Espiando o céu com enormes telescópios

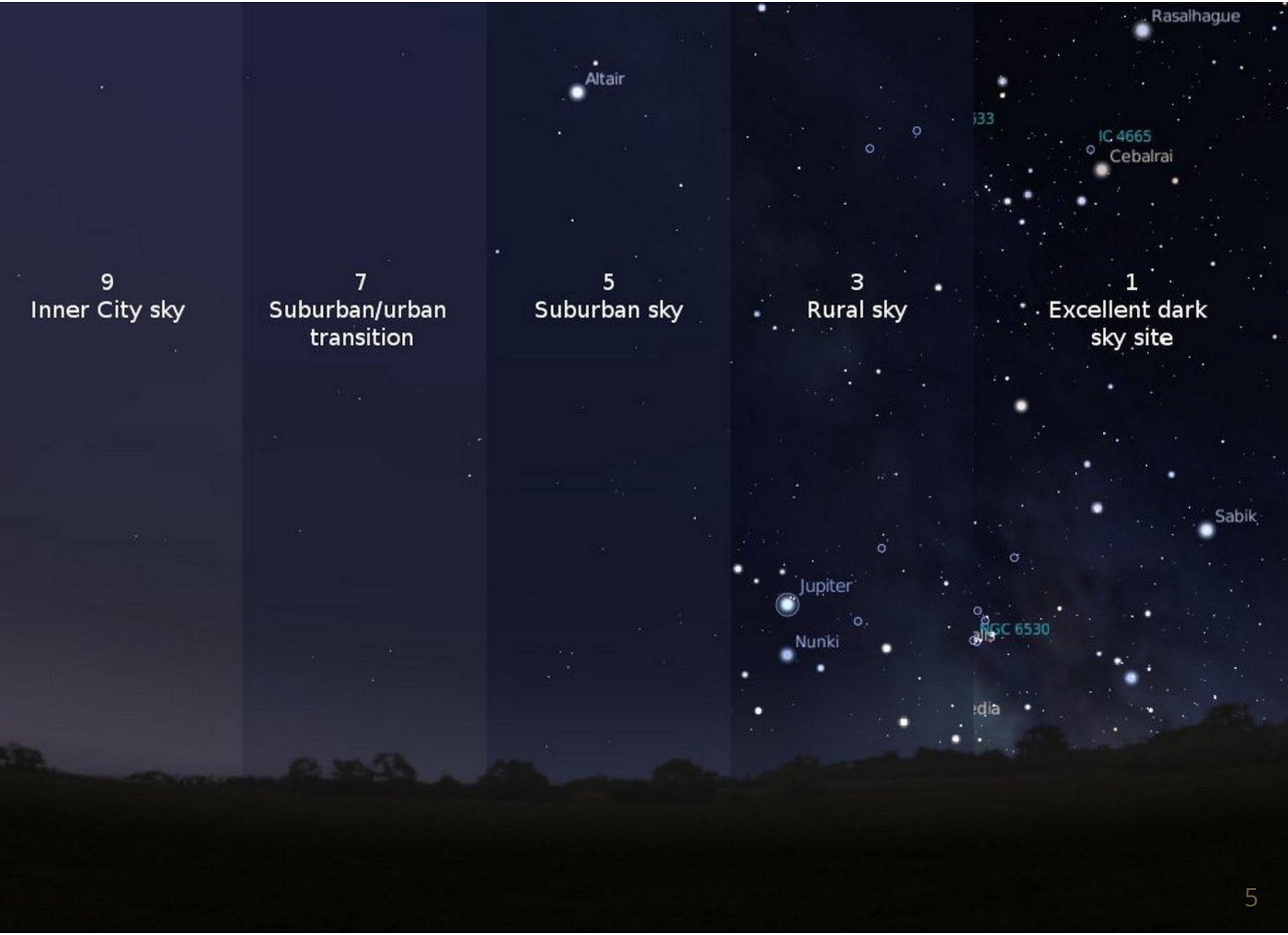
Daniel Moser
IAG, 20/abr/2017

Aviso legal

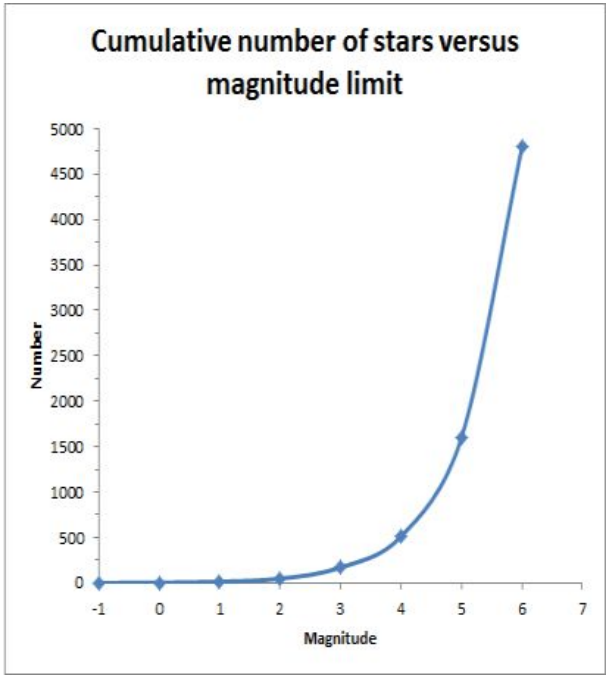
Subtítulo: “Como são as observações profissionais e o que esperar dos futuros telescópios gigantes”

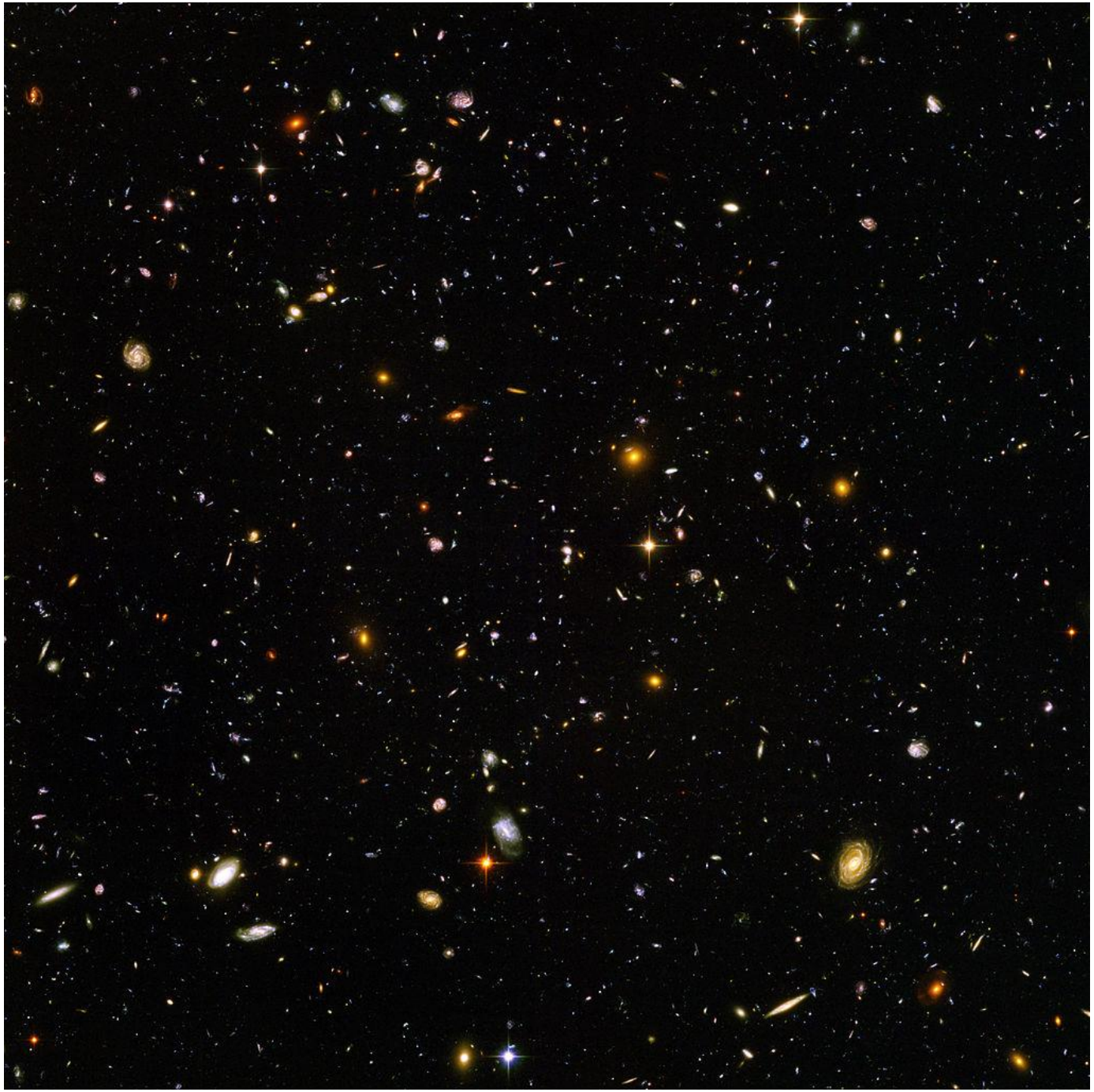
Desafio: combinar as visões de gerência e ciência dos observatórios em solo.

Por que grandes telescópios?


9
Inner City sky
7
Suburban/urban transition
5
Suburban sky
3
Rural sky
1
Excellent dark sky site
Rasalhague
Altair
IC 4665
Cebalrai
Sabik
Jupiter
Nunki
NGC 6530

Magnitude	Range	Number of Stars per Range	Cumulative Stars	% Increase in Stars Seen
-1	-1.50 to -0.51	2	2	
0	-0.50 to +0.49	6	8	400%
1	+0.50 to +1.49	14	22	275%
2	+1.50 to +2.49	71	93	423%
3	+2.50 to +3.49	190	283	304%
4	+3.50 to +4.49	610	893	316%
5	+4.50 to +5.49	1,929	2,822	316%
6	+5.50 to +6.49	5,946	8,768	311%
7	+6.50 to +7.49	17,765	26,533	303%
8	+7.50 to +8.49	51,094	77,627	293%
9	+8.50 to +9.49	140,062	217,689	280%
10	+9.50 to +10.49	409,194	626,883	288%
11	+10.50 to +11.49	1,196,690	1,823,573	291%
12	+11.50 to +12.49	3,481,113	5,304,685	291%
13	+12.50 to +13.49	10,126,390	15,431,076	291%
14	+13.50 to +14.49	29,457,184	44,888,260	291%
15	+14.50 to +15.49	85,689,537	130,577,797	291%
16	+15.50 to +16.49	249,266,759	379,844,556	291%
17	+16.50 to +17.49	725,105,060	1,104,949,615	291%
18	+17.50 to +18.49	2,109,295,881	3,214,245,496	291%
19	+18.50 to +19.49	6,135,840,666	9,350,086,162	291%
20	+19.50 to +20.49	17,848,866,544	27,198,952,706	291%

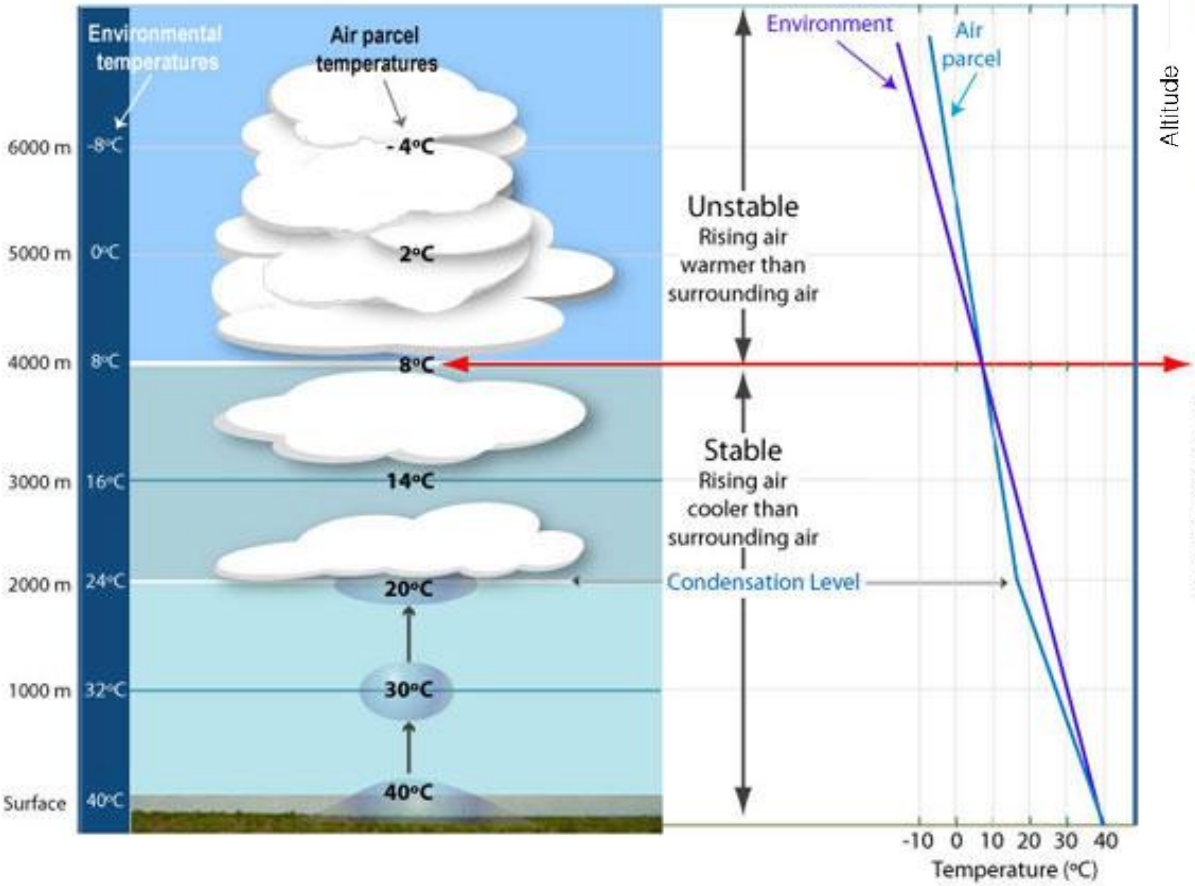


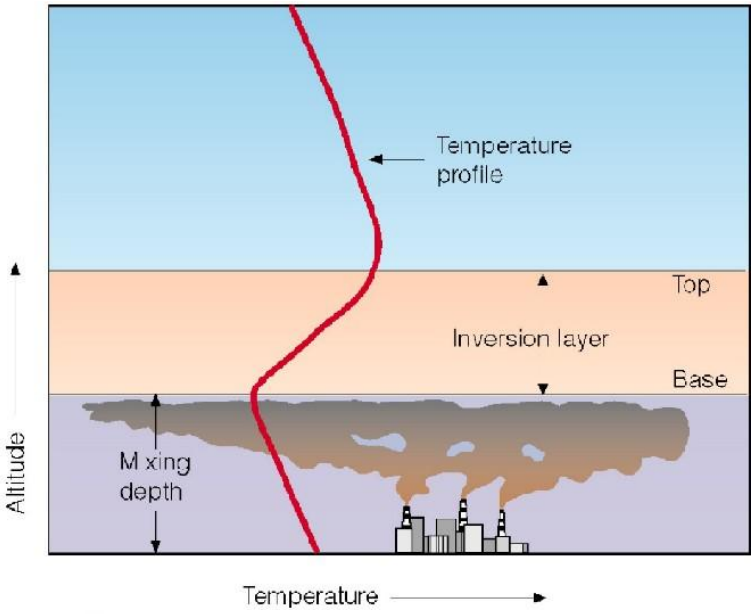


Telescópios: Onde ficam?

Telescópios: Onde ficam?

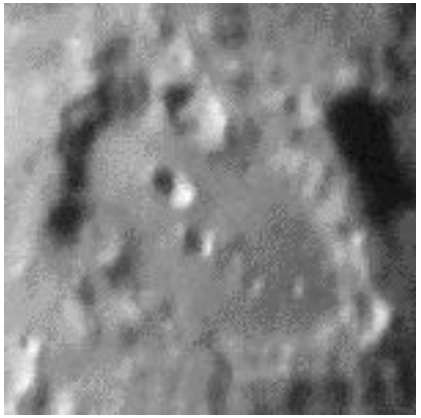
A camada de inversão

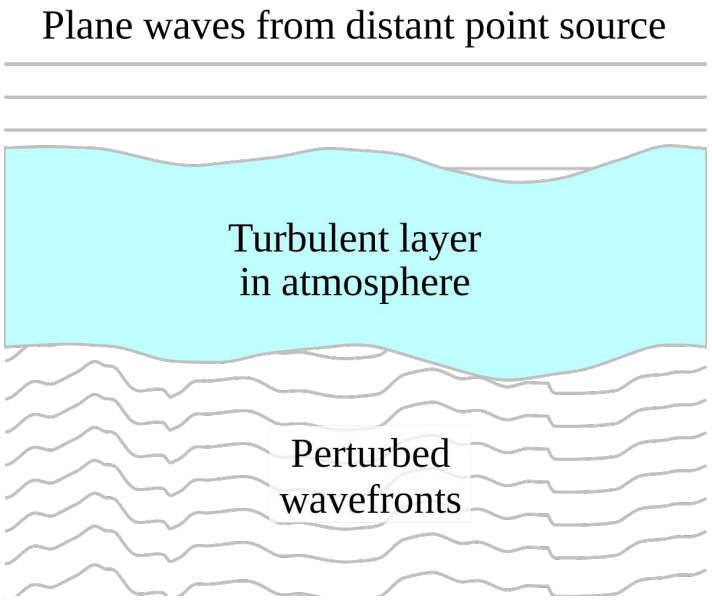


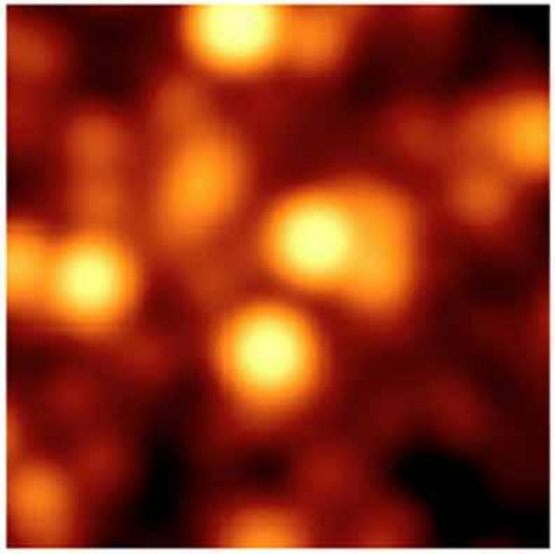


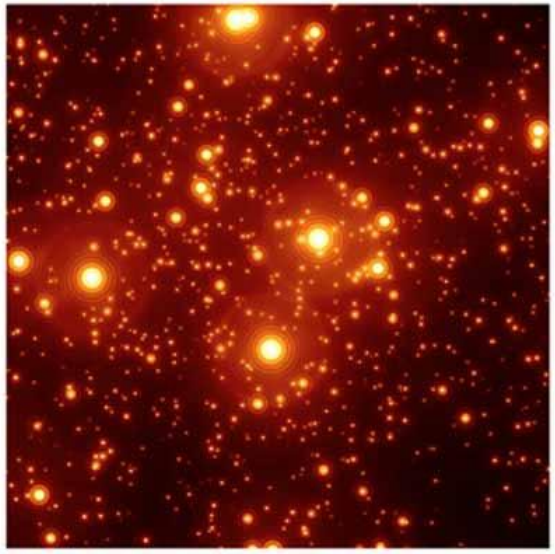
When the temperature of the rising air parcel exceeds the environmental temperature, the air becomes unstable and saturated, generating towering clouds and storms.

Atmosfera turbulenta

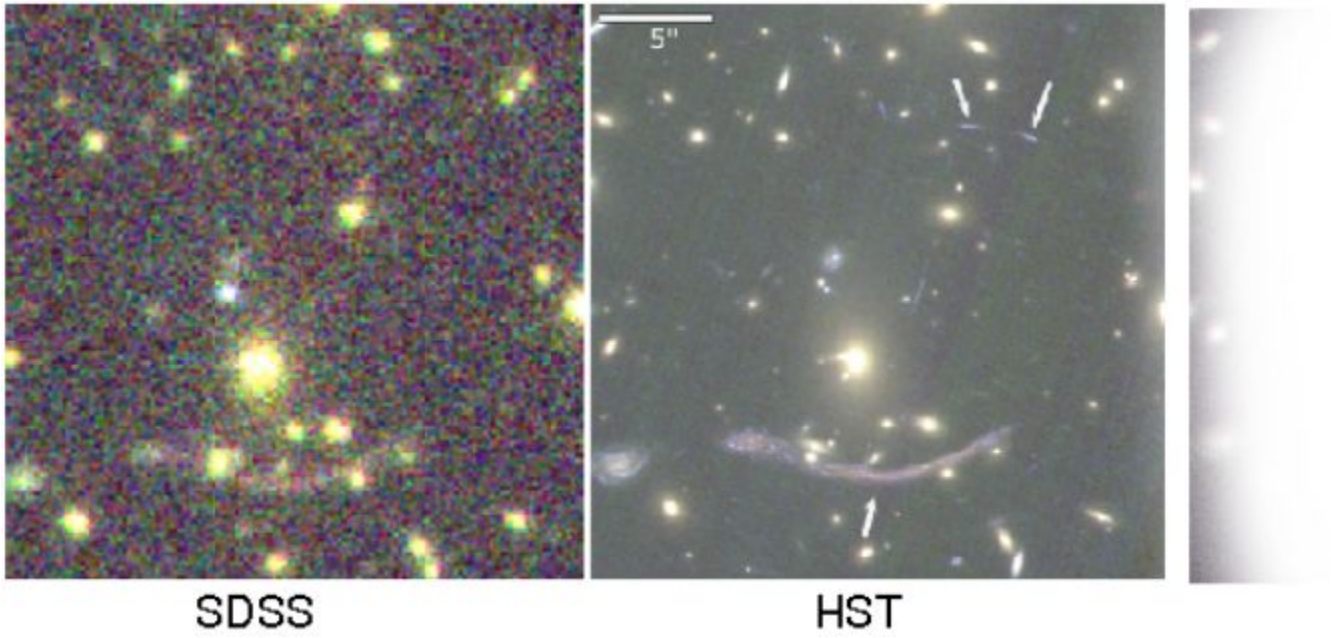








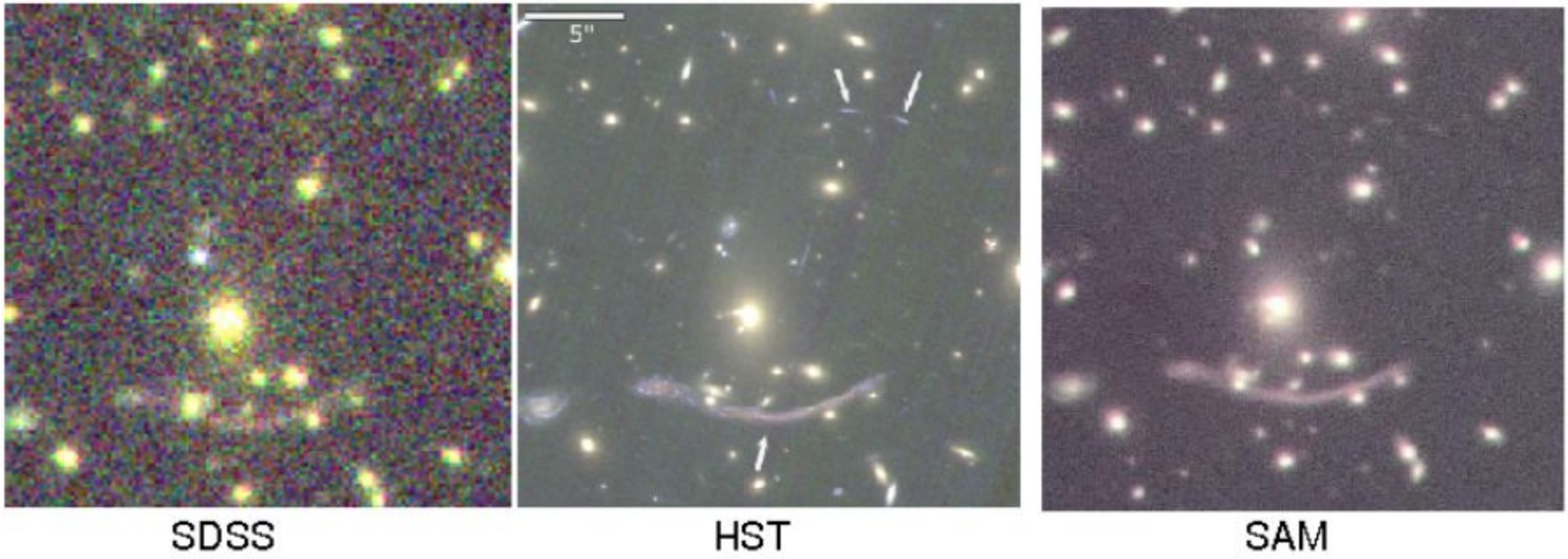
Superando a turbulência



SDSS: Sloan Digital Sky Survey
HST: Hubble Space Telescope

Superando a turbulência = Óptica Adaptativa

E.g.: SAM @ SOAR



SAM: SOAR Adaptive Module
SOAR: SOuthern Astrophysical Research [Telescope]

Telescópios: como nascem?

