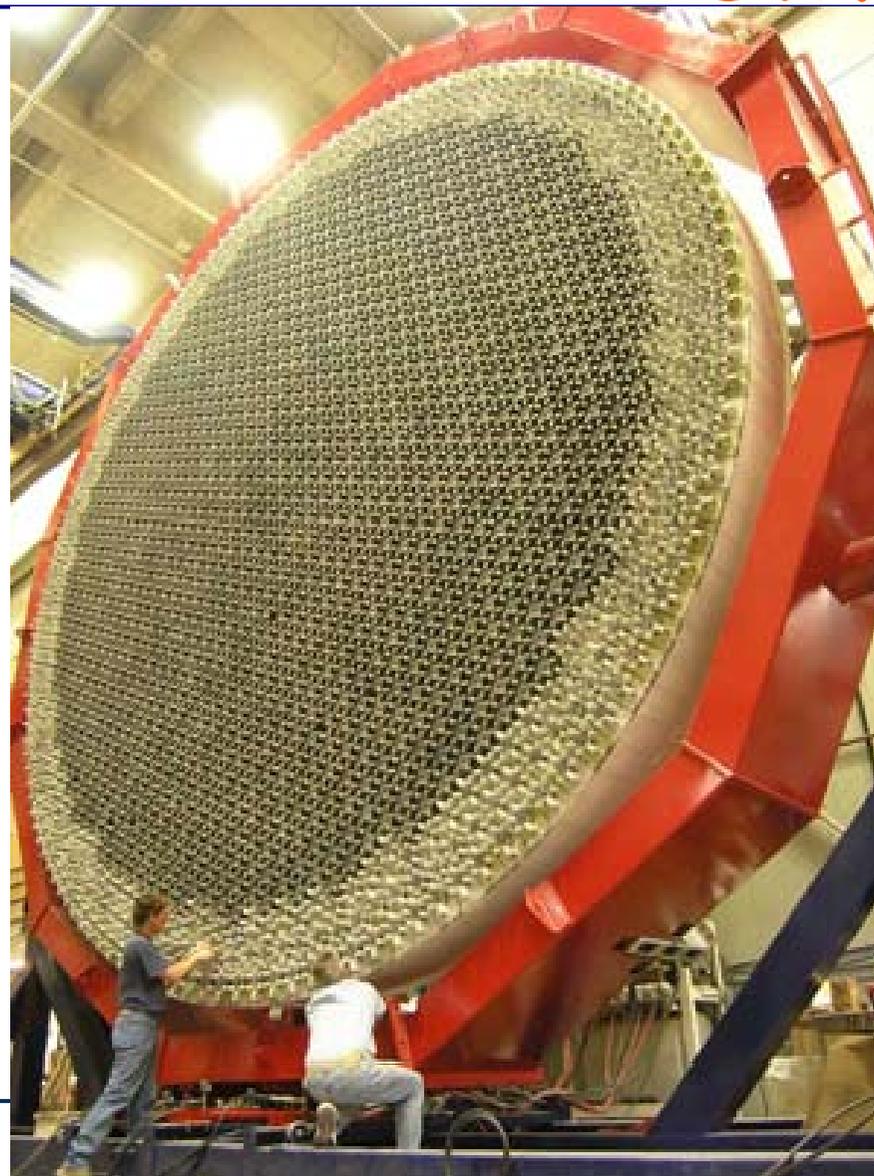
- Caltech + Univ. Californie + Canada
 - Japon (?)
- 30 mètres de diamètre
- Phase B
- 2015
- ~ 600 - 800 M\$
 - 200 M\$ + 100 M\$ acquis
 - 2 sites pre-sélectionnés (Hawaii, Chili)



