

François Mernier

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

ESA (European Space Agency),
ESTEC, Noordwijk



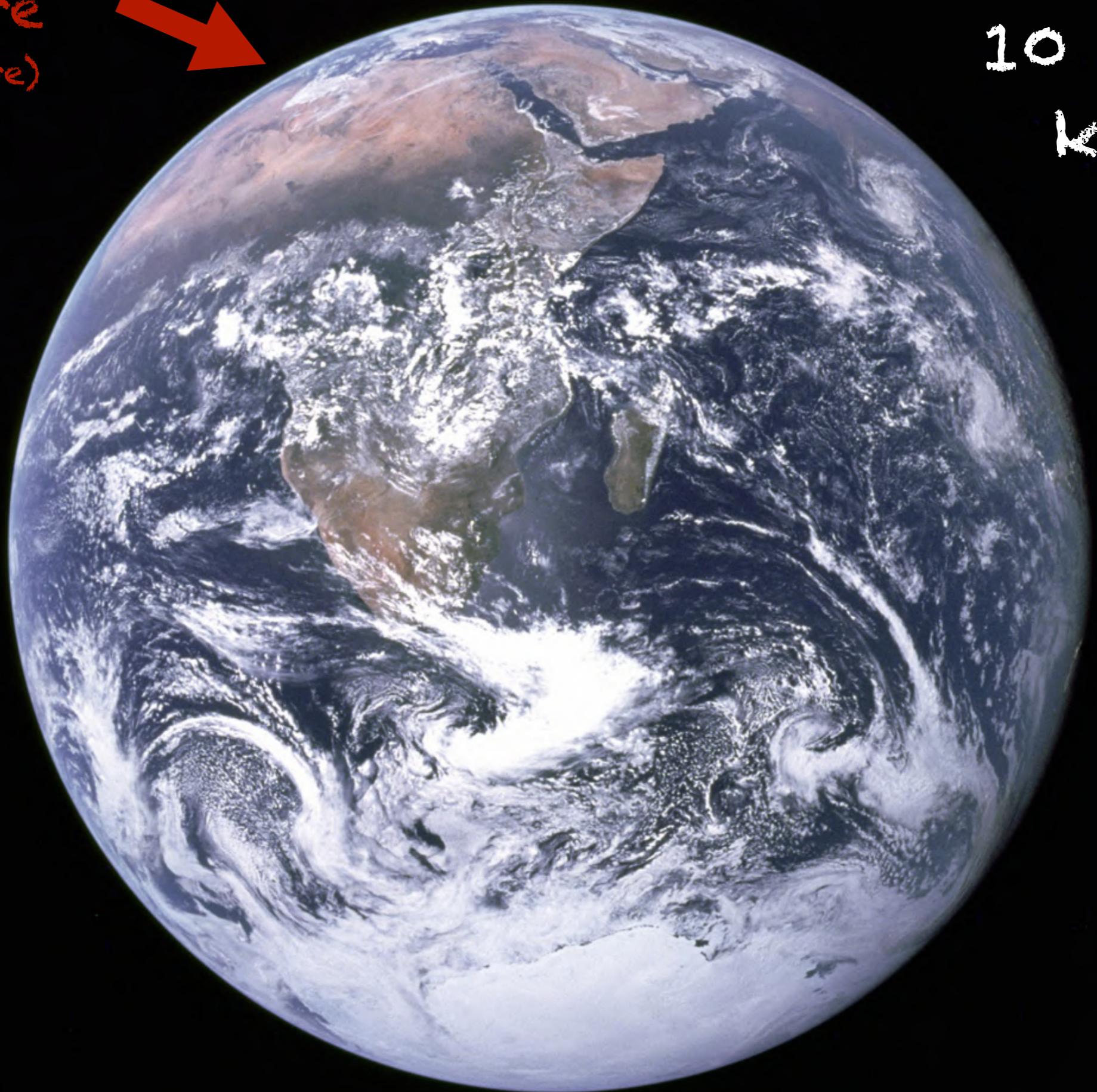
You are here!

BURGEMEESTERS- EN
PROFESSORENWIJK

You are
(somewhere)
here!



10 000
KM



You are here!



(and this is the Moon)



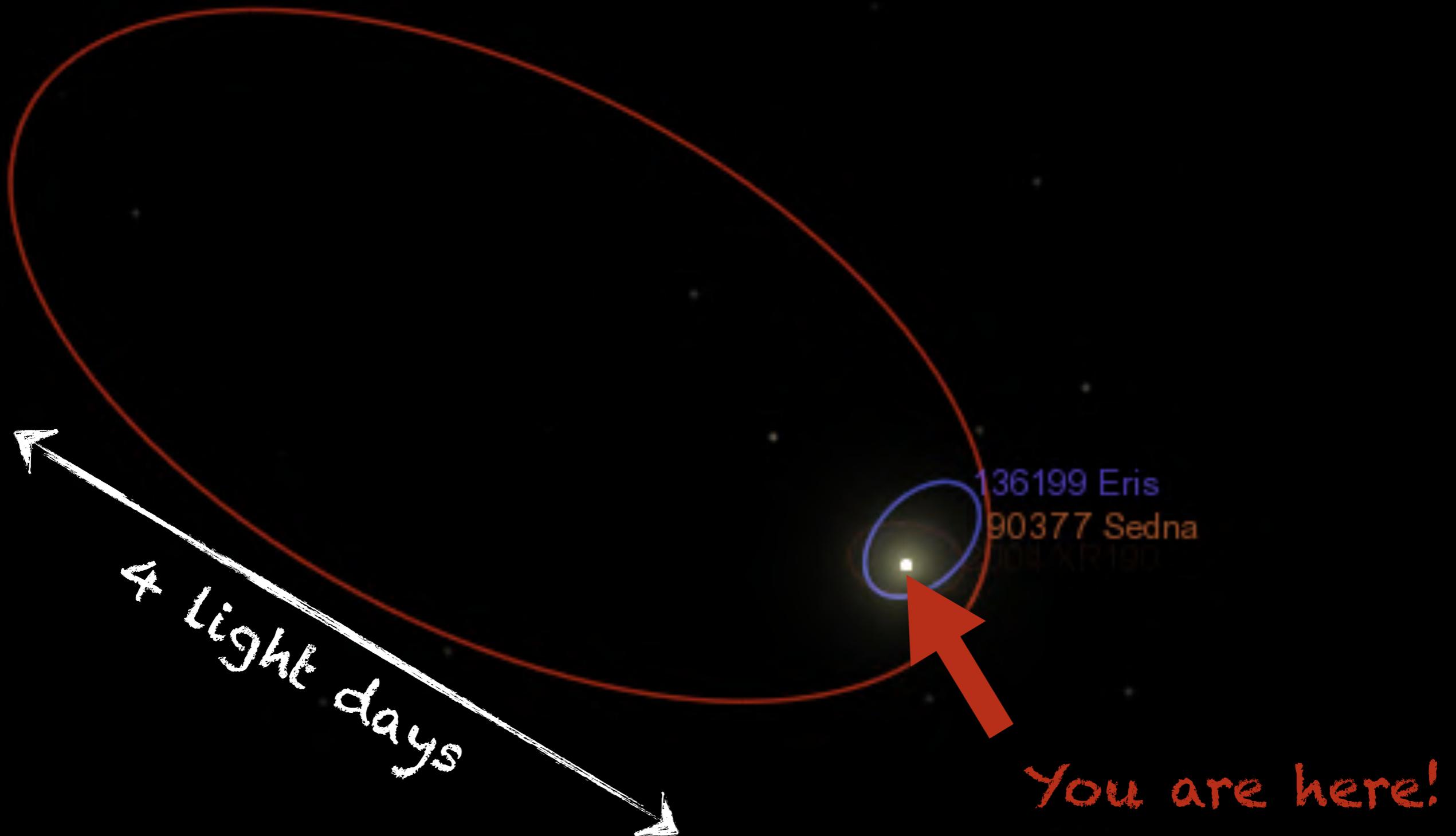
1 million km

= 3.3 light seconds



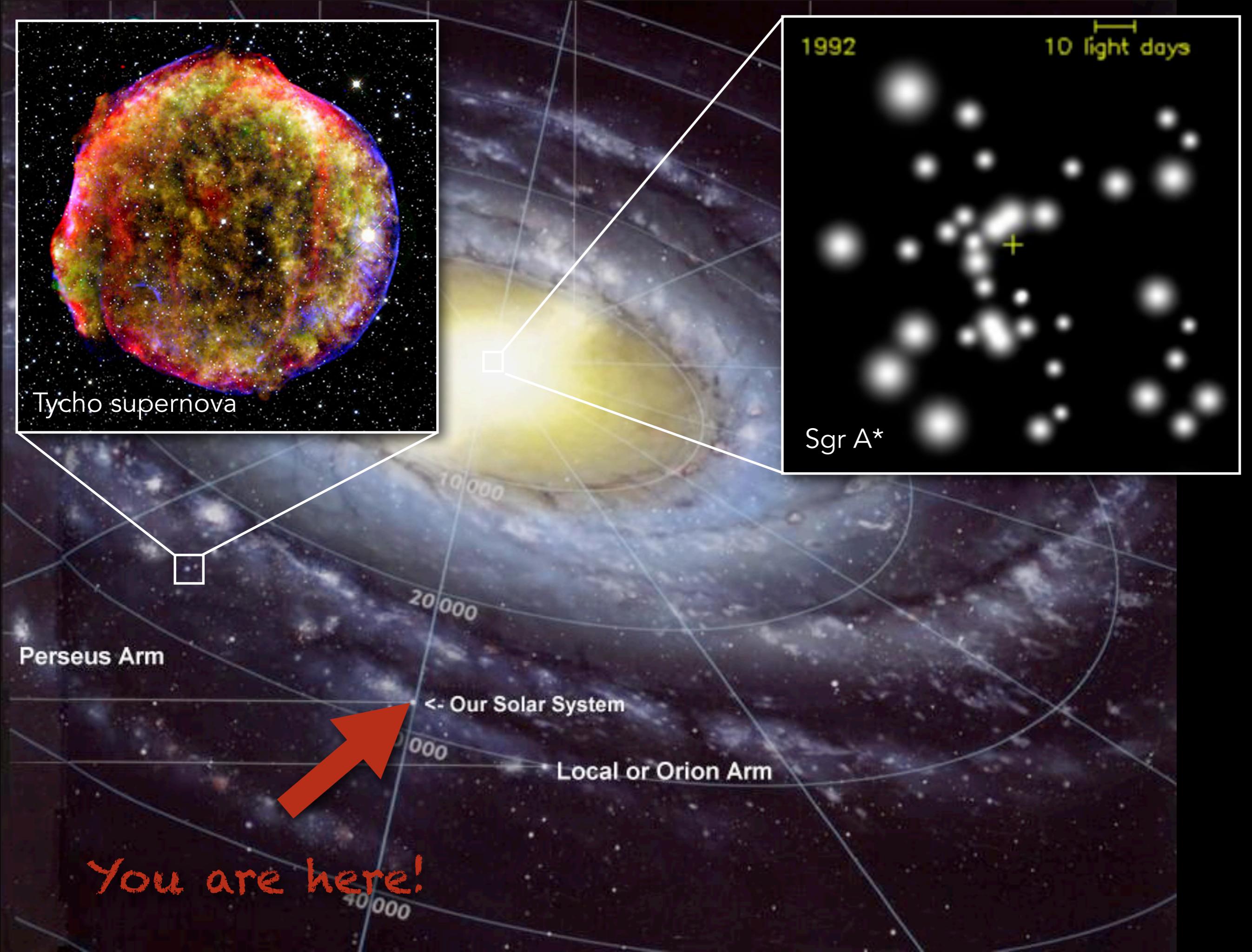
You are here!