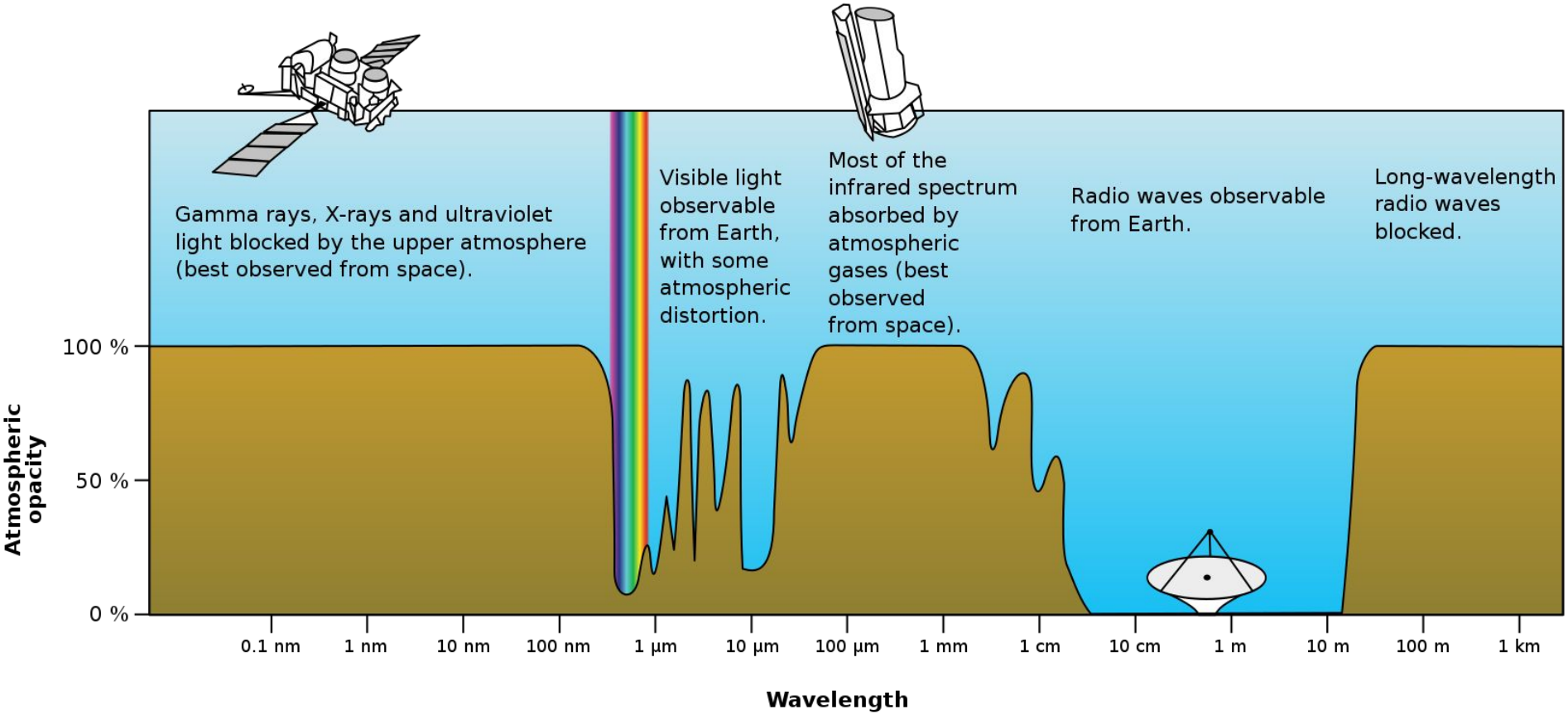
Telescópios: como nascem?

Projetos

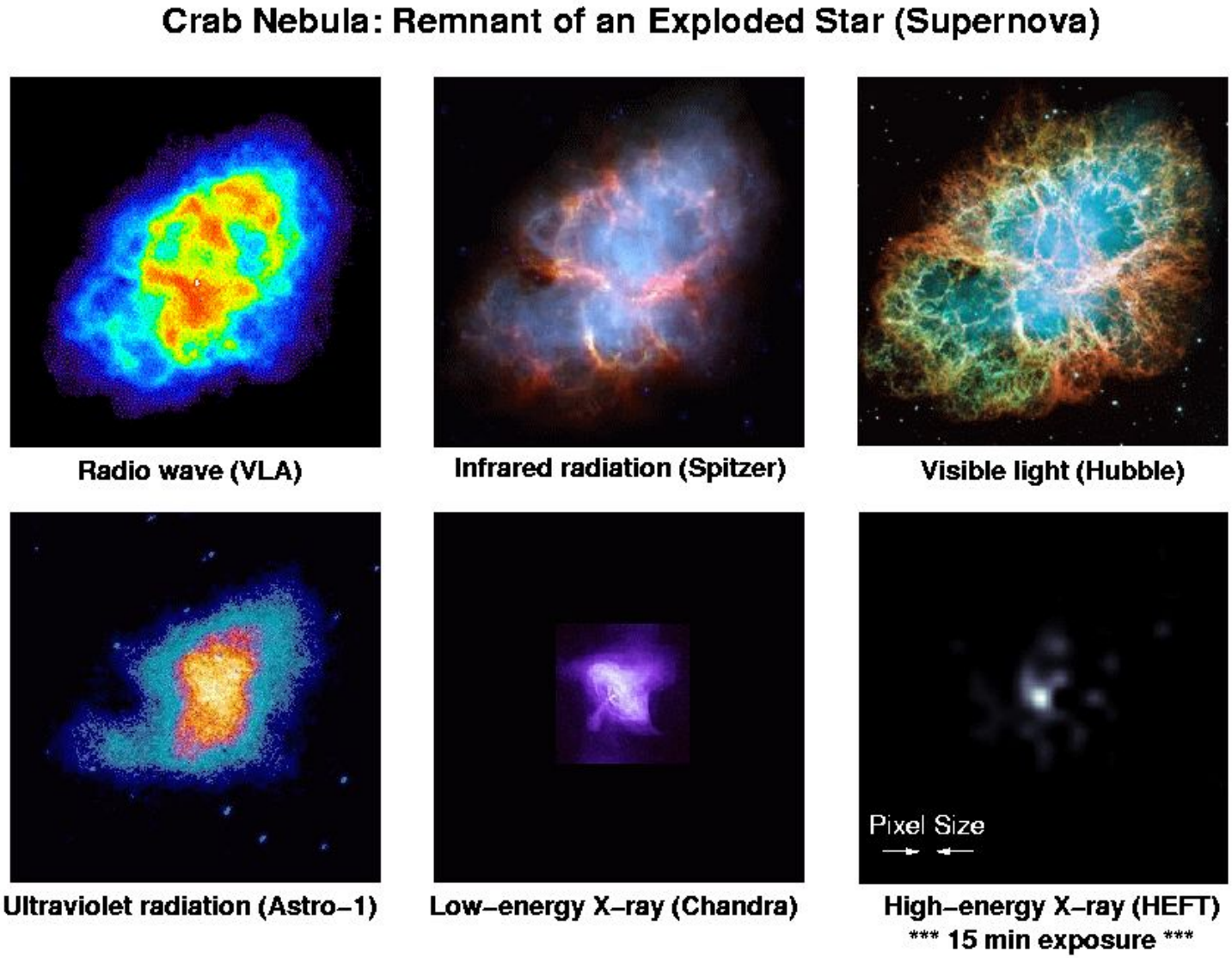
Tamanhos e início operação
2-inch (0.1m) “primeiro telescópio”, 1609
72-inch (1.8m) *Leviatã de Parsonstown*, 1845
100-inch (2.5m) Hooker telescope*, 1917
200-inch (5.1m) Hale telescope, 1948
(...)
Hubble space telescope, 1990

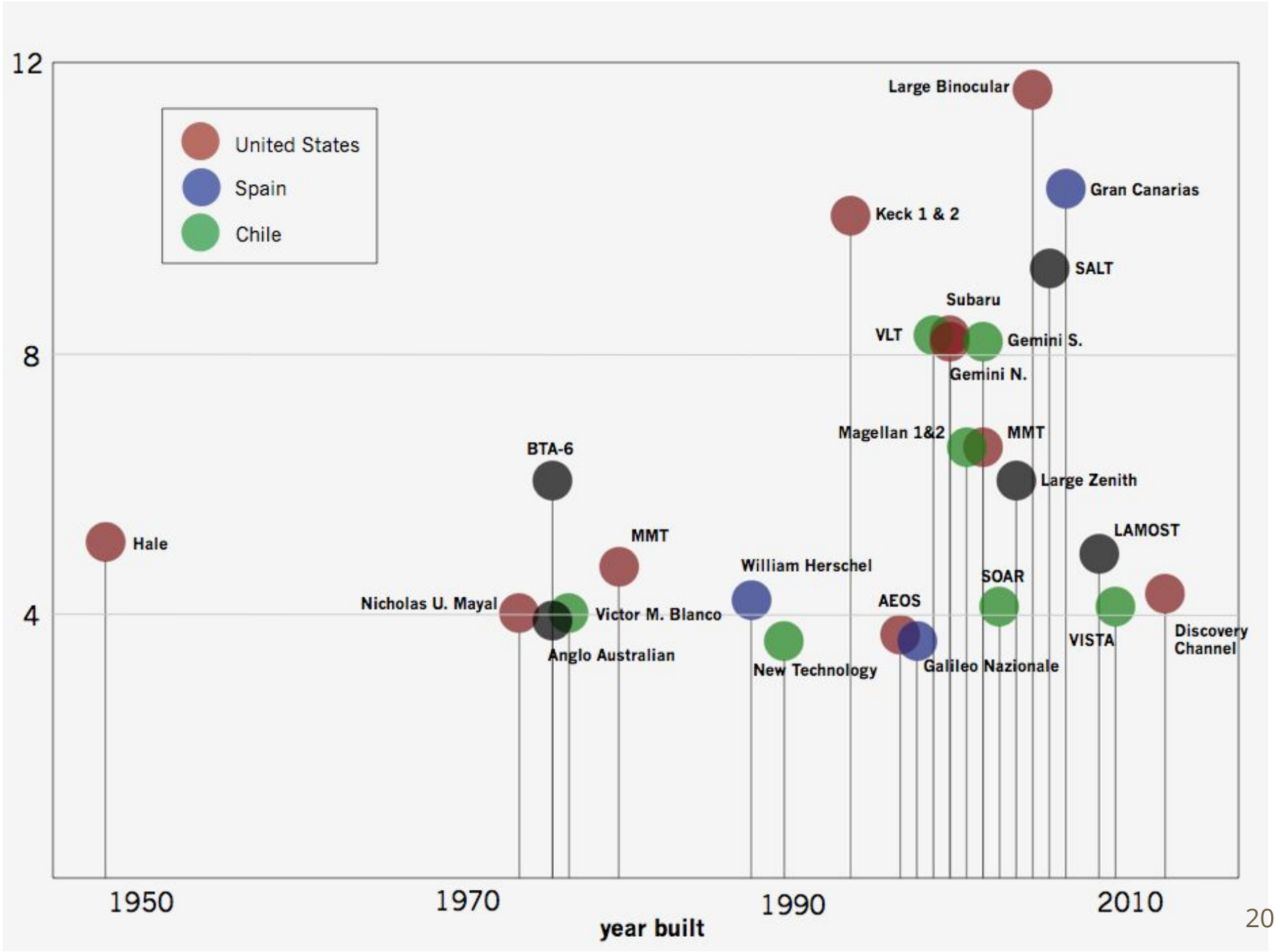
Custos e construção
James Webb ST [1996-2018] = $8 bi
Hubble [1978-1990**] = $2.7 bi
($1.2 bi in 1986)
GMT [2012-2023] = $1.3 bi

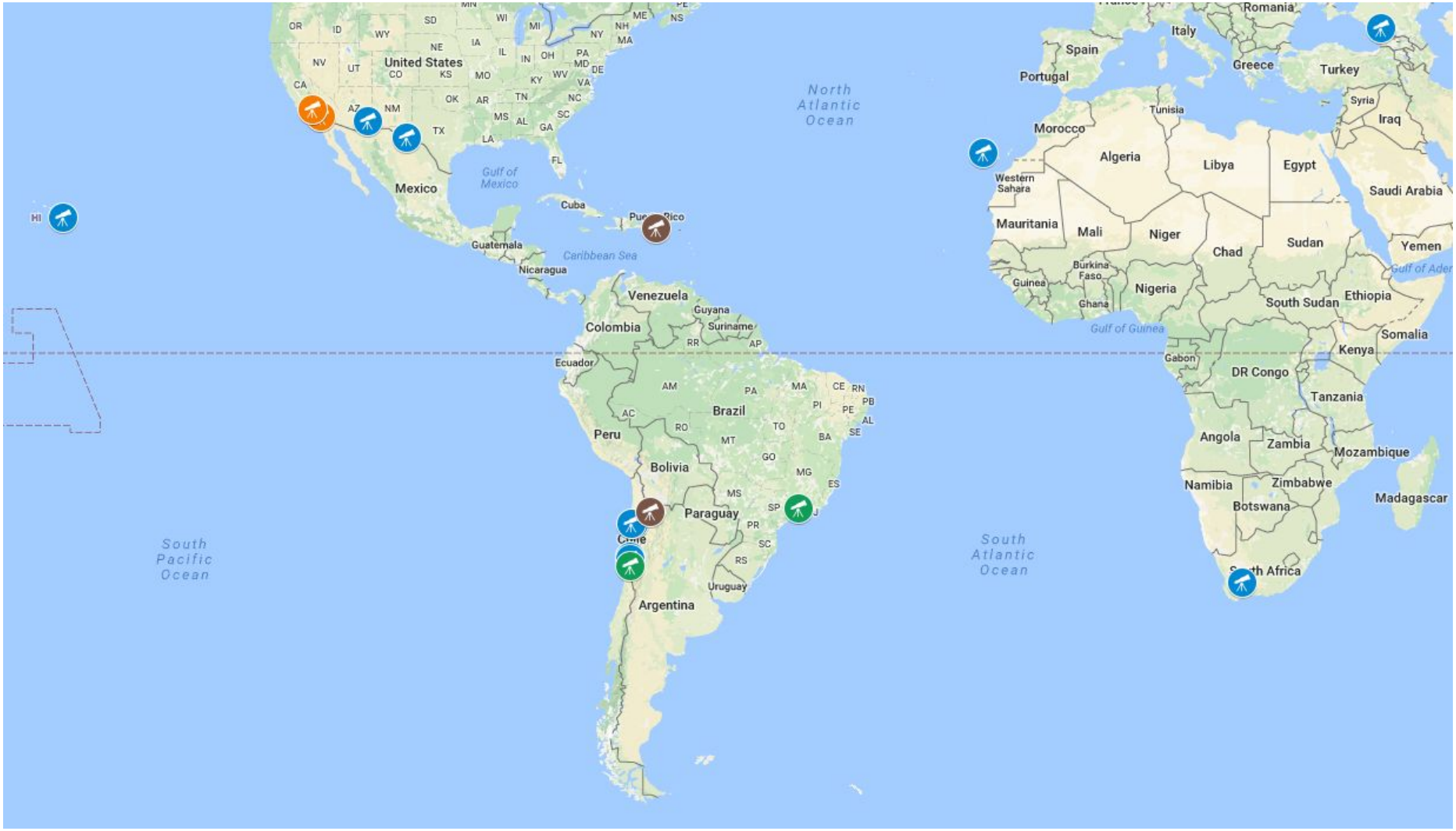
Telescópios e a atmosfera

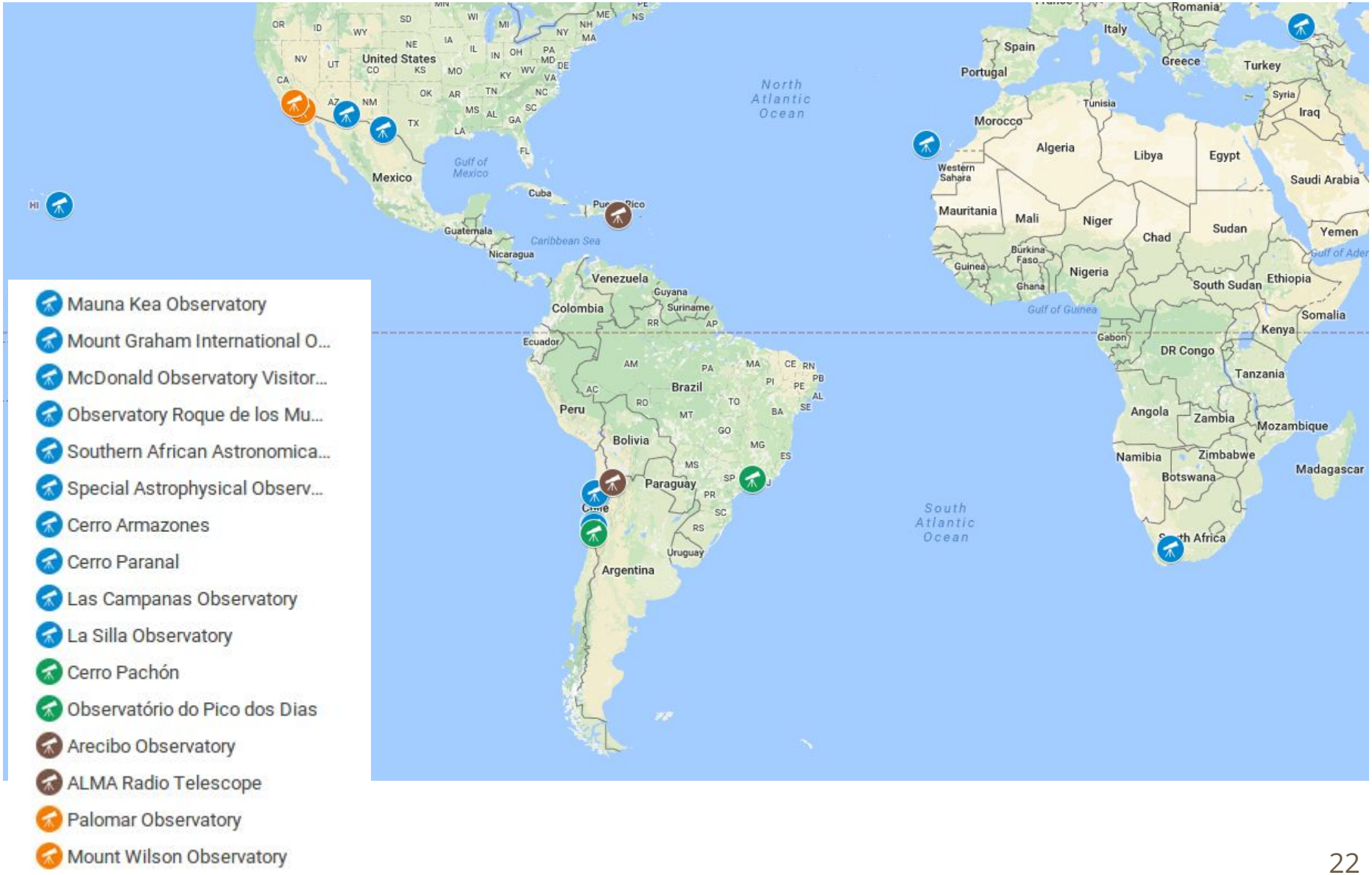


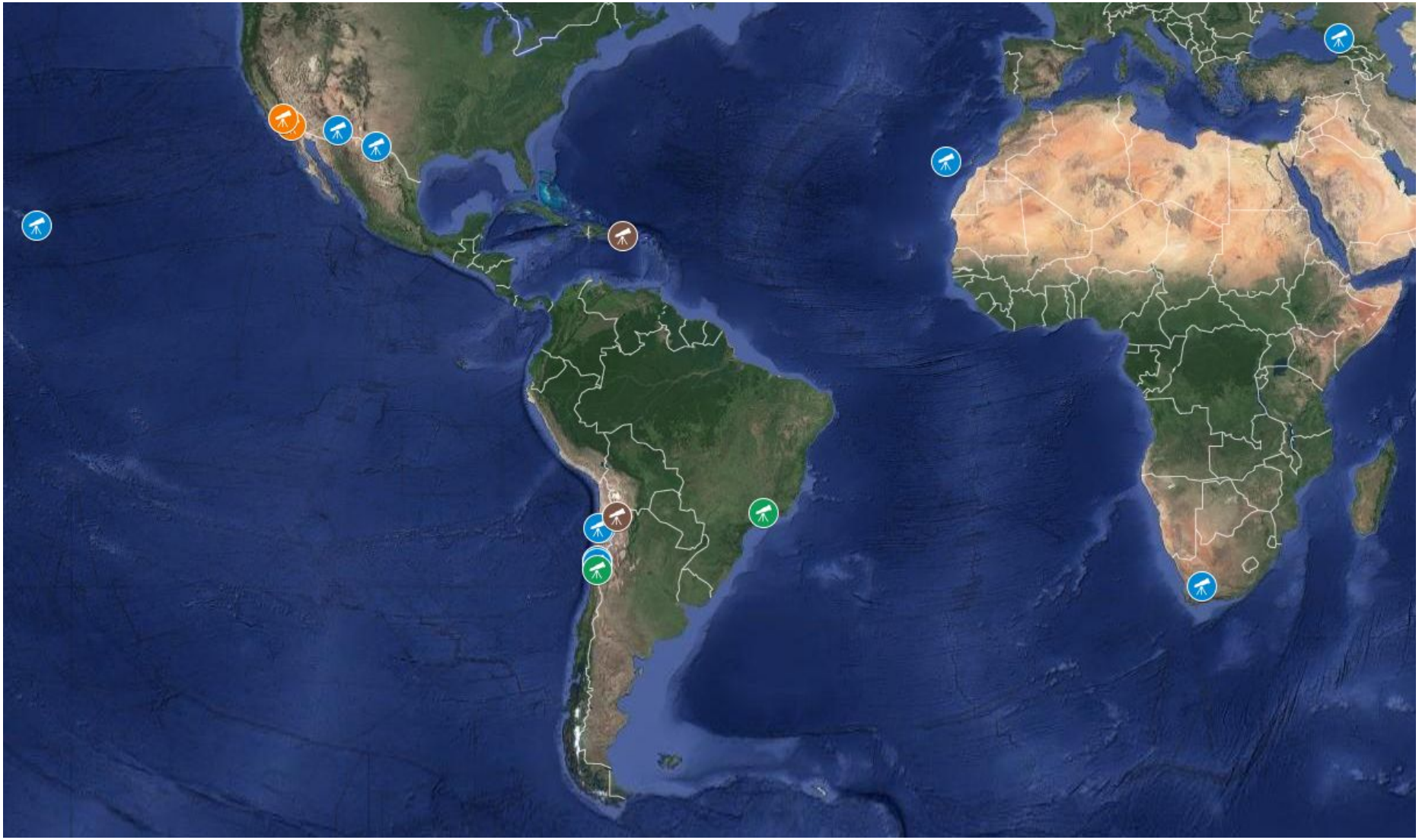
Vendo o invisível




12
8
4
United States
Spain
Chile
Large Binocular
Gran Canarias
Keck 1 & 2
SALT
Subaru
VLT
Gemini S.
Gemini N.
Magellan 1&2
MMT
BTA-6
Large Zenith
LAMOST
Hale
MMT
William Herschel
SOAR
Nicholas U. Mayal
Victor M. Blanco
AEOS
VISTA
Discovery Channel
Anglo Australian
New Technology
Galileo Nazionale
1950
1970
1990
2010
year built