CEA-SPP



GMT

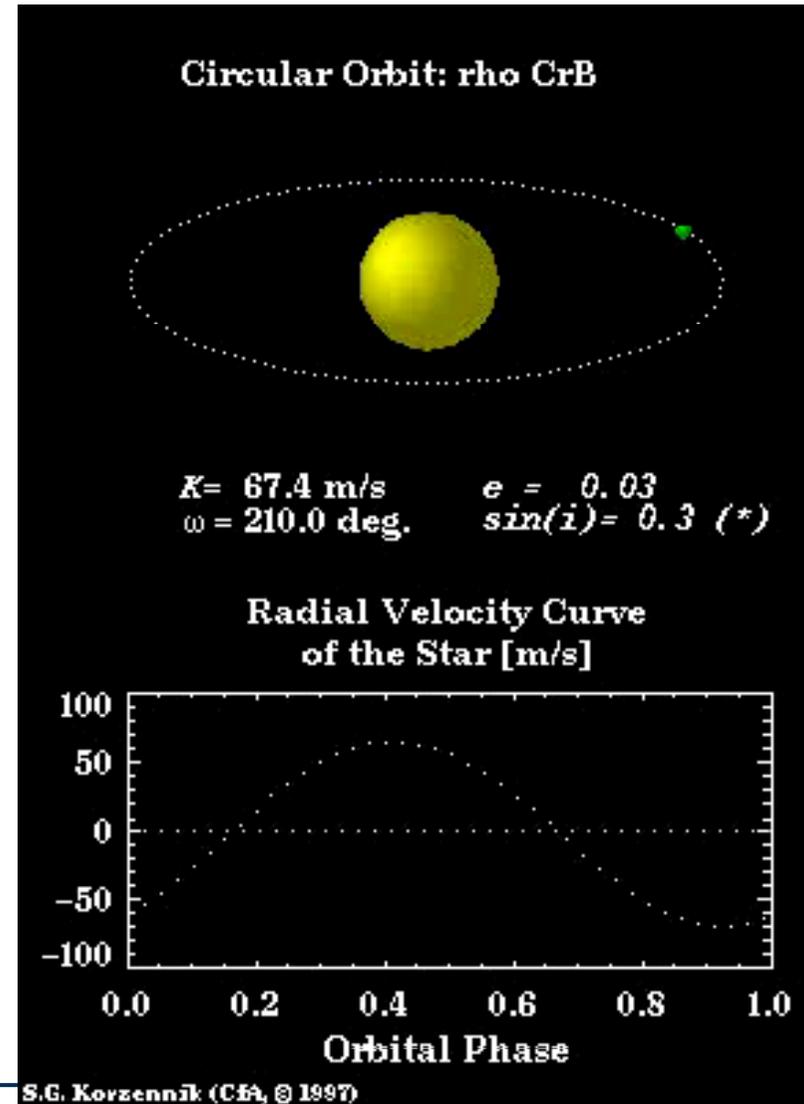


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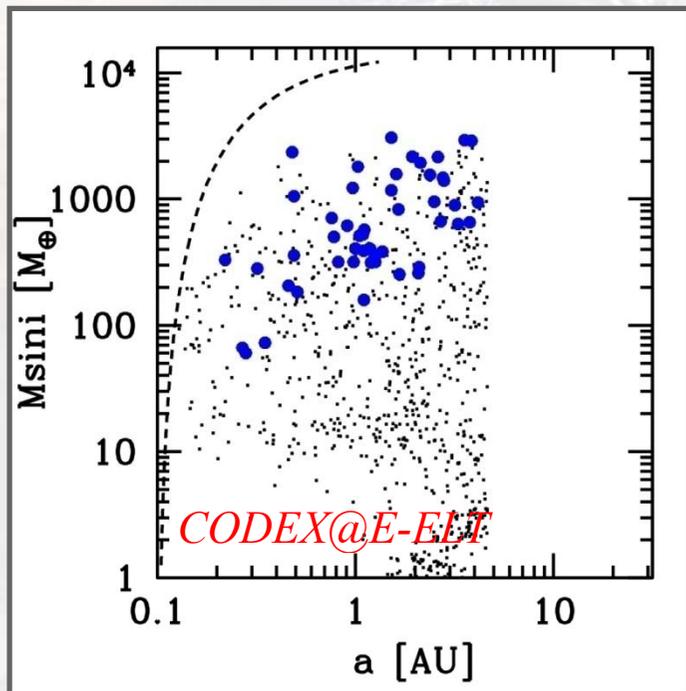
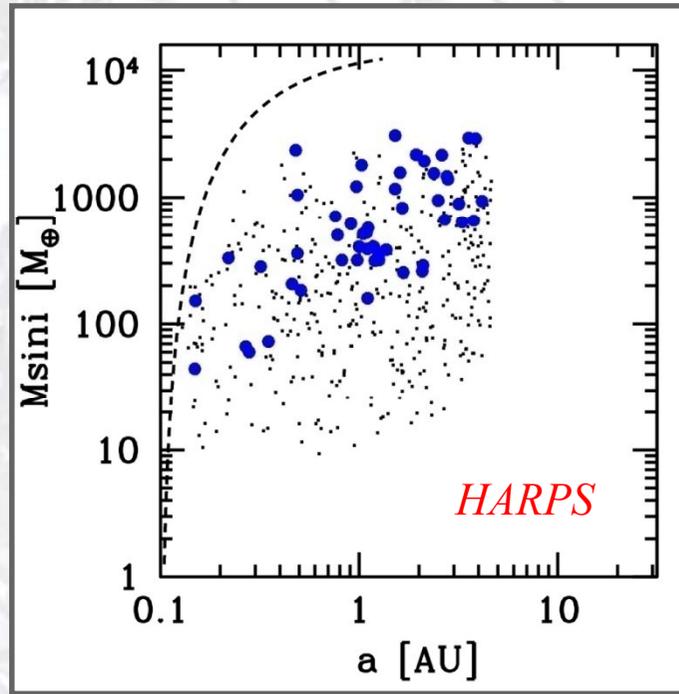
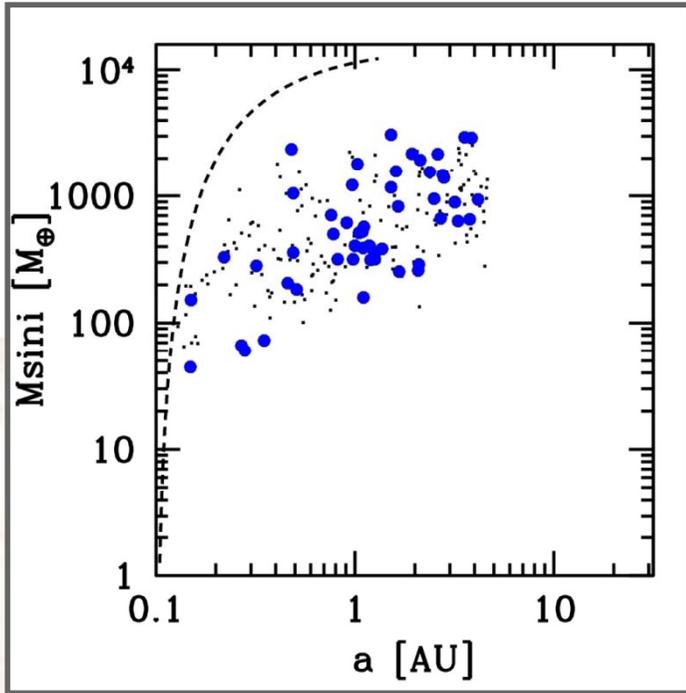
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Les exoplanètes

- Méthodes de détection des planètes extra-solaires
 - Les vitesses radiales
 - La détection directe
 - Les transits - Espace (Corot)
 - Astrometrie
 - "Micro-lensing"



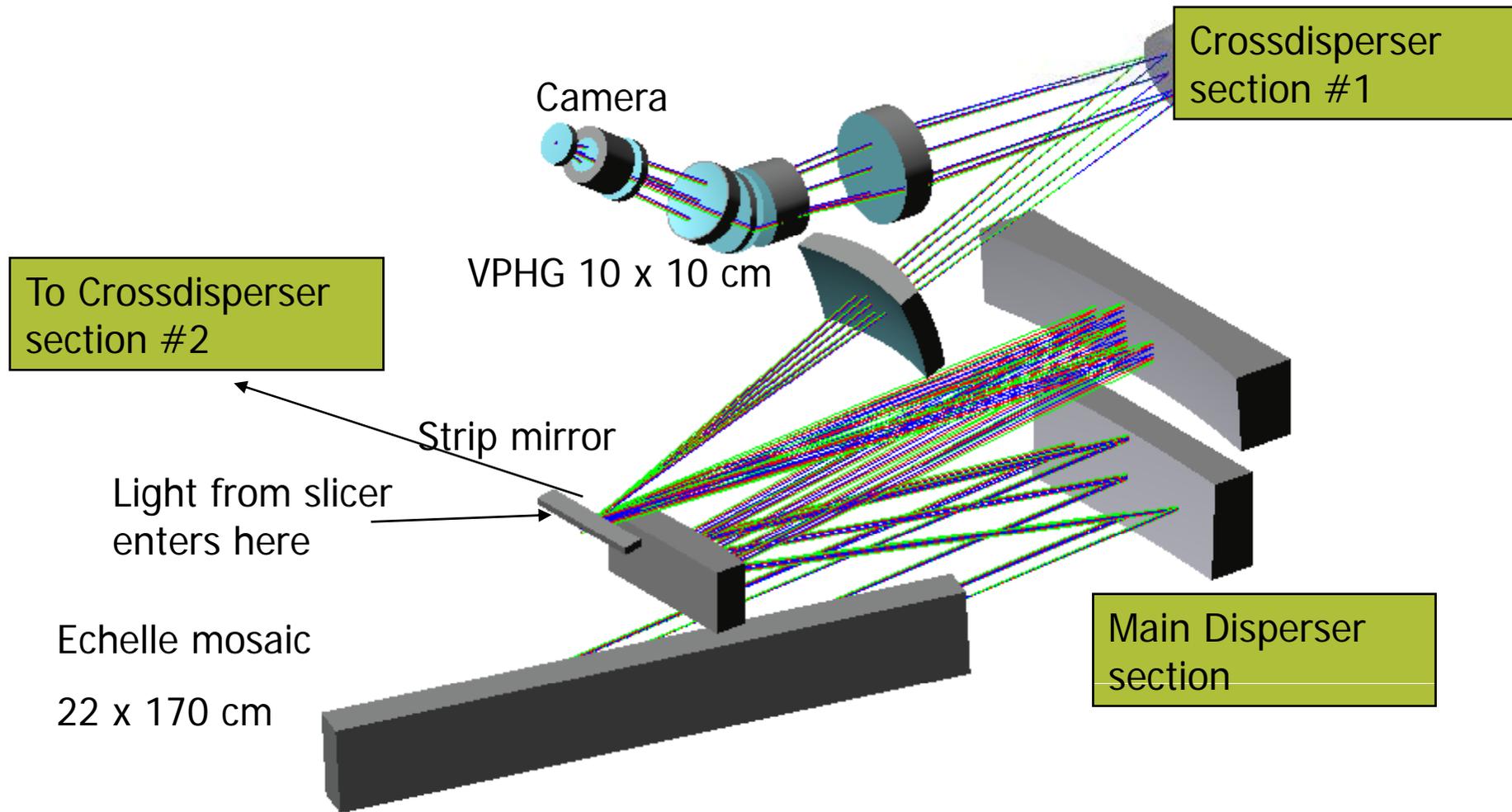
Vitesse radiales: précision



- Précision 1 m/s:
 - essentiellement des Neptunes
- Précision 0.1 m/s
 - quasiment toutes les planètes

