

Luz y polvo en las galaxias

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CEA Saclay

Conferencia en ANCEF

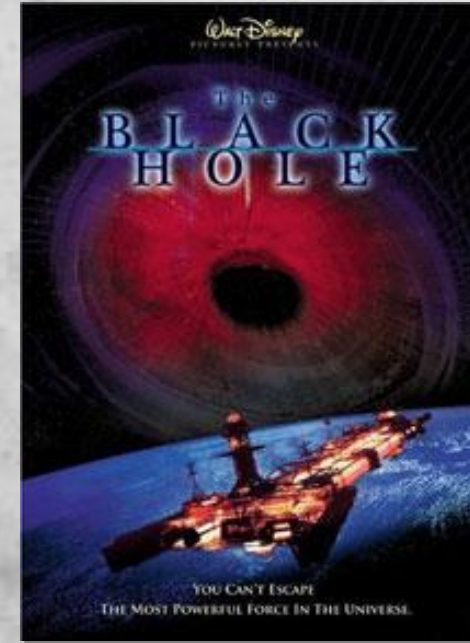
Noviembre 2013



Les objets de l'astronomie

- Quand on parle d'astronomie, on pense:

- Planètes
- Étoiles
- Galaxies
- Trous noirs



- Contrairement à une idée préconçue, ces objets ne flottent pas dans le vide absolu...

- On oublie une composante importante mais difficile à voir (identifiée au 20^{ème} siècle)
 - Le milieu interstellaire

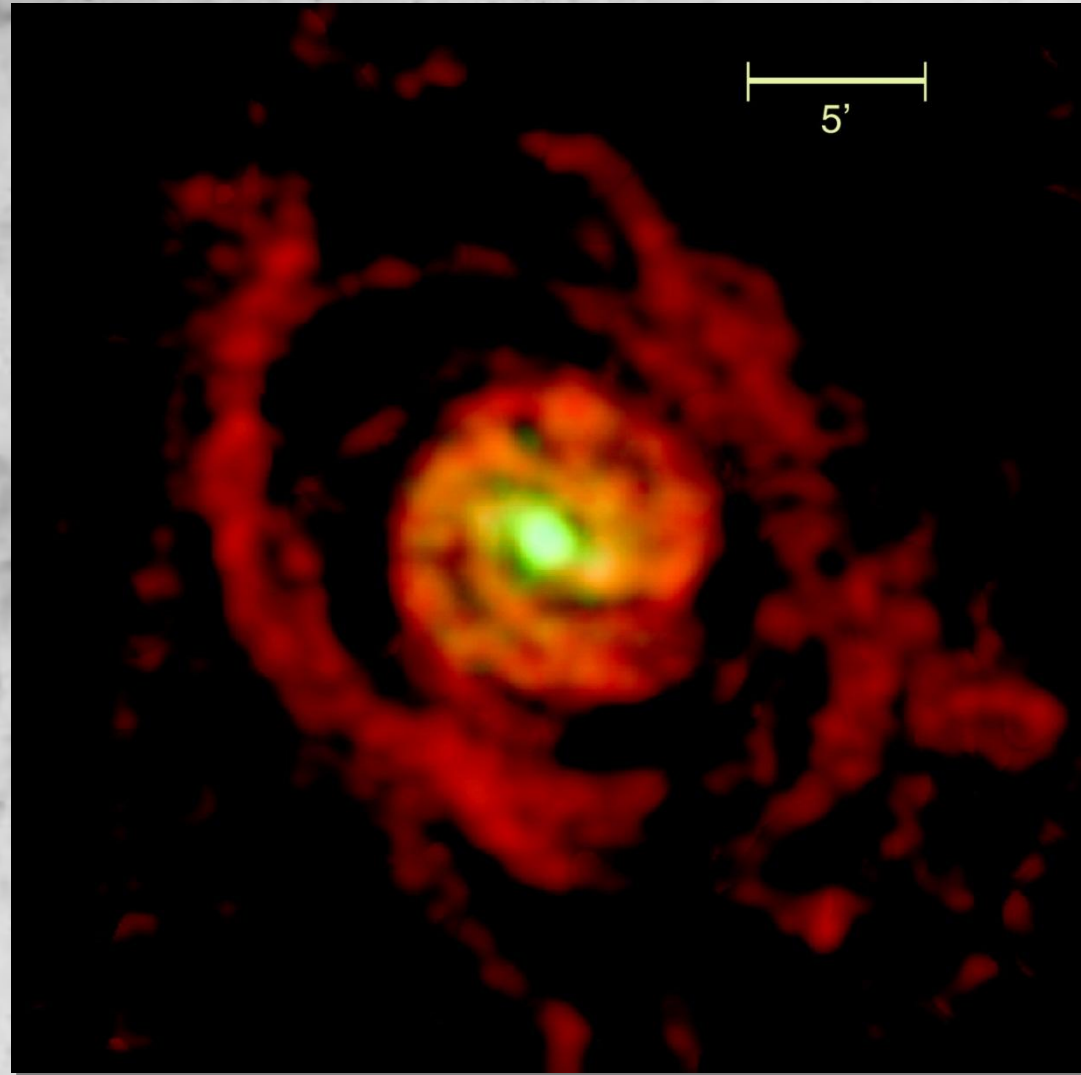


Le gaz interstellaire

- Le gaz atomique est observable depuis le développement des observations dans le domaine radio grâce à la raie à 21 cm de l'hydrogène (interaction electron-proton dans le niveau fondamental).



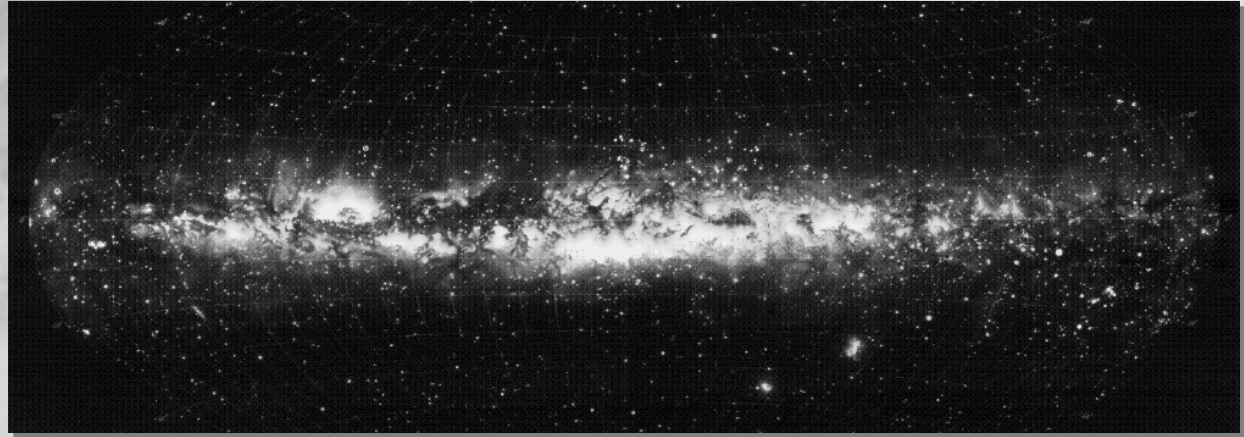
M83 visible



M83 HI (rouge) et CO (jaune)

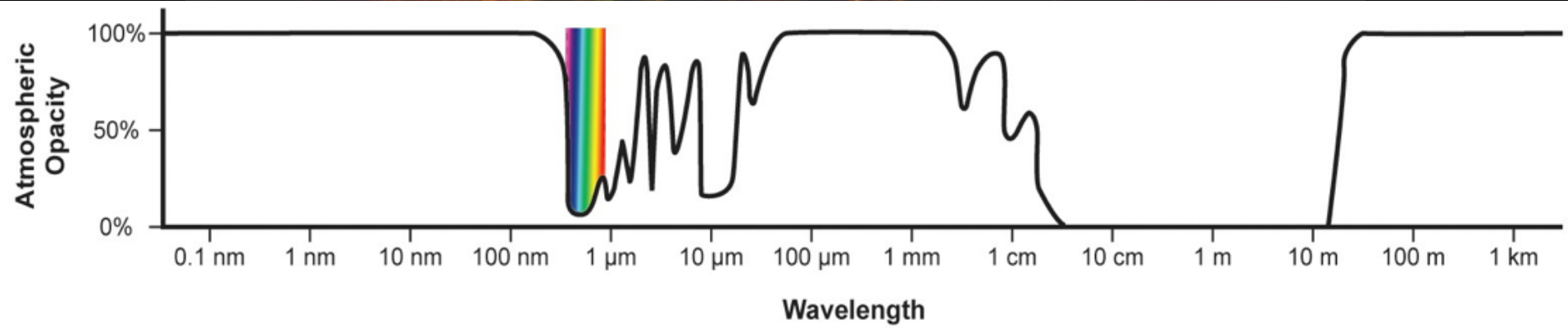
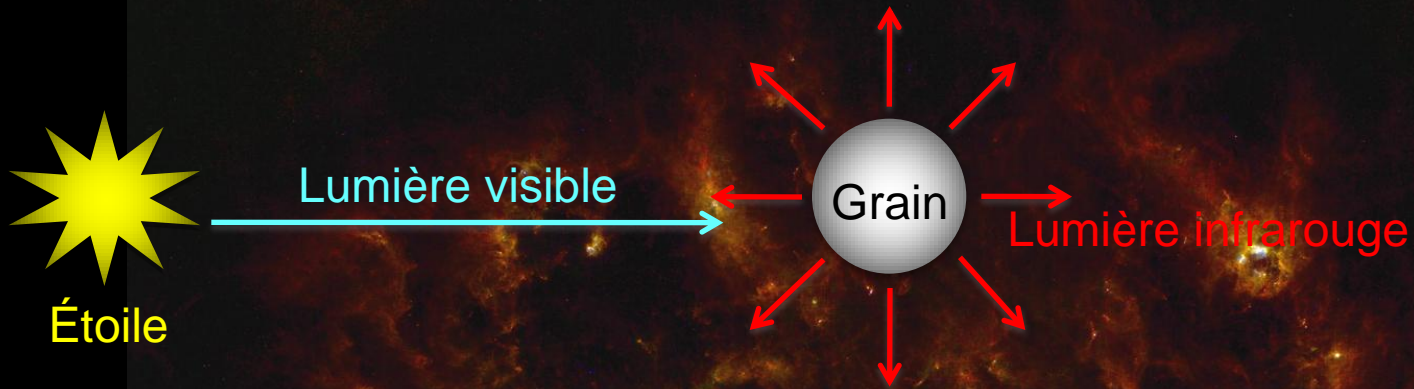
La poussière interstellaire

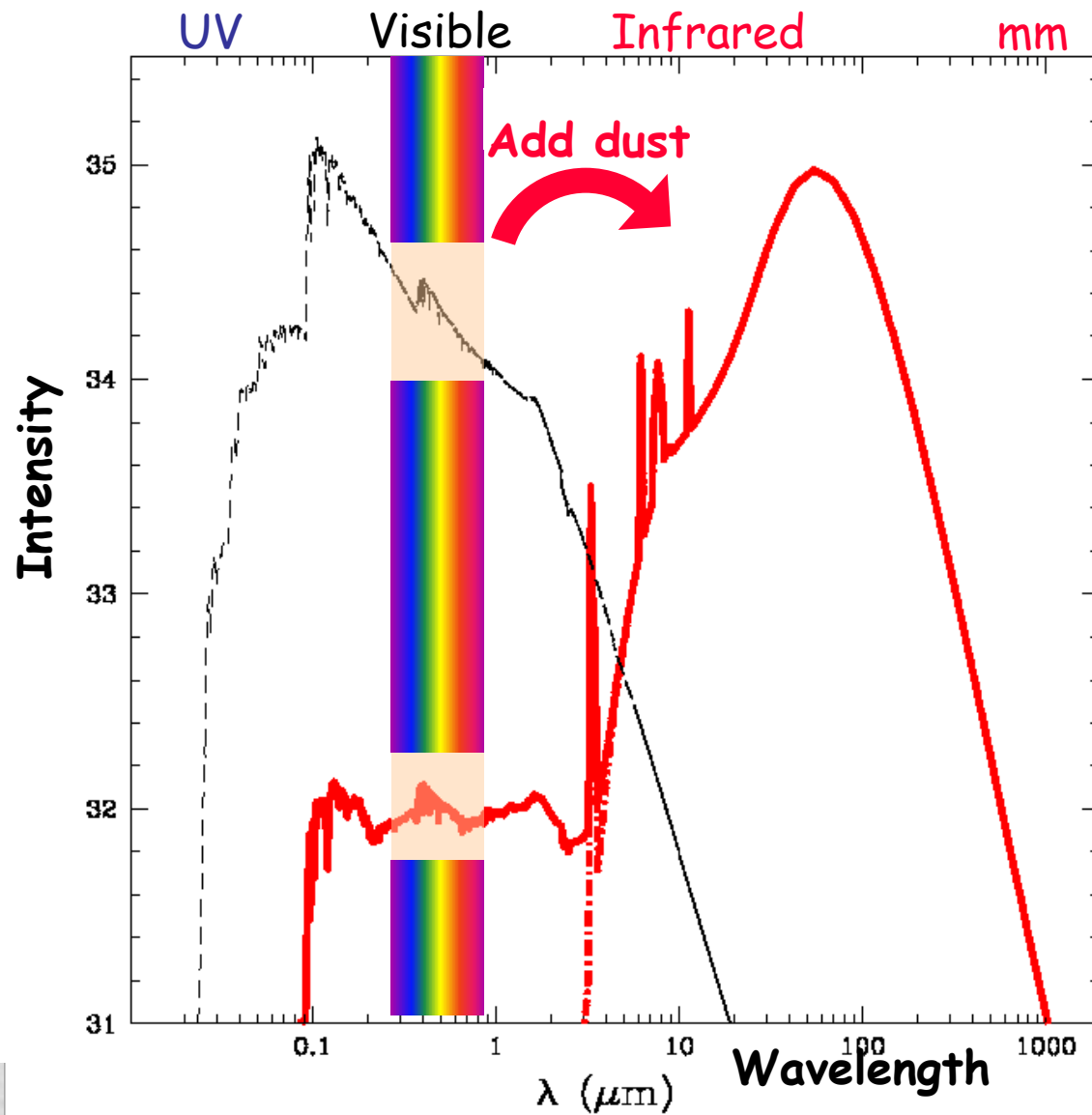
- Visible à l'œil nu dans la voie lactée