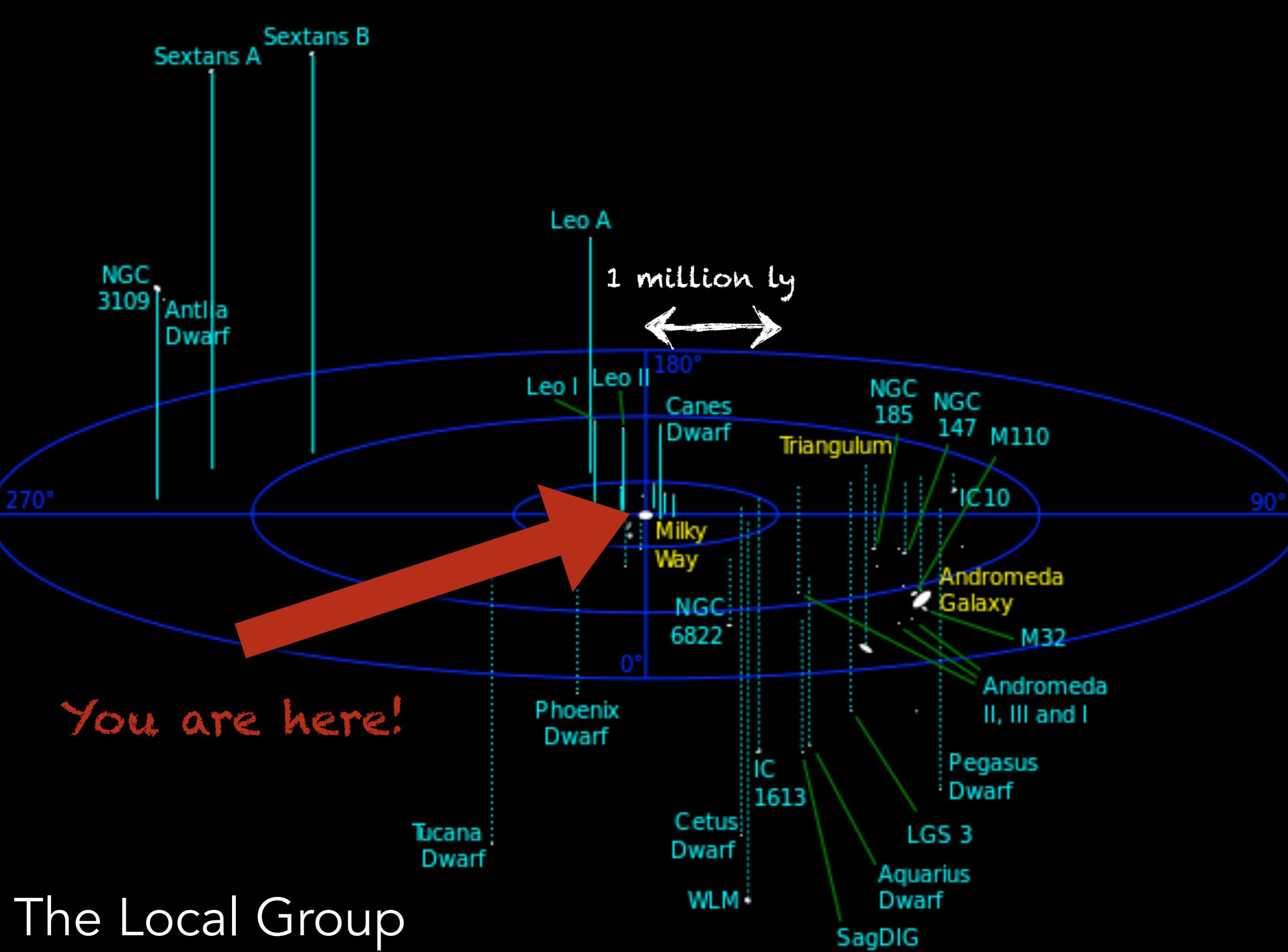
55.5 Light minutes

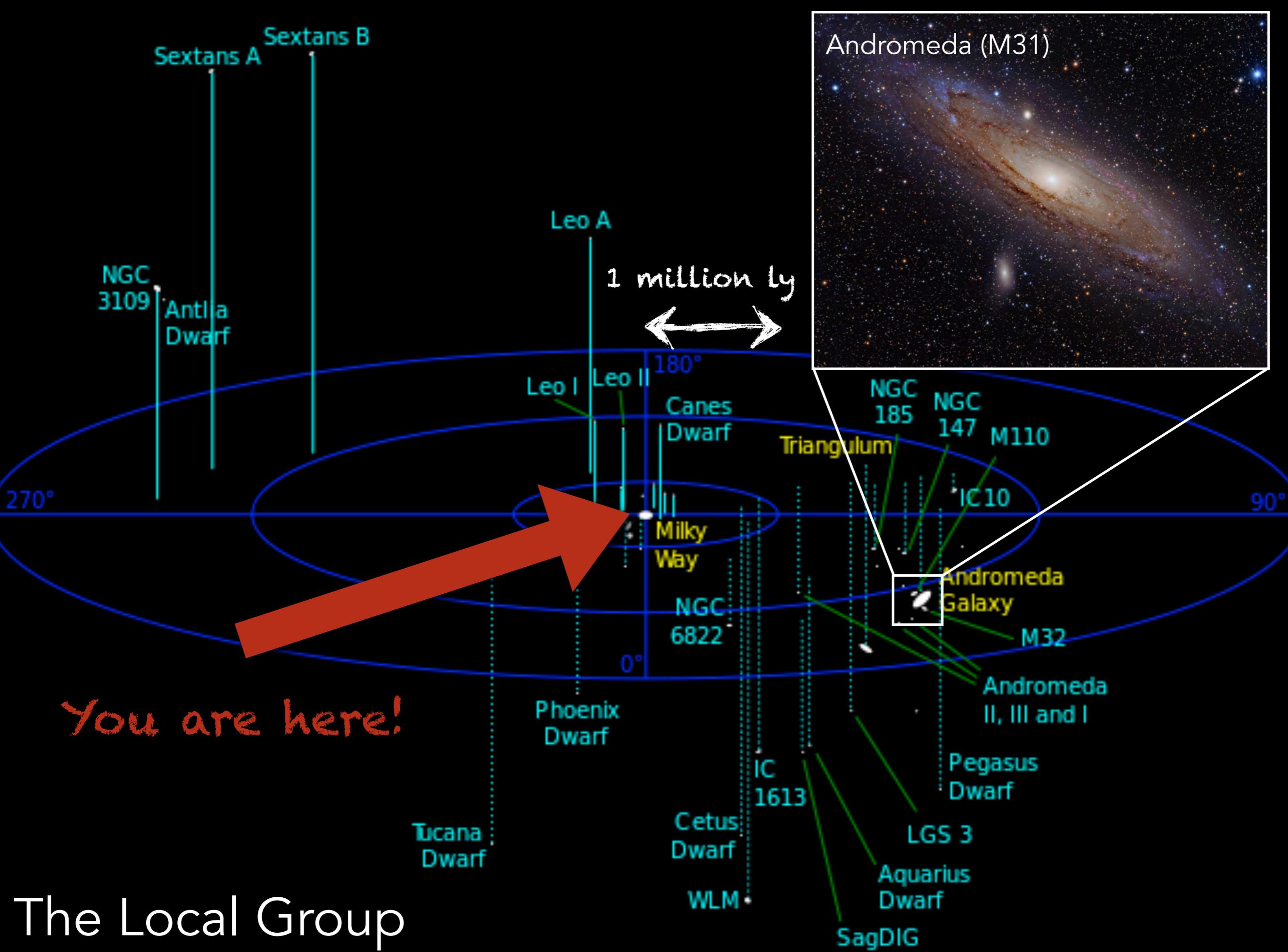


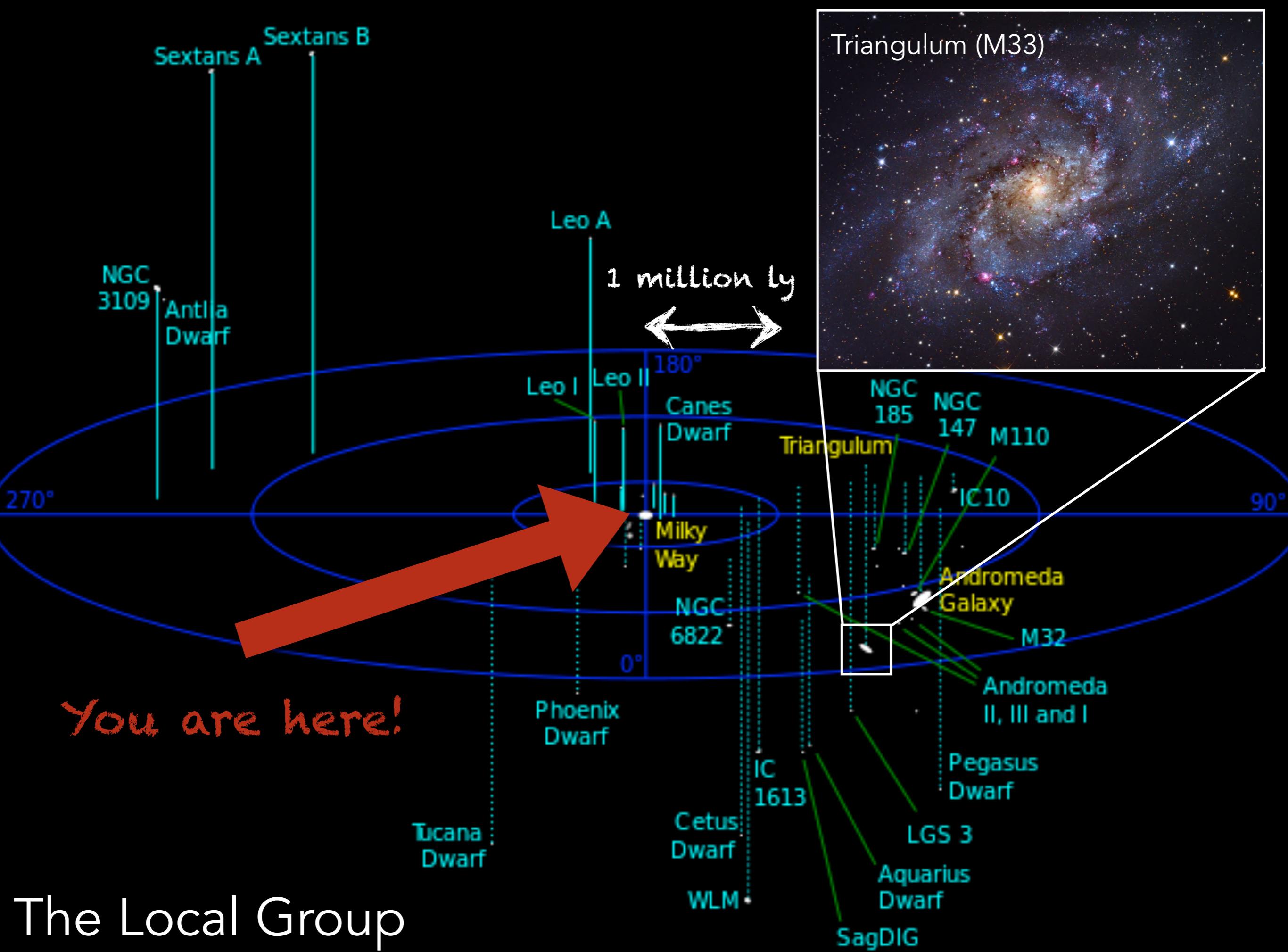


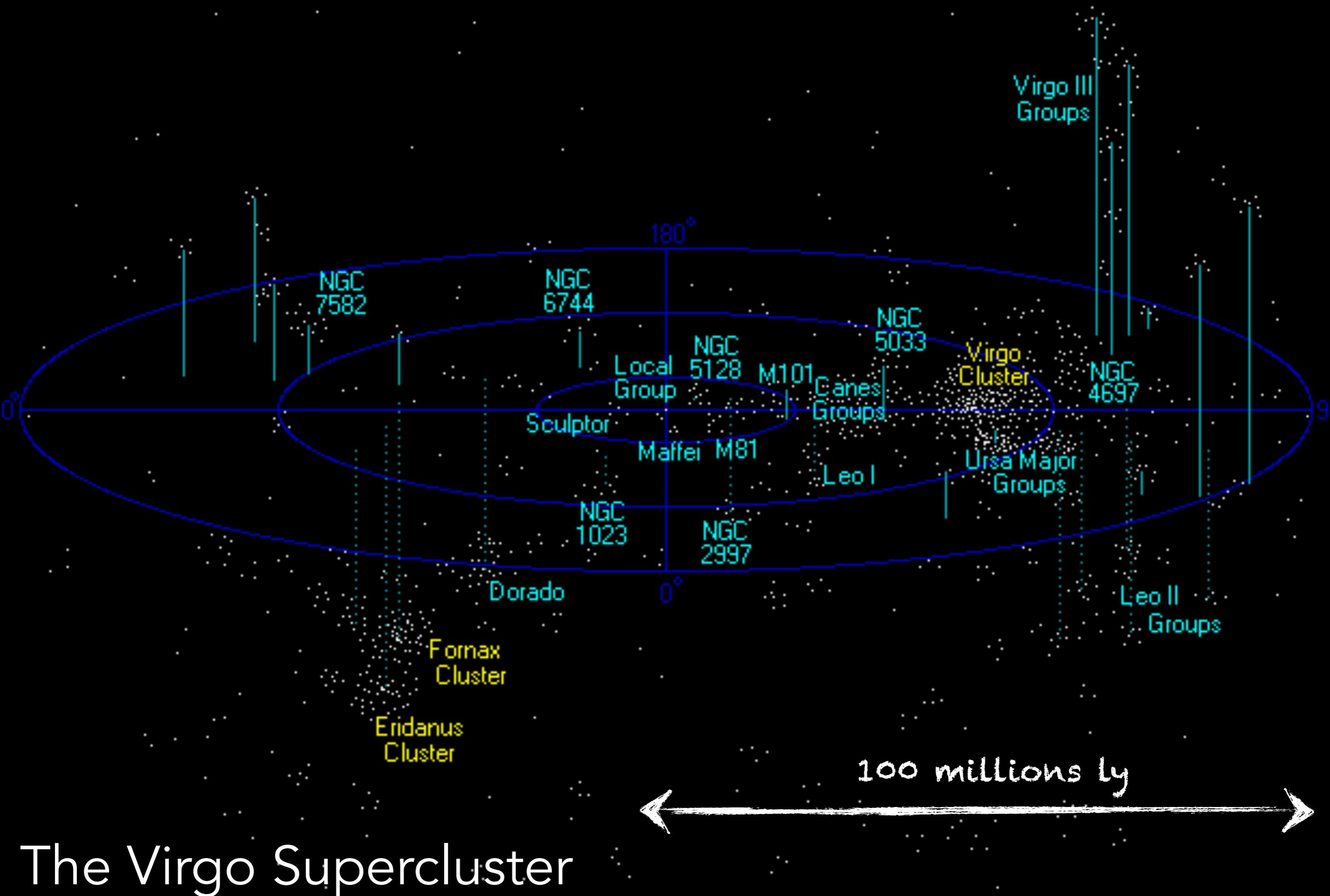




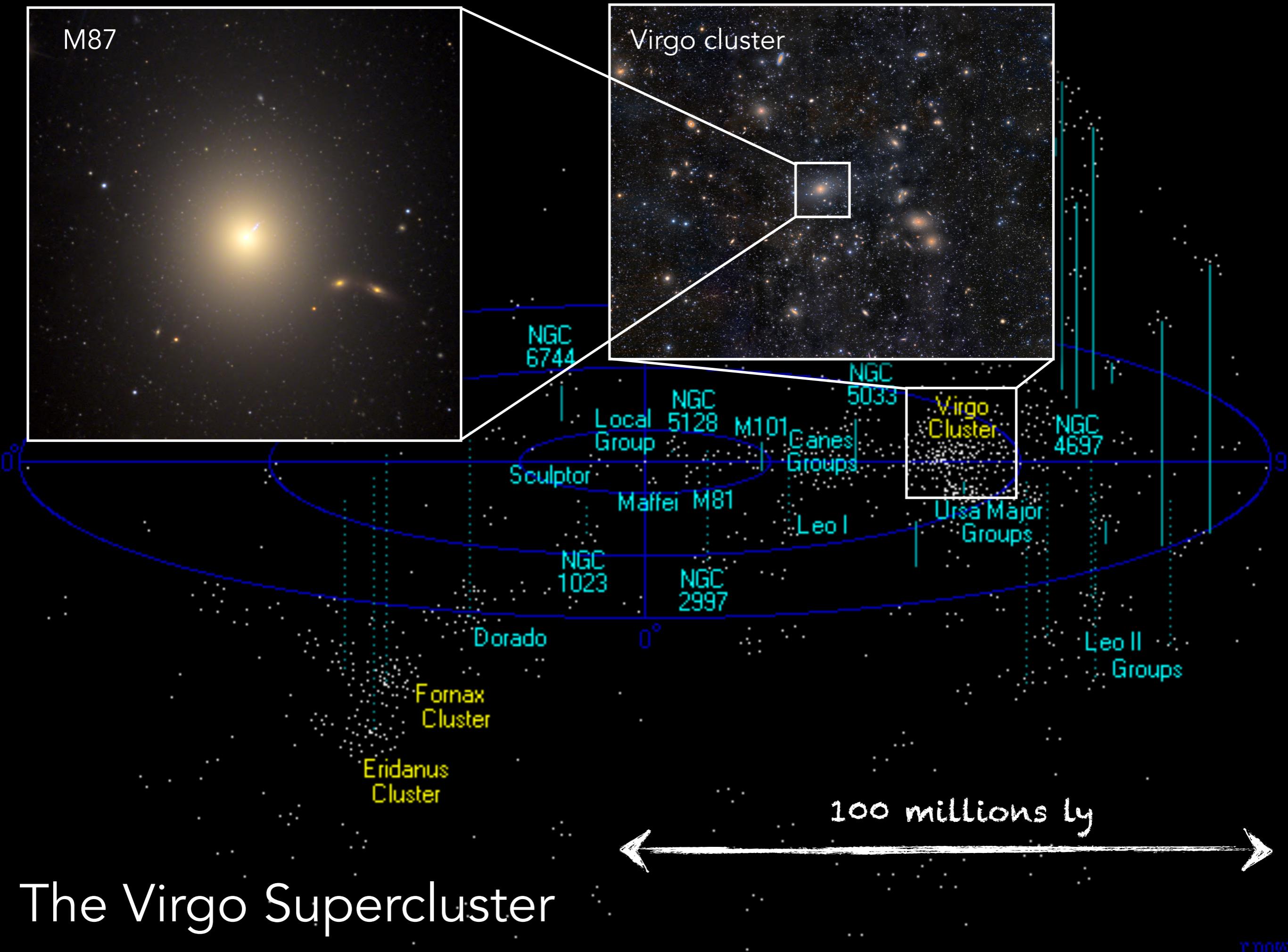


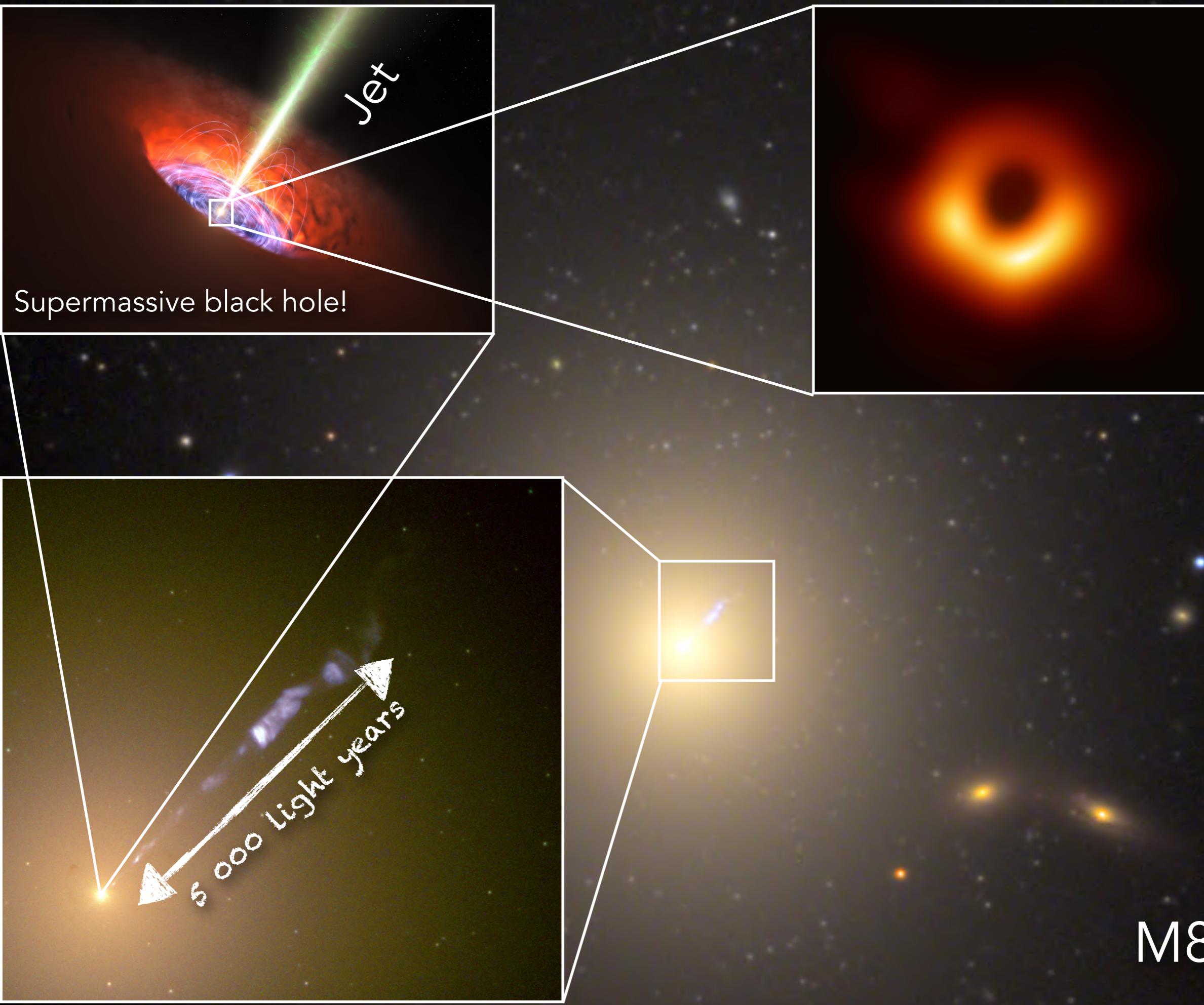


