High Energies and the other wavelengths: problematics and prospects of observations at UV, Optical, Infrared and Radio wavelengths

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OUTLINE and GOALS

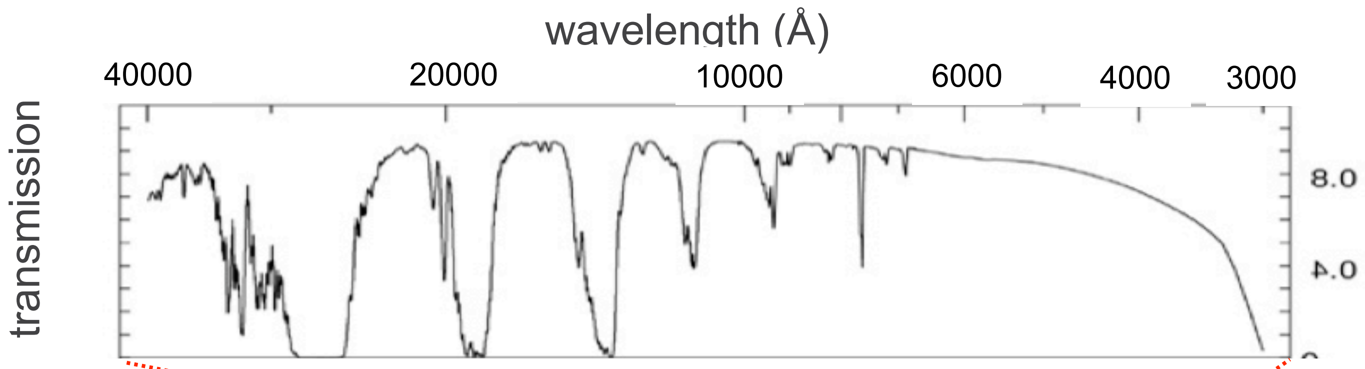
- Provide an overview of the problematics of observations

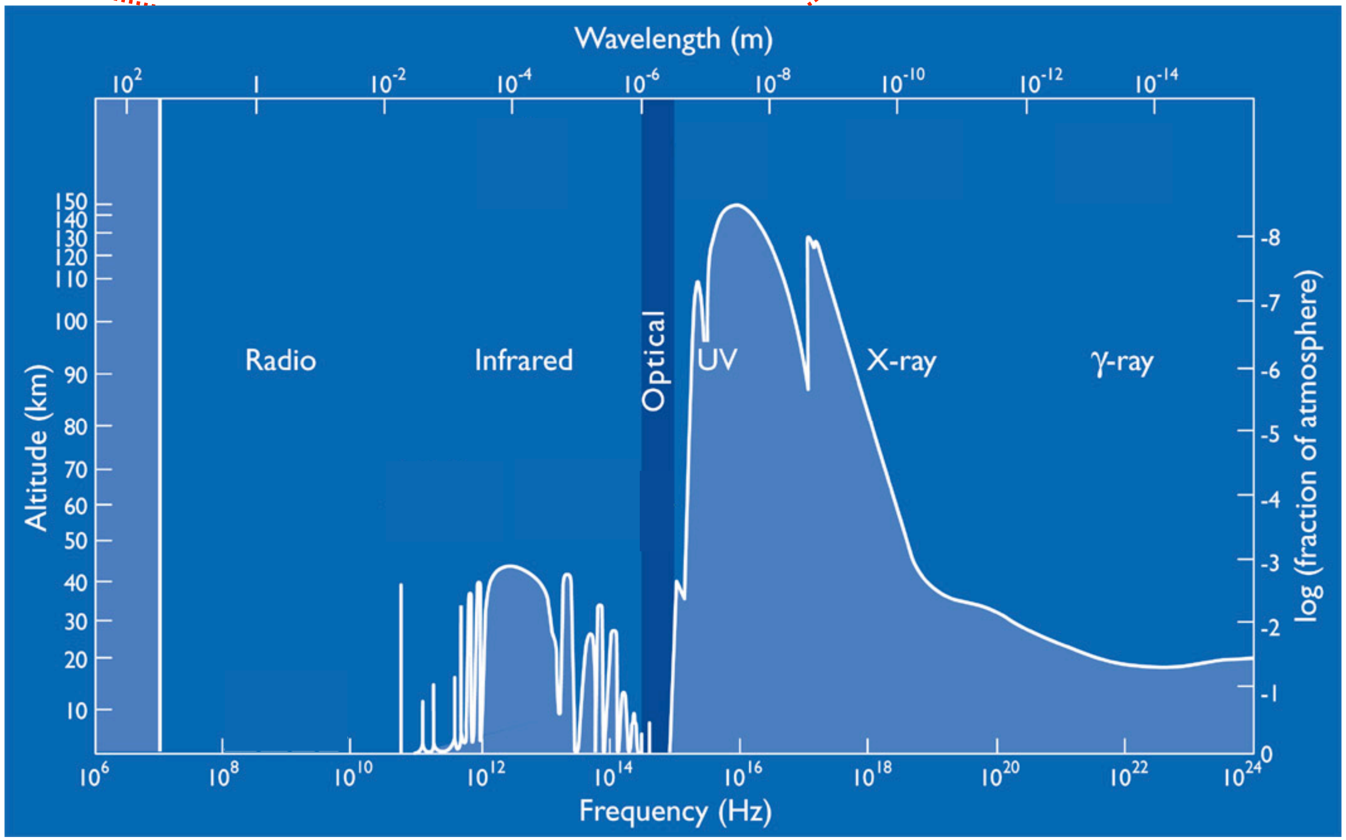
- Provide an overview of current
  Multi Wavelength (<100 eV) facilities

- Provide an overview of future/planned
  Multi Wavelength (<100 eV) facilities

(WARNING: really shallow and incomplete overviews,
far from being exhaustive)

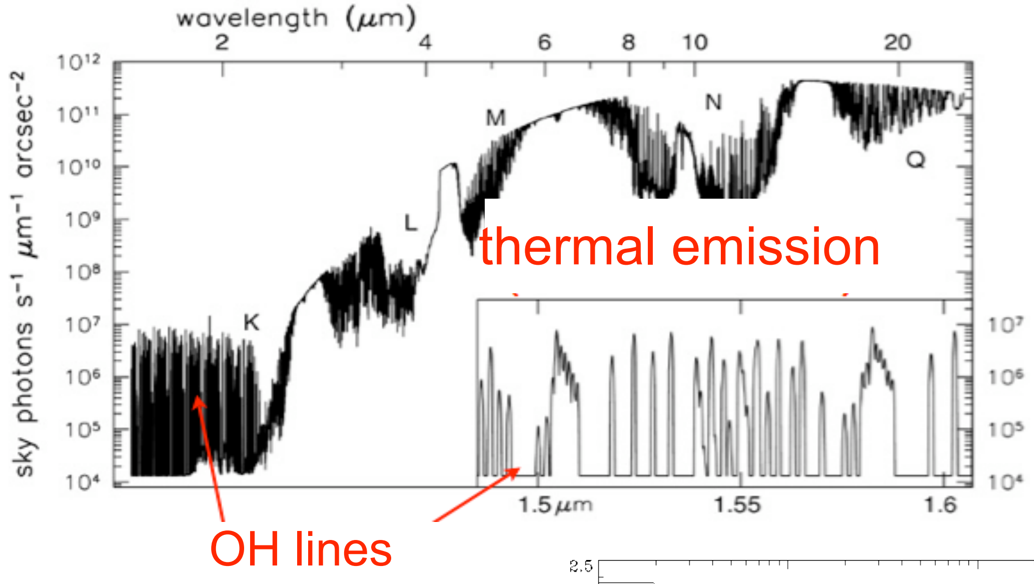
Atmospheric transmission



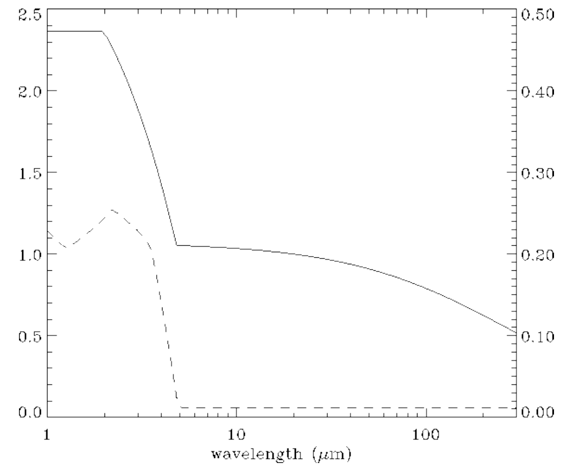


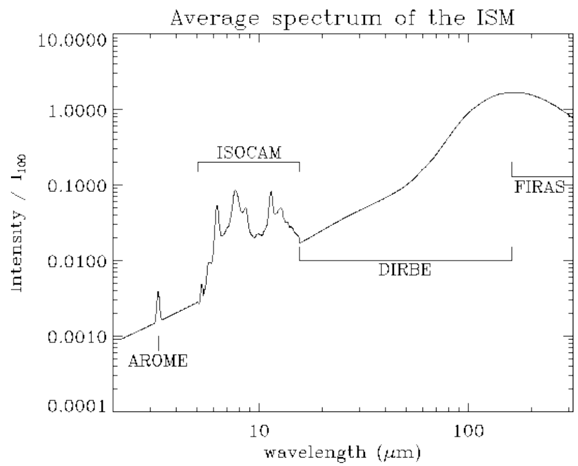
Background (Foreground) emission

From ground:
- Moon scattered light
- OH emission lines
- Thermal emisison



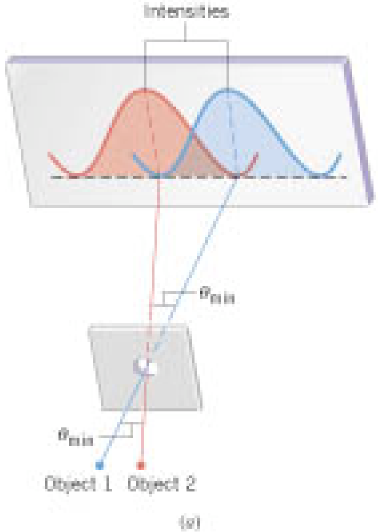
From space:
- Thermal (if telescope not cooled)
- Zodiacal light
- IR cirrus
- CMB