- Facile à reconnaître même dans les images des astronomes amateurs



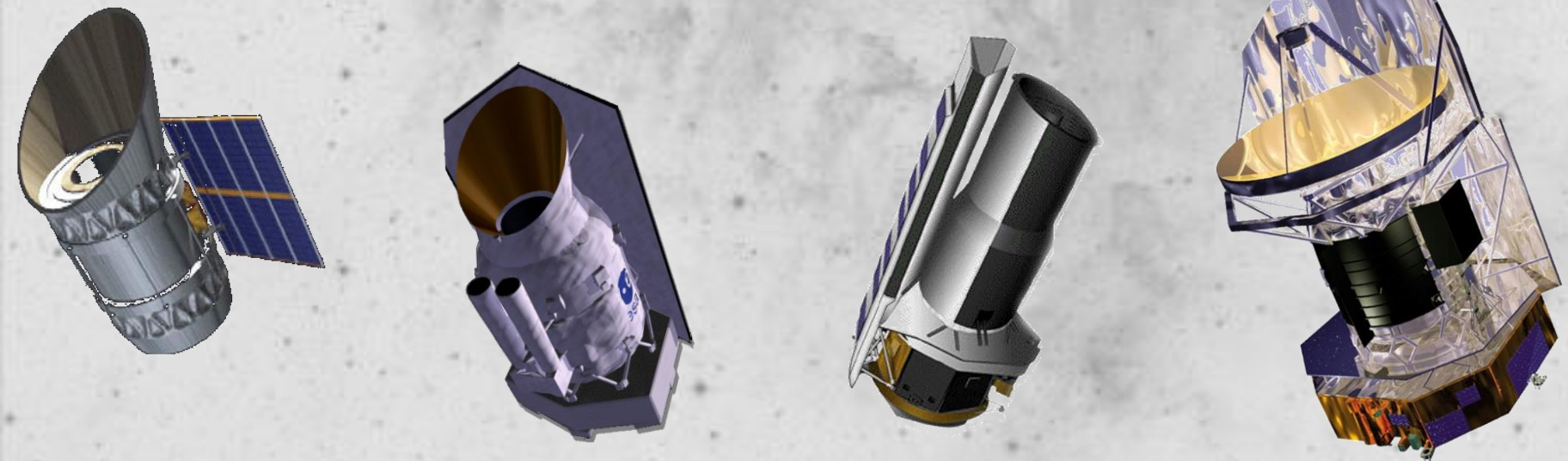




De l'importance des développements technologiques

Dans les années 1970, la technologie de détection infrarouge naît et les astronomes s'en emparent

- 1983: vol du satellite IRAS, qui réalise un relevé complet du ciel en infrarouge (on utilise encore ses observations aujourd'hui), miroir de 60 cm
- 1995-1998: vol du satellite ISO, le premier véritable observatoire spatial infrarouge, miroir de 60 cm
- 2003-2009: satellite Spitzer, successeur d'ISO, miroir de 85 cm
- 2009-2013: satellite Herschel, miroir de 3,5m
- Au sol: radiotélescopes dans le mm et submm



Infrarouge

- Le ciel n'est plus vide, il est rempli de structures extrêmement complexes: des nuages de poussière interstellaire



Image visible de la constellation d'Orion



Composite 12-100 μ m

Retour sur les régions de formation stellaire

- Les images infrarouges de ces régions font apparaître un véritable "continent inconnu" dont les régions visibles ne semblent parfois être qu'une lisière.
- Les véritables étoiles jeunes ne sont pas celles que l'on "voit", elles sont en fait dans la région que seule l'émission infrarouge révèle.
 - Le rayonnement visible de ces jeunes étoiles est absorbé par les cocons de poussière qui les entourent, et seule l'émission de ces poussières chauffées nous parvient.



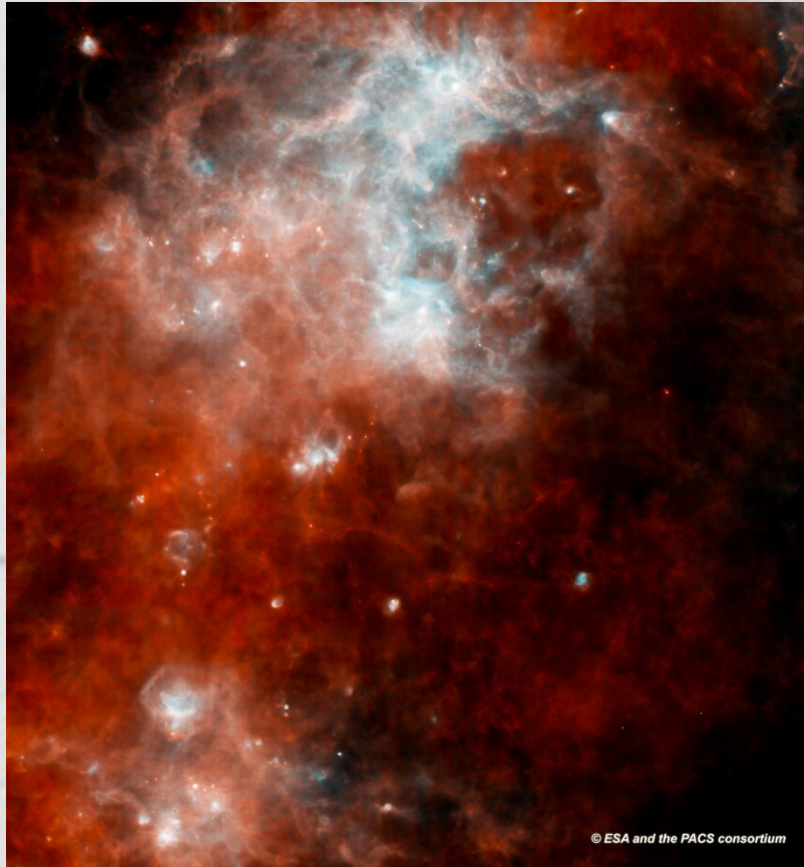
☐ Oph dans le visible



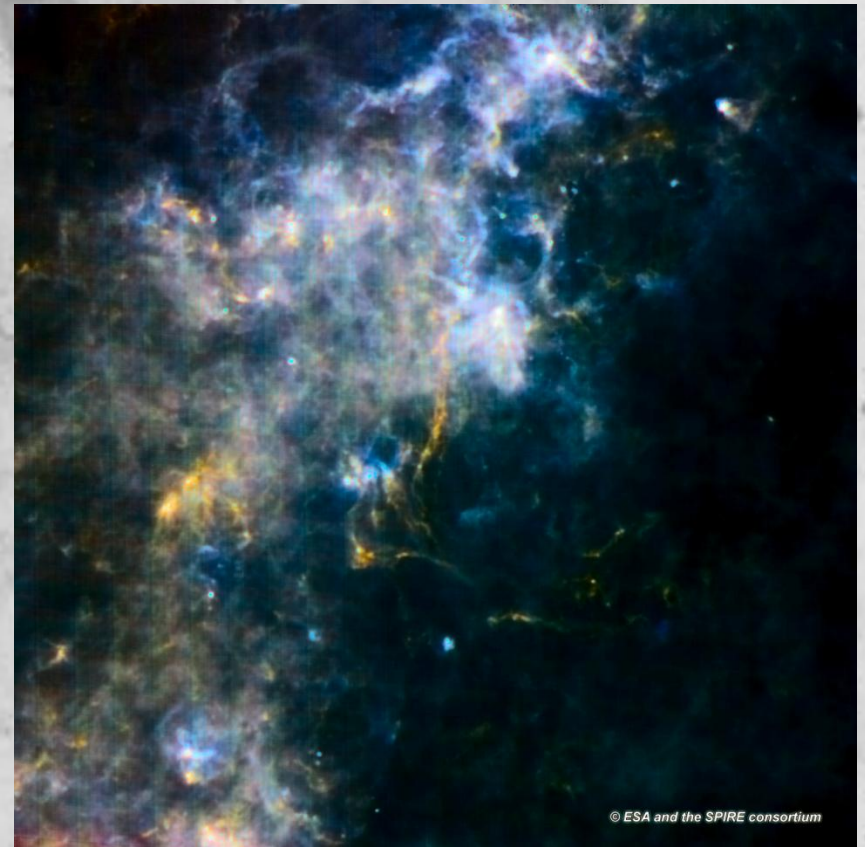
☐ Oph dans l'infrarouge moyen (ISOCAM – Abergel, CC et al. 1996)

La Croix du Sud

PACS 70 μm 160 μm

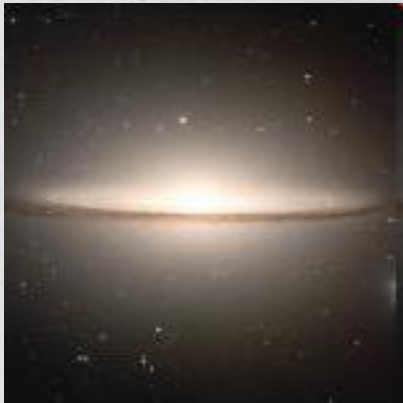


SPIRE 250 μm 250 μm 500 μm






La galaxie
Sombbrero



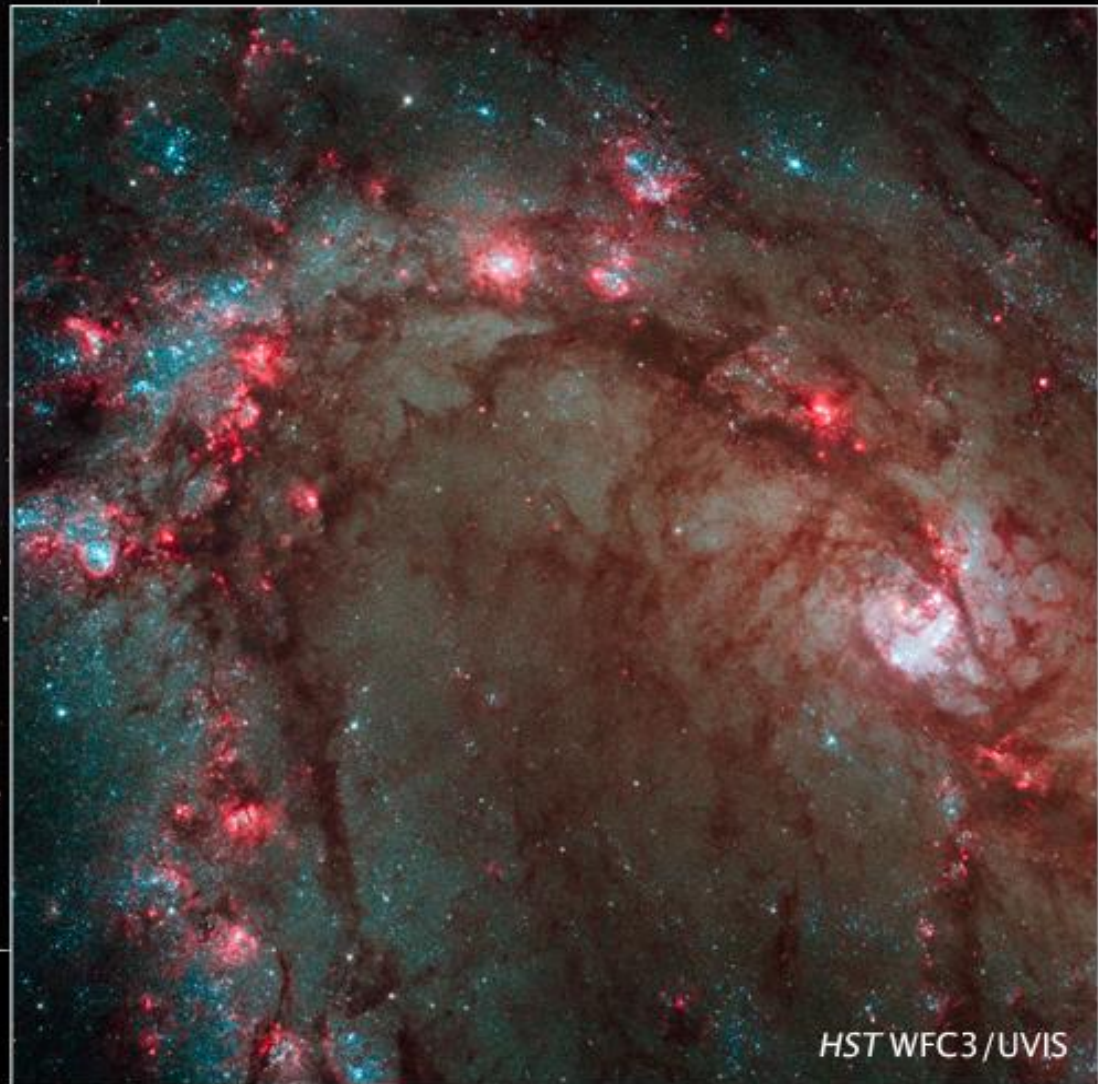
Presence de poussiere dans les galaxies
spiraales

Spiral Galaxy M83
Hubble Space Telescope ■ WFC3/UVIS

A wide-field ground-based image of the spiral galaxy M83. The galaxy is shown in a dark field of stars. It has a bright central core and several prominent spiral arms. A white rectangular box is drawn around the central region, indicating the area shown in the Hubble Space Telescope inset. The colors are primarily blue and white, with some reddish spots scattered throughout.