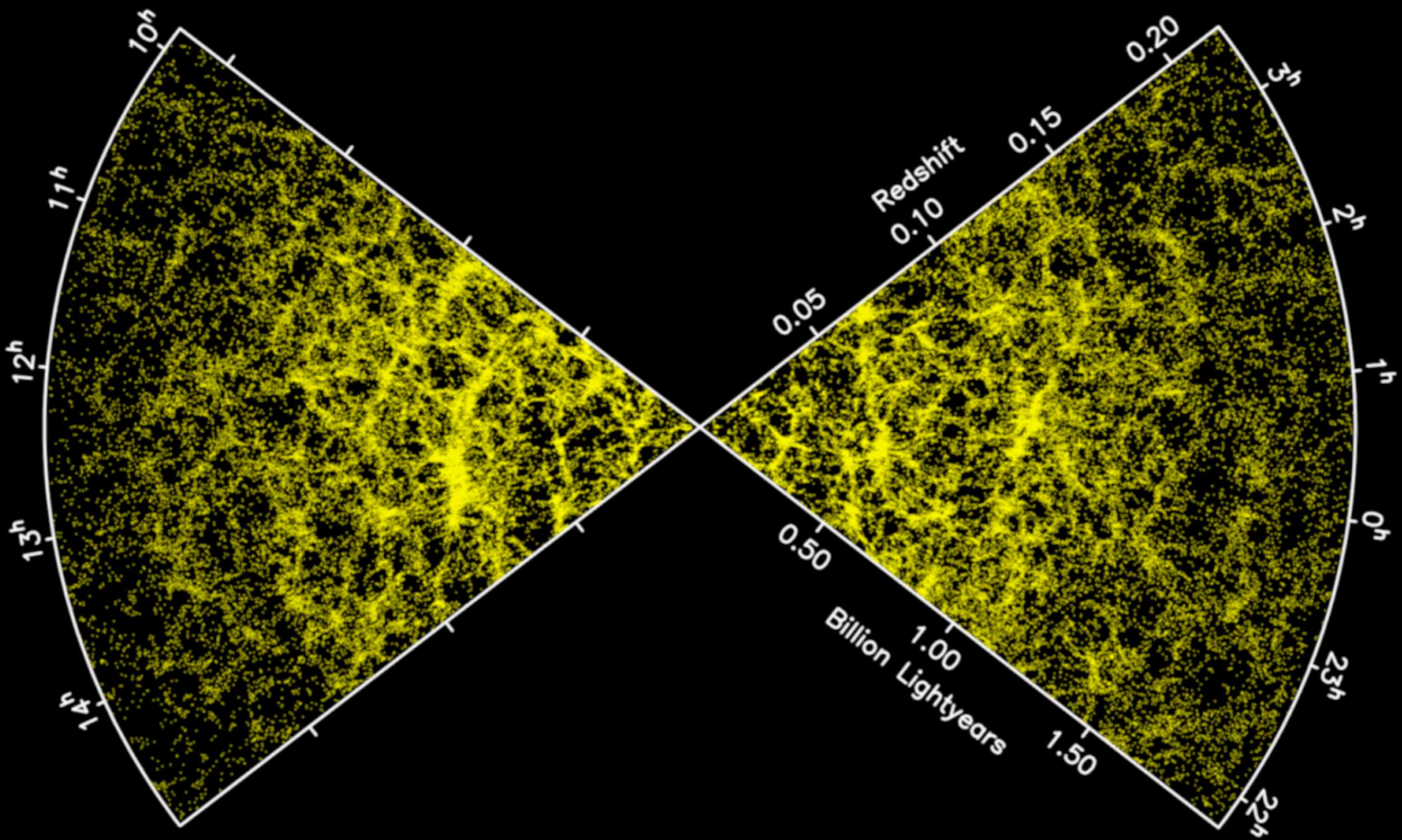




M87







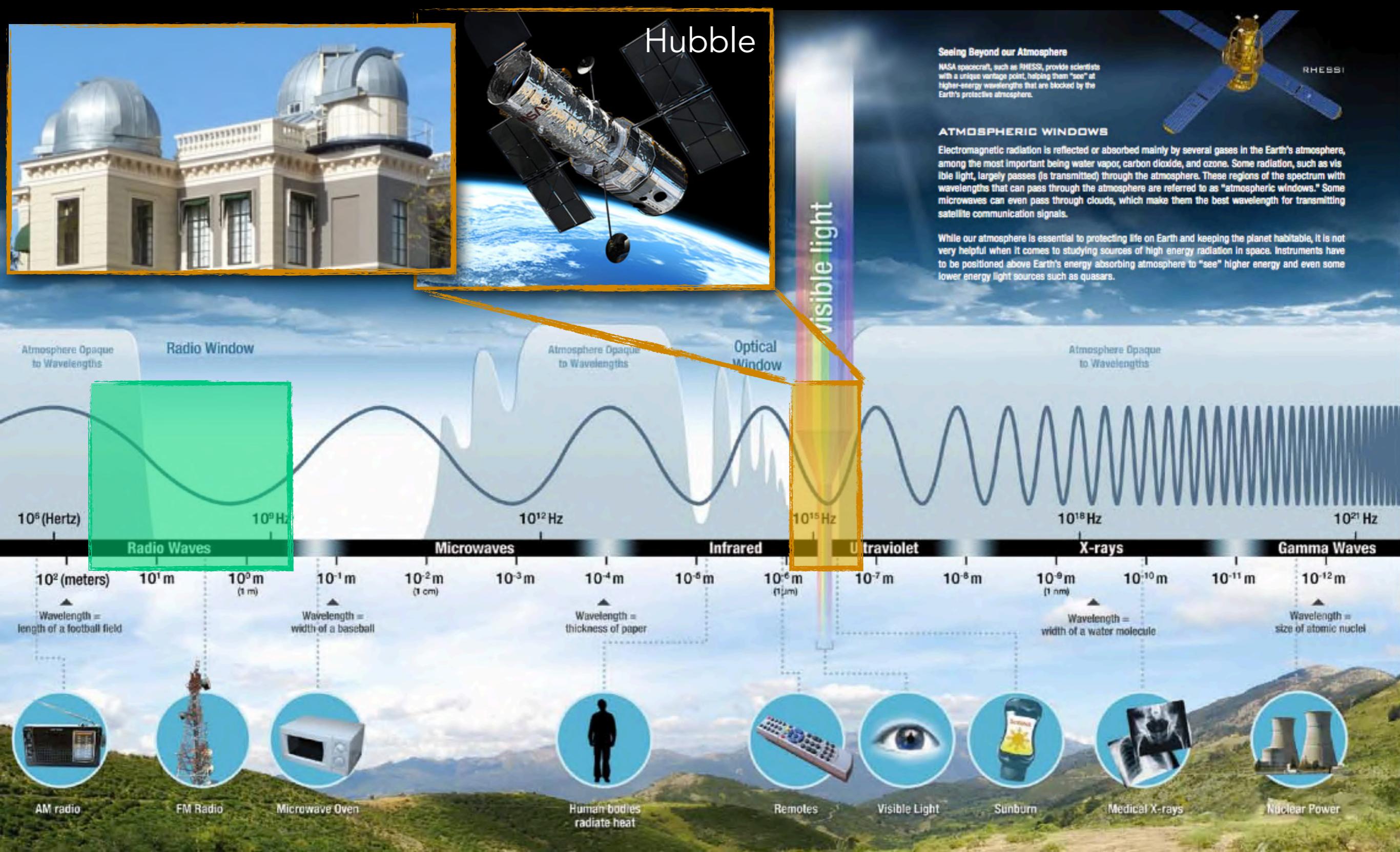
The large scale structure of the universe



Abell 1689 (2.2 billion light years)

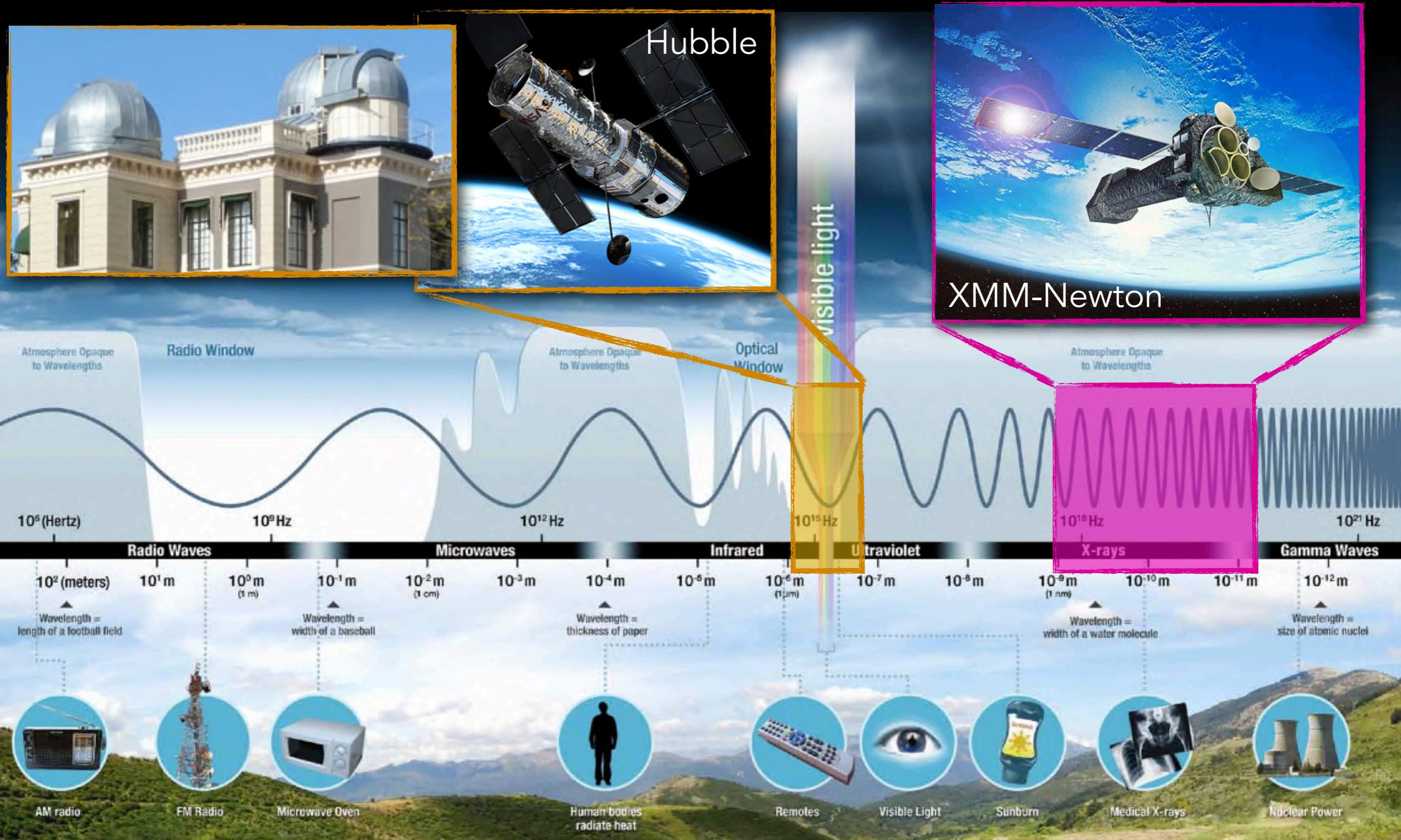
Light emits at optical "colors"...