Courtesy W. Benz

CODEX @ E-ELT





CODEX laboratory floor plan

Underground hall 20 x 30 m; height 8 m

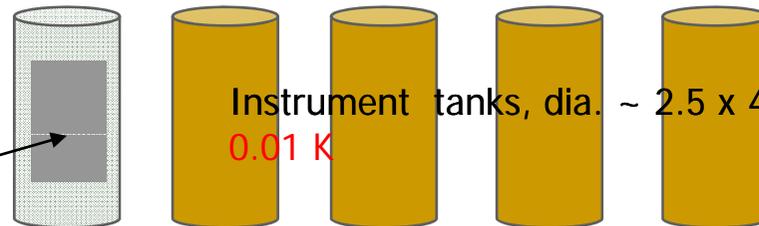
1 K

Instrument room 10 x 20 m; height 5 m

0.1 K

Optical bench and detector

0.001 K



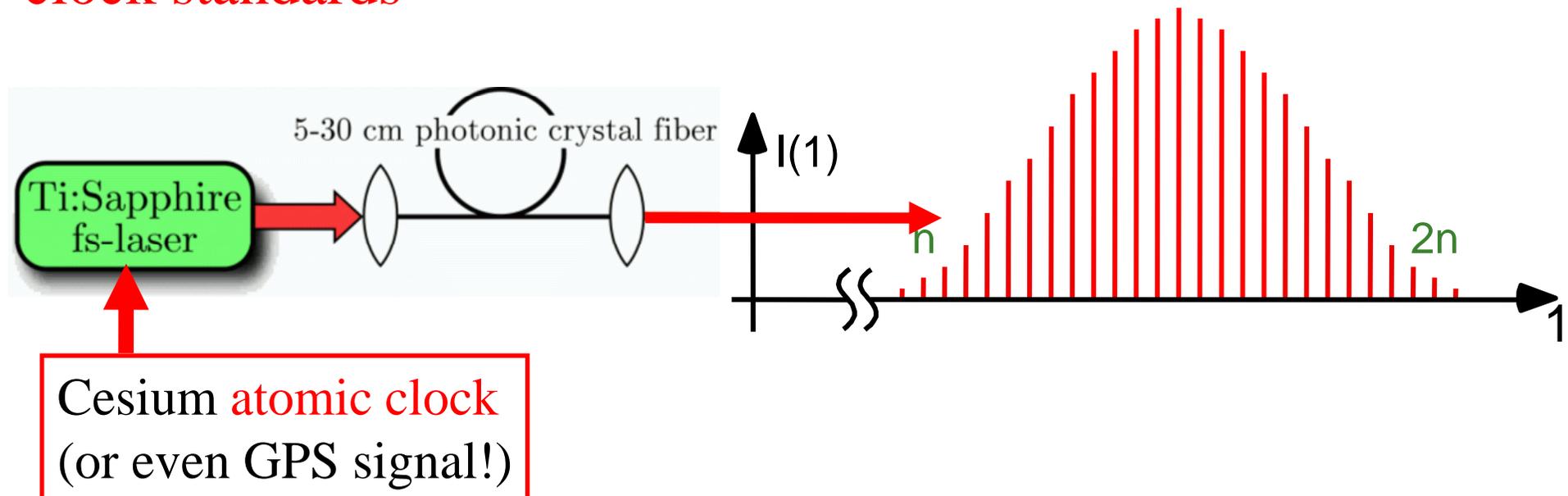
Instrument tanks, dia. ~ 2.5 x 4 m,
0.01 K

Control room and aux. equipment (laser)

1 K

Calibration Unit: Frequency COMB

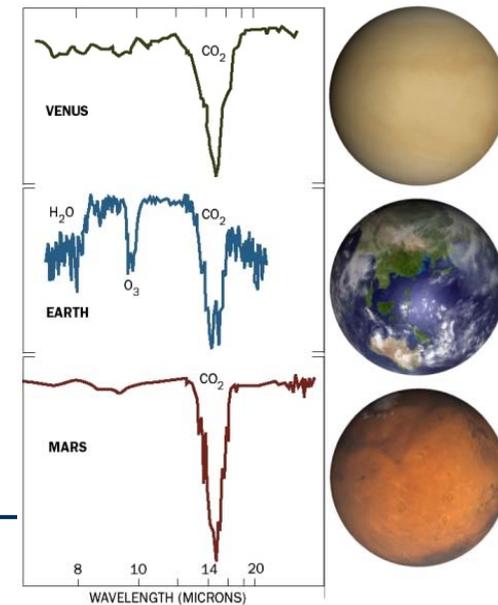
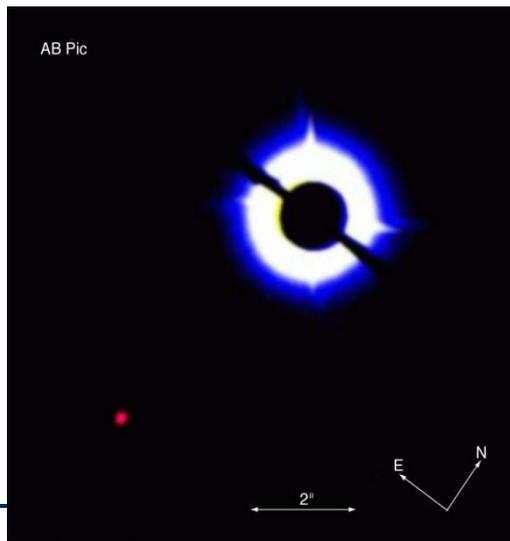
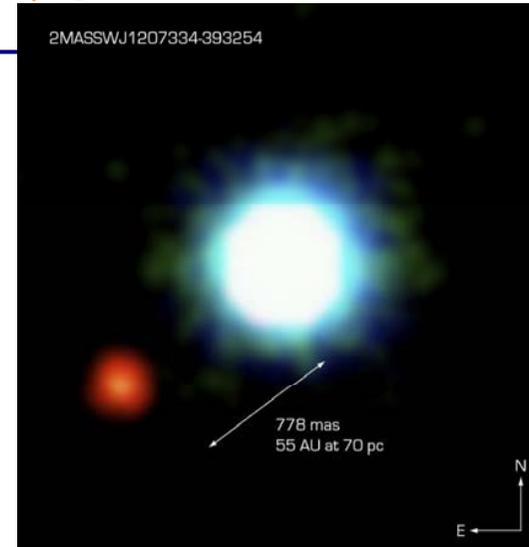
❖ Metrology labs recently revolutionized by introduction of femtosecond-pulsed, self-referenced lasers driven by atomic clock standards



❖ Result is a **reproducible, stable** “comb” of **evenly spaced** lines whose **frequencies are known *a priori*** to better than **1 in 10^{15}**

Exoplanètes: détection directe

- ❑ Télescopes 8-m: planètes plusieurs fois la masse de Jupiter
- ❑ ELT permettra de faire des images et des spectres d'étoiles géantes gazeuses, voire d'étoiles rocheuses s'approchant d'un type terrestre...
- ❑ Nécessite une correction très fine des perturbations induites par l'atmosphère par optique adaptative



