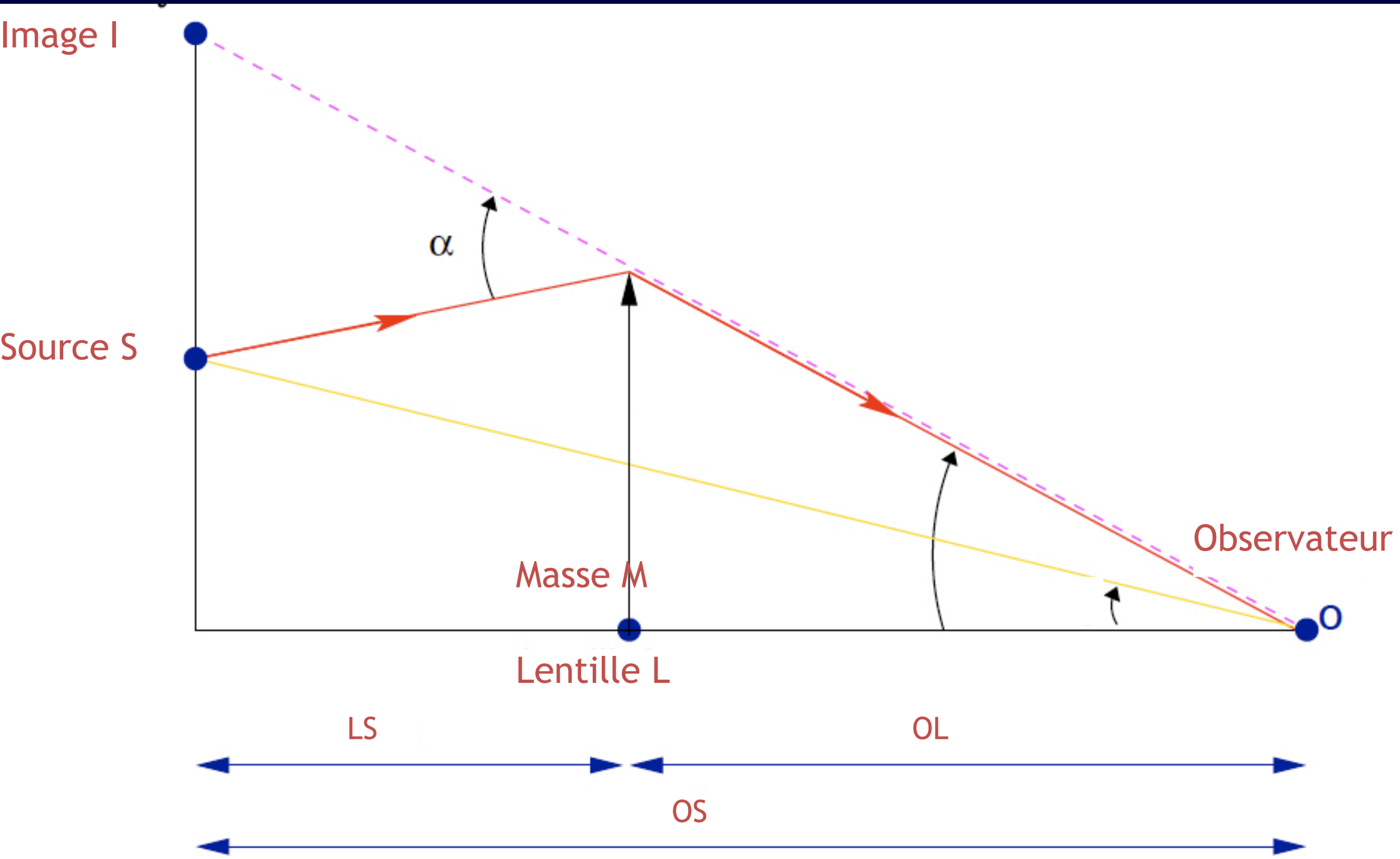
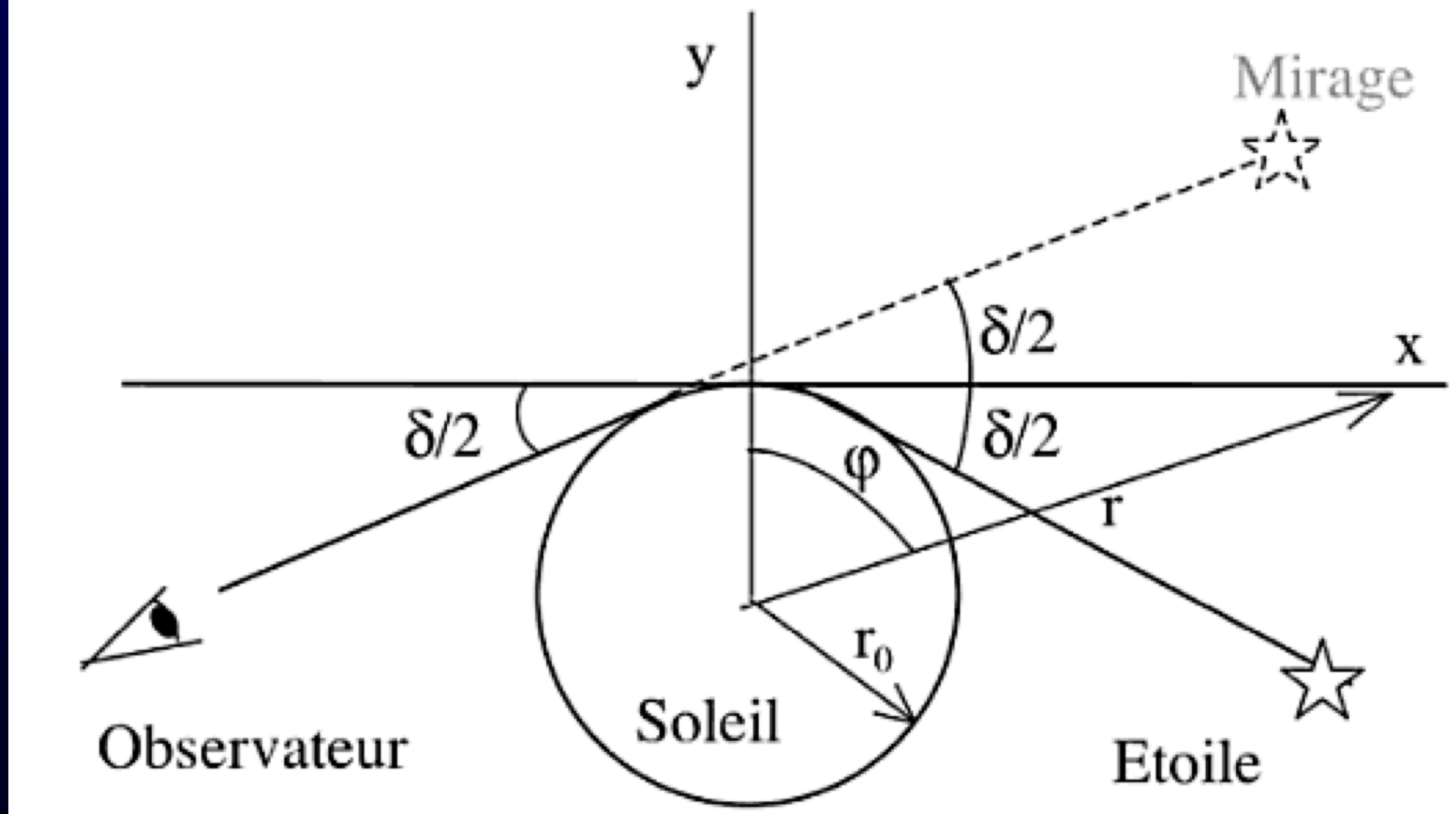
Mirages Cosmiques

“Optique Gravitationnelle”