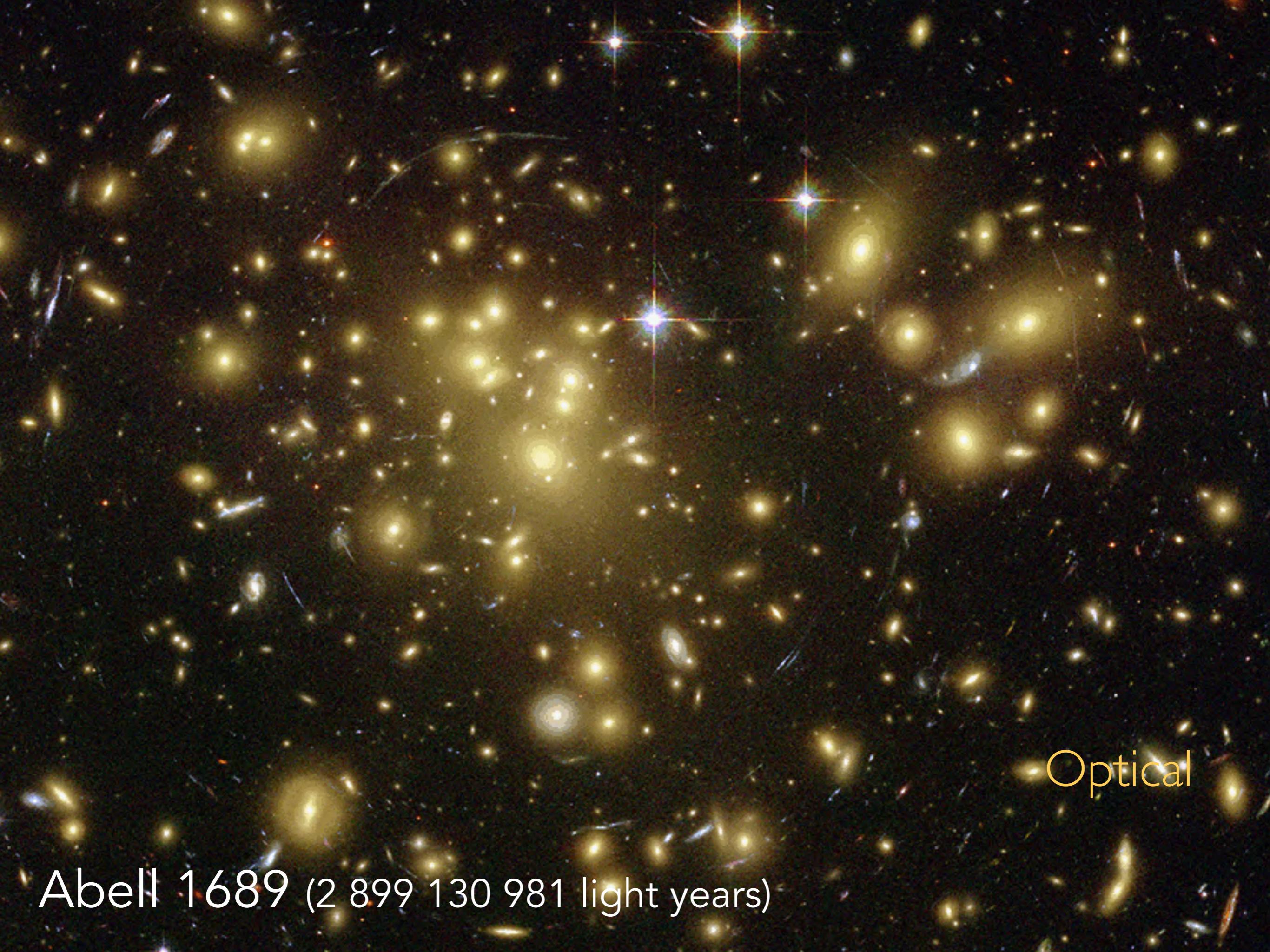
...but also in infrared, **radio**, ...and **X-ray**!



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

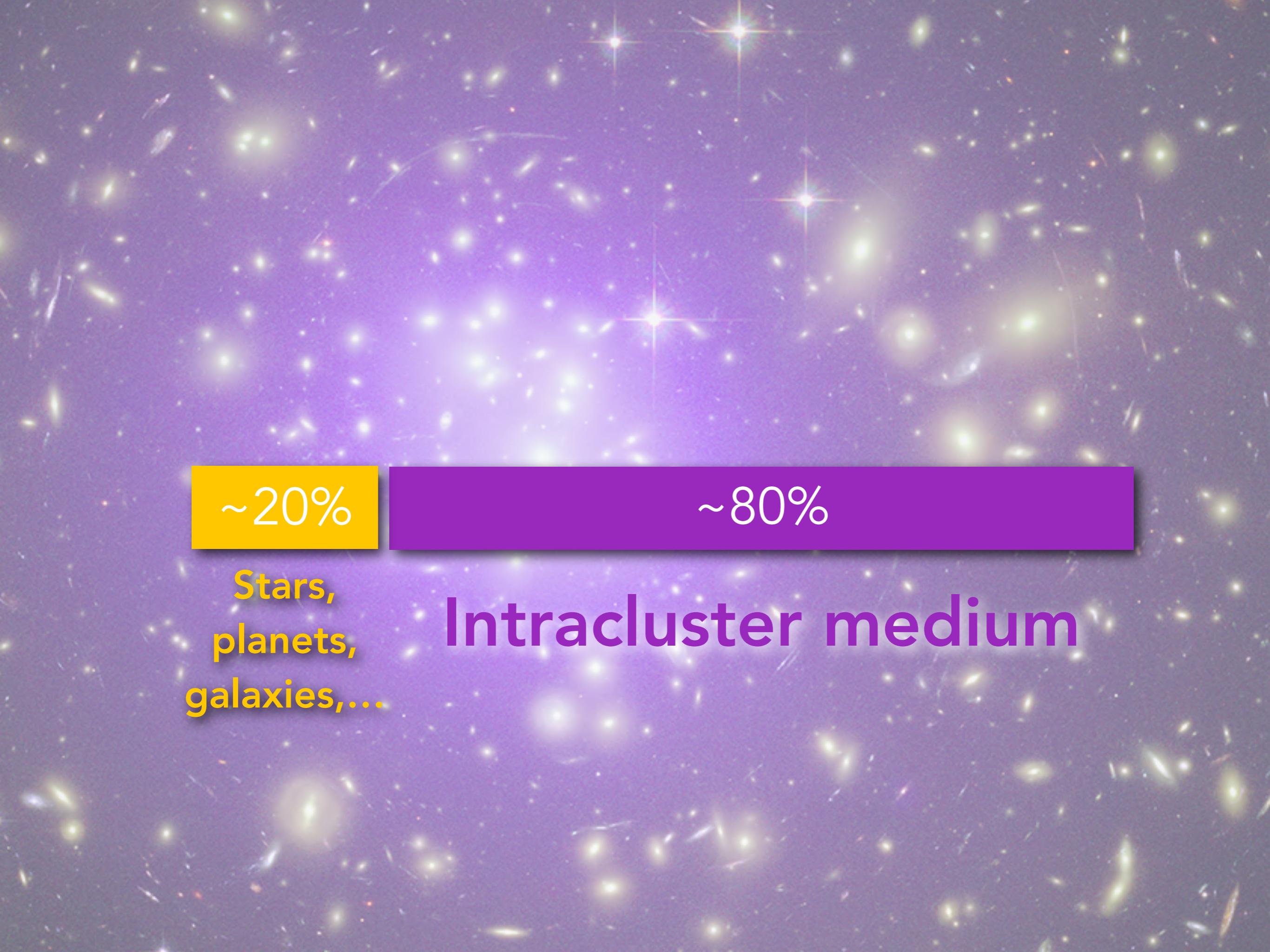
- **hot** (~10 to 100 millions °C!)
- **tenuous** (~1 particle per dm³)
- **heavily ionised** (lots of free electrons)

X-rays

Optical



Stars,
planets,
galaxies,...



\sim 20%

\sim 80%

Stars,
planets,
galaxies,...