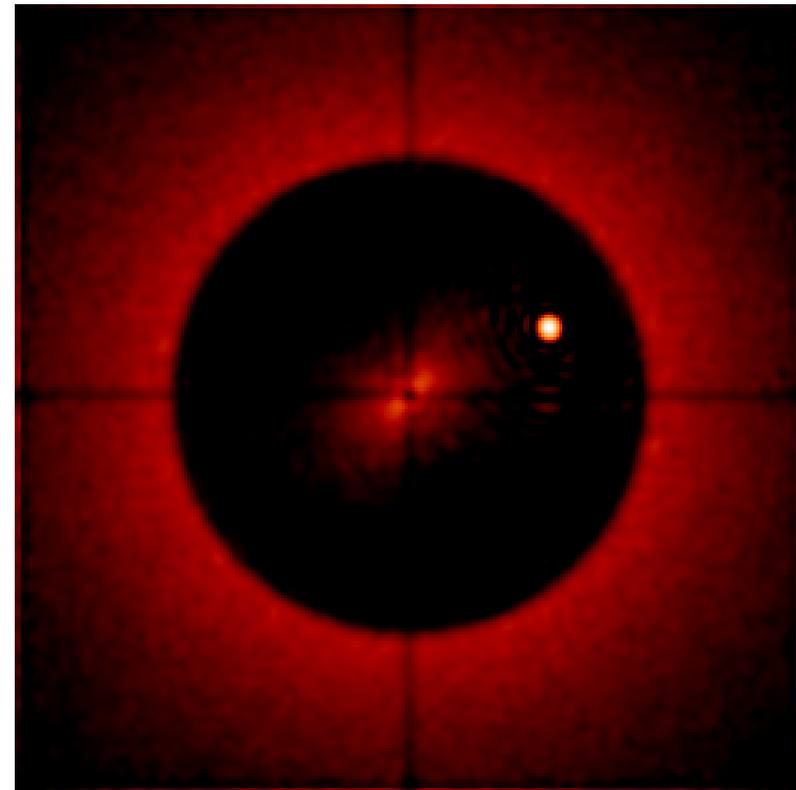
June 8, 2009

CEA-SPP

35

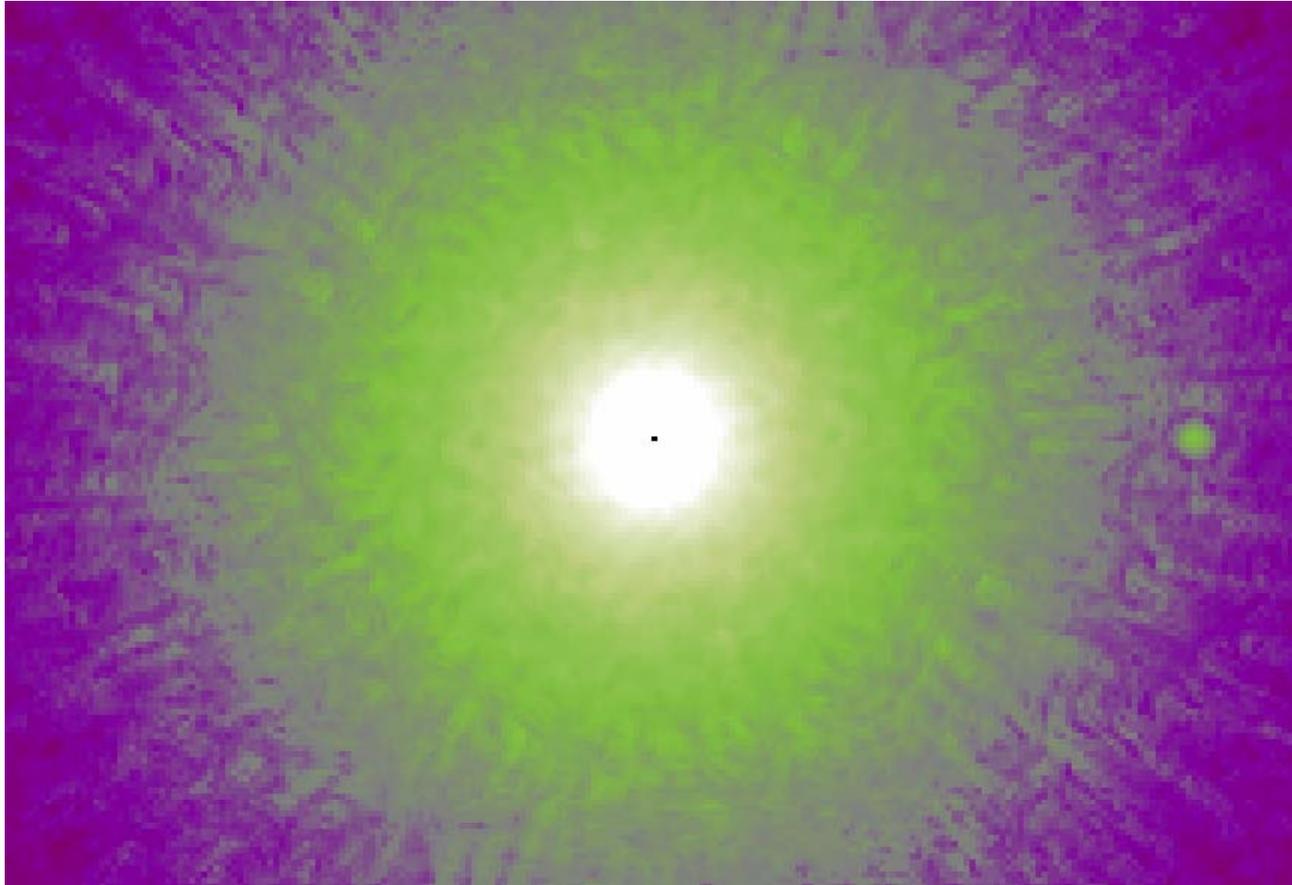
Exoplanètes: détection directe

- ❑ L'optique adaptative ne suffit pas. Il faut ensuite supprimer l'image de l'étoile (coronagraphie) et chasser les effets résiduels