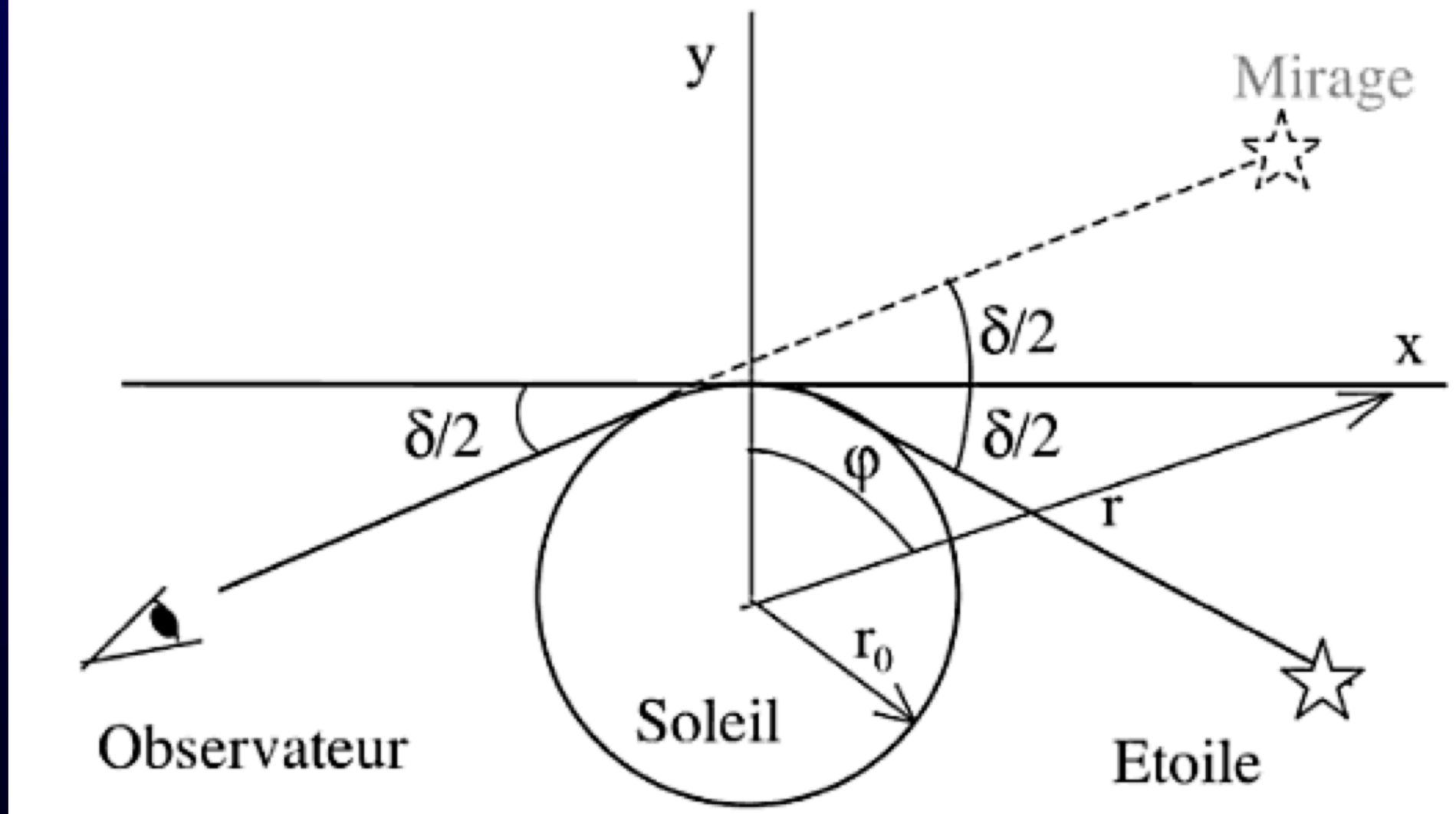




Newton

1” = (1/3600)°

$$\frac{2\,GM}{R_0\,c^2} \sim 0.8”$$

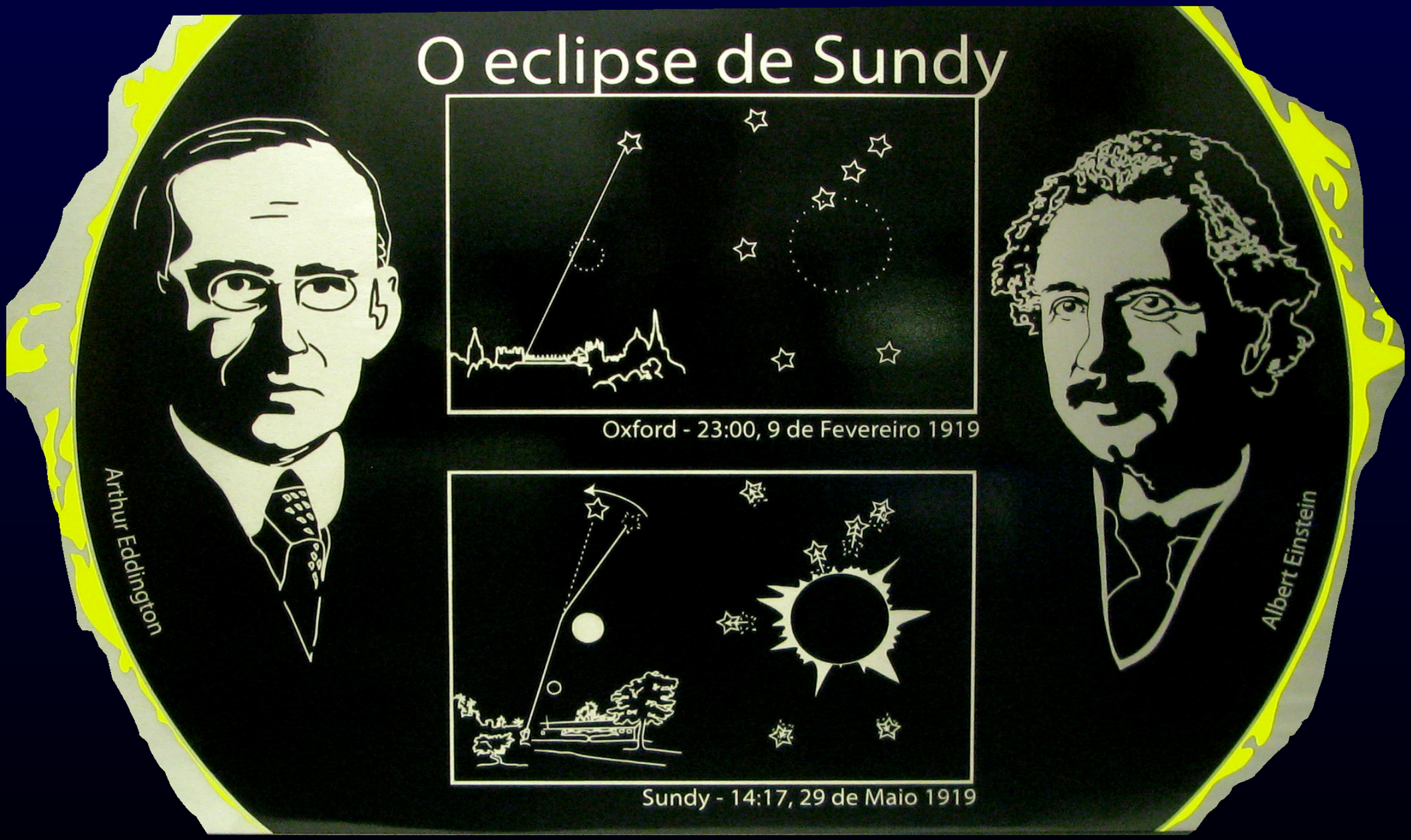


Einstein

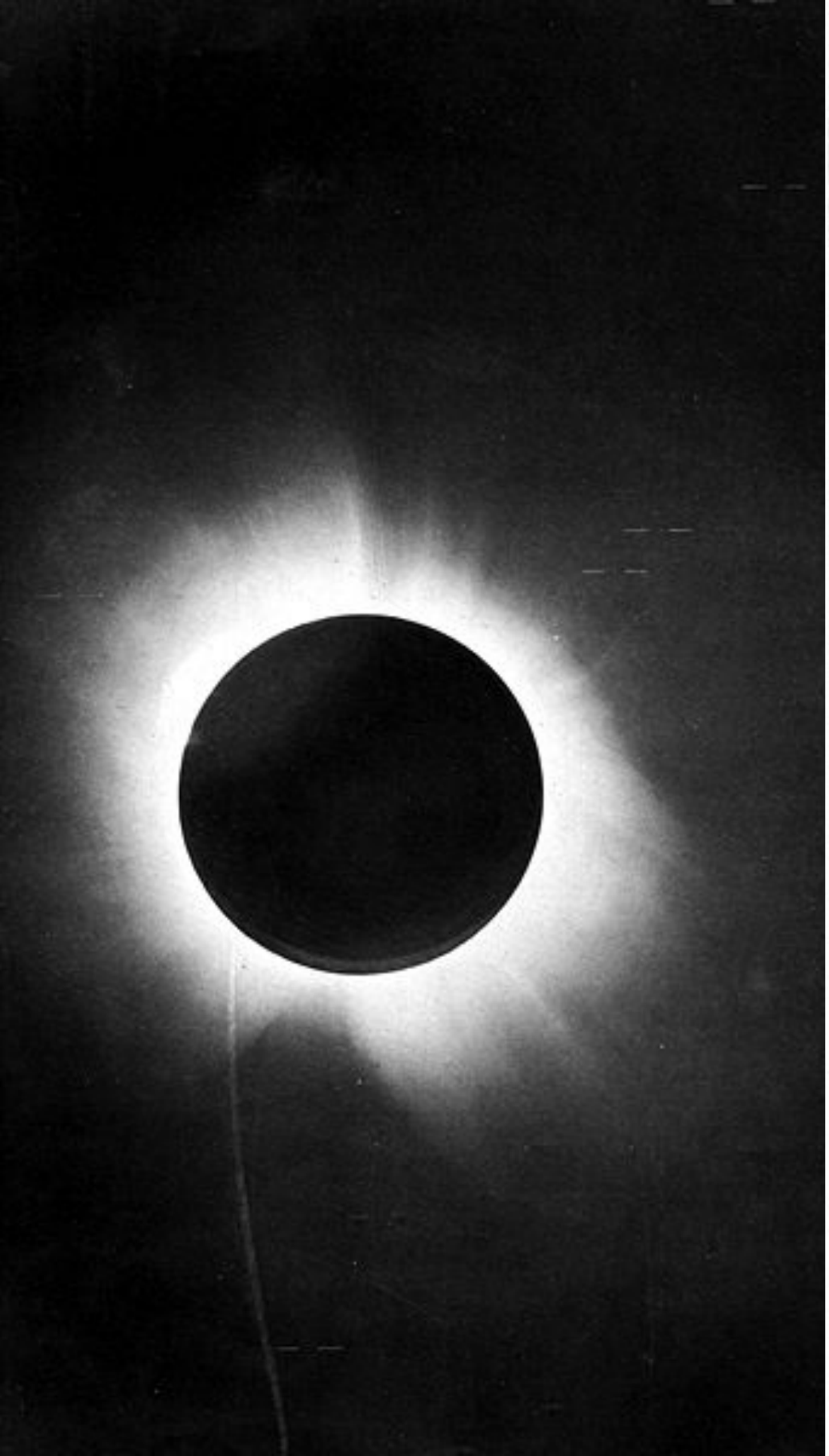
1” = (1/3600)°

$$\frac{4\,GM}{R_0\,c^2} \sim 1.6”$$

Expérience d'A.Eddington



Eclipse solaire du 29 Mai 1919, île de Príncipe



Actual Position of the Star

Apparent Position of the Star

Distance from the Earth to the Stella Background is more than 93,000,000,000,000 miles.

This Diagram shows the proportional Displacement of the Stars in relation to the distance from the Sun.

The amount of Displacement is exaggerated about 600 times

Apparent Position :
Actual Position :

THE SUN

Distance from the Earth 93,000,000 miles

THE SUN

AFRICA

Principe I.

Sobral

SOUTH AMERICA

ATLANTIC OCEAN

Showing Path of Total Eclipse of May 28-29, 1919, and positions of the two Observation Stations.

THE OBSERVATION STATION AT SOBRAL, IN BRAZIL

The Corona

Rayon d'Einstein

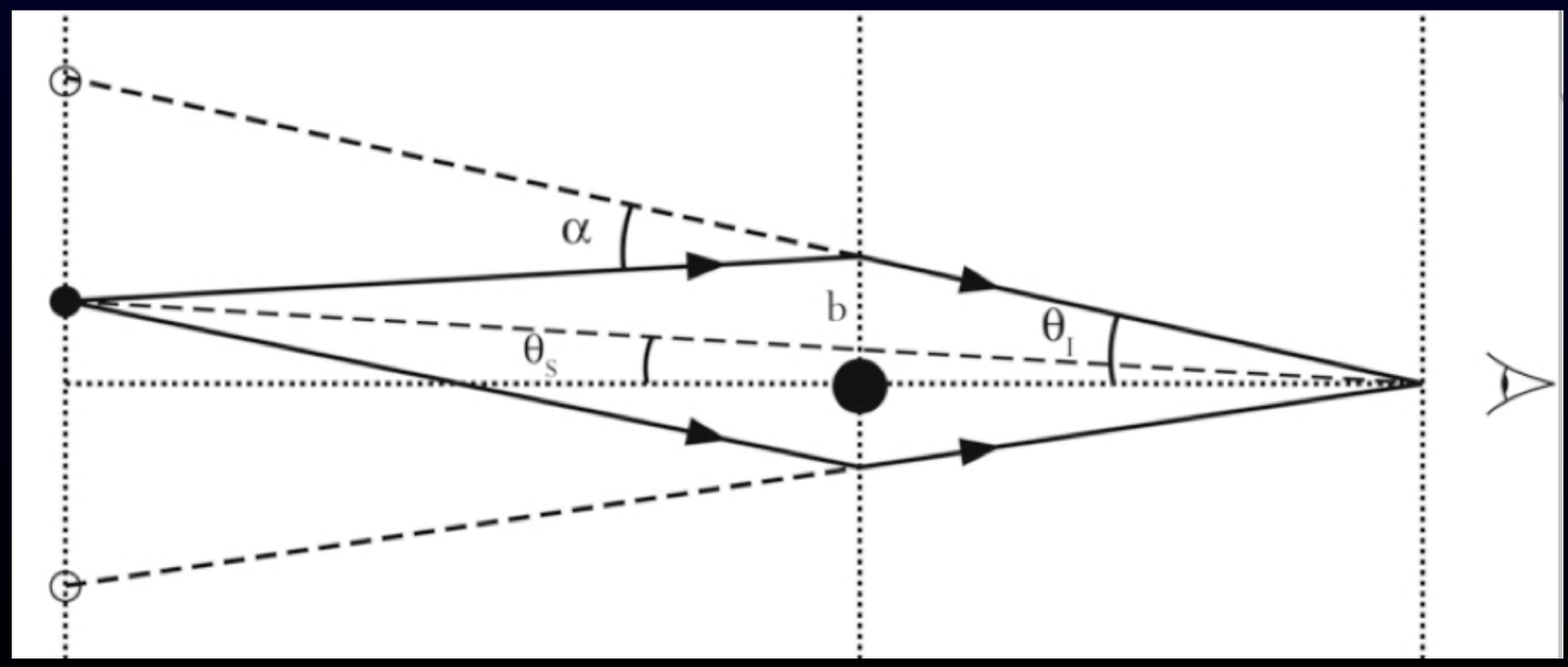
Echelle de l'effet de lentille gravitationnelle

$1'' = (1/3600)^\circ$

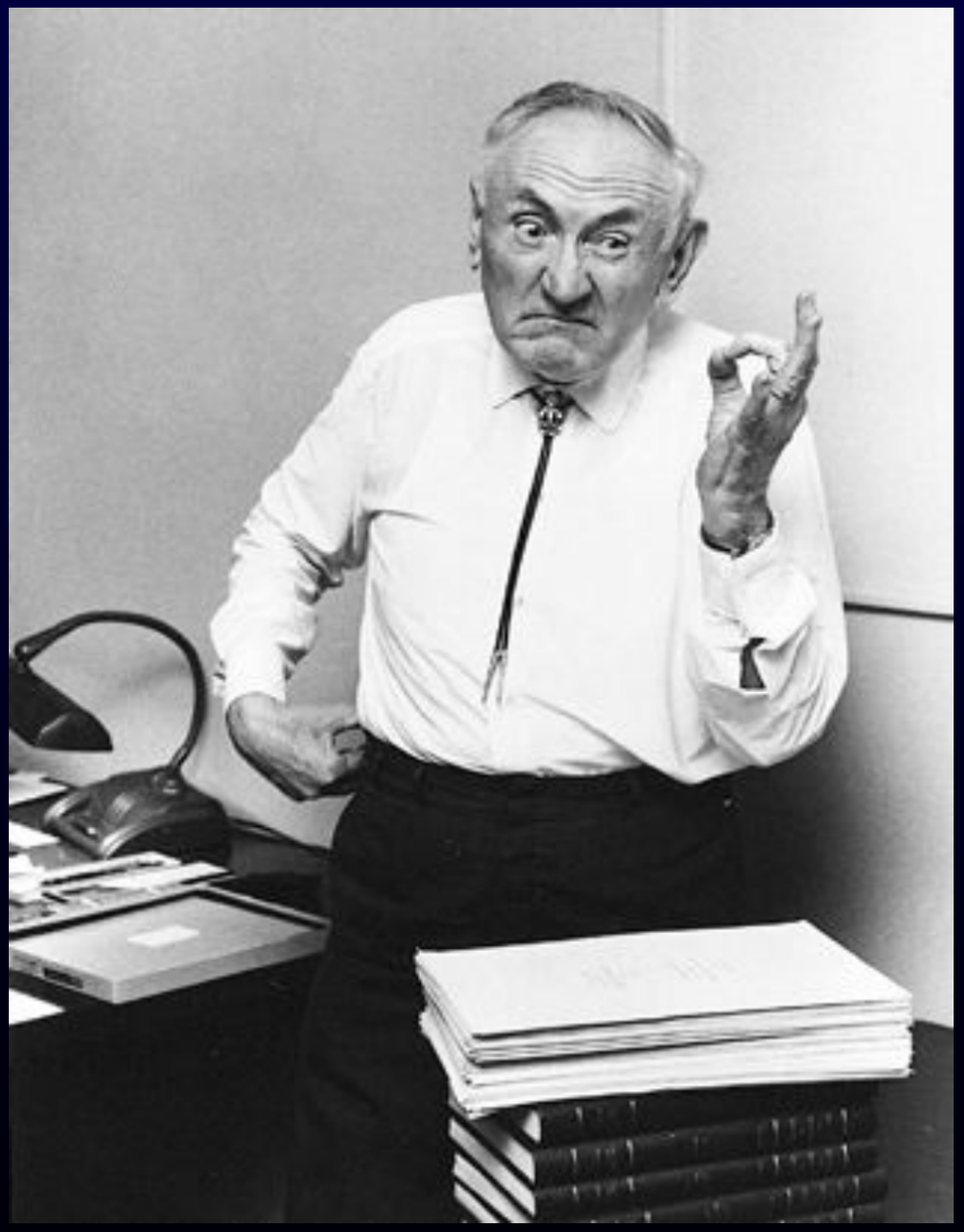
Re

- Soleil + étoile: 1.8”
- Etoile + étoile: 0.001”
- Galaxie + Galaxie(~1 + 5 Md a-l): 1”