Intracluster medium

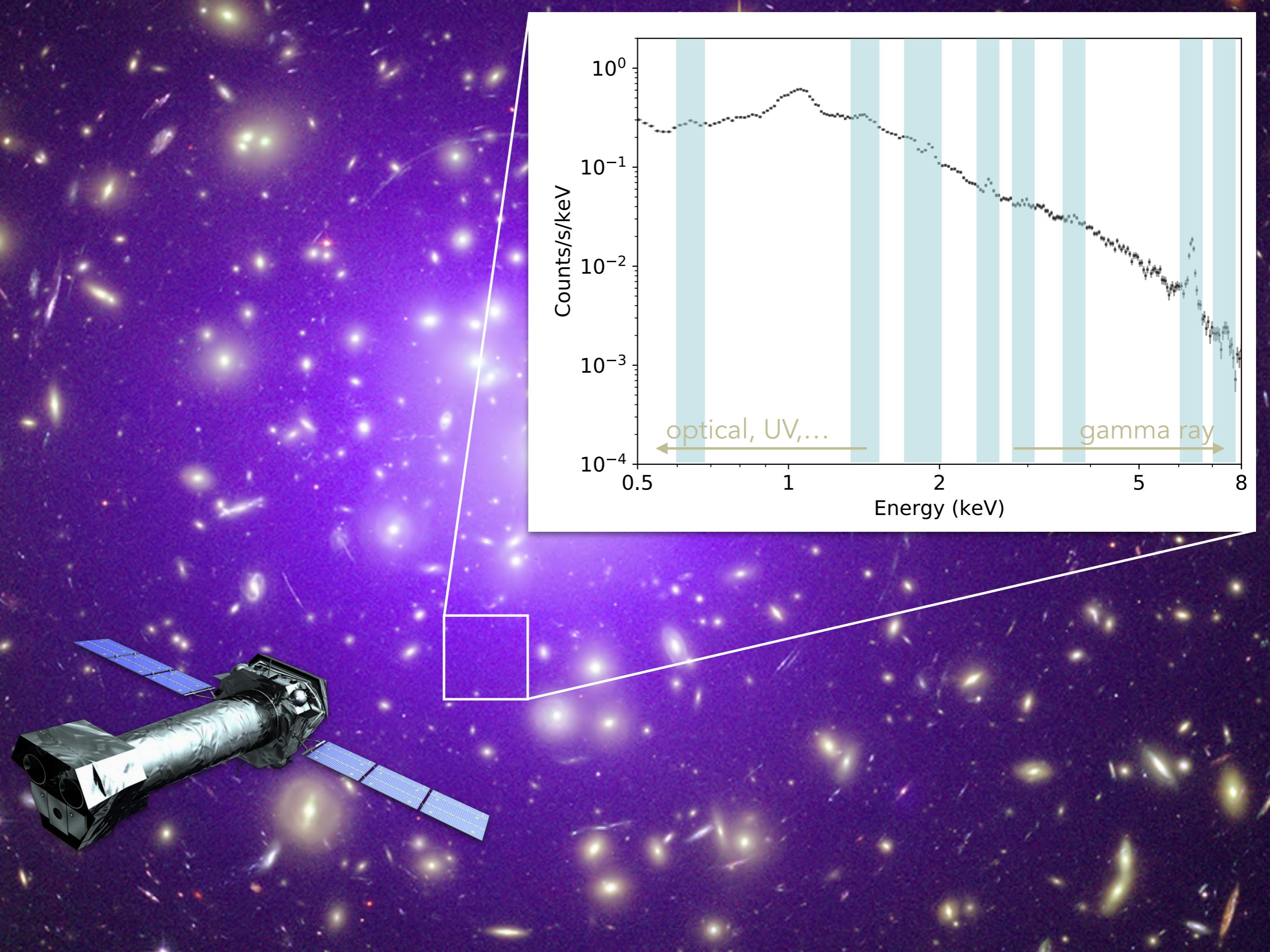


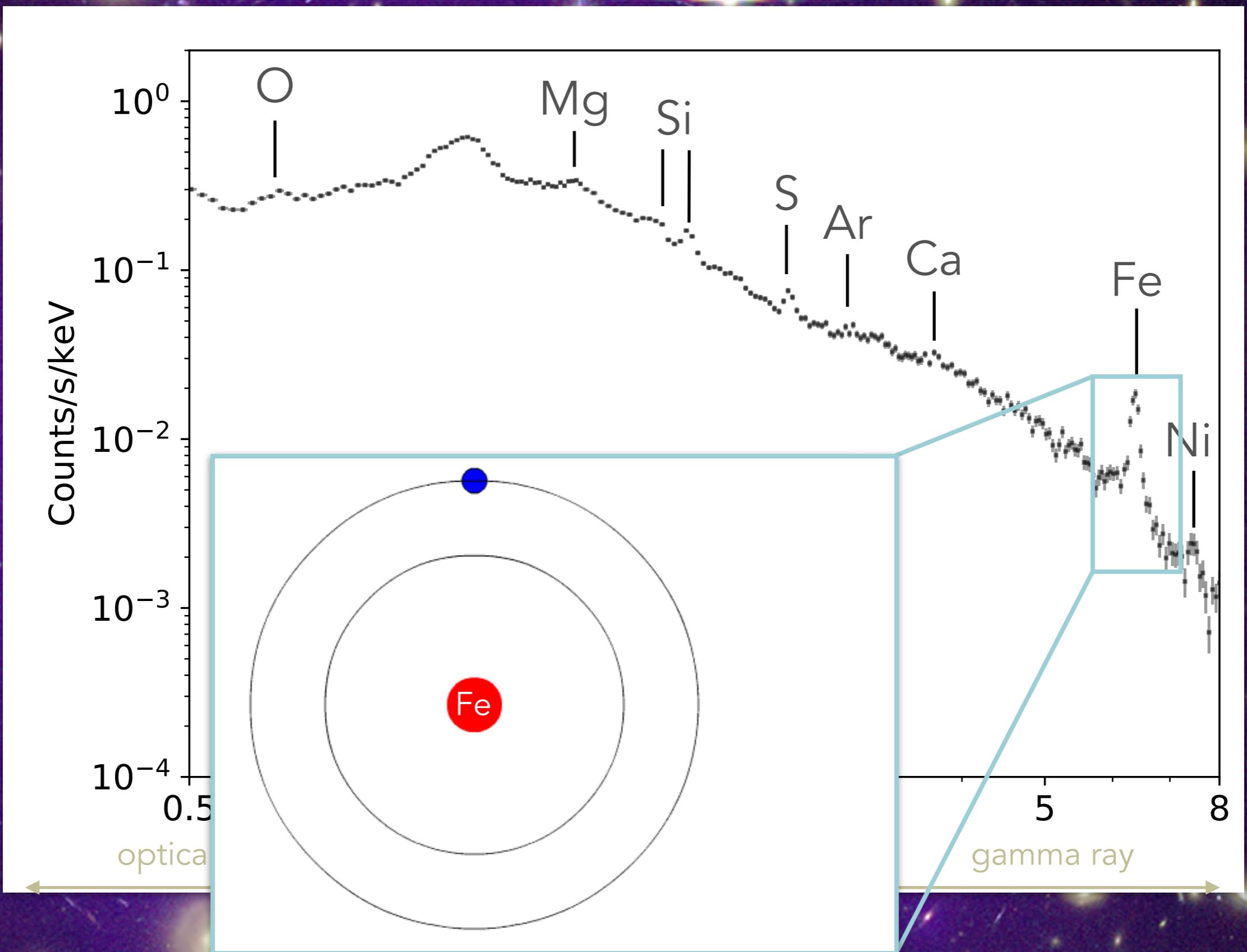
\sim 15%

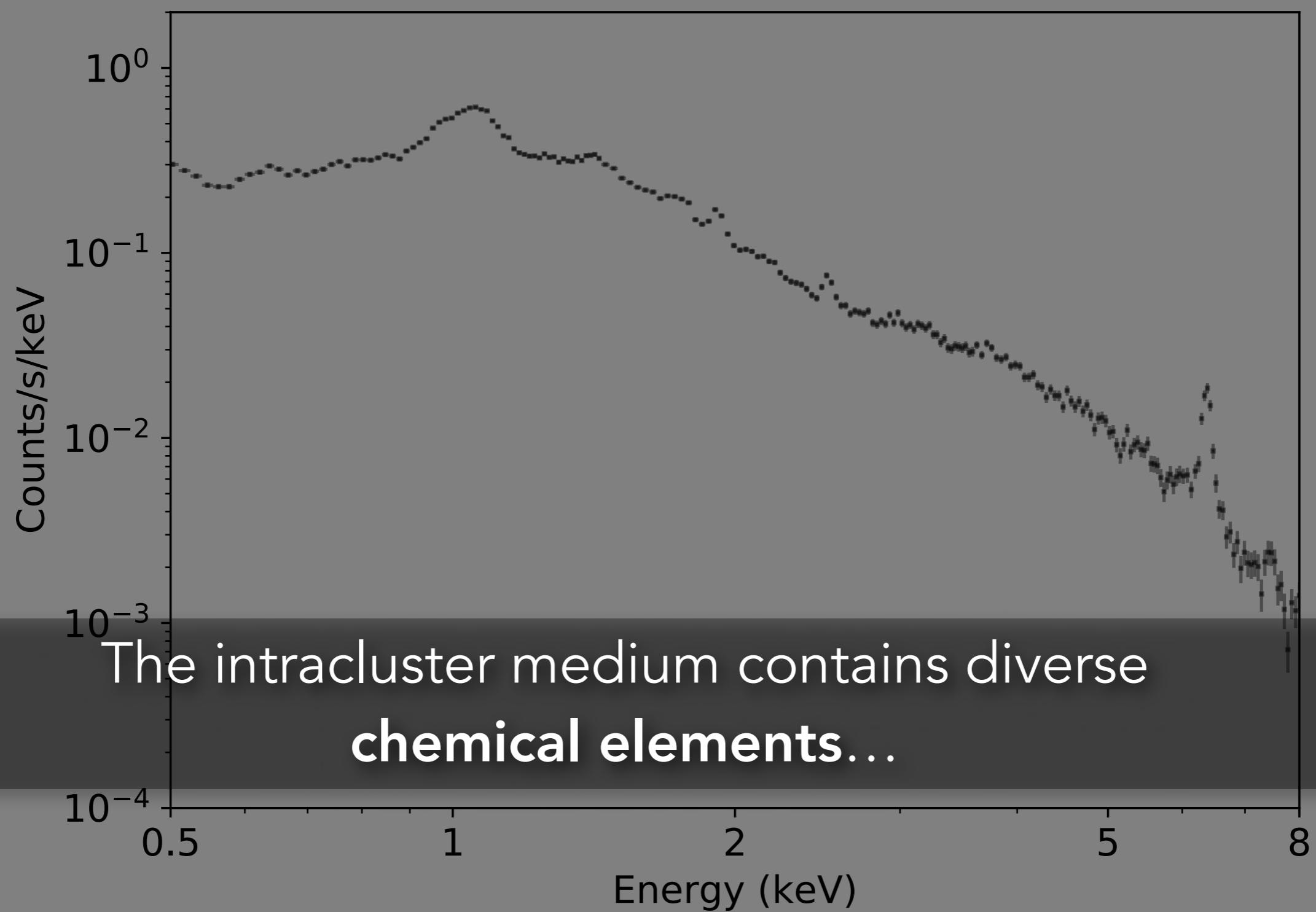
\sim 85%

Stars, Intracluster
planets, medium
galaxies,...