United States
Mexico
Gulf of Mexico
Cuba
Guatemala
Nicaragua
Caribbean Sea
Venezuela
Colombia
Ecuador
Peru
Brazil
Bolivia
Paraguay
Argentina
Uruguay
Chile
North Atlantic Ocean
South Pacific Ocean
South Atlantic Ocean
Spain
Portugal
Italy
Greece
Turkey
Romania
Syria
Iraq
Morocco
Algeria
Tunisia
Libya
Egypt
Western Sahara
Mauritania
Mali
Niger
Chad
Sudan
Saudi Arabia
Yemen
Burkina Faso
Guinea
Nigeria
Ghana
Gulf of Guinea
South Sudan
Ethiopia
Somalia
Kenya
Gabon
DR Congo
Tanzania
Angola
Zambia
Mozambique
Namibia
Zimbabwe
Botswana
Madagascar


Mauna Kea Observatory
Mount Graham International O...
McDonald Observatory Visitor...
Observatory Roque de los Mu...
Southern African Astronomica...
Special Astrophysical Observ...
Cerro Armazones
Cerro Paranal
Las Campanas Observatory
La Silla Observatory
Cerro Pachón
Observatório do Pico dos Dias
Arecibo Observatory
ALMA Radio Telescope
Palomar Observatory
Mount Wilson Observatory
United States
Mexico
Gulf of Mexico
Cuba
Guatemala
Nicaragua
Caribbean Sea
Venezuela
Colombia
Ecuador
Peru
Brazil
Bolivia
Paraguay
Argentina
Uruguay
North Atlantic Ocean
South Atlantic Ocean
Spain
Portugal
Italy
Greece
Turkey
Romania
Syria
Iraq
Morocco
Algeria
Tunisia
Libya
Egypt
Western Sahara
Mauritania
Mali
Niger
Chad
Sudan
Saudi Arabia
Yemen
Burkina Faso
Guinea
Nigeria
Ghana
South Sudan
Ethiopia
Somalia
Kenya
Gulf of Guinea
Gabon
DR Congo
Tanzania
Angola
Zambia
Mozambique
Namibia
Zimbabwe
Botswana
Madagascar




Calama
San Pedro de Atacama
Mejillones
Antofagasta
Taltal
Chile
Copiapó
Vallenar
La Serena
San Juan
Mendoza
Valparaíso
Santiago


Calama
San Pedro de Atacama
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Antofagasta
Taltal
Chile
Copiapó
Vallenar
La Serena
San Juan
Mendoza
Valparaíso
Santiago


MAGELLAN
TELESCOPES
GMT SITE
Summit Offices
SUPPORT SITE 1
Labs and Workshops
SUPPORT SITE 2
PAD 1: 68 Dorm Building
PAD 2: Kitchen, Dining, and Recreation Buildings
PAD 3: 24 Dorm Building

Os telescópios gigantes

Rádio *vs* óptico

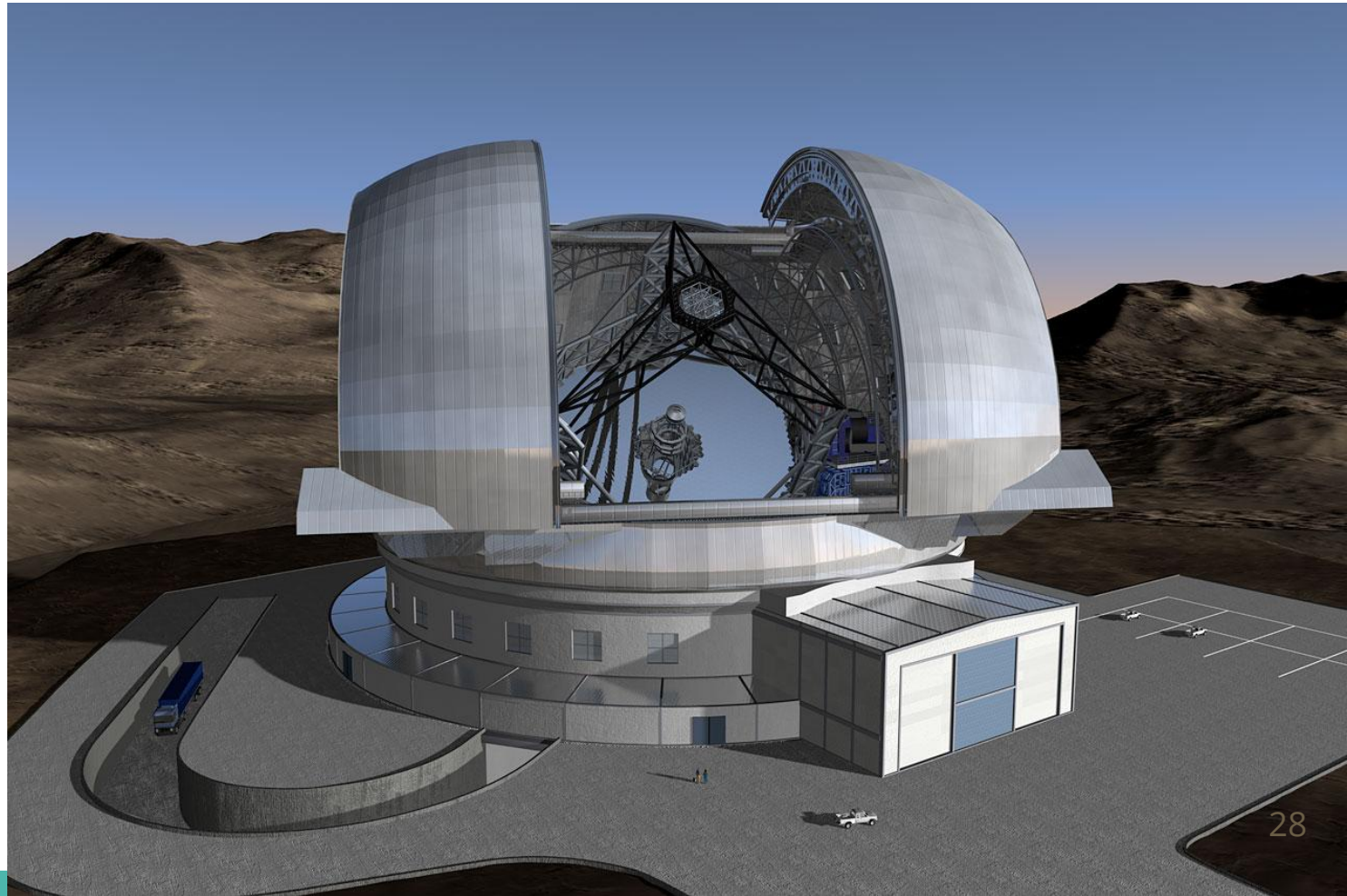
Cássio Barbosa: “O maior telescópio do mundo”

Os projetos de telescópios gigantes

ELT: Extreme Large Telescope (ESO)

D= 39m

A= 978m^2



Os projetos de telescópios gigantes

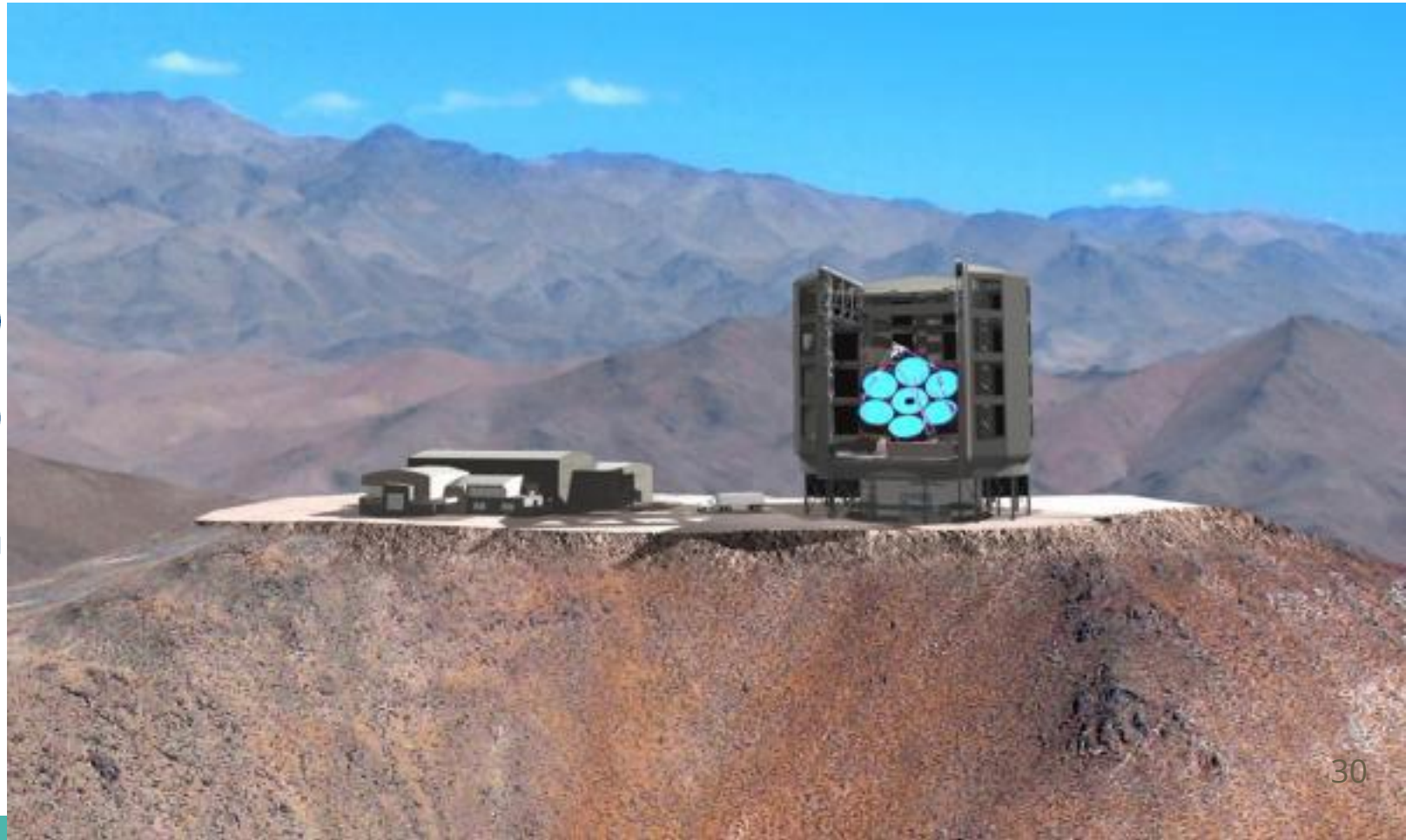
TMT: Thirty Meter Telescope
D= 30m
A= 655m^2

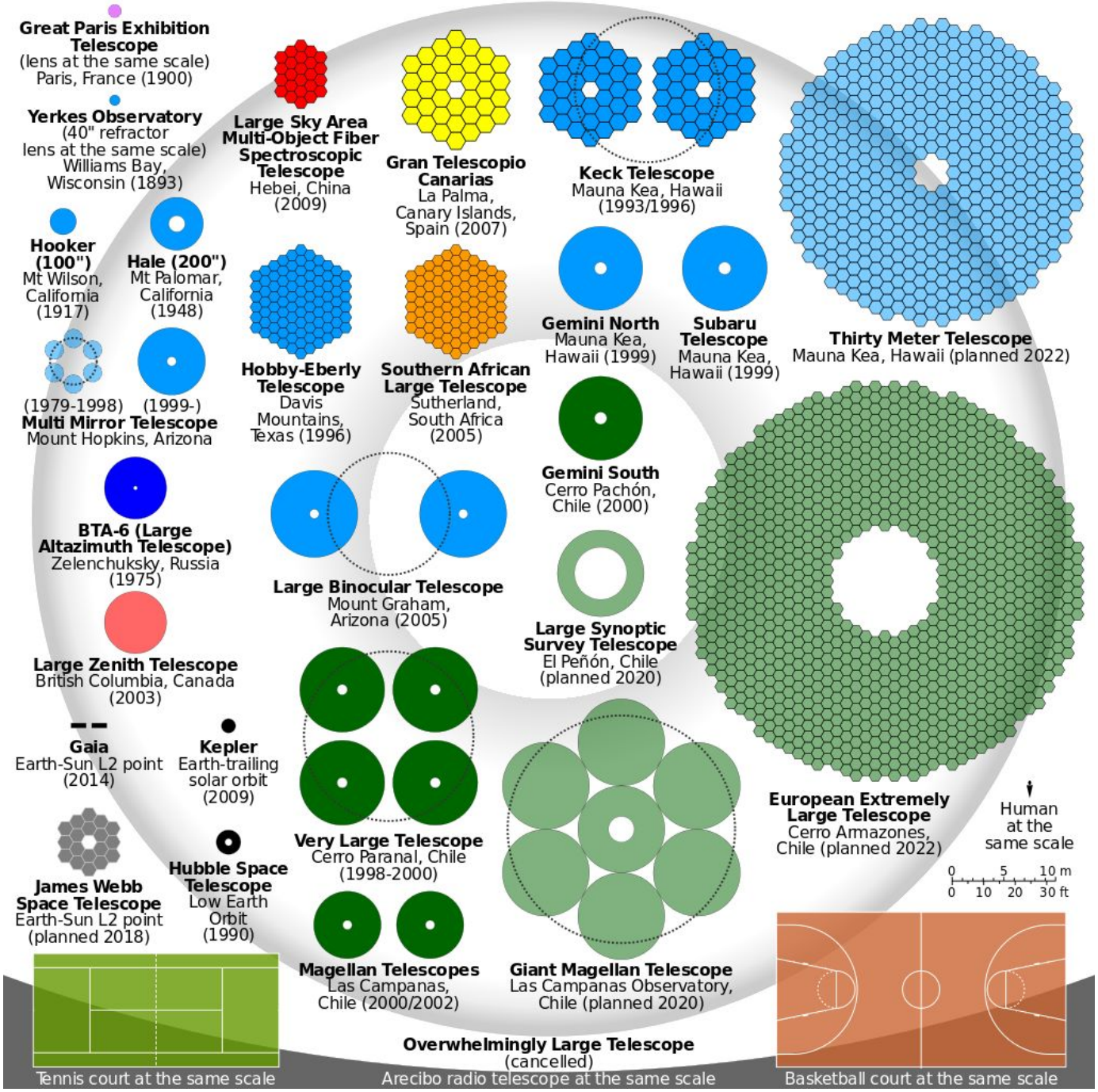
Os projetos de telescópios gigantes

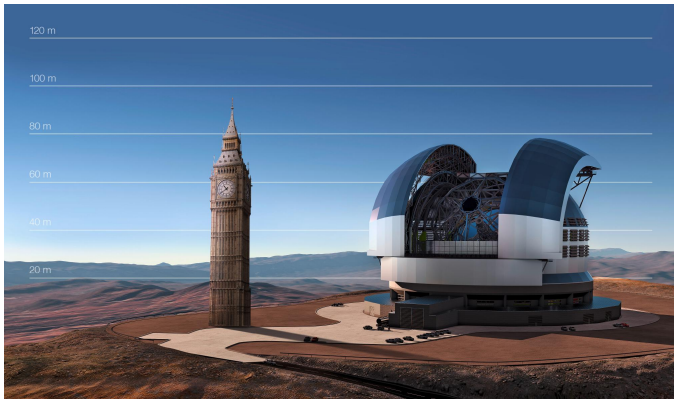
GMT: Giant Magellan Telescope

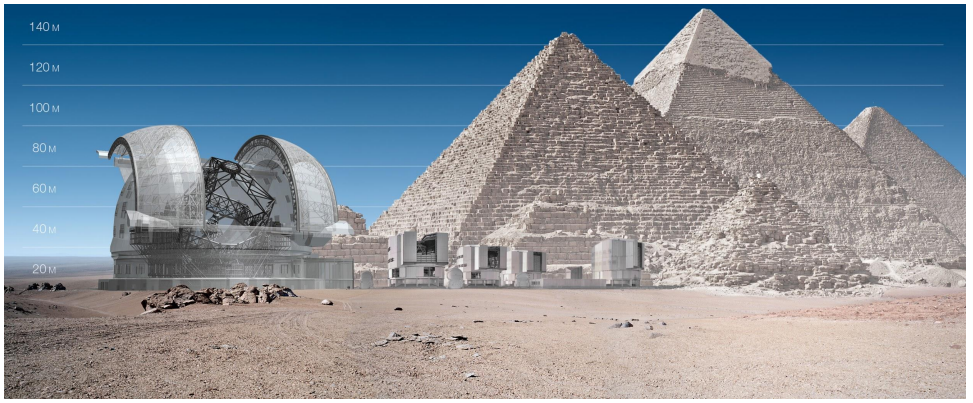
D= 25m

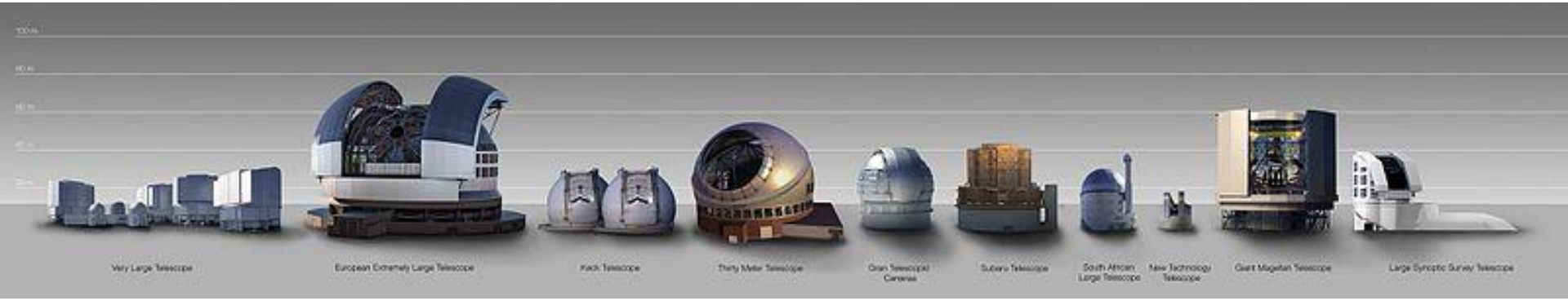
A= 368m^2




Great Paris Exhibition Telescope
(lens at the same scale)
Paris, France (1900)
Yerkes Observatory
(40" refractor
lens at the same scale)
Williams Bay,
Wisconsin (1893)
Large Sky Area Multi-Object Fiber Spectroscopic Telescope
Hebei, China
(2009)
Gran Telescopio Canarias
La Palma,
Canary Islands,
Spain (2007)
Keck Telescope
Mauna Kea, Hawaii
(1993/1996)
Hooker (100")
Mt Wilson,
California
(1917)
Hale (200")
Mt Palomar,
California
(1948)
Hobby-Eberly Telescope
Davis
Mountains,
Texas (1996)
Southern African Large Telescope
Sutherland,
South Africa
(2005)
Gemini North
Mauna Kea,
Hawaii (1999)
Subaru Telescope
Mauna Kea,
Hawaii (1999)
Thirty Meter Telescope
Mauna Kea, Hawaii (planned 2022)
(1979-1998)
(1999-)
Multi Mirror Telescope
Mount Hopkins, Arizona
Gemini South
Cerro Pachón,
Chile (2000)
BTA-6 (Large Altazimuth Telescope)
Zelenchuksky, Russia
(1975)
Large Binocular Telescope
Mount Graham,
Arizona (2005)
Large Zenith Telescope
British Columbia, Canada
(2003)
Large Synoptic Survey Telescope
El Peñón, Chile
(planned 2020)
Gaia
Earth-Sun L2 point
(2014)
Kepler
Earth-trailing
solar orbit
(2009)
Very Large Telescope
Cerro Paranal, Chile
(1998-2000)
European Extremely Large Telescope
Cerro Armazones,
Chile (planned 2022)
Human at the same scale
0 5 10 m
0 10 20 30 ft
James Webb Space Telescope
Earth-Sun L2 point
(planned 2018)
Hubble Space Telescope
Low Earth
Orbit
(1990)
Magellan Telescopes
Las Campanas,
Chile (2000/2002)
Giant Magellan Telescope
Las Campanas Observatory,
Chile (planned 2020)
Overwhelmingly Large Telescope
(cancelled)
Tennis court at the same scale
Arecibo radio telescope at the same scale
Basketball court at the same scale


120 m
100 m
80 m
60 m
40 m
20 m


140 м
120 м
100 м
80 м
60 м
40 м
20 м


Very Large Telescope
European Extremely Large Telescope
Keck Telescope
Thirty Meter Telescope
Gran Telescopio Canarias
Subaru Telescope
South African Large Telescope
New Technology Telescope
Giant Magellan Telescope
Large Synoptic Survey Telescope


140 м
120 м
100 м
80 м
60 м
40 м
20 м

Telescópios: Quem usa?

Telescópios: Quem usa?