Re



Le retour de Fritz Zwicky

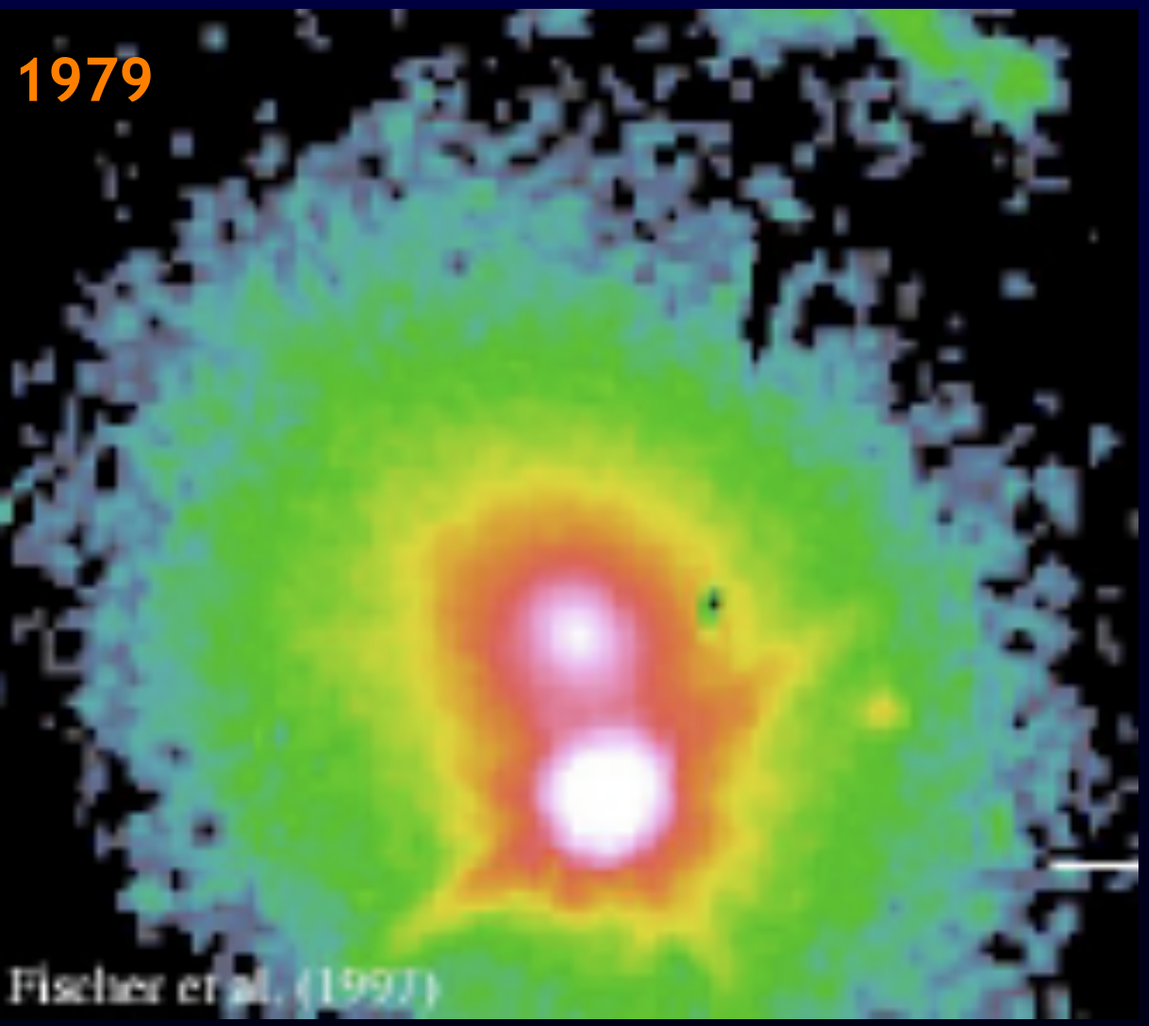


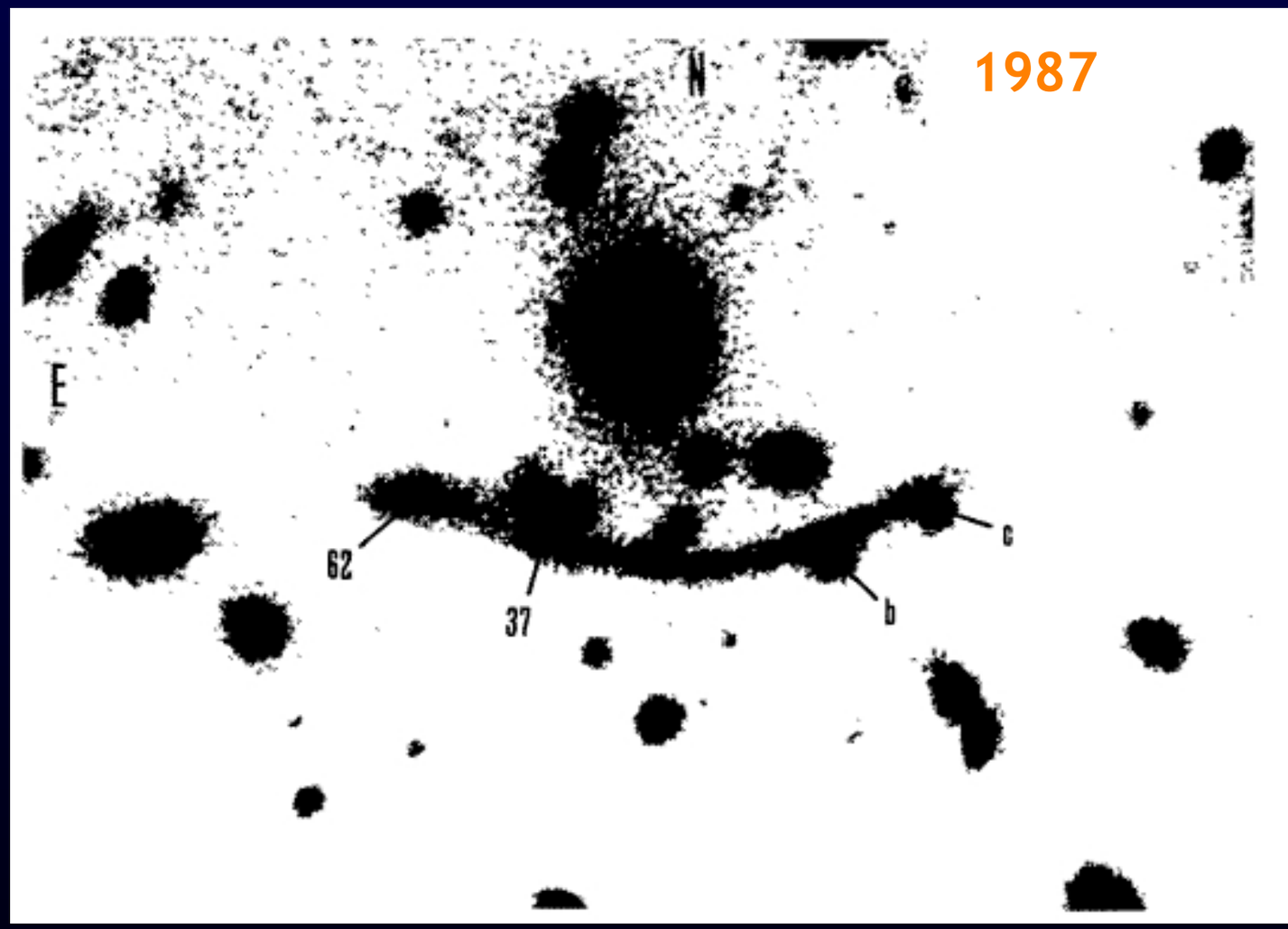
Groupes et amas de galaxies contiennent une majorité de matière noire, n'émettant pas de rayonnement.

1937: Telescope gravitationnel

- Groupe de galaxies + Galaxie: 10”
- Amas de galaxies + Galaxie: 30”