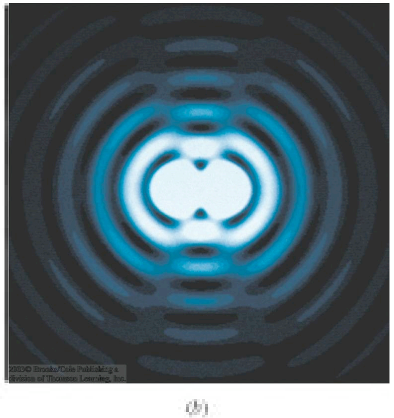




Angular resolution

Diffraction limit

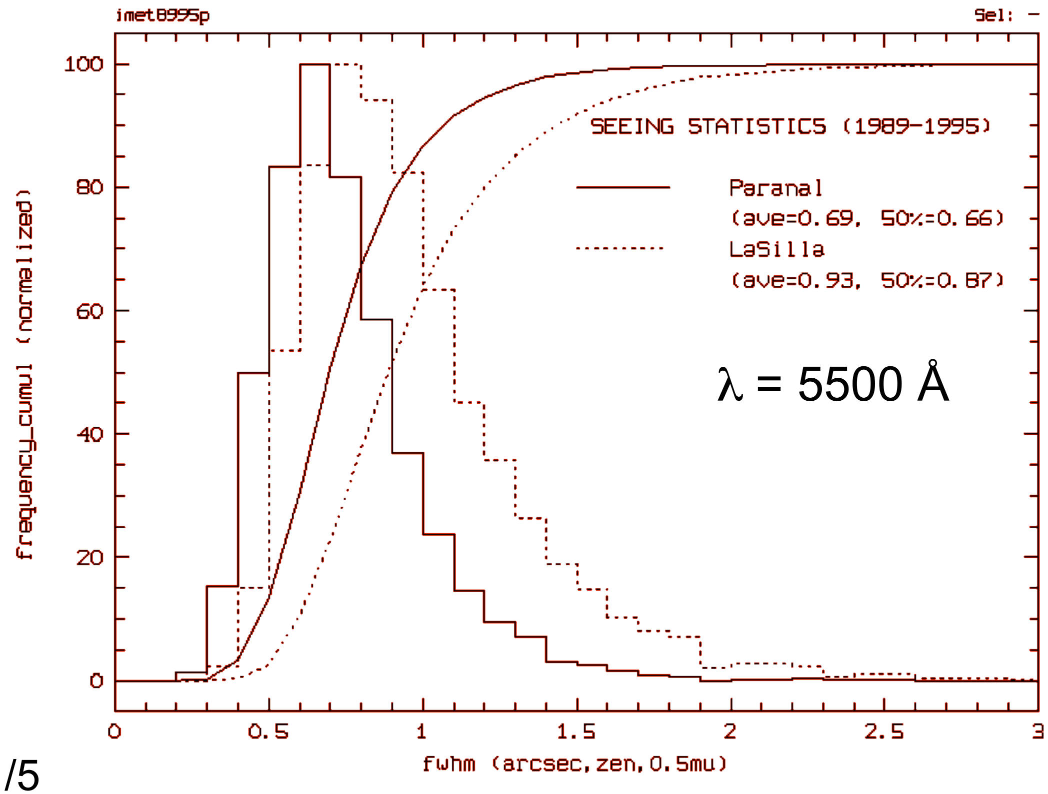




$$\theta_{min} = 1.22\,\frac{\lambda}{D} = 0.07''\left(\frac{\lambda}{2.2\mu m}\right)\left(\frac{D}{8m}\right)^{-1} = 8''\left(\frac{\lambda}{1mm}\right)\left(\frac{D}{30m}\right)^{-1}$$

Angular resolution

Seeing limit



Seeing scales as $\theta_{seeing} \propto \lambda^{-1/5}$

At λ > ~10μm relatively easy to reach the diffraction limit even at 8m class telescopes (θ_{seeing} <0.4”, $\theta_{diff.}$>0.3”)

At λ < ~ 10μm reaching the diffraction limit requires space observatories or the use of Adaptive Optics tecniques

Current (-forthcoming) UV missions

(atmosphere opaque -> need to observe from space)

HST

WFC3

high sensitivity imaging
angular resolution ~0.02"

COS

high sensitivity spectroscoy
λ ~ 1000-3000 Å
R~20,000
(post-FUSE)

GALEX

50 cm telescope
λ ~ 1300-3000 Å

All-sky survey

Future UV missions

World Space Observatory / Ultraviolet (WSO/UV)

1.7 m telescope

Spectroscopy and Imaging $\Delta\lambda$ = 100-320 nm

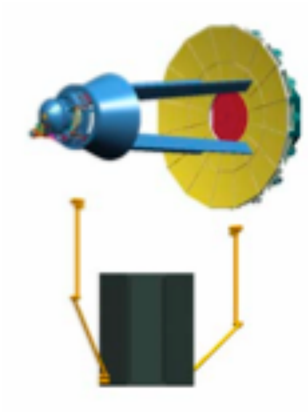
Launch ~ 2011

Modern Universe Space Observatory (MUST)

10 m telescope

UV-Optical imaging and spectroscopy

Launch ~ 20??

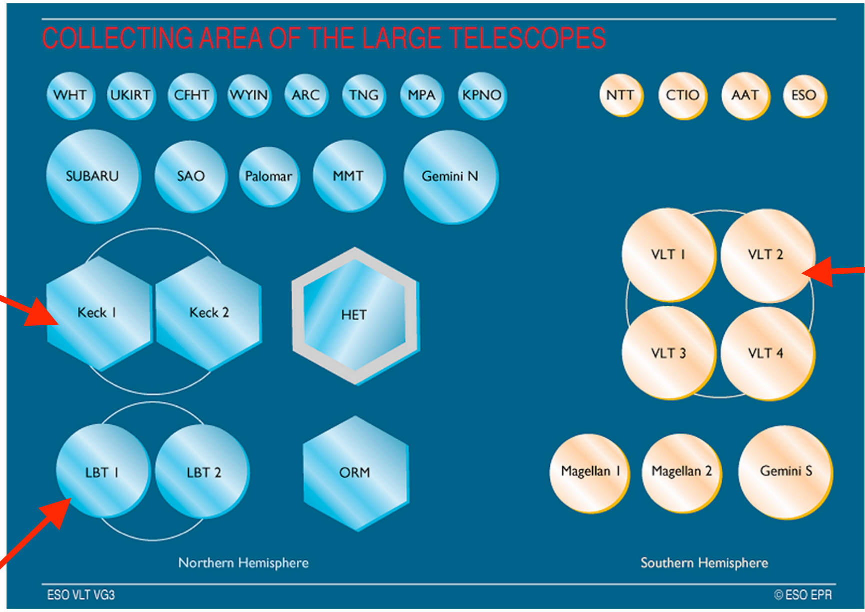


Current (-forthcoming) Optical/near-IR telescopes

HST

WFC3 + ACS : the most sensitive cameras at $\Delta\lambda$ = 2000 Å - 1.7μm

Groundbased



segmented

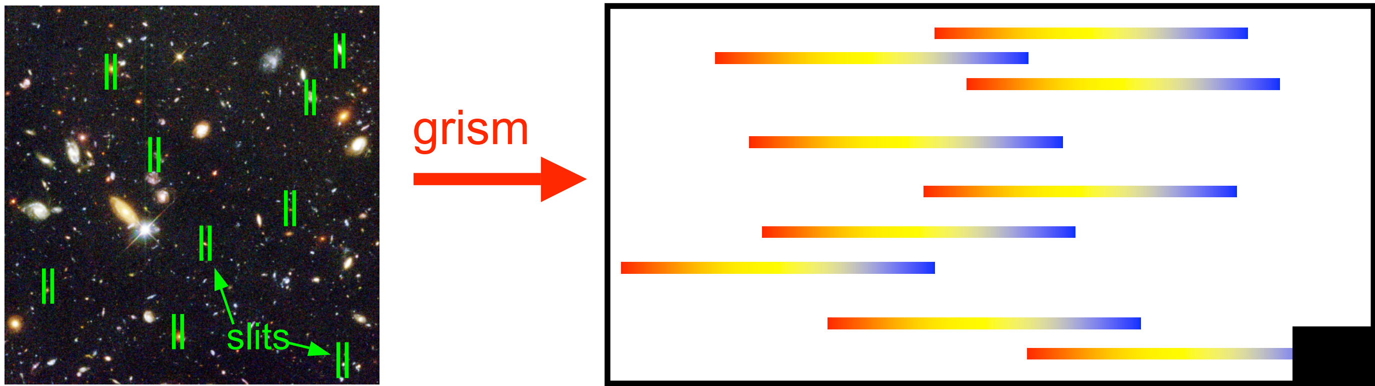
honeycomb

thin + active optics

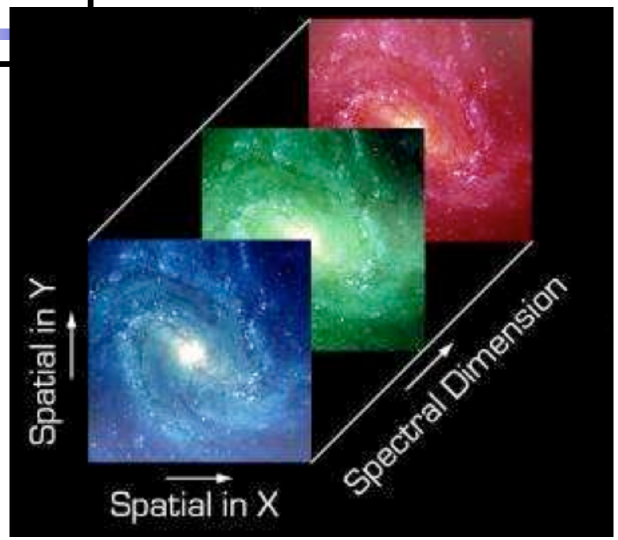
Current Strategic Optical/near-IR instruments