Consórcios internacionais ou multi-institucionais

Agências nacionais ou internacionais para a astronomia:
- Europa, ESO = European Southern Observatory
- EUA, NOAO = National Optical Astronomy Observatory
- Brasil, LNA = Laboratório Nacional de Astrofísica

Agências de fomento científico:
- EUA, NSF = National Science Foundation
- Brasil, FAPESP = Fundação de Amparo à Pesquisa do Estado de SP

Instituições de Pesquisa e Ensino:
- Universidades
- Observatórios, institutos...

Qual a fatia do bolo?

- Proporcional ao capital investido (e.g., Gemini)

  Cada participante decide com quanto contribui.

- Proporcional ao mérito científico (e.g., ESO)

  Cada participante entra com uma quota "equivalente".

Quando se observa?

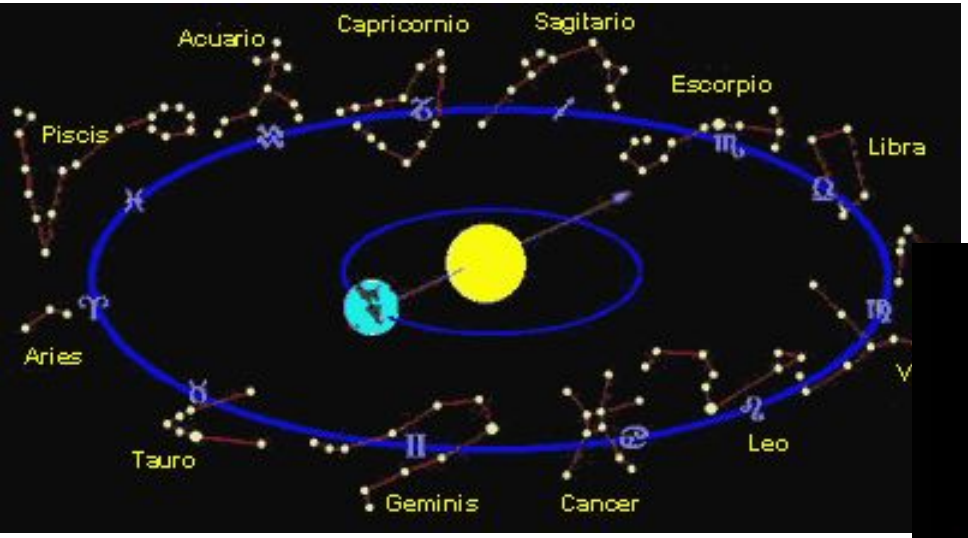
Quando se observa?

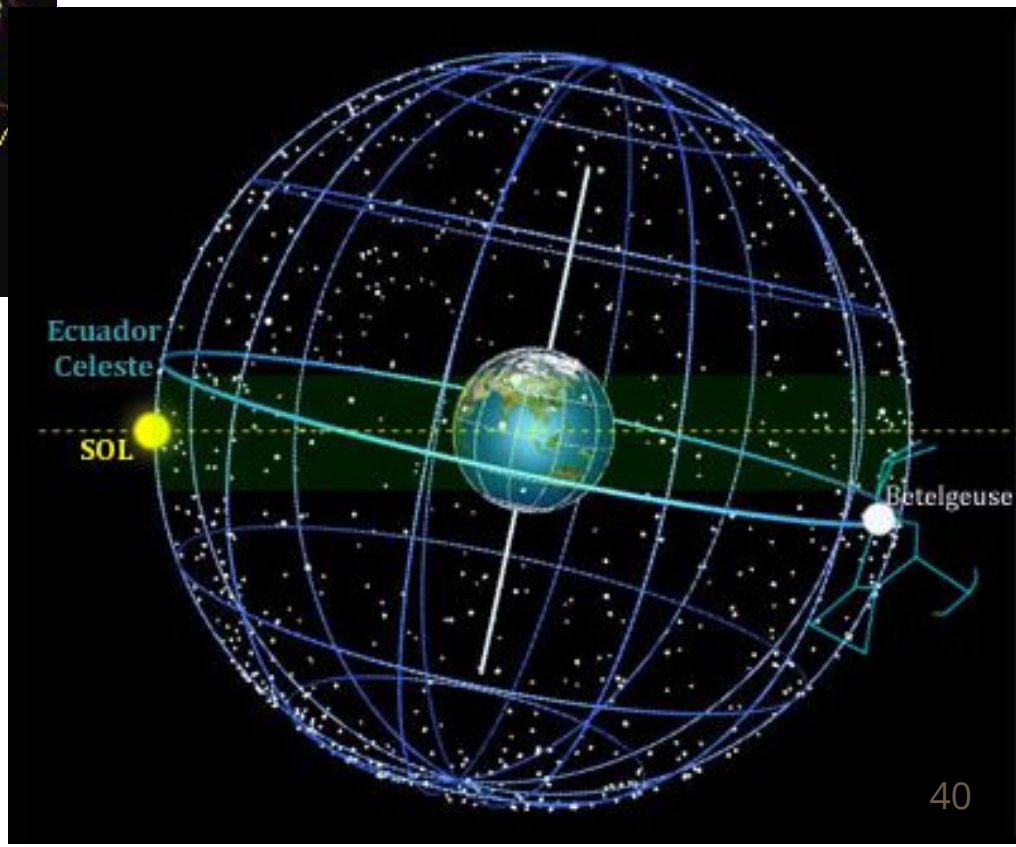
De noite

Editais, julgamentos, filas...

- *"Survey mode"*: levantamento sistemático do céu.
- *"Call for proposals"*: a direção dos observatórios avalia quais instrumentos (ou "modos" do telescópio) estão disponíveis, e faz um chamado aos astrônomos.
- Uma comissão avalia quais pedidos "farão melhor uso" do telescópio. Quais novas descobertas poderão ser alcançadas e como (novo) uso o telescópio se justifica para este fim.
- Conhecimento do equipamento é muito importante, bem como intervalos de tempo de observação (posição dos astros no céu).

Época do ano e o movimento de translação

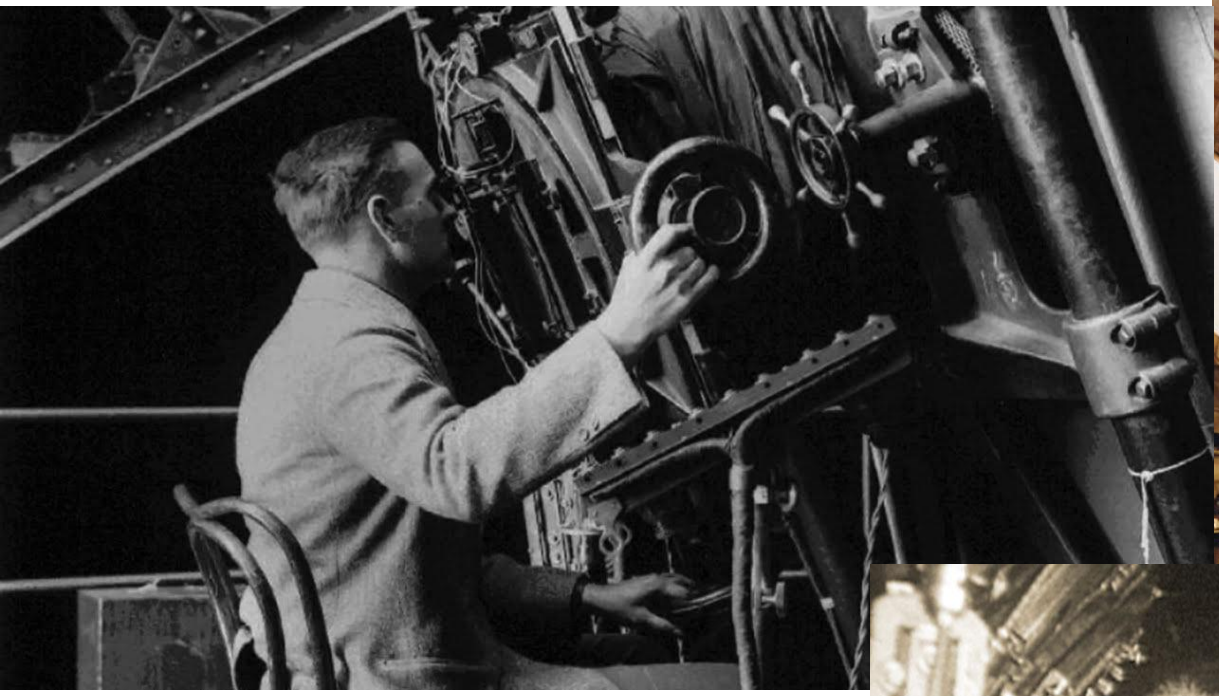


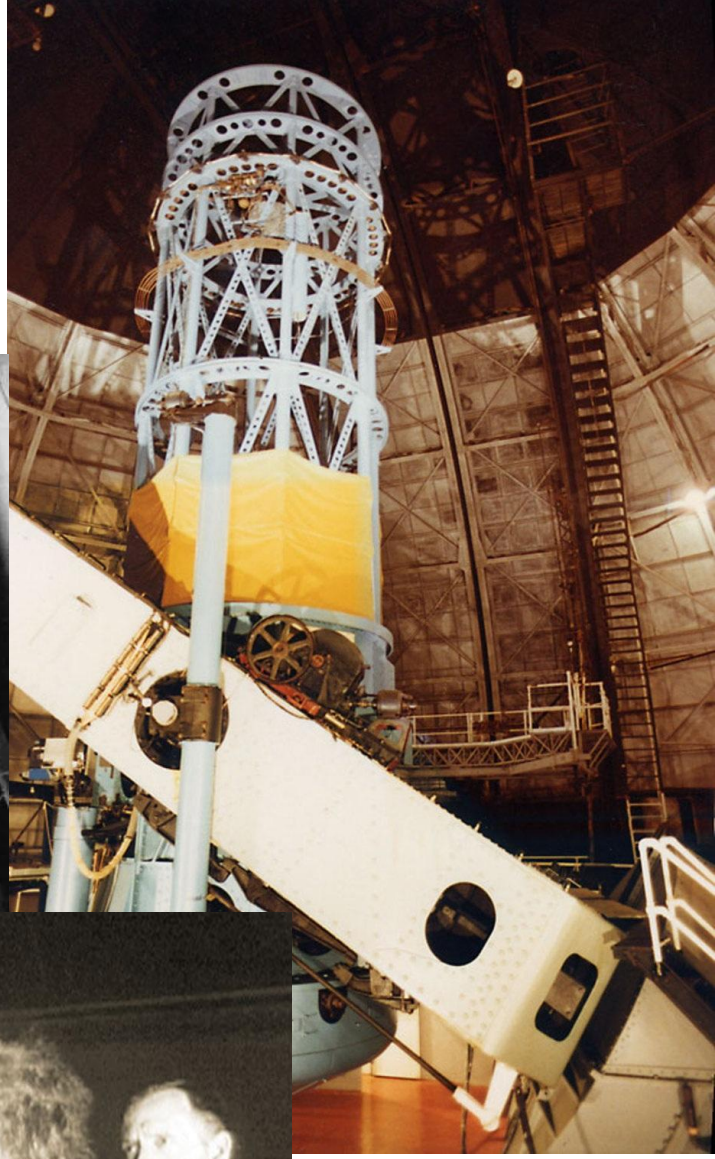


Quem opera?

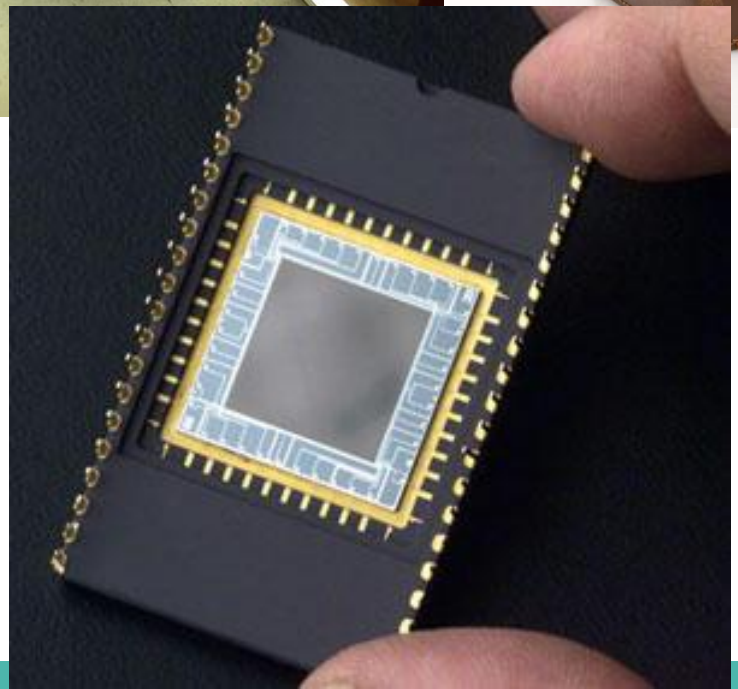
Quem opera?

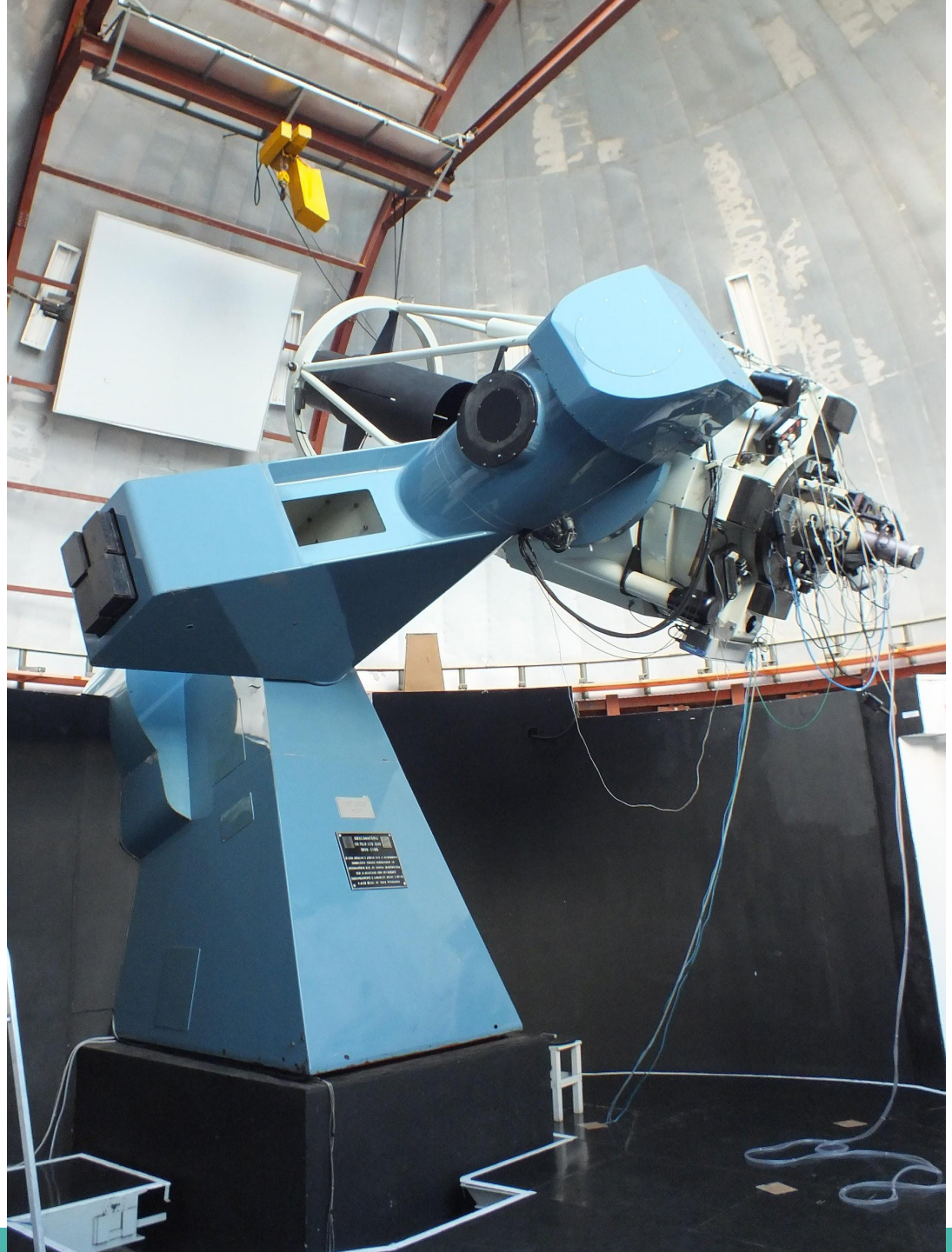
Tempos gloriosos (?)



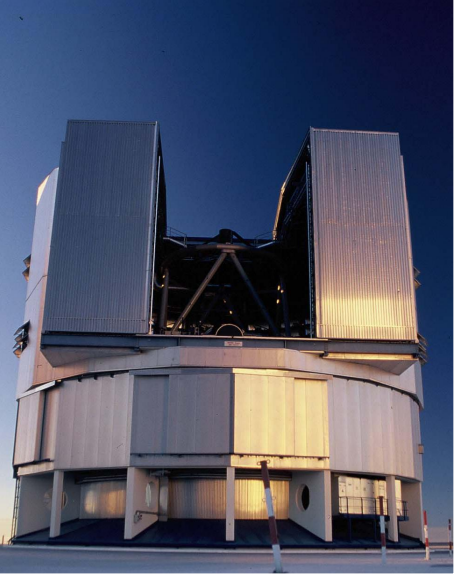


Matrix: computers everywhere



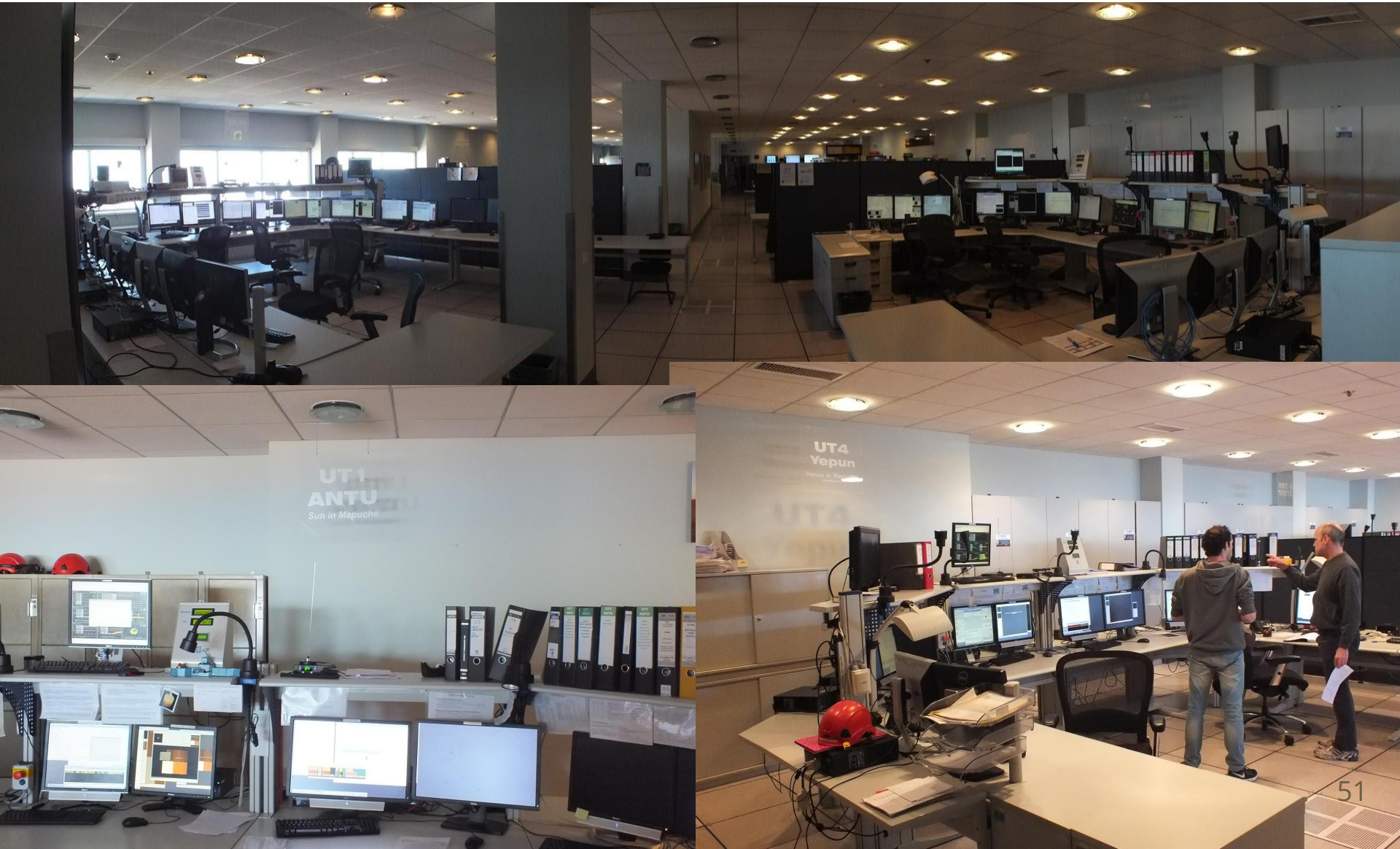


Salas de Controle do OPD



Paranal

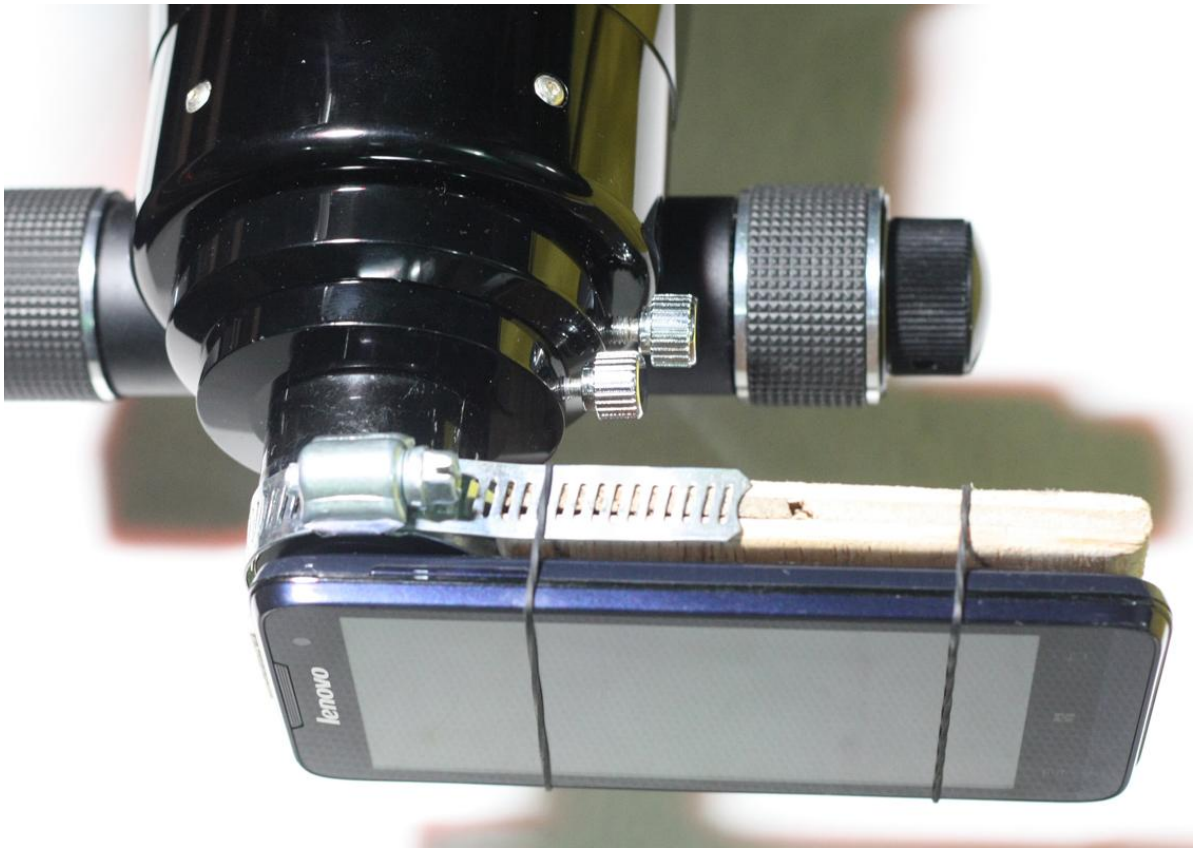
Sala de Controle do Paranal



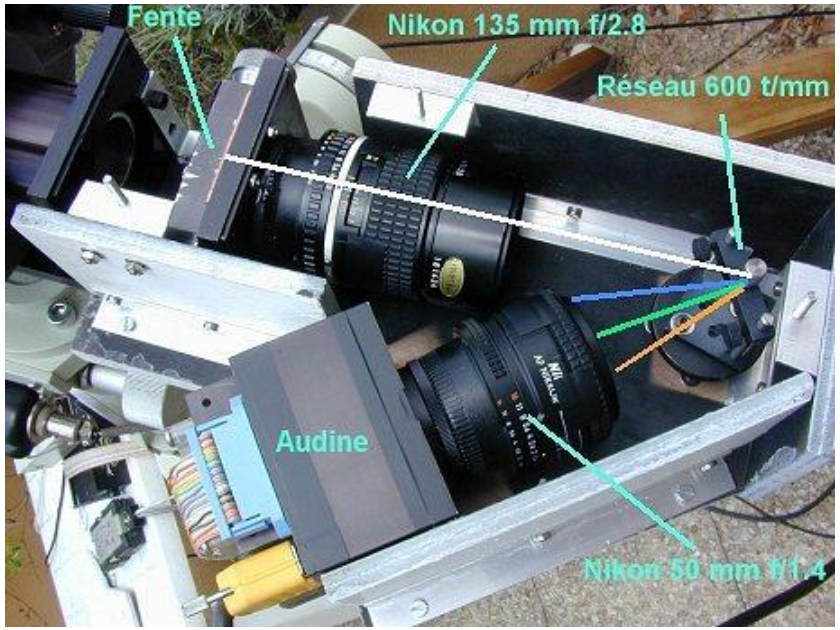
O que se "vê"?