Historique récente

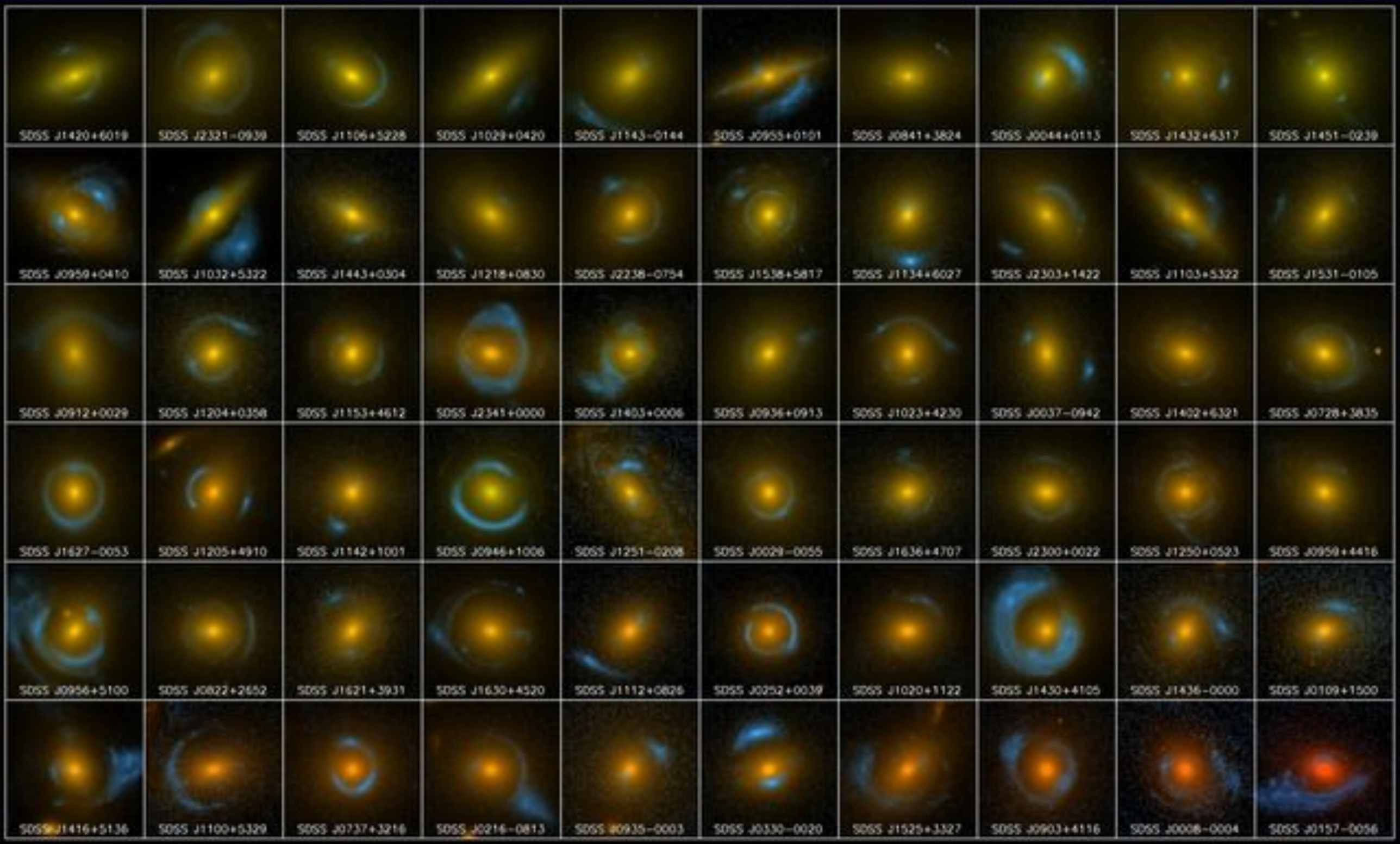




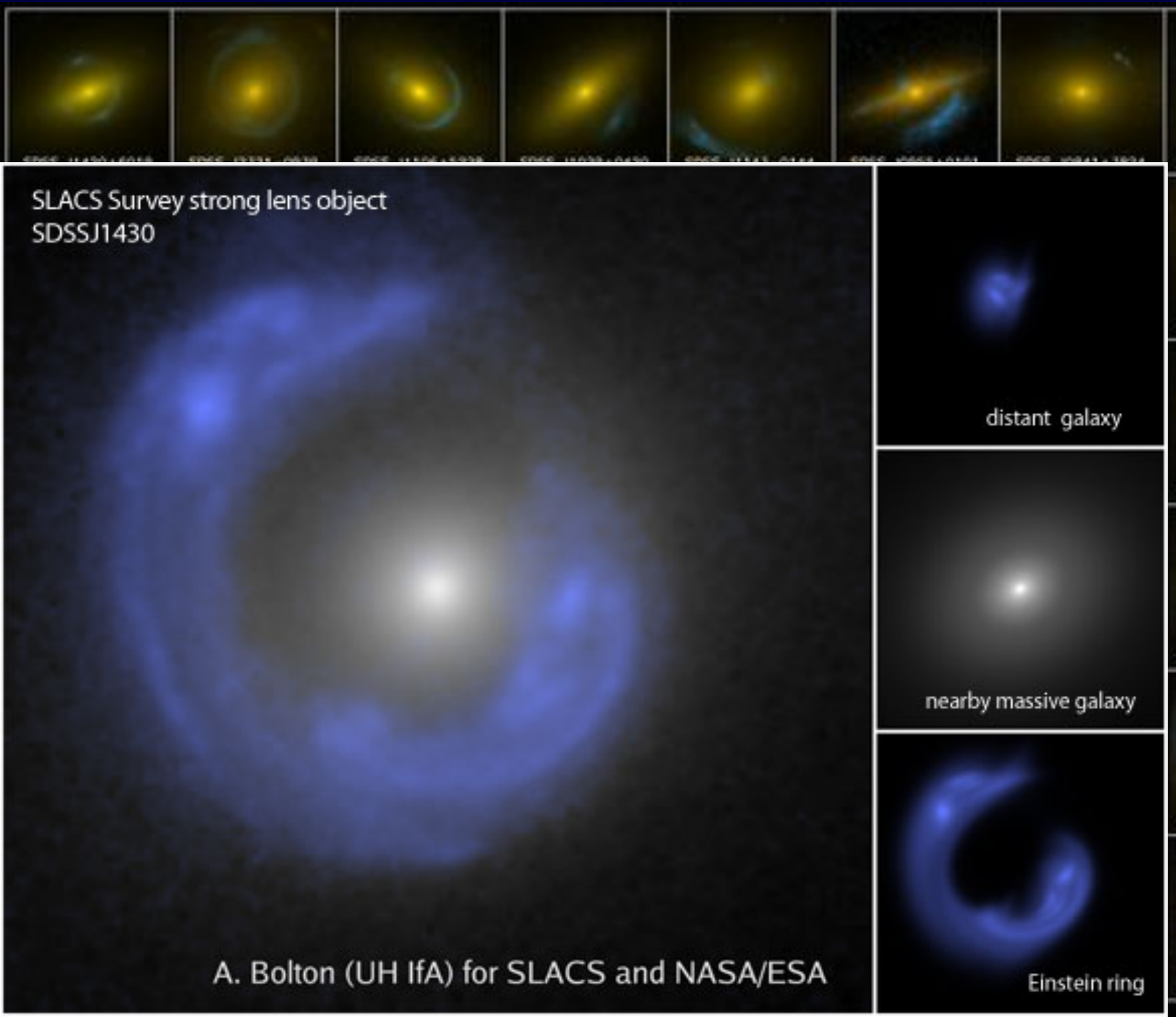
Walsh: première
Image double

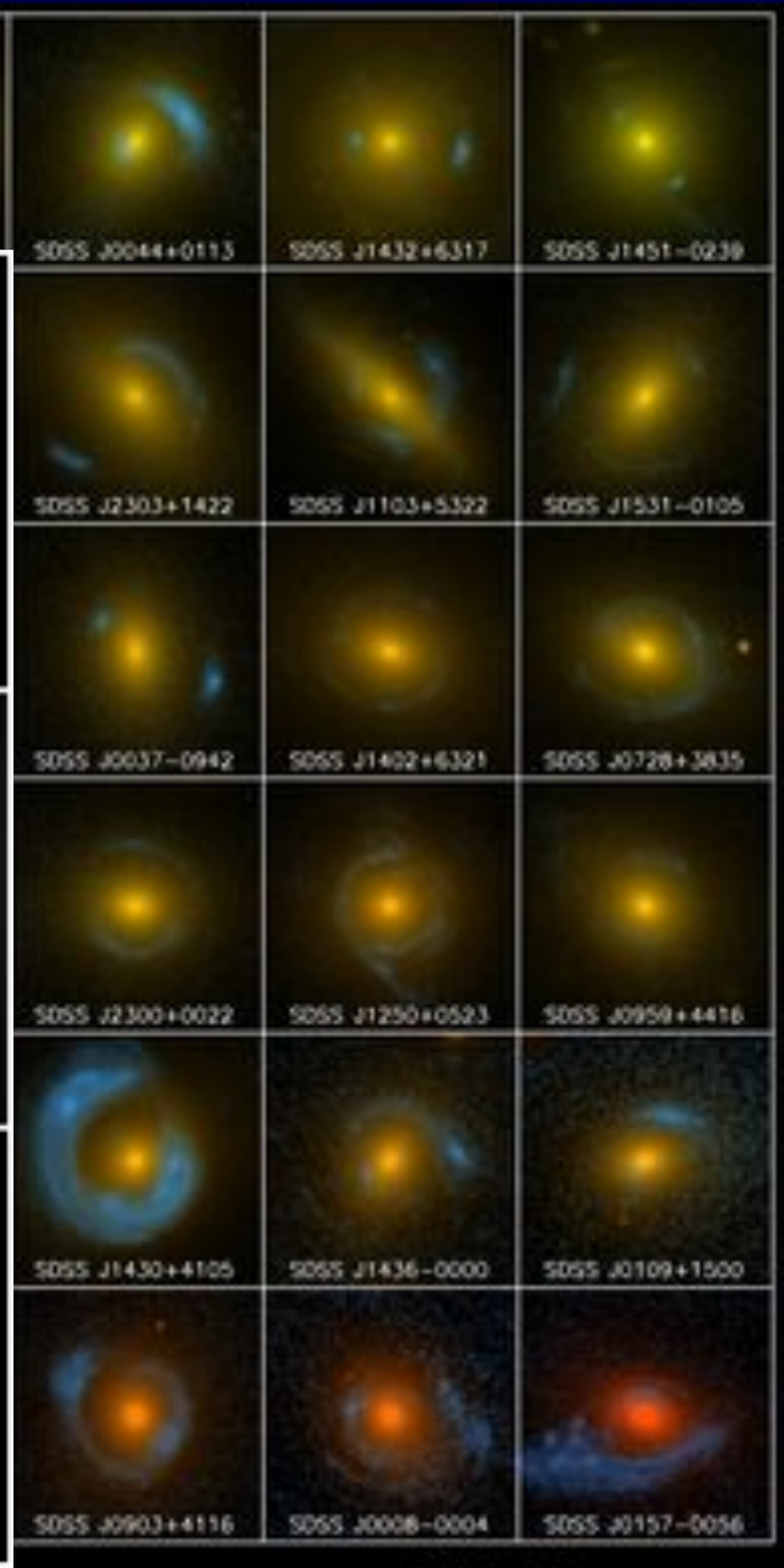
Soucail: première confirmation d'un
arc géant à 8.4 Mds a.-l.

Exemples de lentilles: galaxies



Exemples de lentilles: galaxies

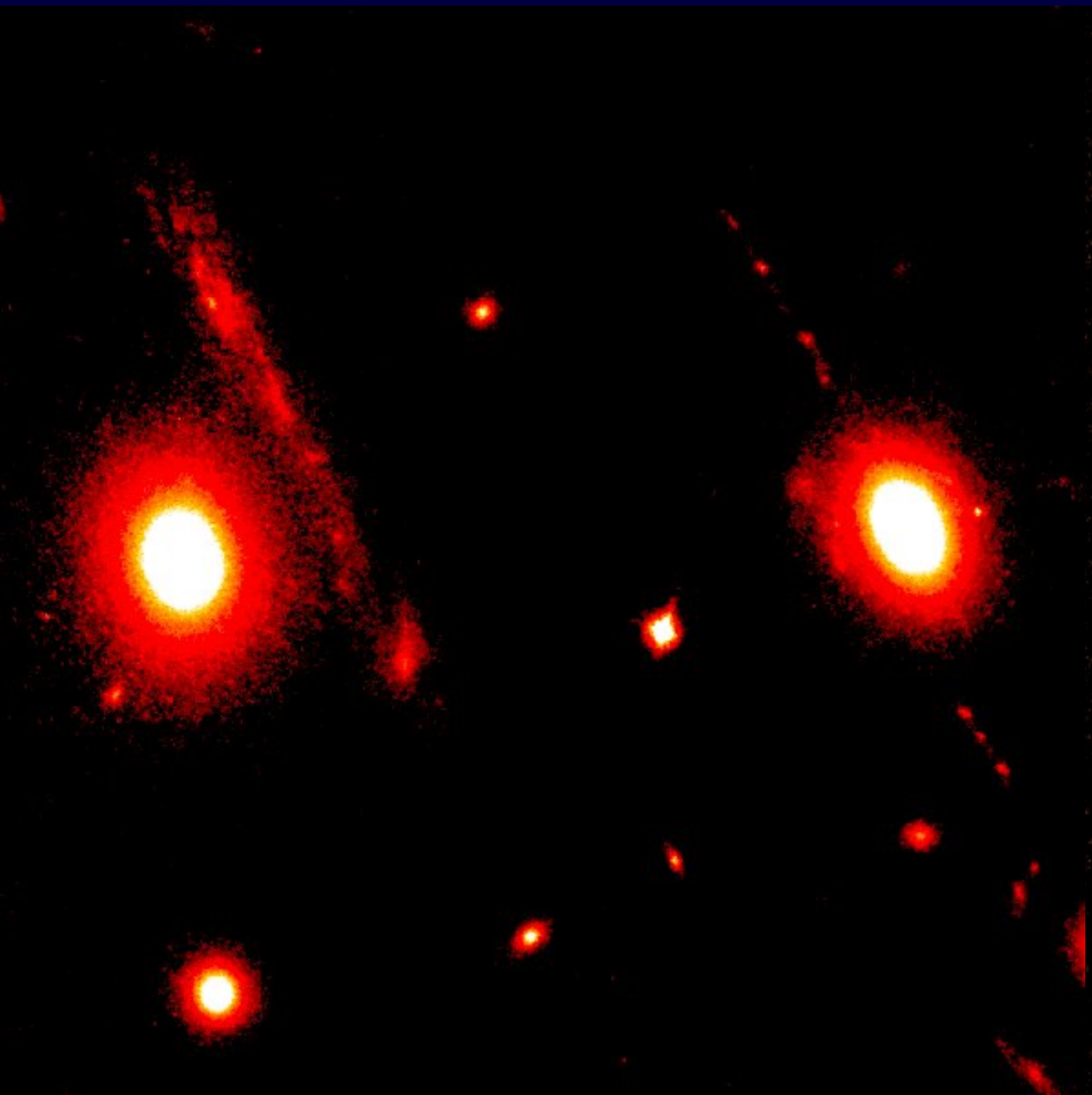


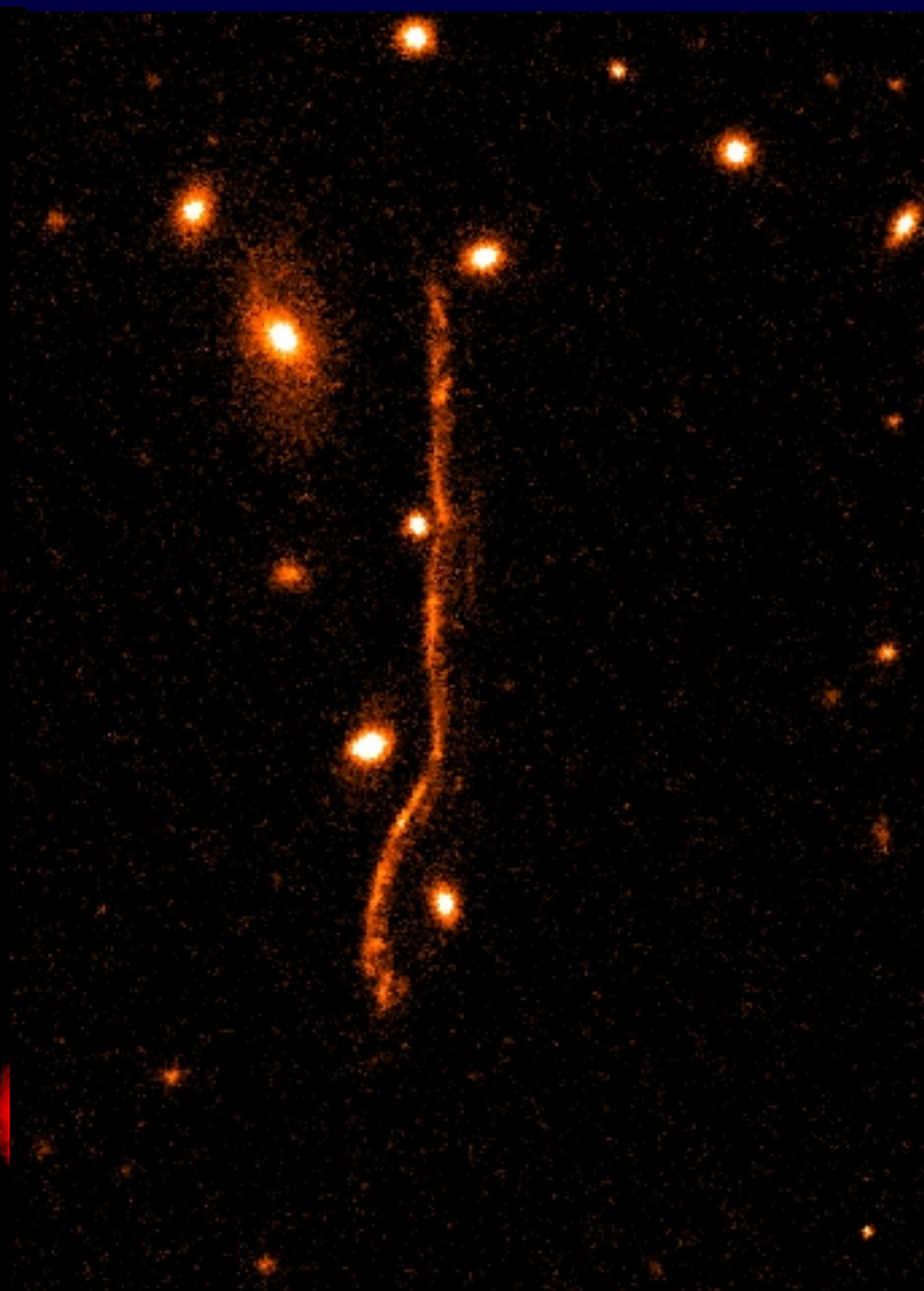


Exemples de lentilles: amas de galaxies

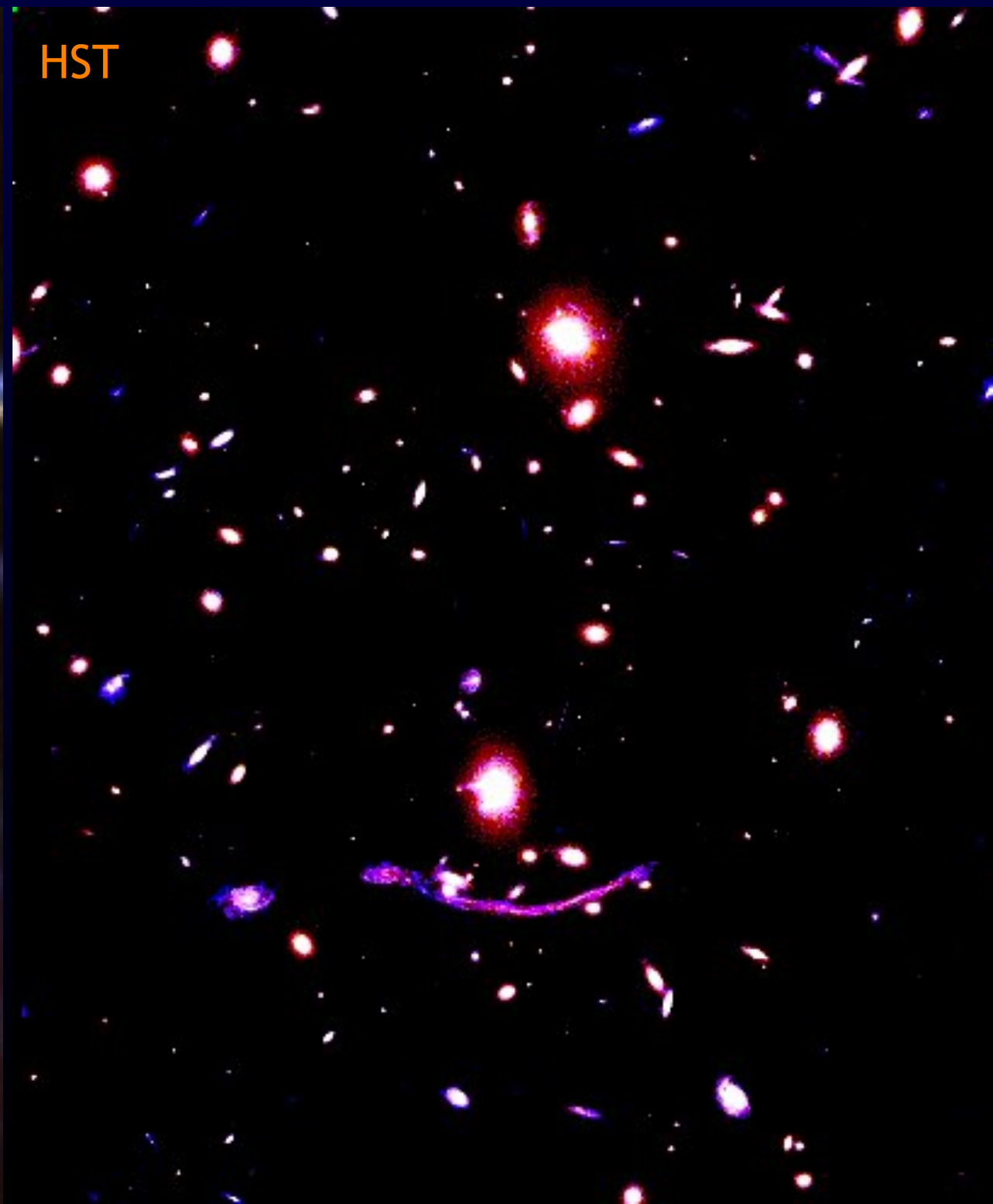
Abell 2218

Arcs “droits” et “serpents”