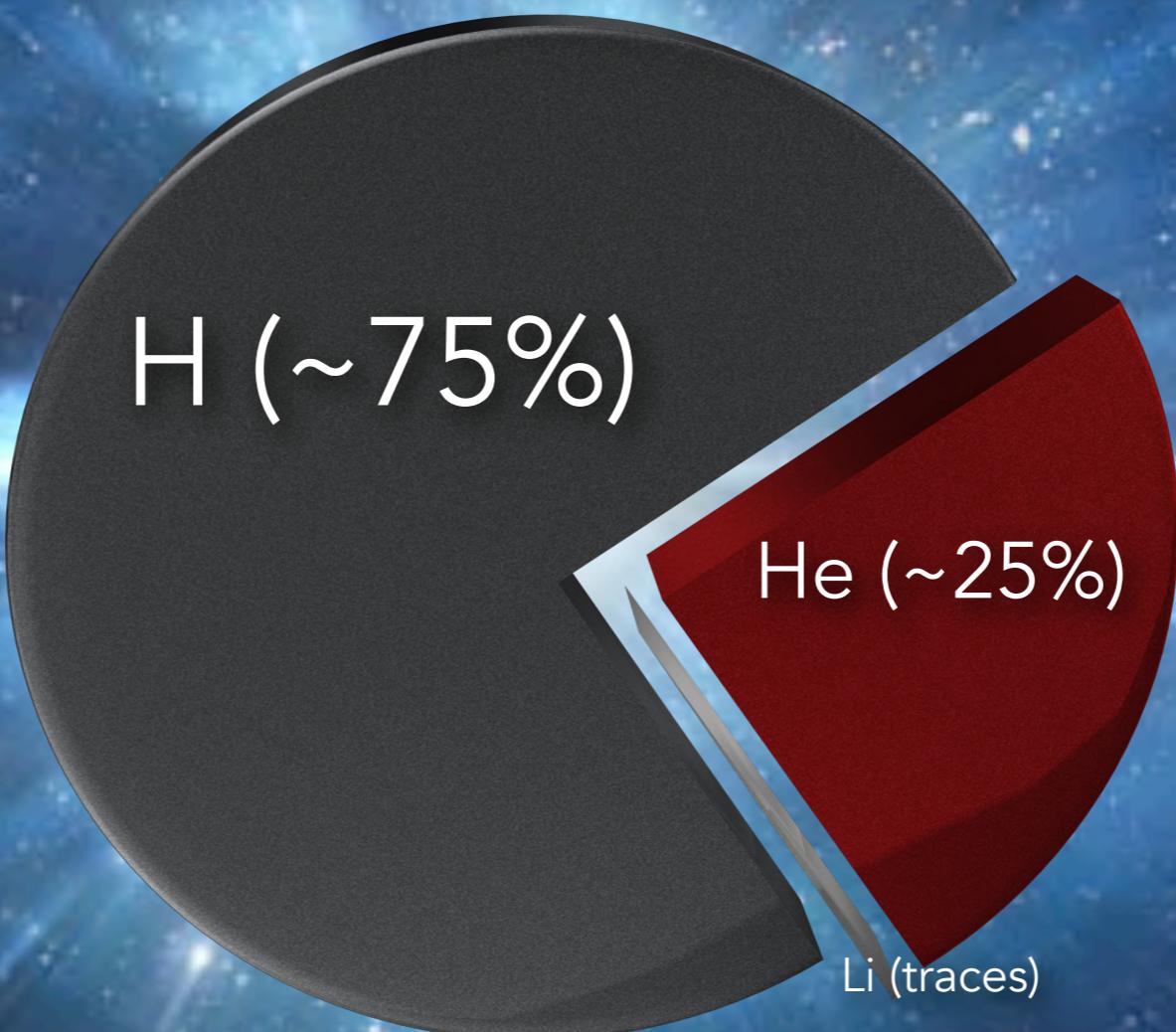
Dark matter







Primordial nucleosynthesis



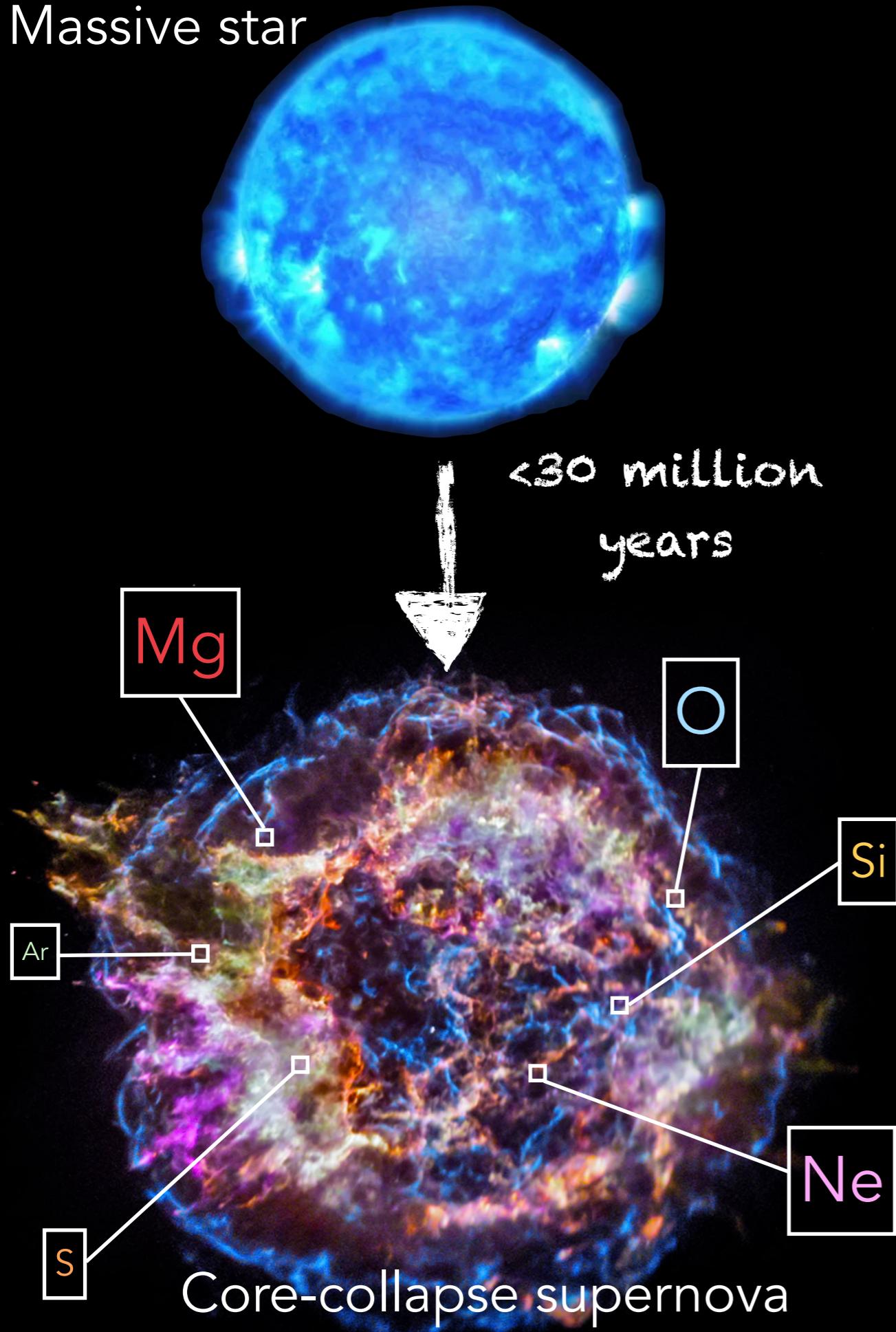
Big Bang



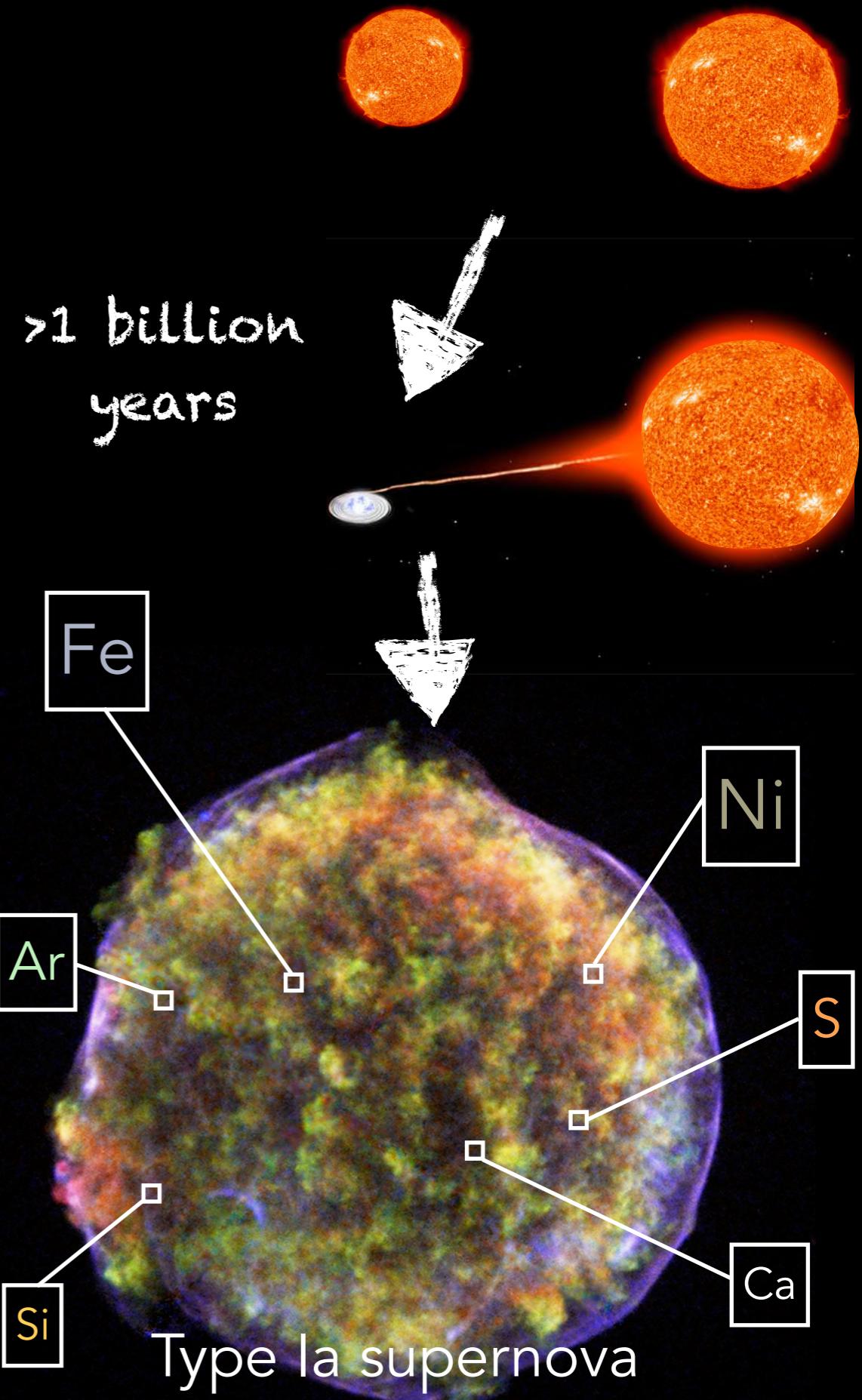
Supernovae are the **only way** to produce metals
(i.e. elements heavier than H and He...)

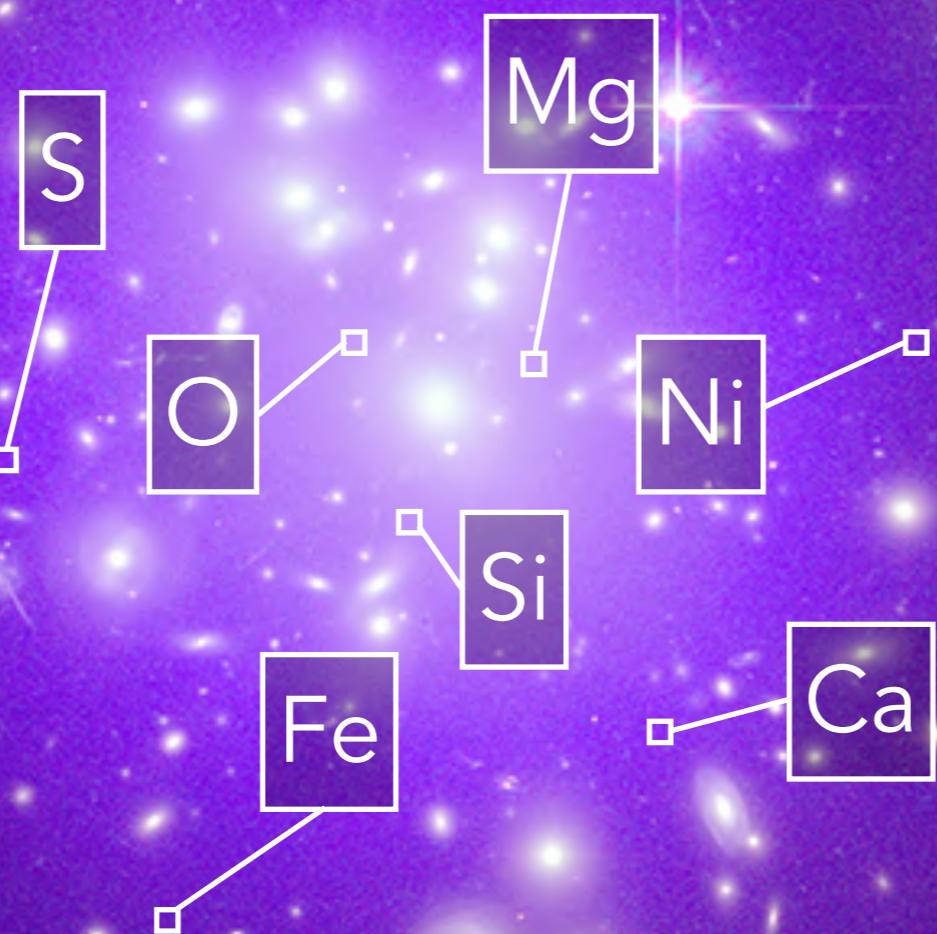
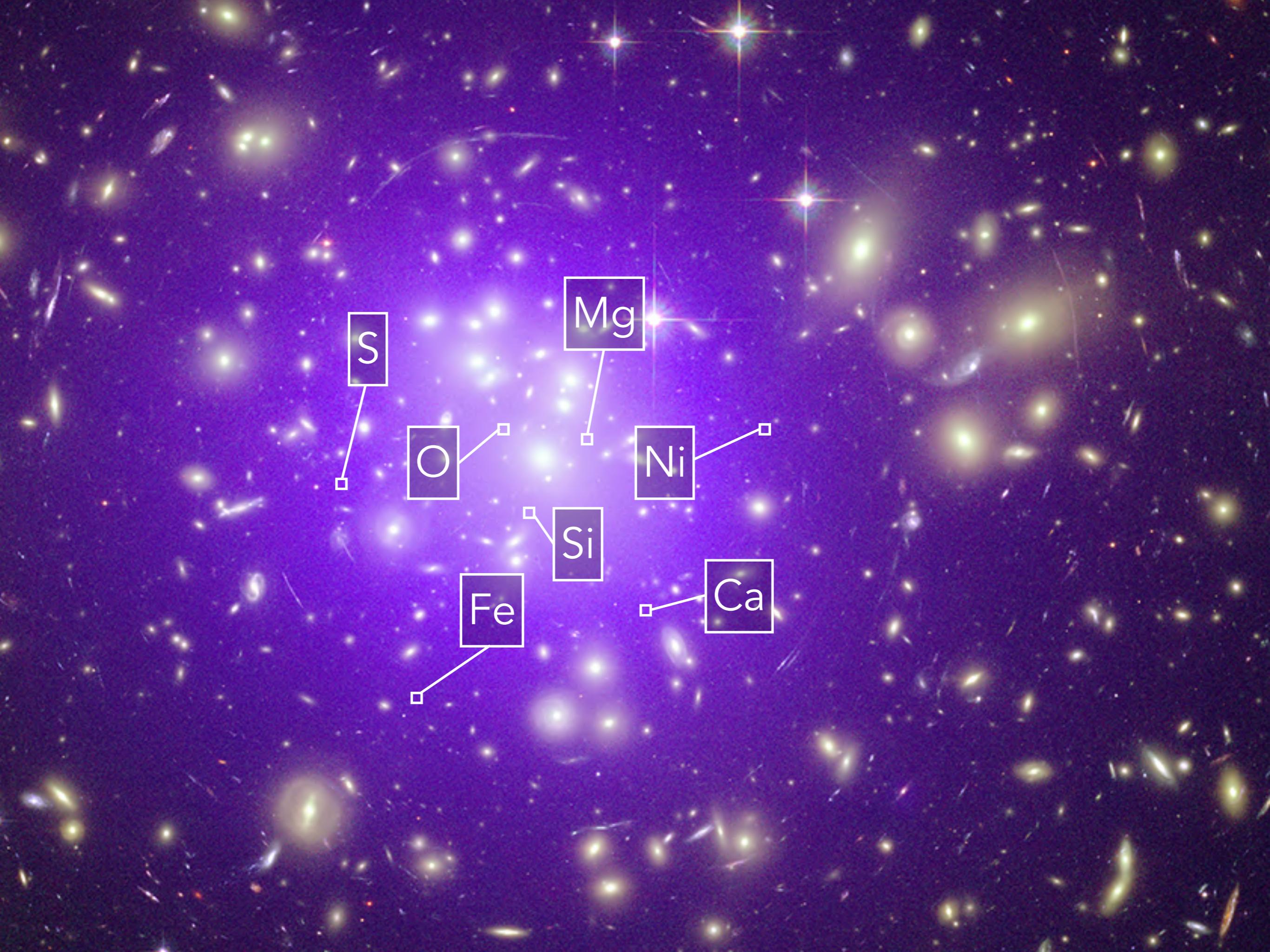
“We are made of starstuff.” - Carl Sagan