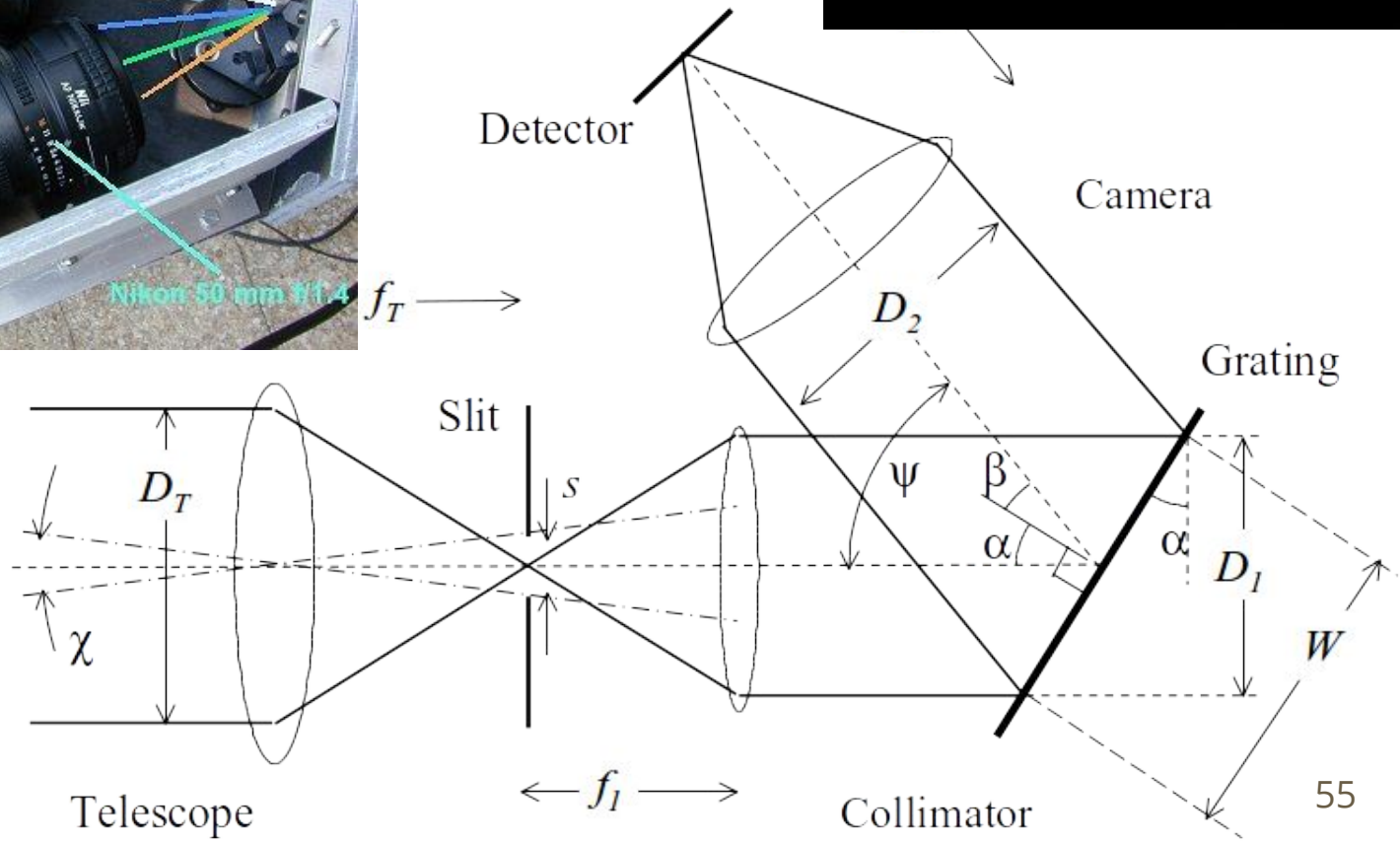
O que se "vê"?

Instrumentos e detectores



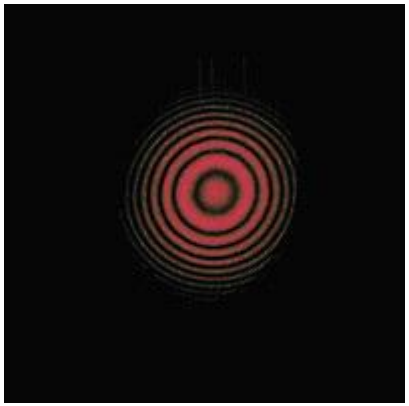
Espectrógrafo

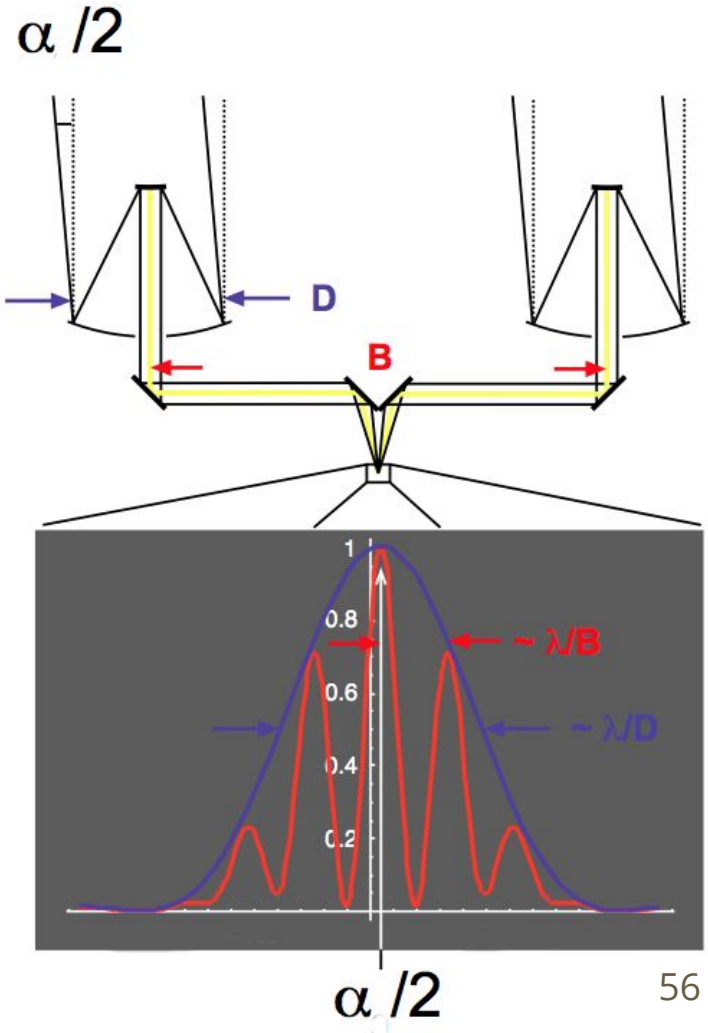




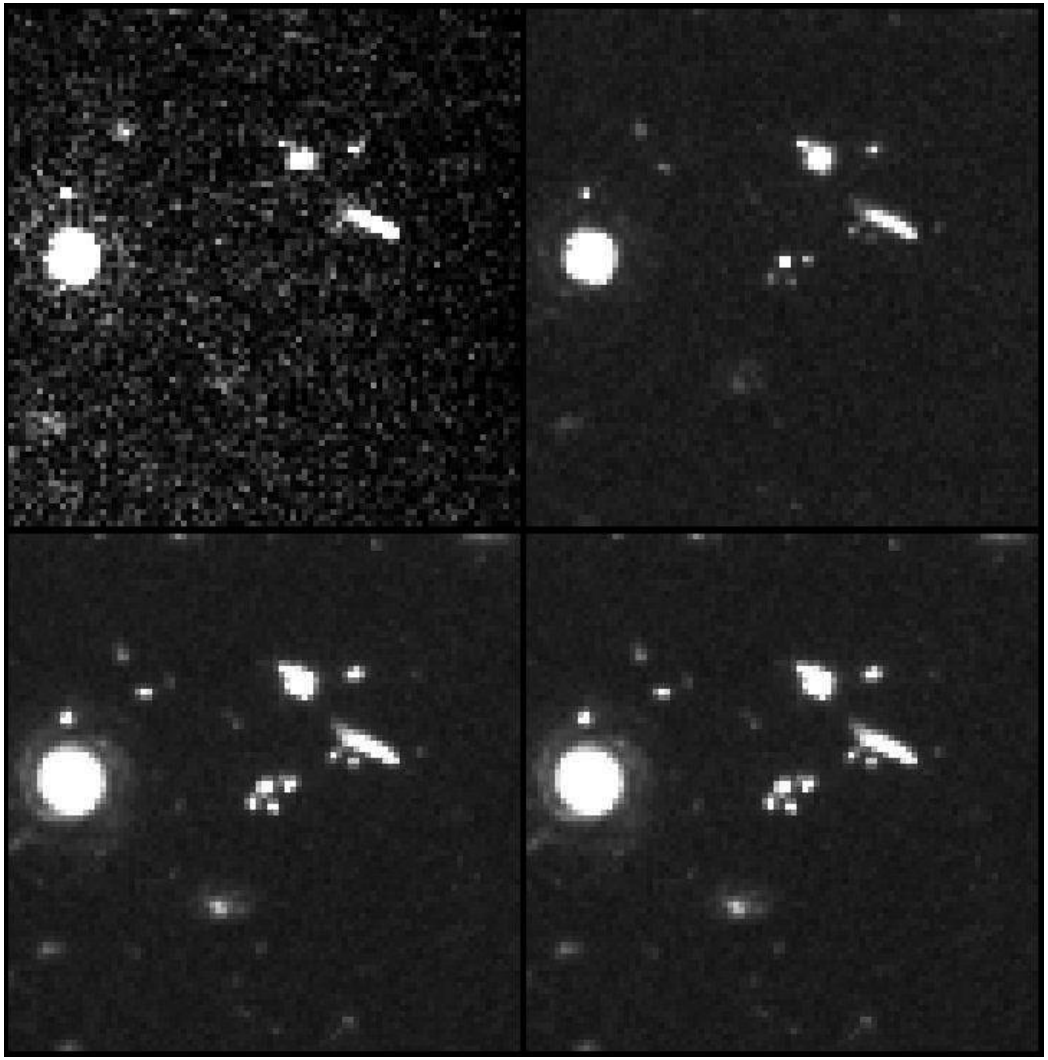
Instrumento = propriedades da luz

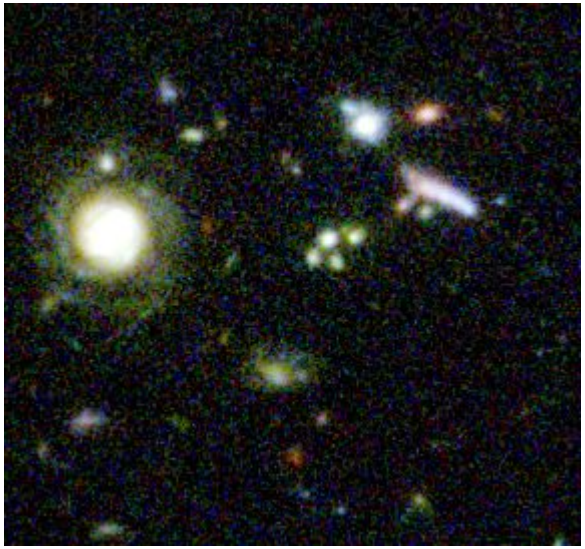
- Imageador = posição e intensidade
  - Filtros
- Espectrógrafo = difração
  - Multi-objeto, dispersão cruzada...
- Polarização = orientação e intensidade rel.
  - Linear e circular. Birefrigência e polaroid...
- Interferometria = interferência
  - Spectro-interferometria. Fabry-perot...
- Interferômetro de intensidade = coerência
  - "CTA"



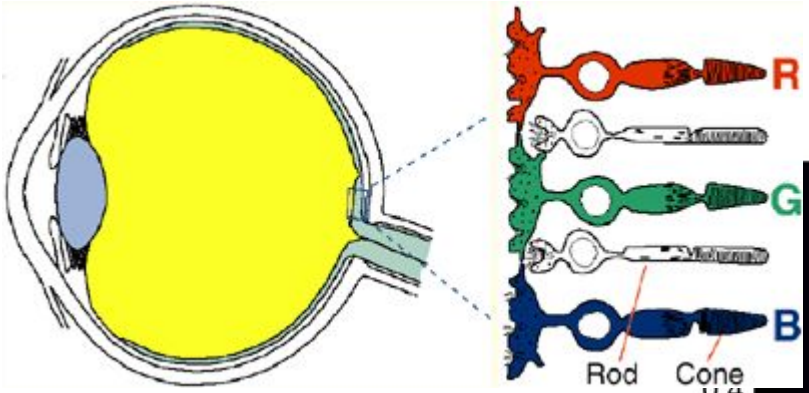


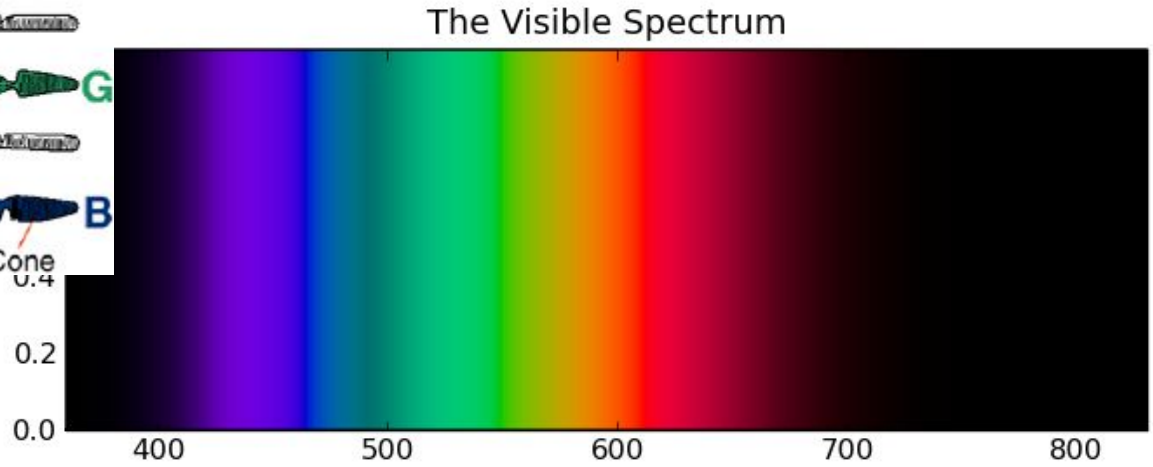
Instrumento = propriedades da luz

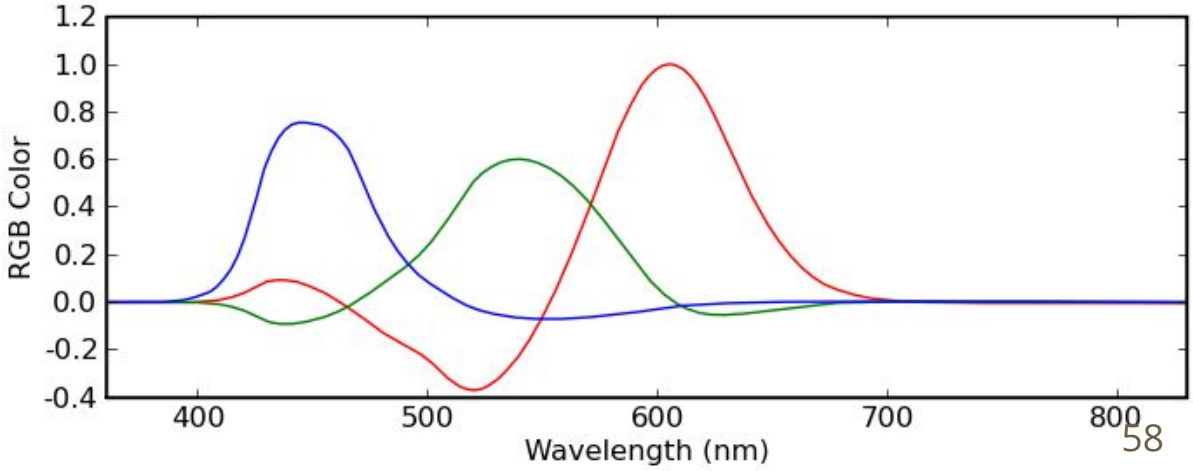




As cores e as frequências EM

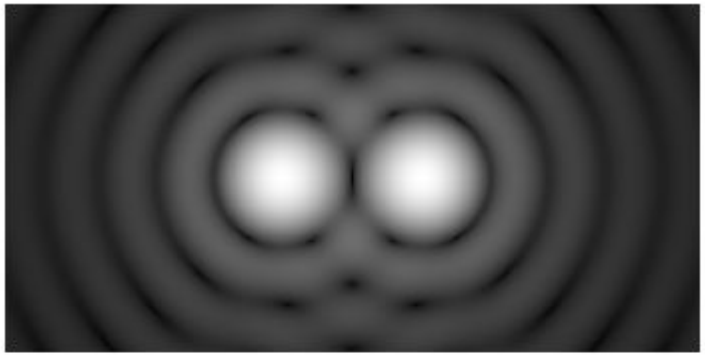


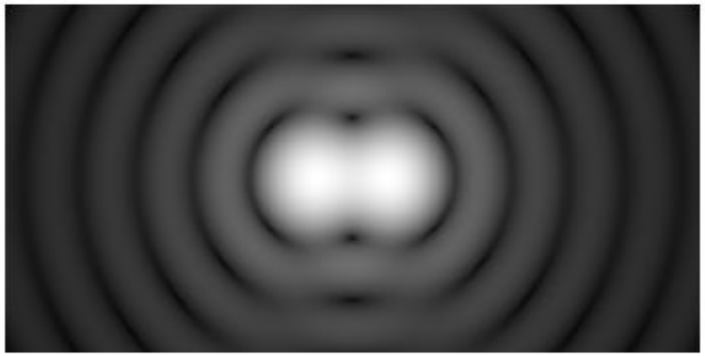


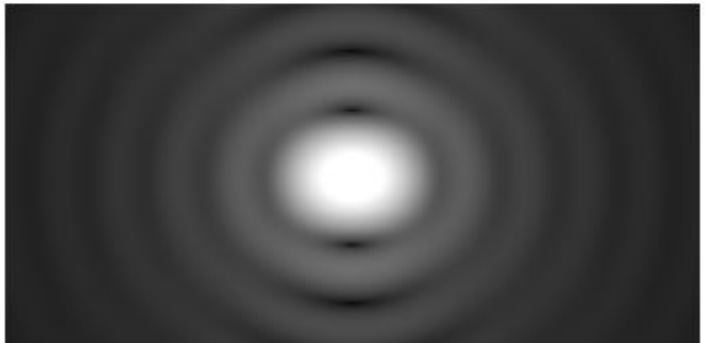


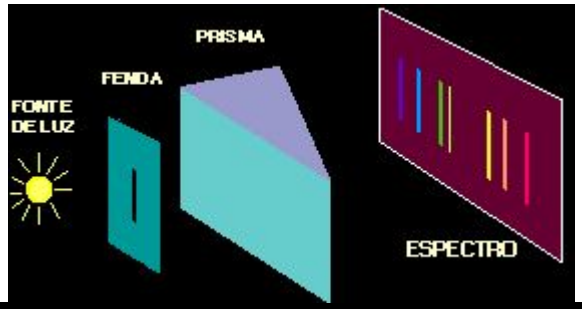
Espectrógrafos!