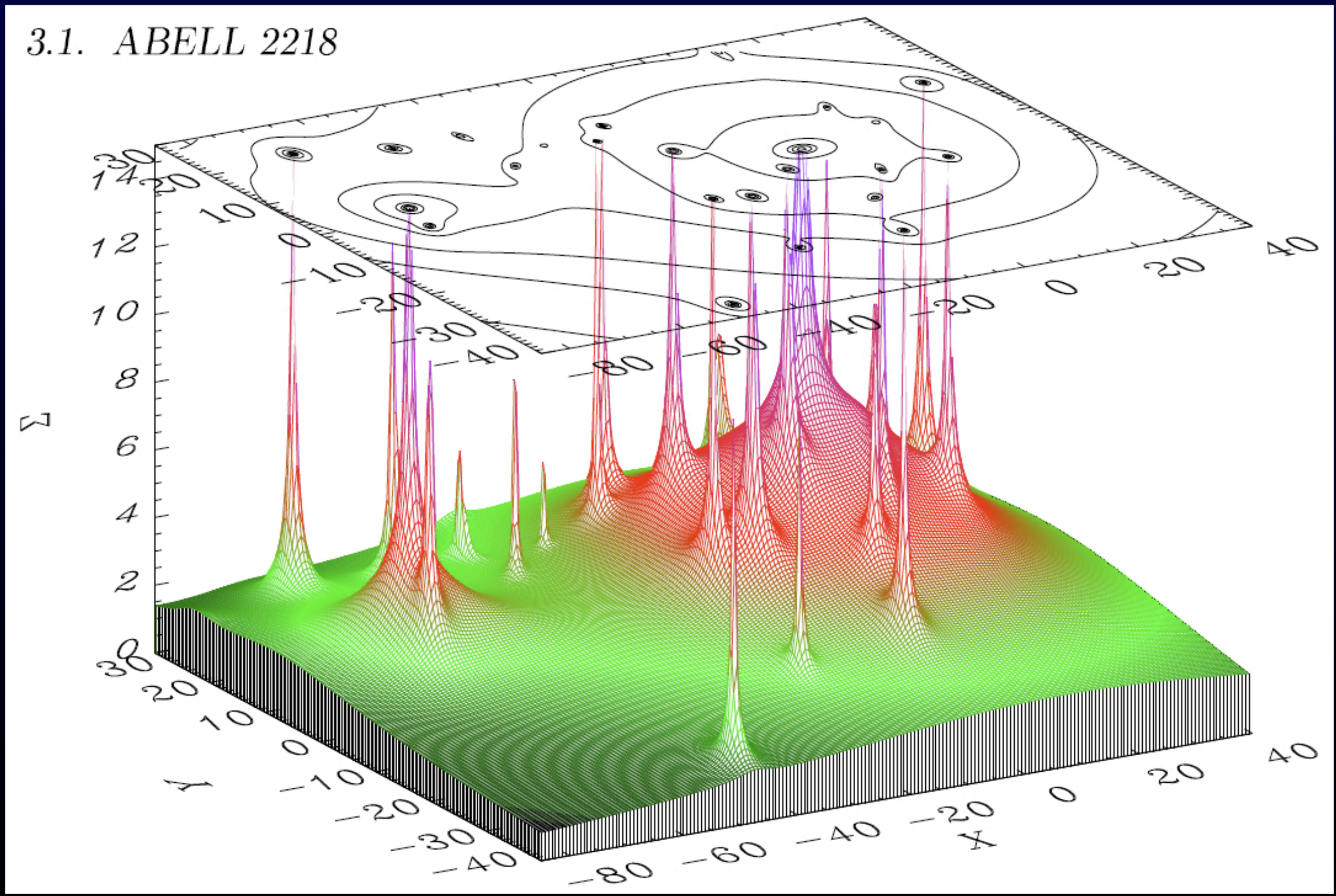
Le pouvoir de Hubble



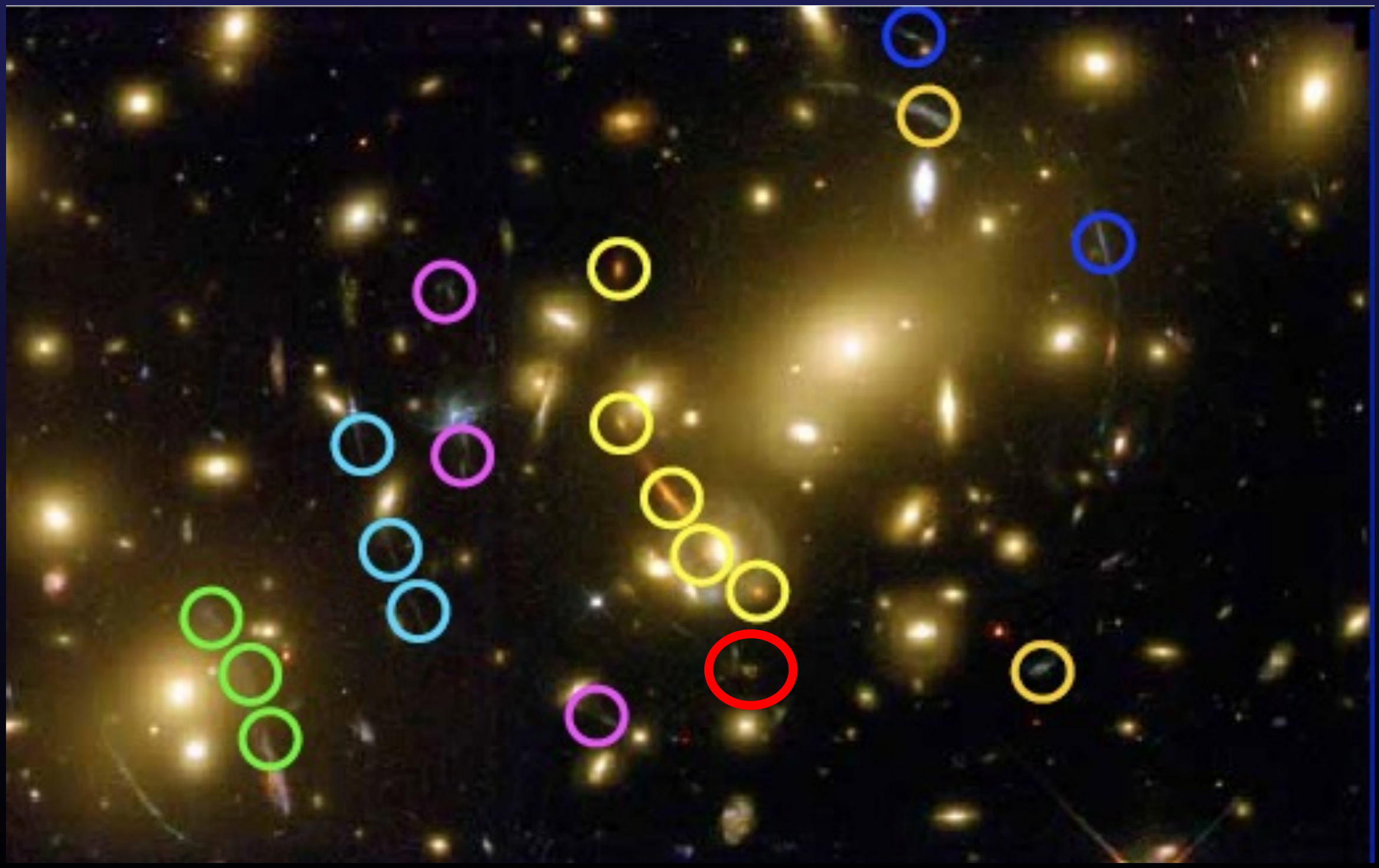
Le pouvoir de Hubble

>30 galaxies, 100 images

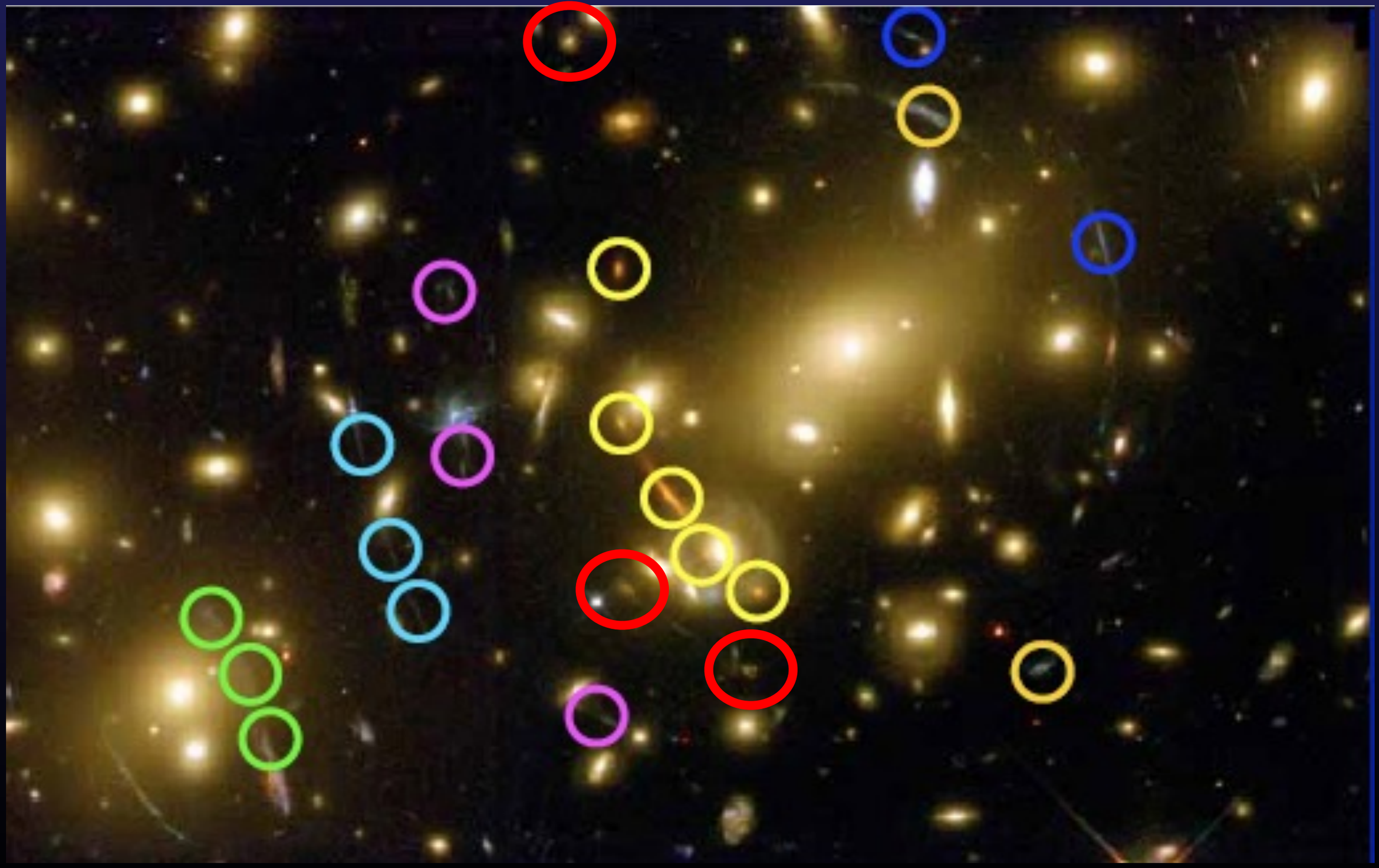
Prédictions



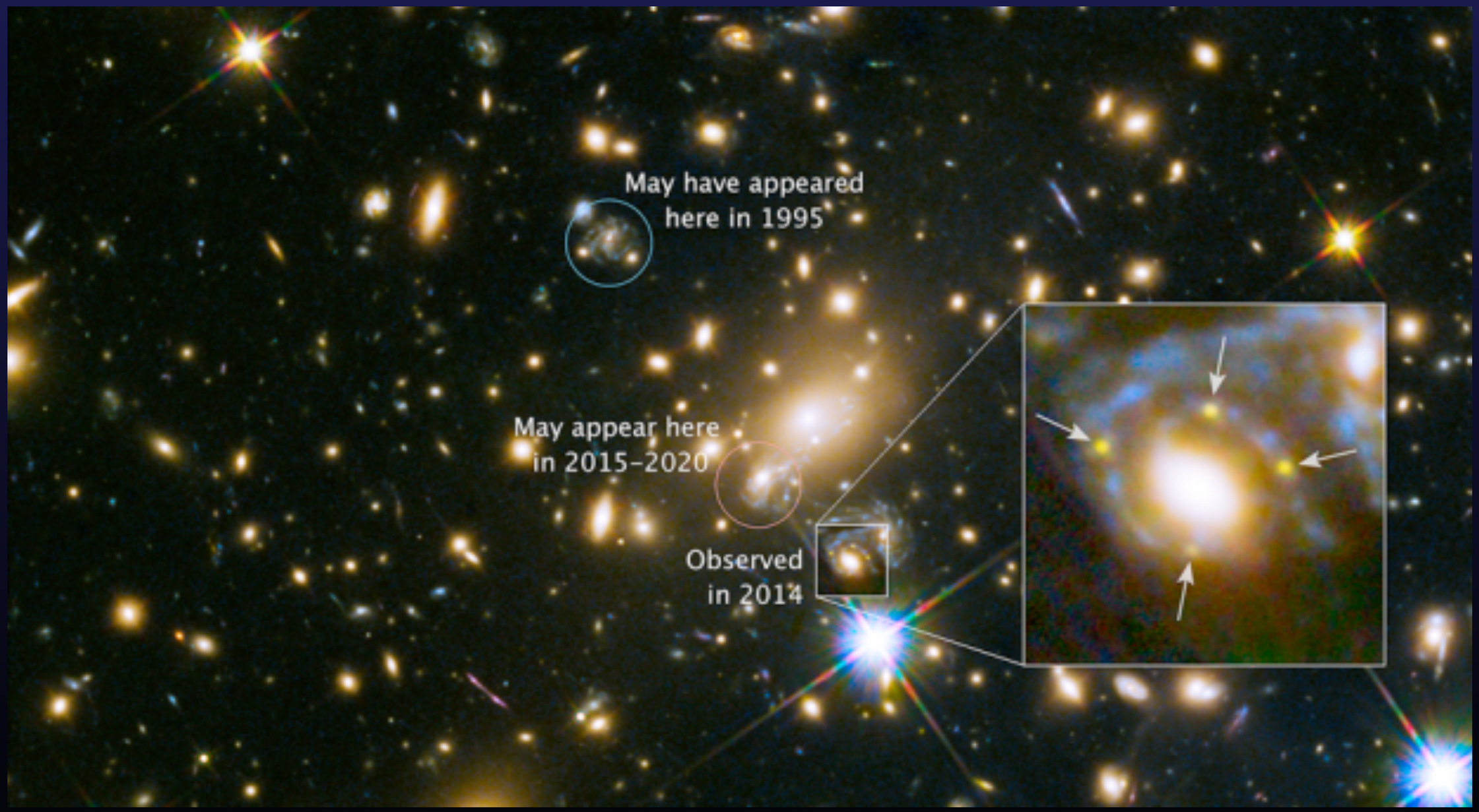
Prédictions



Prédictions

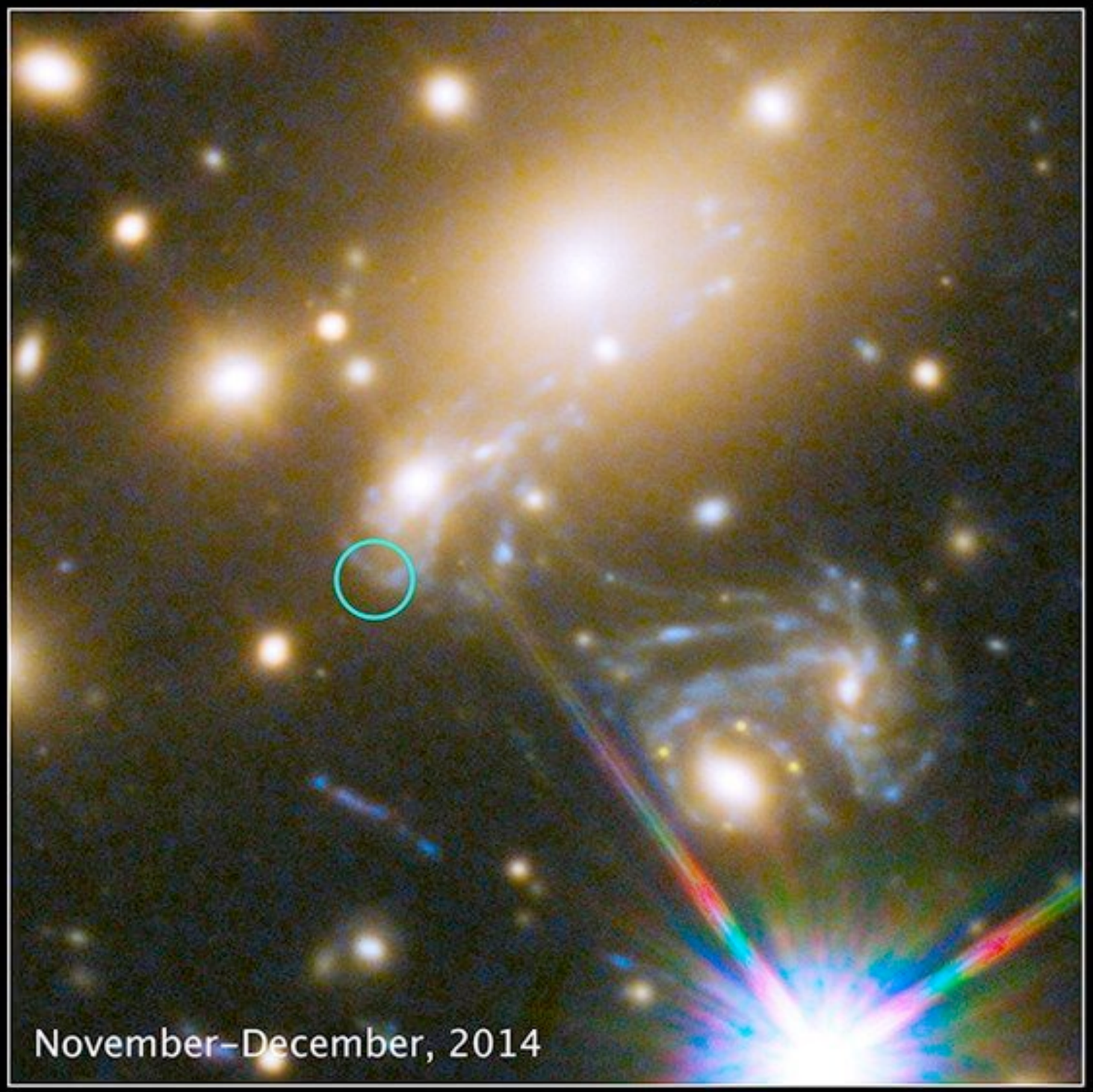


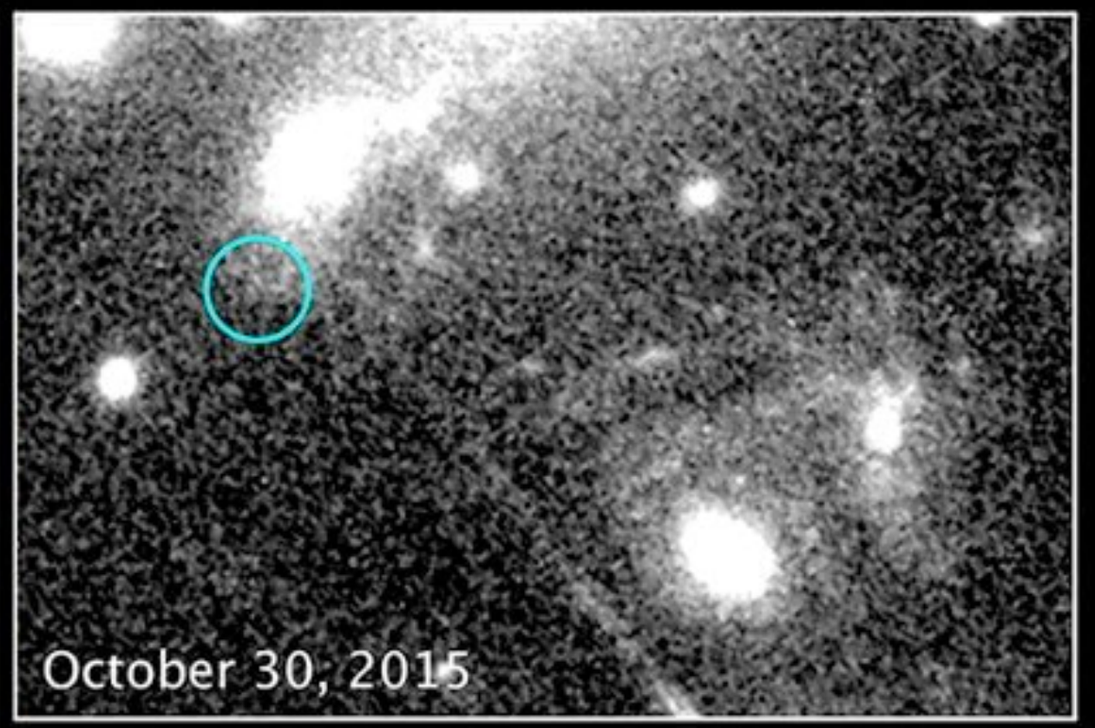
Décalage temporel

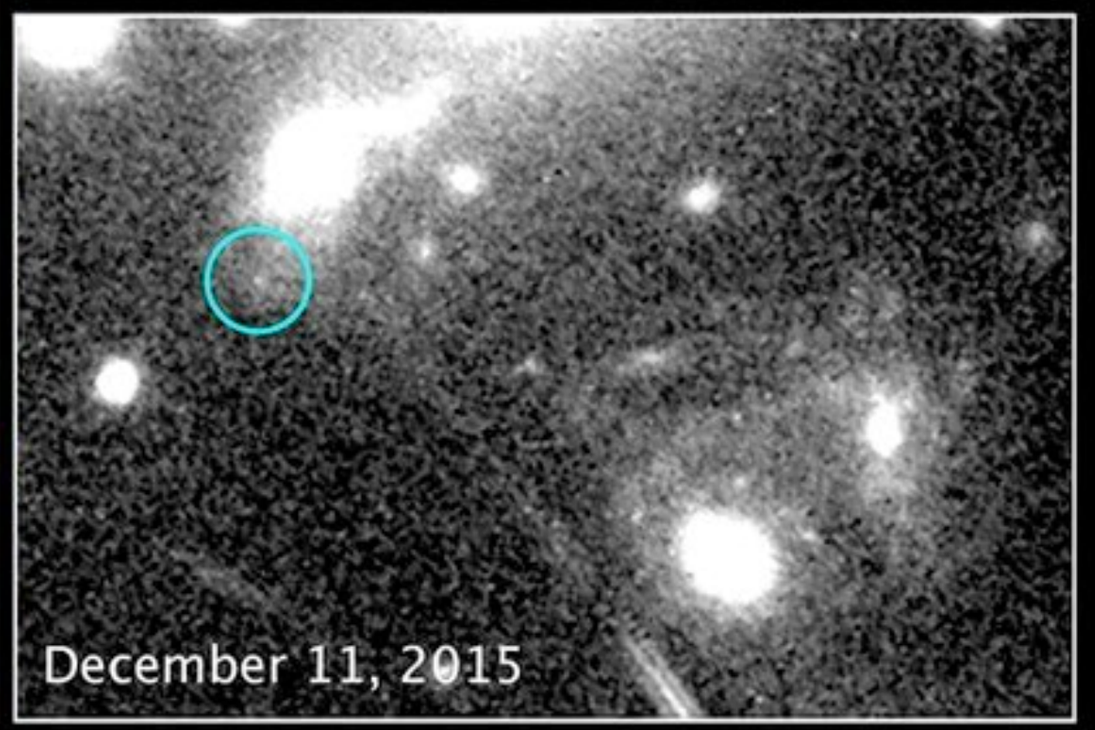


Décalage temporel

Supernova Refsdal • Galaxy Cluster MACS J1149.5+2223 • *HST* WFC3 ACS