Wide-Field Imagers, at 8m telescopes
and survey-dedicated telescopes (SDSS,VISTA,...)
-> wide/deep multicolour surveys

Multi-Object Spectrometers: up to a few 1000 spectra
in one shot within a field of view of several arcmin^2
(first near-IR MOS' in operation)



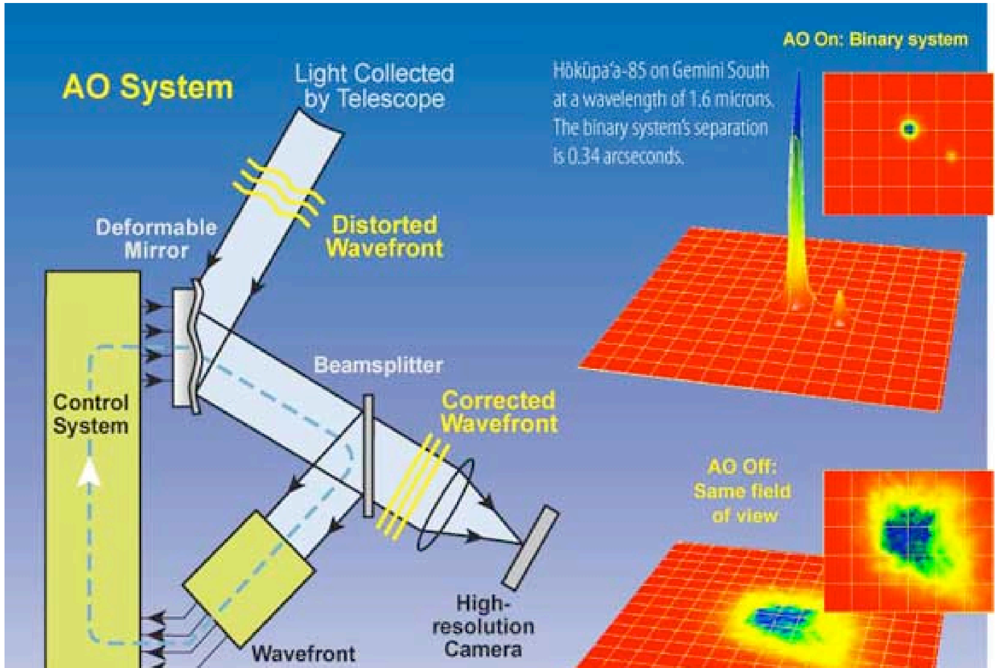
Integral Field Spectrometers:
two-dimensional spectroscopic information

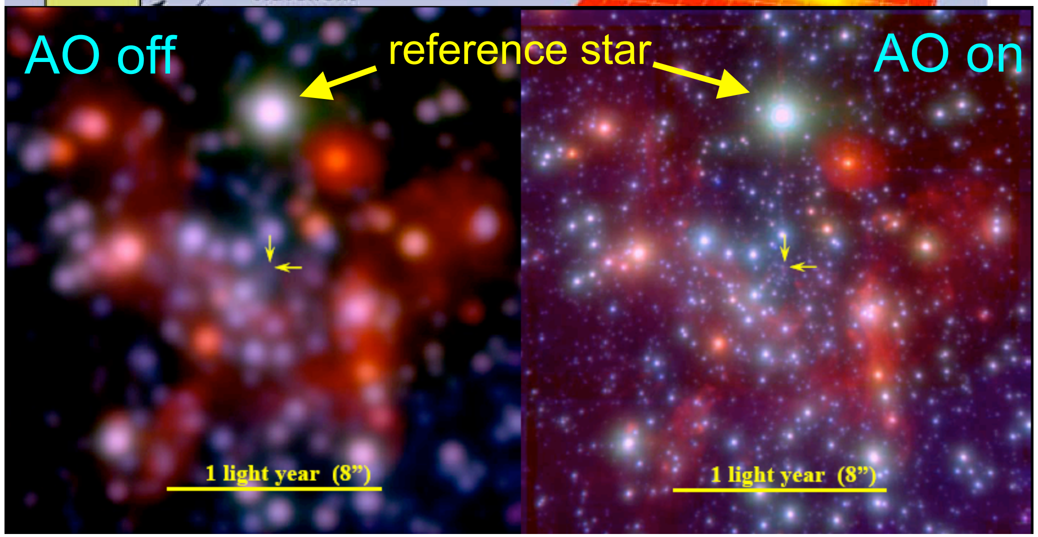


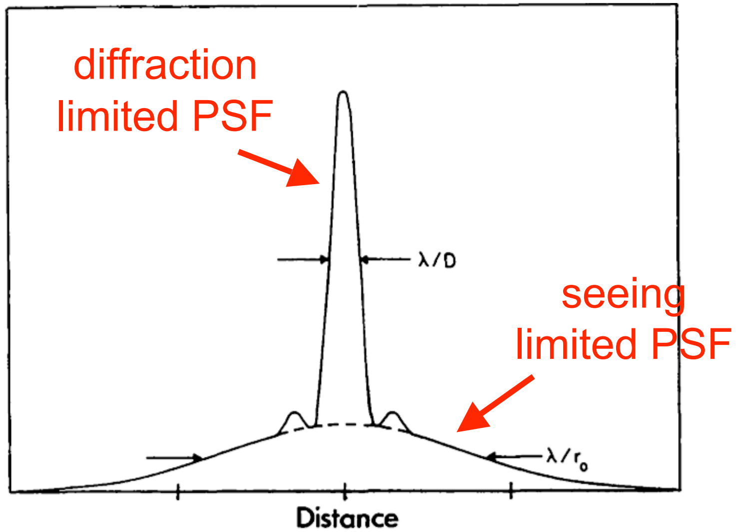
Current Strategic Optical/near-IR instruments

Adaptive Optics

(partly) correct the turbulence introduced by the atmosphere by exploiting a (bright) reference next to the target