Espectrógrafos

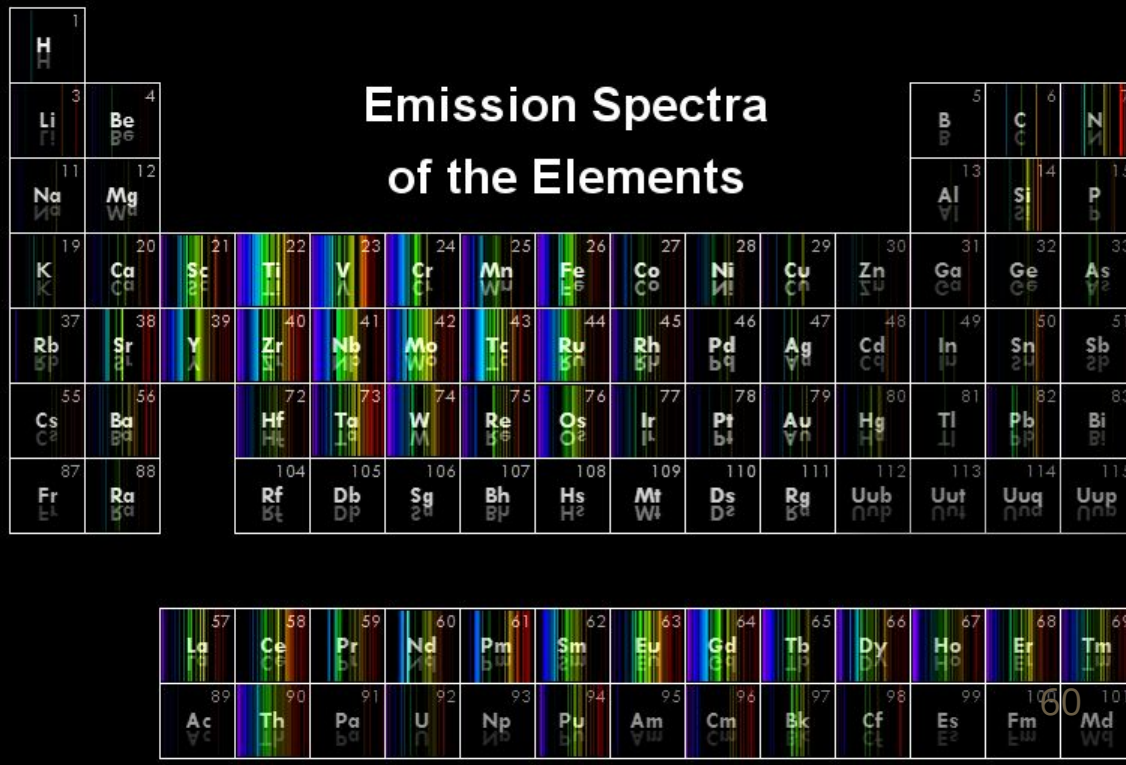






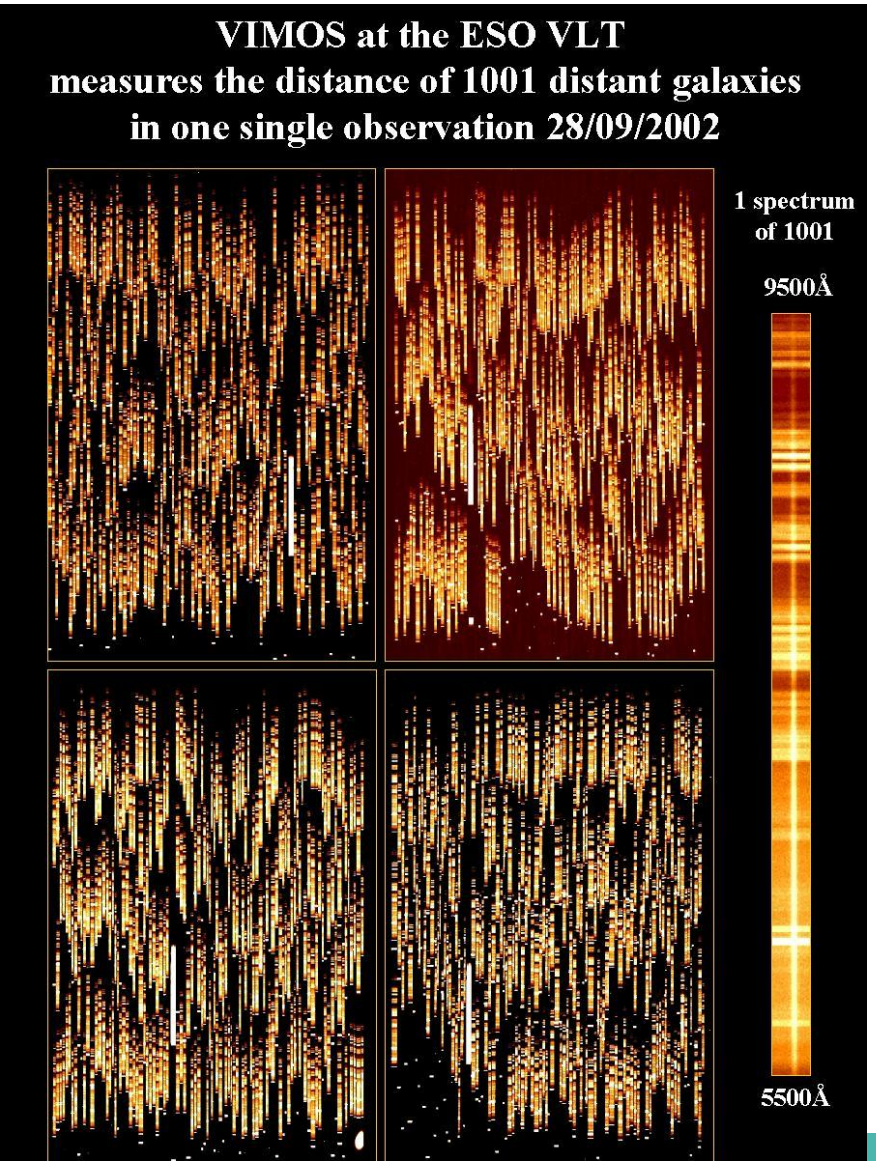


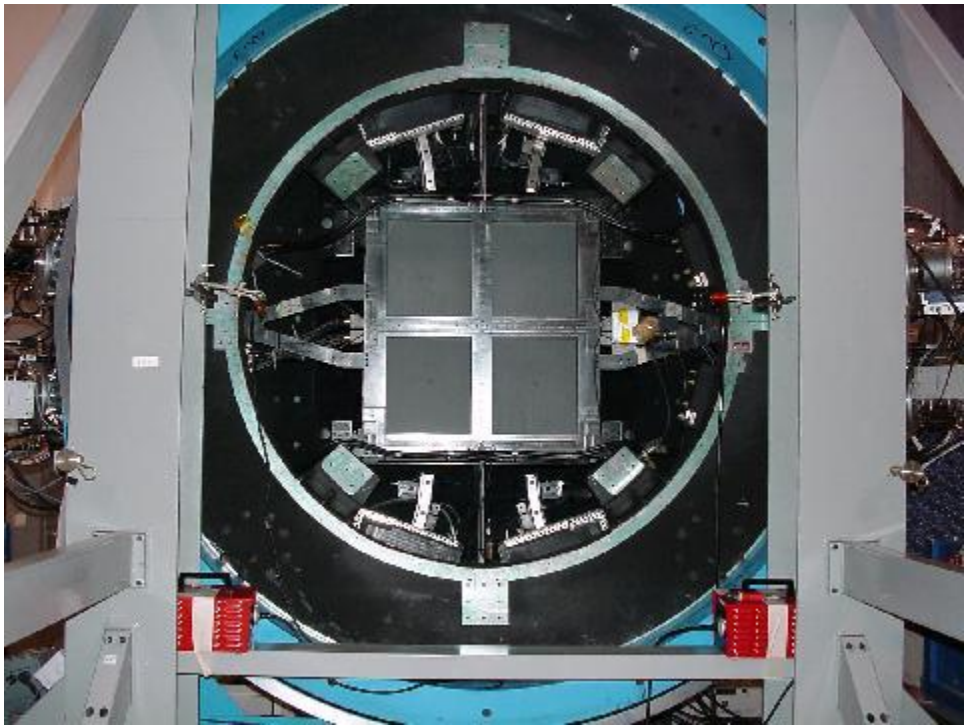
When you burn something
you can see what is it made of.



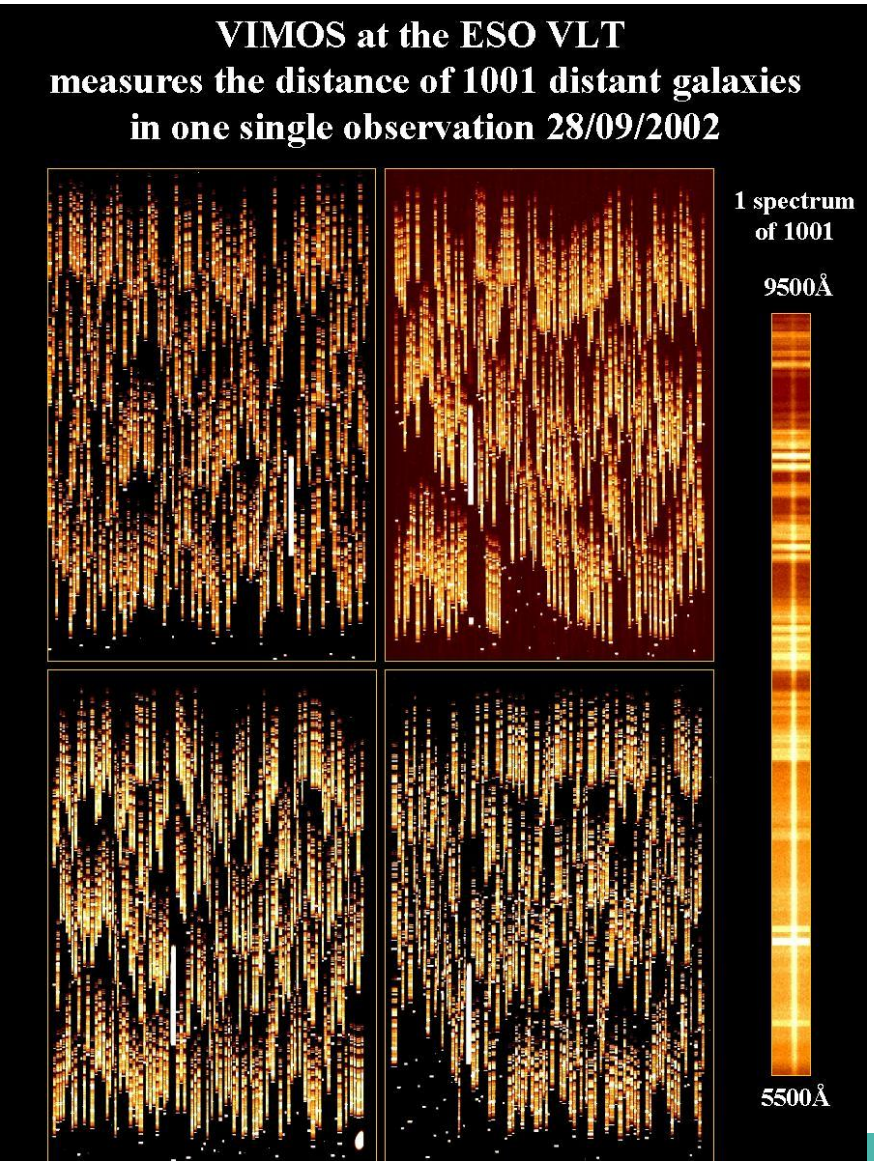
Cassegrain @OPD

VIMOS @VLT


VIMOS at the ESO VLT
measures the distance of 1001 distant galaxies
in one single observation 28/09/2002
1 spectrum
of 1001
9500Å
5500Å



VIMOS @VLT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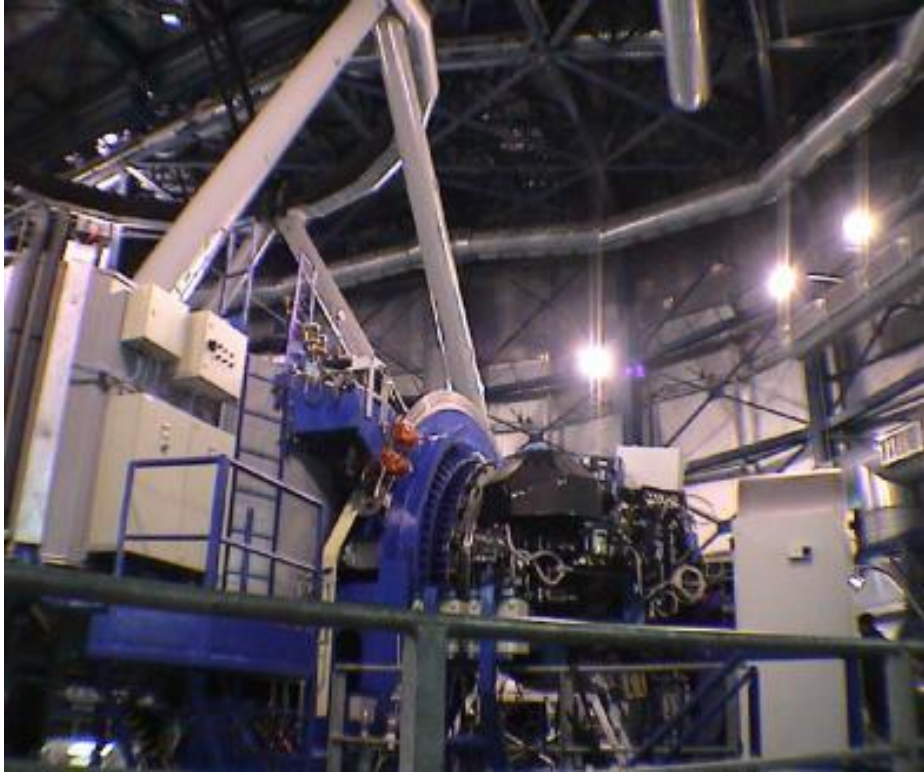
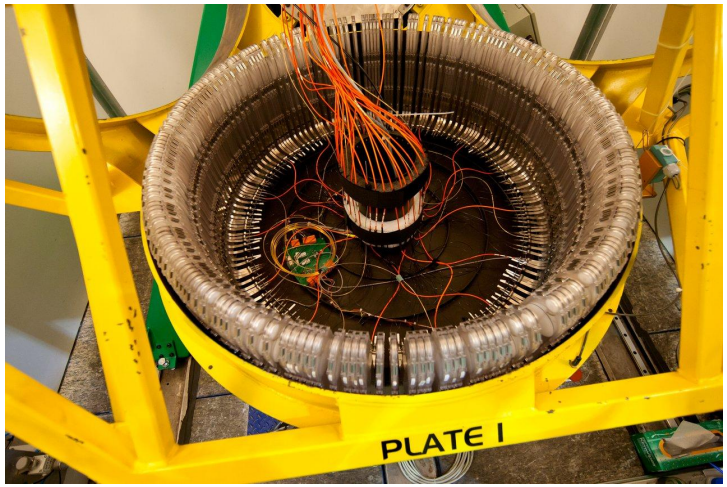
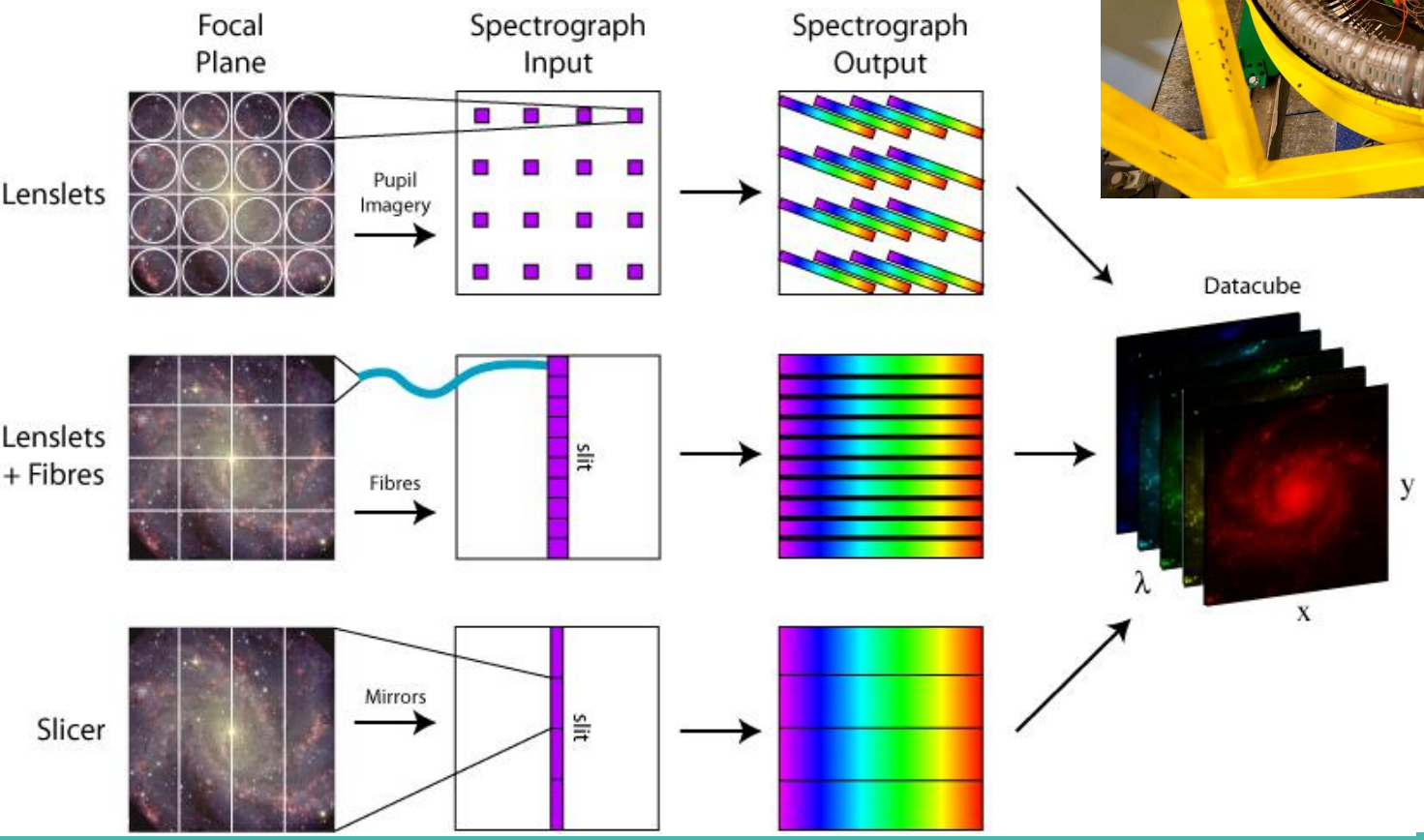