Ground: MPG/ESO 2.2m/WFI

NASA, ESA, R. O'Connell (University of Virginia),
the WFC3 Science Oversight Committee, and ESO
STScI-PRC09-29



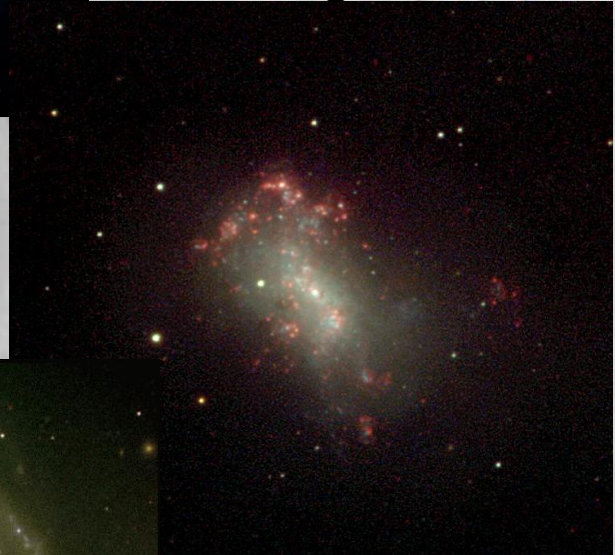
HST WFC3/UVIS

Univers proche: divers types de galaxies

Spirales



Irregulieres



Spirales
barrees



Elipsoïdes

Découverte des galaxies infrarouges

1983 IRAS :déttection de LIRGs et ULIRGs locaux

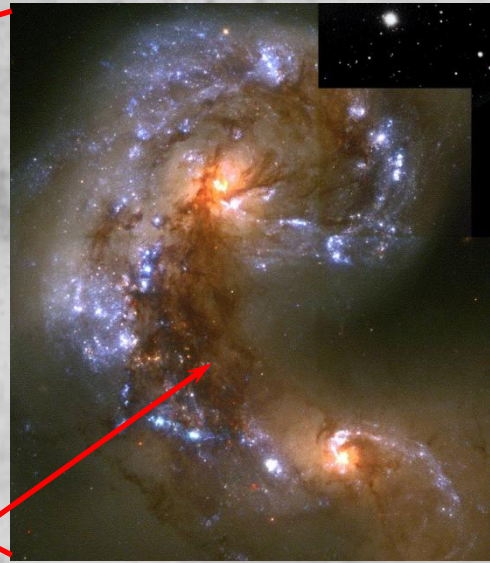
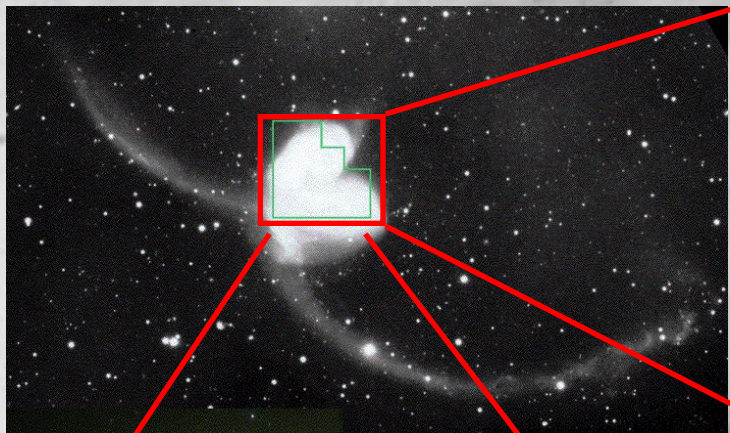
detection de LIRGs ($11 < \log(L_{\text{IR}}/L_{\odot}) < 12$)

ULIRGs ($12 < \log L_{\text{IR}}/L_{\odot}$)



- objets rares, et parmi les plus brillants dans l'univers proche,
- Responsables de 6% de l'émission IR dans l'univers local , et de 2% de la luminosité bolométrique
- souvent associés à des fusions de galaxies

Un prototype de flambée enfouie: les Antennes



HST WFPC2
V & I
Whitmore et al.
1997

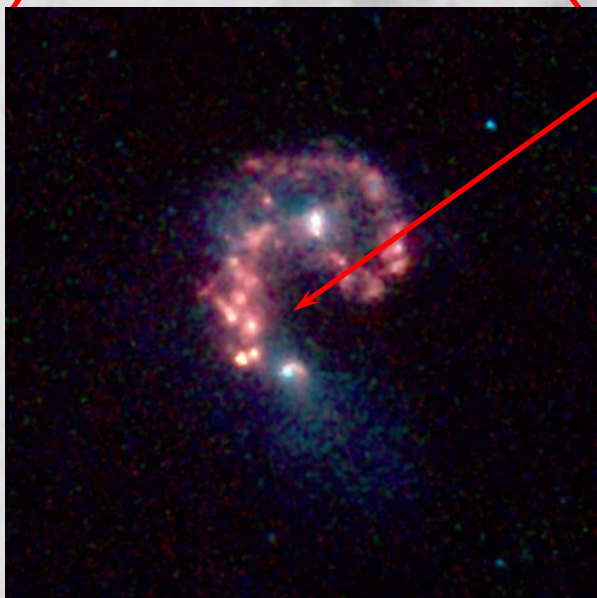
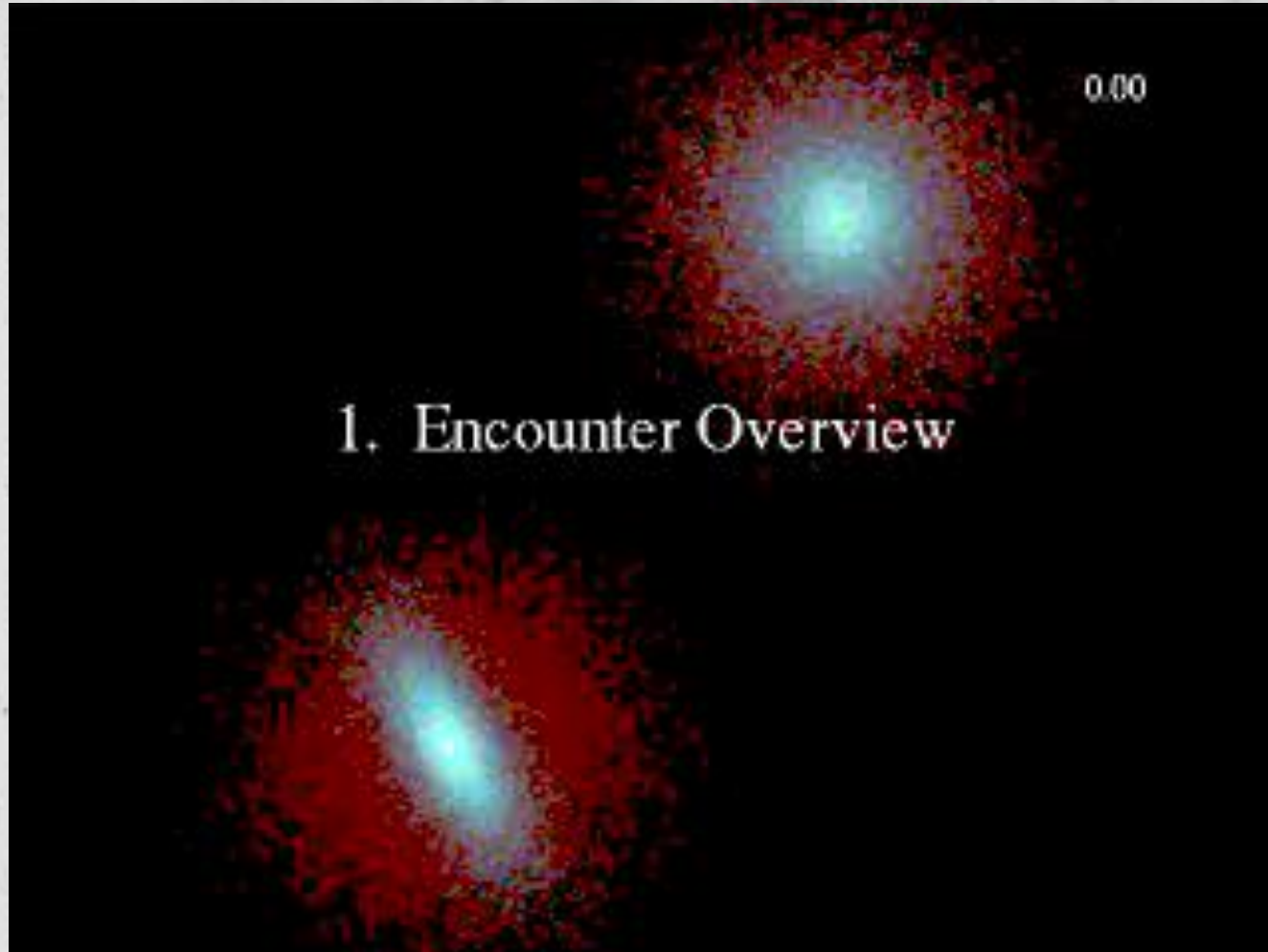


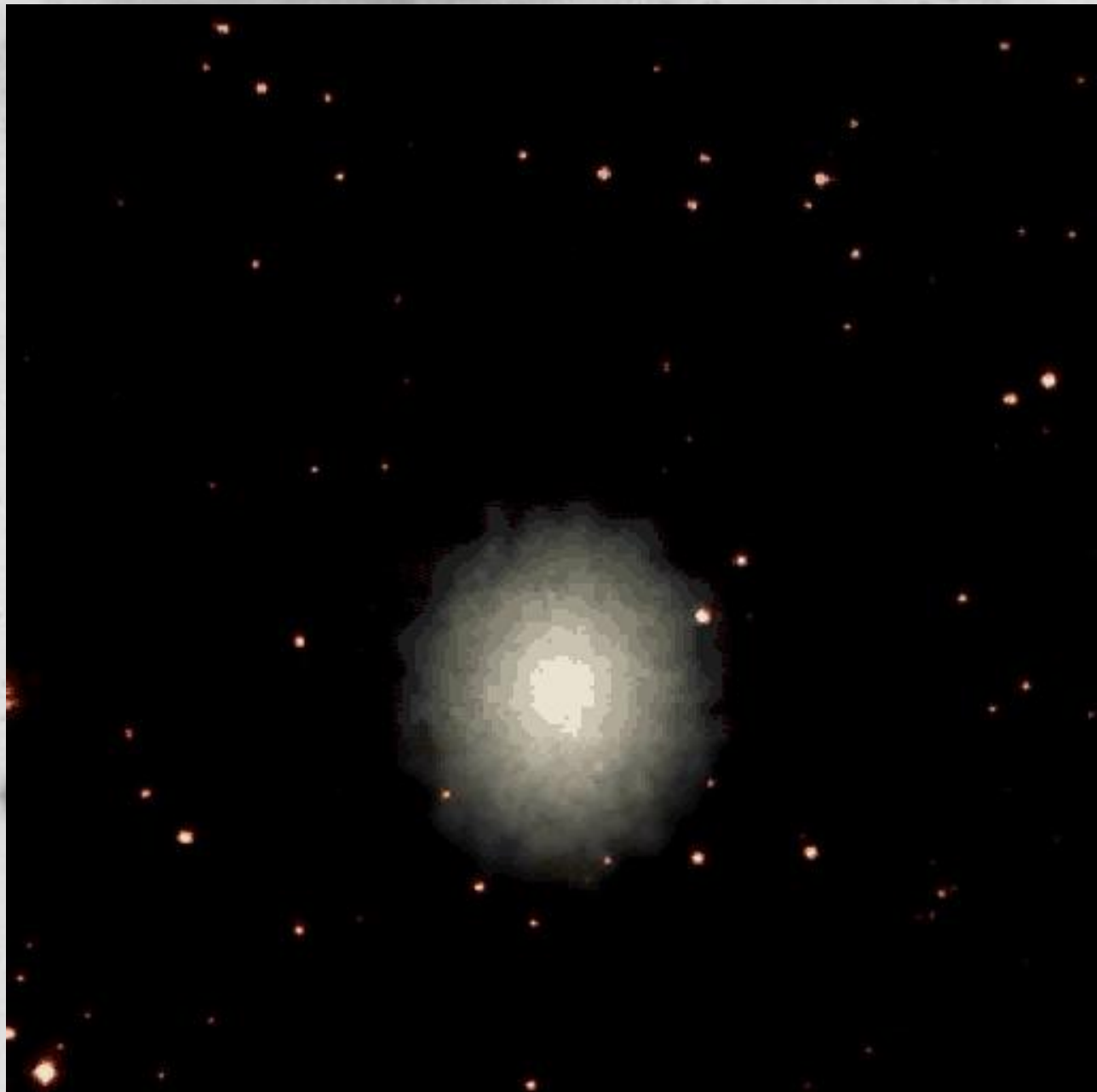
image ISOCAM 15 \AA m
(Vigroux, CC et al. 96, Mirabel, CC et al. 98)

Image Spitzer-IRAC 3.6-8 \AA m

l'émission pique dans la région sombre dans le visible

Collision de galaxies



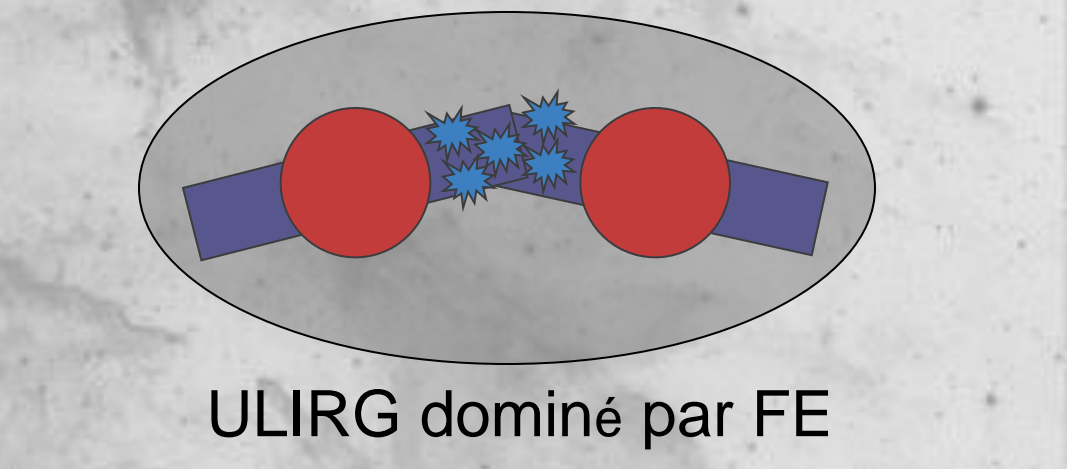
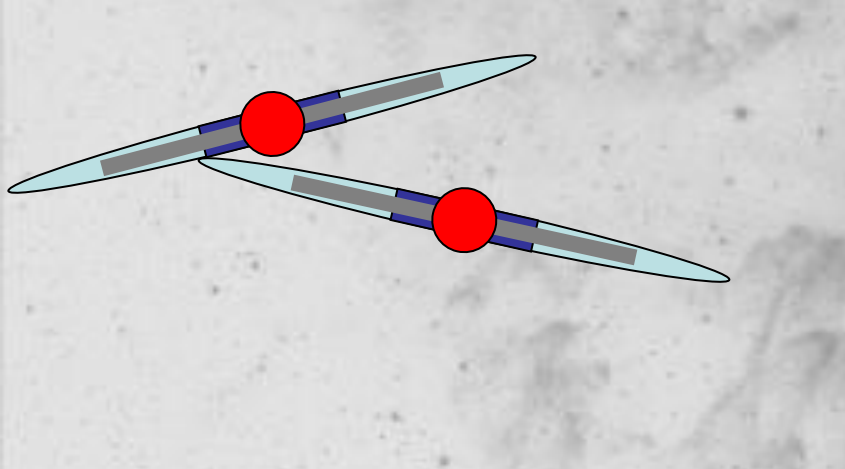