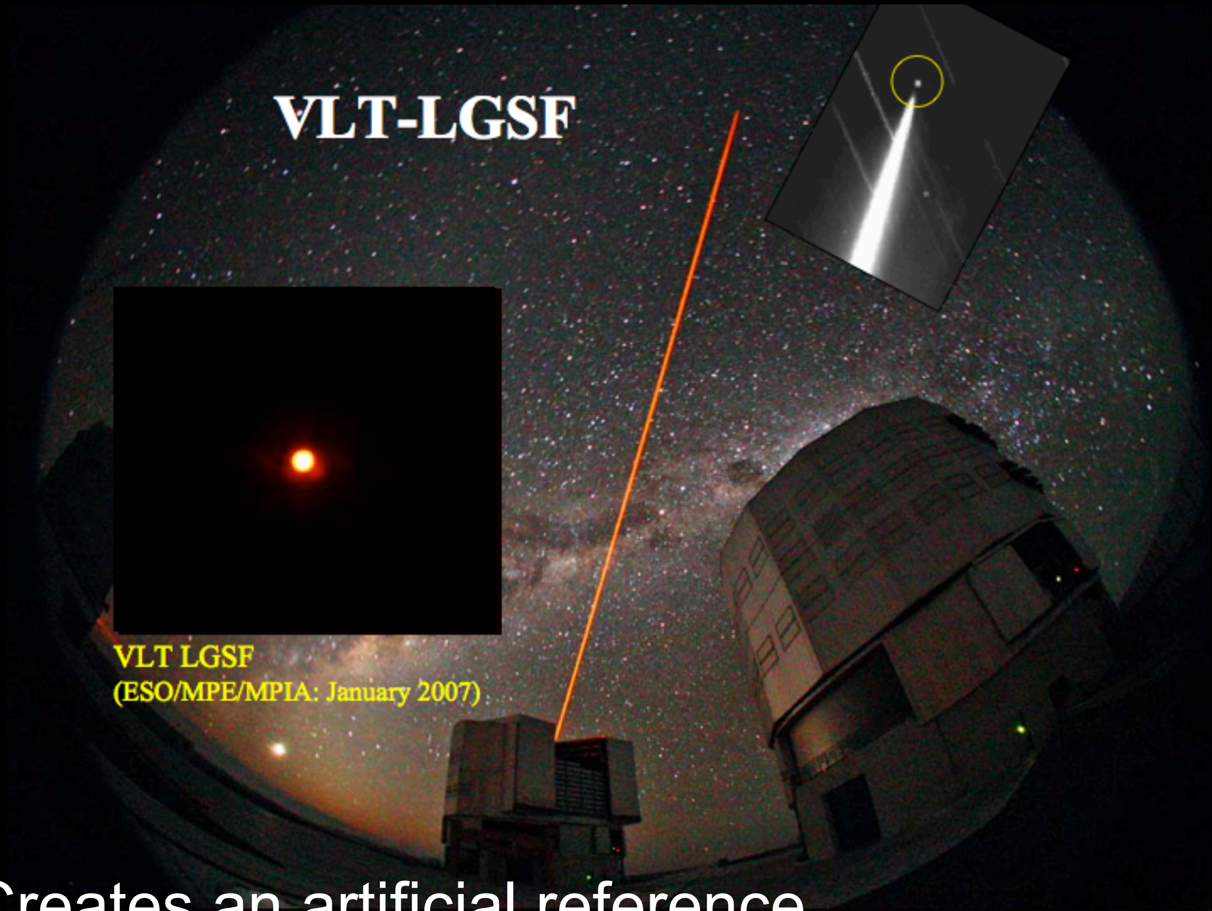


Can rescue part of the diffraction-limited PSF

Not only increased resolution but also higher sensitivity

Current Strategic Optical/near-IR instruments

Adaptive Optics + Laser Guide Star



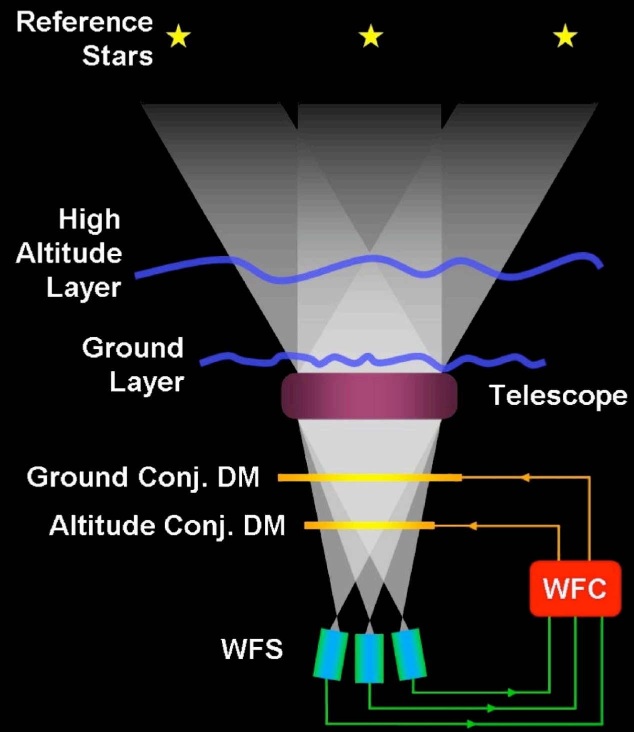
Creates an artificial reference star -> allows to extend the use of AO even far from bright natural stars

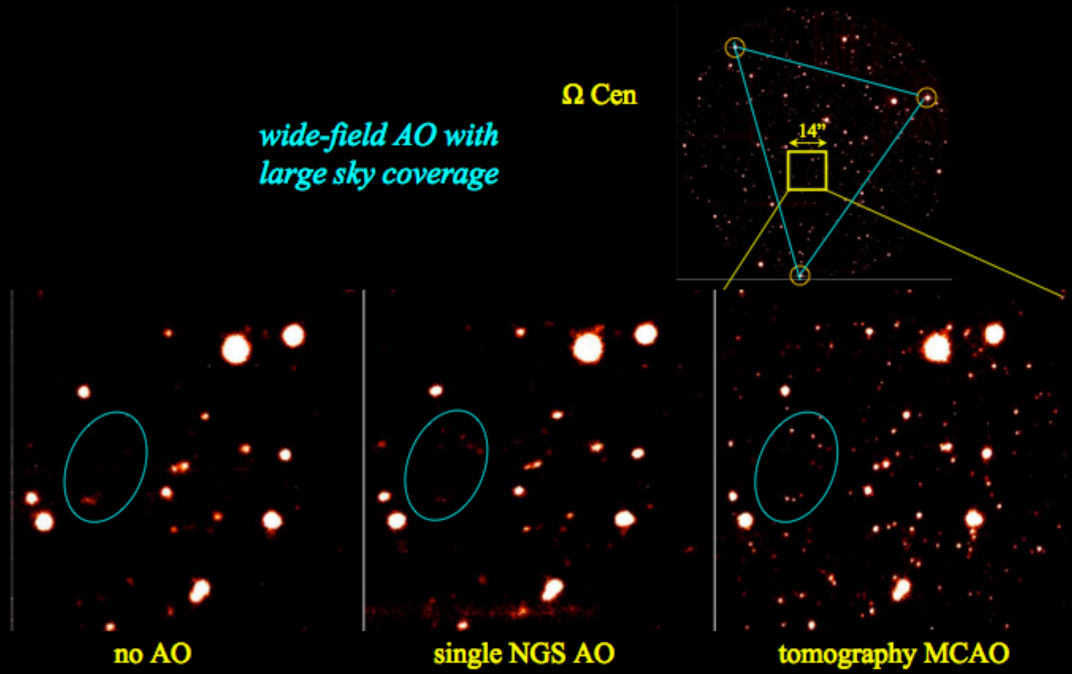
Issue: relatively small corrected field (~20” around reference star)

Current (-forthcoming) Strategic Optical/near-IR instruments

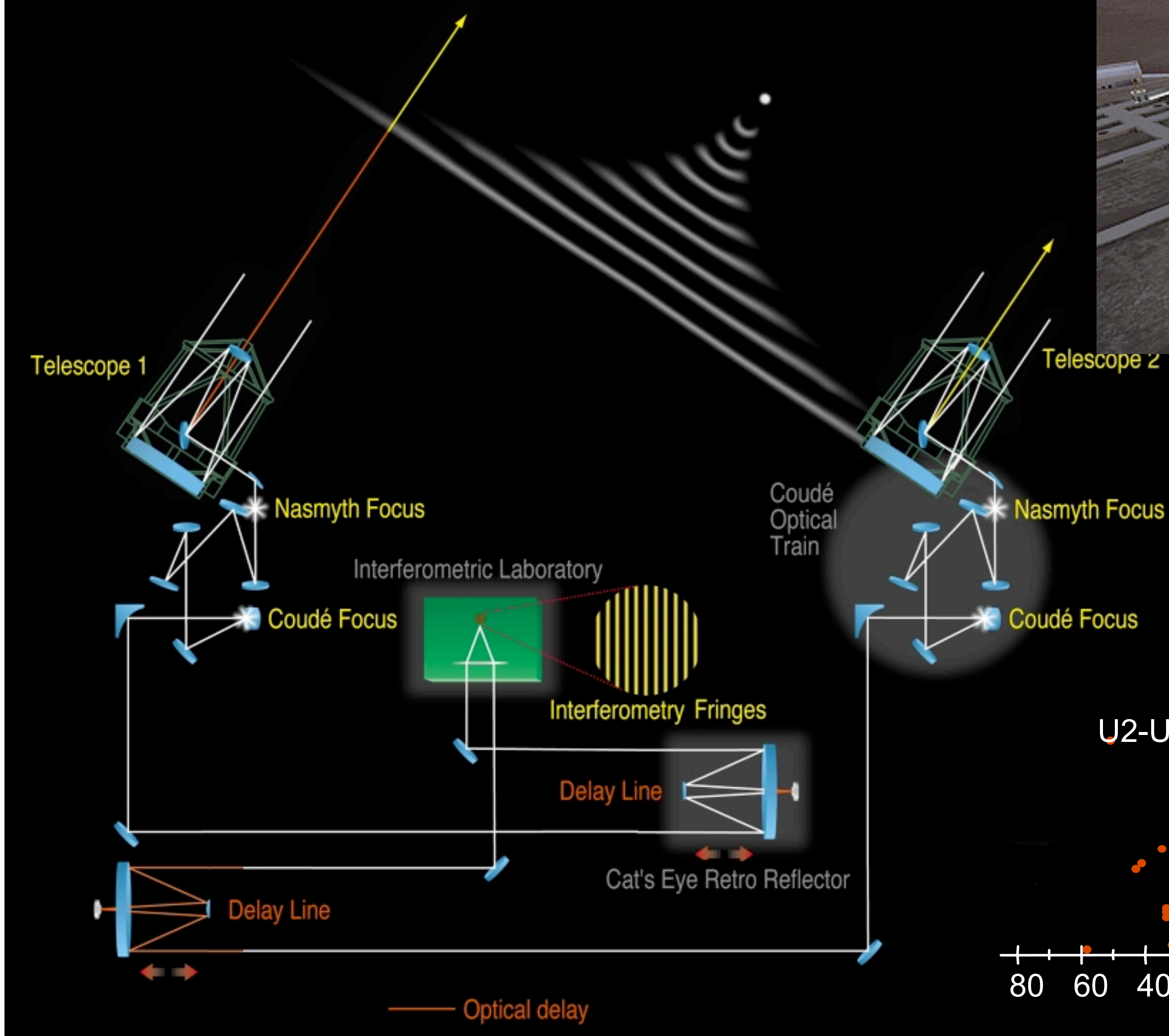
MCAO

Use multiple reference stars or multiple lasers to expand the corrected field

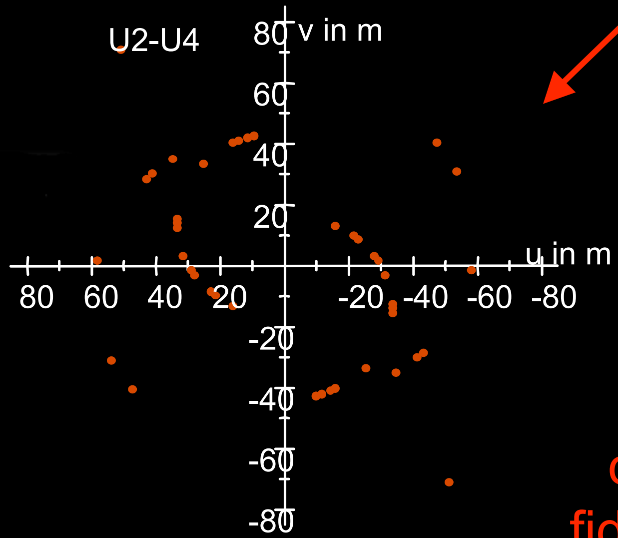




Infrared (-optical) Interferometry



VLTI can reach an angular resolution of 2 milliarcsec But it does not produce images, “sparse” values on the “u-v” plane