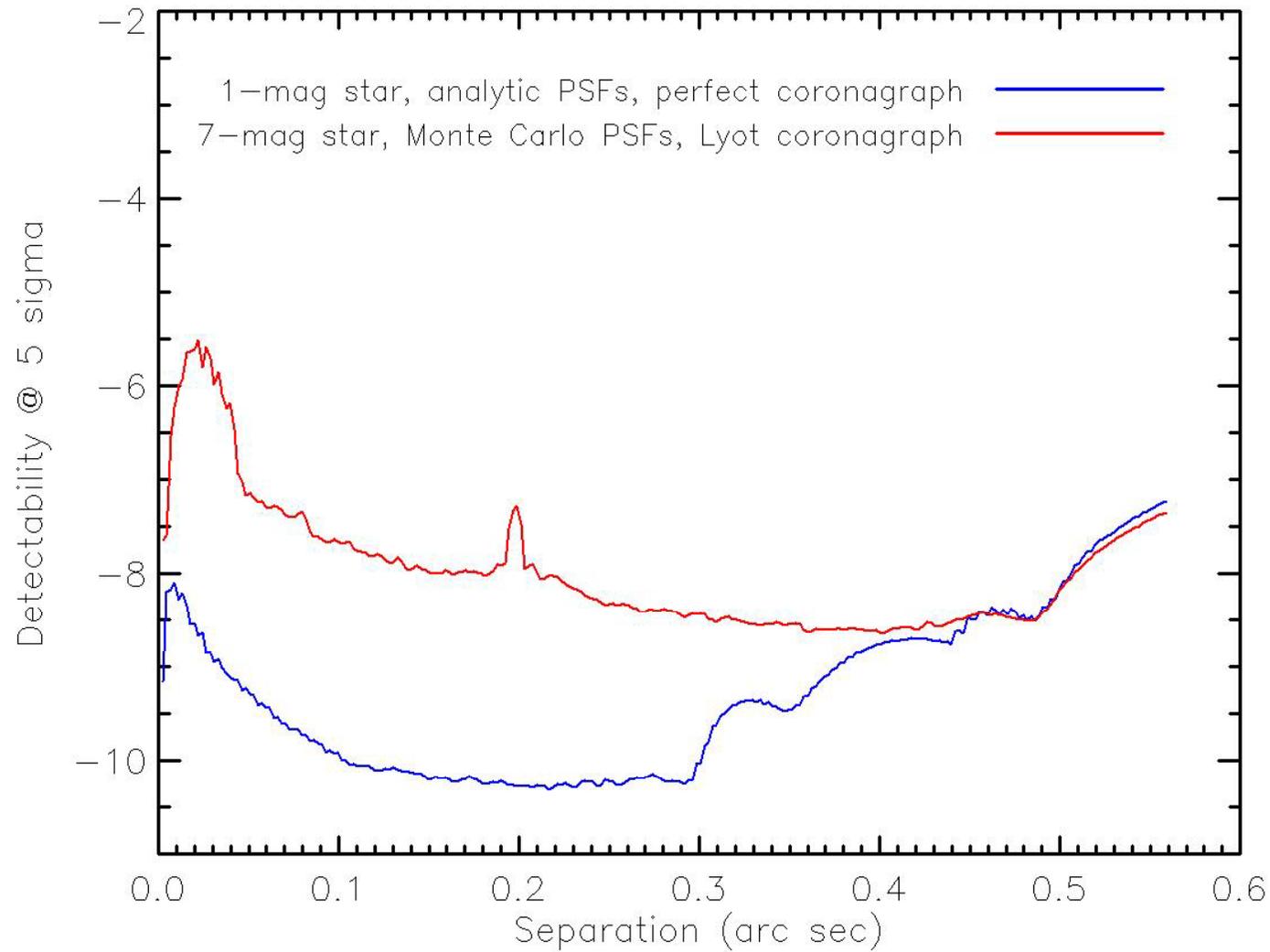


Courtesy J. L. Beuzit

Exoplanètes: détection directe



Exoplanètes: détection directe



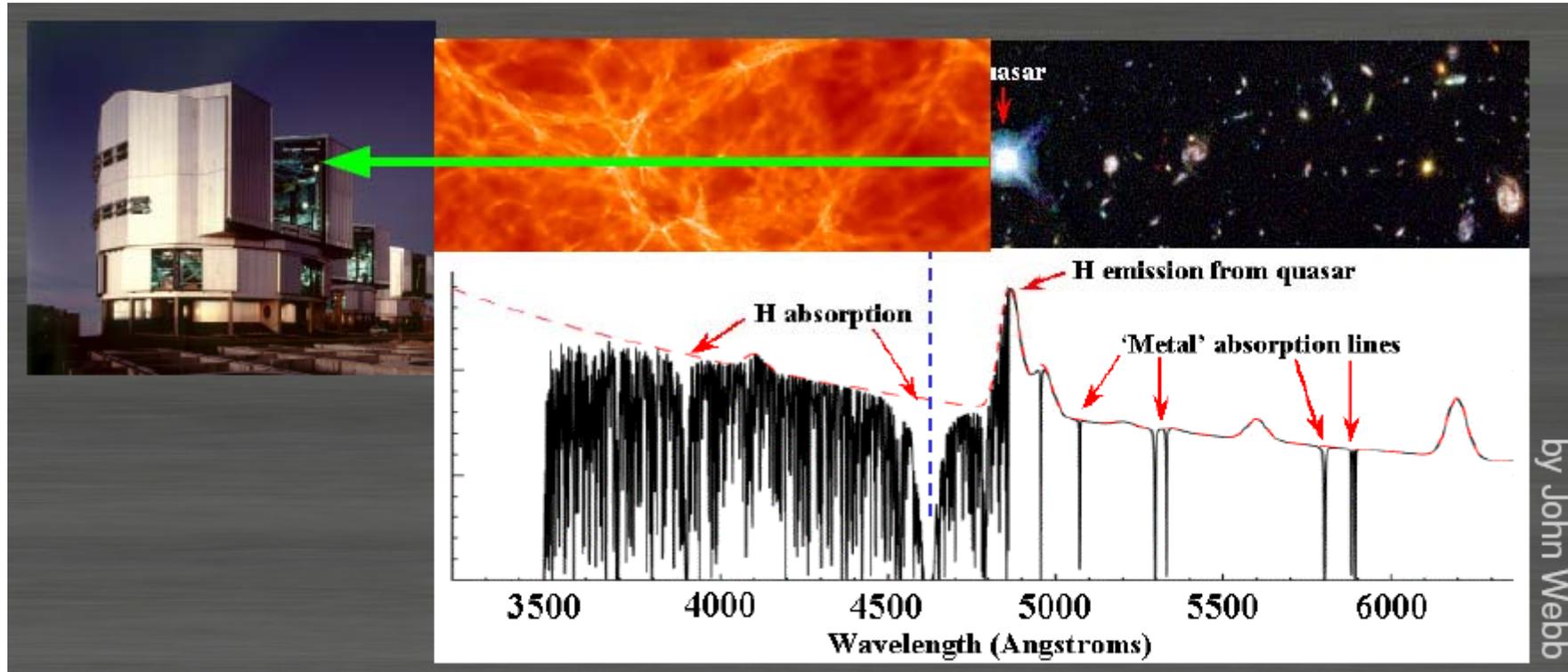
Plan de l'exposé

- Les projets d'ELT
 - L'E-ELT
 - Les projets américains
- Exemples de programmes scientifiques
 - Exoplanètes
 - Expansion de l'Univers
 - Evolution des galaxies
- Conclusions

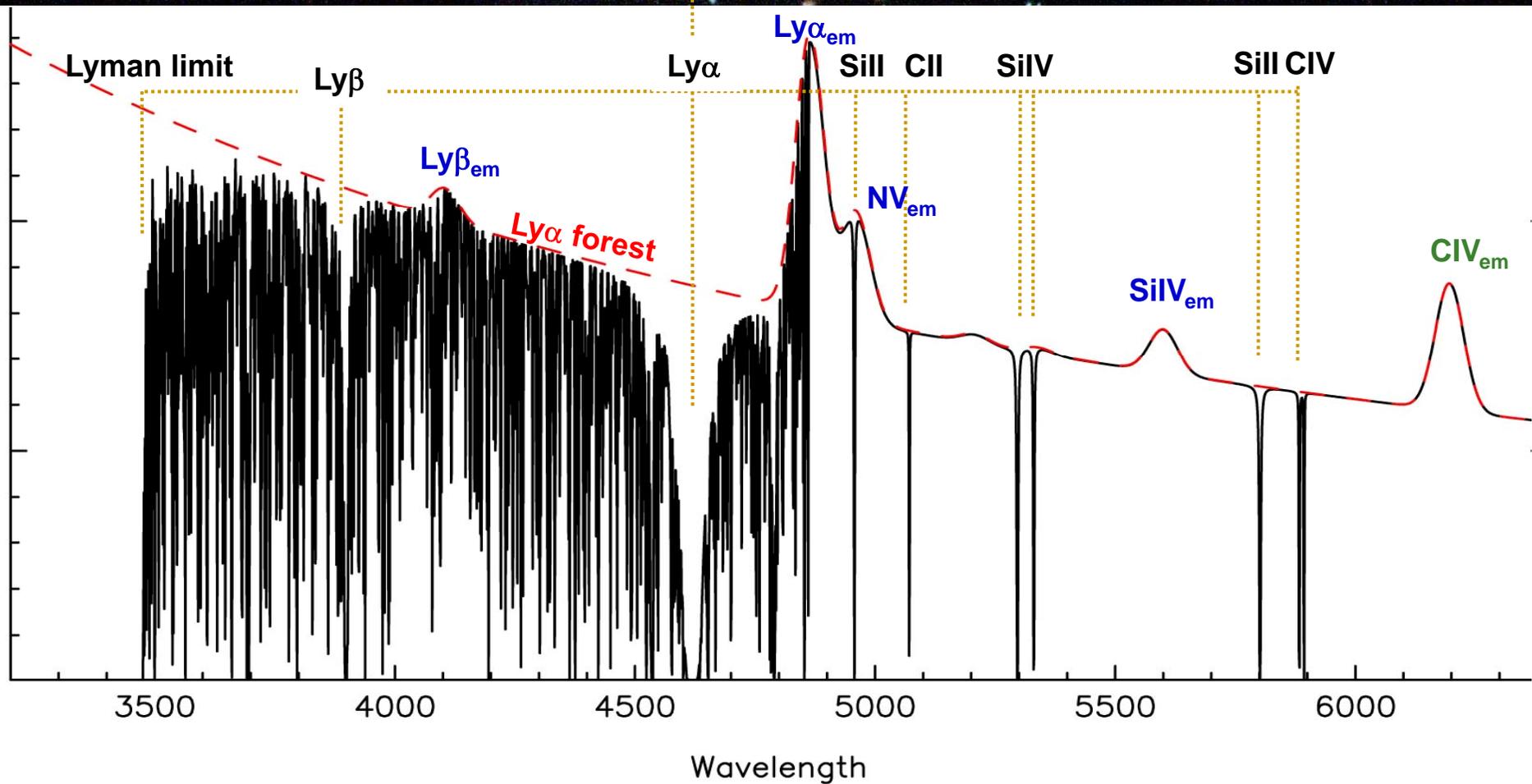
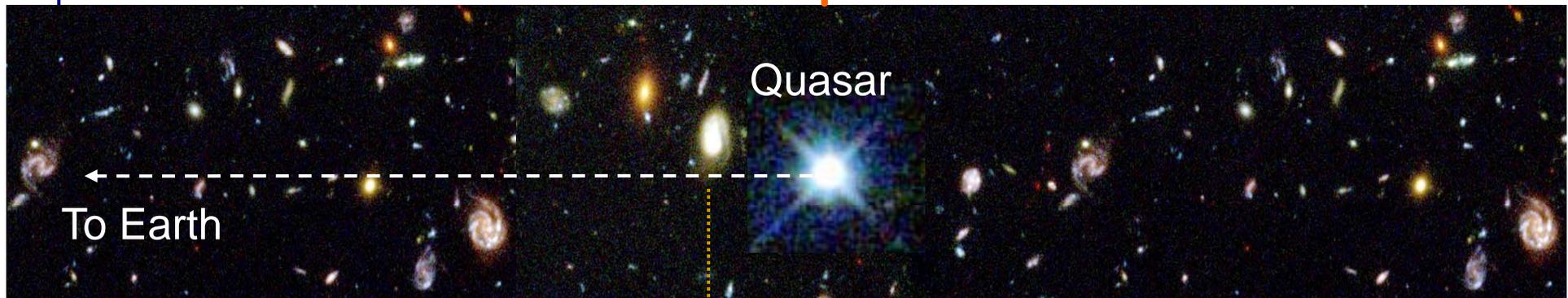
Mesure directe de l'expansion de l'Univers

- L'Univers est en expansion, et cette expansion s'accélère sous l'effet de l'énergie noire
- Mais mesures indirectes
 - Rayonnement cosmologique
 - Supernovae
- Une mesure directe consisterait à mesurer la vitesse d'expansion à deux époques différentes