Liens avec les quasars et la formation des galaxies elliptiques

3

1. Fusion de galaxies spirales

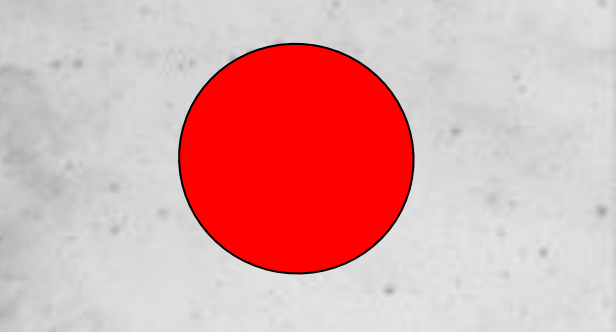
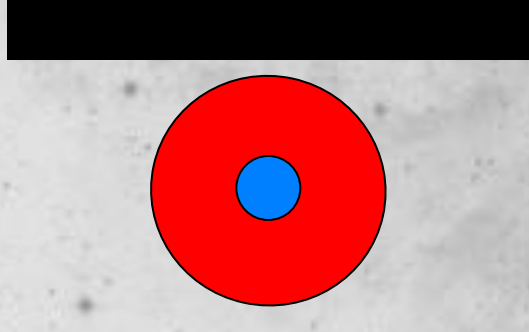
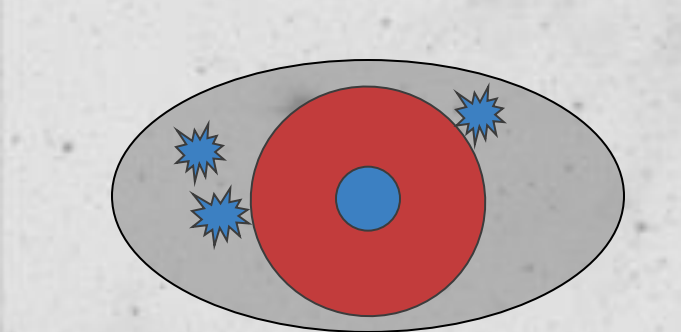
2. Flambée de formation d'étoiles (FE)



3. Gaz sur Noyau Actif (NA)

4. NA repousse le gaz et arrête la FE

5. Combustible épuisé

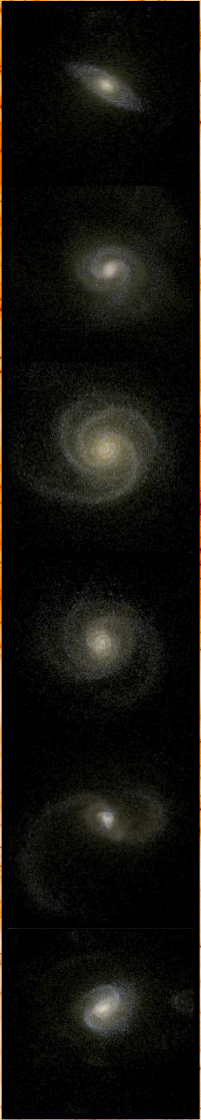


ULIRG dominé par NA

Quasar

Galaxie elliptique

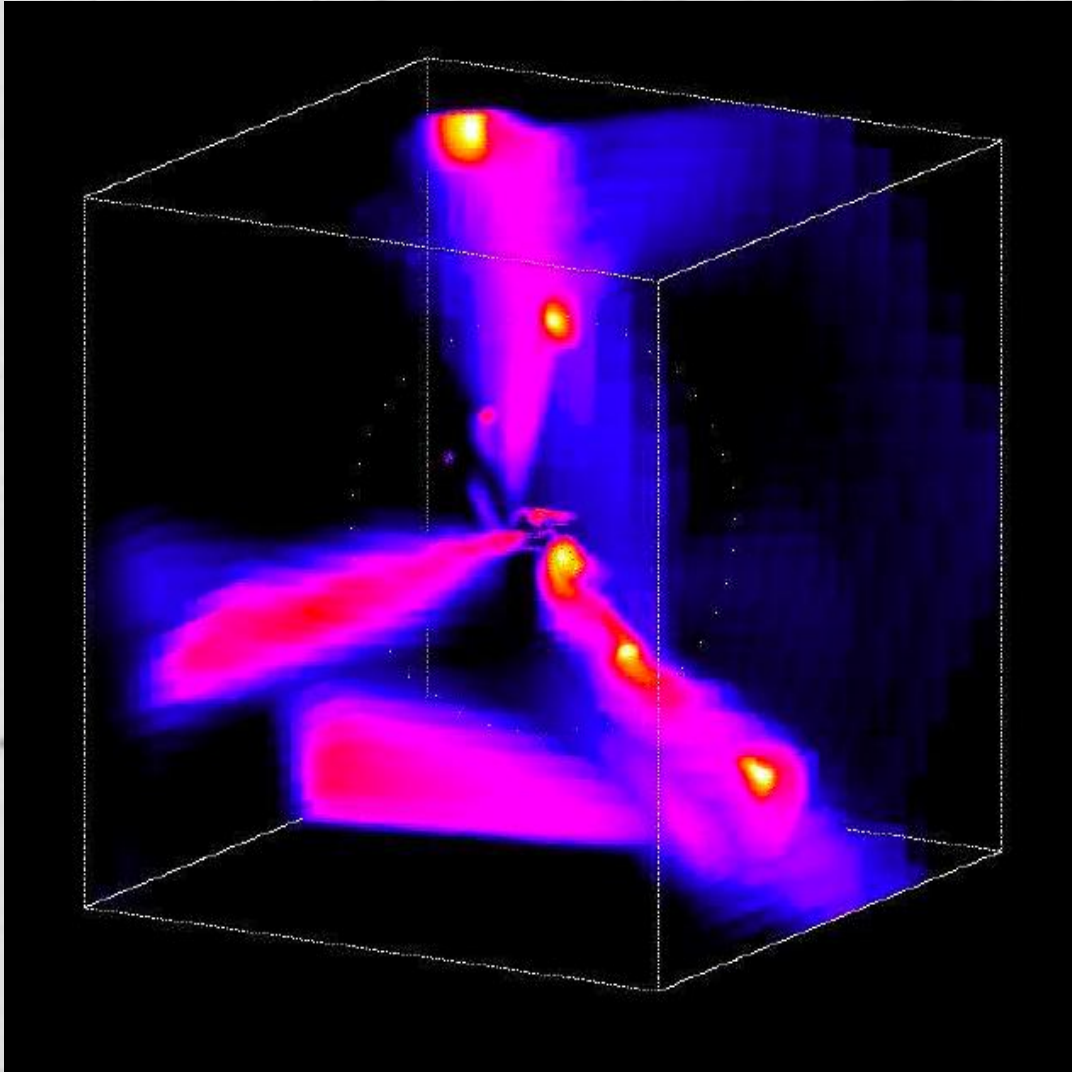
Un peu de
théorie...



z=15.54

Copyright R. Teysler (2008)

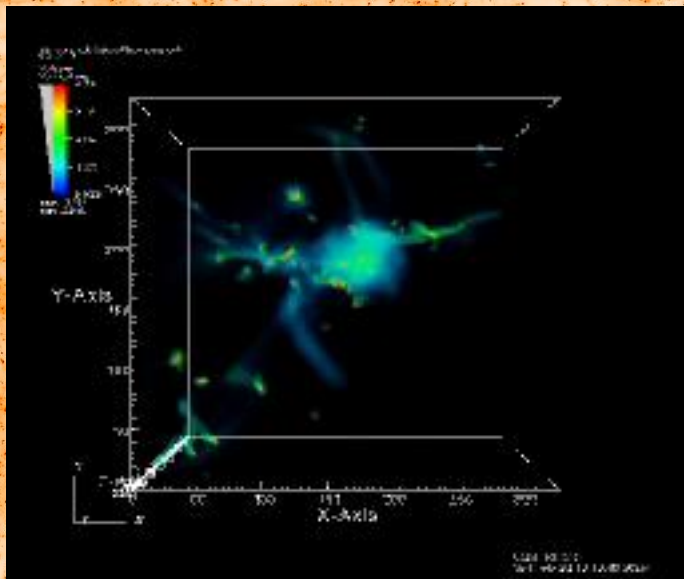
Toward a paradigm shift in galaxy formation/evolution: Cold streams in early massive hot haloes as the main mode of galaxy formation



Cold gas stream feeds
high- z massive galaxies:
Shown in 3 dimensions
(box of side length 320 kpc)

Dekel et al 2009 Nature

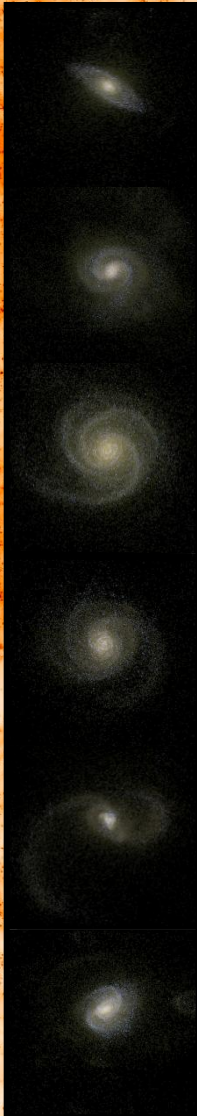
Une image virtuelle dans l'univers âgé de 1,5 milliards d'années: des filaments de gaz froid nourrissent les disques galactiques



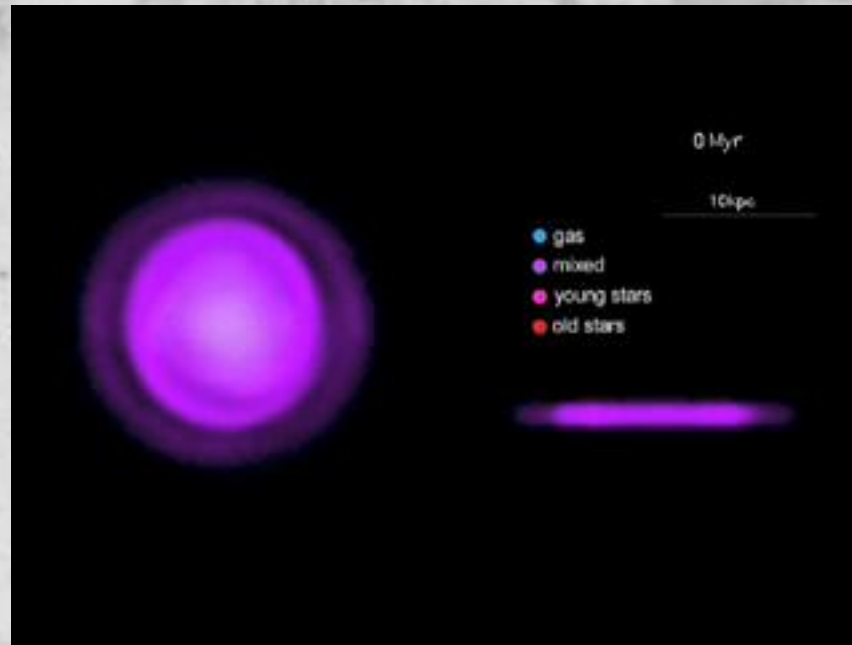
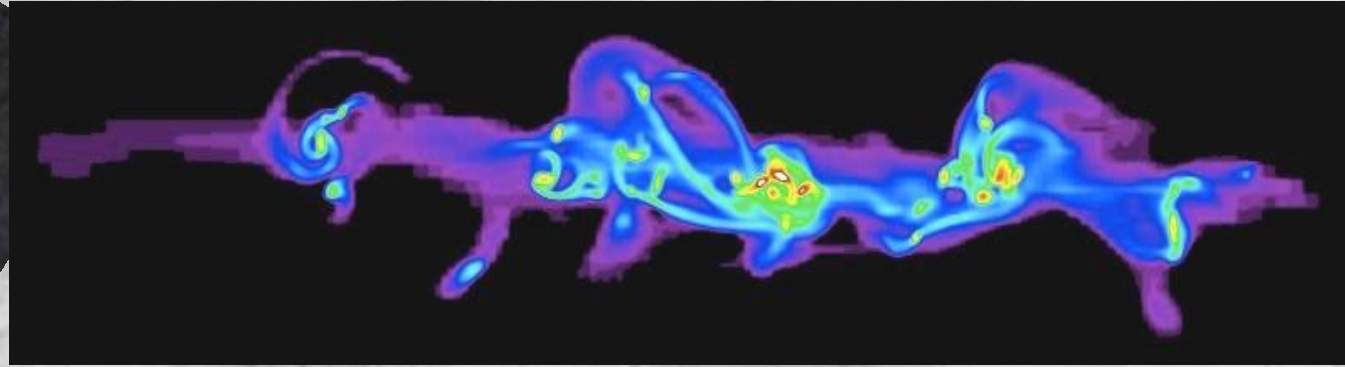
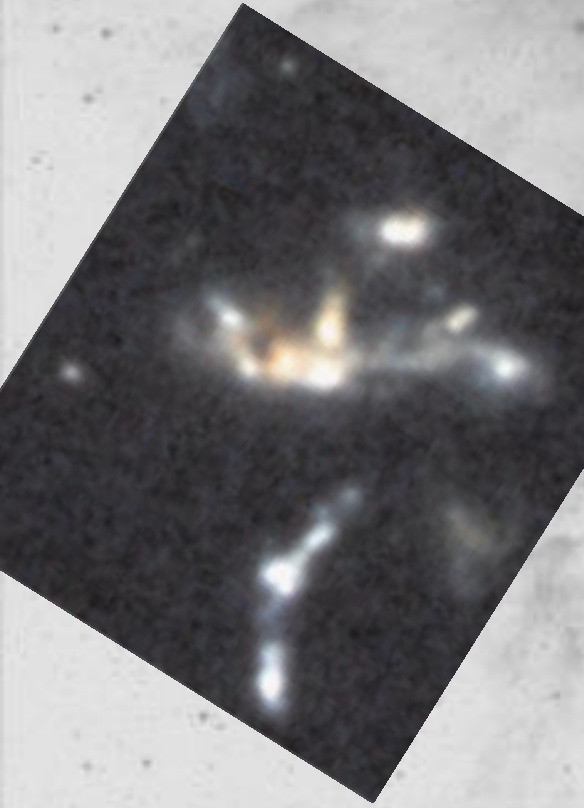
Simulation numérique du projet HORIZON

(R.Teyssier - CEA Saclay et al.)