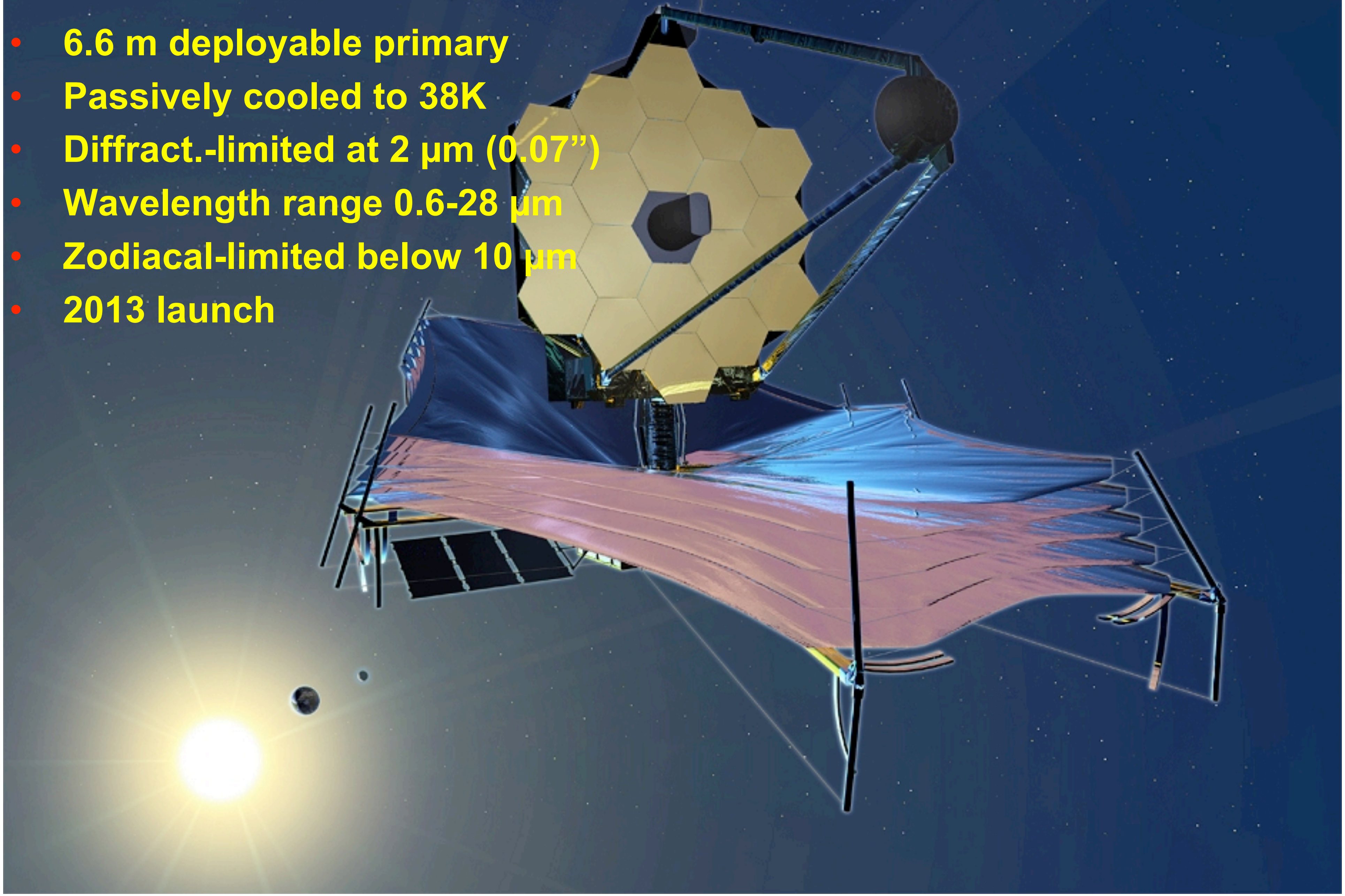
(Fourier transform of the image)

Difficult to obtain high fidelity images

“Near” future Optical/near-IR facilities:

James Webb Space Telescope (JWST)

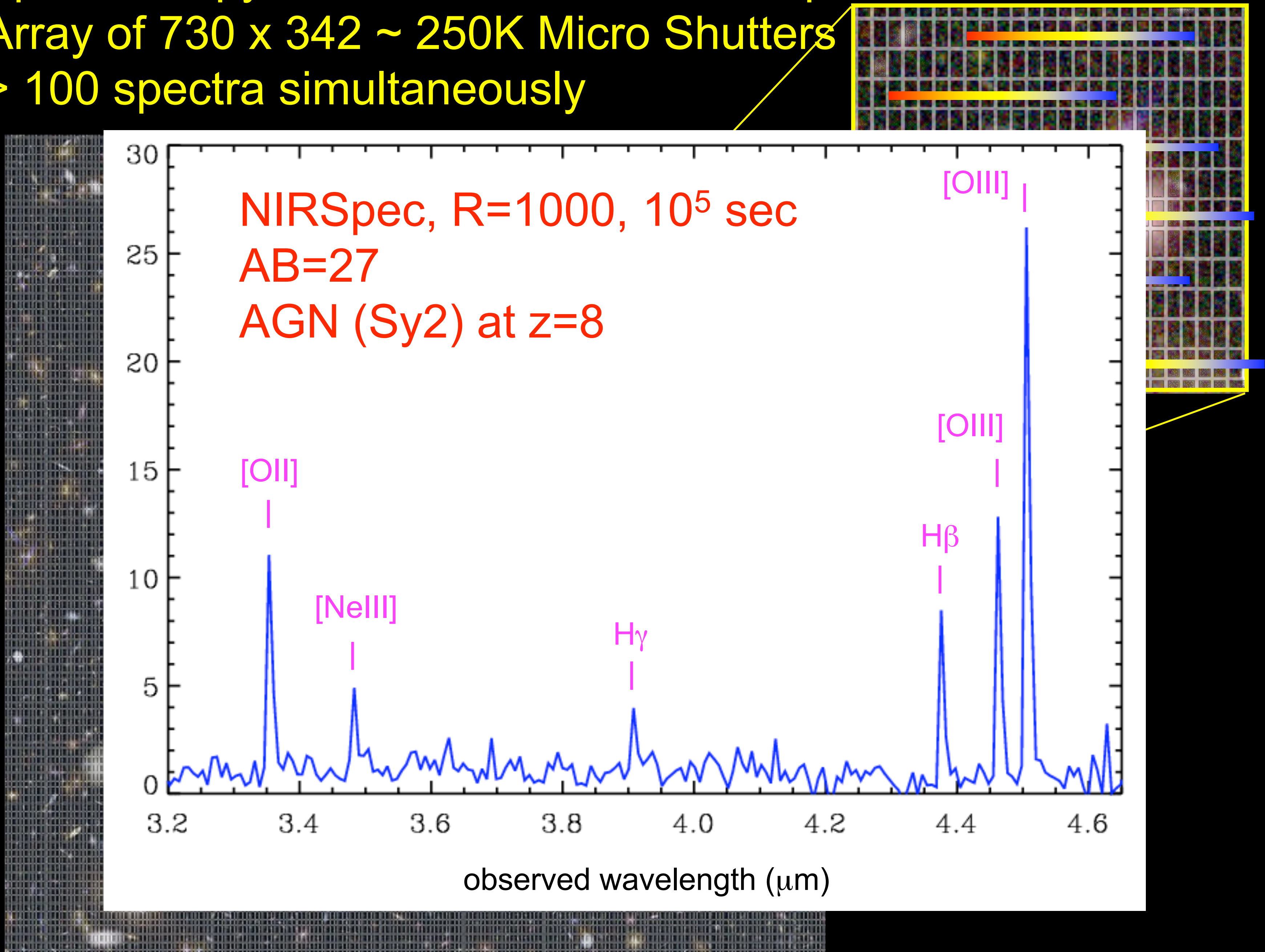
- **6.6 m deployable primary**
- **Passively cooled to 38K**
- **Diffract.-limited at 2 μm (0.07”)**
- **Wavelength range 0.6-28 μm**
- **Zodiacal-limited below 10 μm**
- **2013 launch**