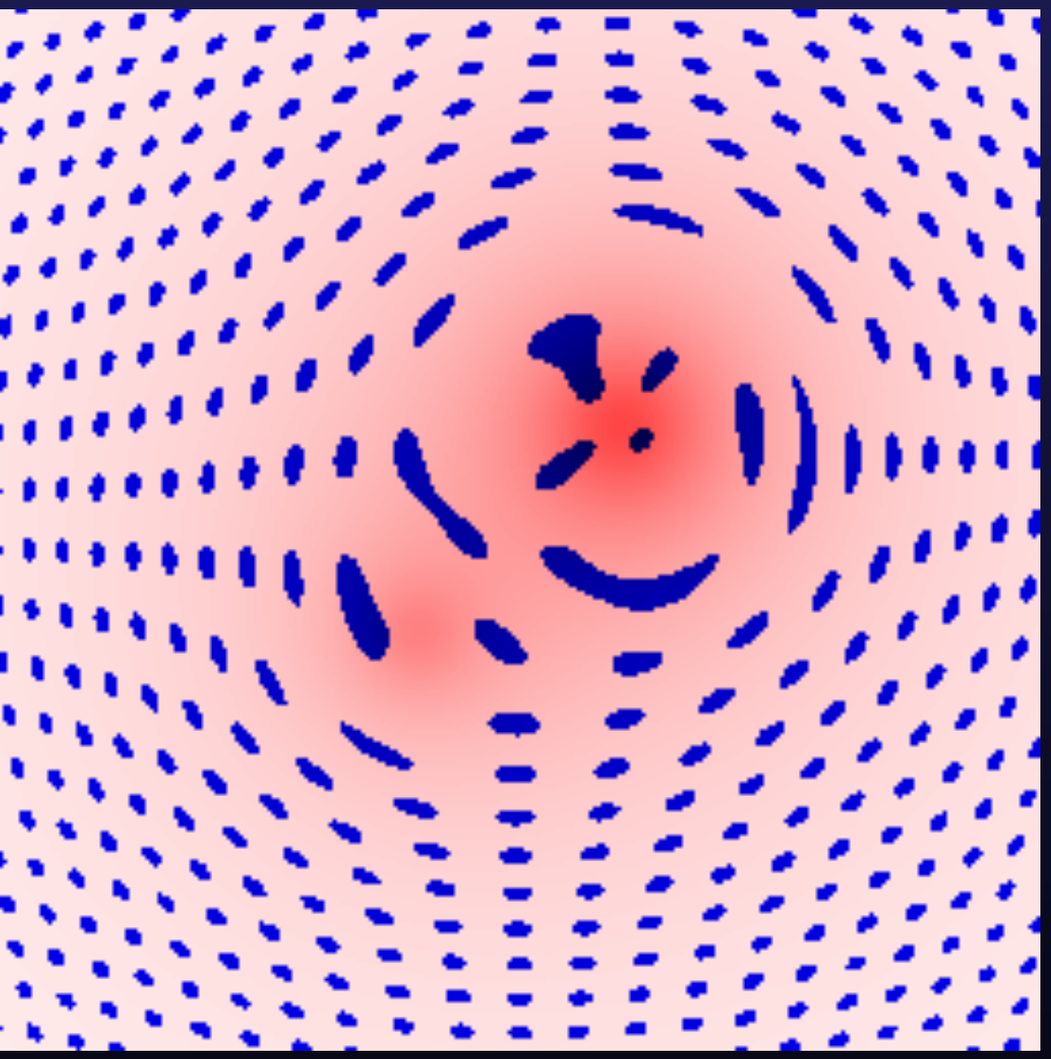


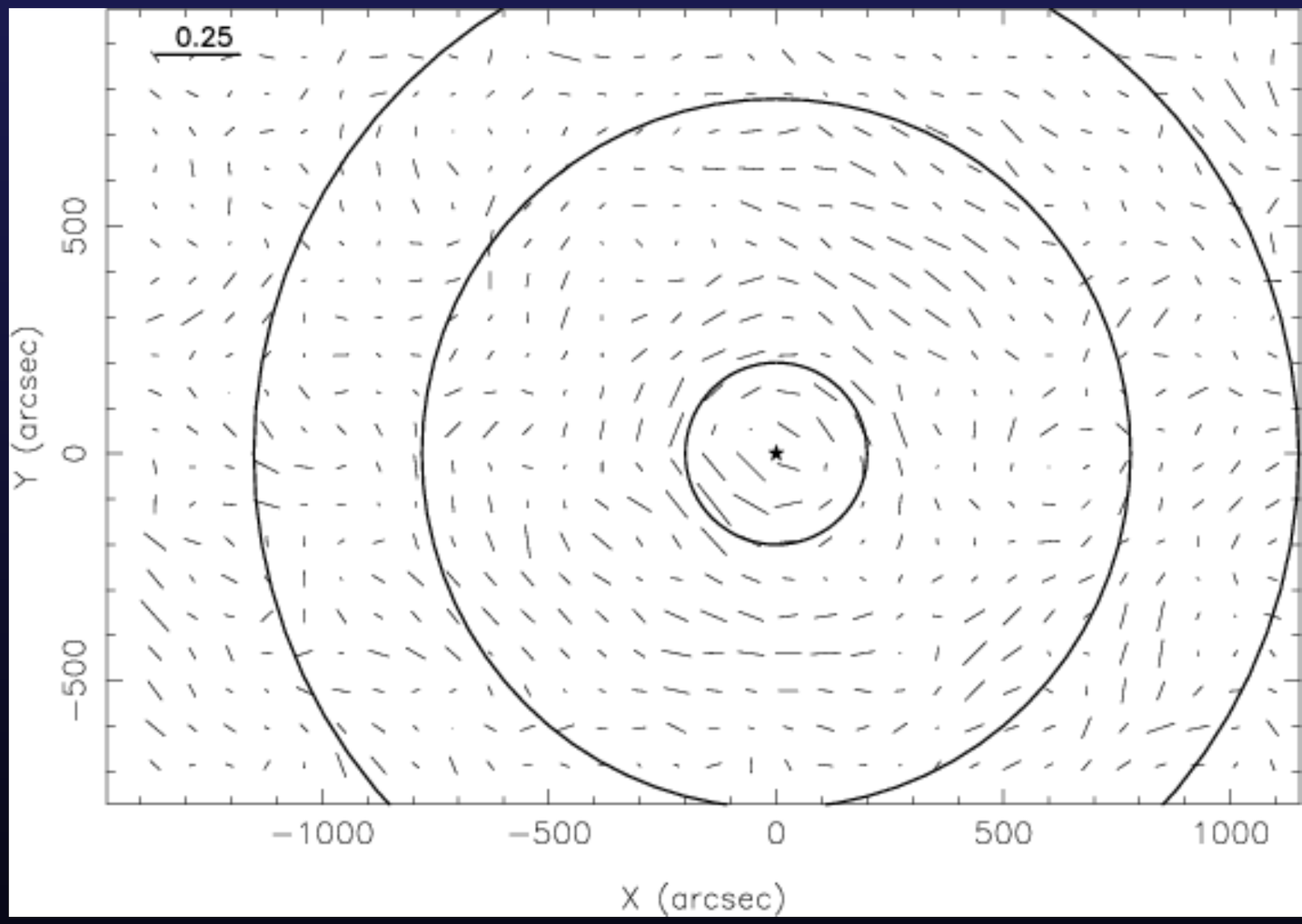


NASA, ESA, and P. Kelly (University of California, Berkeley)

STScI-PRC15-46a

Effet de lentille faible: distortions





Mesure statistique sur un grand nombre de galaxies d’arrière plan : grandes échelles

“Télescopes Gravitationnels”

Les amas-lentilles sont des outils pour étudier les galaxies distantes

- Font apparaître les galaxies plus grandes