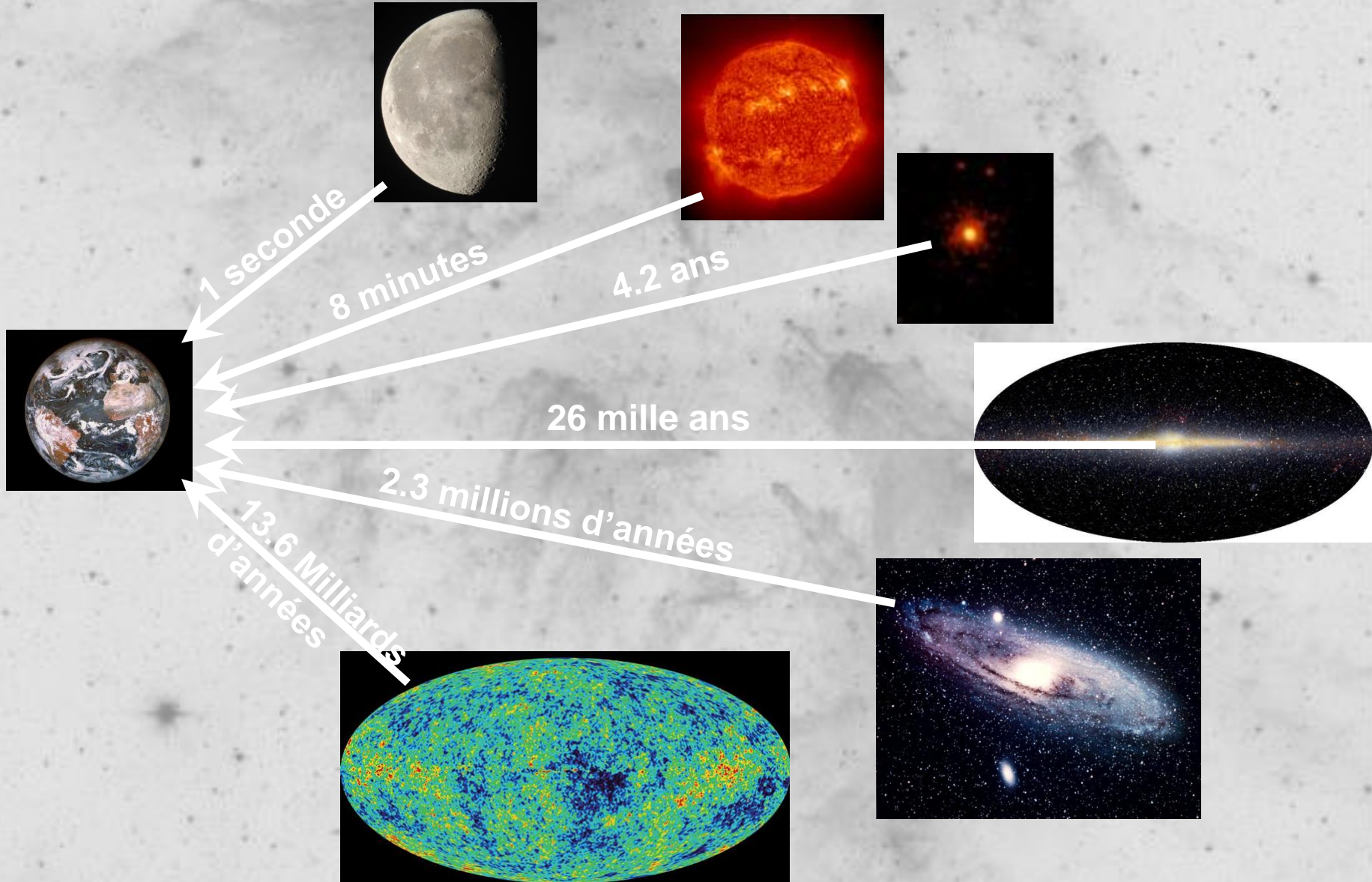
Ordinateur MareNostrum (Barcelone): 94 mille milliards d'opérations/seconde



Instabilités dynamiques et morphogénèse des galaxies



Voir loin = voir tôt (vitesse finie de la lumière)



Hubble Deep Field

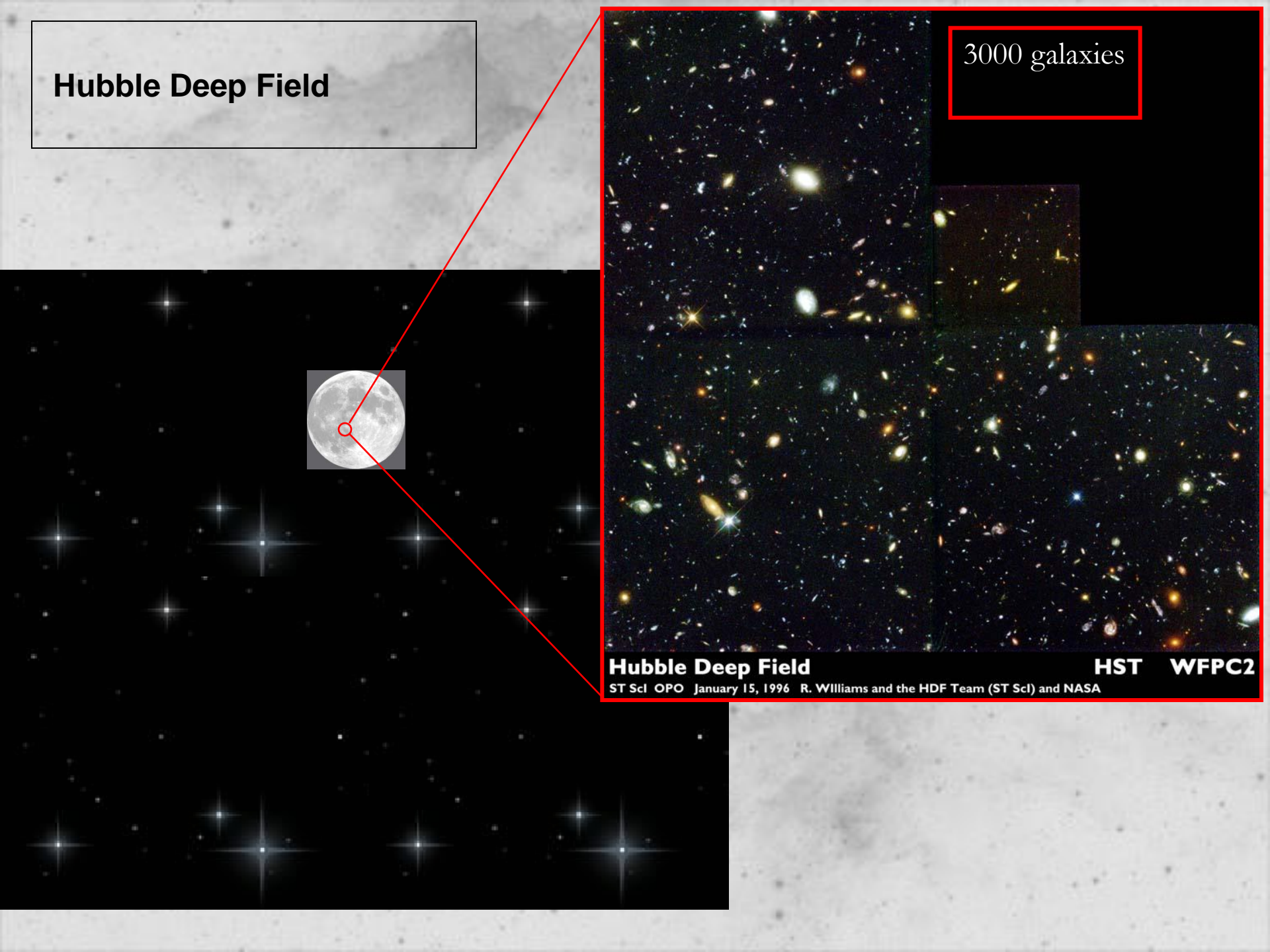


3000 galaxies

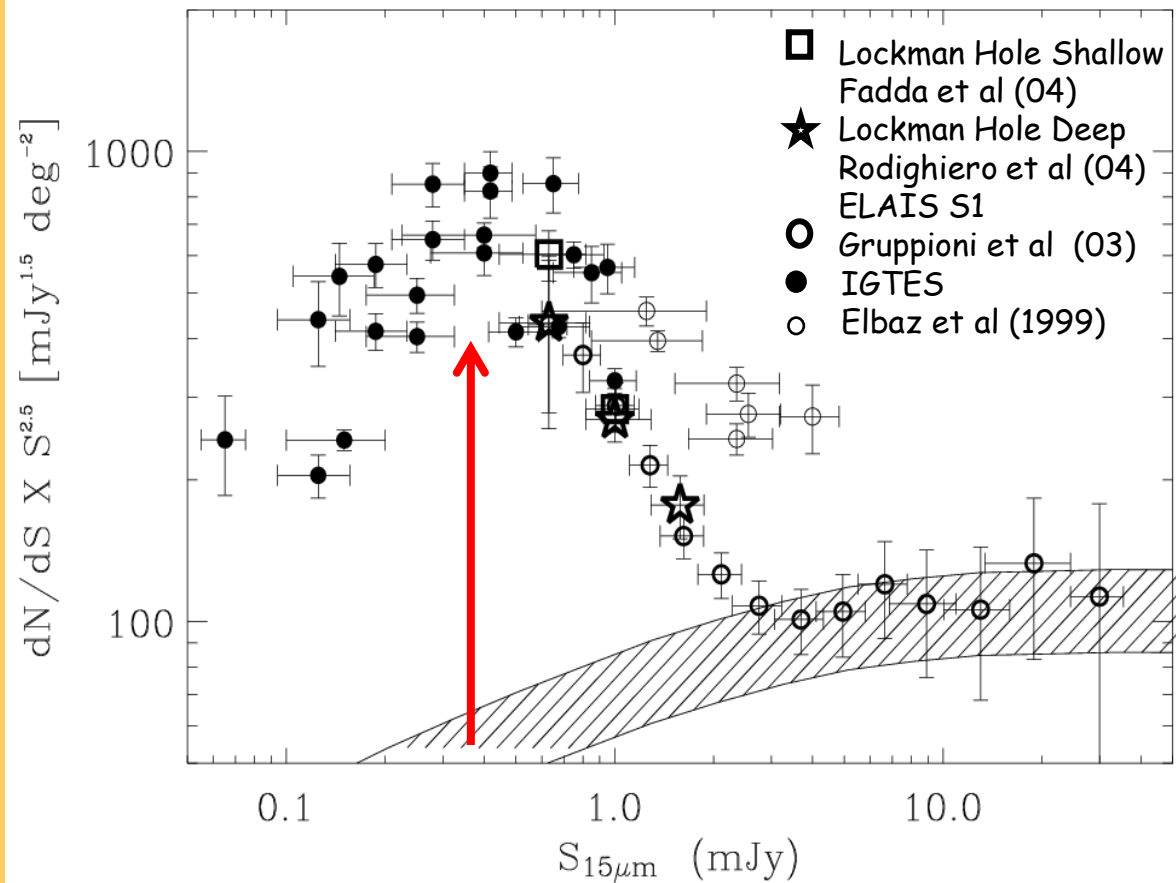
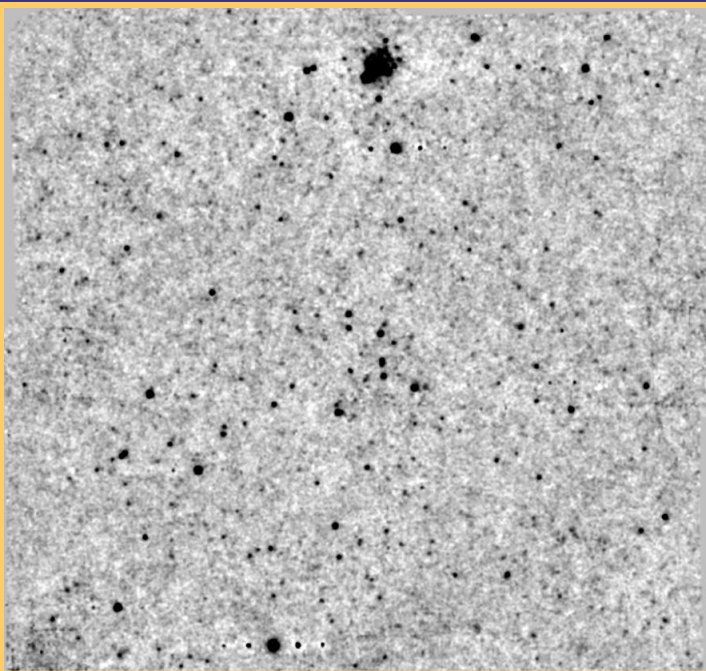
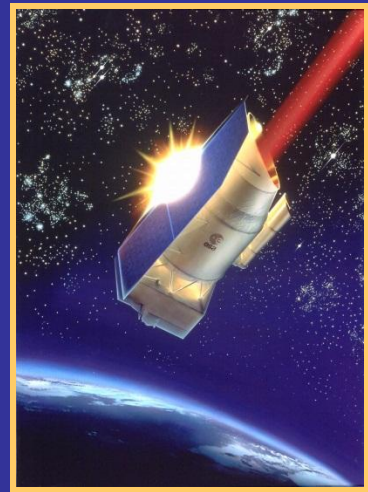
Hubble Deep Field

ST ScI OPO January 15, 1996 R. Williams and the HDF Team (ST ScI) and NASA

HST WFPC2



Comptages ISOCAM a 15 μm (1000 galaxies $< 2\text{mJy}$)



ISO, 1999

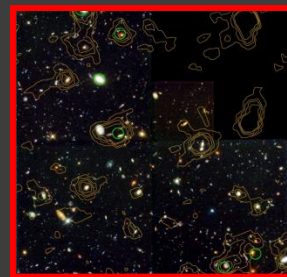
SPITZER, 2003

**Les
Galaxies
infrarouges
dominaient
par le
passé**

$L_{IR} > 2 \times 10^{10} L_{\odot}$, or $SFR > 3 M_{\odot} \text{ yr}^{-1}$ at $z < 1$

15'

10'



