

François Mernier

*The link between **supernovae**, **supermassive black holes**, and the **large-scale Universe***

ESA (European Space Agency),
ESTEC, Noordwijk



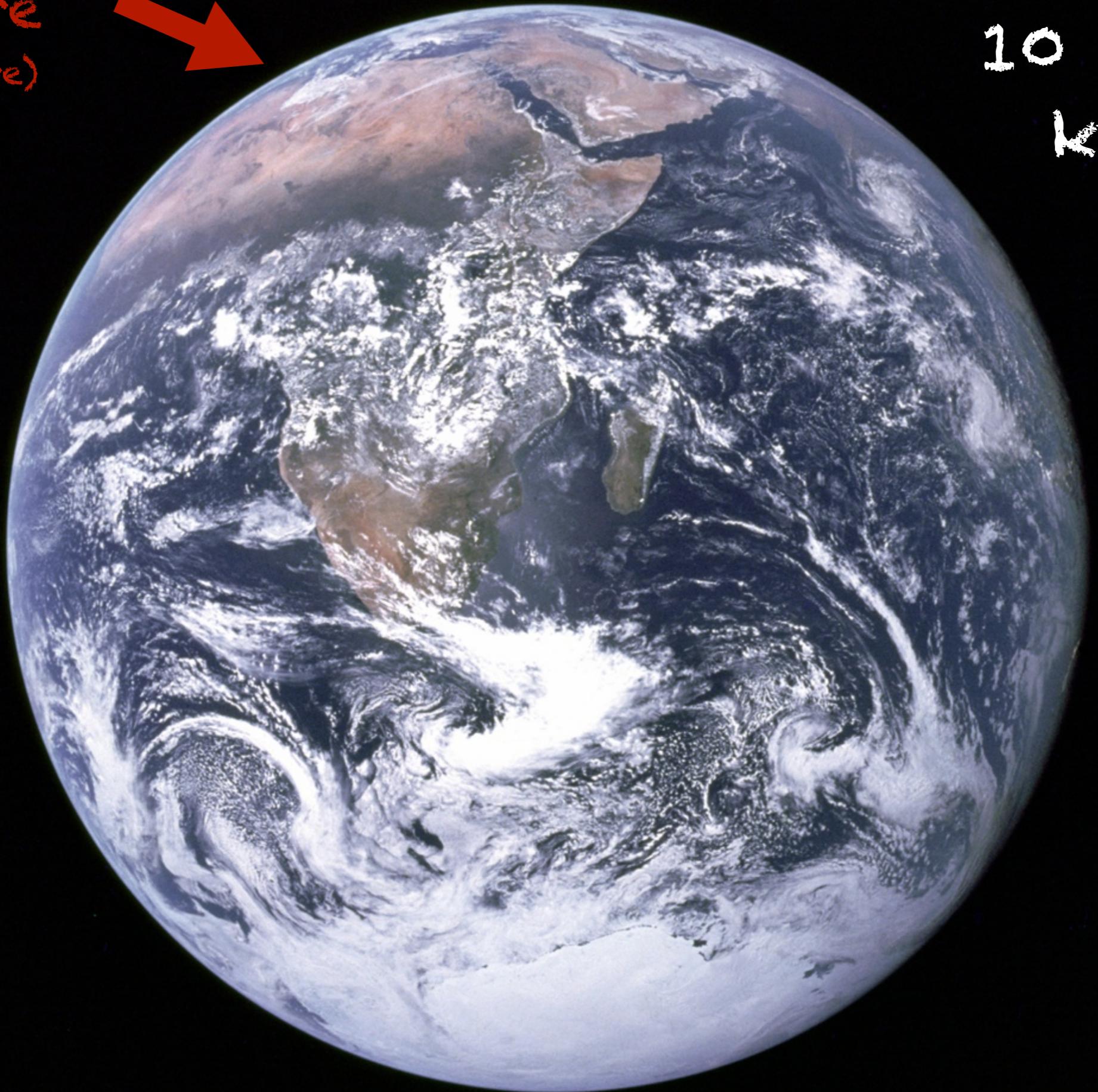
You are here!

BURGEMEESTERS- EN
PROFESSORENWIJK

You are
(somewhere)
here!



10 000
KM



You are here!



(and this is the Moon)



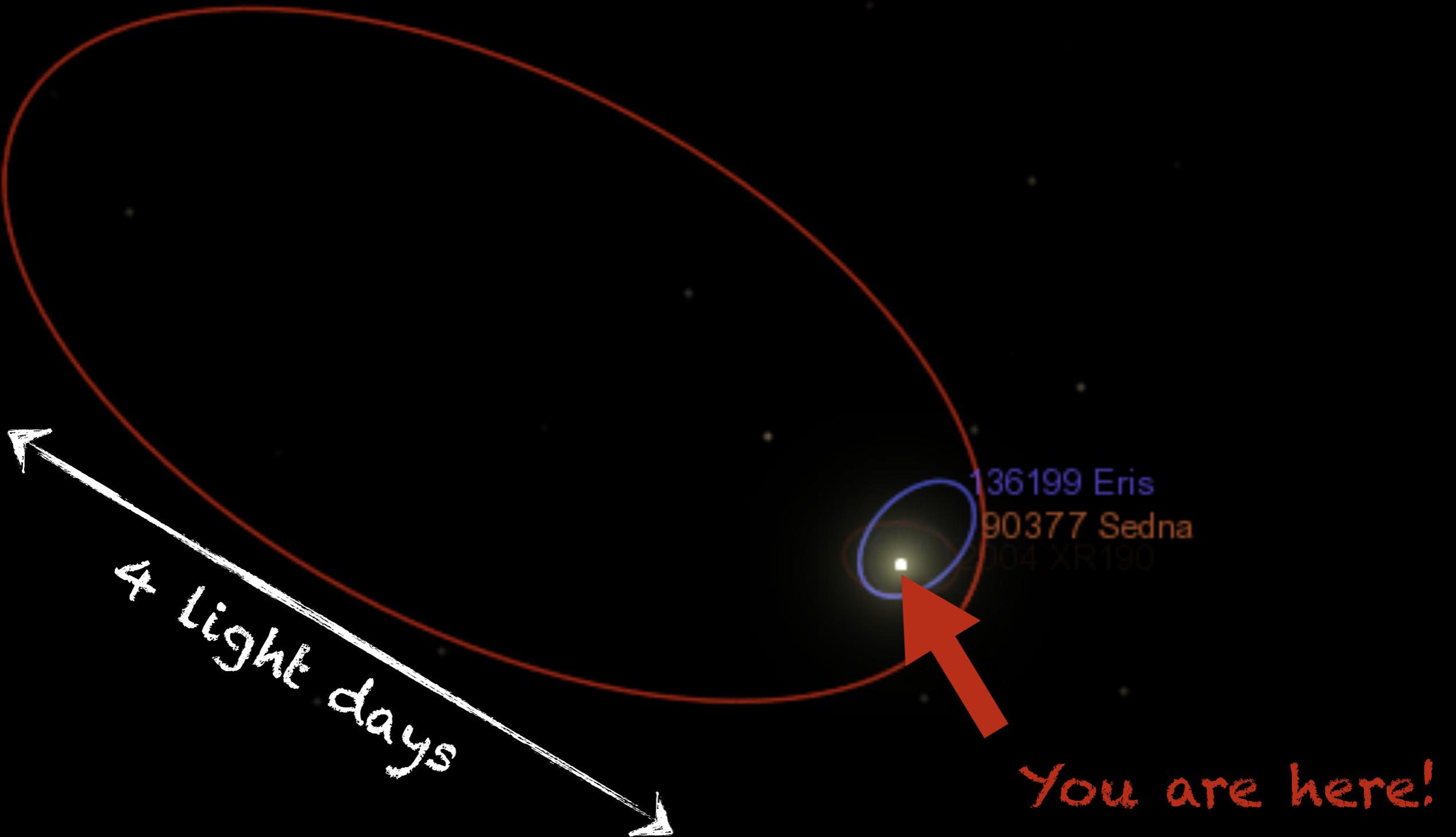
1 million km

= 3.3 light seconds



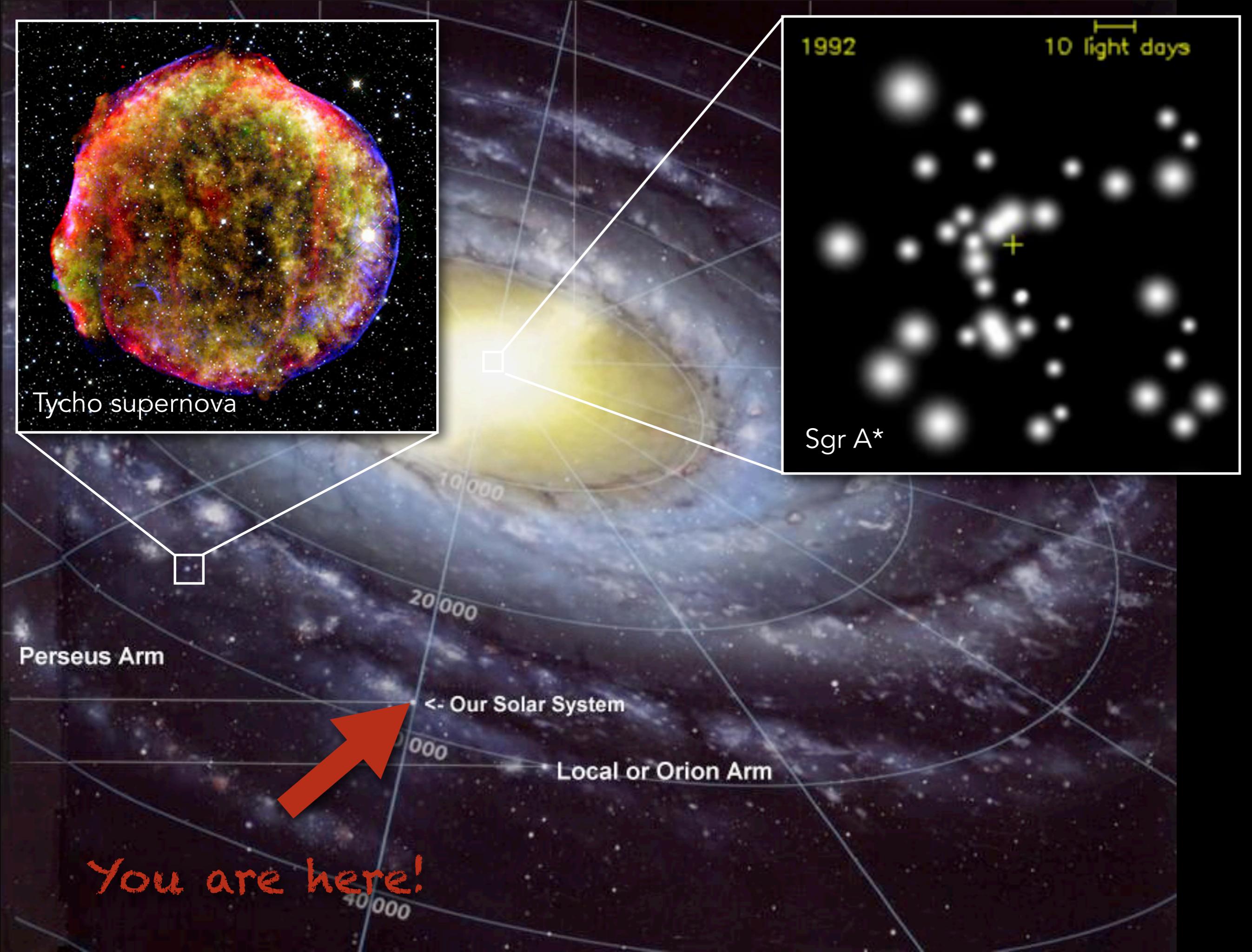
You are here!