- Font apparaître les galaxies plus brillantes

- Le champ de vue est réduit
- Ils n’existent que dans certaines régions du ciel

Applications

1. Galaxies distantes à haute résolution

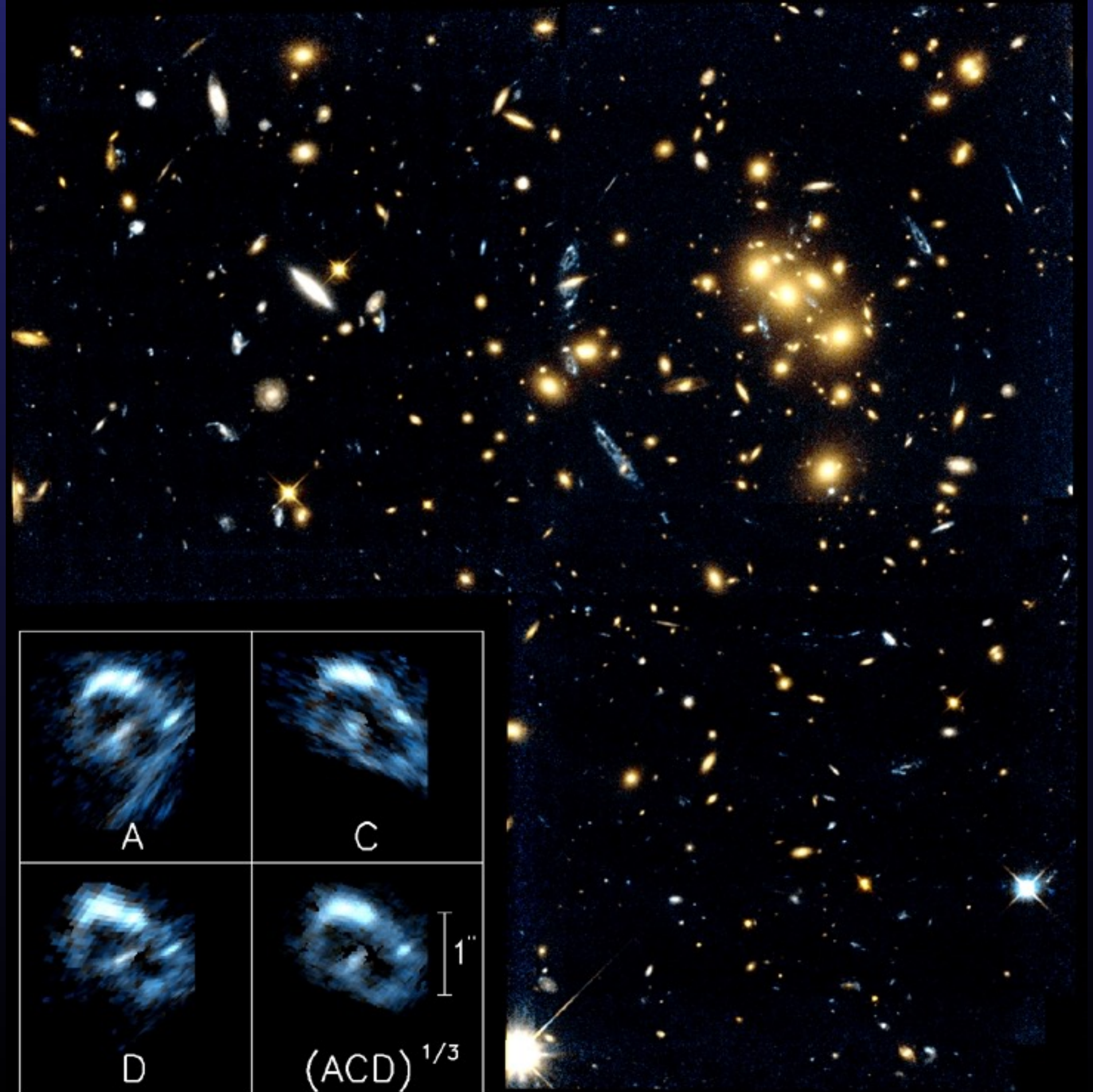
   Evolution du contenu des galaxies

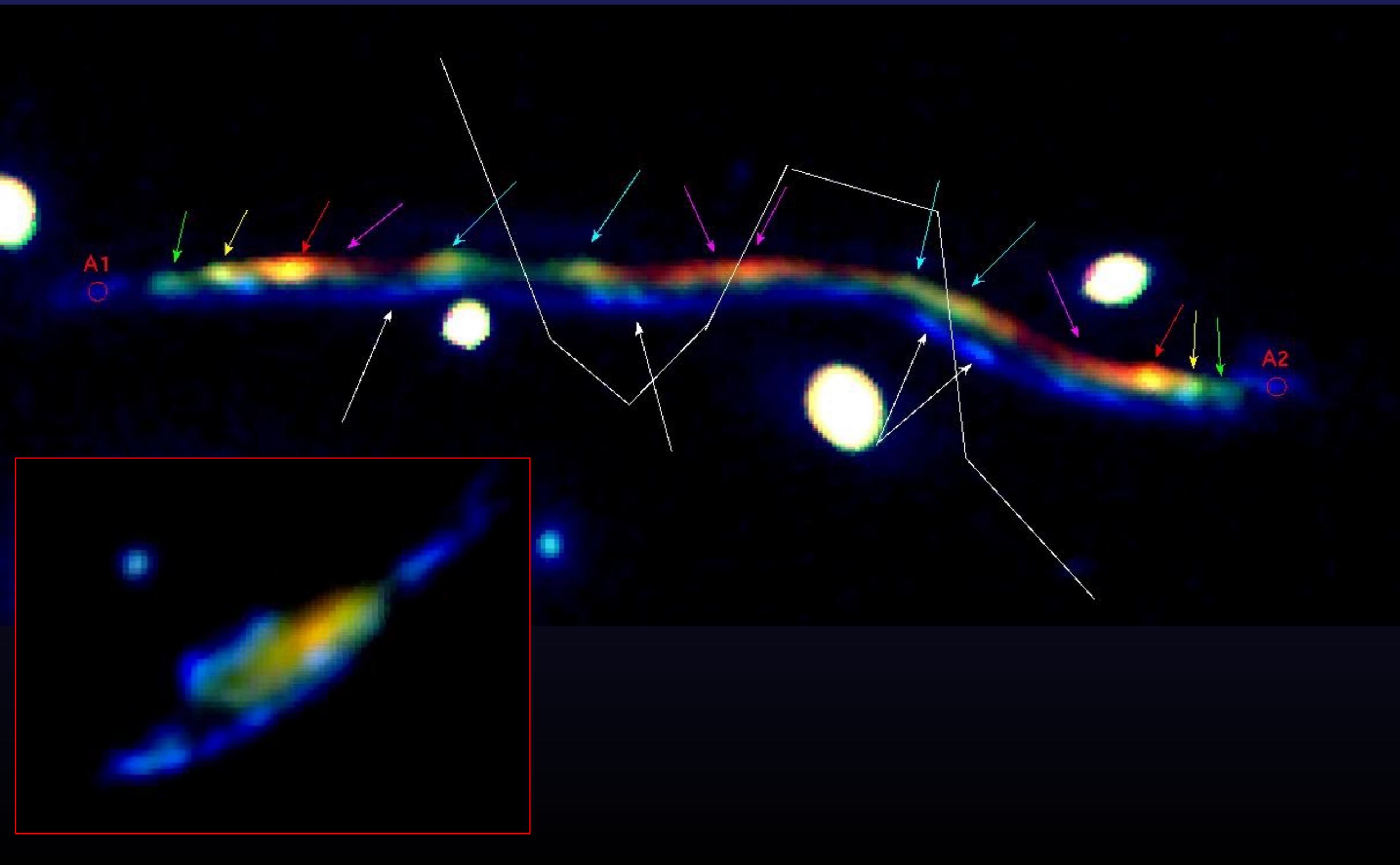
2. Galaxies les plus distantes

   Formation des premières galaxies

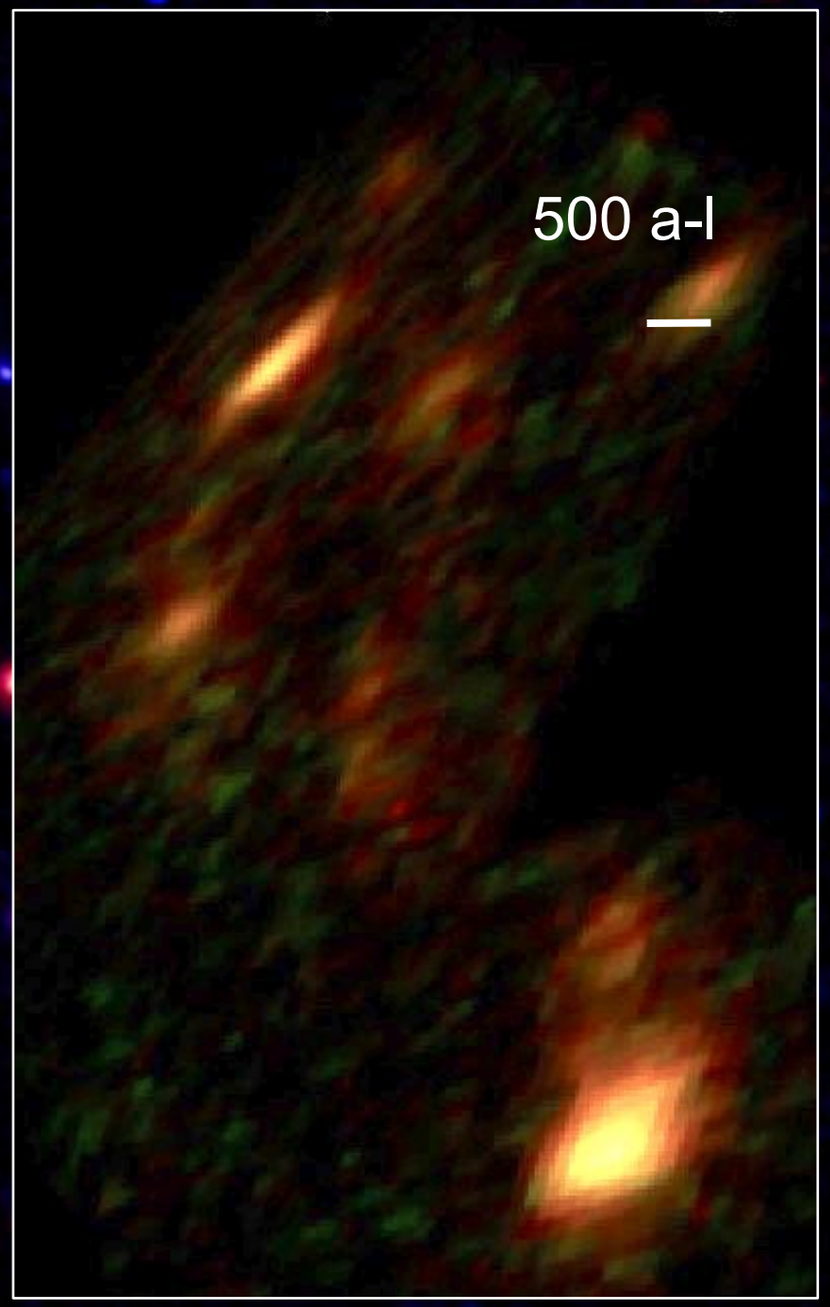
3. Galaxies “poussiéreuses”

   Le côté obscur de la formation des étoiles


A
C
D
(ACD) 1/3
1"