Mesure directe de l'expansion de l'Univers



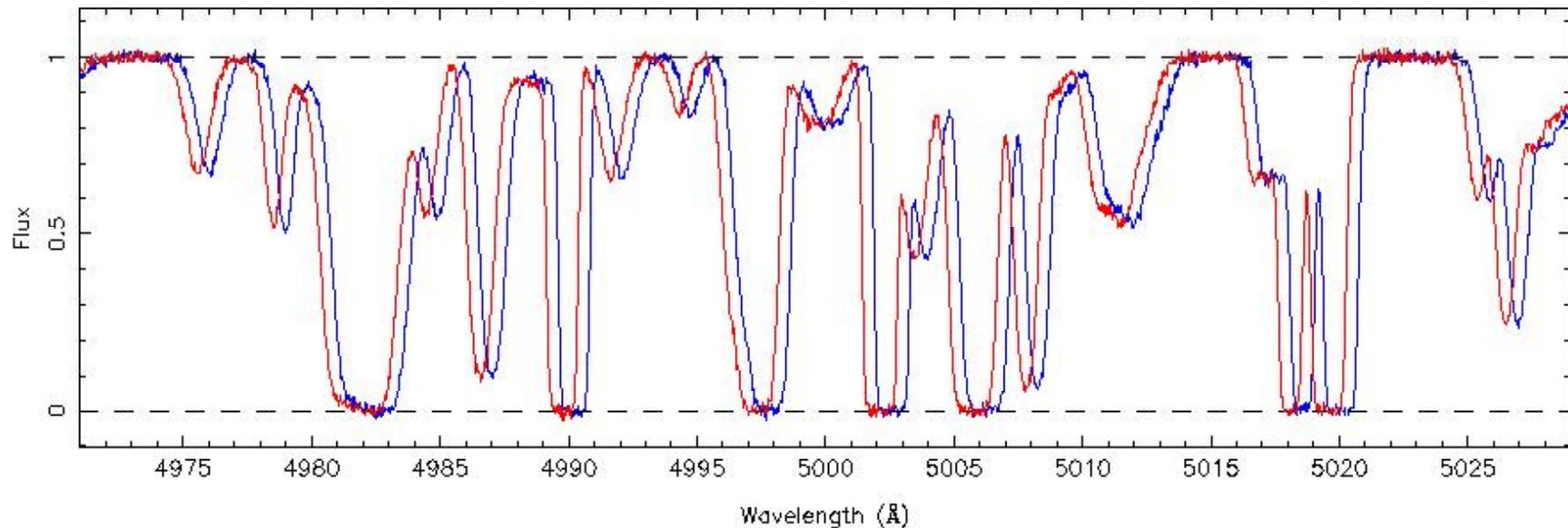
Mesure directe de l'expansion de l'Univers



Mesure directe de l'accélération de l'Univers

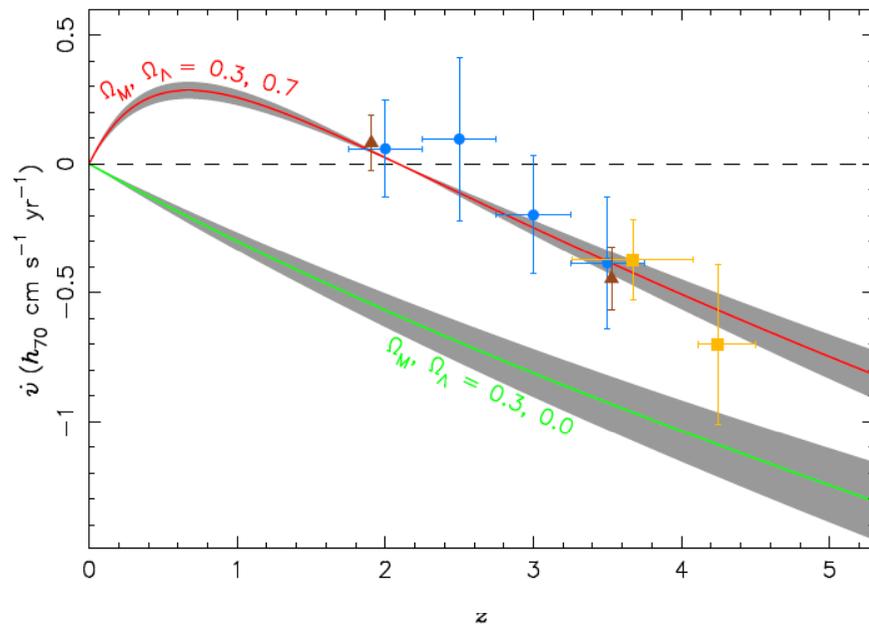
Un signal fort ...

Mais sur 10^7 ans !!!

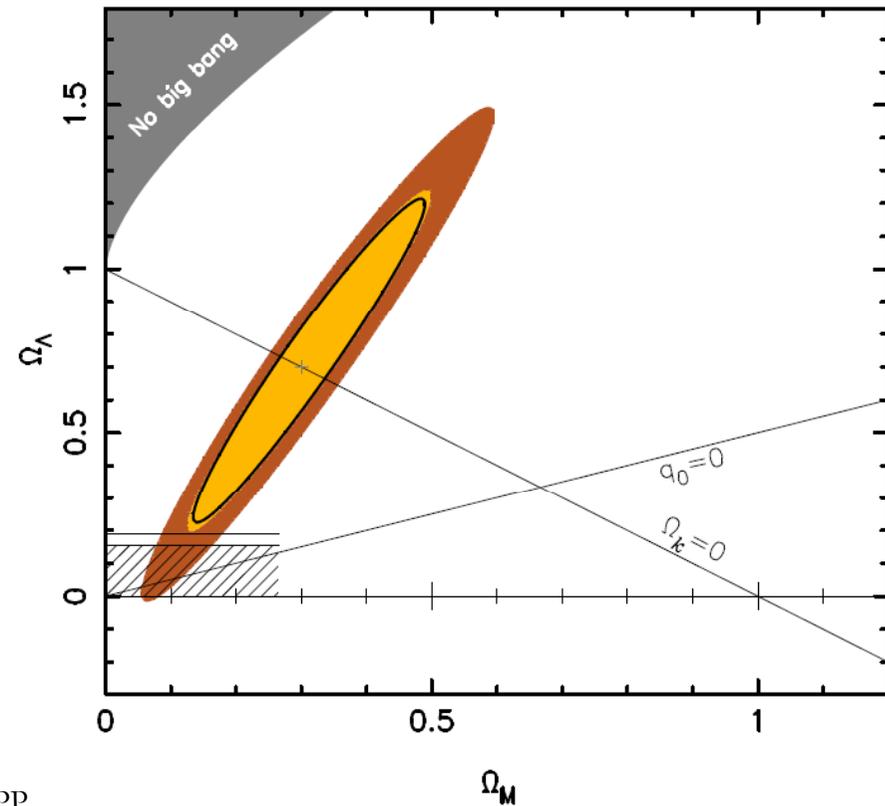


Effet mesurable avec un spectrographe haute résolution spectrale de ~ quelques cm/s de précision en 10-20 ans

Mesure directe de l'accélération de l'Univers

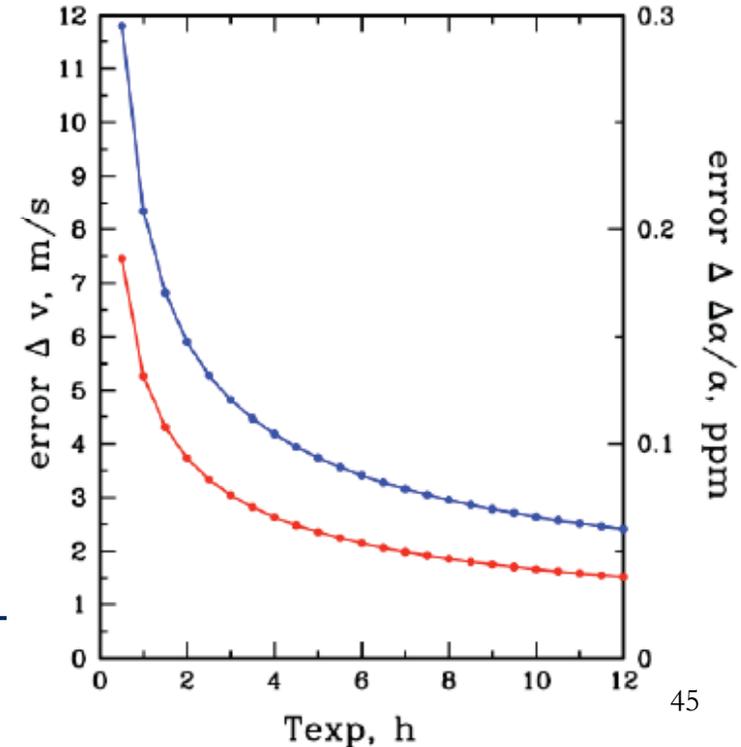
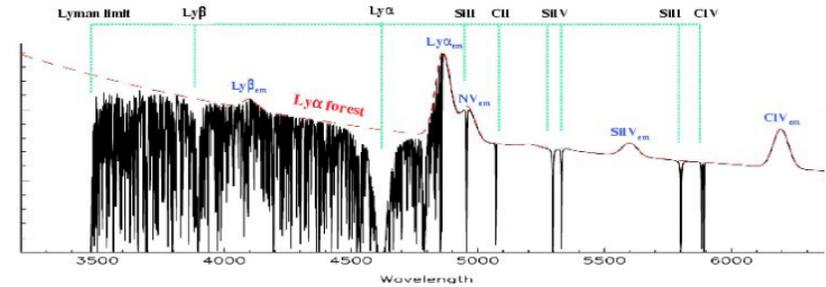
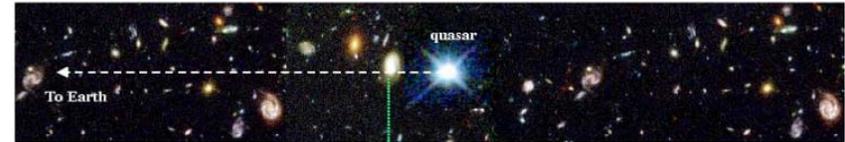