JWST: the most sensitive near/mid-IR observatory

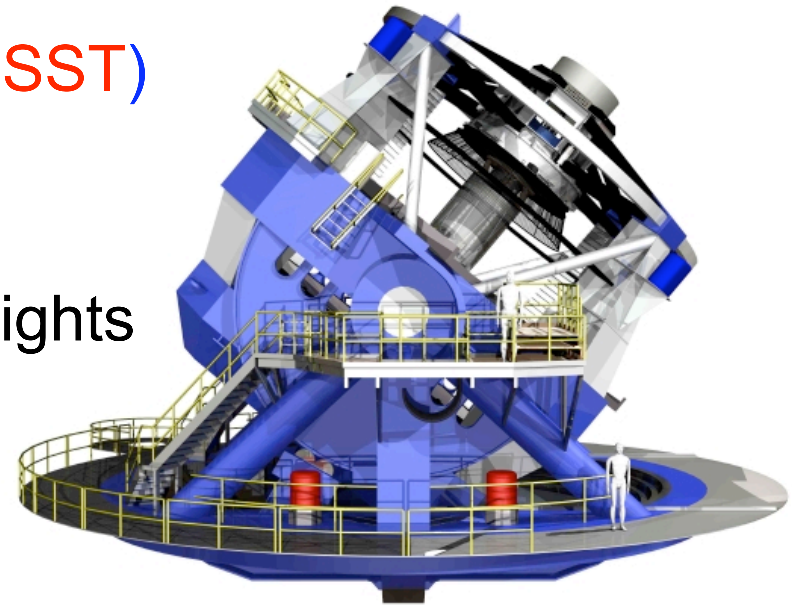
imaging sensitivity

Spectroscopy with JWST: first MOS in space
Array of 730 x 342 ~ 250K Micro Shutters
> 100 spectra simultaneously



“Near” future Optical/near-IR facilities

Large Synoptic Survey Telescope (LSST)



8.4m telescope
Optical imaging over 10 deg^2
All (southern) sky imaged every 3 nights
First light ~2013?

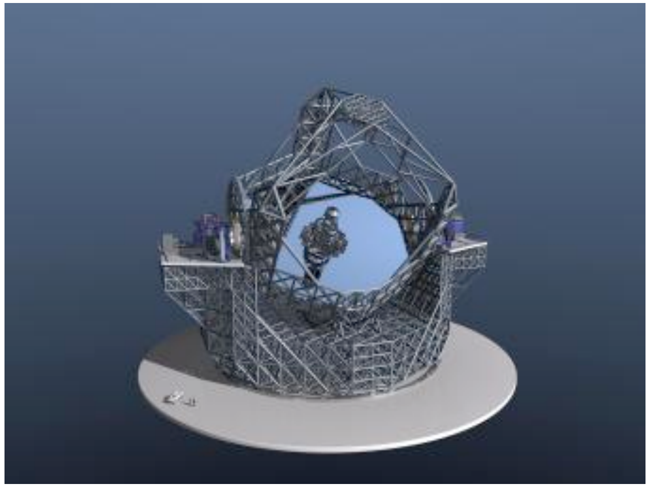
Wide Field Multi Object Spectrographs (WFMOS)

Planned for Gemini/Subaru and other telescopes
Several thousands simultaneous spectra
over ~ a few deg^2
→ will deliver spectra and redshift for millions
of galaxies out to z~3

“Far” future Optical/near-IR facilities

30-40m class telescopes

(Extremely Large Telescope - ELT)



Deep imaging at the diffraction limit (~3-10 milliarcsec) through AO+LGS

The most sensitive spectroscpic machine (at $\lambda<2\mu m$)

First light ~ 2017

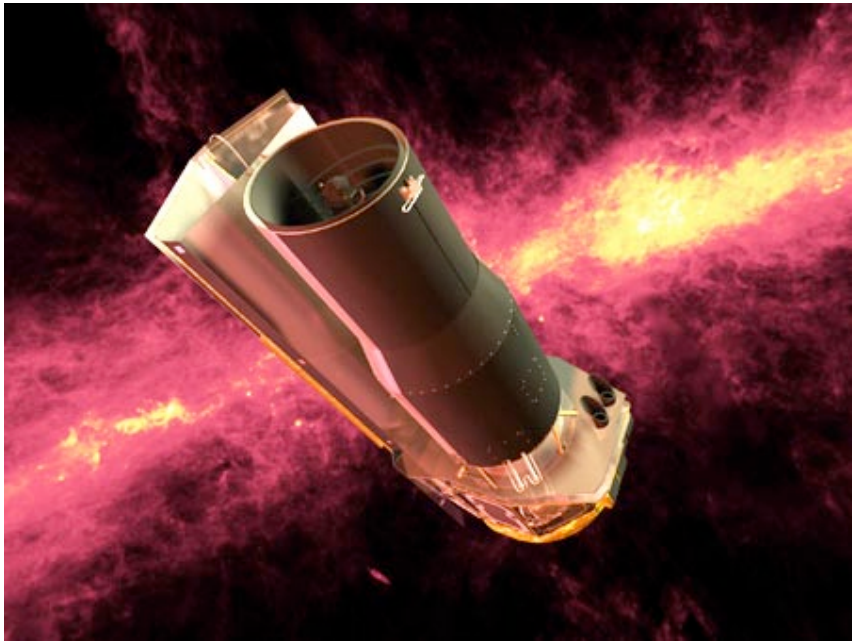
Euclid - JDEM

(Dark Energy Missions)

All-sky imaging at m_{AB}~26 (optical/near-IR) and angular resolution 0.3”

All-sky spectroscopic survey at m_{AB}~22

Current mid/far-IR facilities



Spitzer Space Telescope

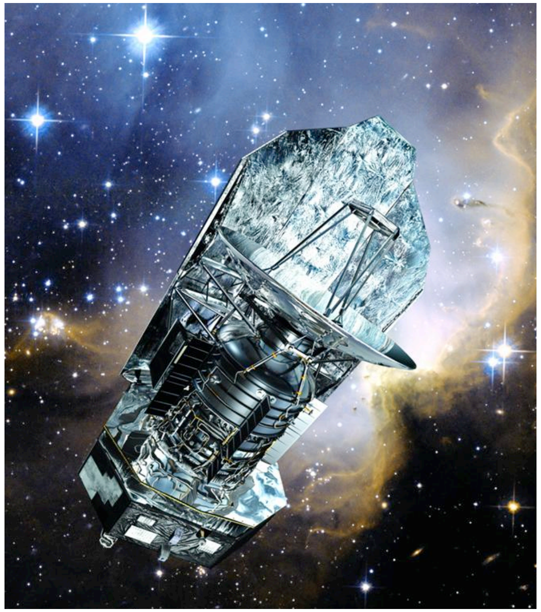
Cooled (3K) 80cm telescope

$\Delta\lambda$ = 3-160 μm

both imaging and spectroscopic modes

ang. resol. ~ 1" at λ~4μm

(last "cool" observations ongoing)



Herschel Space Observatory

Passively cooled (70K) 3.5m telescope

$\Delta\lambda$ = 70-600 μm

both imaging and spectroscopic modes

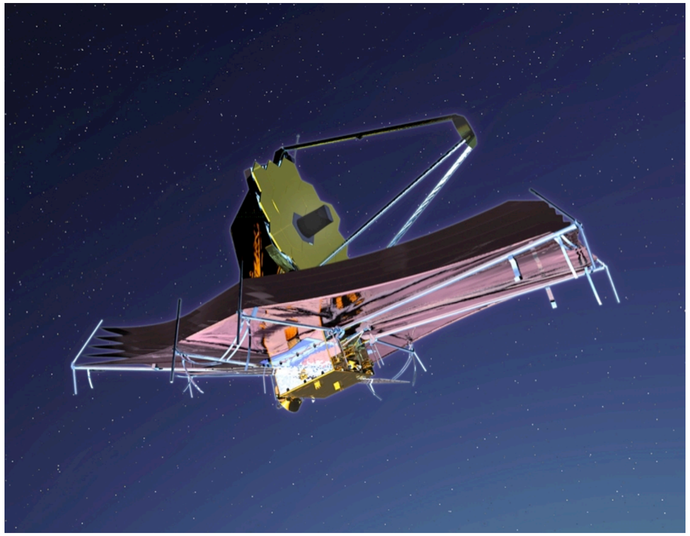
ang. resol. ~ 1" at λ~4μm

Scheduled for launch in Feb 2008

Near-far future mid/far-IR facilities

JWST (2013)

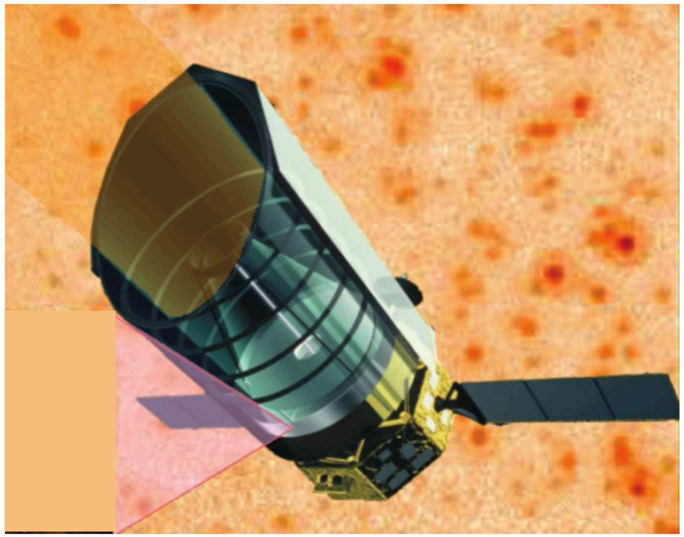
$\Delta\lambda$ = 0.6-30 μm



SPICA (2017?)