gAj0roMar1ogIfS

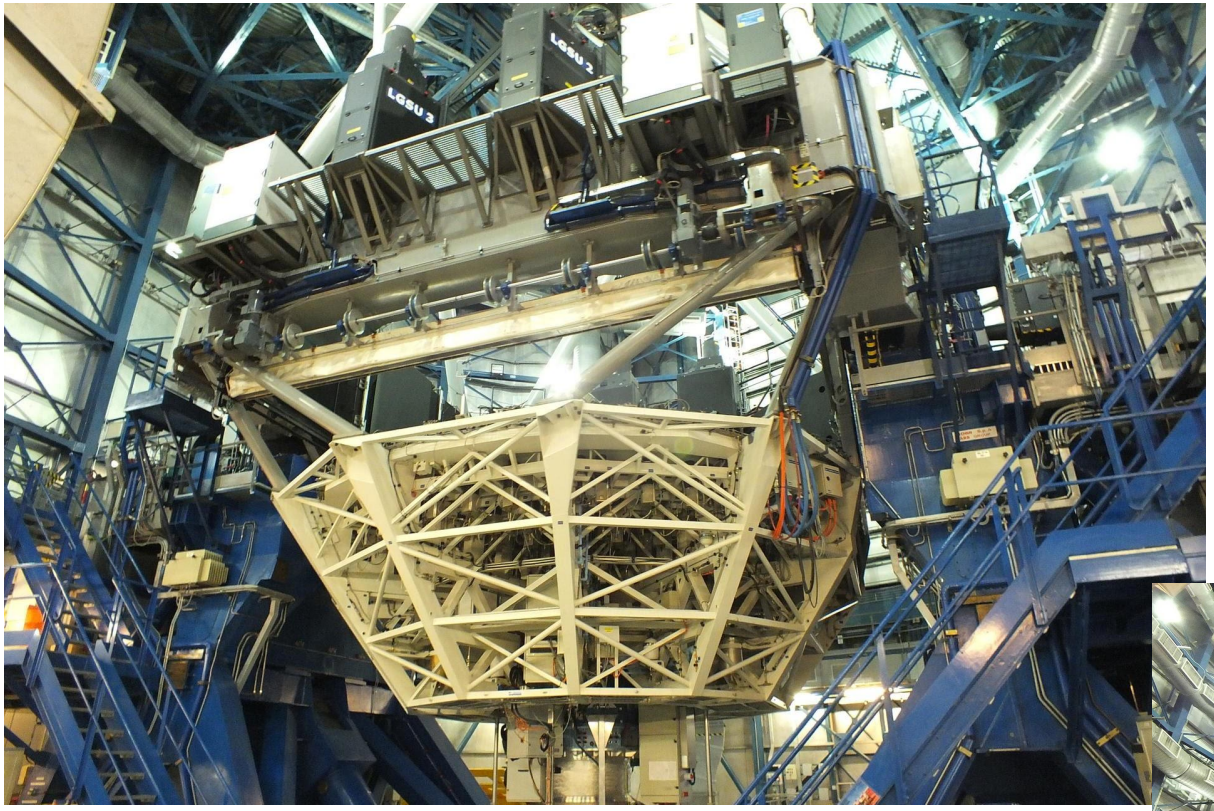
Espectroscopia de Campo integral

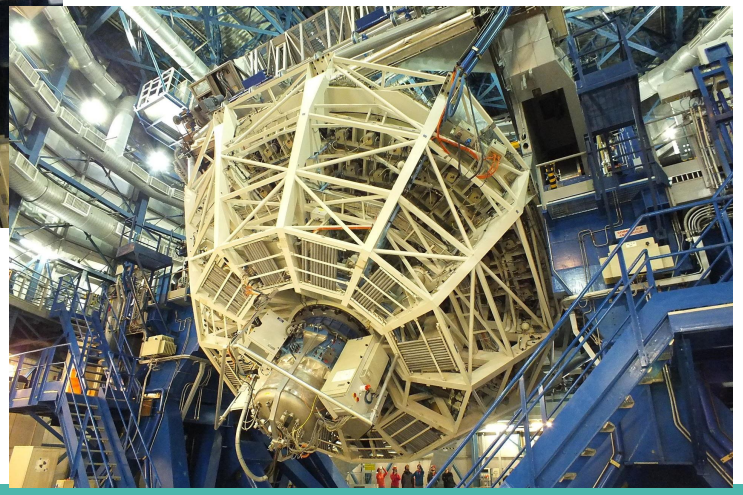




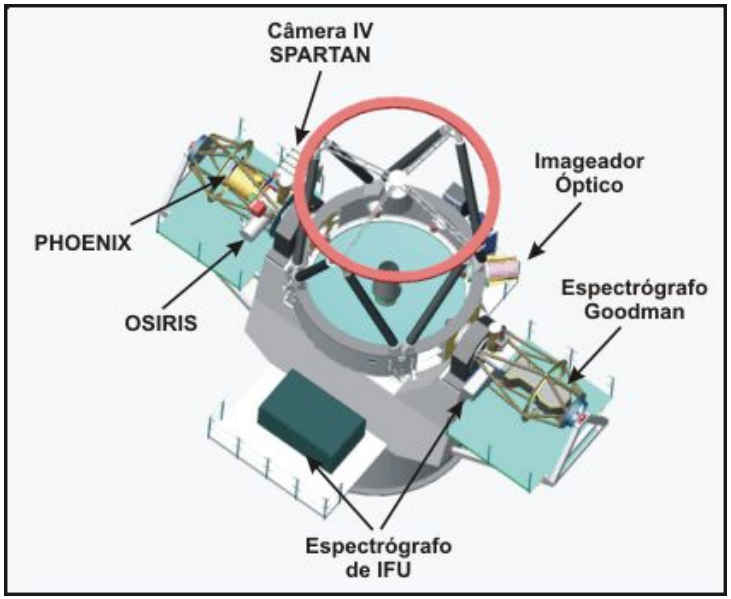
Espectrógrafos dos gigantes

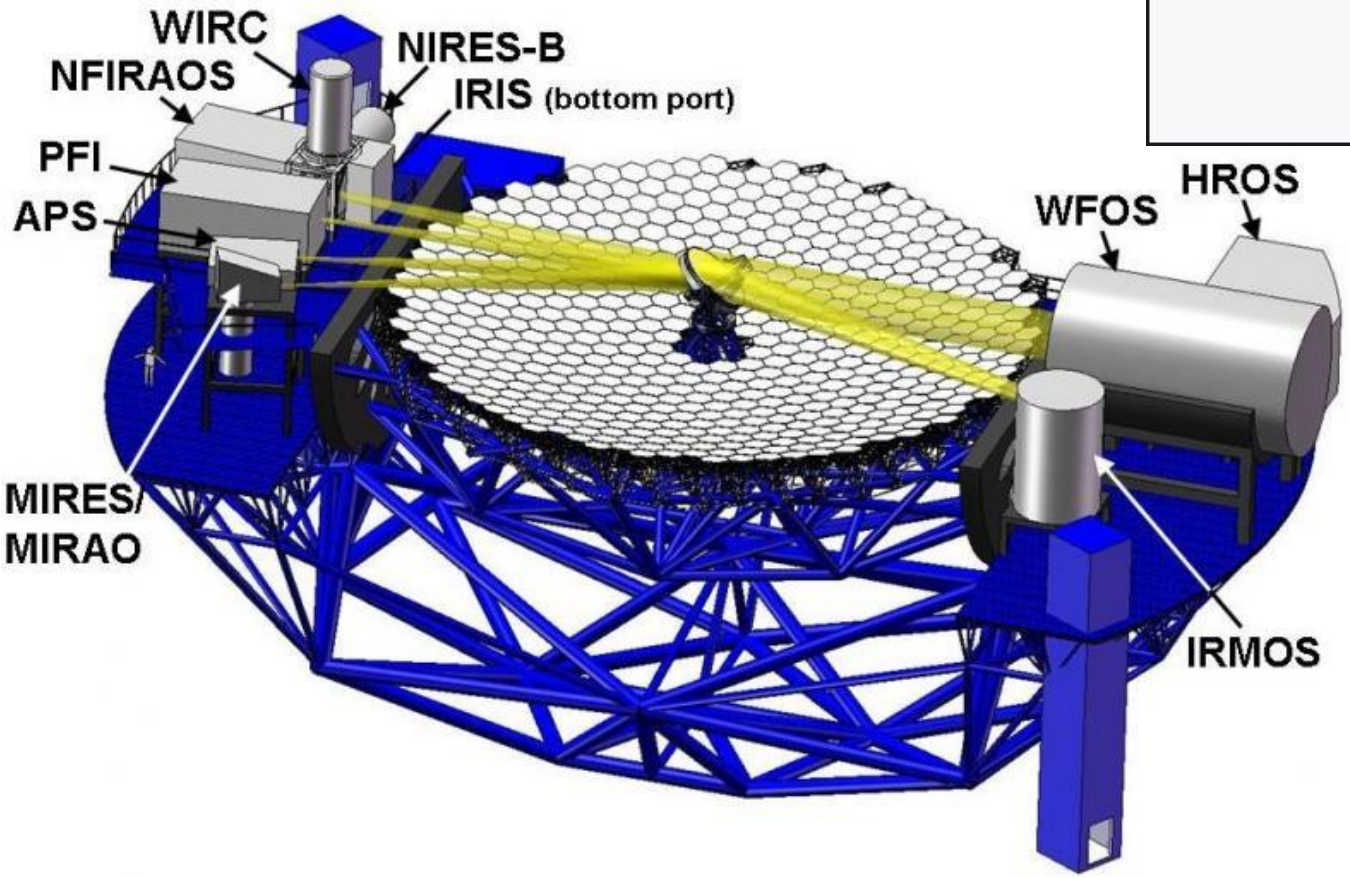
Onde vão os instrumentos?

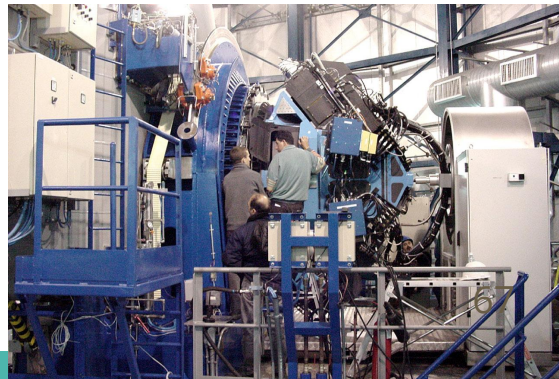




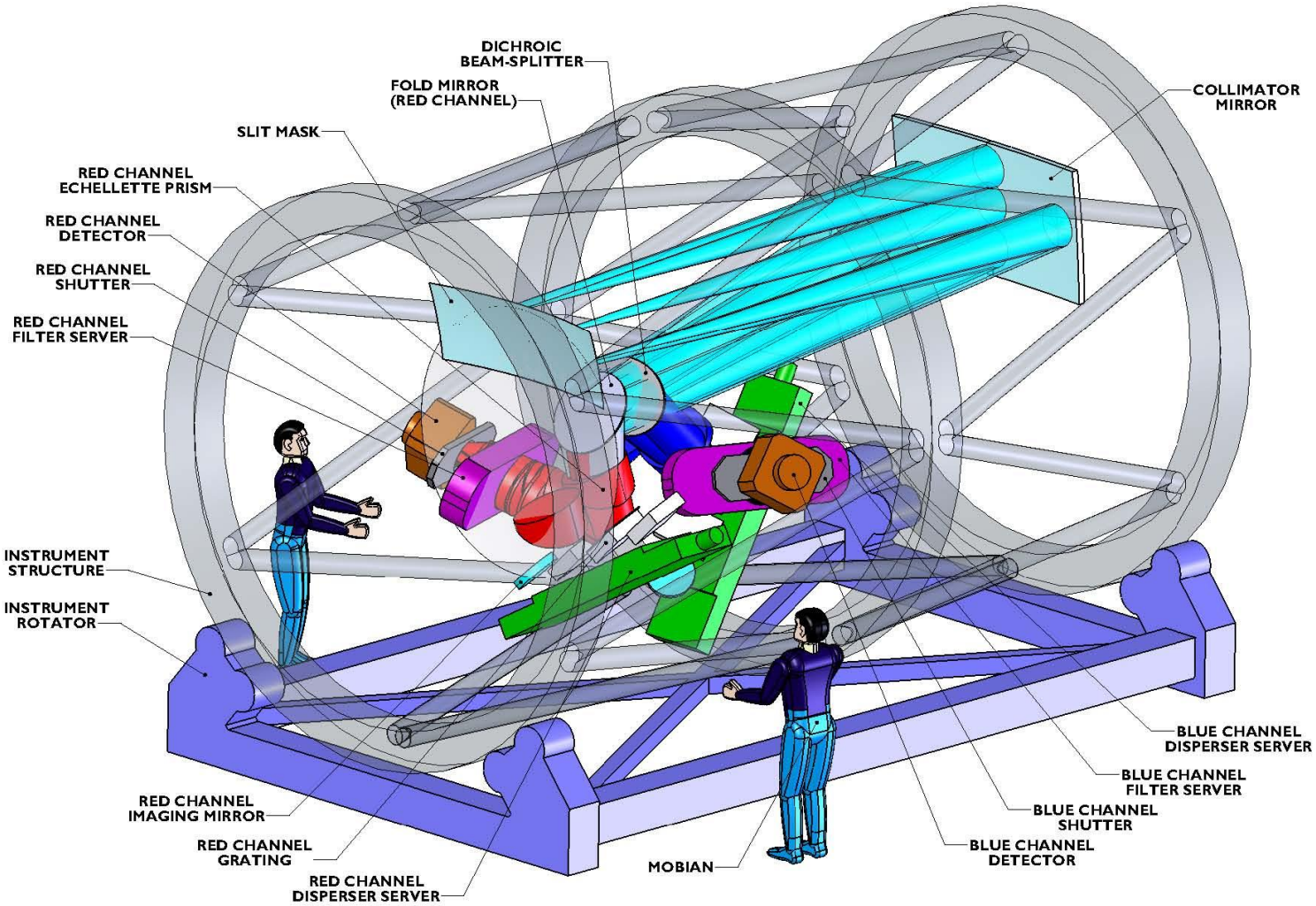
Onde vão os instrumentos?