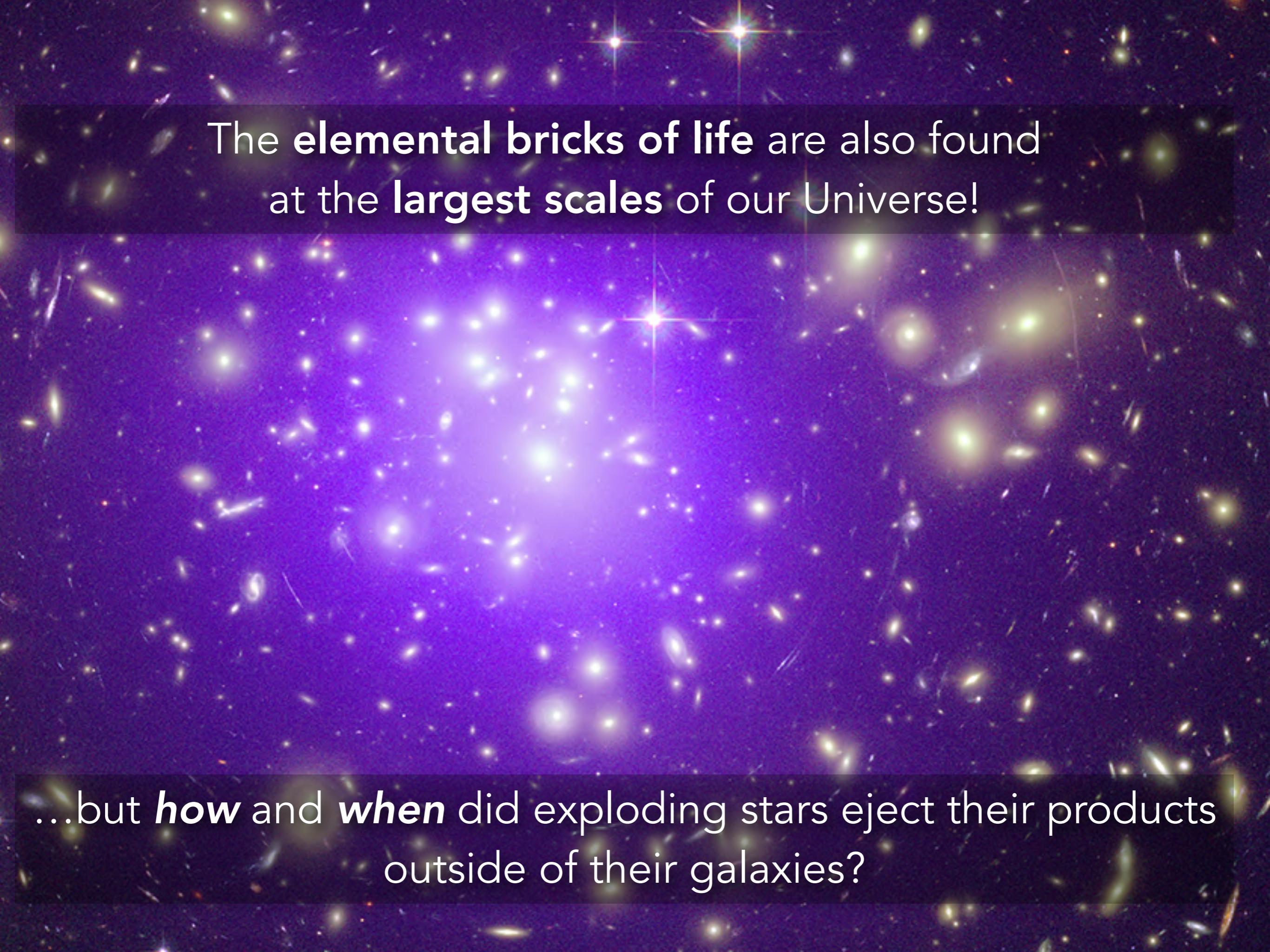
Massive star



Low-mass stars





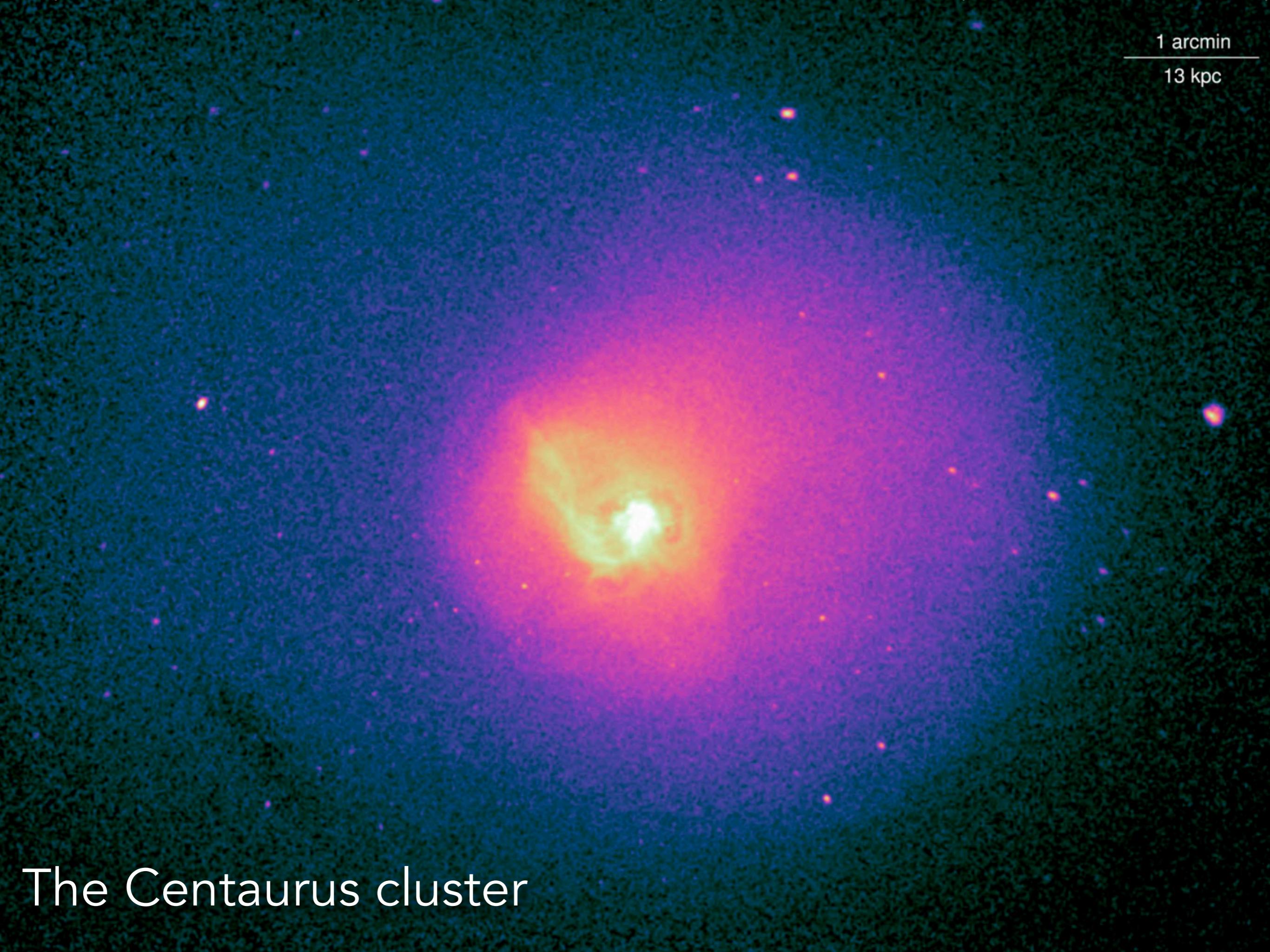


The **elemental bricks of life** are also found
at the **largest scales** of our Universe!