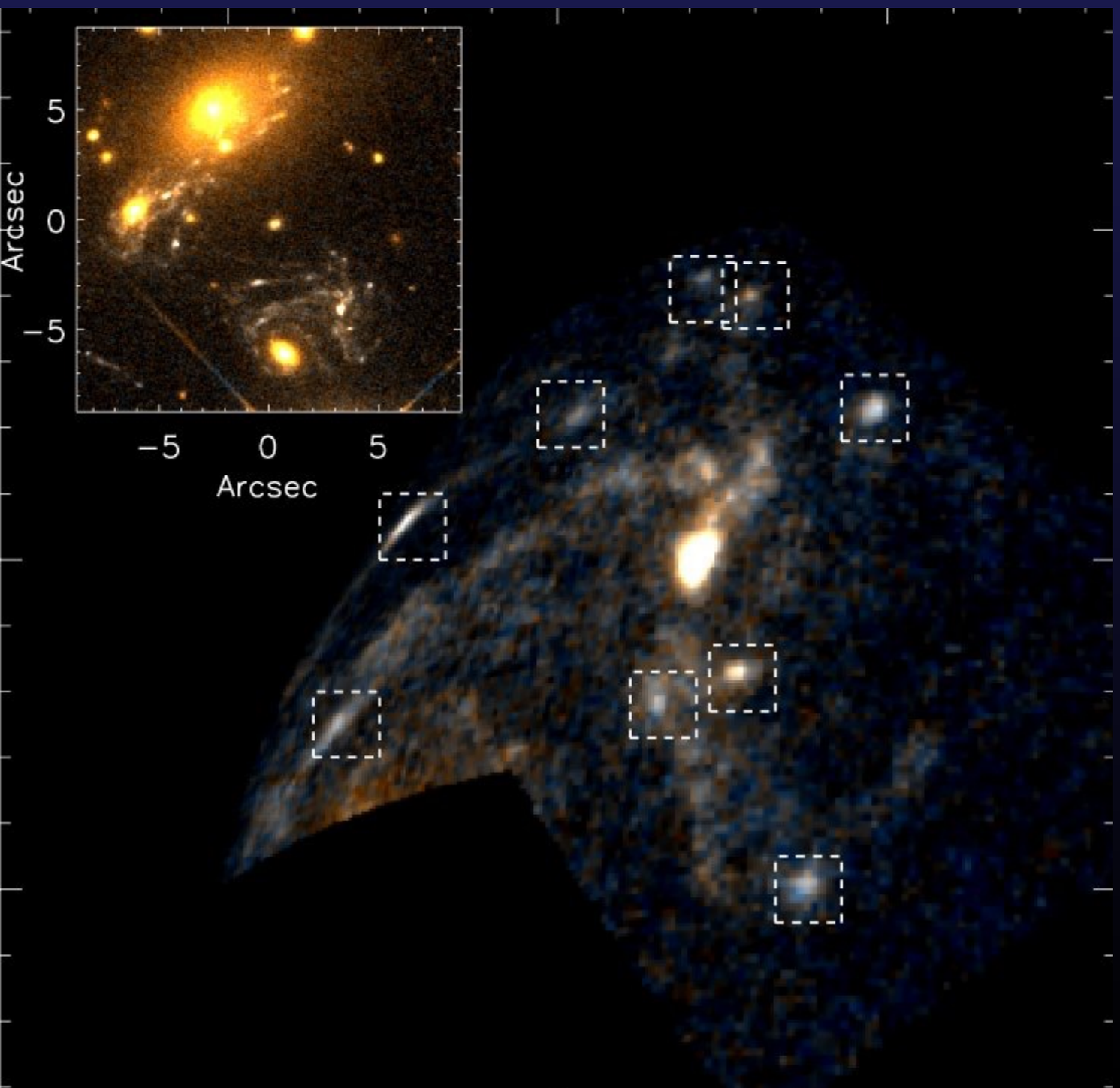

A1
A2

20”



20”

Régions de formation stellaire



- A l'aide du microscope gravitationnel on résout des régions où se forment des étoiles jeunes
- Ces régions étaient plus compactes par le passé: conditions physiques différentes !

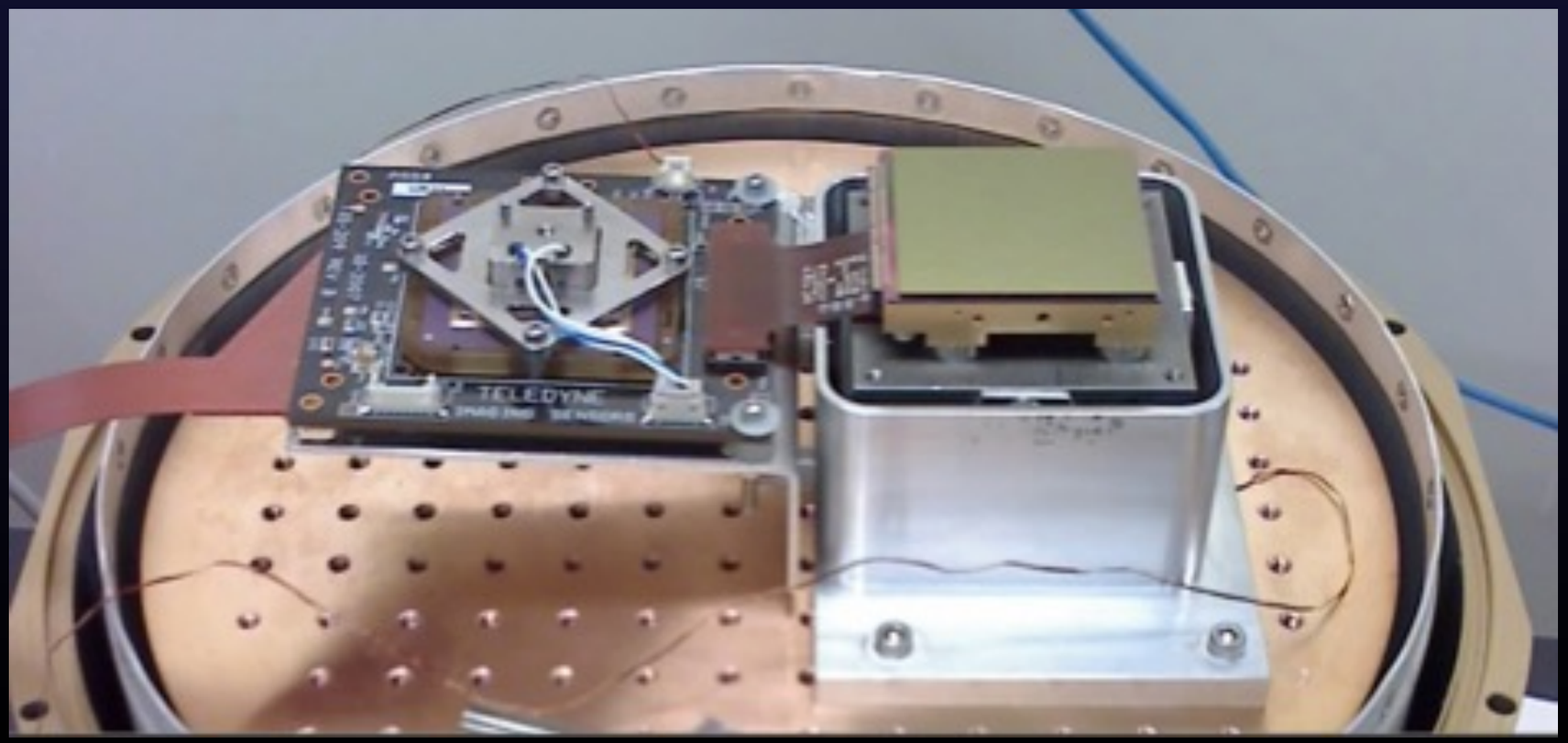
Galaxies les plus distantes

Effet de distance: objets plus faibles

x 8 entre $z = 3$ (11.6 Md années)

et $z = 7$ (12.7 Md années)

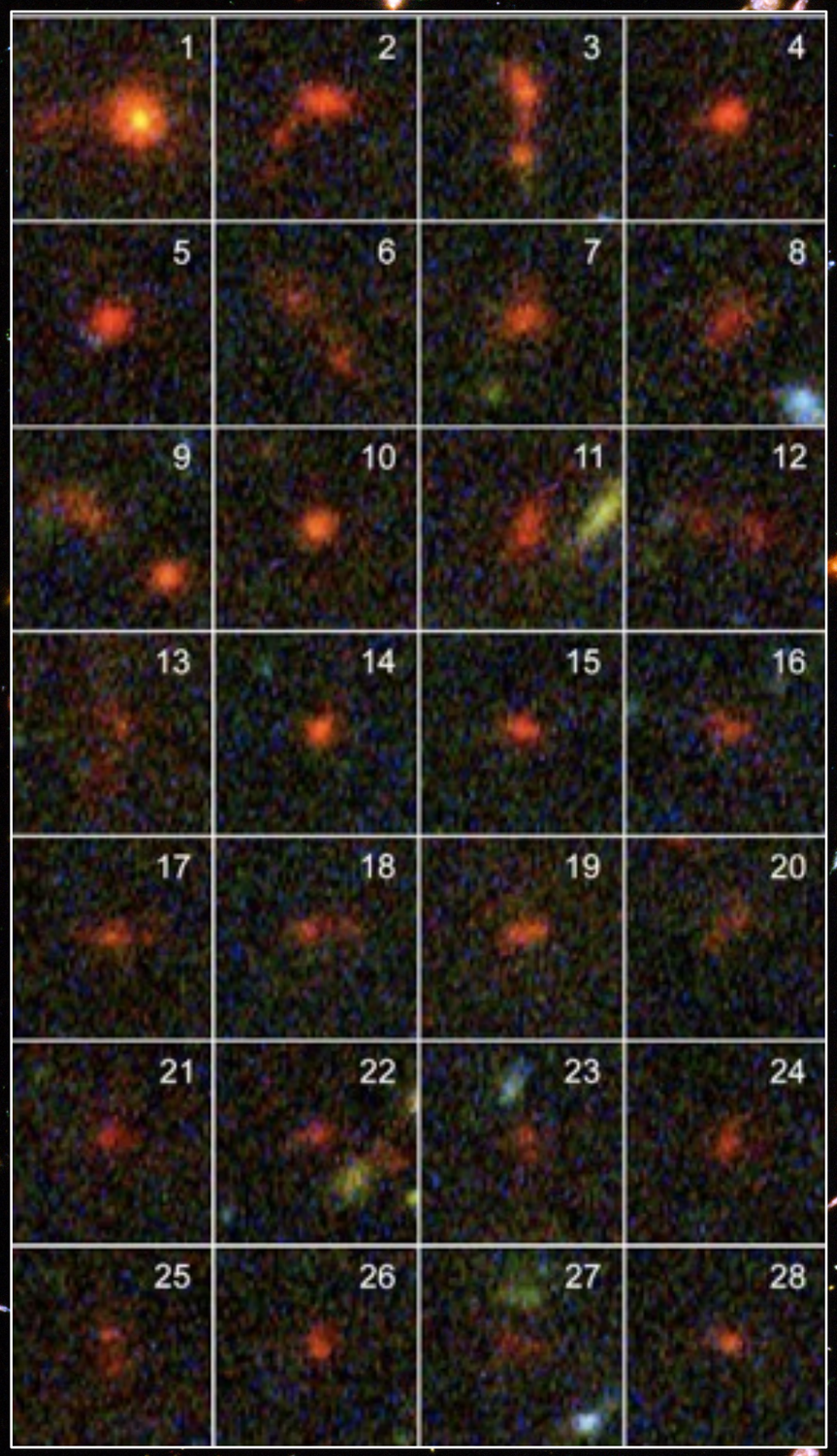
Décalage vers le rouge: $z > 7$ UV ⟶ IR



Detecteur infrarouge

Hubble Ultra Deep Field

Hubble Ultra Deep Field

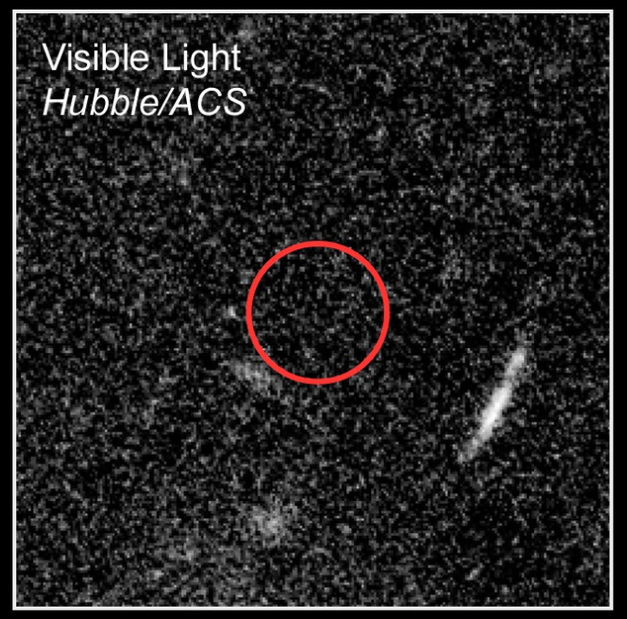


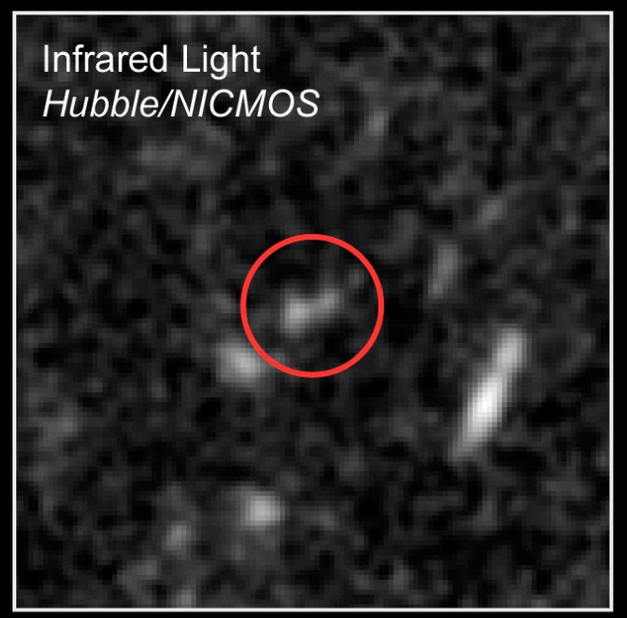
- Champ ultra-profond
- 11 jours d'observation
- ~ 30 000 galaxies dans le champ
- ~ 30 galaxies très distantes

(~12 Md années-lumière)

- 4 Md de fois plus faible que la vision humaine!

Galaxies amplifiées à grande distance





- ~ 20 galaxies distantes, avec amplification x10

Complémentaire à l'Ultra Deep Field