3.5m cooled telescope (3K)

$\Delta\lambda$ = 5-200 μm



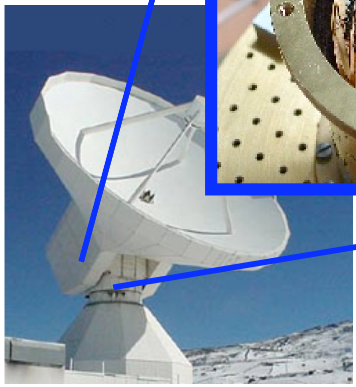
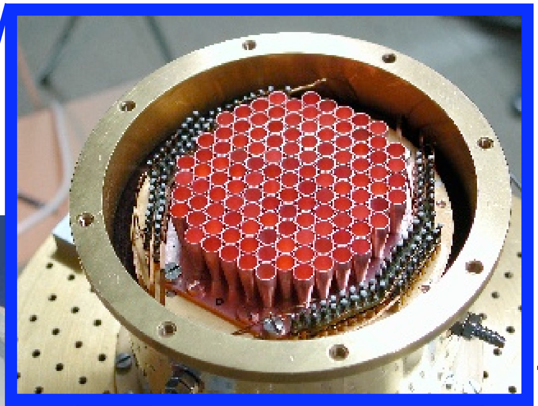
Performance summary of current-future mid/far-IR facilities

imaging

spectroscopy

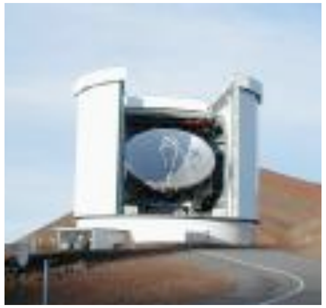
bmm facilities: single dish

mostly focused on continuum mapping

1mm
het. receivers (spectr.)
MAMBO: 117 x bol. array
(cont.) FOV ~ 3 arcmin^2

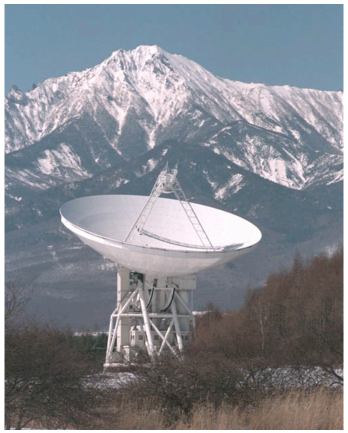
APEX 12m
$\Delta\lambda$ = 350μm-1mm
beam ~ 18” at λ=870 μm
het. receivers (spectr.)
LABOCA: 295 x bol. array
(cont.) FOV ~ 11 arcmin^2



JCMT 15m
$\Delta\lambda$ = 450μm-1mm
beam ~ 15” at λ=850 μm
het. receivers (spectr.)
SCUBA-2: 10^4 x bol. array
(cont.) FOV ~ 50 arcmin^2
(12xSCUBA)

ASTE 10m
$\Delta\lambda$ = 350-850μm
beam ~ 17” at λ=870 μm
het. receivers (spectr.)

CSO 10.4m
$\Delta\lambda$ = 350μm-1mm
beam ~ 9” at λ=350 μm
het. receivers (spectr.)
SHARC-II: 384 x bol. array
(cont.) FOV ~ 2.5 arcmin^2



Nobeyama 45m
$\Delta\lambda$ = 3mm-1cm
beam ~ 15” at λ=3 mm
het. receivers (spectr.)

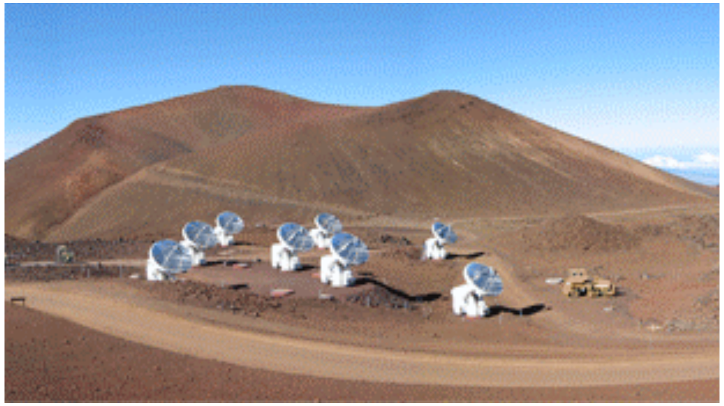
Current mm-submm facilities: interferometers

mostly, high resolution (& high sensitivity) line images

IRAM PdBI
6 x 15m antennas
max ang. res = 0.35”
λ= 1-3 mm
(highest sensitivity)

good coverage of the u-v plane -> provide real mm-submm images (submm shortest λ where this can be achieved)

CARMA
6 x 10.4m + 10 x 6m antennas
max ang. res = 0.1”
λ= 1-3 mm

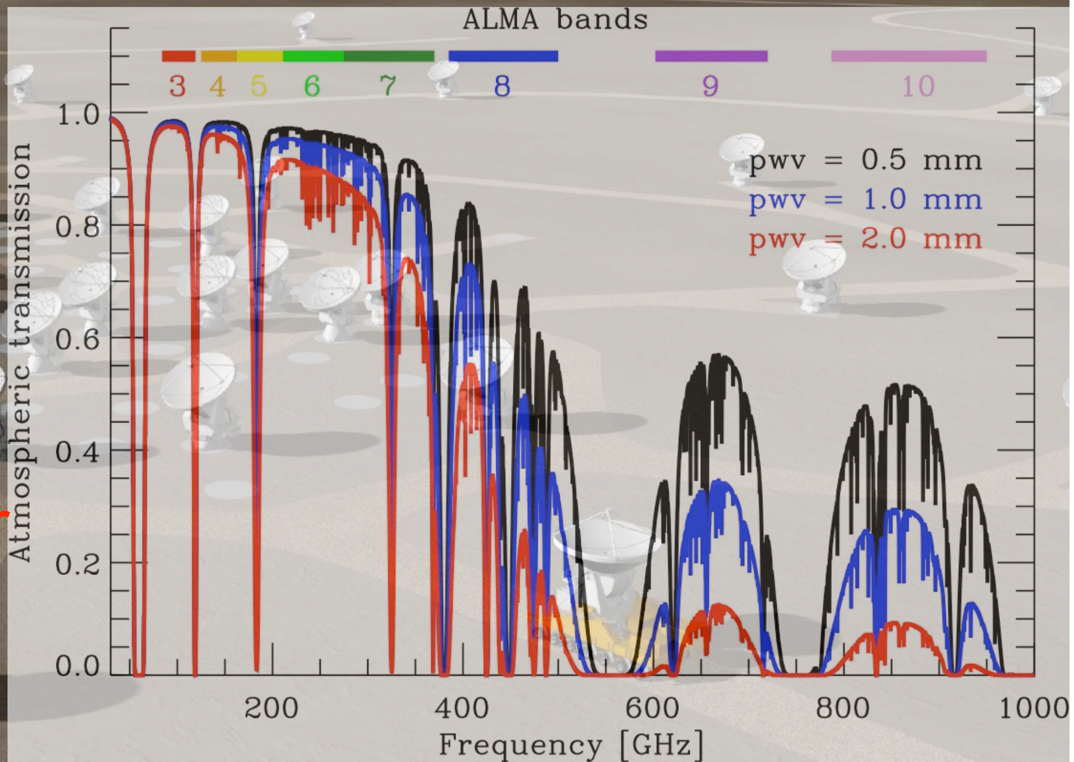


SMA
8 x 6m ant.
λ= 350μm-850μm-1mm
max ang. resol. = 0.1”