- Contraintes apportées au bout de 2000 heures d'observations d'un échantillon de quelques dizaines de quasars sur 20 ans.



Evolution / Stabilité des constantes (α , μ)

Transition		Scaling
Atomic	Gross Structure	Ry
	Fine Structure	$\alpha^2 Ry$
	Hyperfine Structure	$\alpha^2 (g_p \mu) Ry$
Molecular	Electronic Structure	Ry
	Vibrational Structure	$\mu^{1/2} Ry$ $\frac{\alpha^2 m_e c^2}{2}$
	Rotational Structure	μRy^2
Relativistic Corrections		α^2



$$R_y = \frac{\alpha^2 m_e c^2}{2} \quad \alpha = \frac{e^2}{\hbar c} \quad \mu = \frac{m_e}{m_p}$$

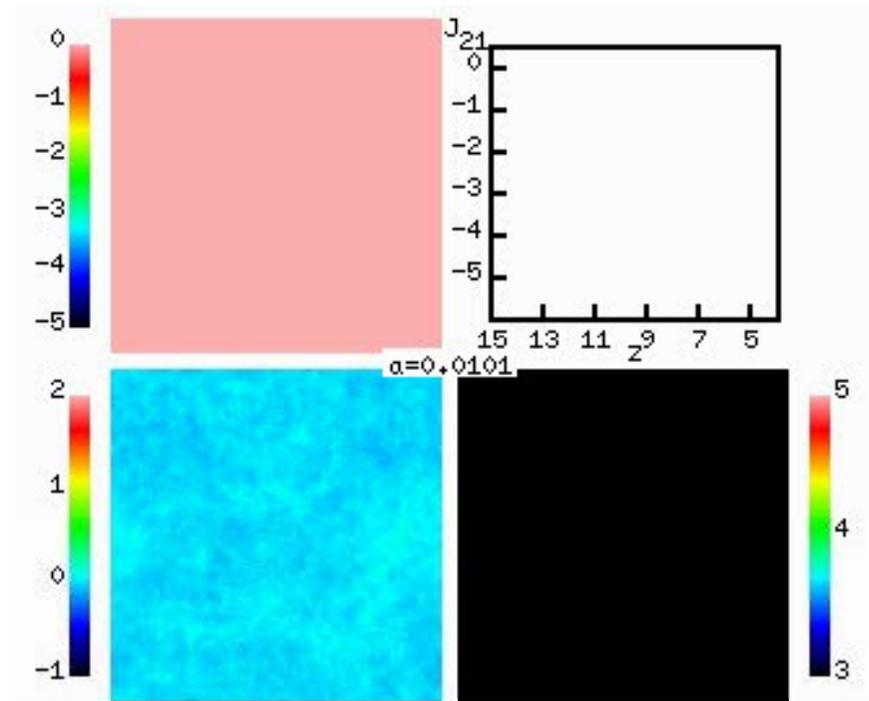
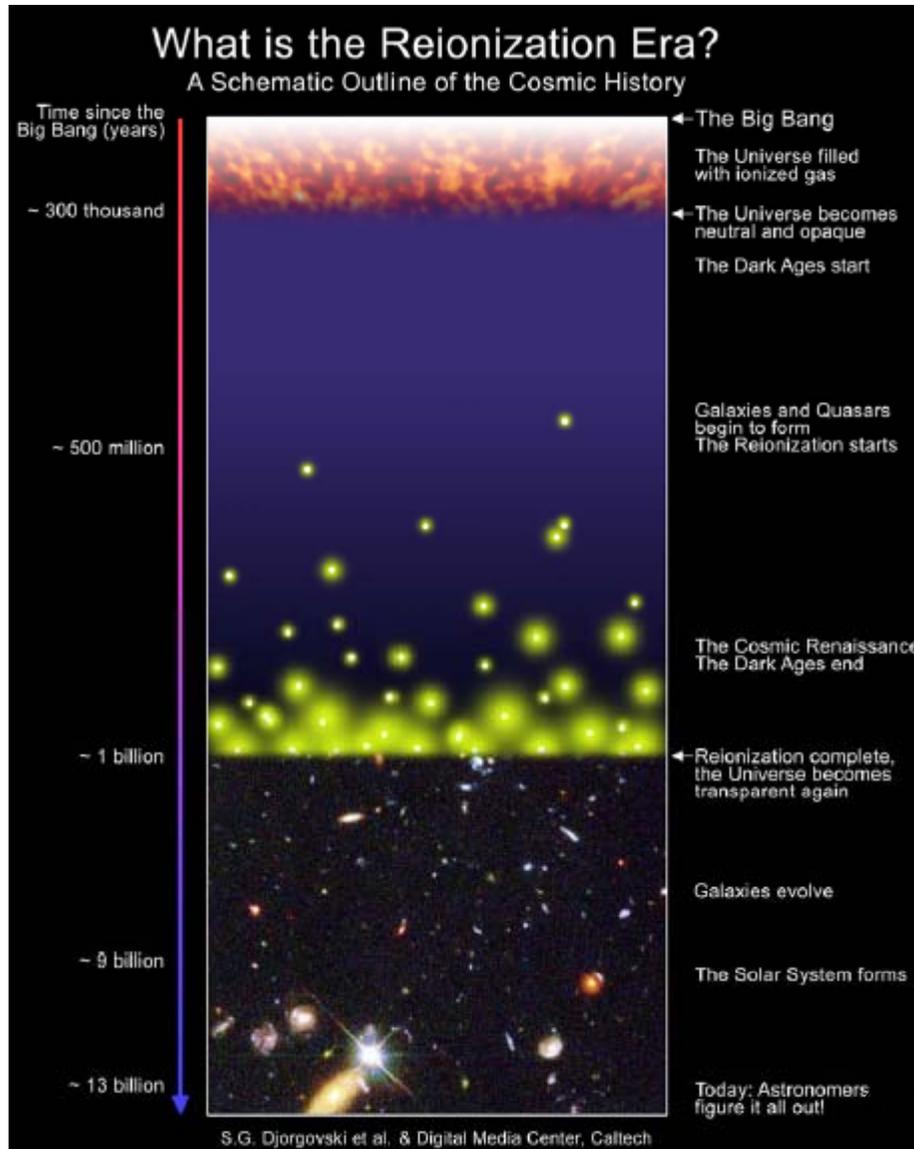
- $\sigma_v \sim 3 \text{ m s}^{-1}$ easy $\rightarrow \sigma_{\Delta\alpha/\alpha} \sim 0.1 \text{ ppm}$
- $\Rightarrow 0.05 \text{ ppm}$ should be within reach