ISOCAM - 15
Om

HDF
GOODS
 $10' \times 15' = 10$ comoving-Mpc at $z=1$



The Moon



Hubble Deep Field

GOODS - HDFN



GOODS - CDFS



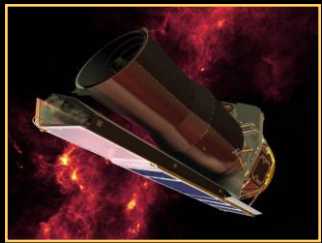
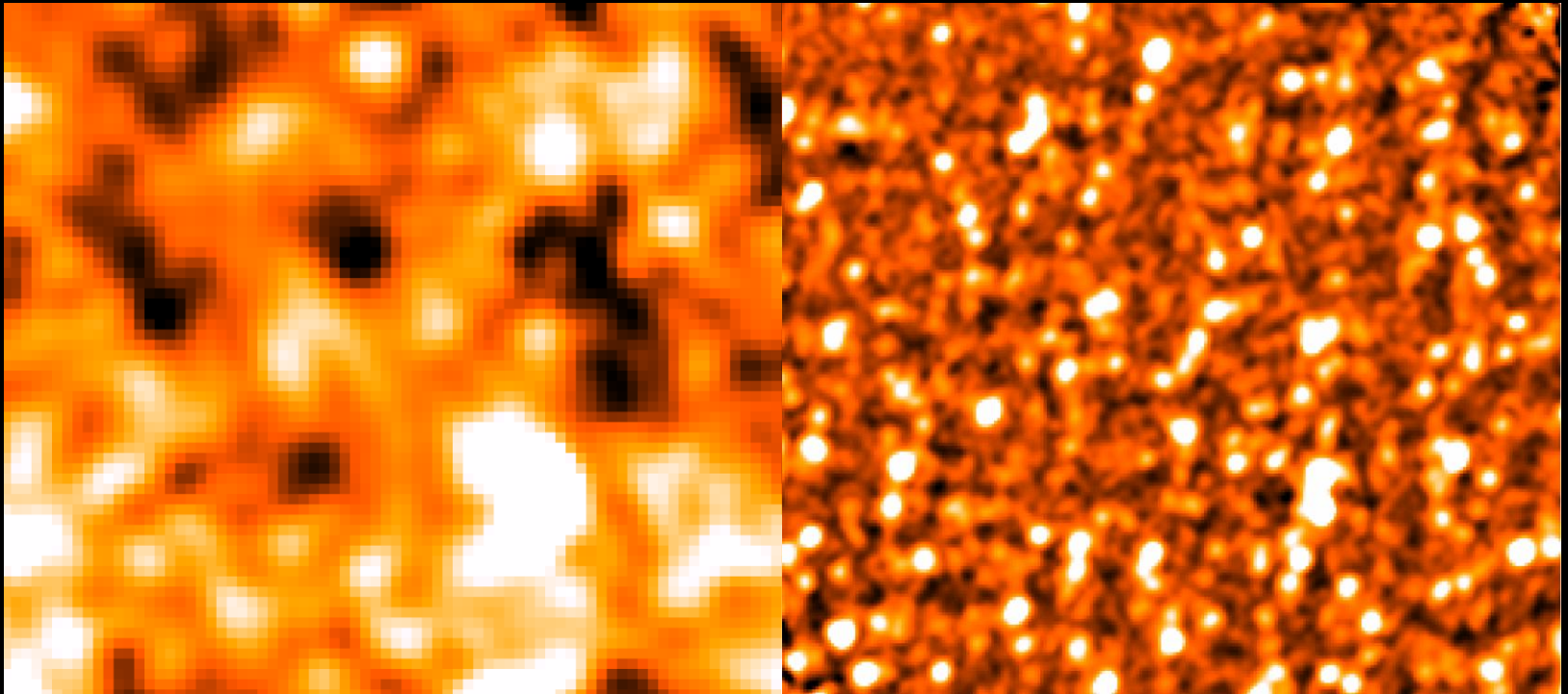
Ultra Deep Field



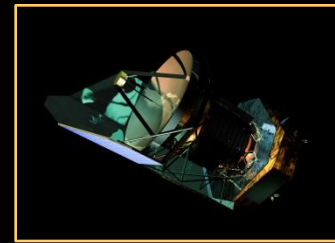
Paranal et le Very Large Telescope de ESO



Repousser la limite de confusion...



Spitzer : 85 cm



Herschel: 3,50 m

The Great Observatories Origins Deep Survey : far IR imaging with Herschel

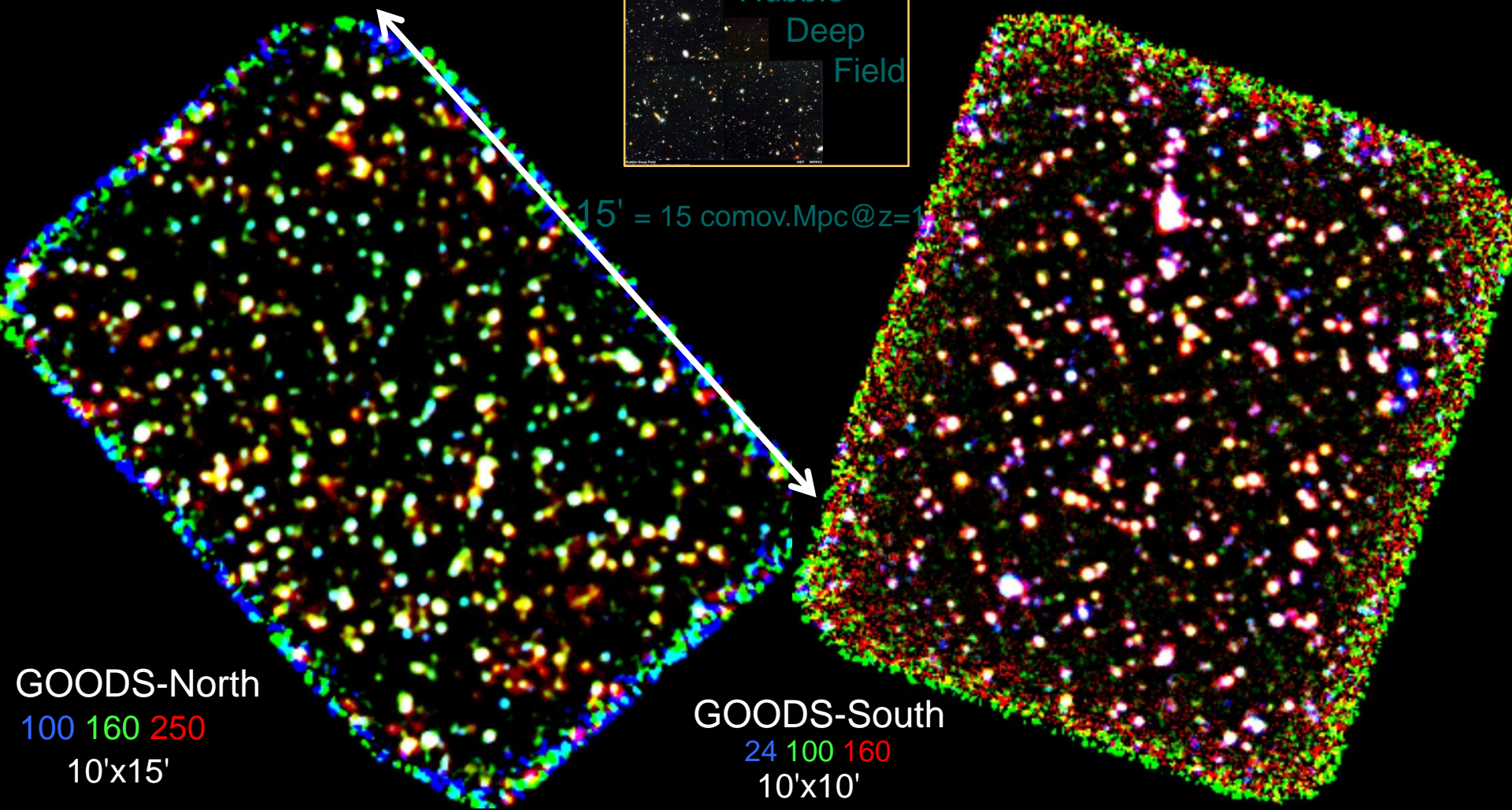
Deepest images of the sky in the far IR : ~2000 sources

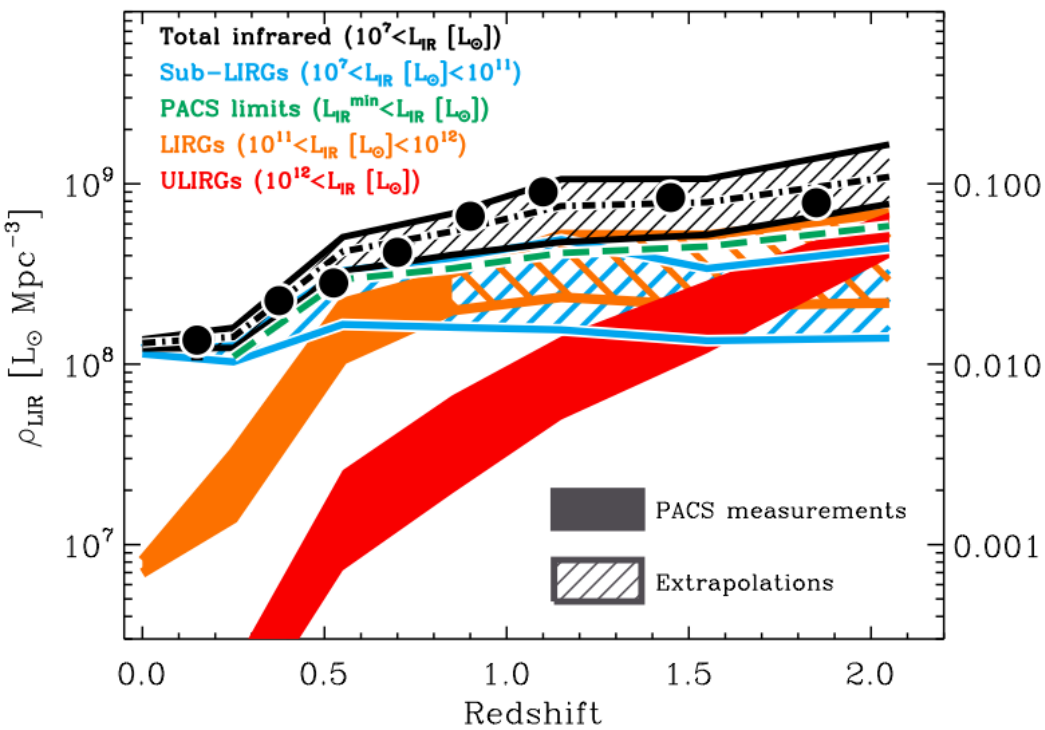
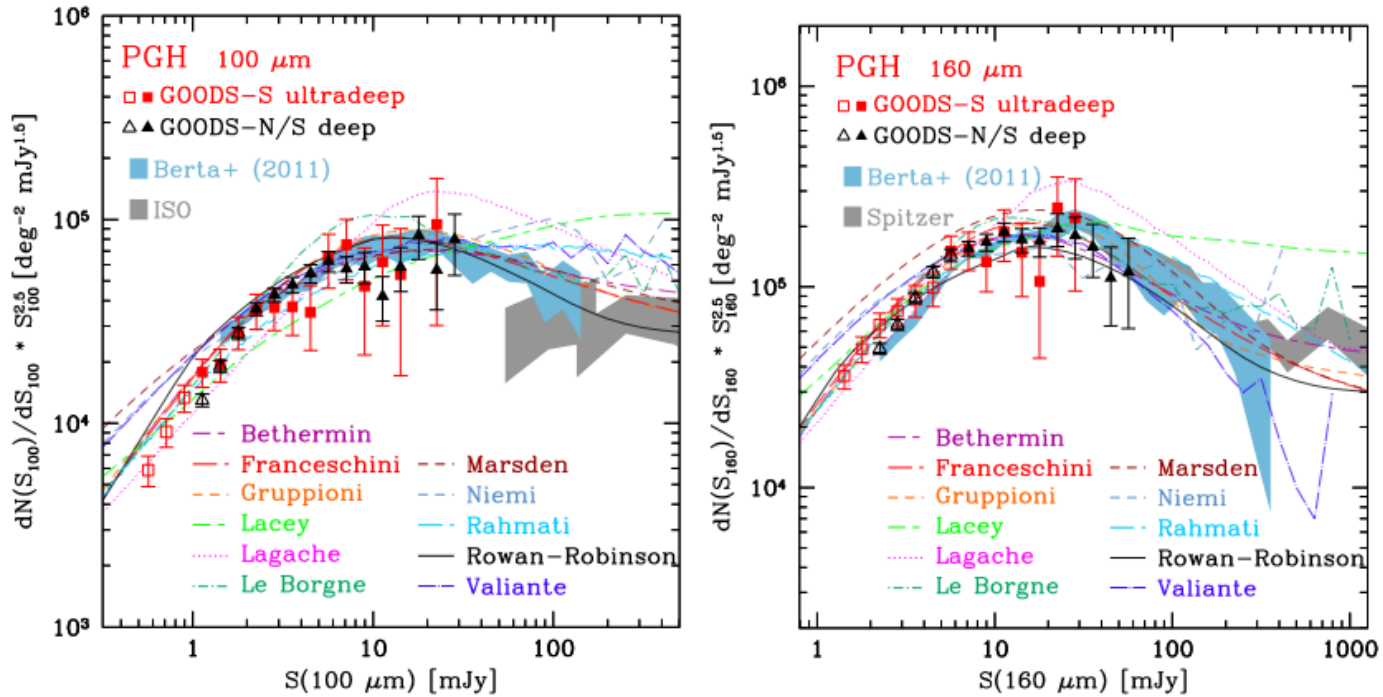
Collaborators (60): Fr, US, G, UK, Gr, It, Can, ESO, ESA -- PI D.Elbaz

362.6 hours (100Om & 160Om PACS + 31h SPIRE) +193.6 h



15' = 15 comov.Mpc@z=1





Magnelli +13 (GOODS-H+PEP)