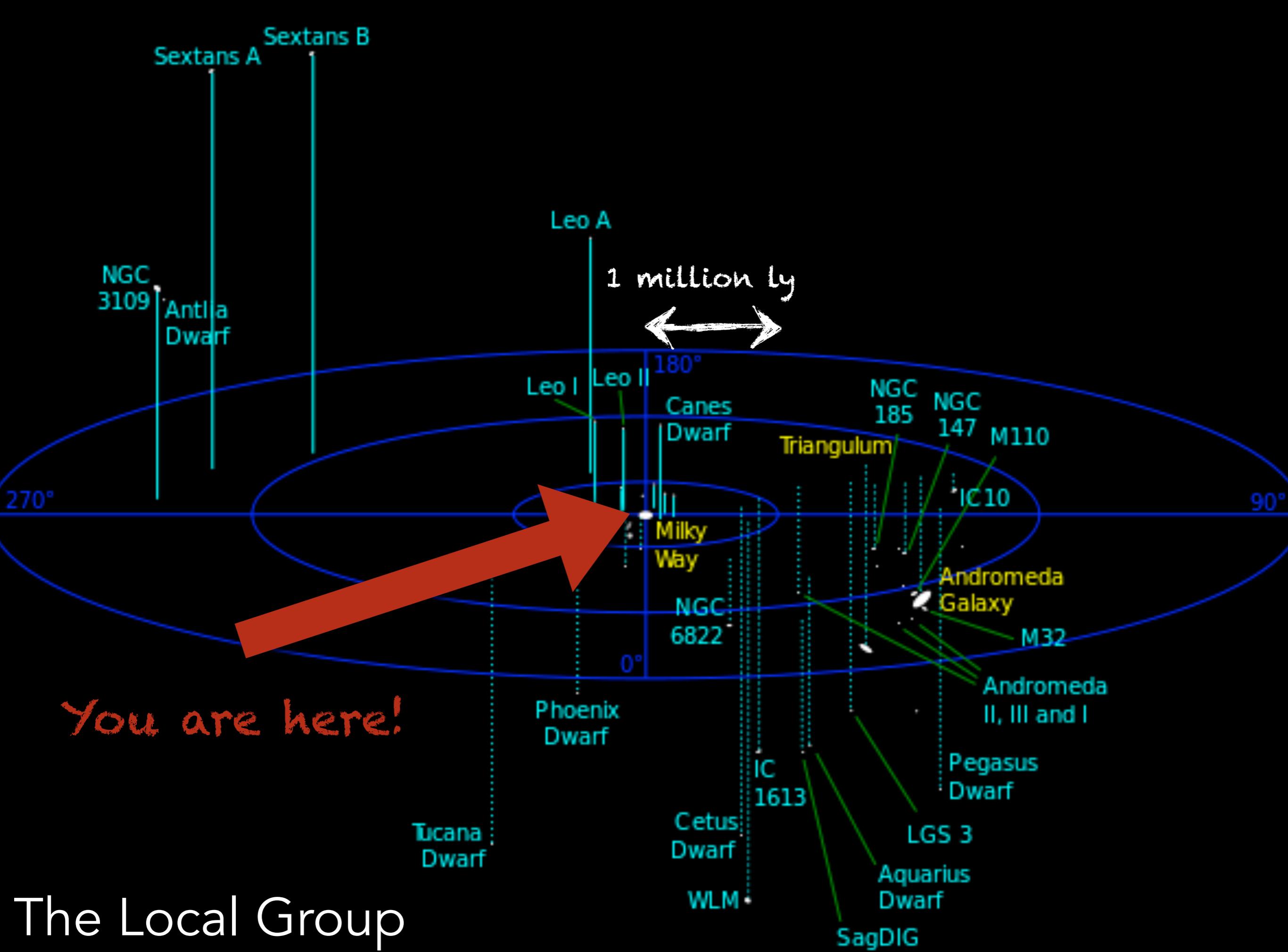
55.5 Light minutes

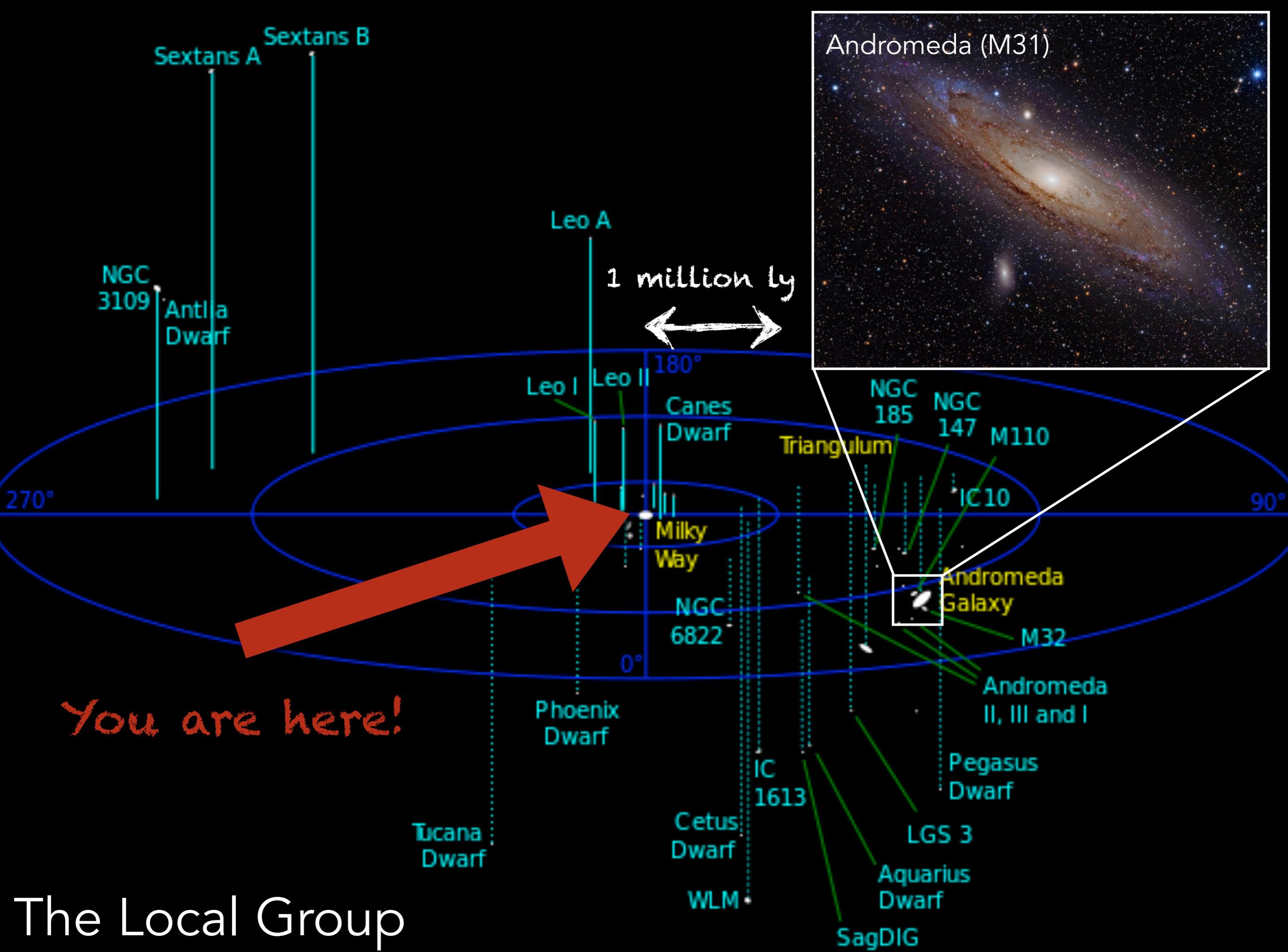


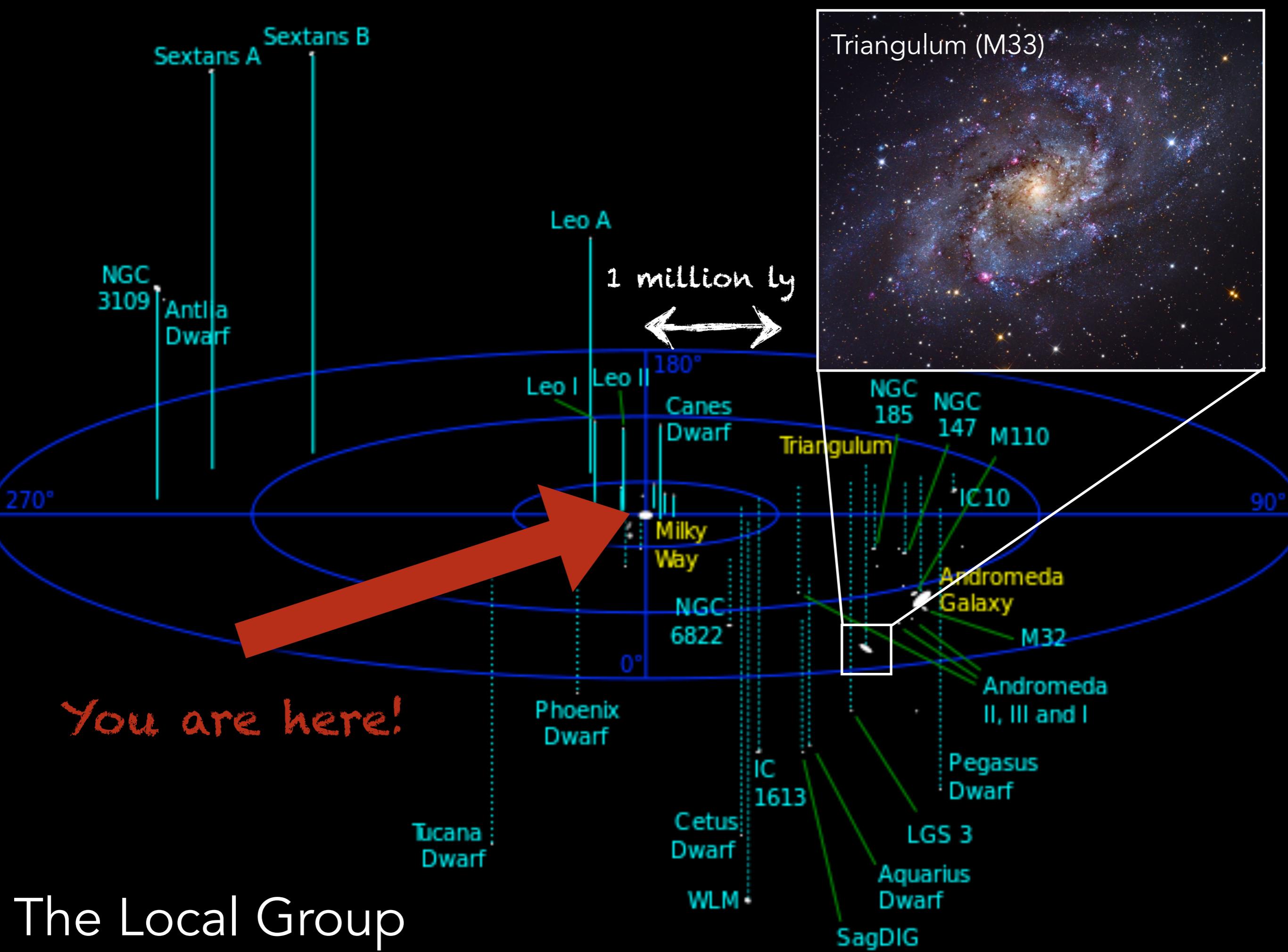


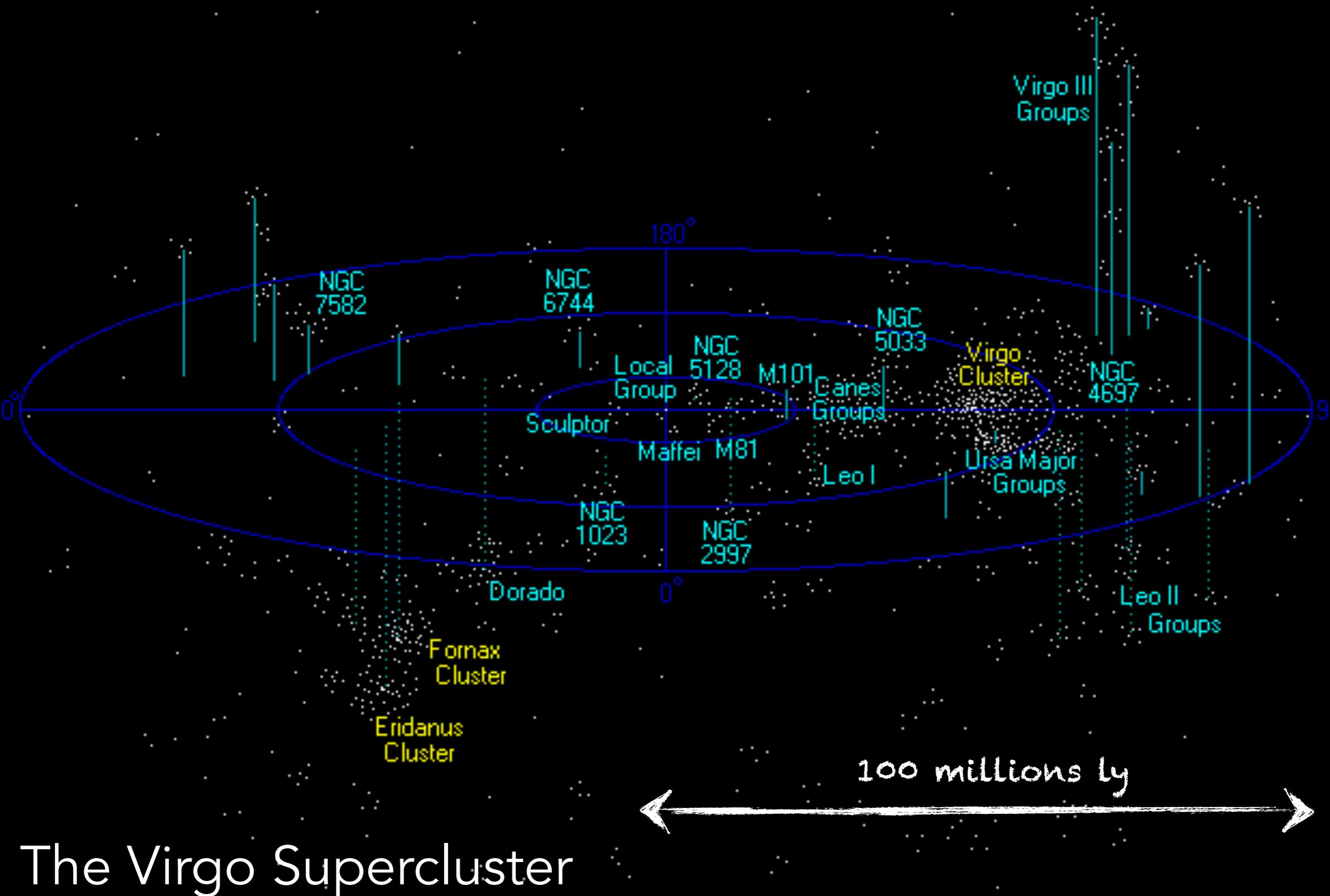




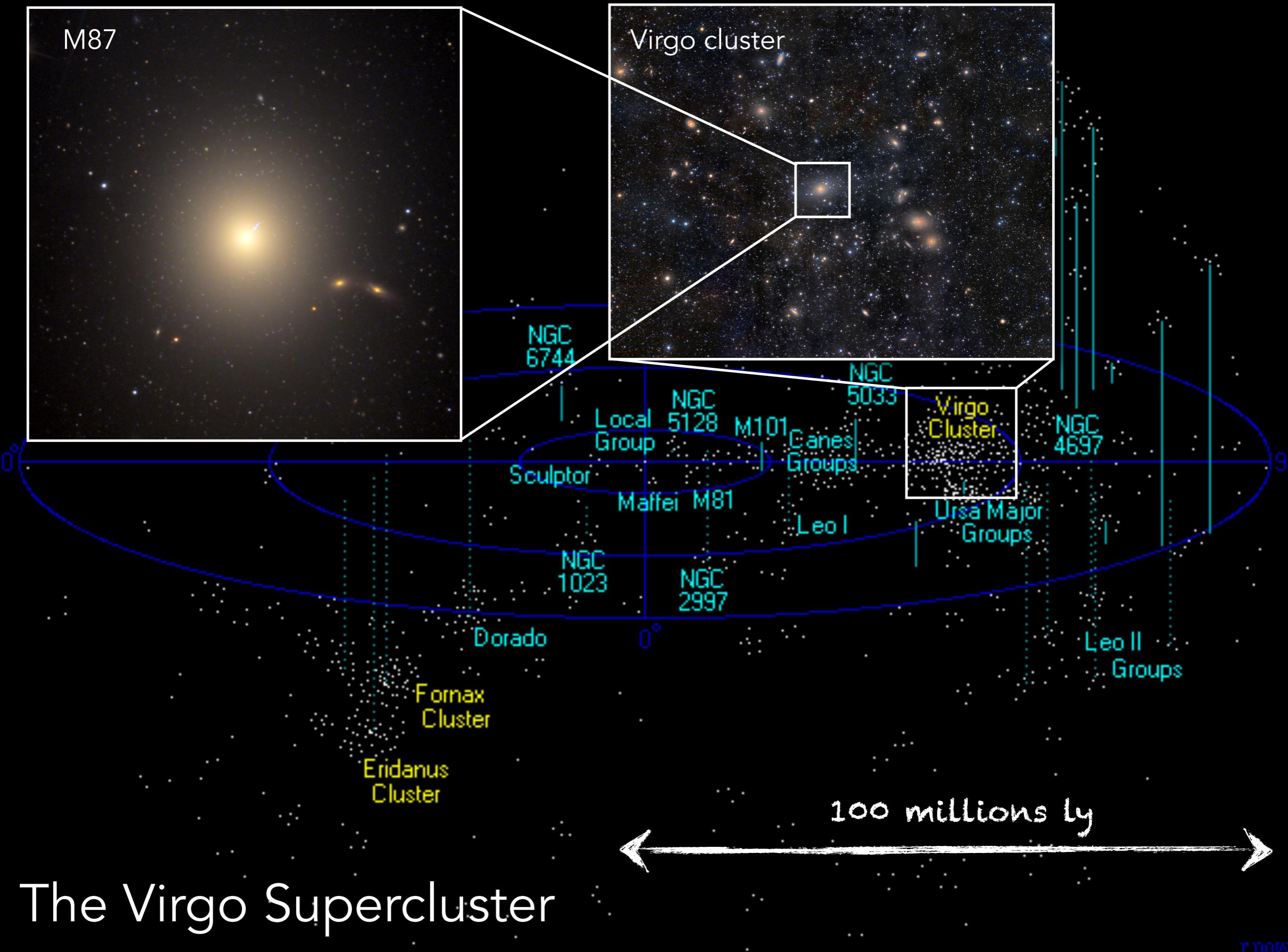


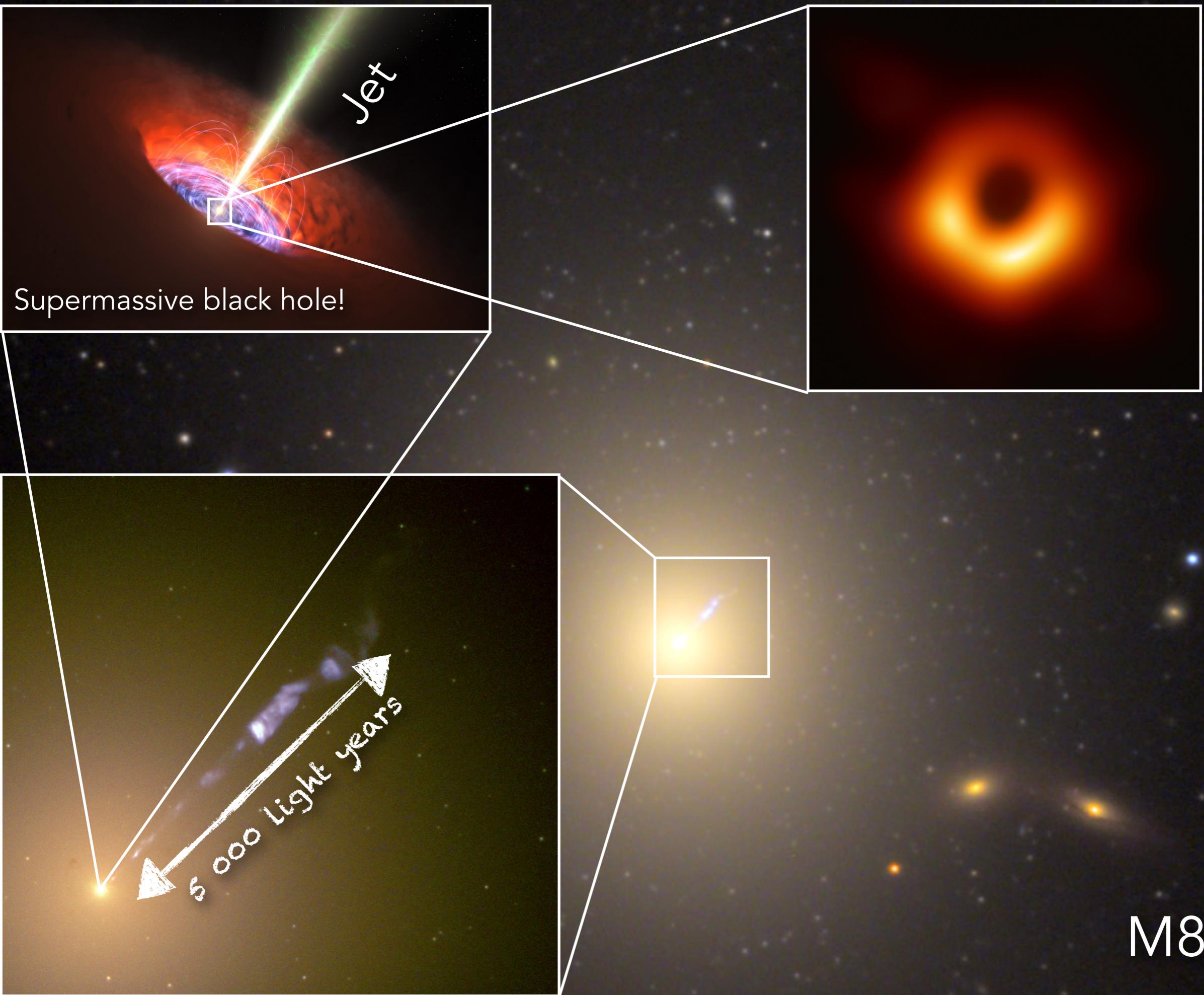