The ALMA revolution

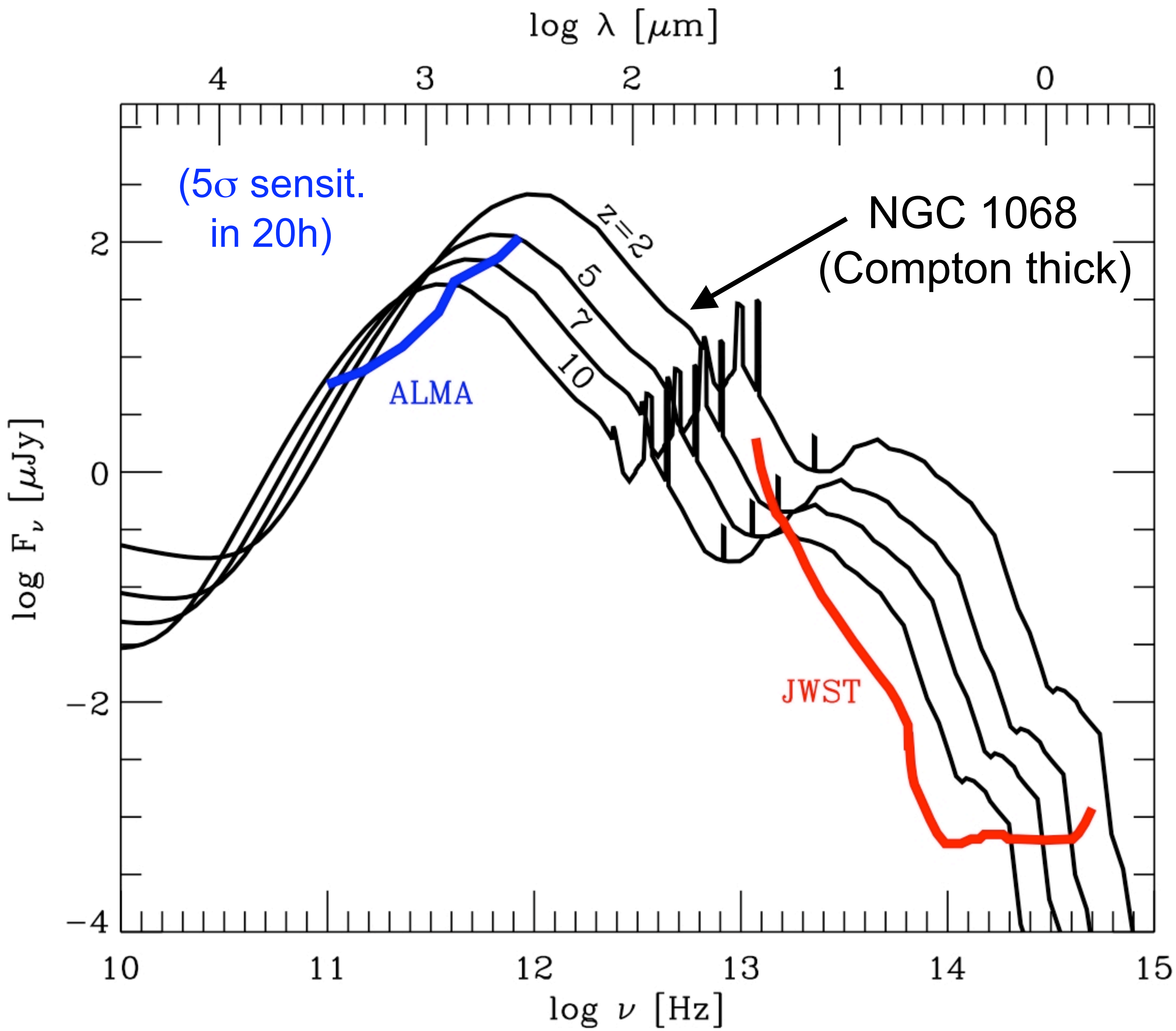
54 x 12m + 12 x 7m antennae ~6500 m^2 collecting area
Located at an altitude of 5000m
Array configurations between 150m and 18km
8 bands between 86-720 GHz = 310μm-3.5mm
Sensitivity 0.2 mJy in 1 min at 345 GHz → ~2 orders of magnitudes better than current facilities
Ang. resolution:
 0.7”-0.005” @ 0.5mm
 4”-0.03” @ 3mm

~1 order of magnitudes better than current facilities



early operations in 2010
full operations in 2012

ALMA & JWST capability of detecting high-z obscured AGNs



(some of the) current radio facilities

25m x 22 antennae
max sep. 36 km
$\Delta\nu$ = 0.07-45 GHz
$\Delta\lambda$ = 0.7-400 cm
max ang. res. = 0.04”

being expanded to “E-VLA”
with max ang. res = 0.004”
and 10 times more sensitive

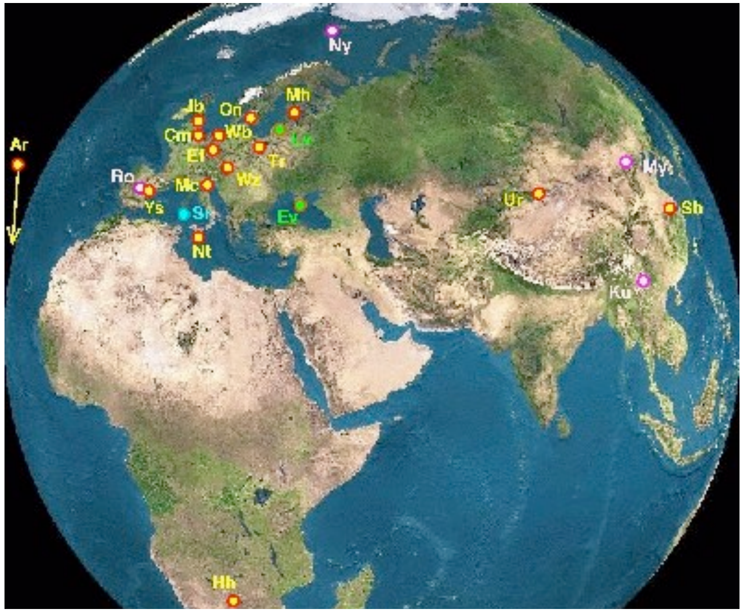
VLBA

25m x 10 antennae
max sep. 8000 km

max angular resolution ~ a few 10^{-4} arcsec

ENV

18 antennae



Upcoming radio observatories: LOFAR

New interferometer concept: 25000 wide beam simple antennas spread over an area of 320 km

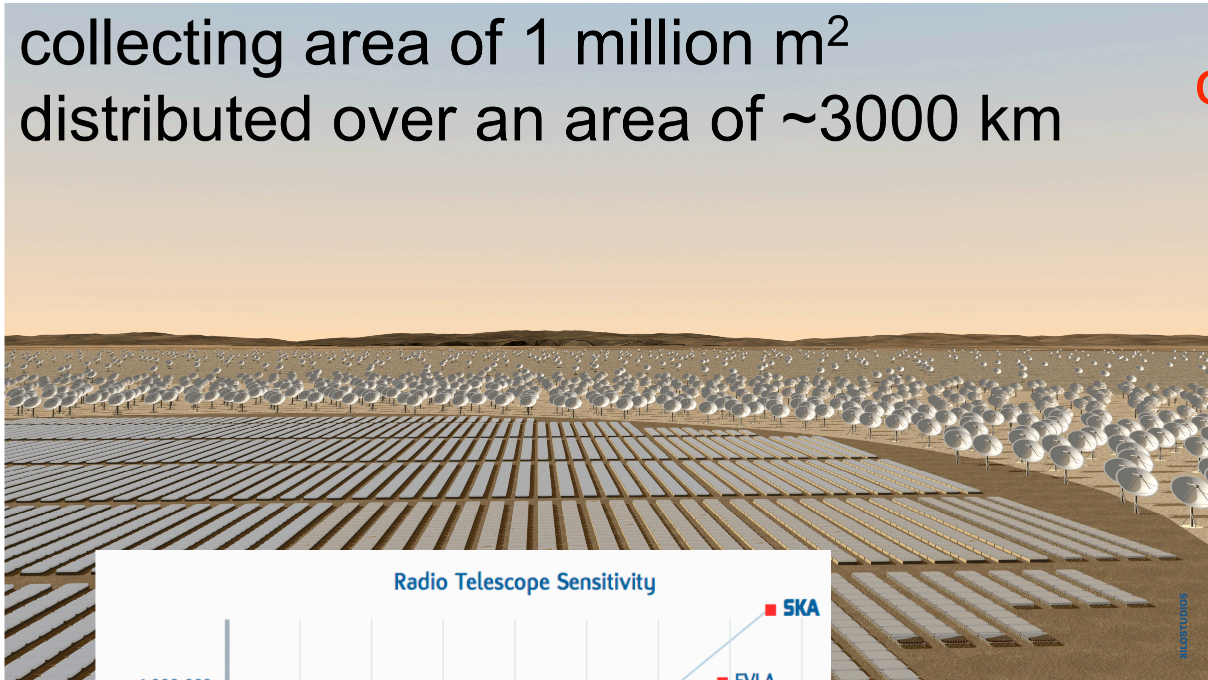
30-80 MHz

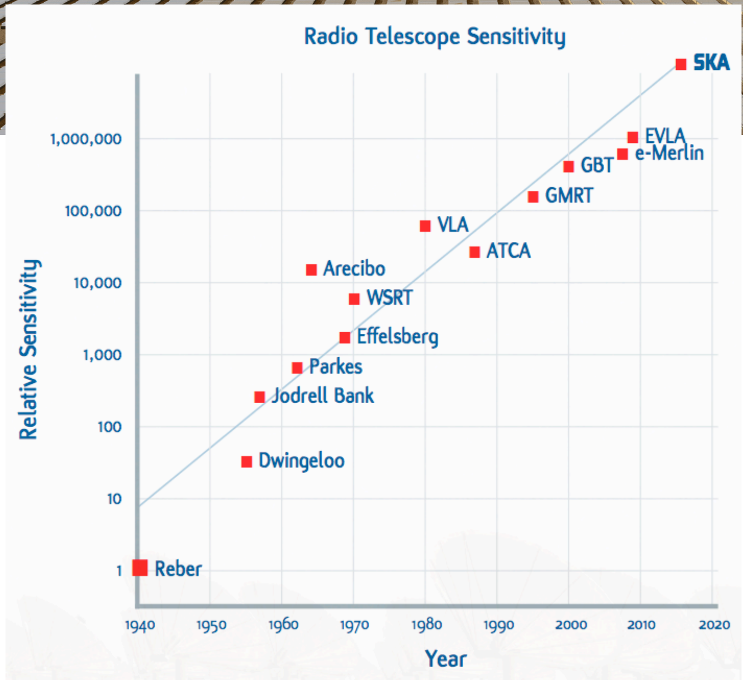
120-240 MHz

...spread over an area of 350 km

100 times more sensitive than current radio telescopes!

Far "radio" future (~2020): the Square Kilometer Array (SKA)





Much more sensitive and much faster mapping speed than any other radio telescope

$\Delta\nu$ = 70 MHz - 25 GHz
ang. resol. < 0.1"
Field of View:
200 deg^2 (low freq.)
1 deg^2 (high freq.)