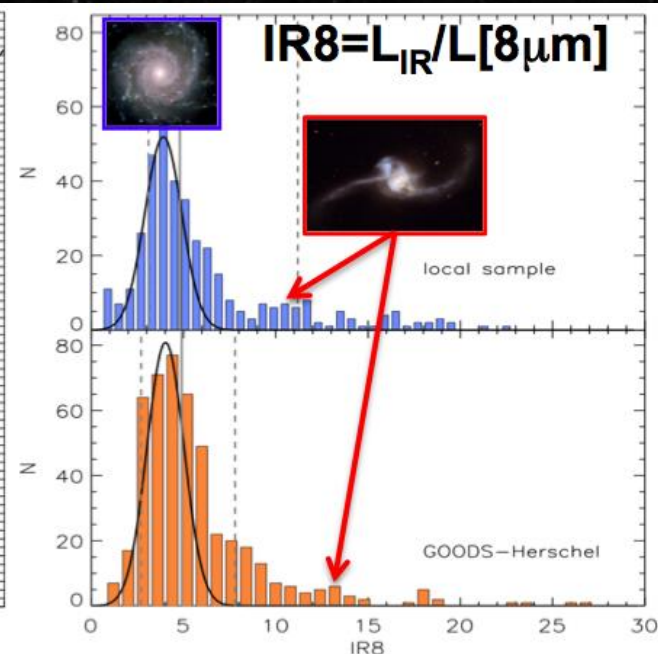
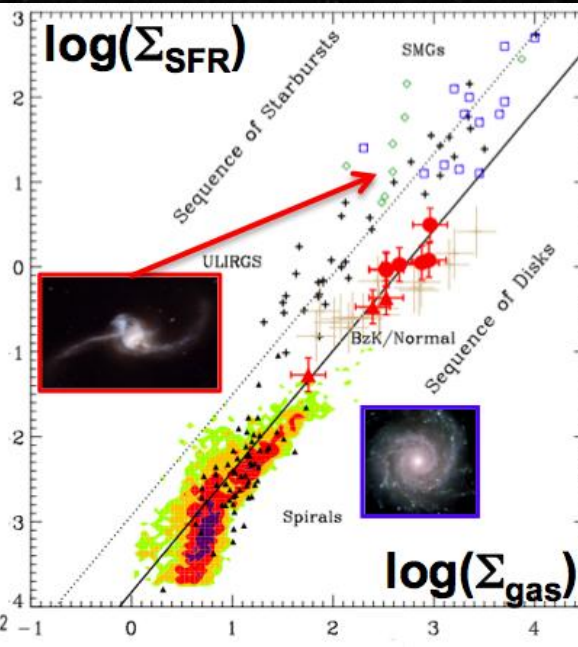
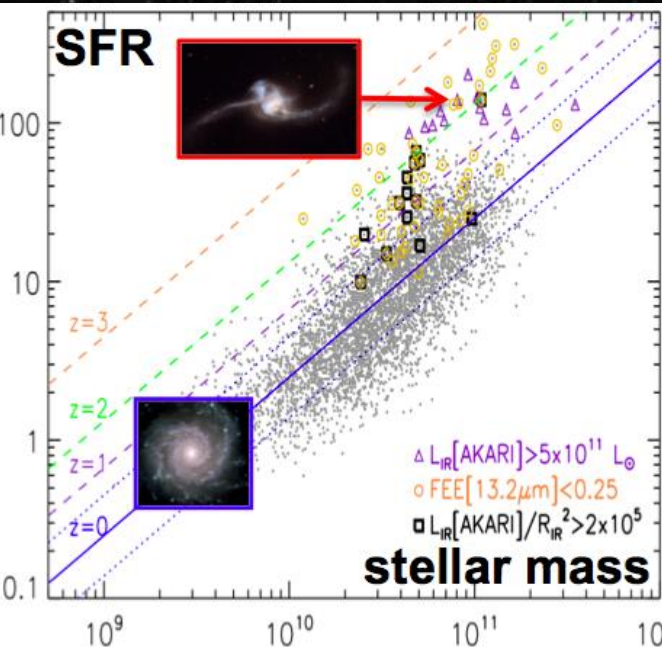
- 100, 160 μm down to 0.6 & 1.3 mJy
 → rise of LIRGs & ULIRGs to $z \sim 2$
 → make up ~80% of SFR density
- resolve 75% of cosmic IR background due to sources $z < 1.5$
 → SPIRE confusion limit 15-20 mJy, <15% resolved (Oliver +10)

the 3 sides of the Main Sequence

sSFR (starburstiness)

SFE (=SFR/M_{gas}, SK law)

IR8 (SF geometry)



Noeske +07, Elbaz +07, Daddi +07 ...

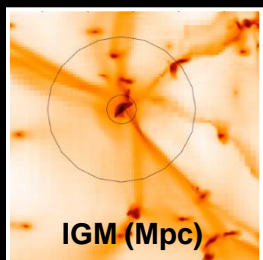
Daddi +10, Genzel +10

Elbaz +11, Nordon +12

mergers modulate star-formation

more numerous in the past, small impact on SF

Main results from Herschel surveys on star-formation mode of galaxies



proof that star formation has been dominantly sustained by gas support external to galaxies over > 12 Gyr

→ *next step: observe infall/gas haloes (ALMA abs^o /SKA)*

role of mergers secondary = paradox in expanding Universe !

→ *What causes the % of starbursts to remain nearly constant at the level of a few % ? Ellipticals mostly formed in main sequence !*

Herschel resolves $>70\%$ of 100-160-250 μm CIRB

→ *global budget of star-formation*

Drop of SFR density since ~ 8 Gyr mostly due to lack of gas rather SF efficiency !

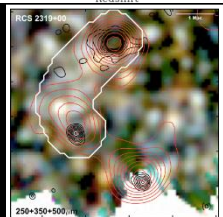
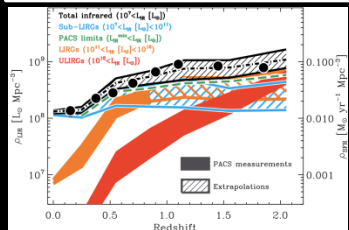
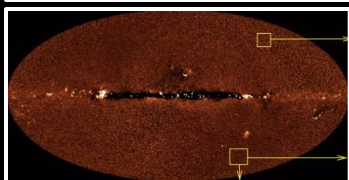
→ *problem: what is preventing gas from infalling onto galaxies.*

role of large-scale environment secondary vs internal physics

→ *hidden role of environment since infall from Mpc scales !*

Black holes grow in parallel with stars (& mildly affect IR)

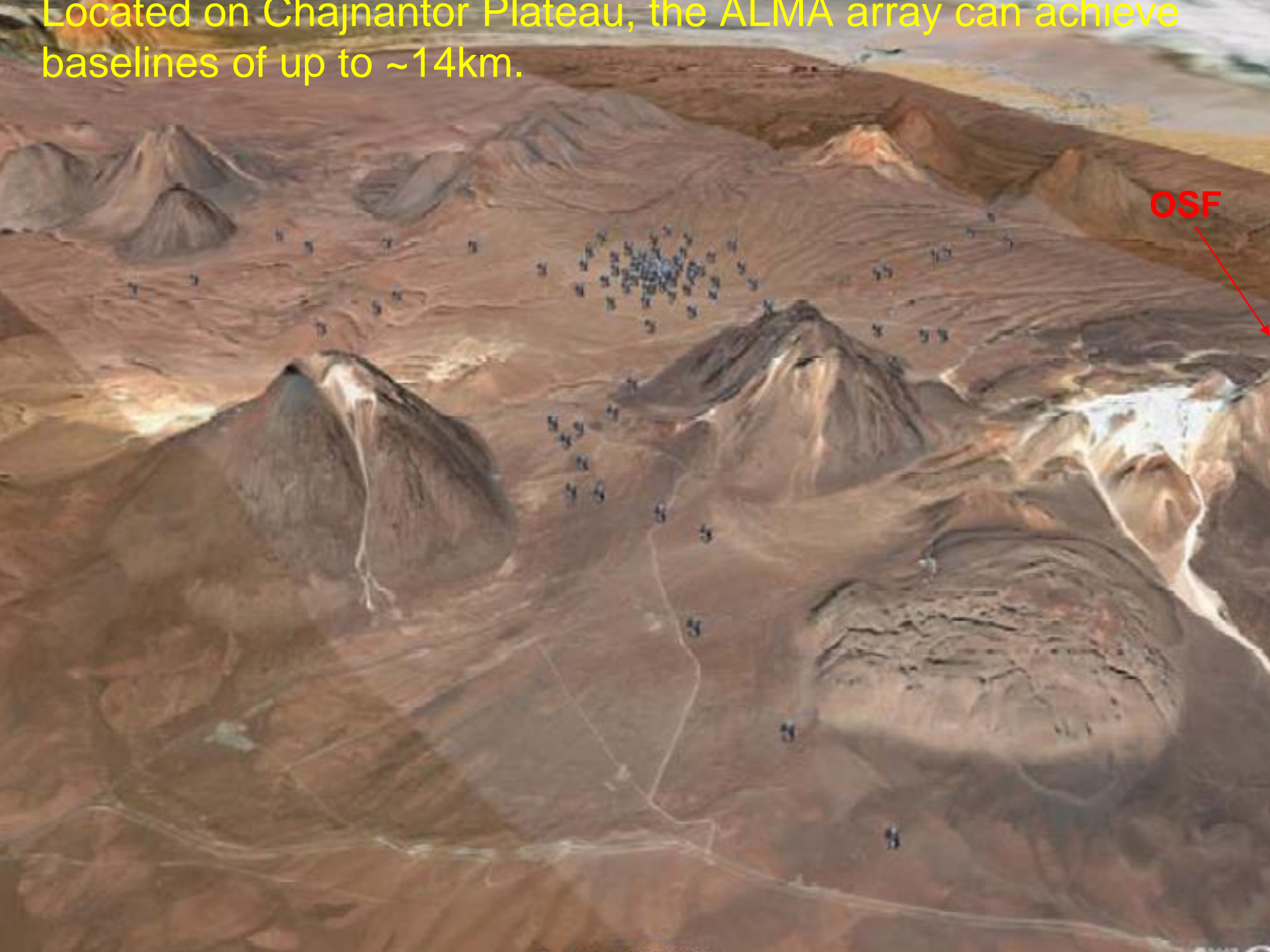
→ *what feeds the central SMBH ? Infall ?...*



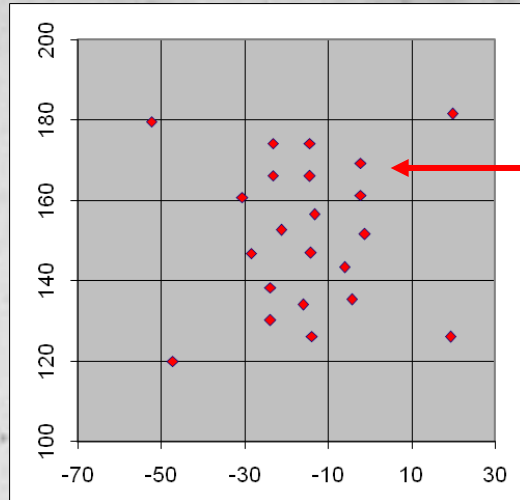
The Atacama Large Millimeter Submillimeter Array (ALMA)



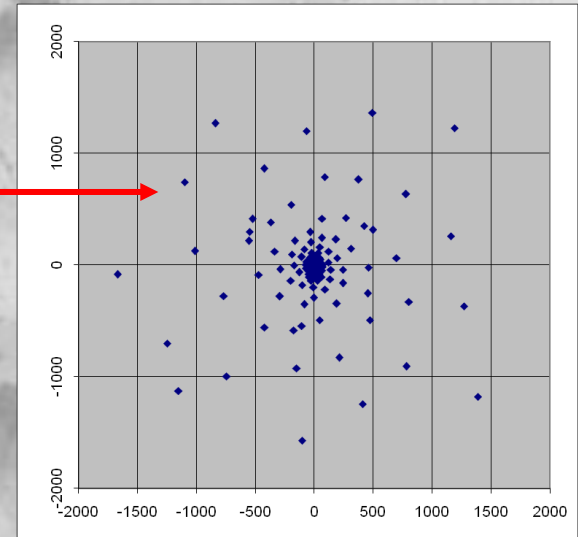
Located on Chajnantor Plateau, the ALMA array can achieve baselines of up to ~14km.



ALMA Operates like a zoom lens...



Antennas

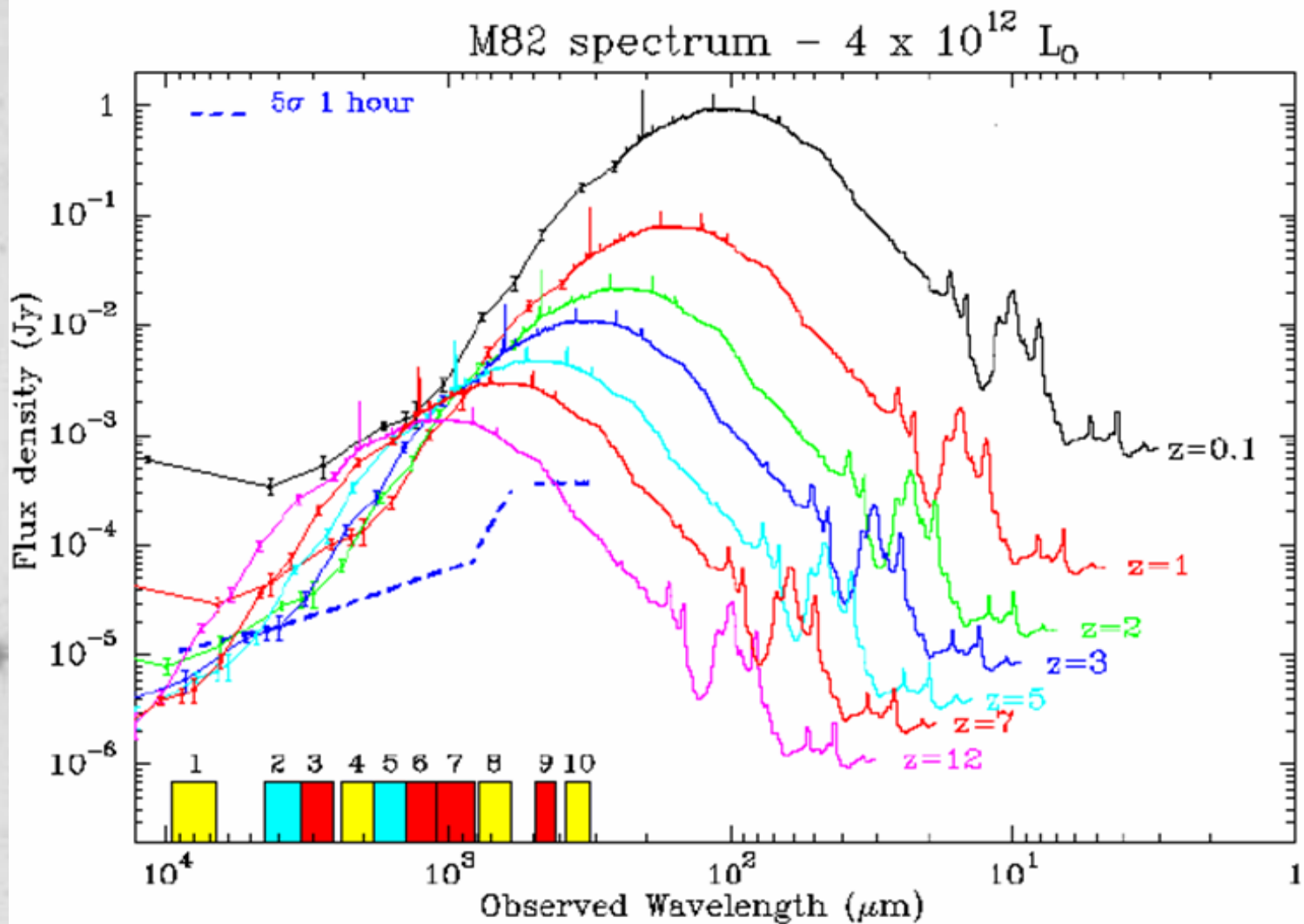


Resolution depends on separation between the antennas





ULIRG SED: poussière et raies moléculaires



HDF: riche en galaxies proches,
pauvre en galaxies éloignées.

Source: K. Lanzetta, SUNY-SB



Nearby galaxies in
HDF

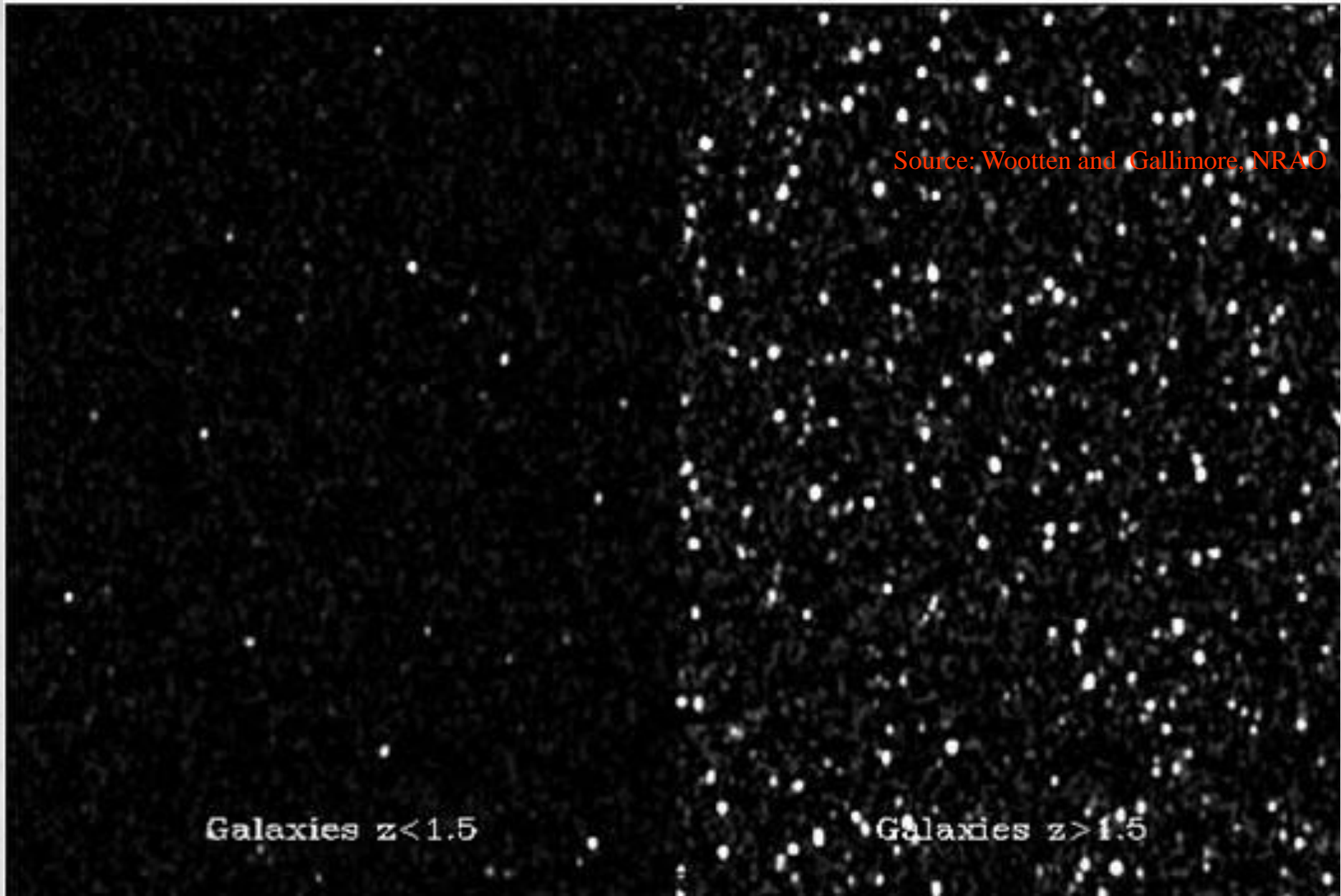


Distant galaxies in
HDF

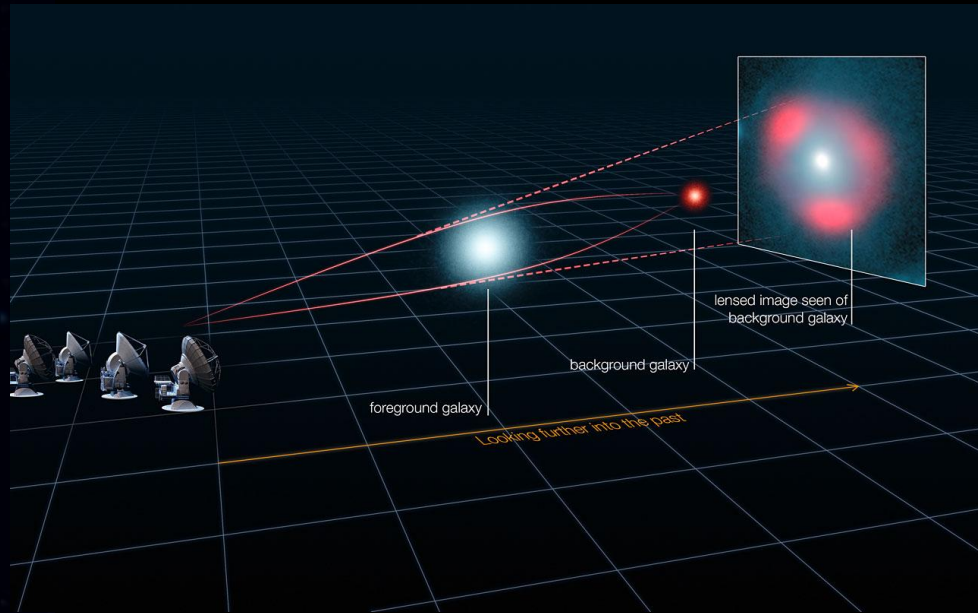
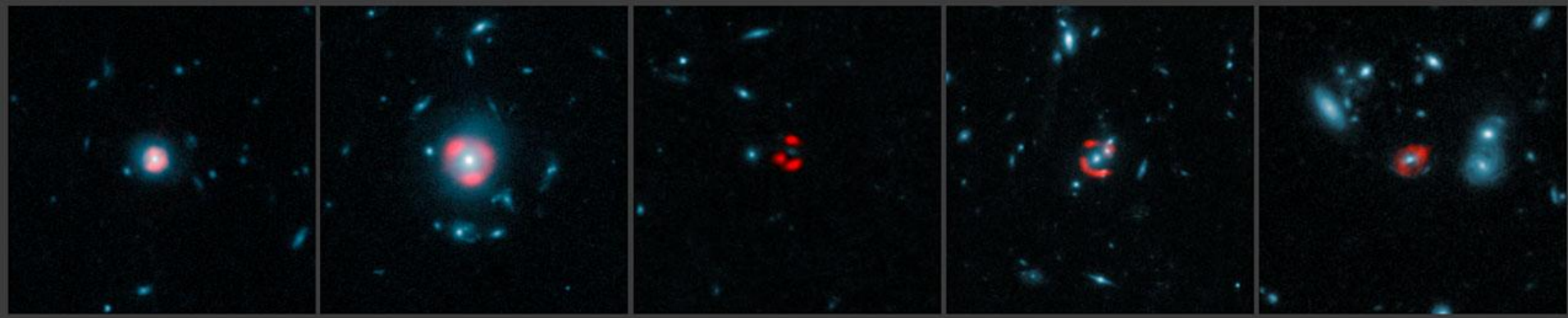
Source: Wootten and Gallimore, NRAO

Galaxies $z < 1.5$

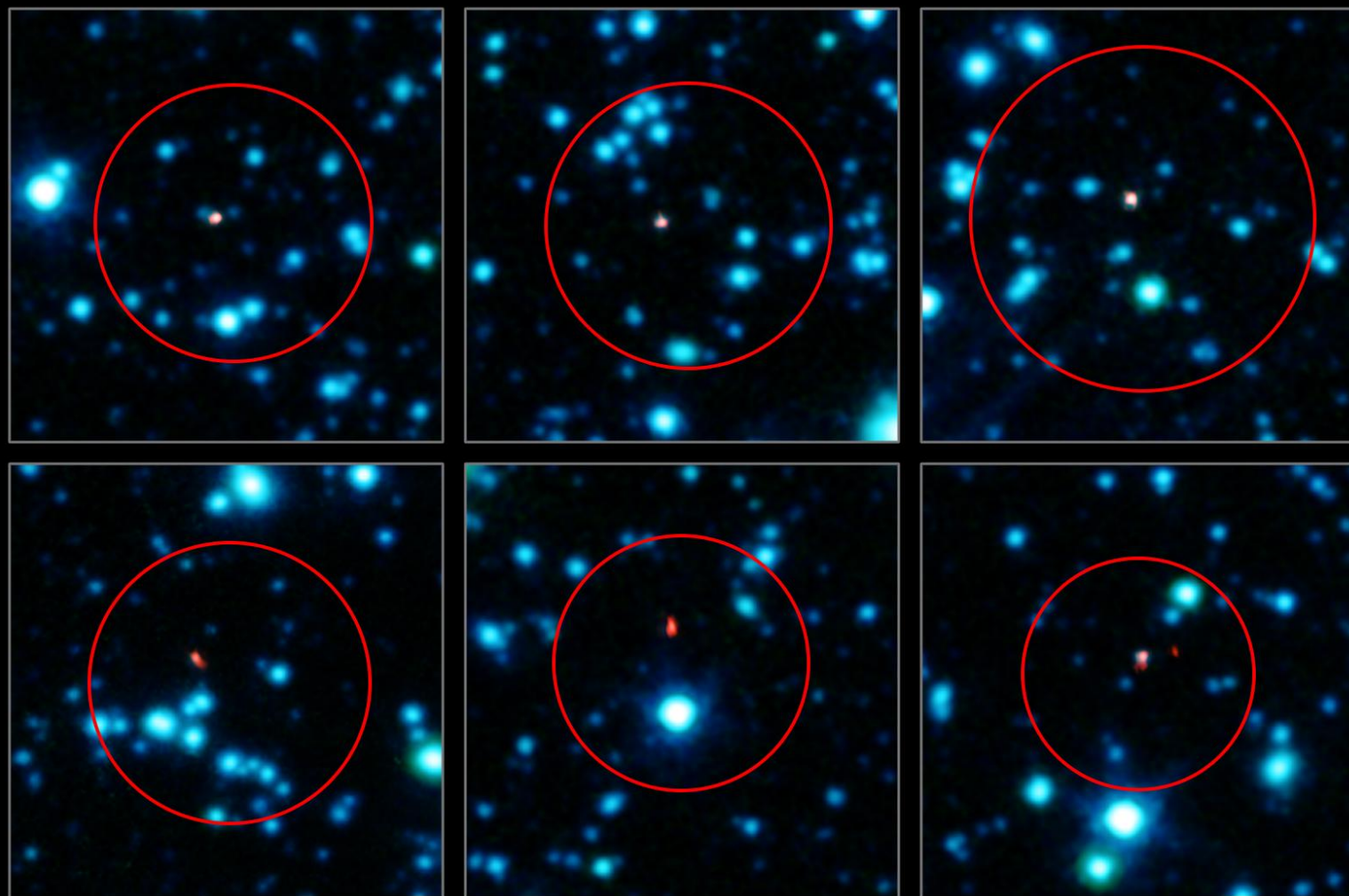
Galaxies $z > 1.5$



ALMA Finds Monster Starburst Galaxies



ALMA Pinpoints Early Galaxies



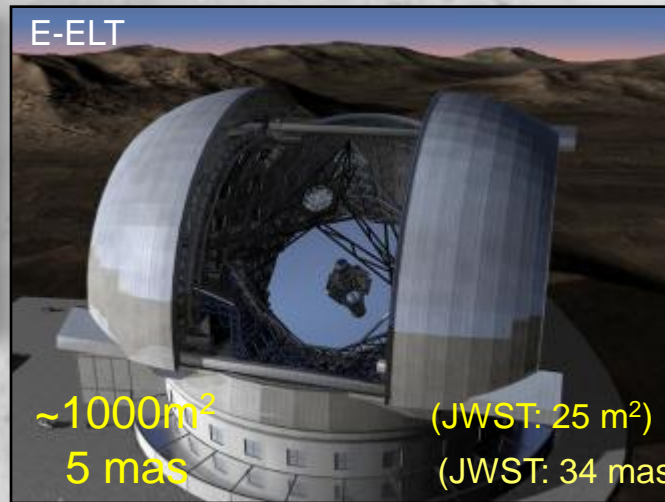
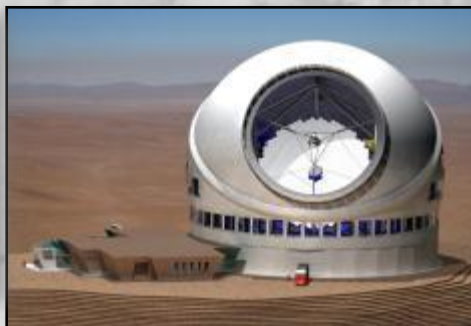


FIN

Extremely large telescope projects

- Discoveries: Opening parameter space (photon sensitivity, spatial resolution)

Aperture	25.4 unfilled	30m filled	39m filled
Primary	7x8.4m	492x1.4	798x1.4
Site	Las Campanas	Mauna Kea	Cerro Armazones



VLT

GMT

TMT

E-ELT

~50 m²

~400 m²

~600 m²

~1000m²

(JWST: 25 m²)

1μm: 25 mas

9 mas

7 mas

5 mas

(JWST: 34 mas)