Plan de l'exposé

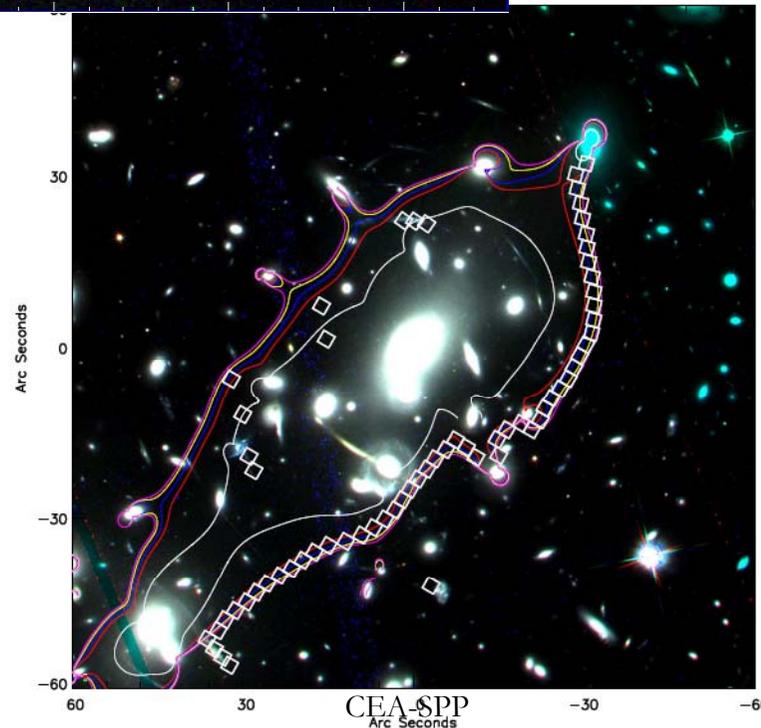
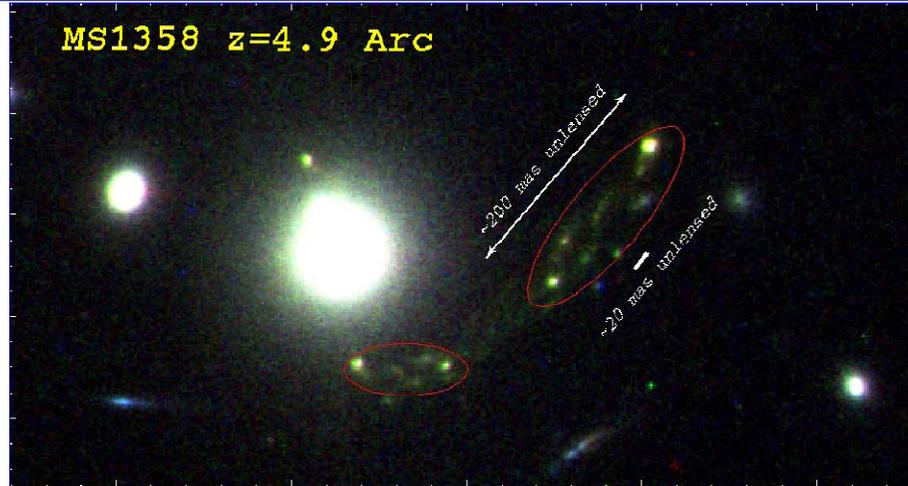
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Premières galaxies dans l'Univers

- Quelles sont les premières galaxies ?
- Quand et comment l'Univers a-t-il été "ré-ionisé" ?
- Comment les galaxies ont-elles évolué ?



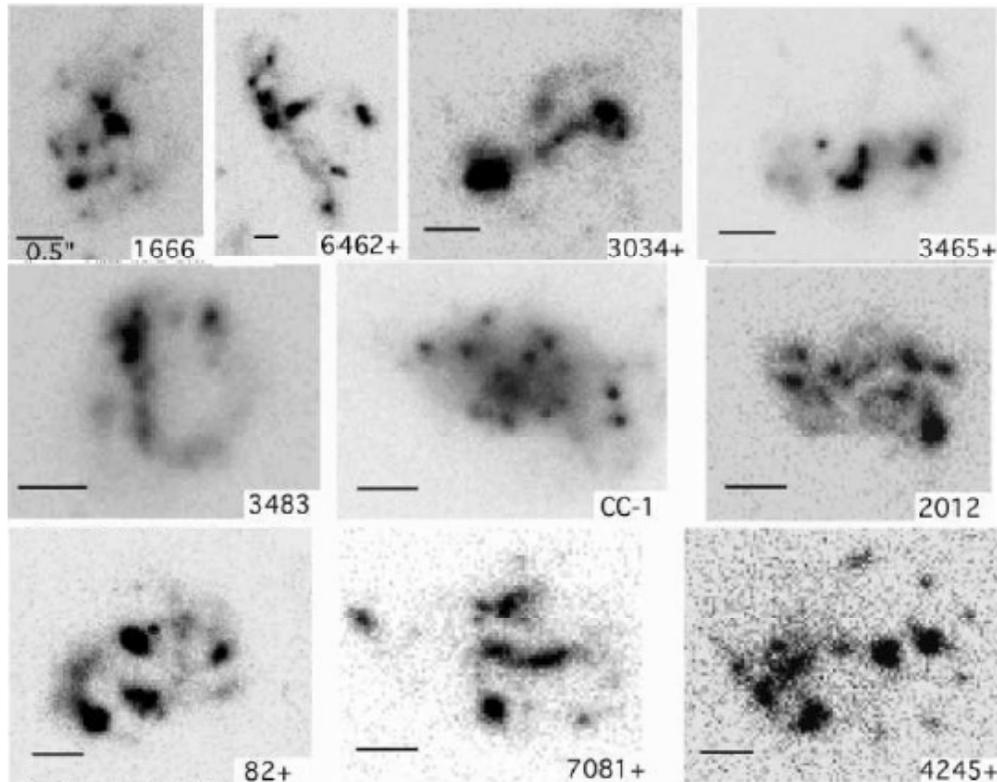
Utilisation de l'amplification gravitationnelle



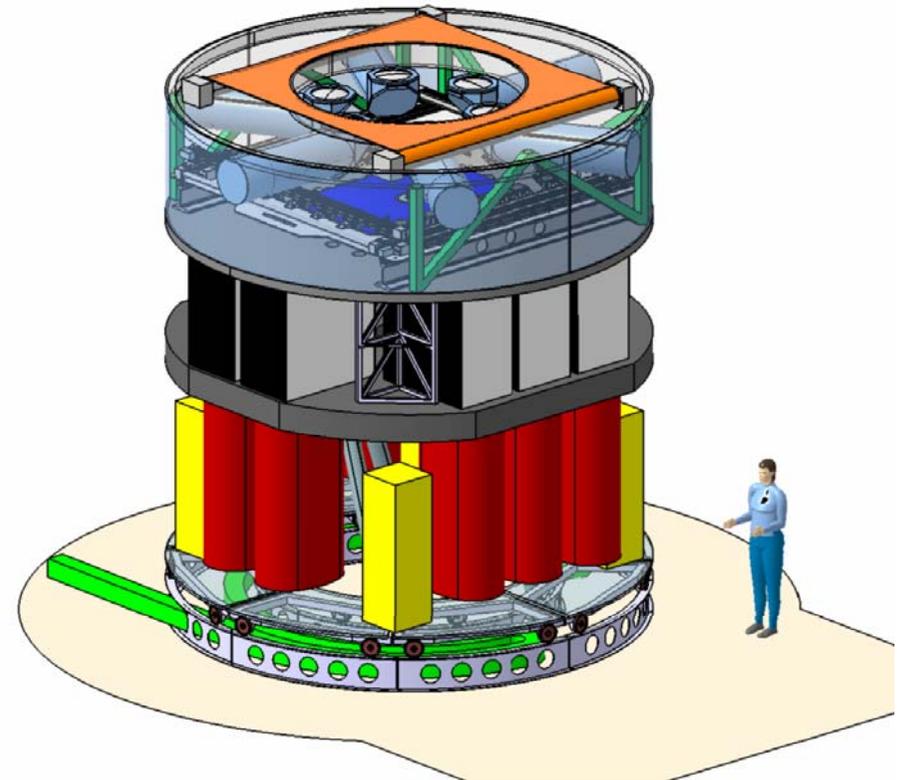
A2218
Lignes critiques
 $z=2, 5, 10$ & 20

Carrés montrent disposition possible des canaux d'un spectrographe multi-champ (multi-IFU)

Formation des galaxies à grand redshift



Elmegreen & Elmegreen, 2005



EAGLE
Multi-IFU (20)
IR proche
Assisté Optique Adaptative

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Conclusion

- E-ELT
 - Projet en phase B
 - Decision construction fin 2010
 - Cout ~ 1 G€ (capital)
 - Puis ~ 50 M € / an pour les opérations
 - Construction ~ 7 ans
 - Debut operations scientifiques avant 2020
 - Un ou deux autres projets 20-30 m US
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