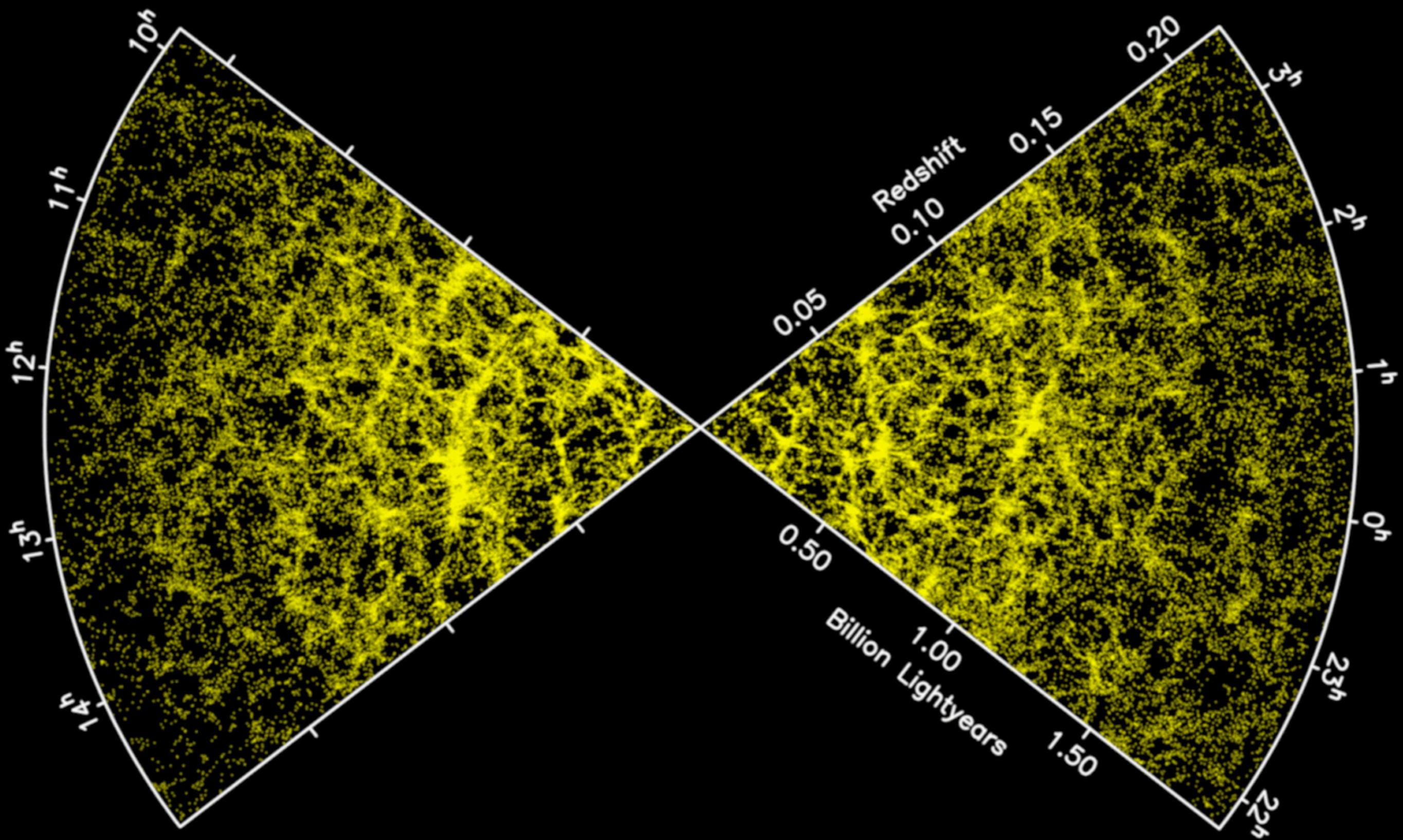




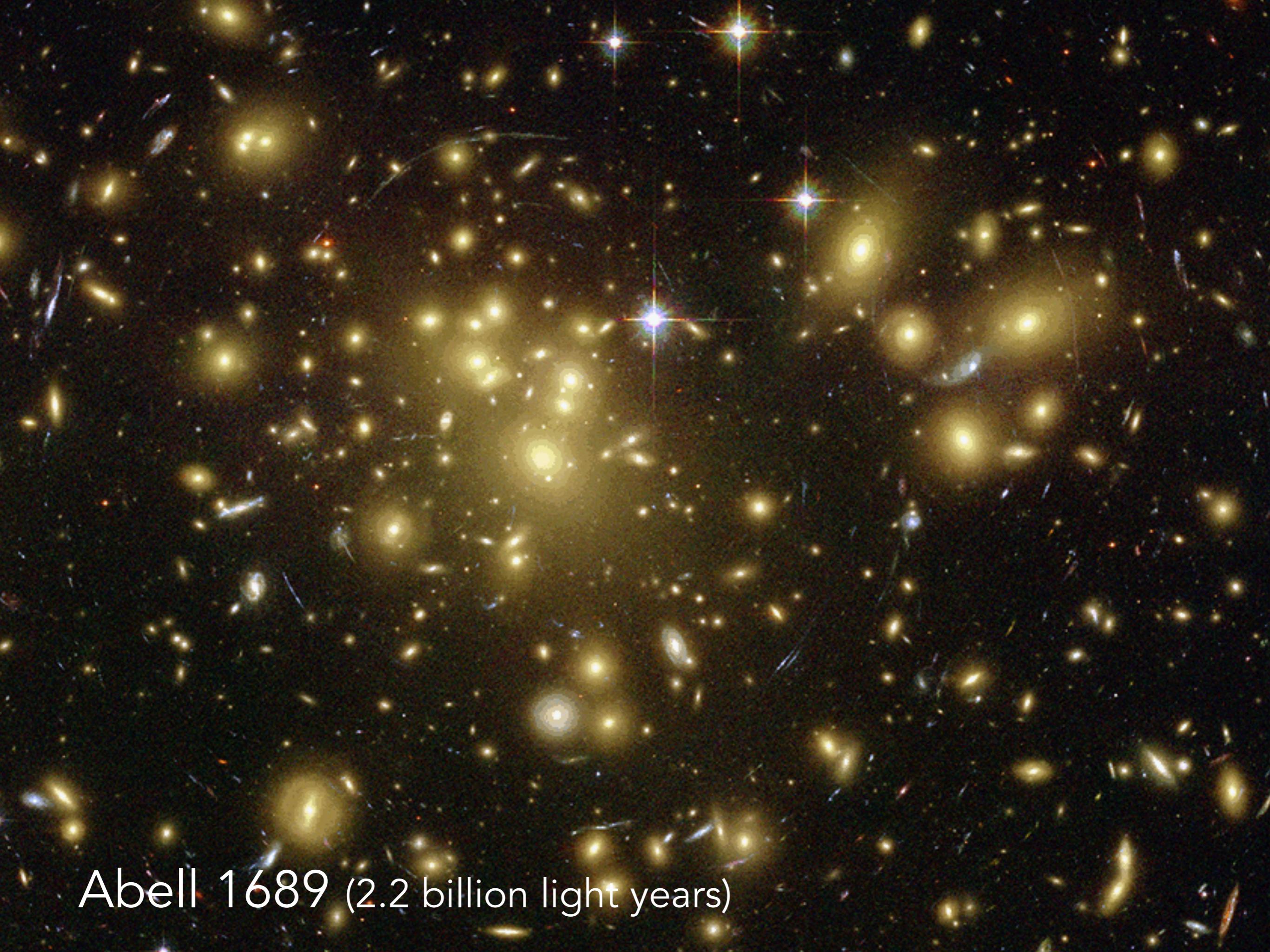
M87







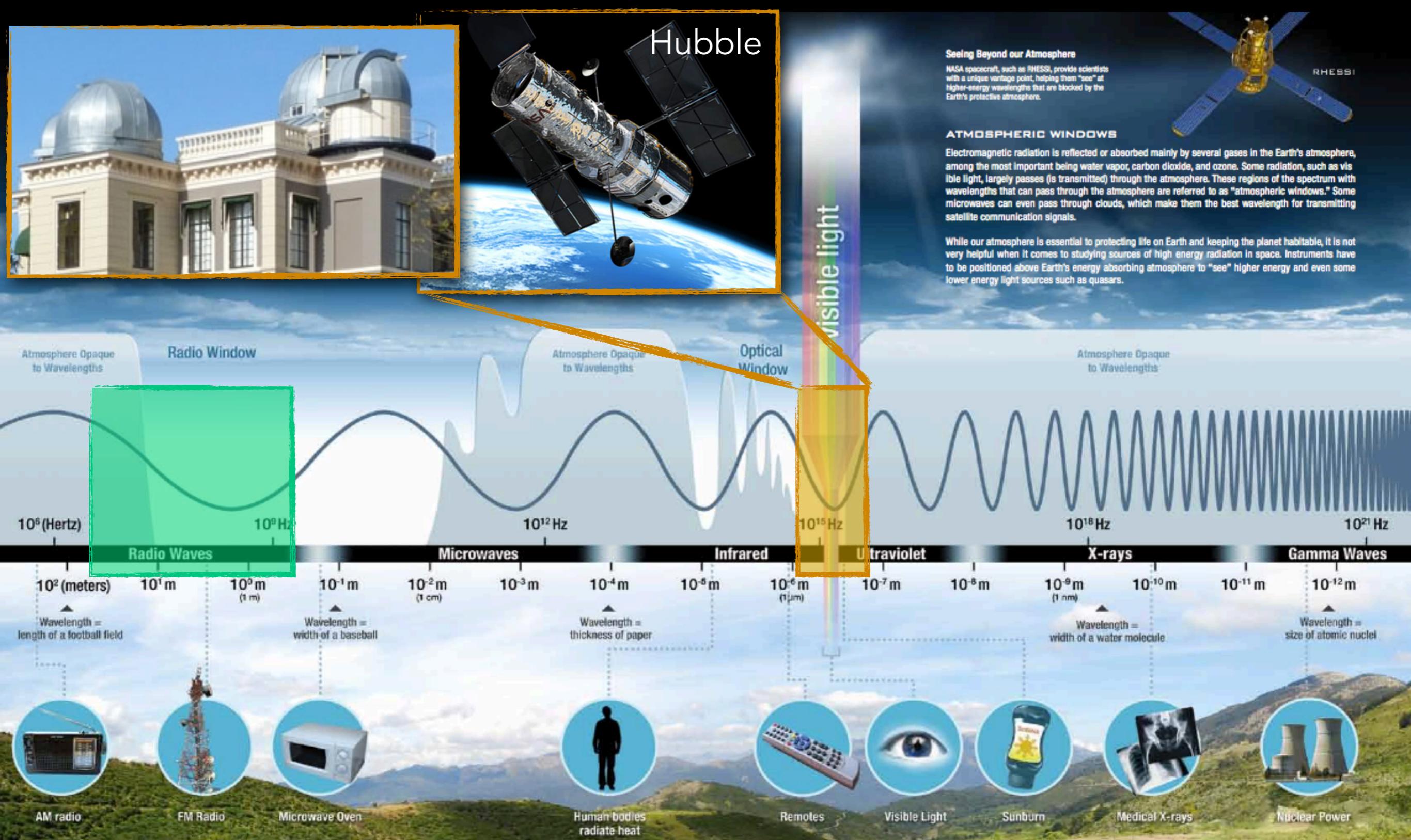
The large scale structure of the universe



Abell 1689 (2.2 billion light years)

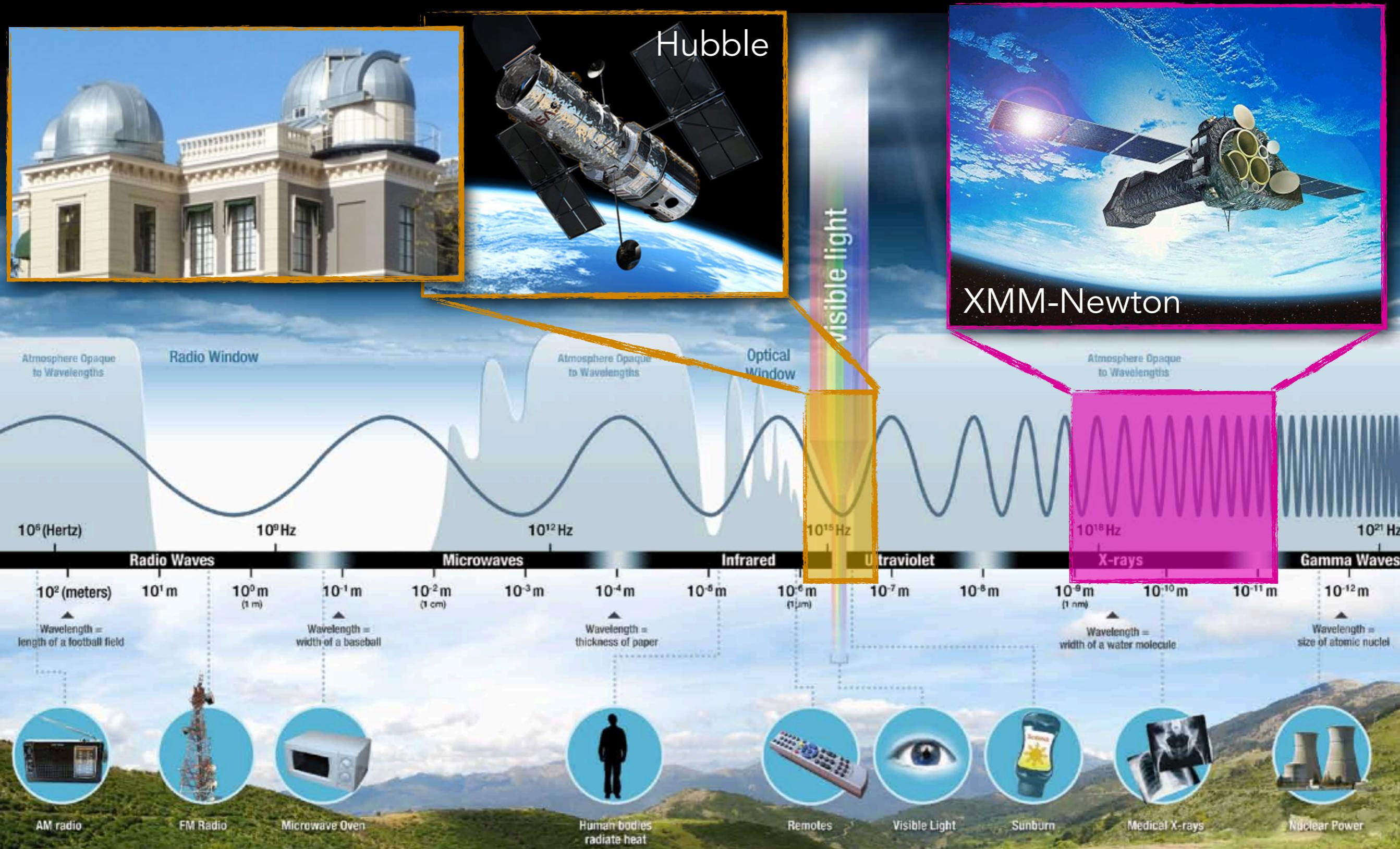
Light emits at optical "colors"...

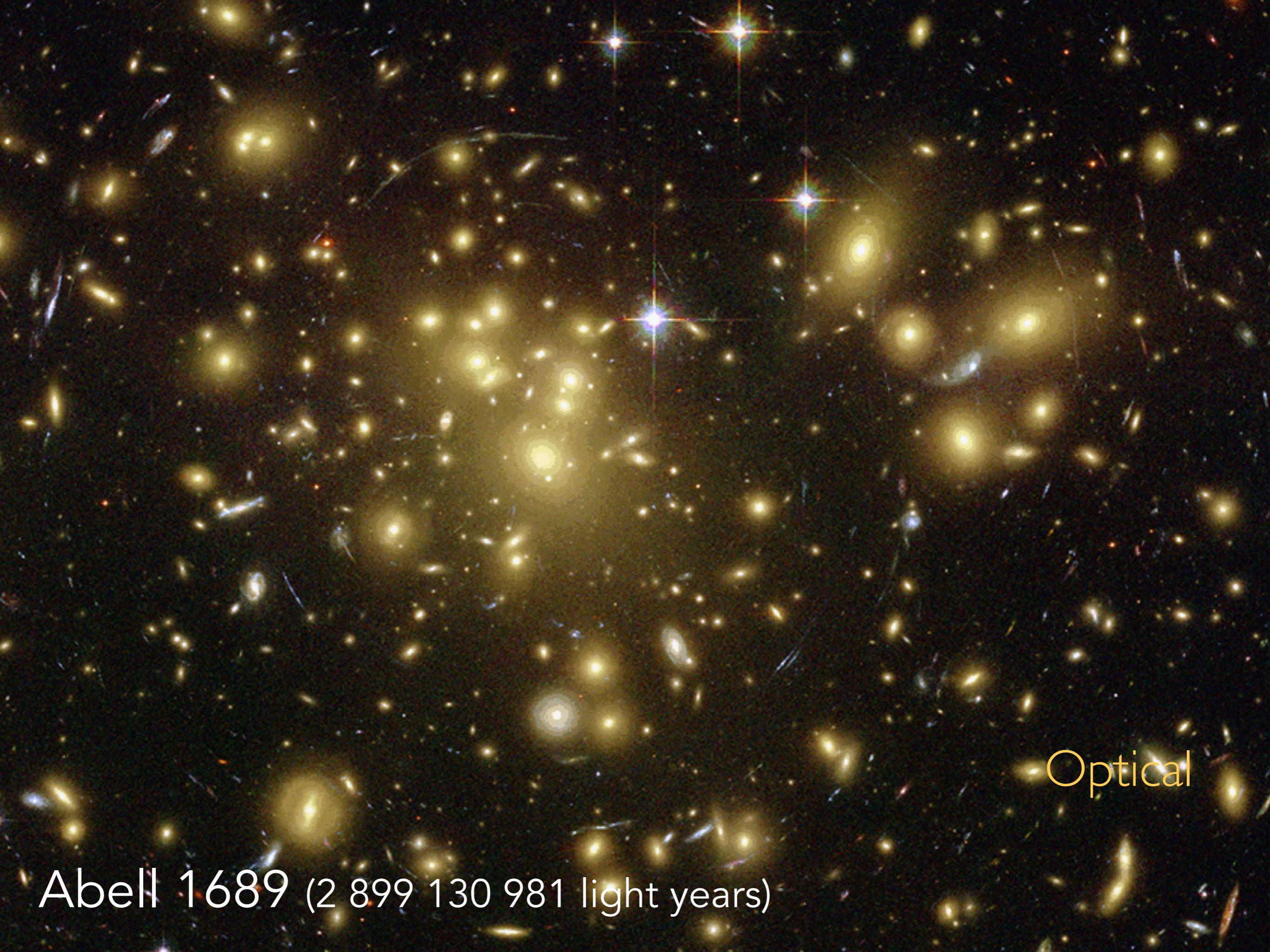
...but also in infrared, **radio**, ...and **X-ray**!



Light emits at optical “colors”...

...but also in infrared, **radio**, ...and **X-ray!**





Abell 1689 (2 899 130 981 light years)

Optical

X-rays

Abell 1689 (2 899 130 981 light years)



Hot gas!

The intracluster medium

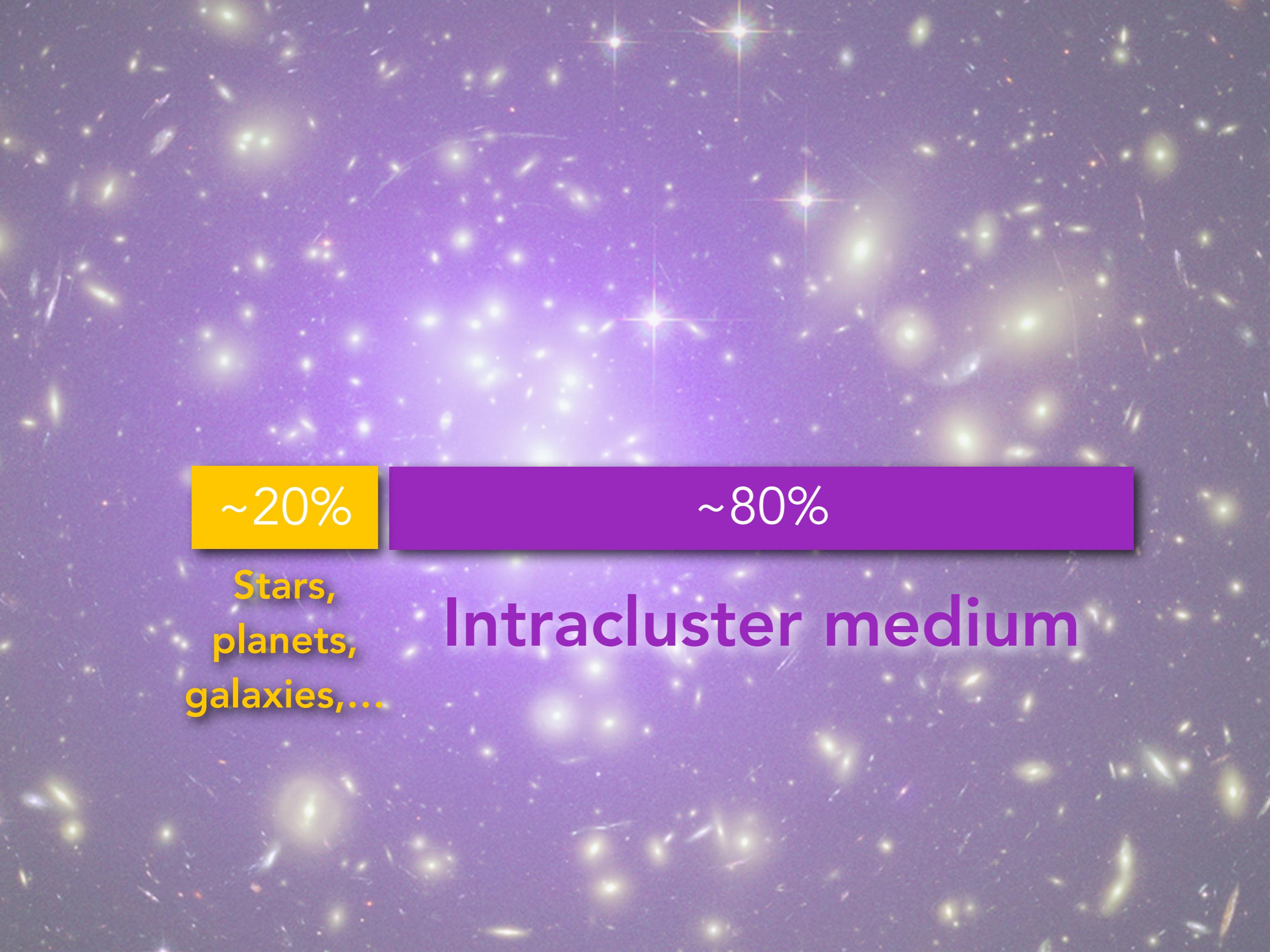
- **hot** (~10 to 100 millions °C!)
- **tenuous** (~1 particle per dm³)
- **heavily ionised** (lots of free electrons)

X-rays

Optical



Stars,
planets,
galaxies,...



A background image of a galaxy cluster, showing a dense concentration of galaxies of various sizes and colors against a dark purple background.

~20%

Stars,
planets,
galaxies,...

~80%

Intracluster medium

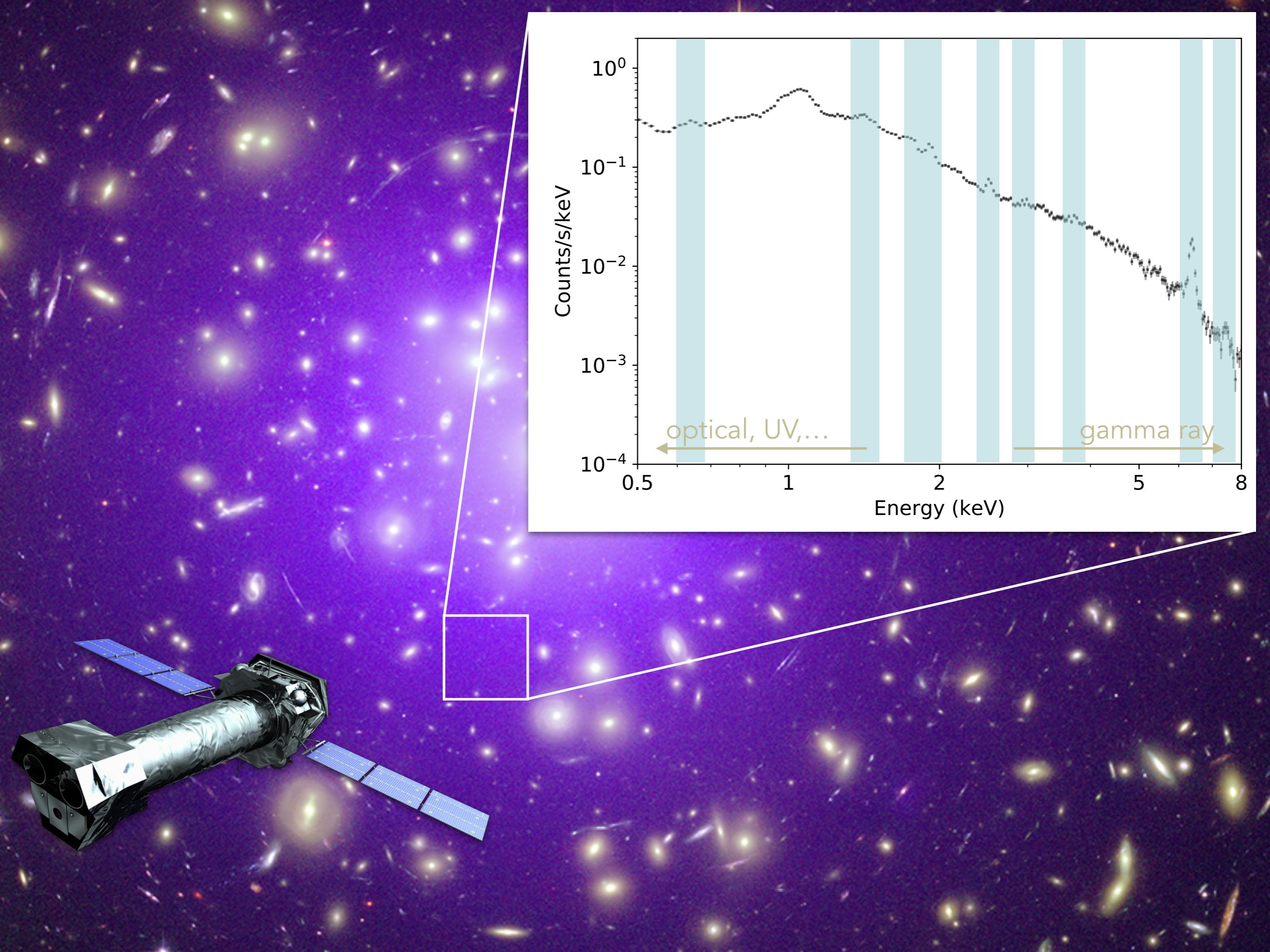


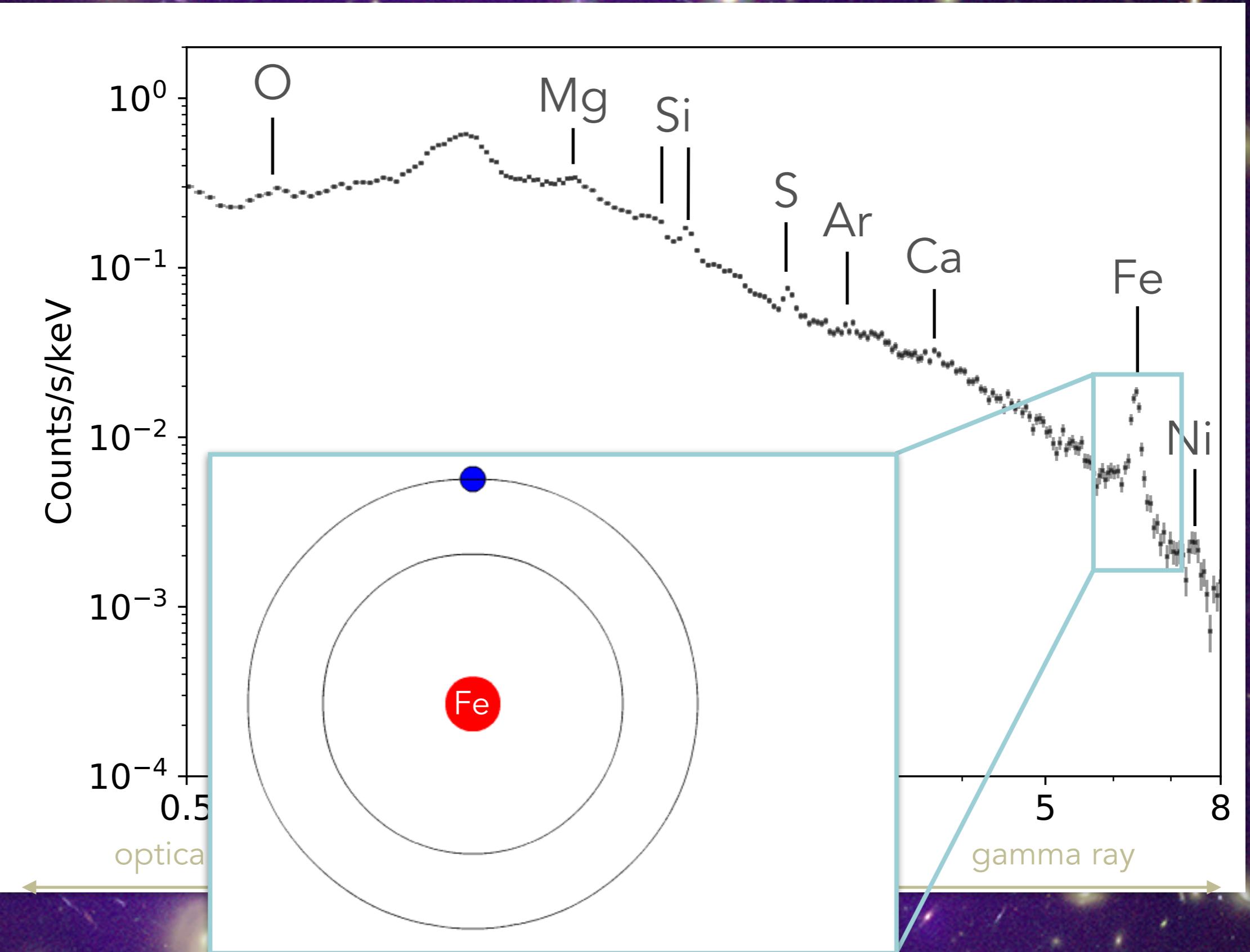
\sim 15%

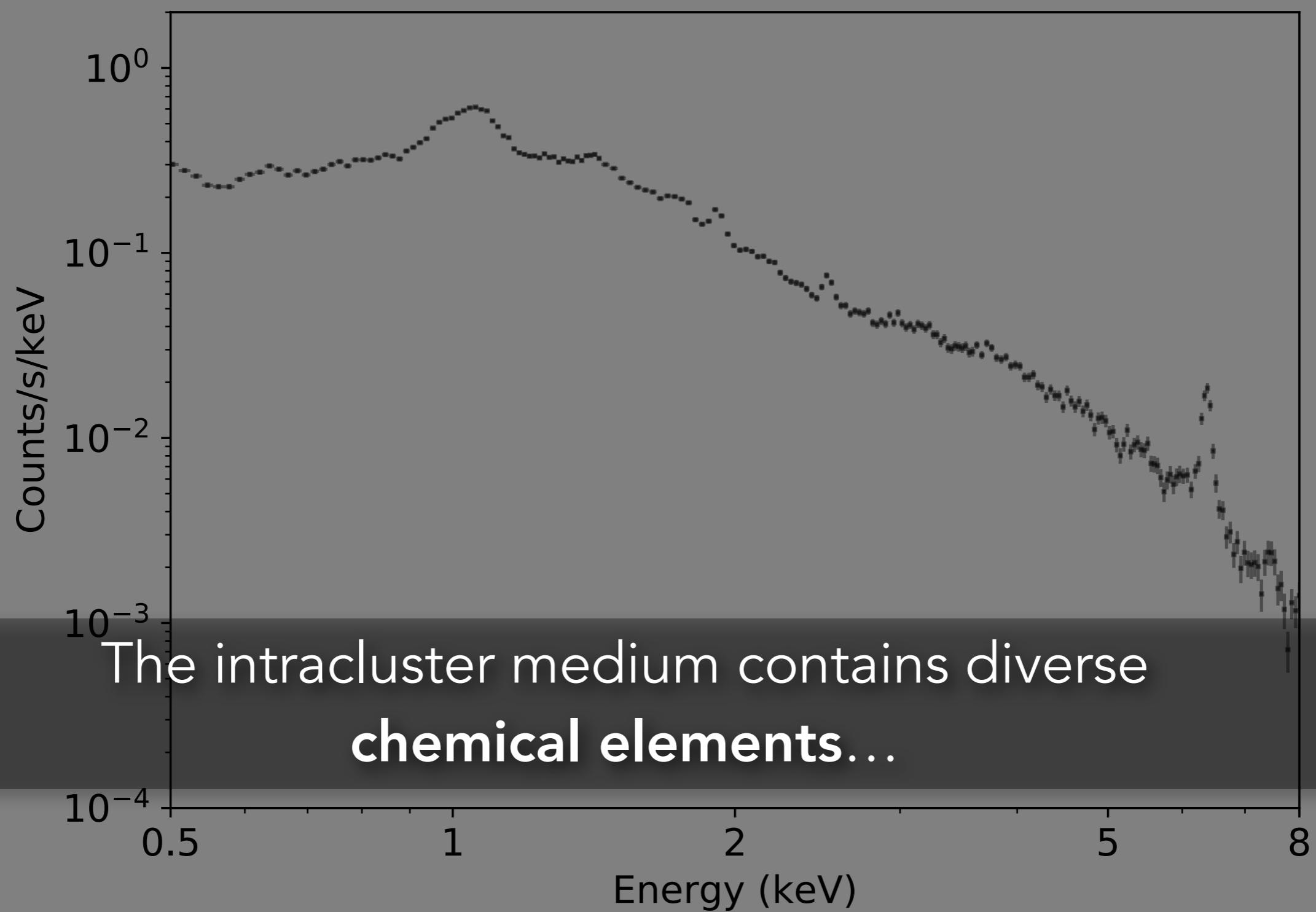
\sim 85%

Stars, Intracluster
planets, medium
galaxies,...

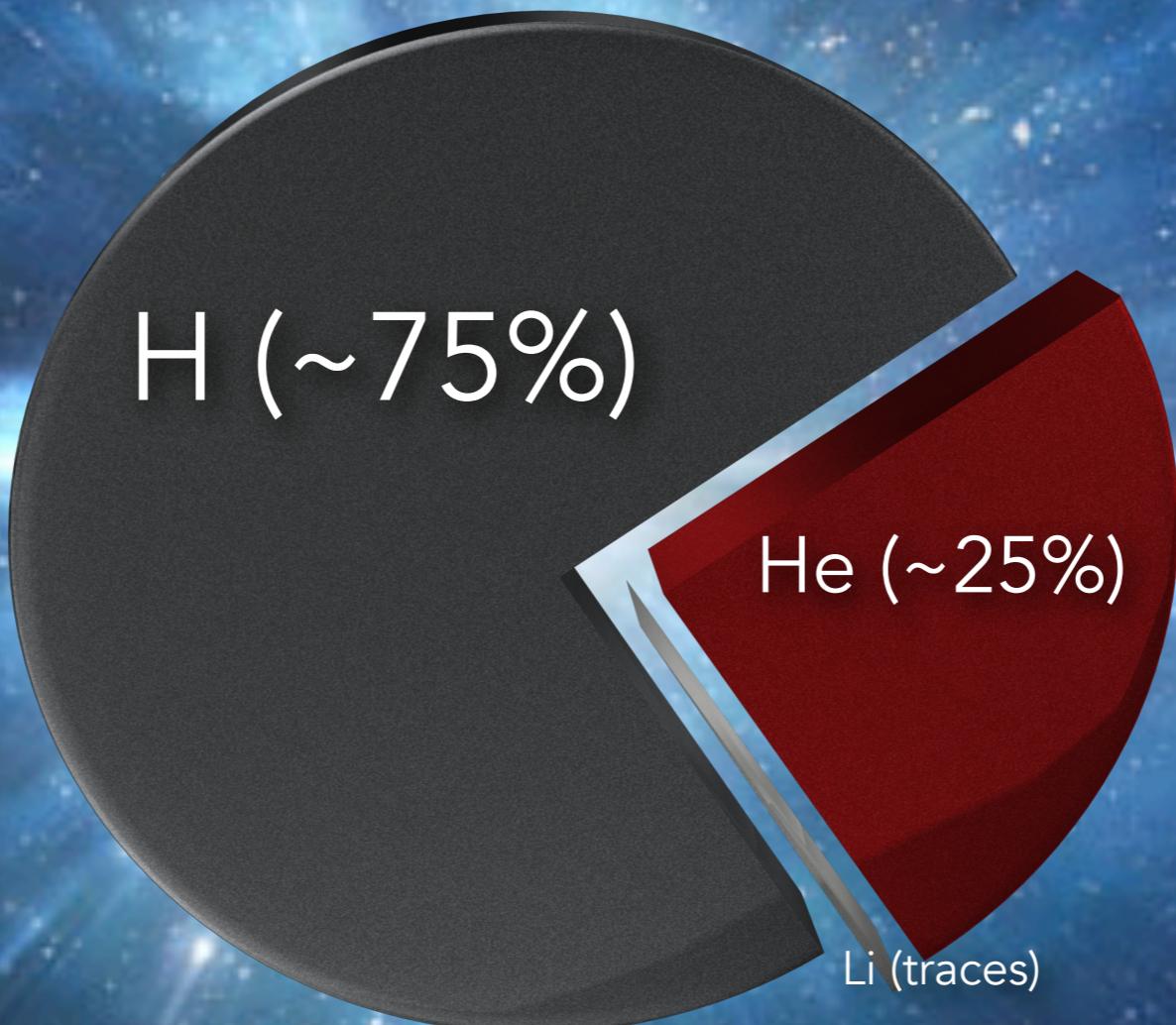
Dark matter







Primordial nucleosynthesis



Big Bang



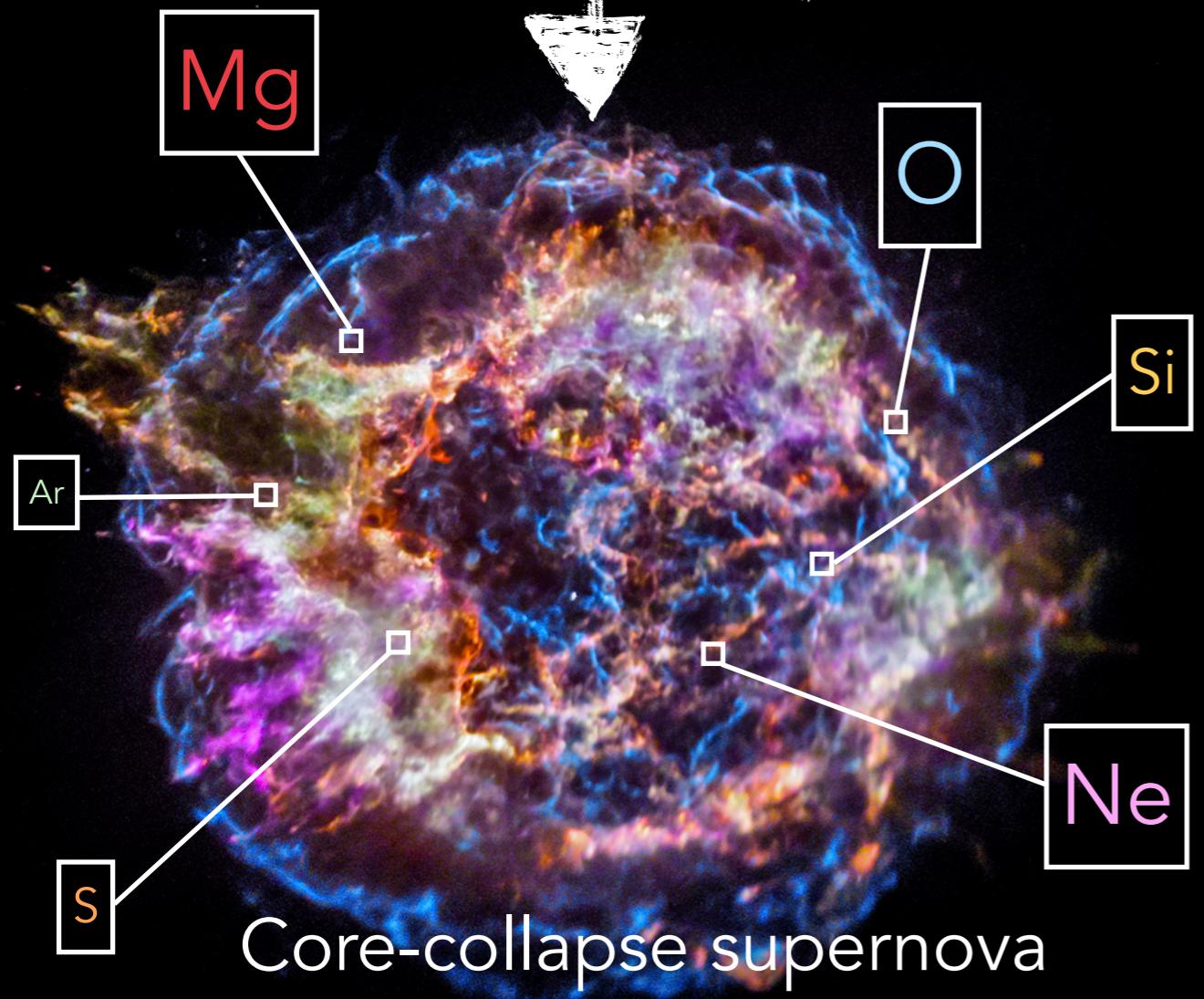
Supernovae are the **only way** to produce metals
(i.e. elements heavier than H and He...)

“We are made of starstuff.” - Carl Sagan

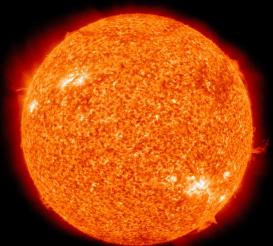
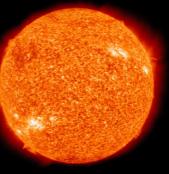
Massive star



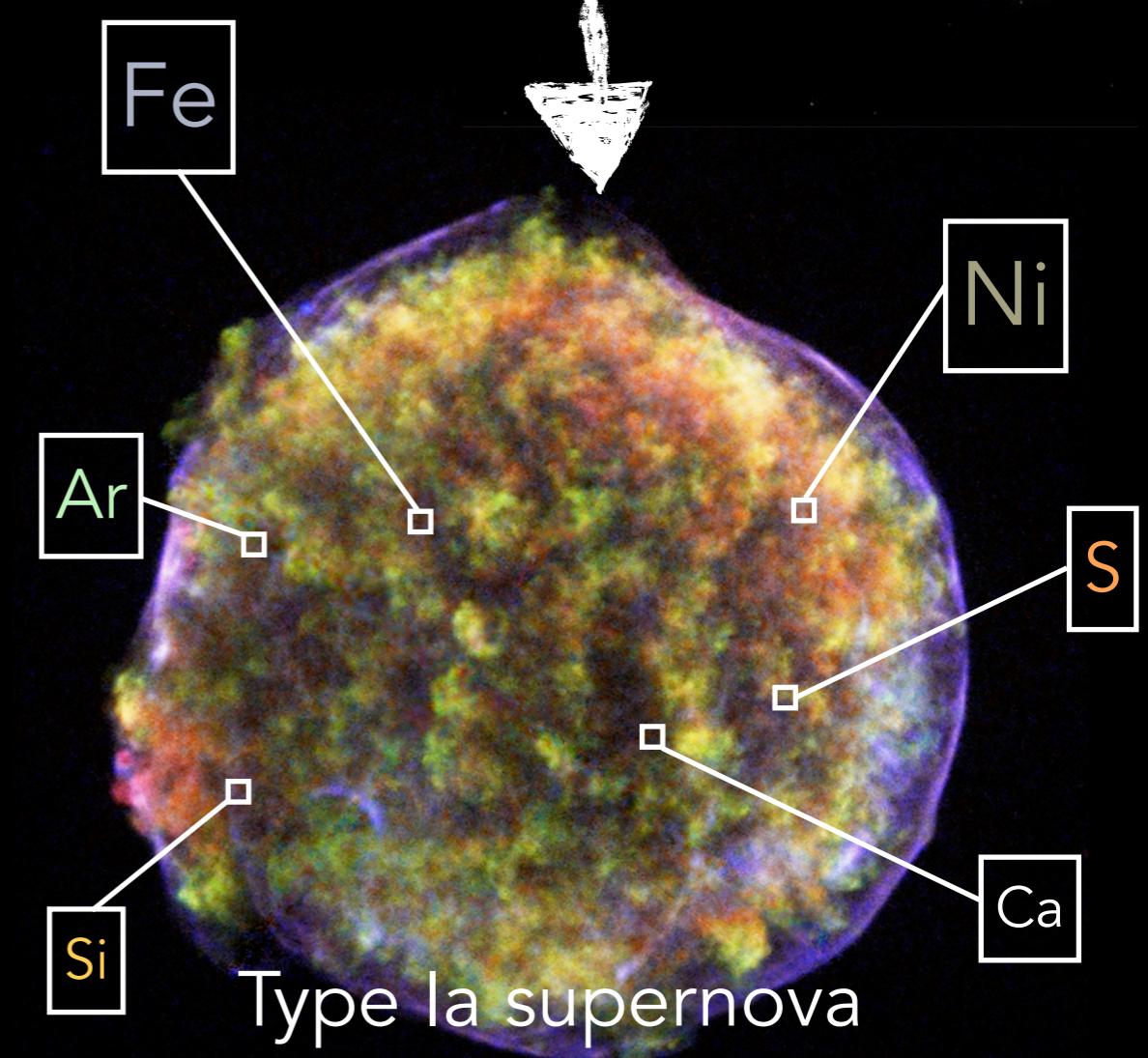
<30 million
years

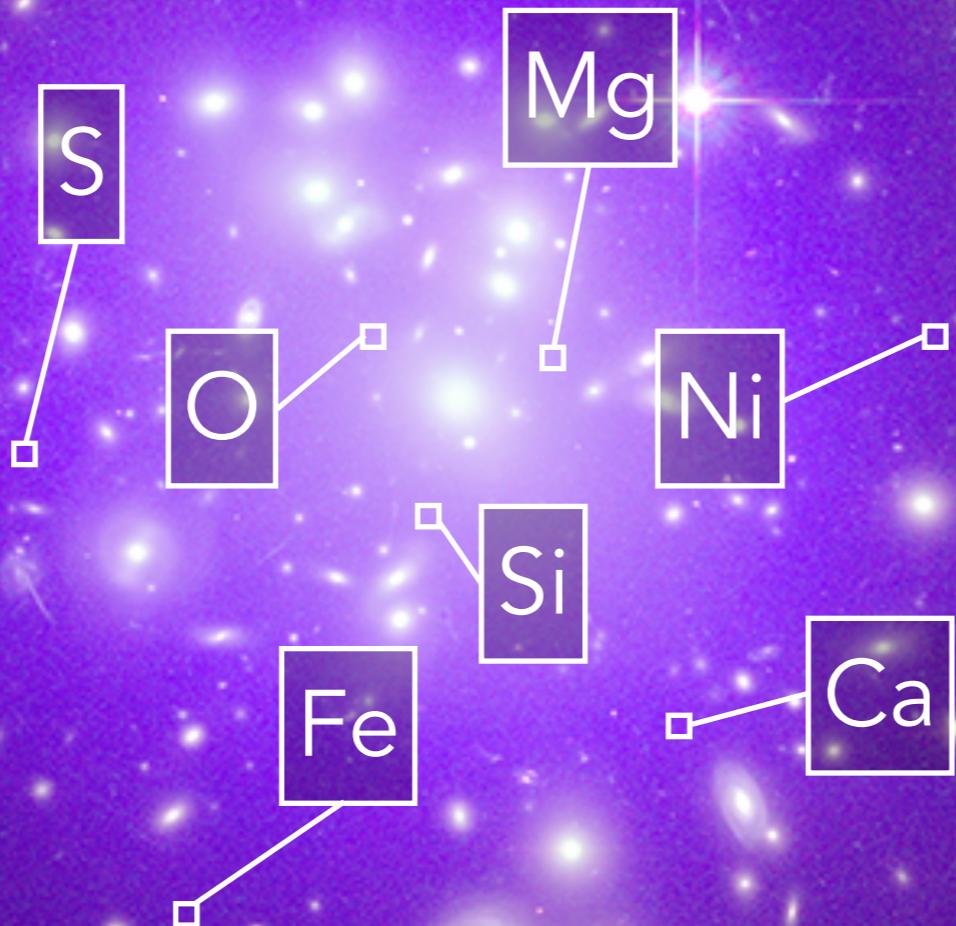


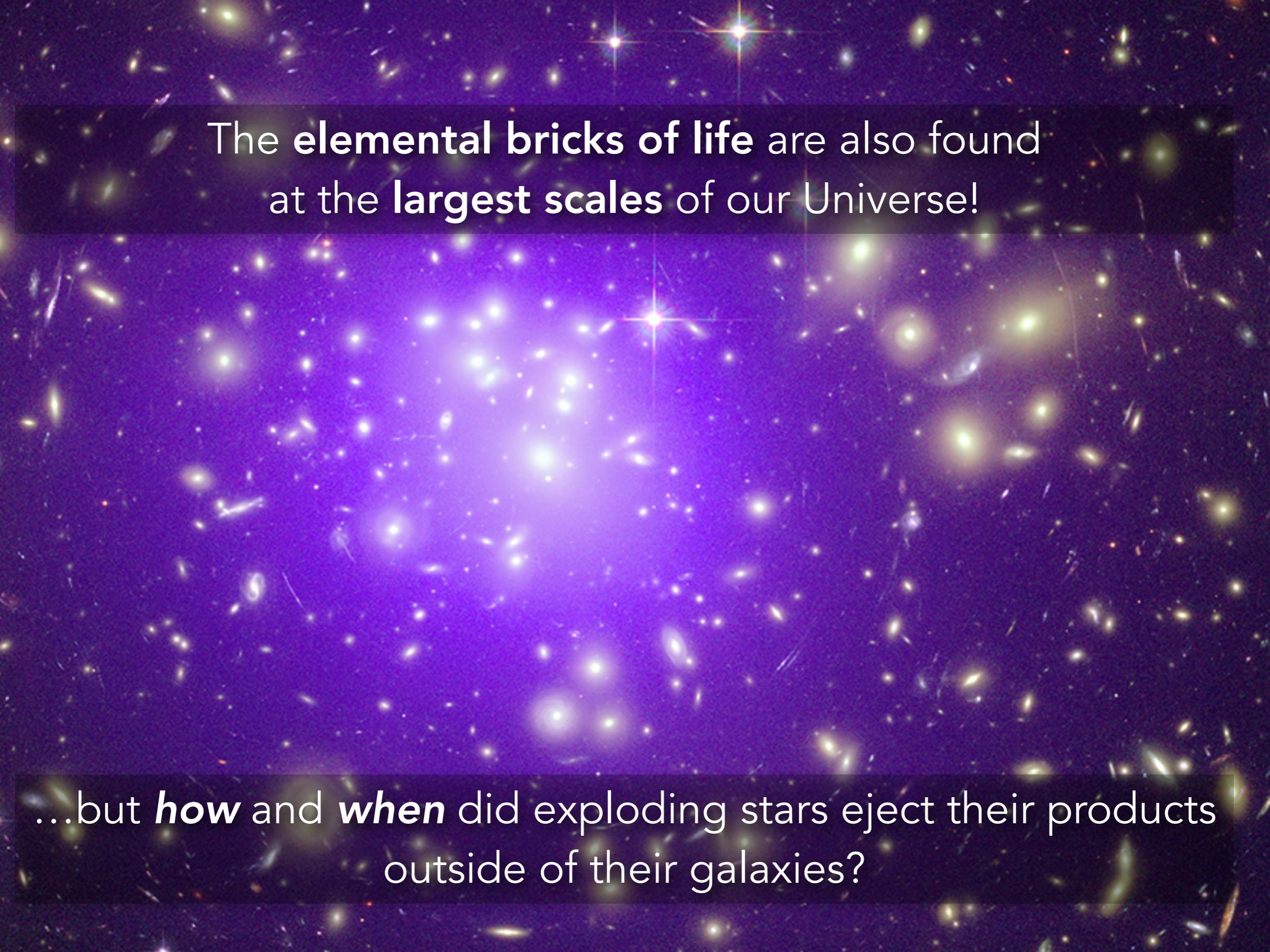
Low-mass stars



>1 billion
years







The **elemental bricks of life** are also found
at the **largest scales** of our Universe!

...but **how** and **when** did exploding stars eject their products
outside of their galaxies?

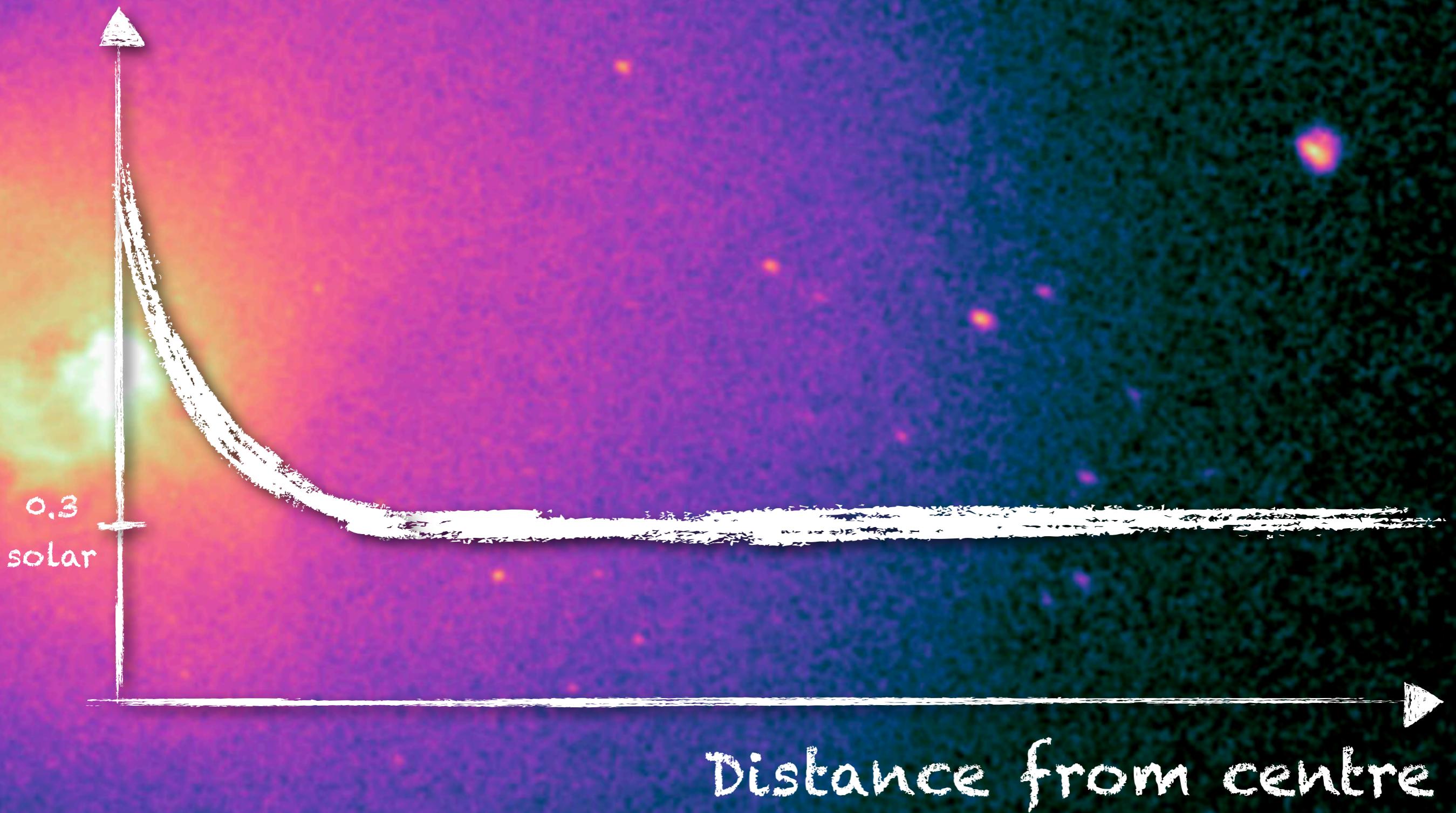


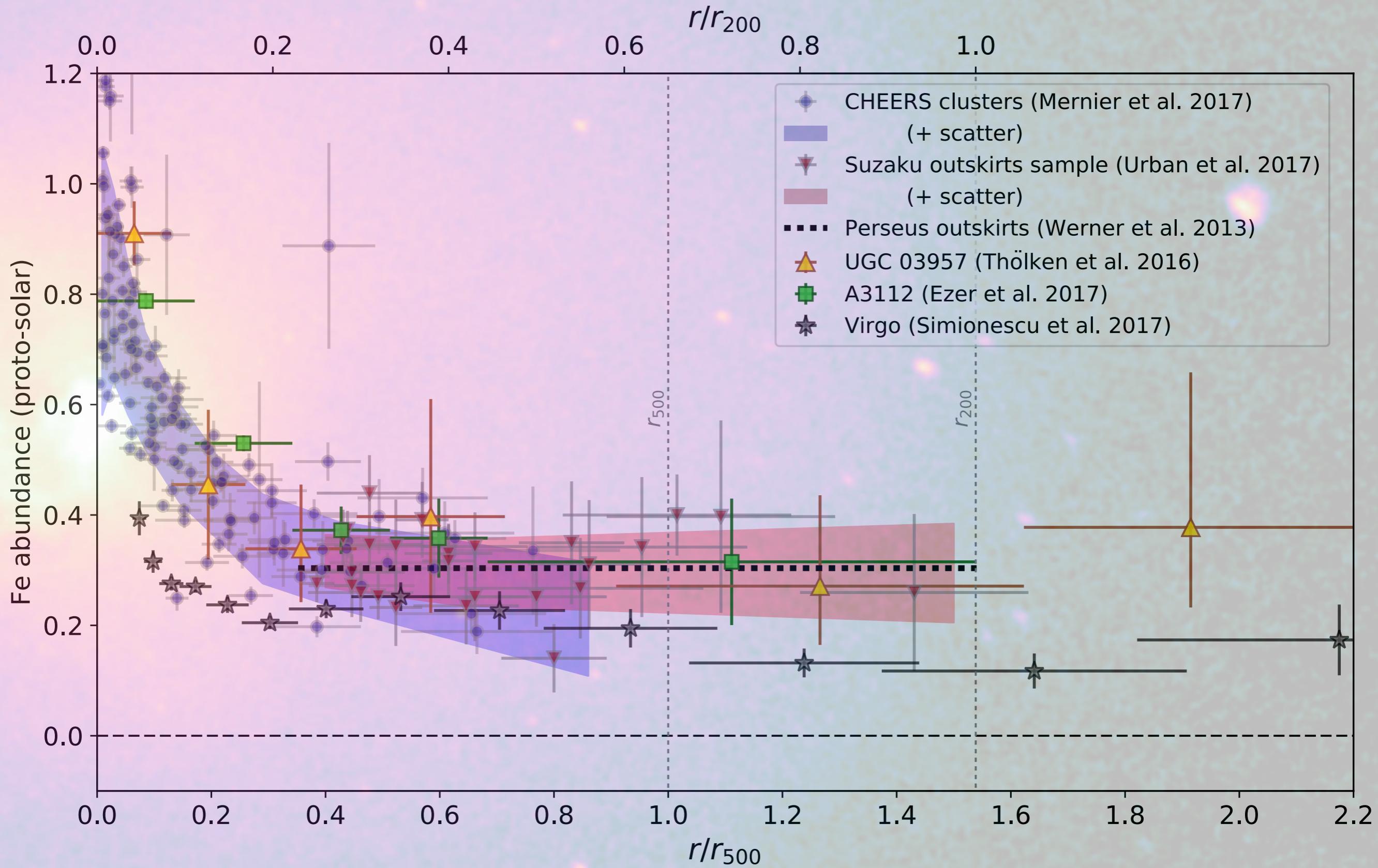
The Centaurus cluster

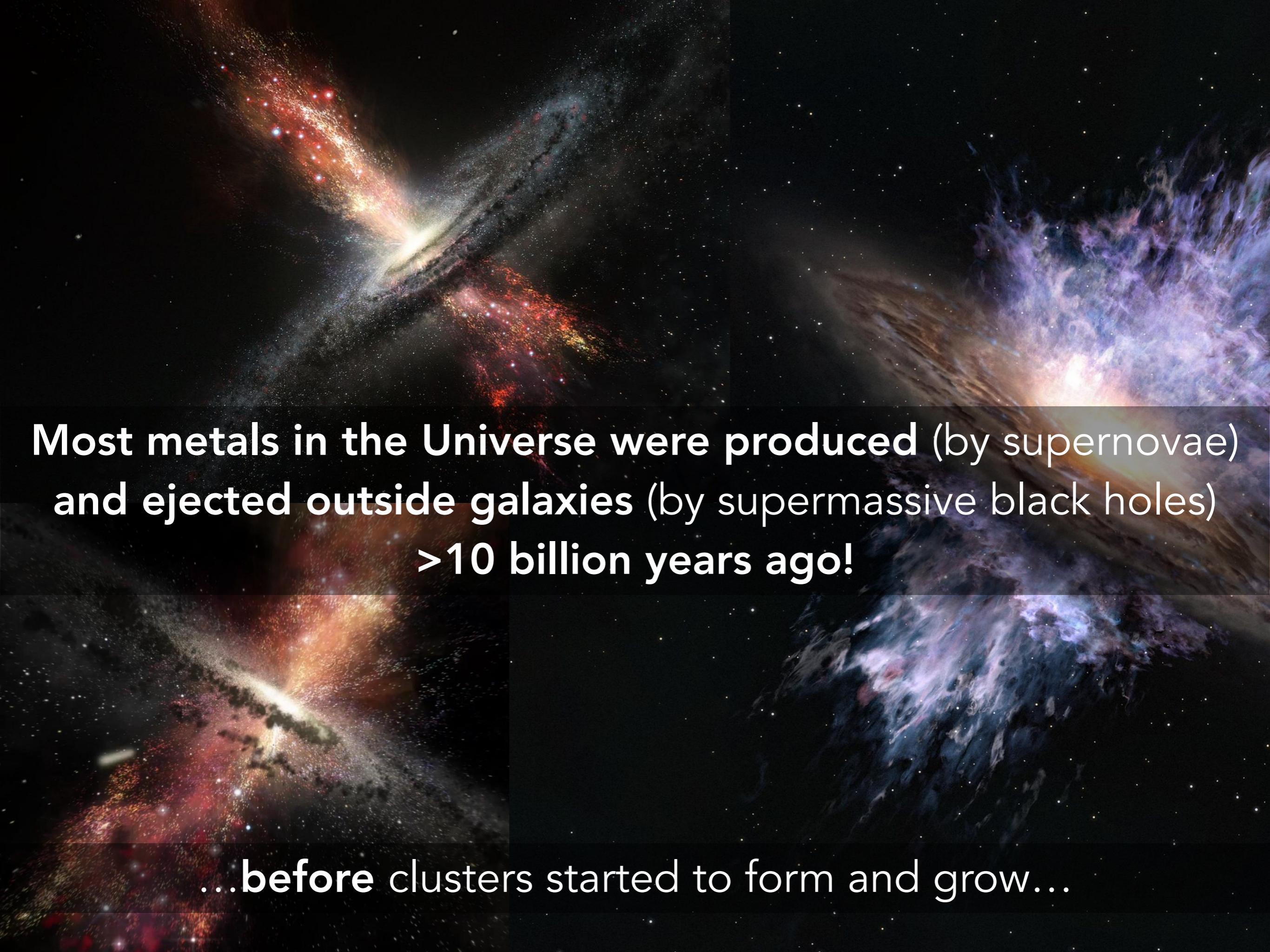


The Centaurus cluster

Metal
abundance



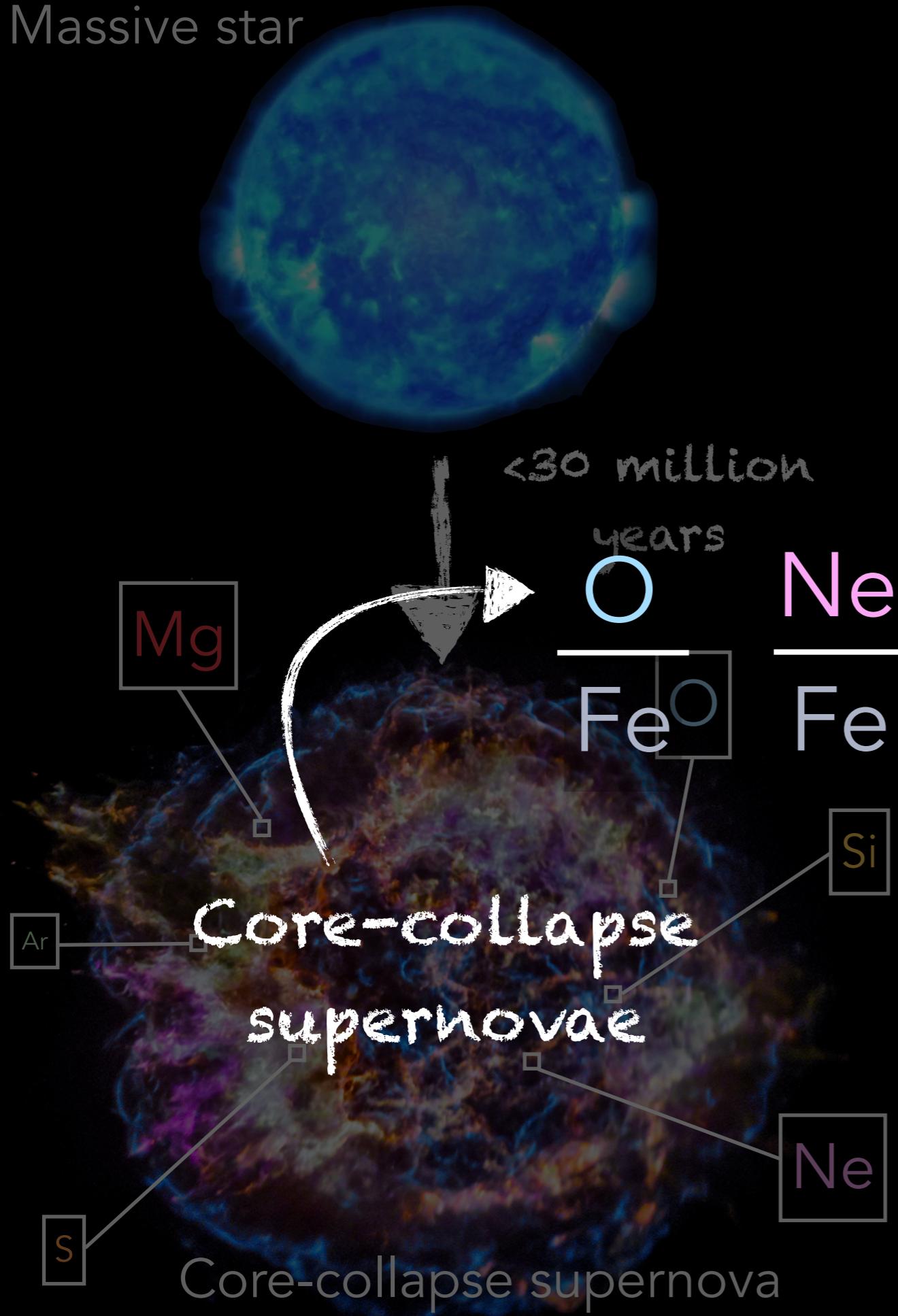




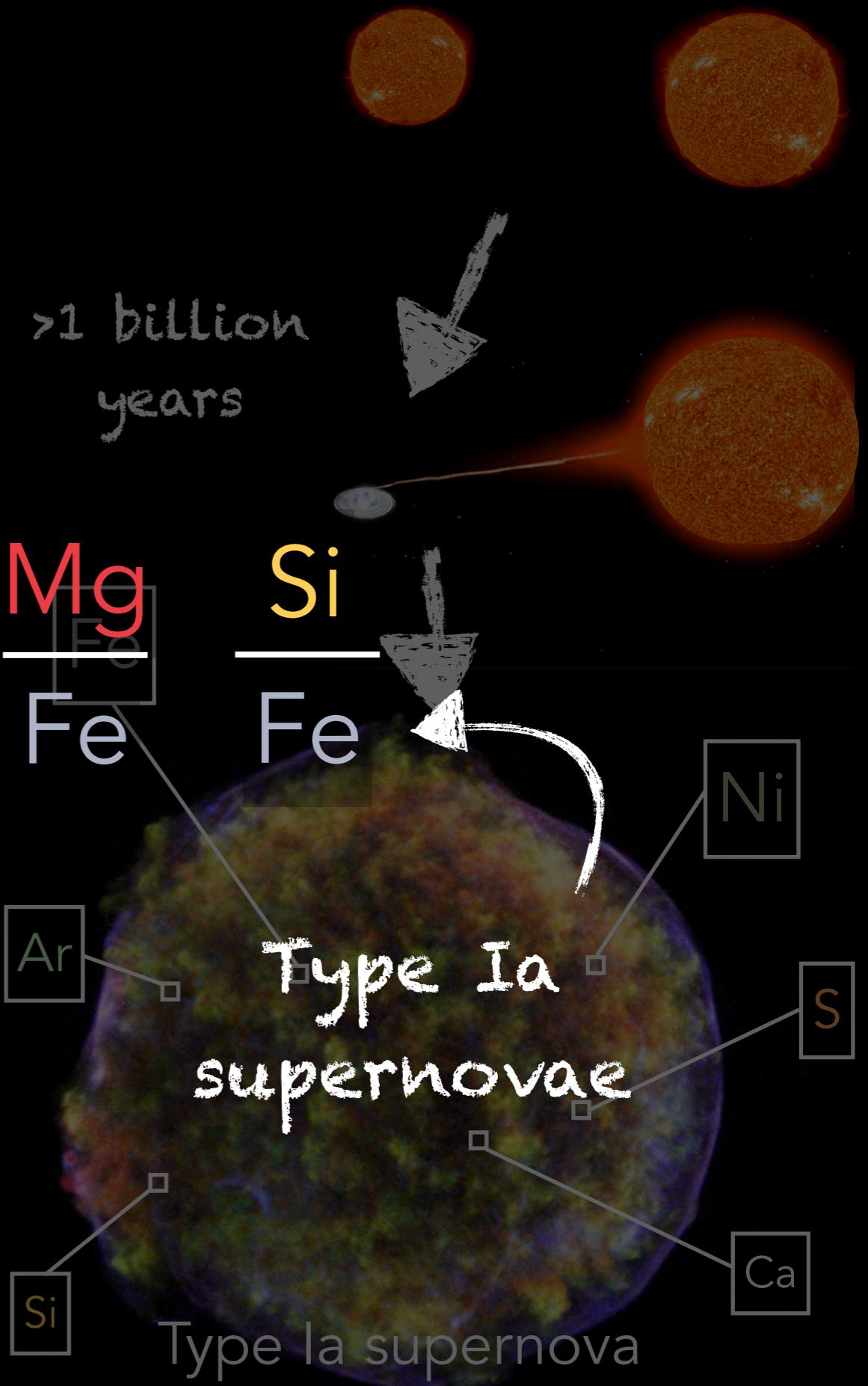
**Most metals in the Universe were produced (by supernovae)
and ejected outside galaxies (by supermassive black holes)
>10 billion years ago!**

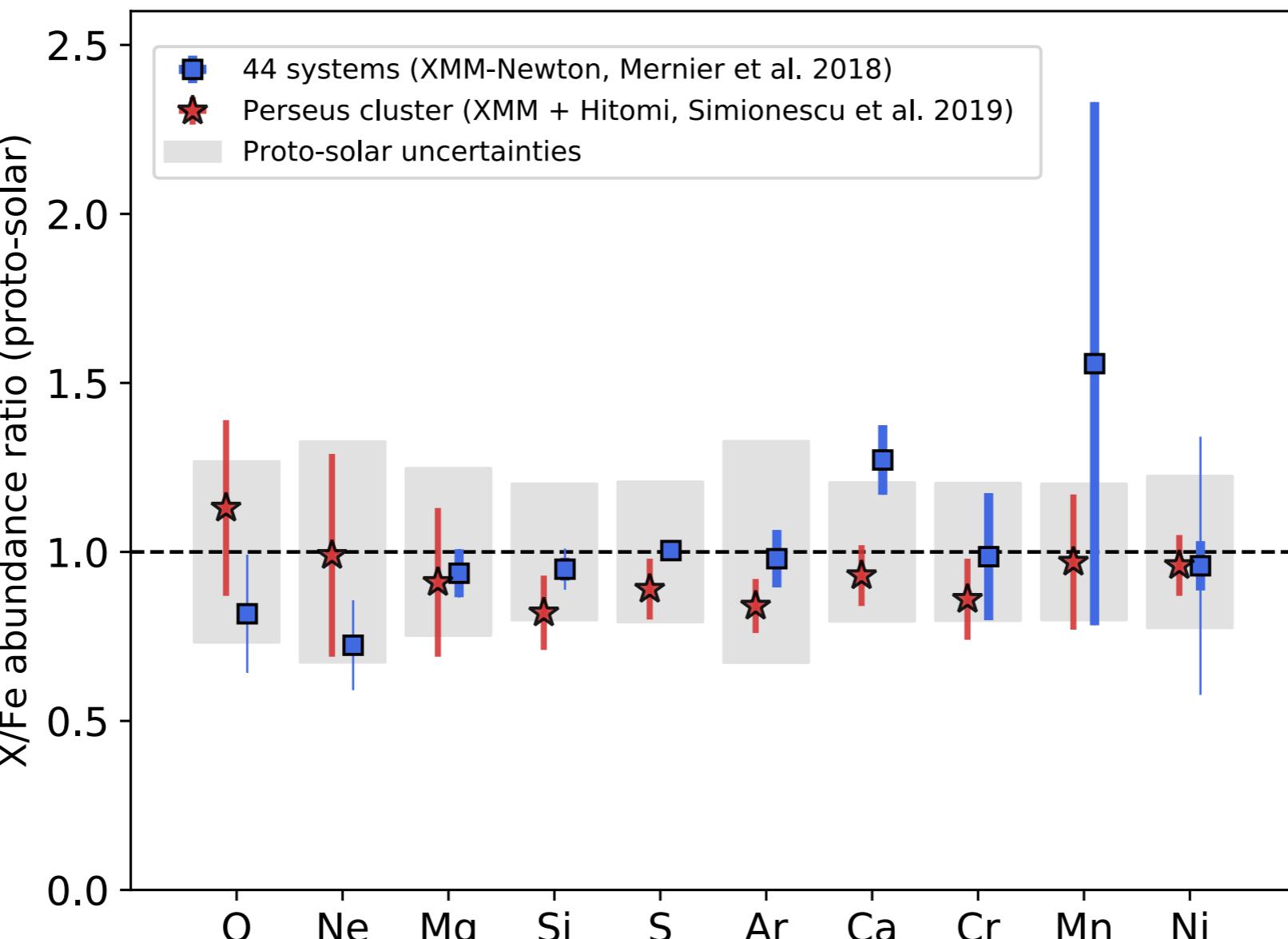
...before clusters started to form and grow...

Massive star



Low-mass stars





Why is the chemical composition of the intracluster medium
so similar to that of our own Sun?



*The link between **supernovae**, **supermassive black holes**,
and the **large-scale Universe***



We are made of starstuff...

Metals!

...which is spread everywhere in the Universe!