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



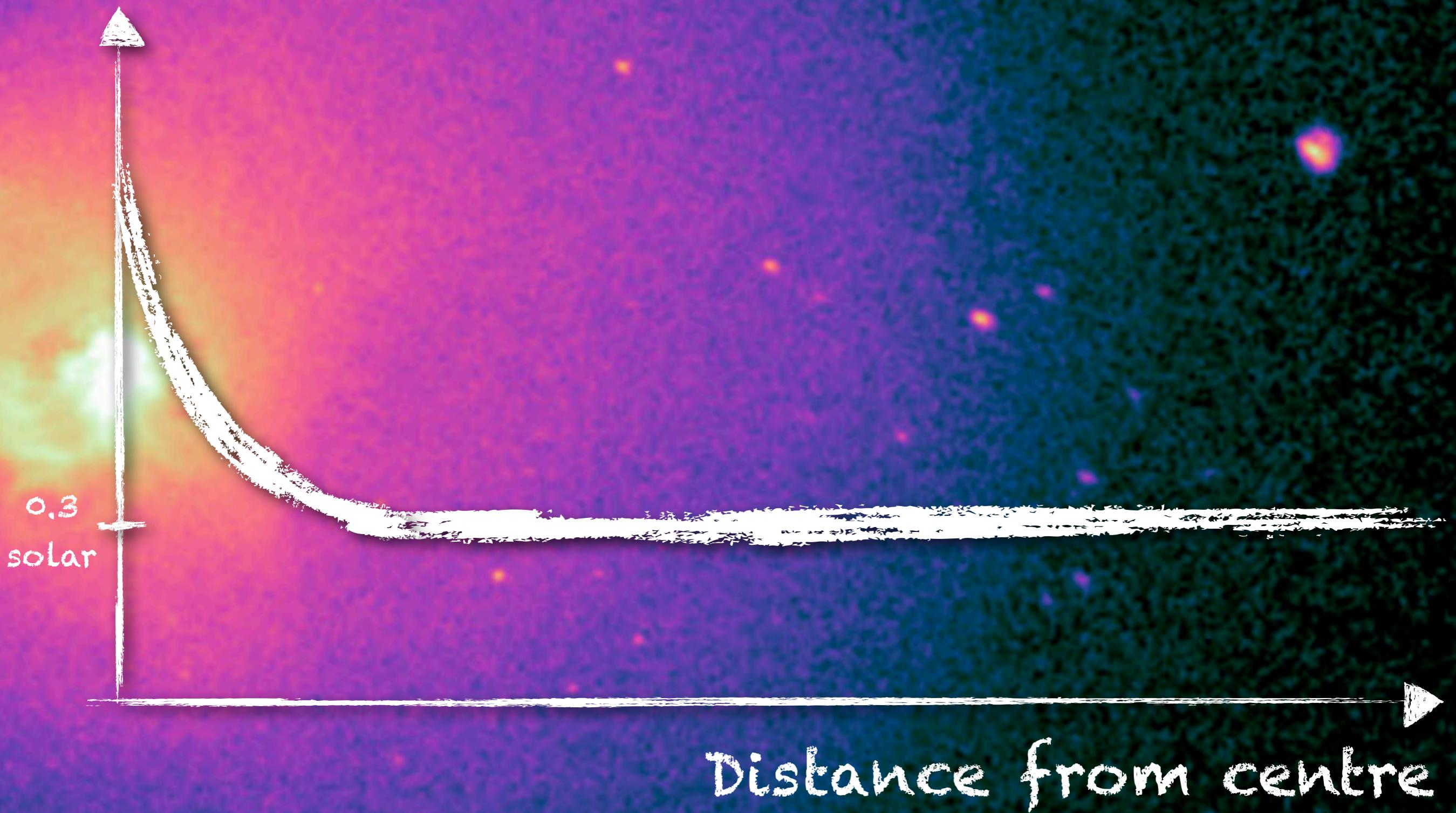
The Centaurus cluster

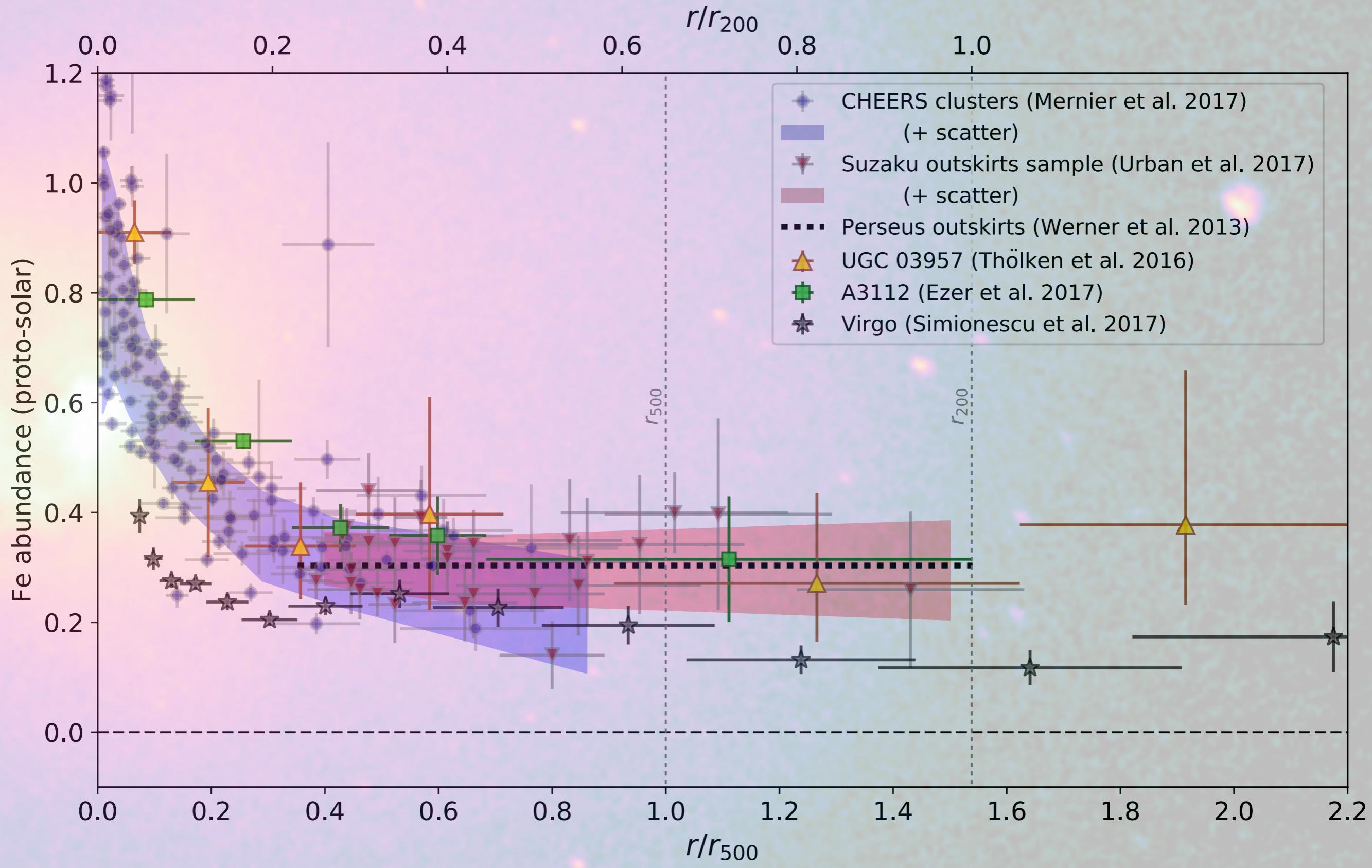


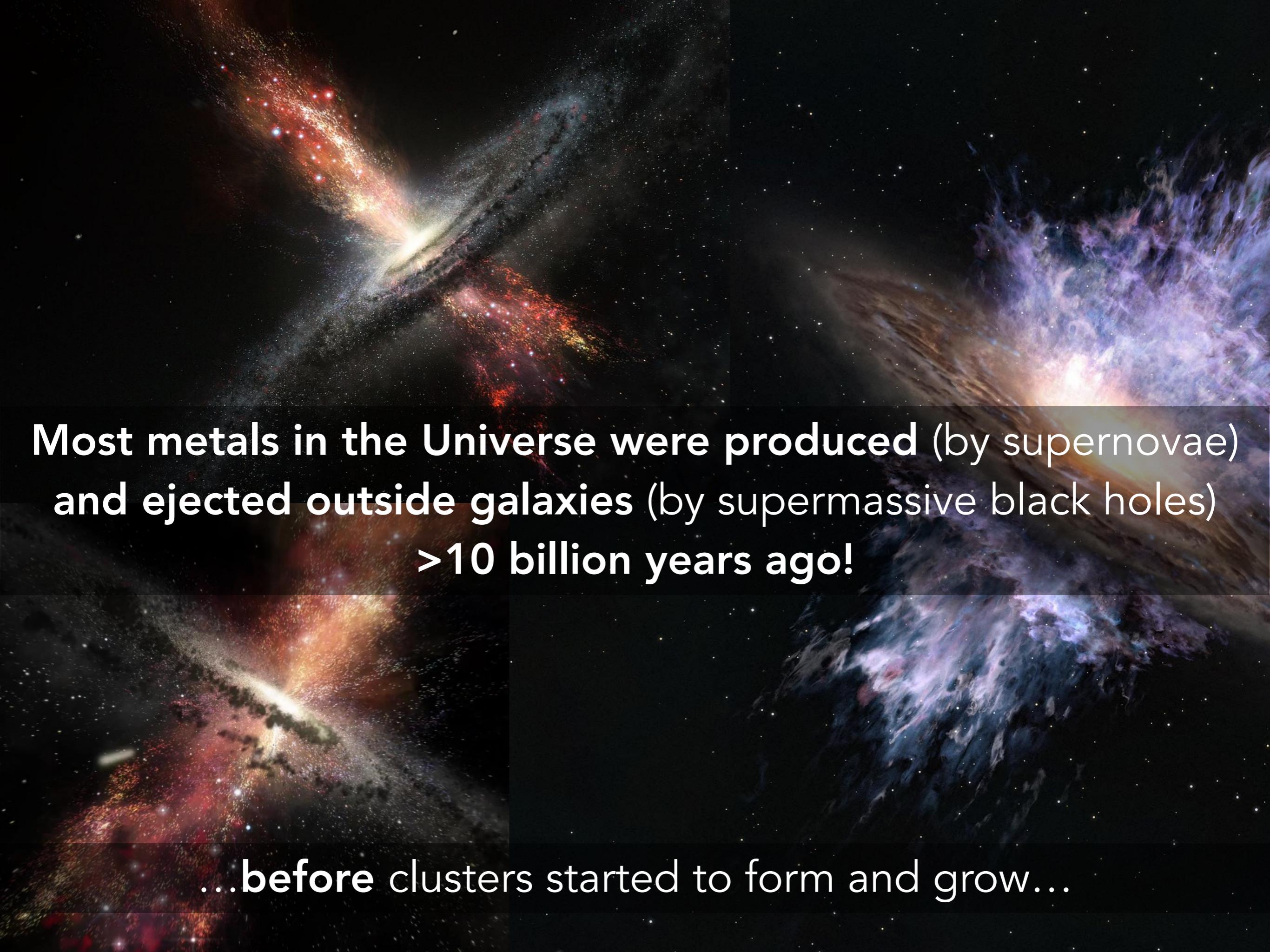
1 arcmin
13 kpc

The Centaurus cluster

Metal abundance



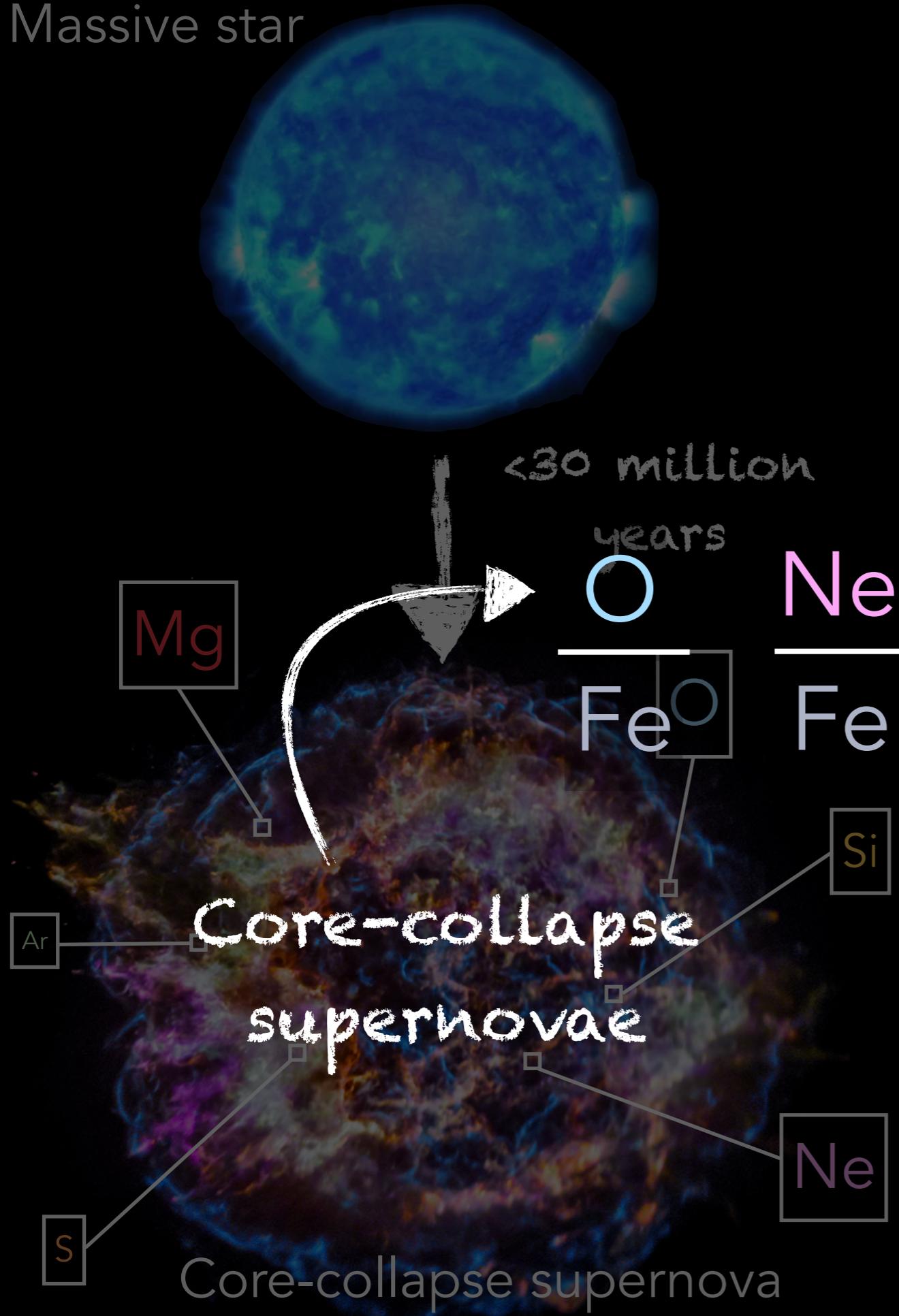




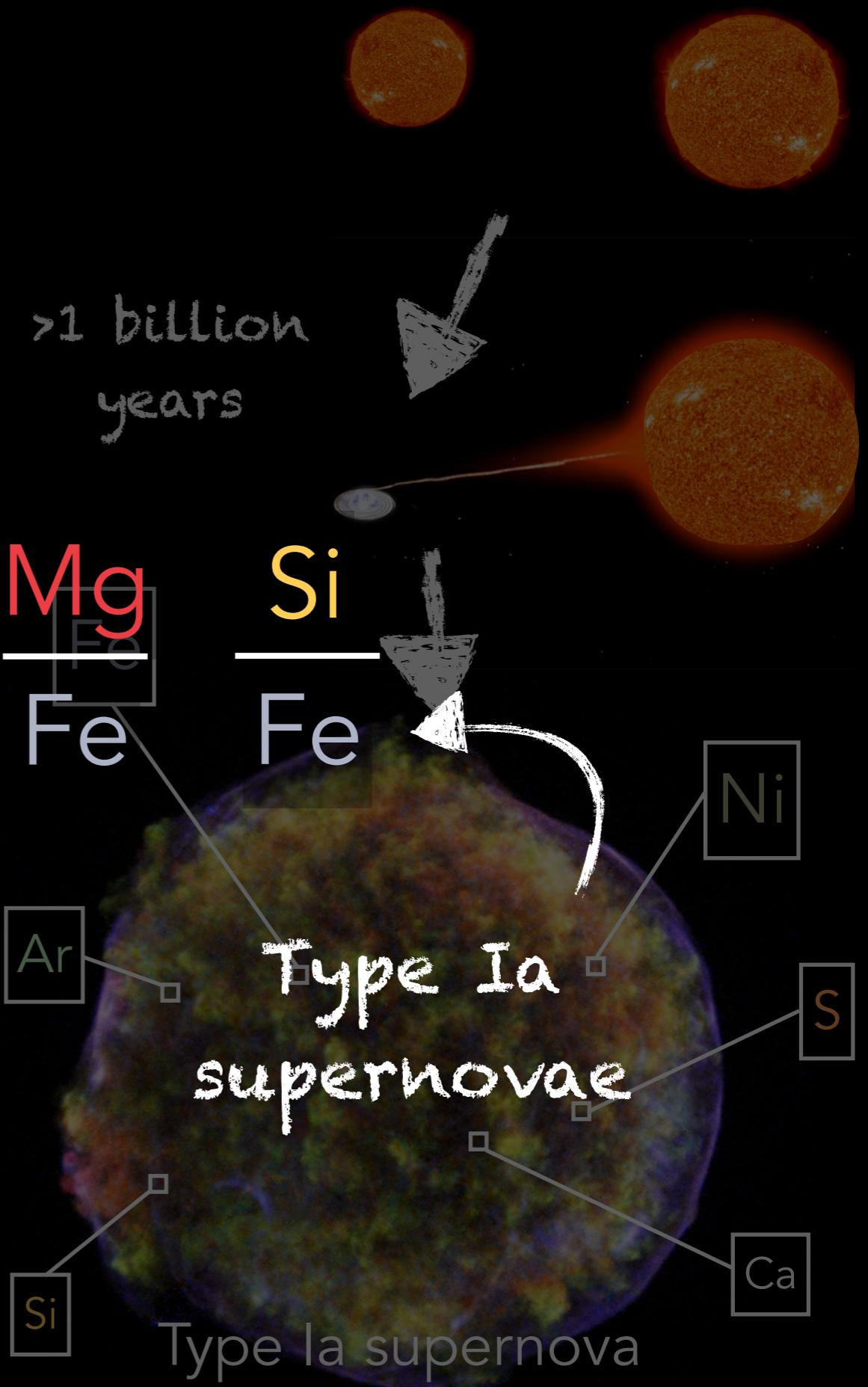
**Most metals in the Universe were produced (by supernovae)
and ejected outside galaxies (by supermassive black holes)
>10 billion years ago!**

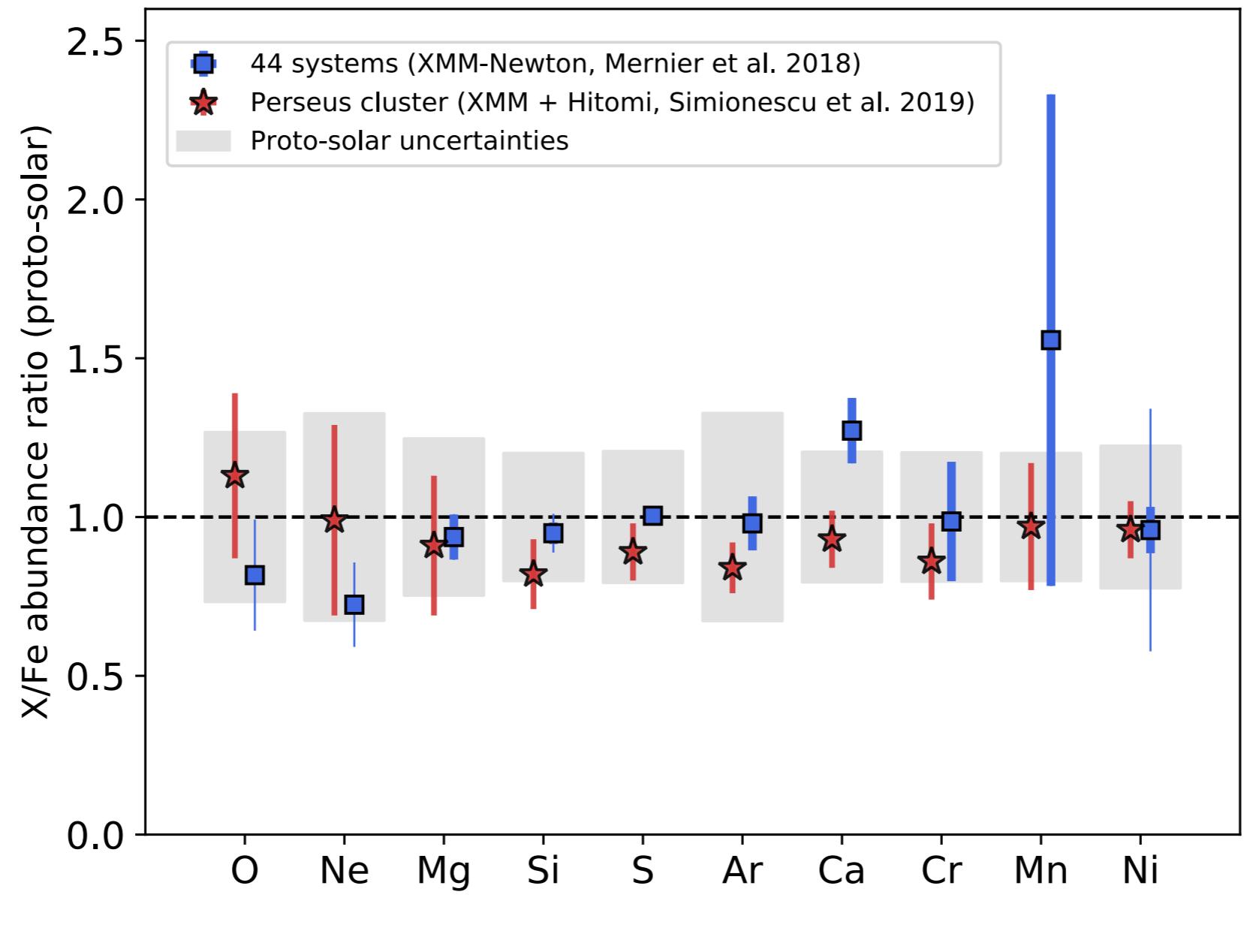
...before clusters started to form and grow...

Massive star

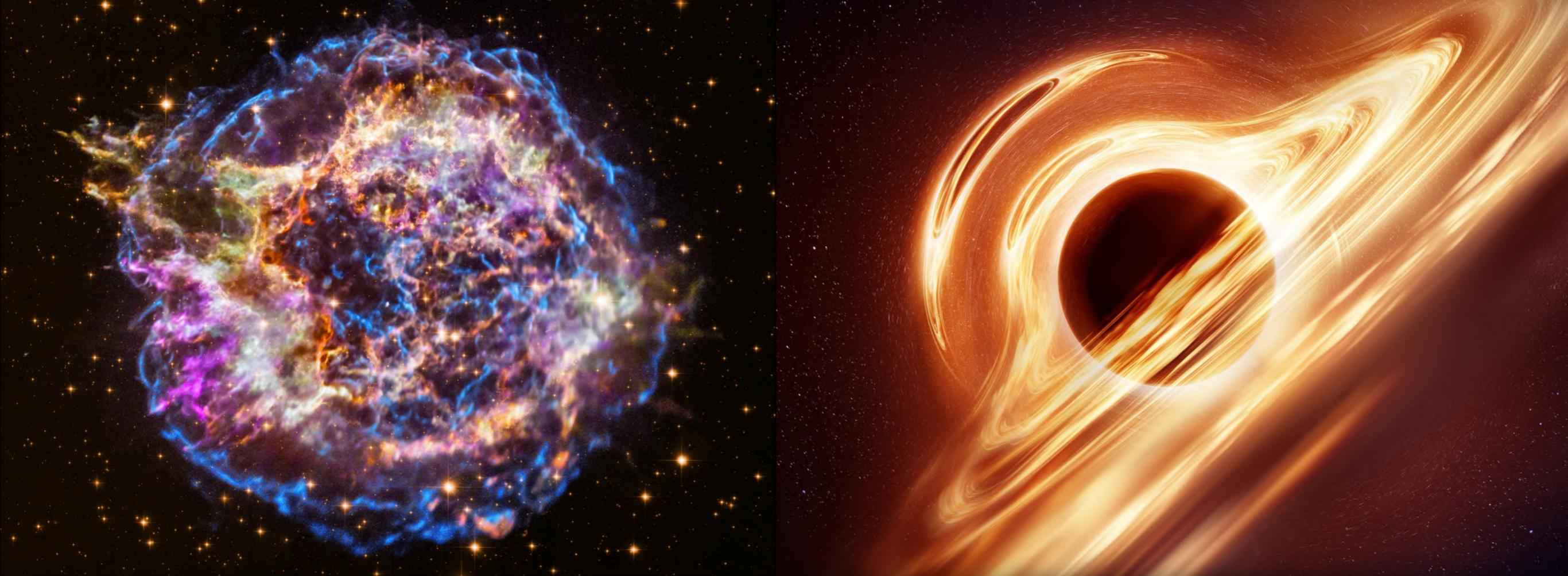


Low-mass stars





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***

A composite image featuring three distinct spiral galaxies. The top-left galaxy is dominated by red and orange hues, with a bright yellow/orange central bulge. The top-right galaxy has a prominent blue and purple nebula-like region on its right side. The bottom-left galaxy is mostly obscured by dark, silhouetted spiral arms, with visible red and orange star-forming regions. All three galaxies have their characteristic spiral arms and central bulges.

We are made of starstuff...

Metals!

...which is spread everywhere in the Universe!