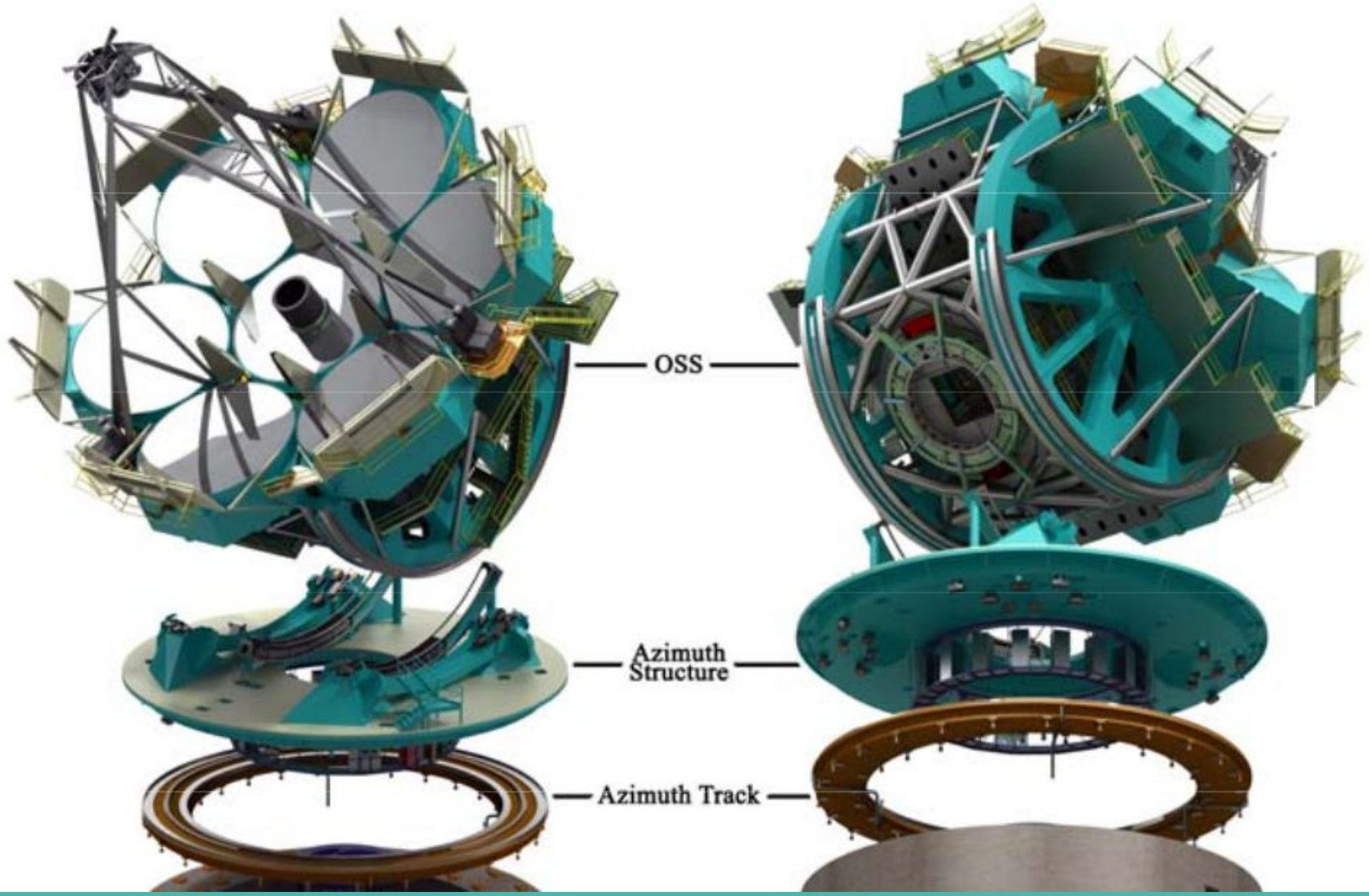




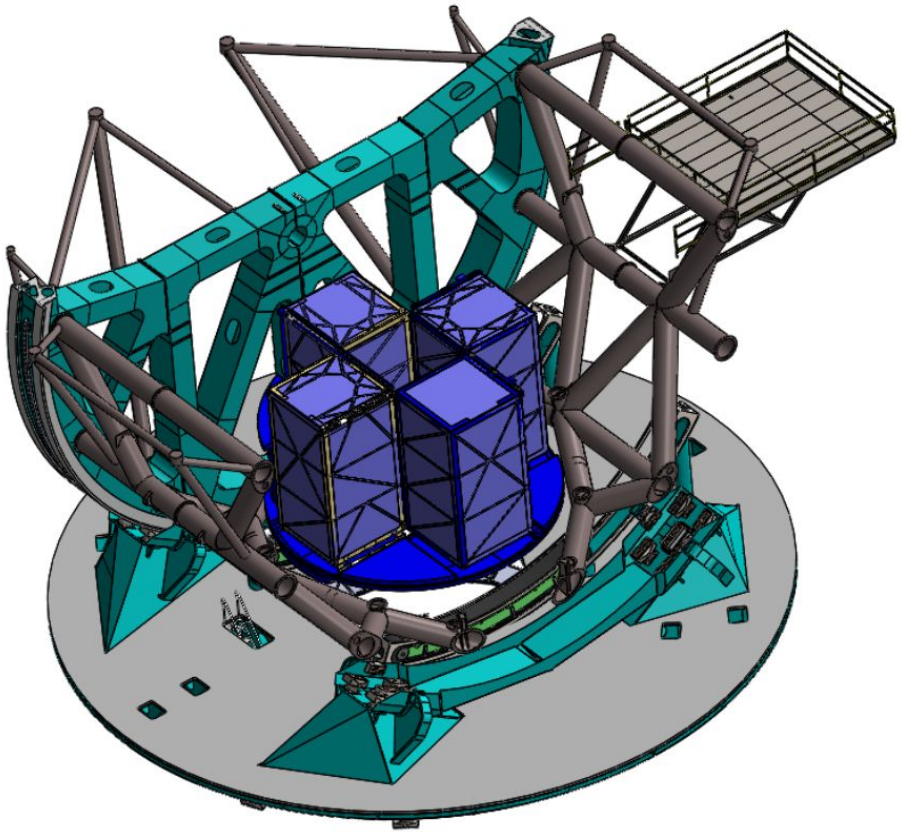
WFOS/MOBIE @TMT

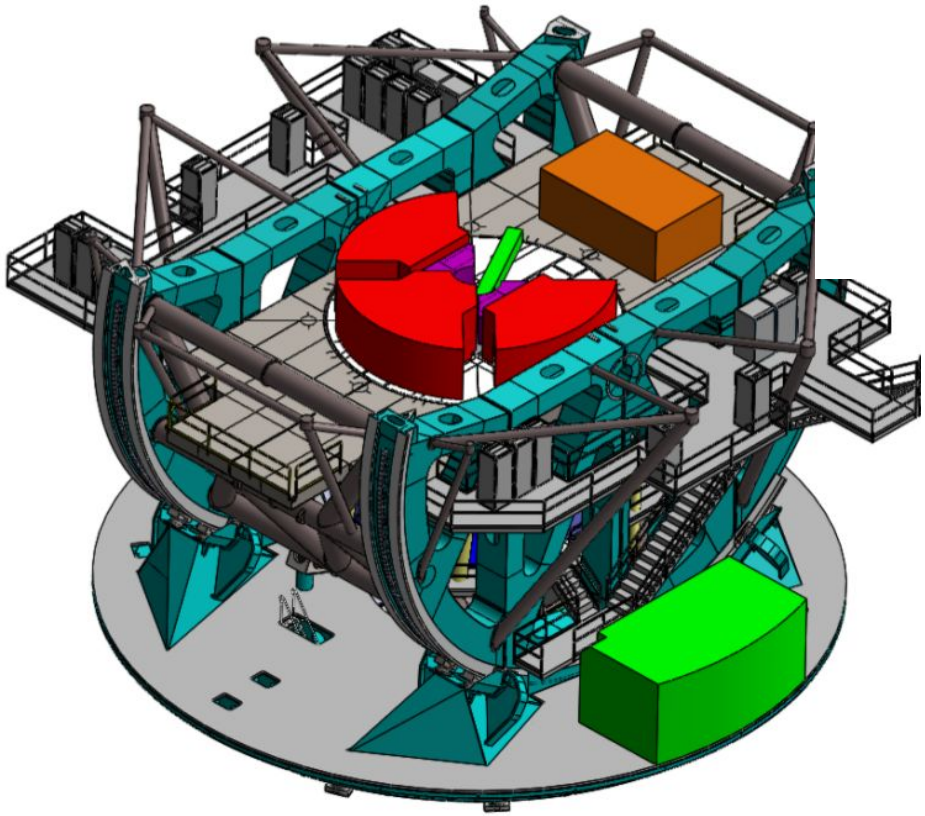


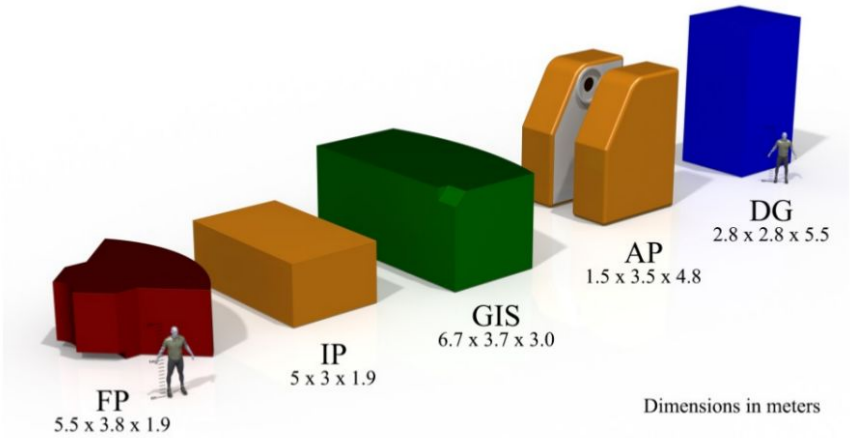
O GMT



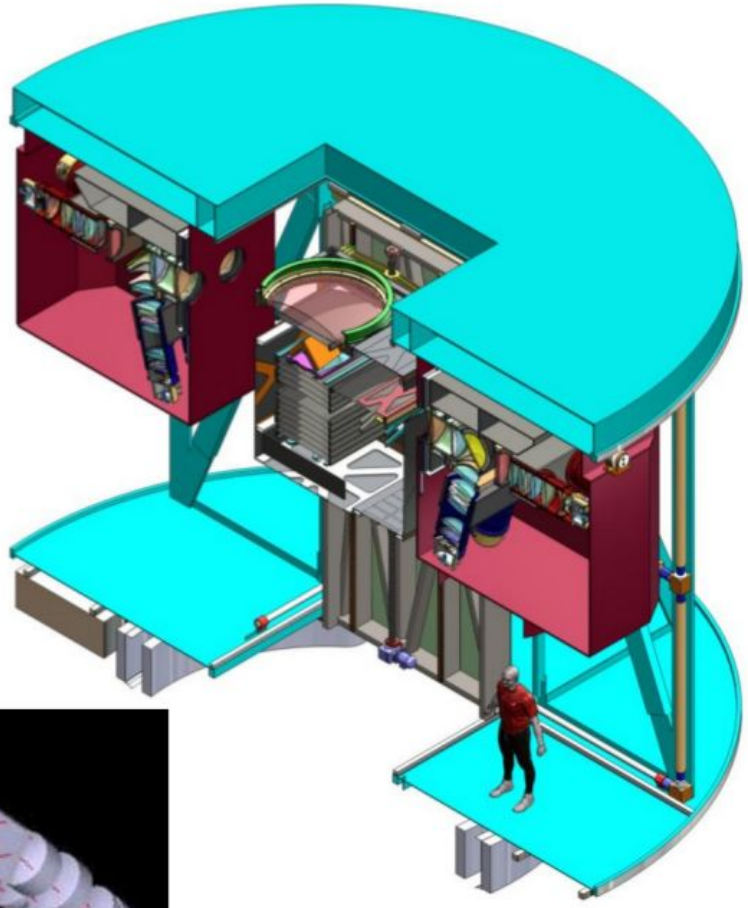
Instrumetos GMT

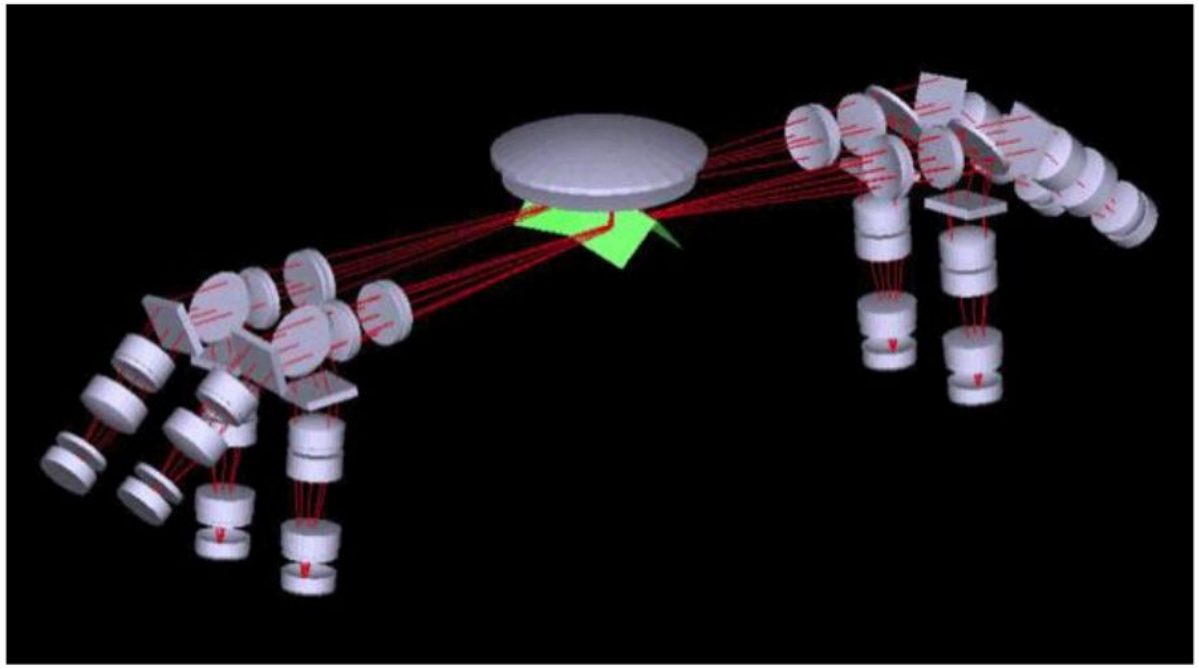




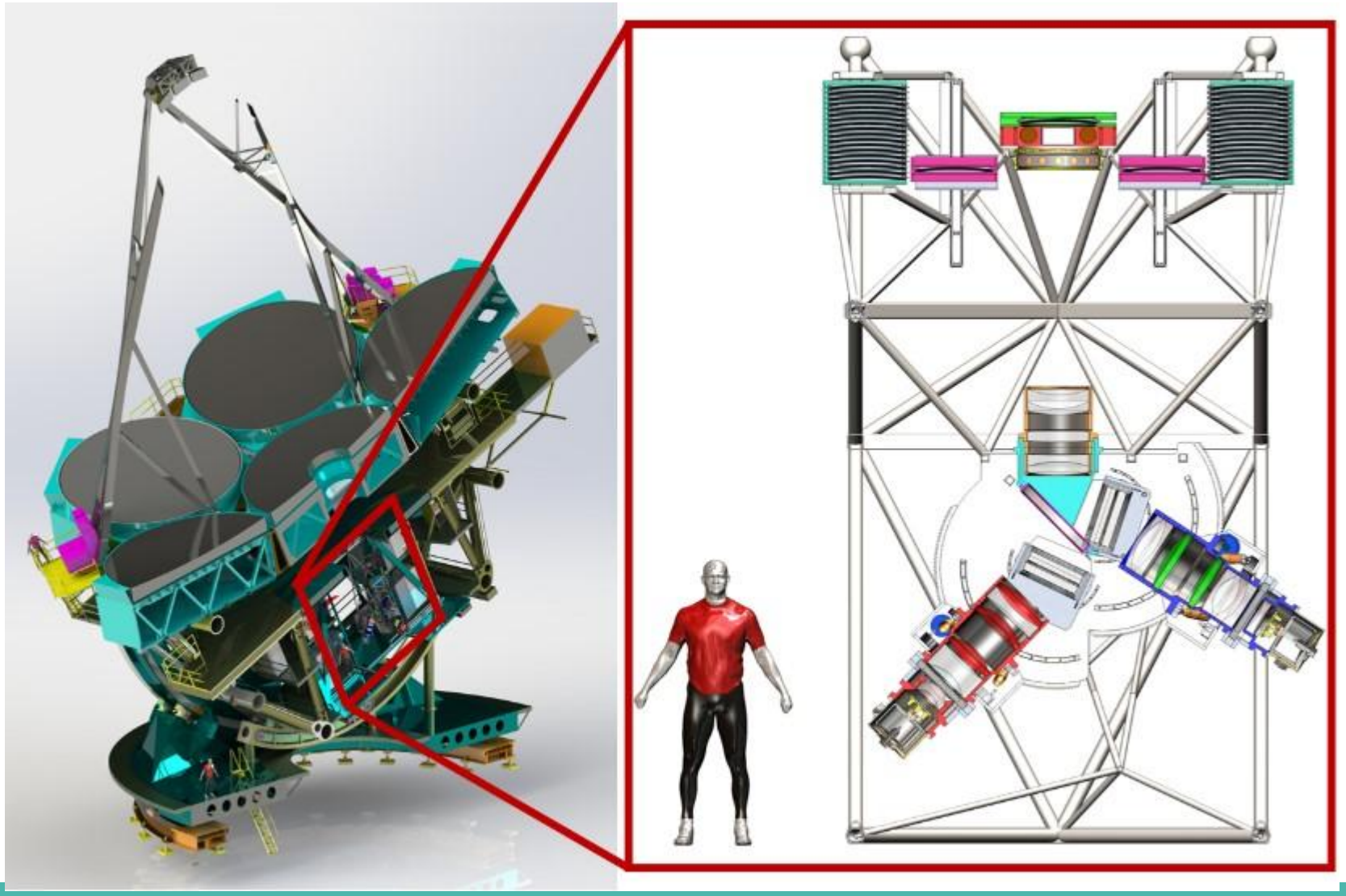


GMACS conceito inicial





GMACS @GMT



Desenvolvendo espectrógrafos

Feitos para durar

On the VLT the most requested ESO instruments for P100 were:

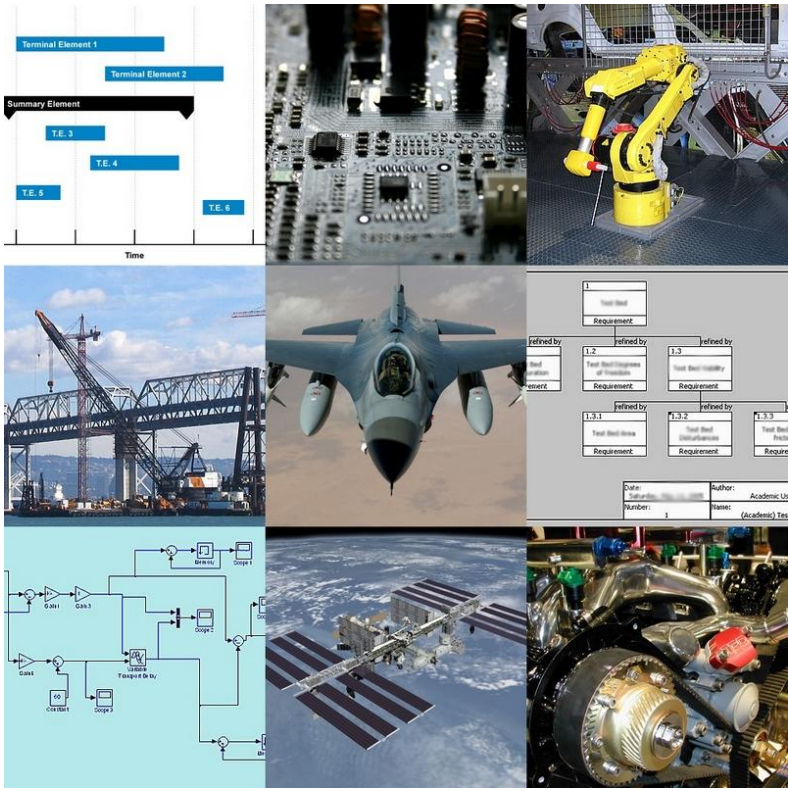
1) X-shooter (since 2009) = 287 nights

2) MUSE (since 2014) = 266 nights

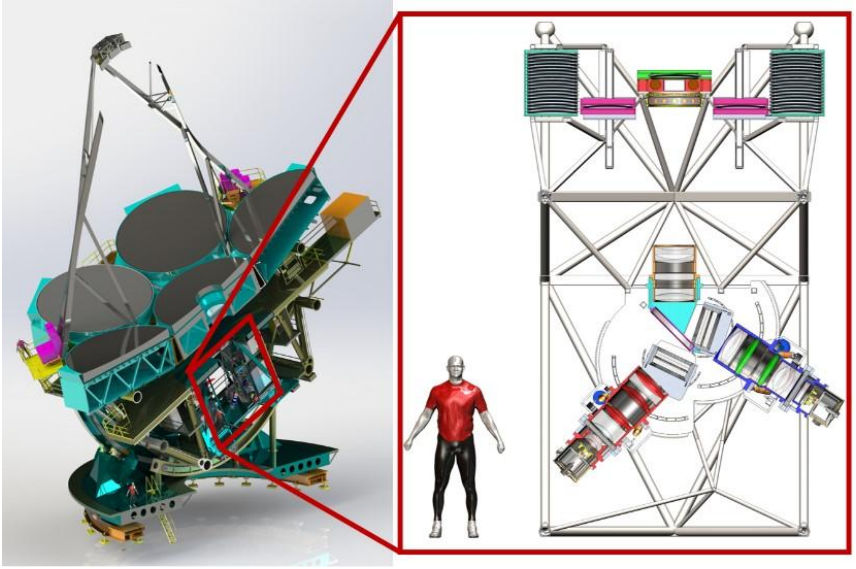
3) FORS2 (since 1998) = 196 nights

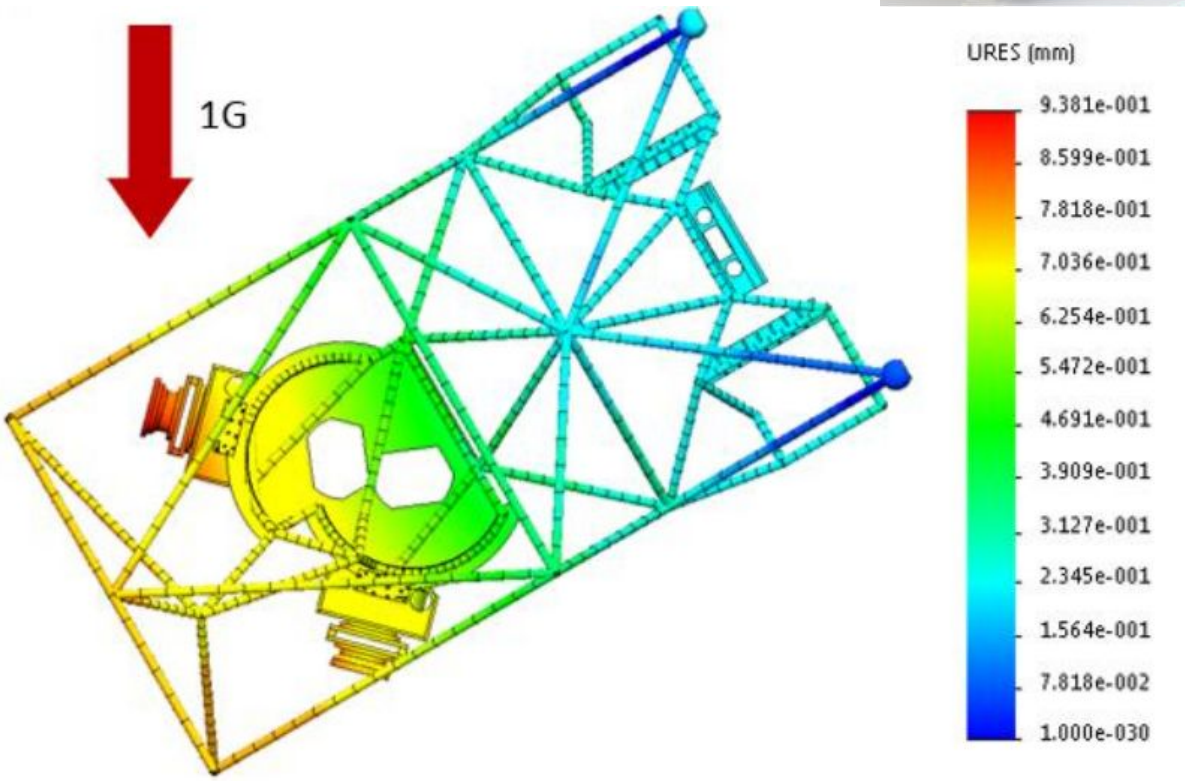
Engenharia de Sistemas

Engenharia de sistemas é um campo **multidisciplinar** de engenharia e engenharia de gerenciamento que foca em como desenvolver e gerenciar **sistemas complexos**.



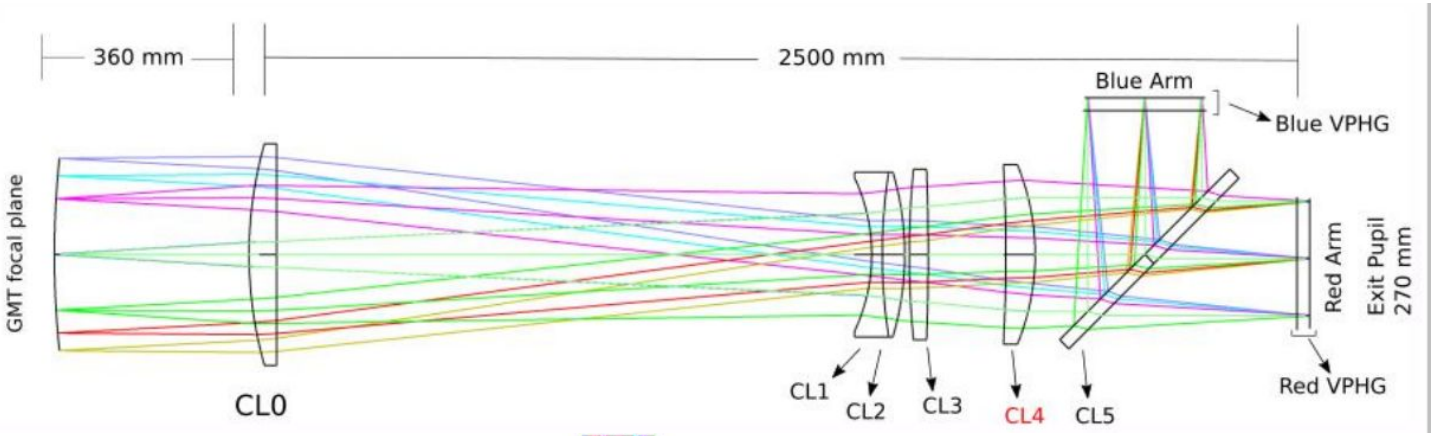
GMACS @GMT

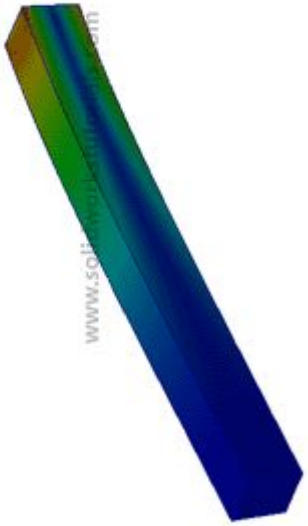


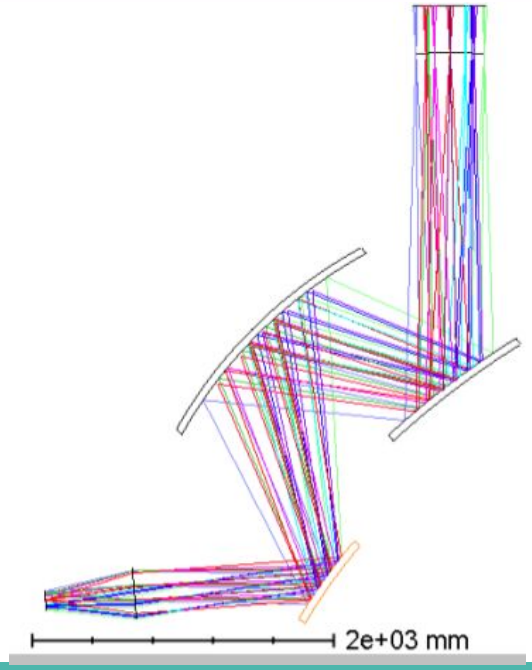


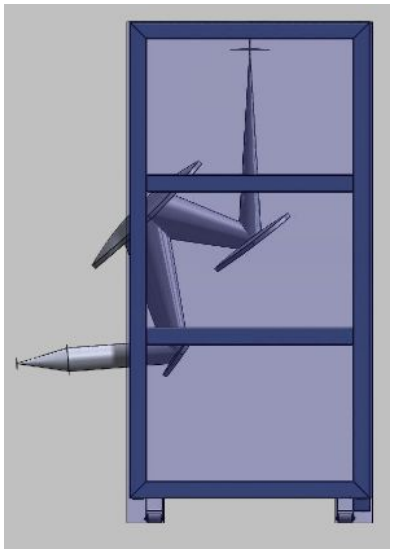
Resultant displacement of GMACS when it is rotated 60° about the X axis.

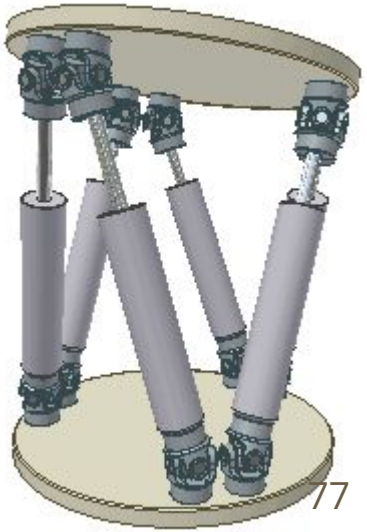
GMACS = Sistema complexo



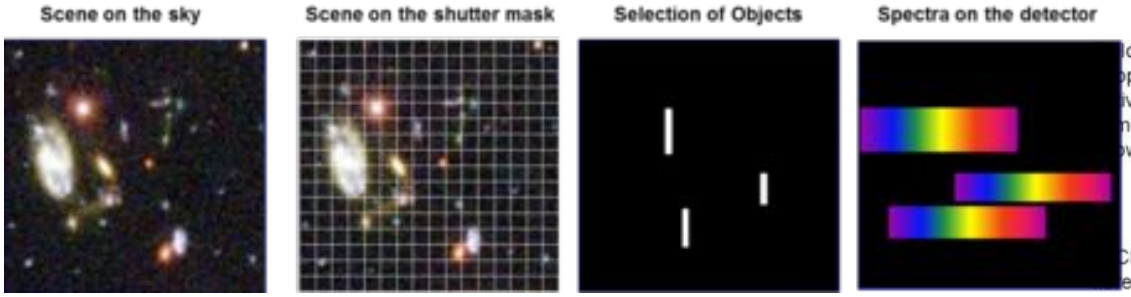


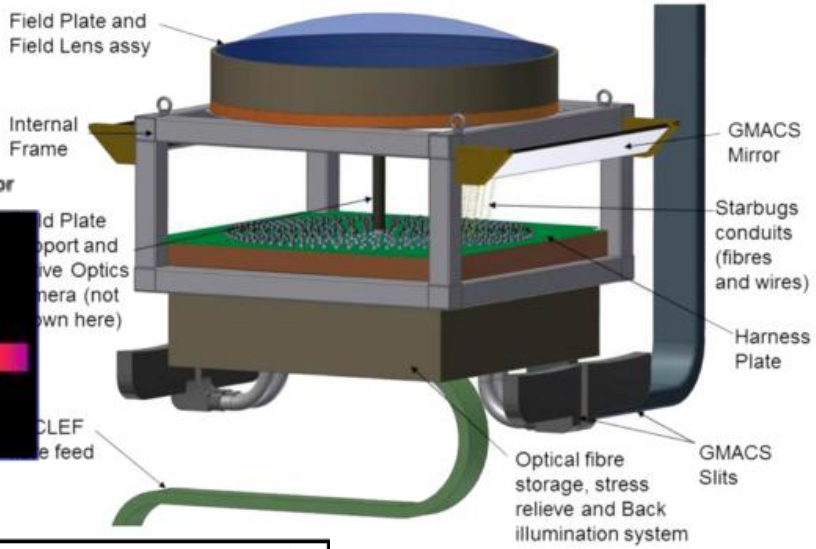


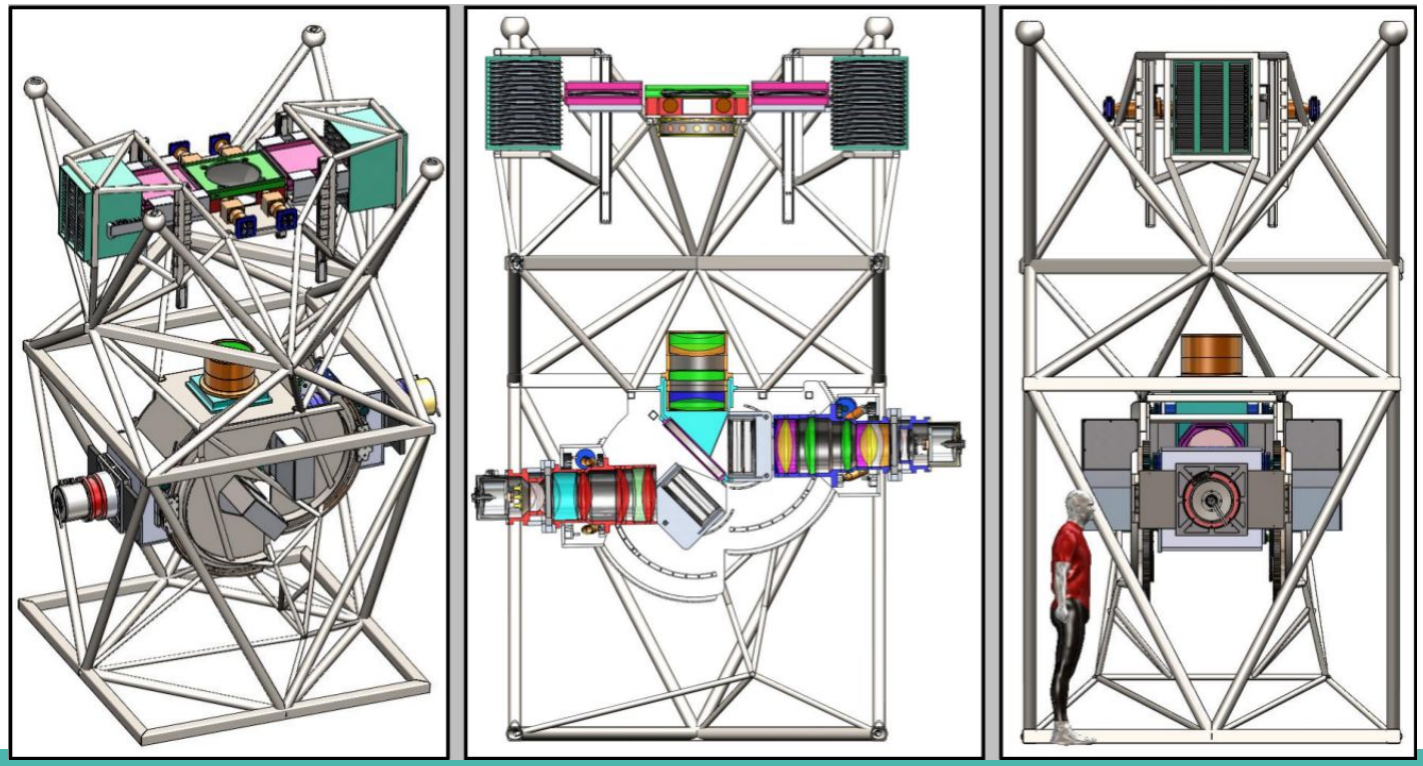




GMACS+MANIFEST







Sumário

Os observatórios

- Telescópios -- e seus instrumentos -- são projetos complexos e caros. Tempo de desenvolvimento típico de uma década. Planejamento e parcerias são fundamentais.
- “Tamanho é documento”. Em projetos de tecnologia de ponta e que envolvem múltiplas disciplinas: óptica, física, engenharias...
  "Cola" = engenharia de sistemas.
- Uma vez em operação, o observatório abre chamadas em função dos instrumentos disponíveis. A comunidade científica ligada ao observatório decidirá o que é prioritário -- e o que não é.
- A noite de observação inicia-se bem antes, com planejamento dos instrumentos, julgamento dos trabalhos, e posição dos astros na época do ano.

A noite do astrônomo profissional

- Existem dois tipos de noites de observação: a de execução do observatório (“fila”) e a de execução do astrônomo (“clássico” ou “visitante”).
- O que o astrônomo vê depende muito do tipo de instrumento que usa -- que depende da ciência que quer fazer. São imagens “feias”, em preto e branco e que só “fazem sentido” depois de análises posteriores.
- A década de 2020 promete a inauguração dos telescópios gigantes, cujo planejamento já ocorreu e os trabalhos da primeira geração de instrumentos já está em andamento.
- Seja um dos futuros **usuários** destes telescópios!
- Ou, ajude a **construí-los**!

Ser astrônomo

Como você pensou que era:

Como seus pais pensam que é:

Como as pessoas pensam que é:

Como realmente é: