



François Mernier

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

*ESA (European Space Agency),
ESTEC, Noordwijk*



PESTHUISWIJK

Leeuwenhoek



STATIONS-DISTRICT

Naturalis Center



esmanlaan

Maresingel



Museum De Lakenhal

Noorderkwartier

De Baand

Kooilaan

Oude Vest

HAVENWIJK-NOORD

Rijksmuseum Boerhaave



ge Mors

De Rijn

Herengracht

Leiden

1 km

Rijksmuseum van Oudheden



Burcht van Leiden

Hortus botanicus Leiden

Nieuwe Rijn

Oranje-gracht

Tijlsingel

De Waard

Haagweg

N206

shuizerkade



Hoge Rijndijk

You are here!

Witte Singel

Levendaal

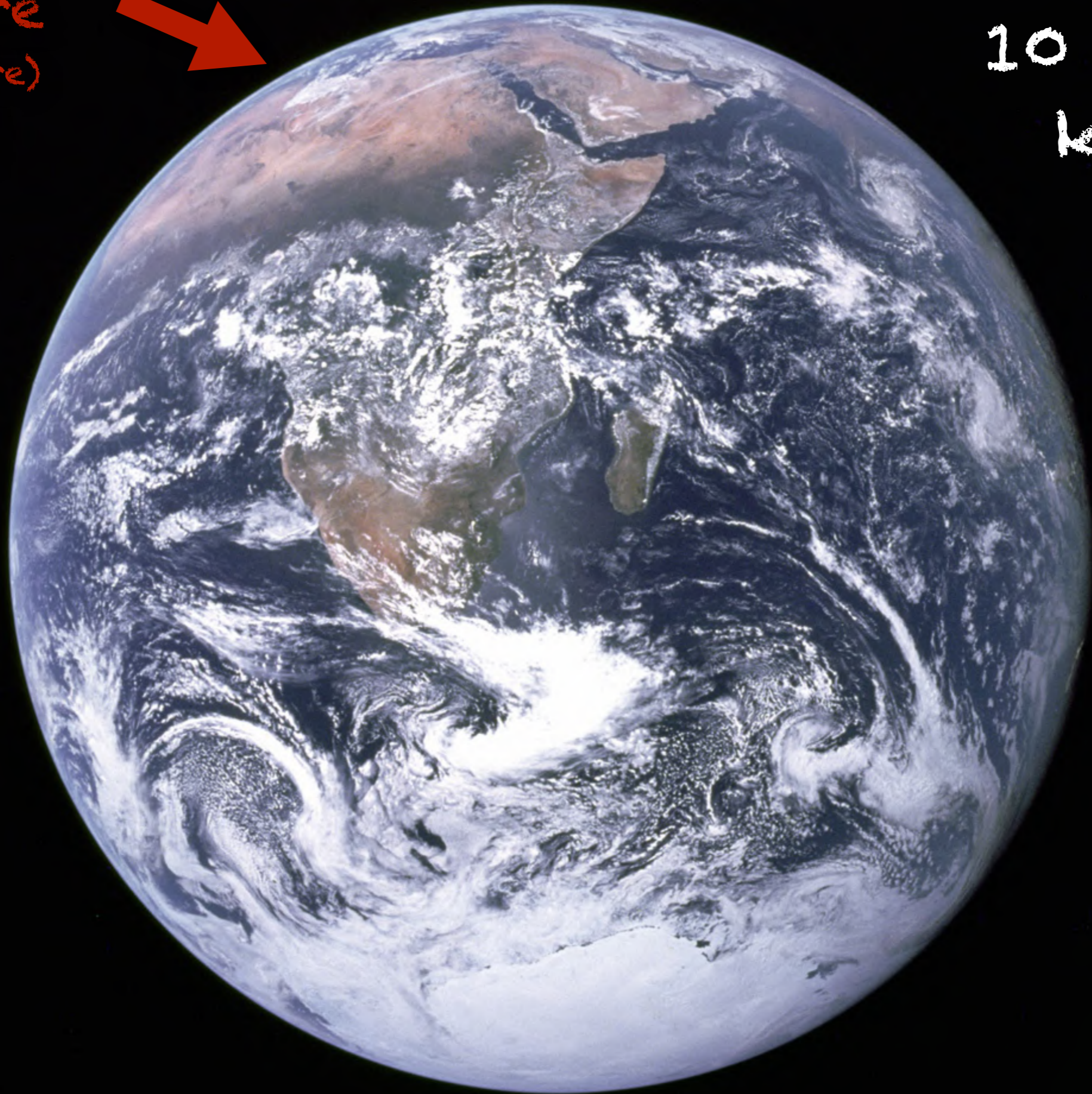
Burggravenlaan

Tuinstadwijk

BURGEMEESTERS- EN PROFESSORENWIJK

ROODENBURGERDISTRICT

You are
(somewhere)
here!



10 000
km



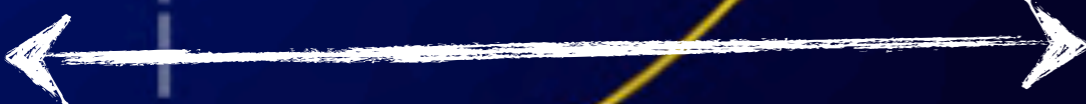
You are here!

(and this is the Moon)

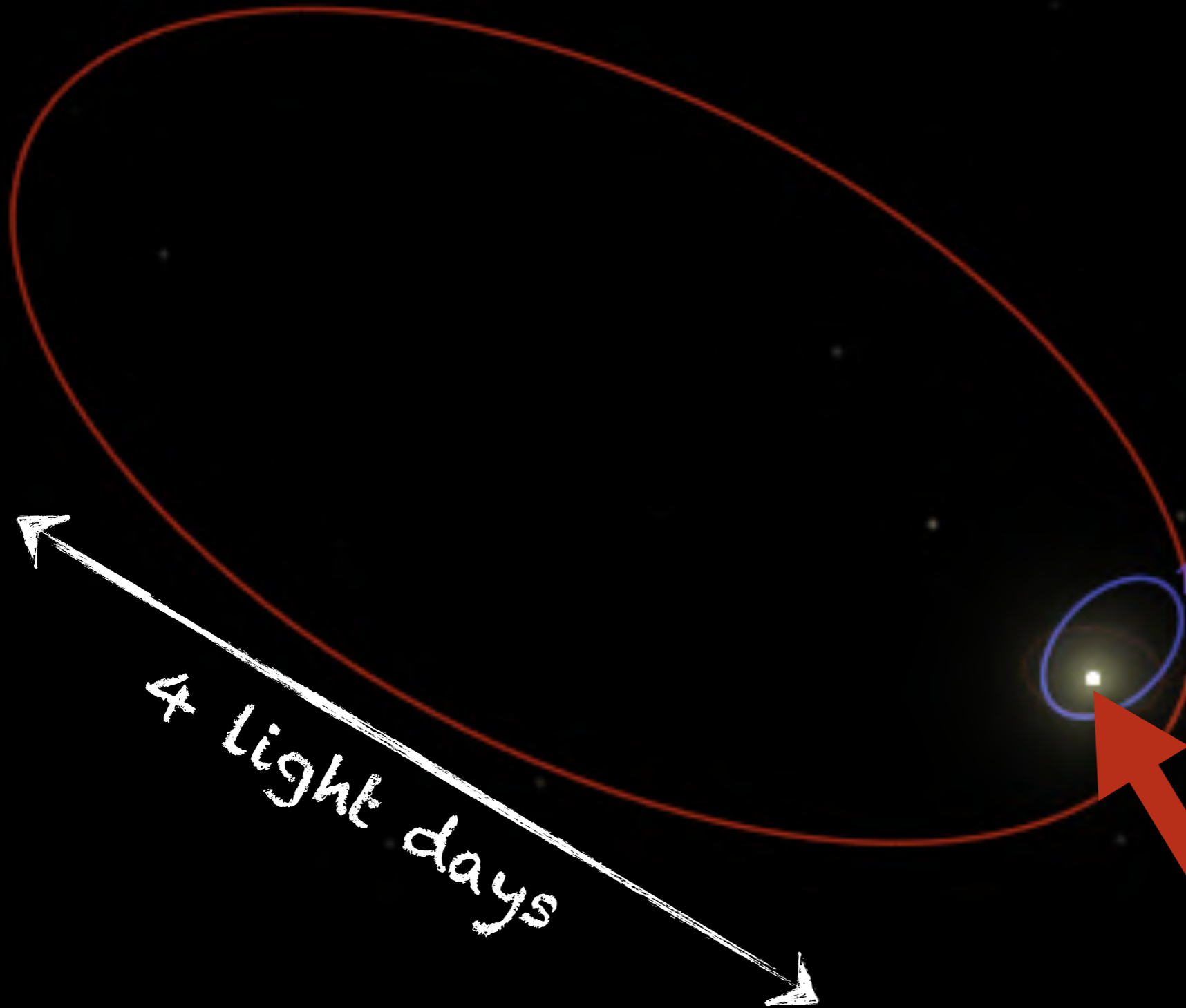


1 million km
≈ 3.3 light seconds

You are here!



55.5 Light minutes



136199 Eris
90377 Sedna
2004 XR190

You are here!



Cygni System

Andromedae System JS 248

Barnard's Star

You are here!

Ross 154

Lalande 21185

EZ Aquarii System

Sun

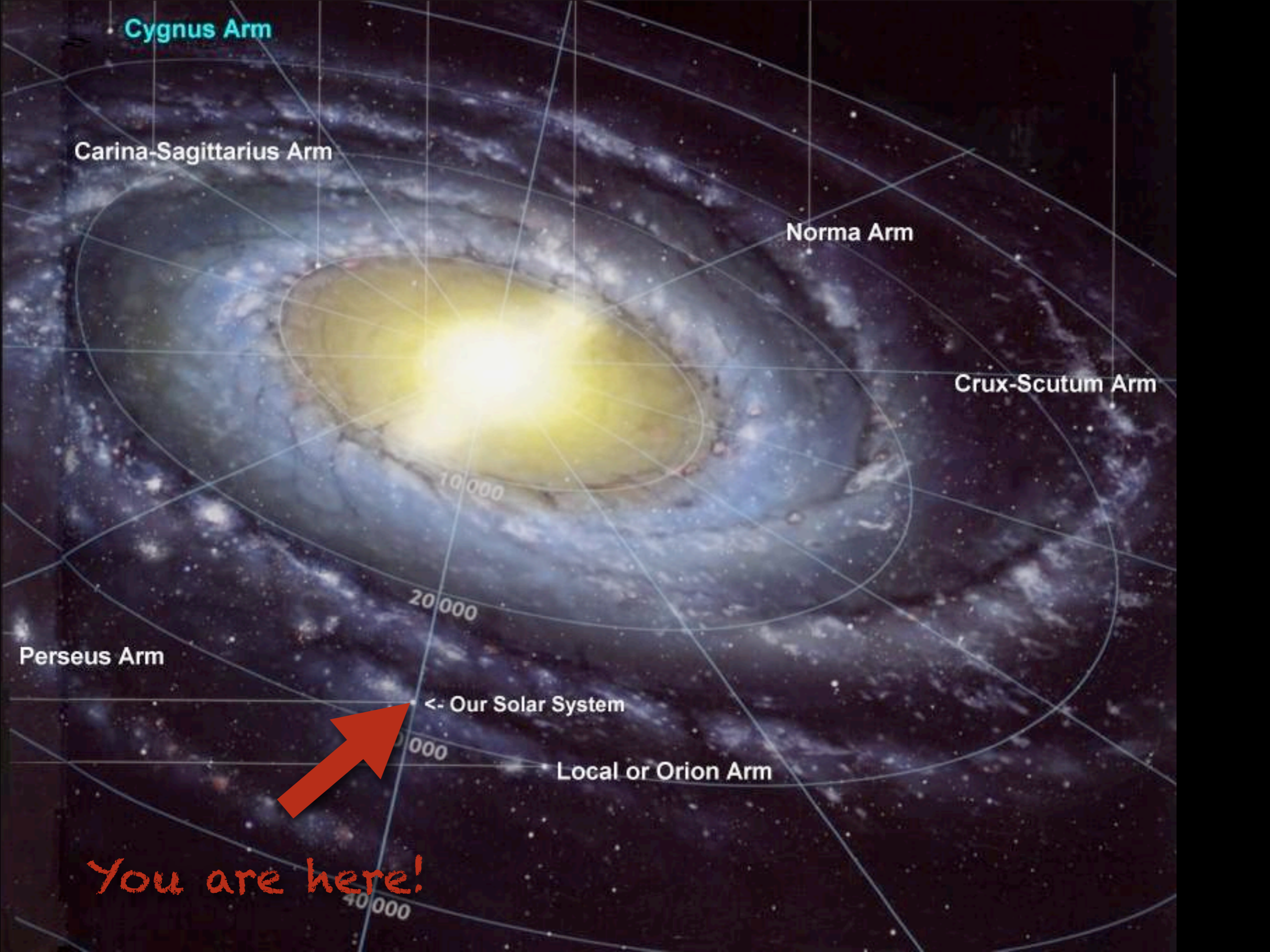
Proxima Centauri

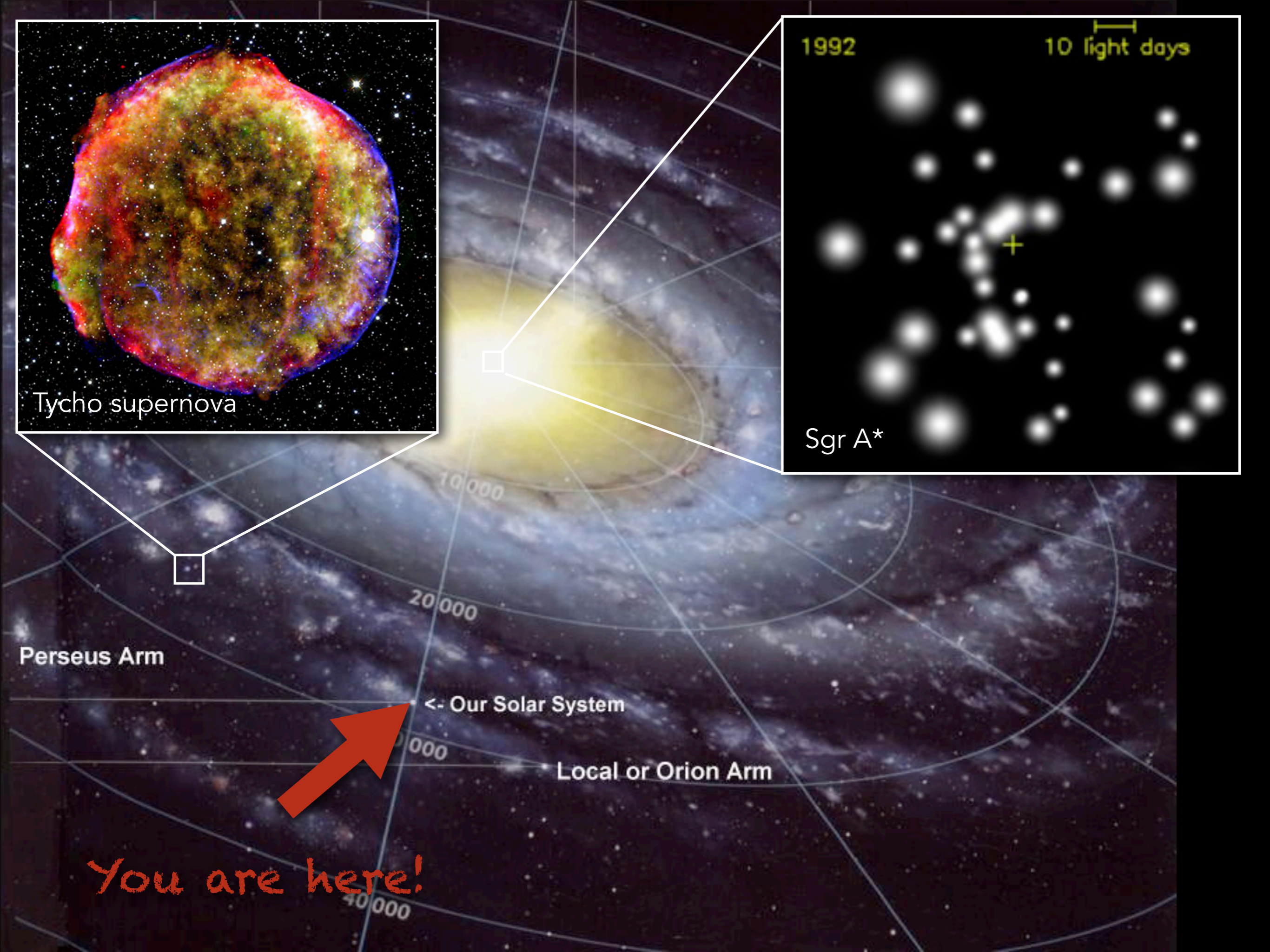
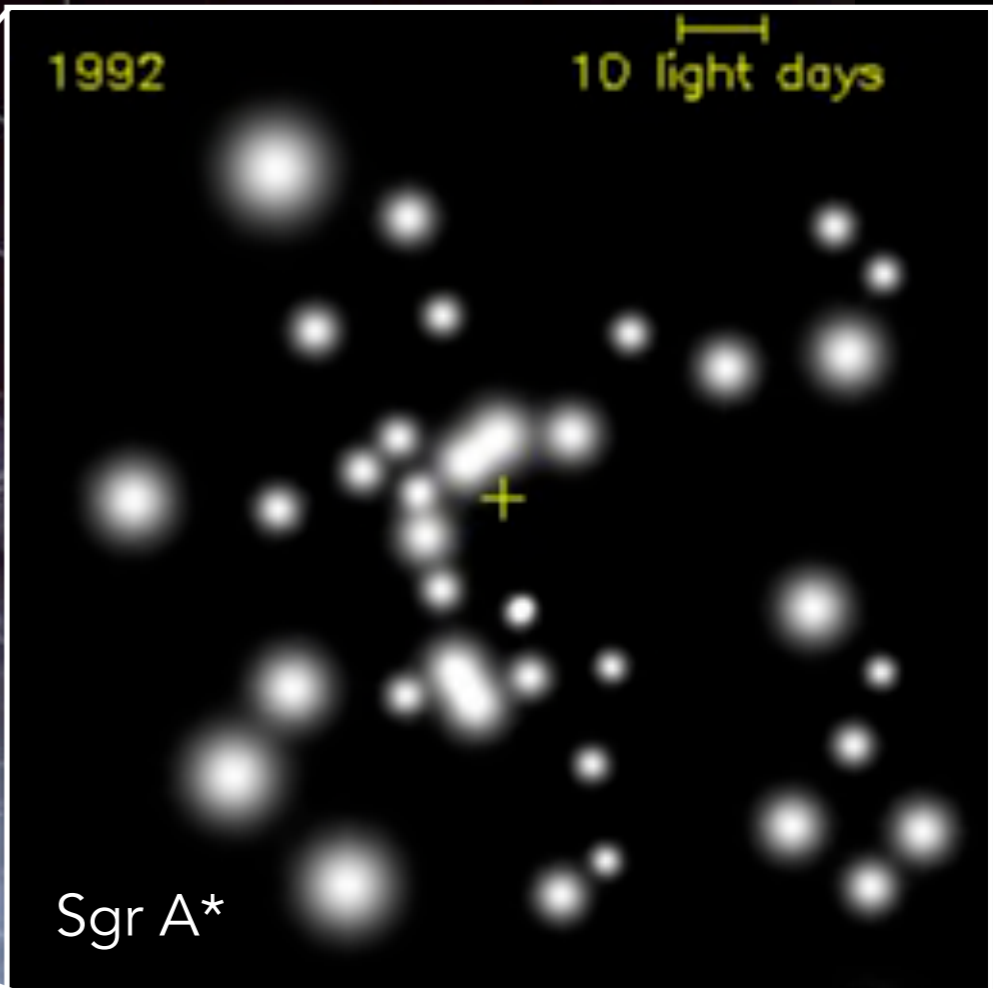
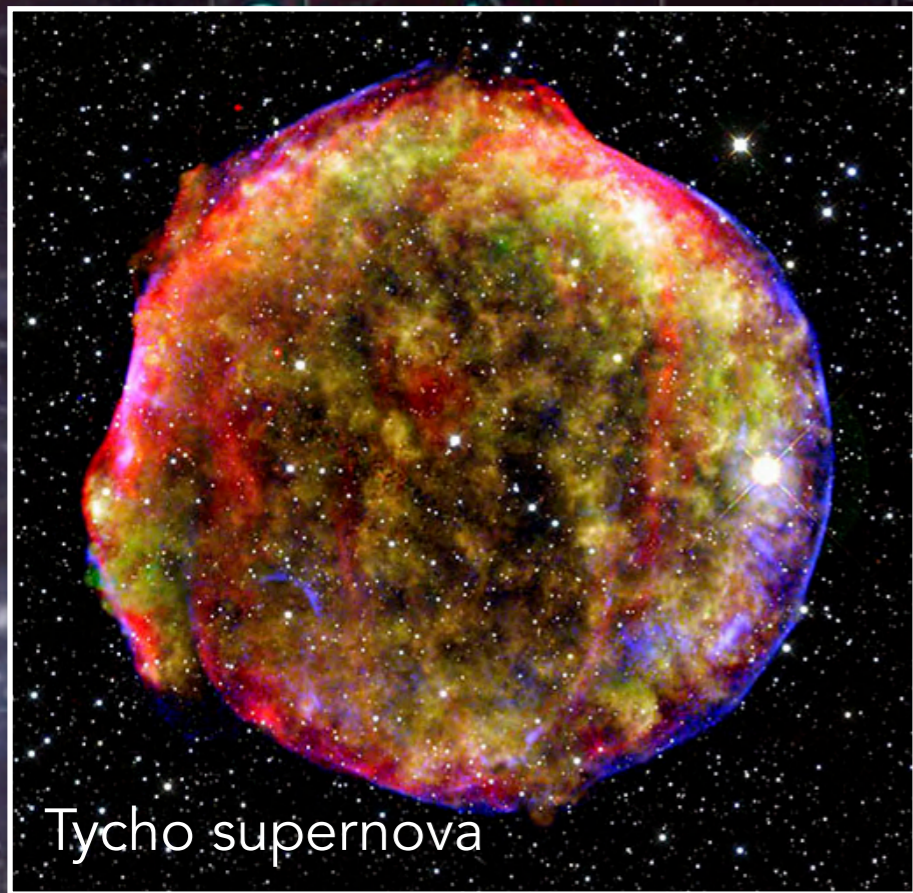
Wolf 359

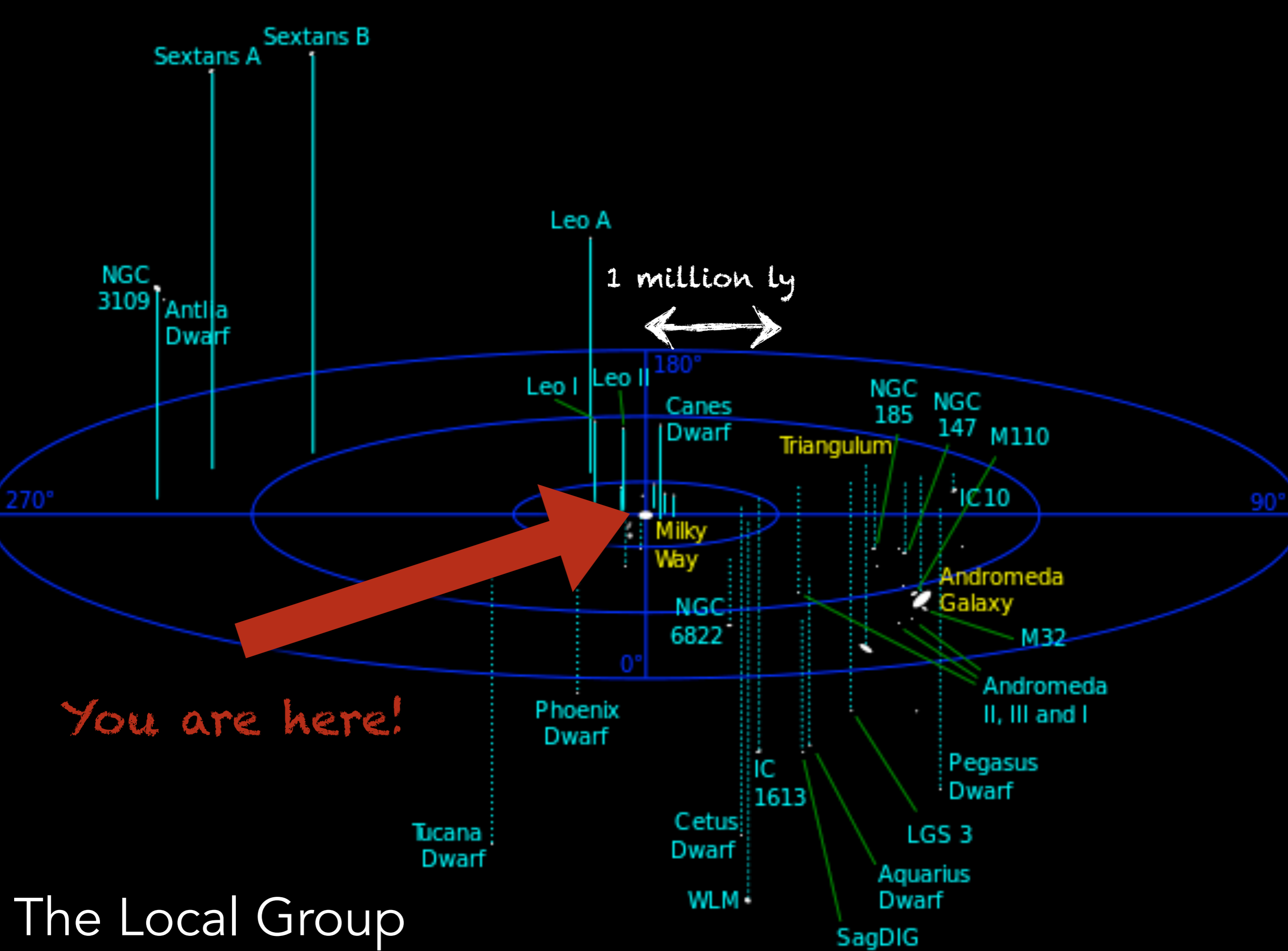
Ross 128

Lacaille 9352

10 light years

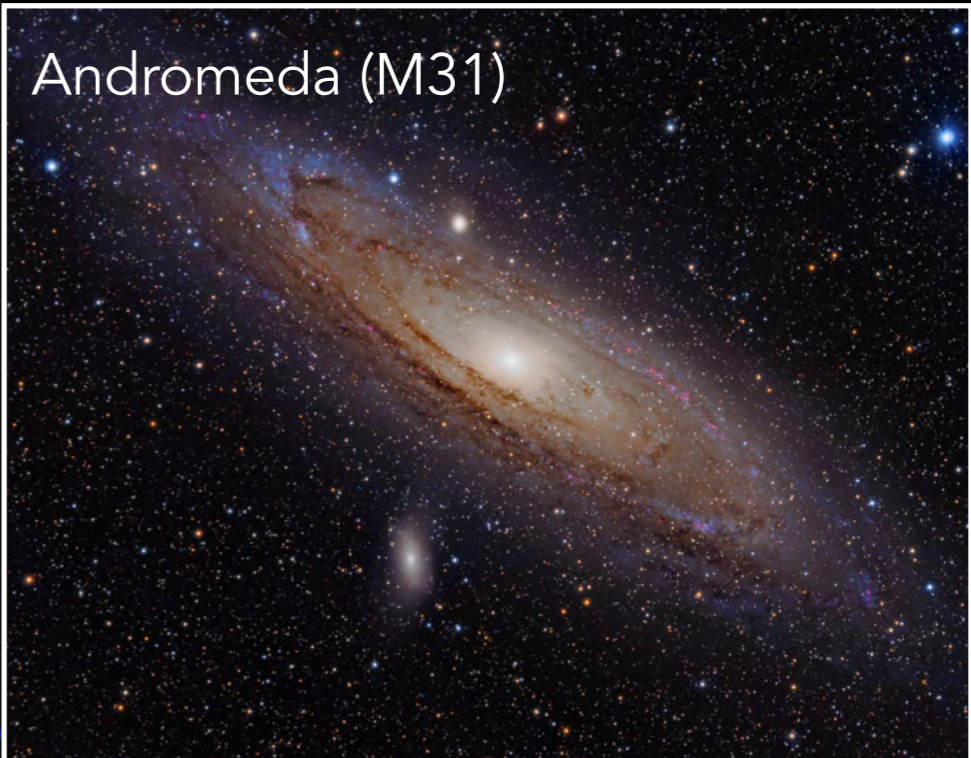
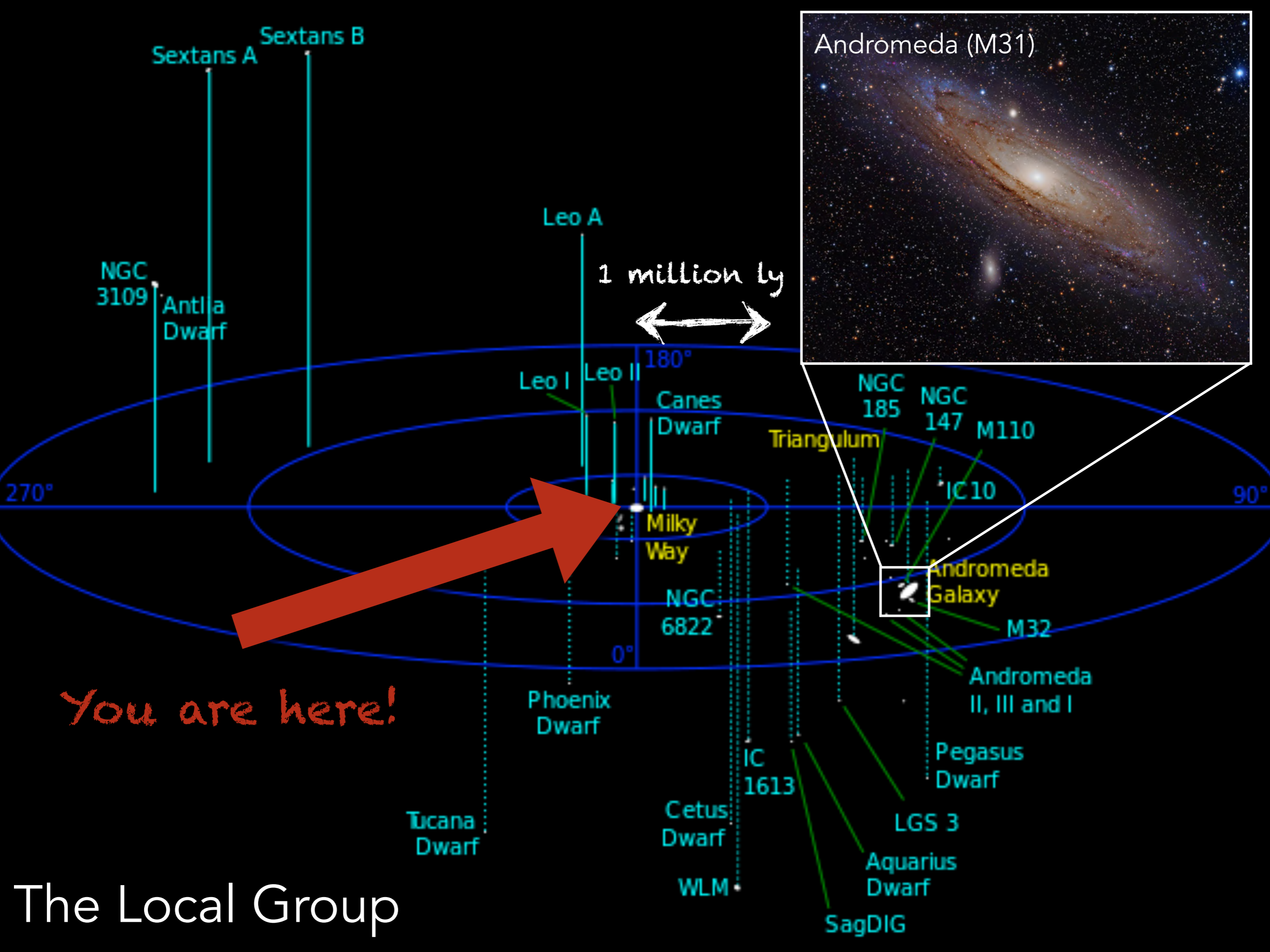






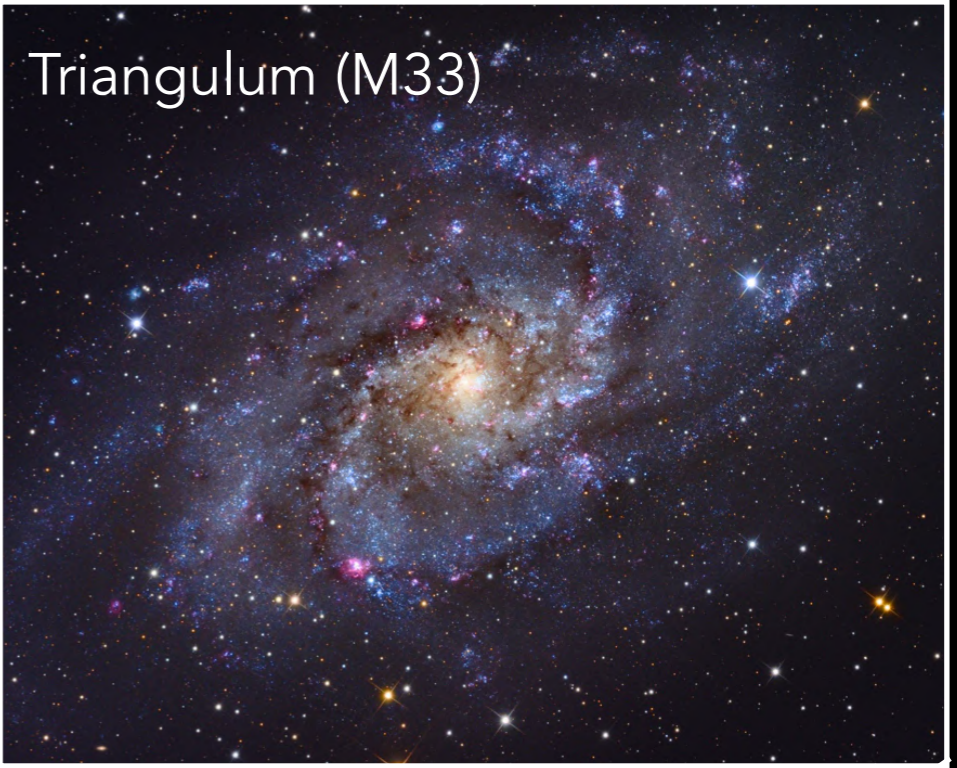
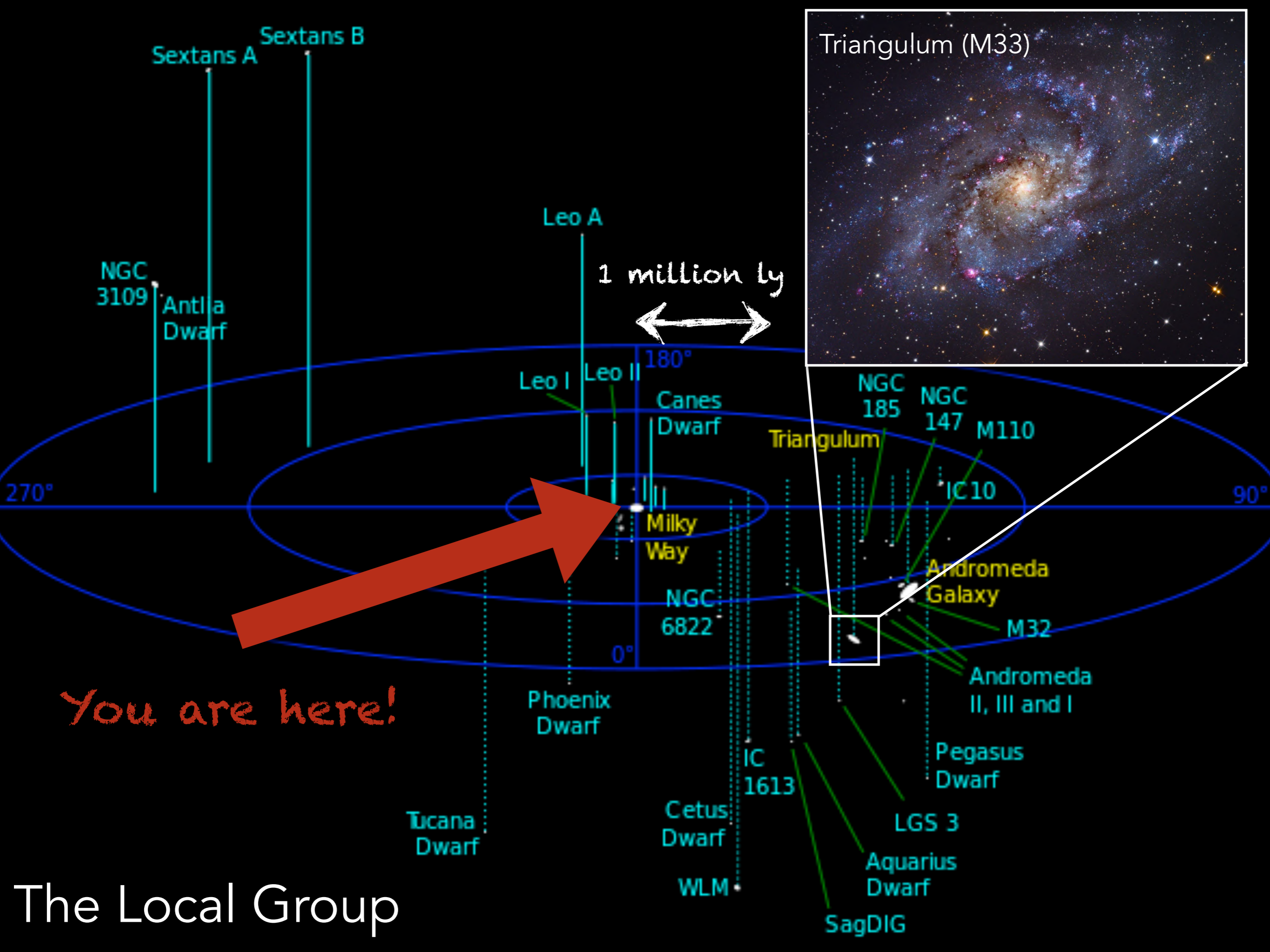
You are here!

The Local Group



You are here!

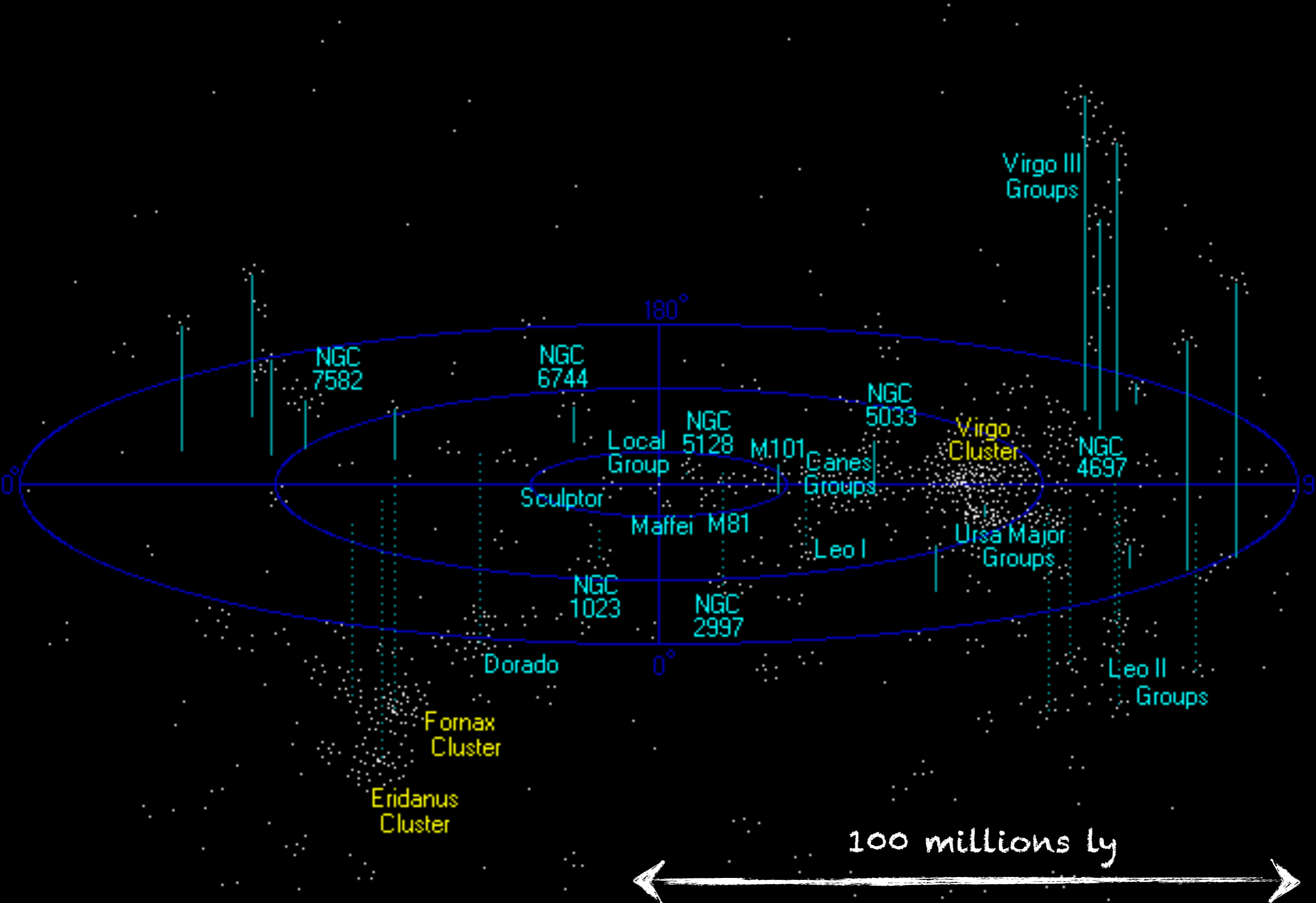
The Local Group



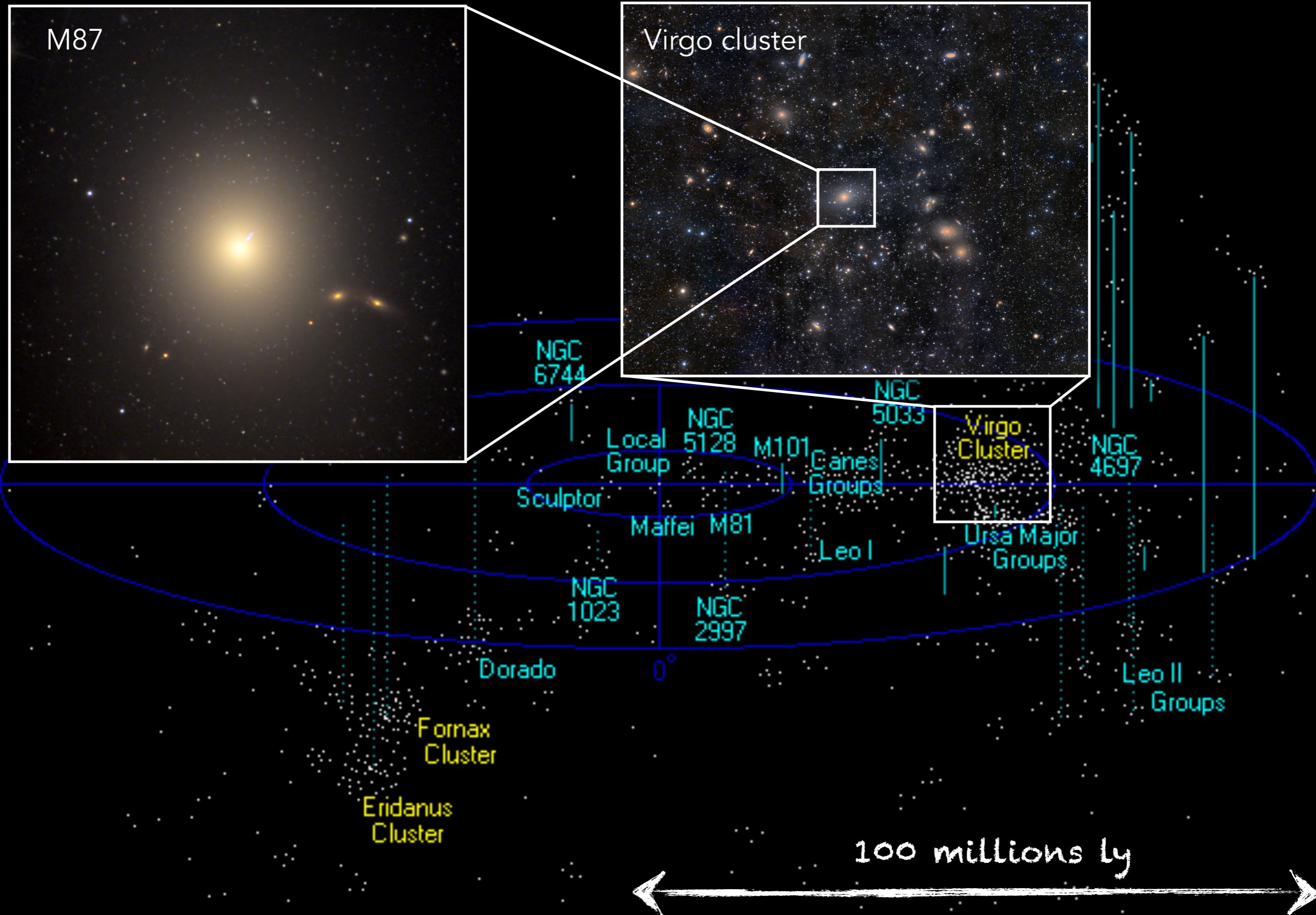
1 million ly
 ←→

You are here!

The Local Group



The Virgo Supercluster



M87

Virgo cluster

NGC 6744

NGC 5033

NGC 4697

Local Group
Sculptor

NGC 5128 M101
Canes Groups

Virgo Cluster

Maffei M81

Leo I

Ursa Major Groups

NGC 1023

NGC 2997

Dorado

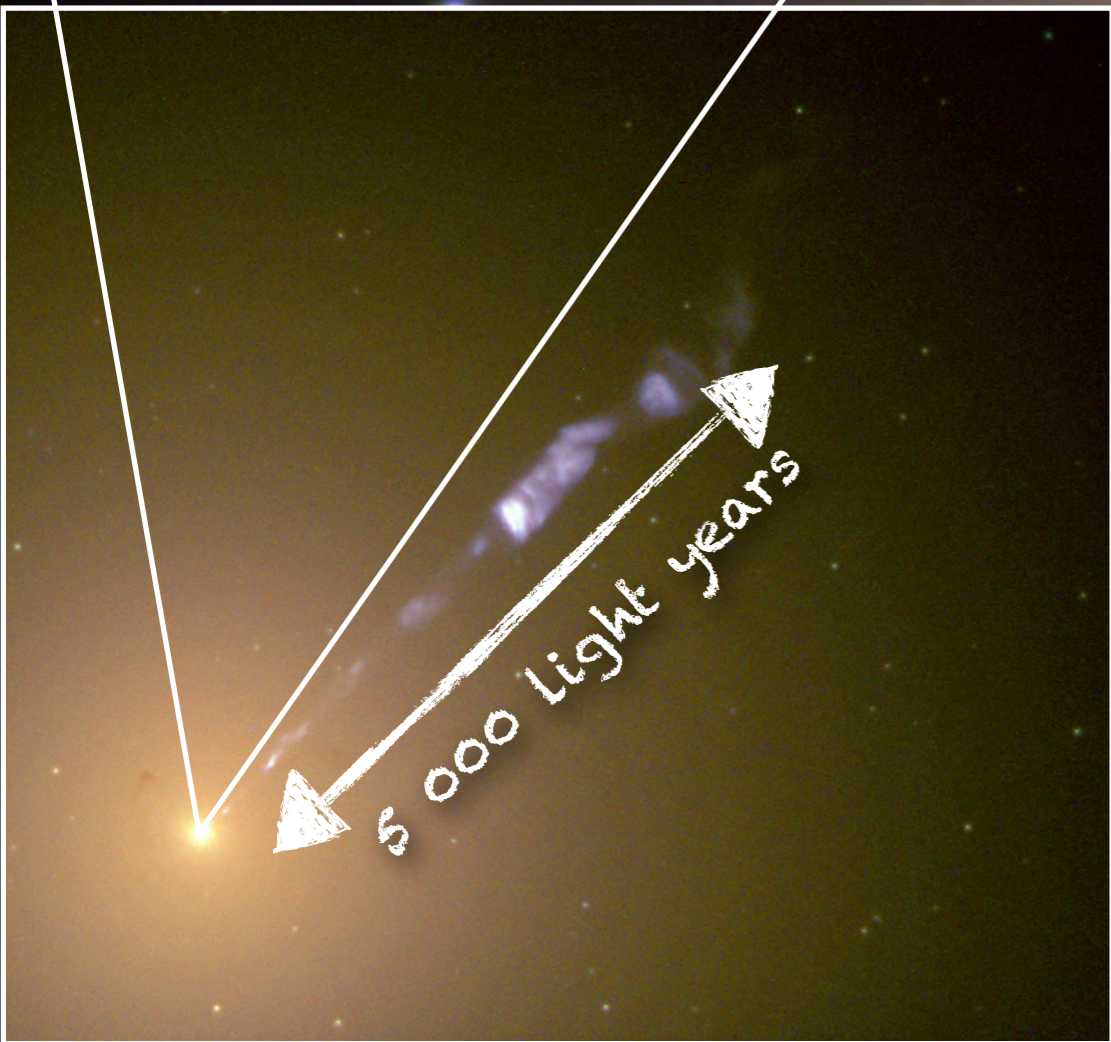
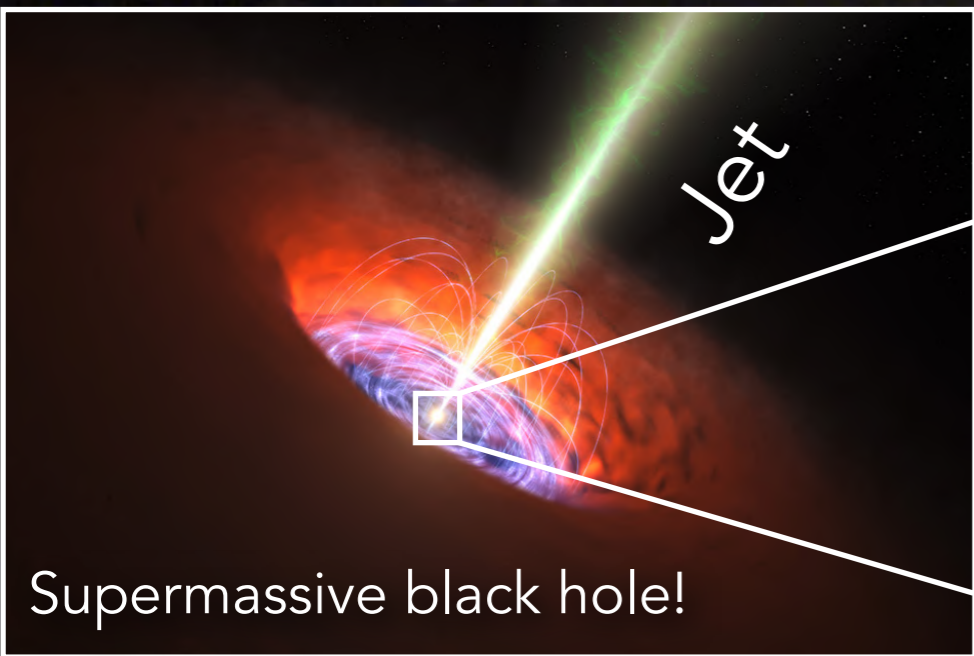
Fornax Cluster

Eridanus Cluster

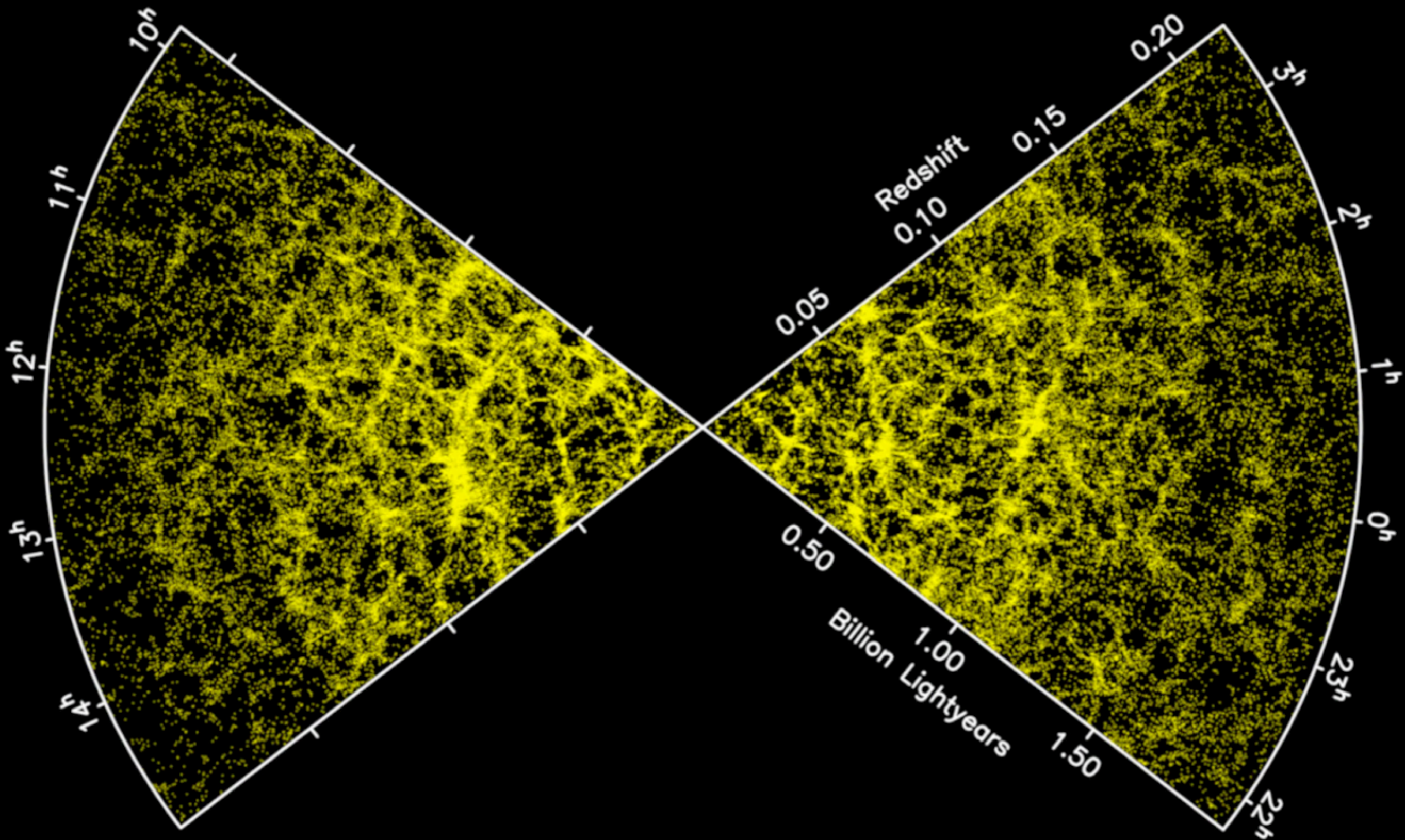
Leo II Groups

100 millions ly

The Virgo Supercluster



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!



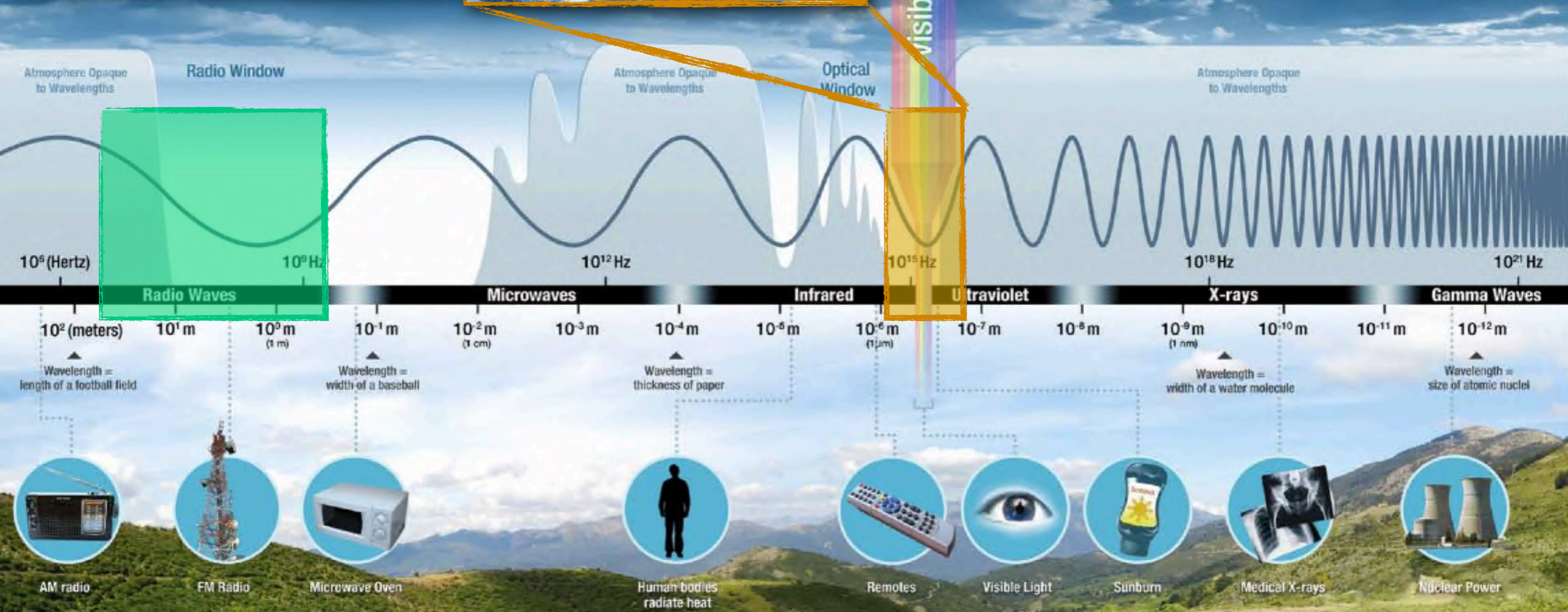
Seeing Beyond our Atmosphere

NASA spacecraft, such as RHESSI, provide scientists with a unique vantage point, helping them "see" at higher-energy wavelengths that are blocked by the Earth's protective atmosphere.

ATMOSPHERIC WINDOWS

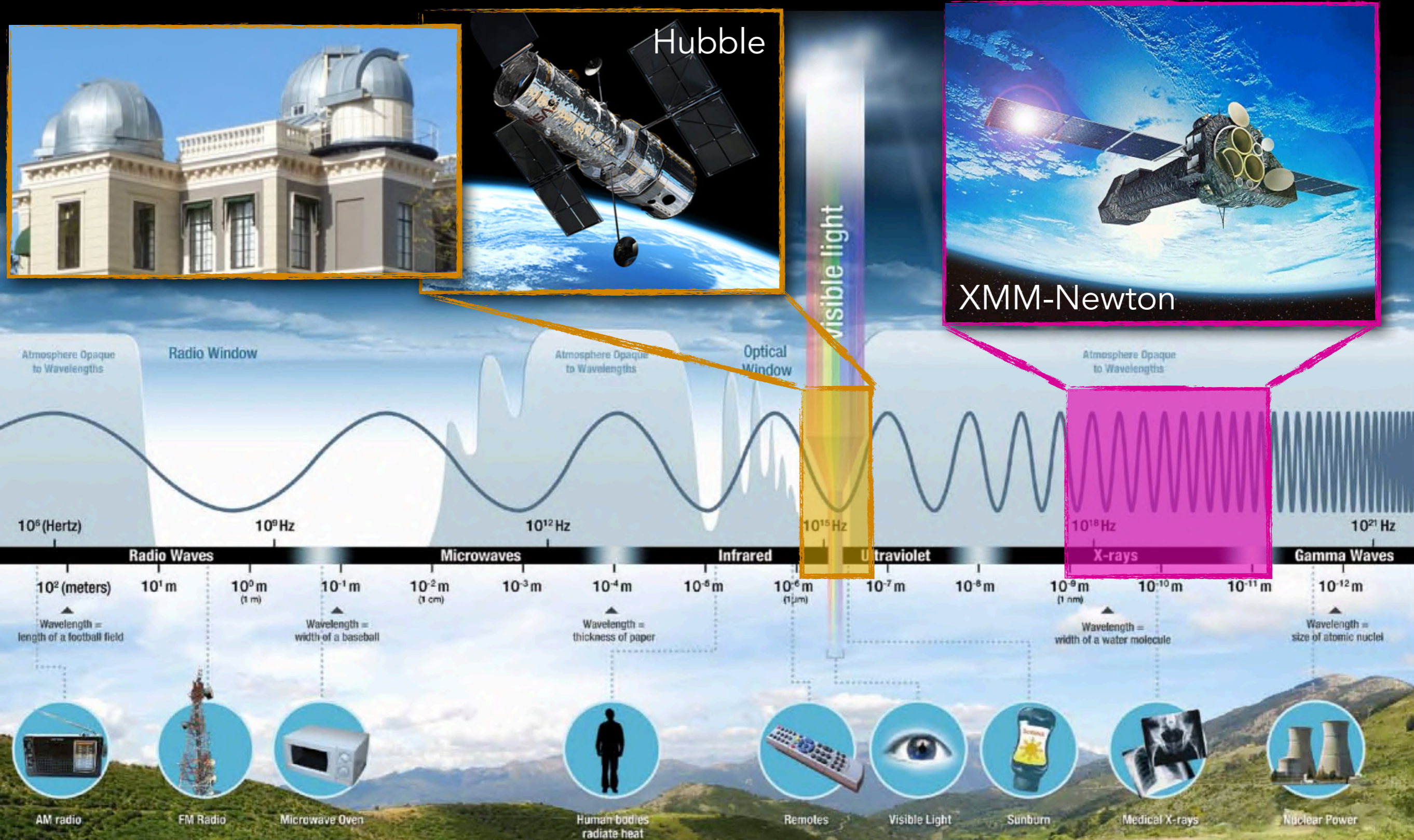
Electromagnetic radiation is reflected or absorbed mainly by several gases in the Earth's atmosphere, among the most important being water vapor, carbon dioxide, and ozone. Some radiation, such as visible light, largely passes (is transmitted) through the atmosphere. These regions of the spectrum with wavelengths that can pass through the atmosphere are referred to as "atmospheric windows." Some microwaves can even pass through clouds, which make them the best wavelength for transmitting satellite communication signals.

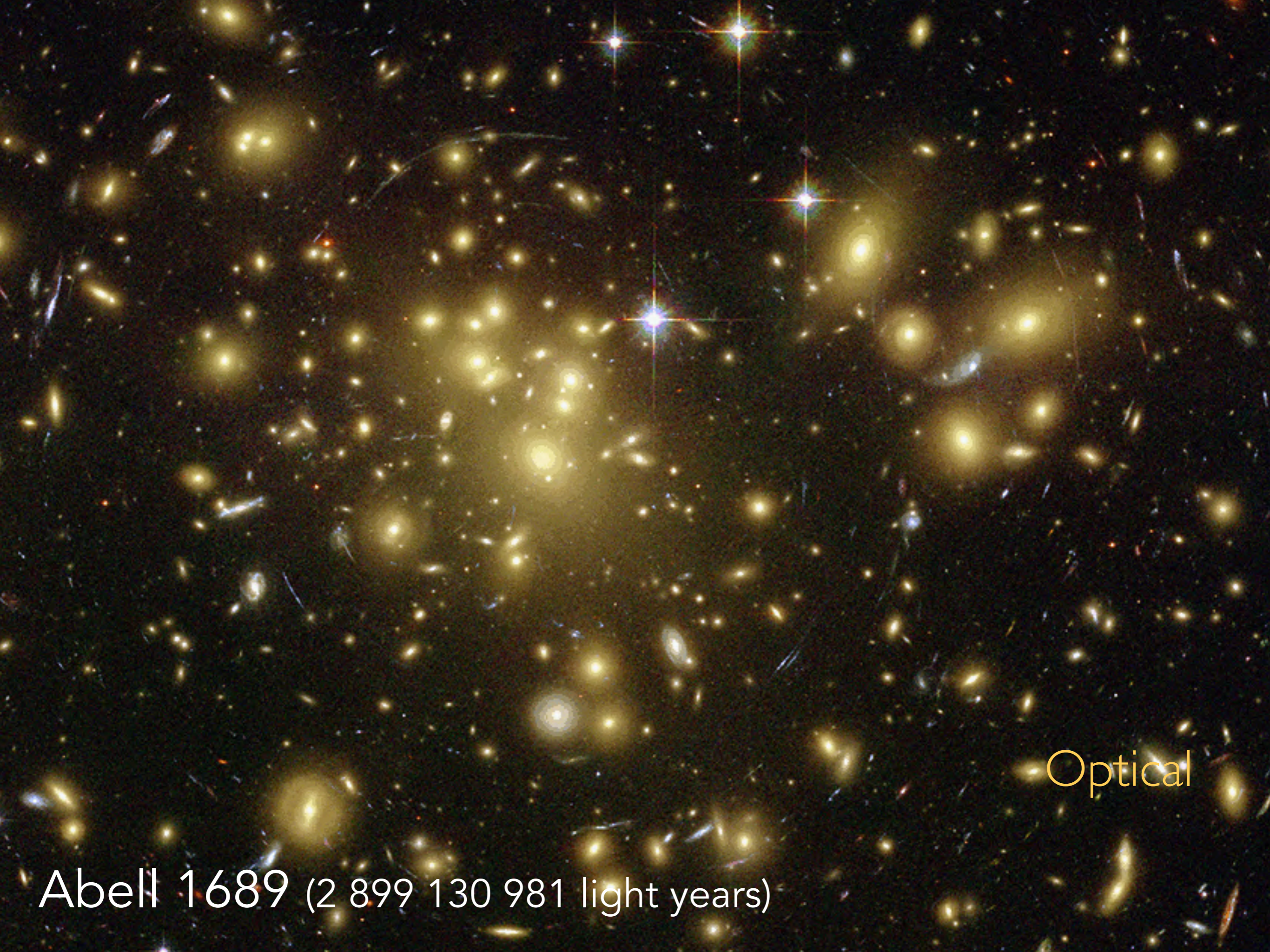
While our atmosphere is essential to protecting life on Earth and keeping the planet habitable, it is not very helpful when it comes to studying sources of high energy radiation in space. Instruments have to be positioned above Earth's energy absorbing atmosphere to "see" higher energy and even some lower energy light sources such as quasars.



Light emits at optical "colors" ...

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





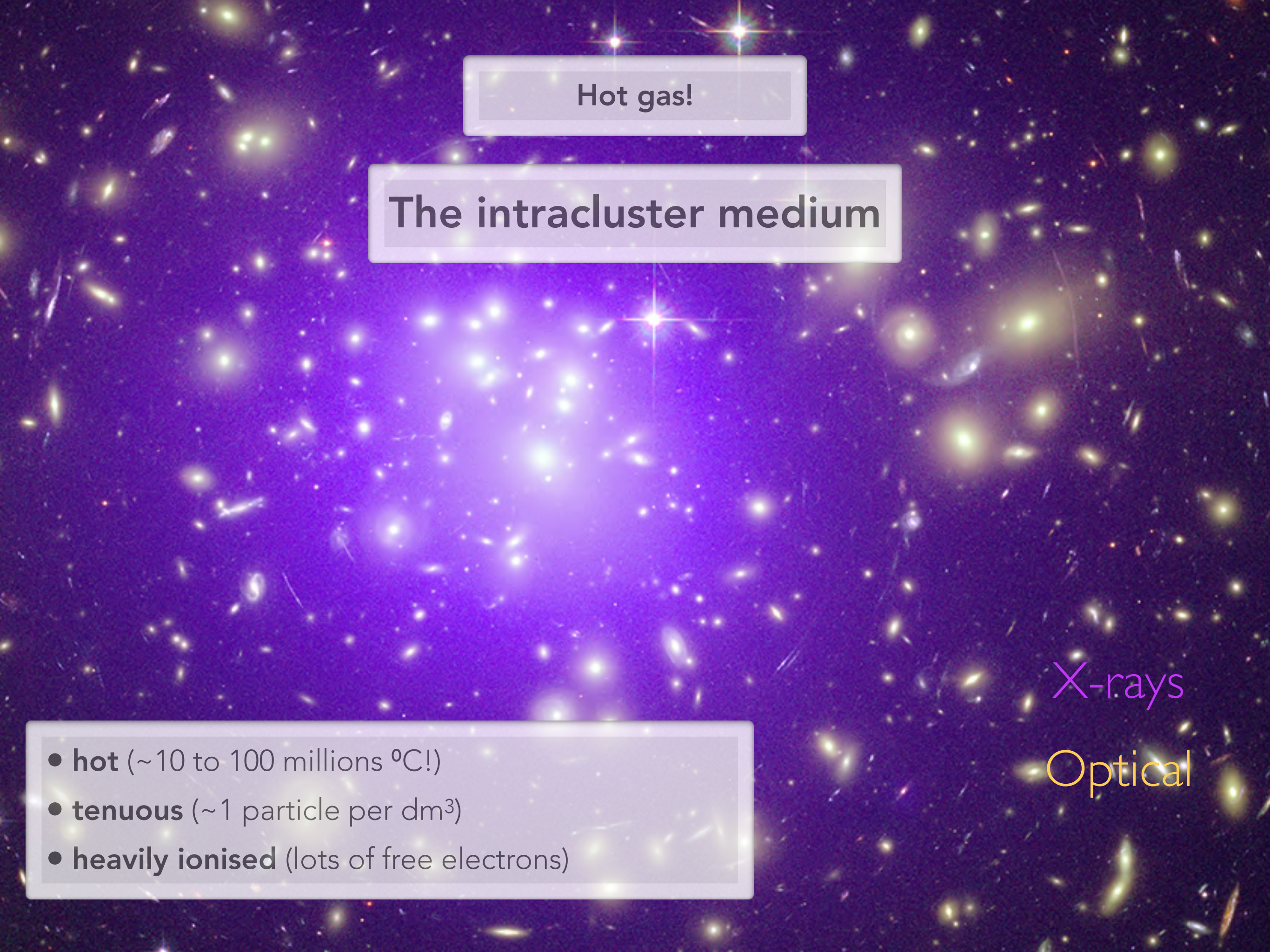
Optical

Abell 1689 (2 899 130 981 light years)



X-rays

Abell 1689 (2 899 130 981 light years)



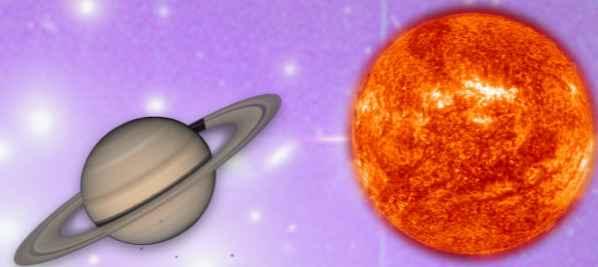
Hot gas!

The intracluster medium

- **hot** (~10 to 100 millions °C!)
- **tenuous** (~1 particle per dm^3)
- **heavily ionised** (lots of free electrons)

X-rays

Optical



Stars,
planets,
galaxies,...

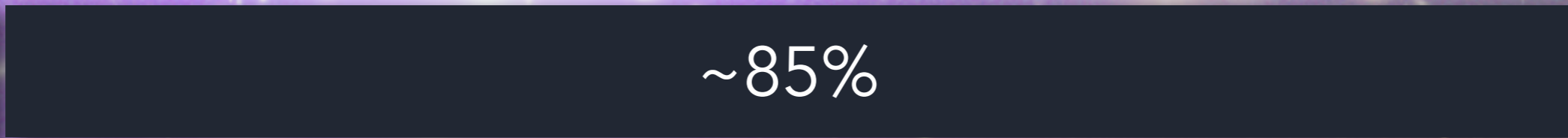
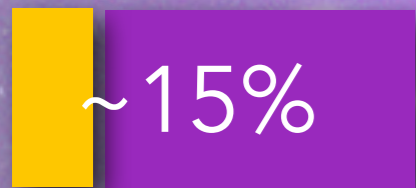


~20%

Stars,
planets,
galaxies,...

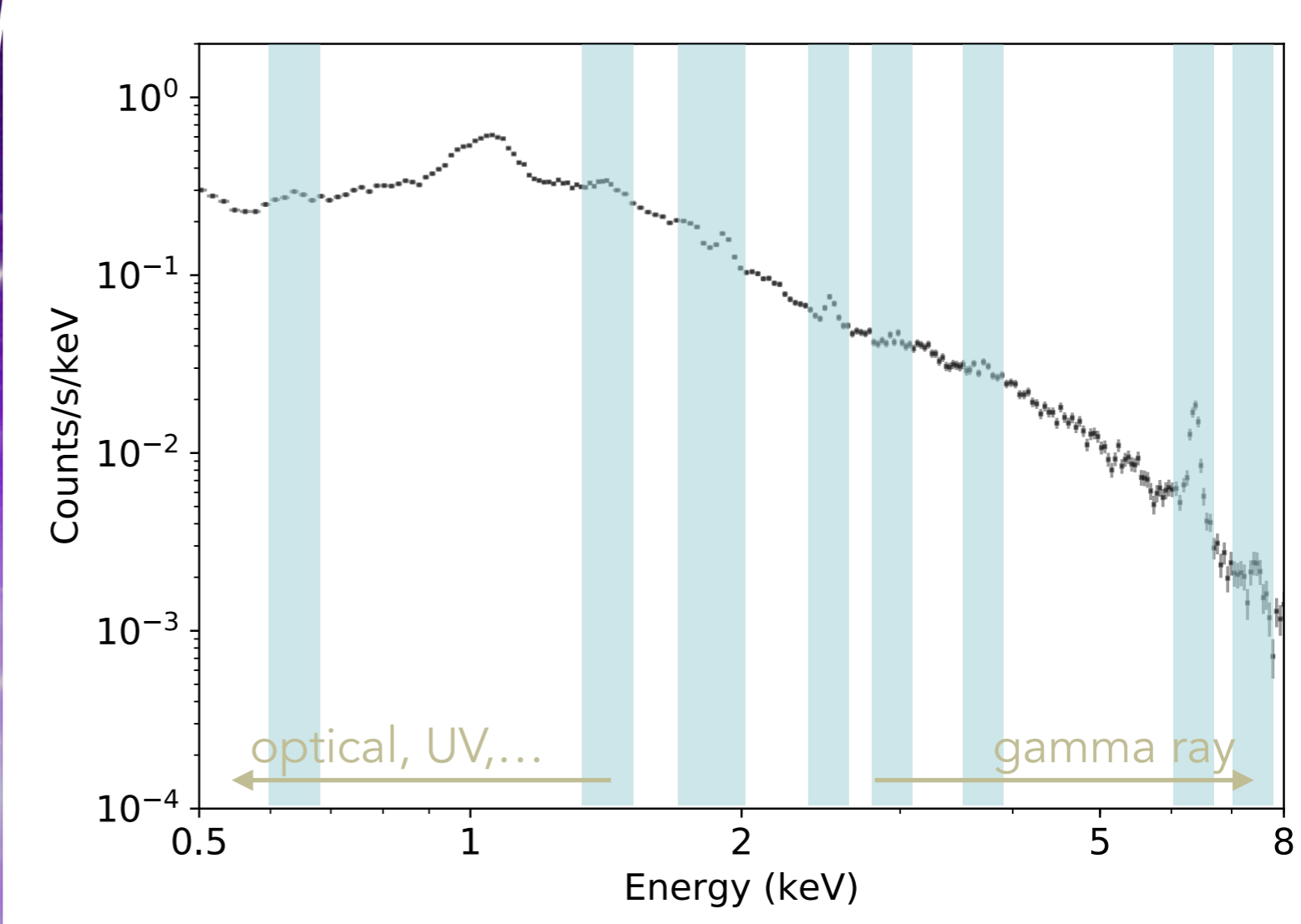
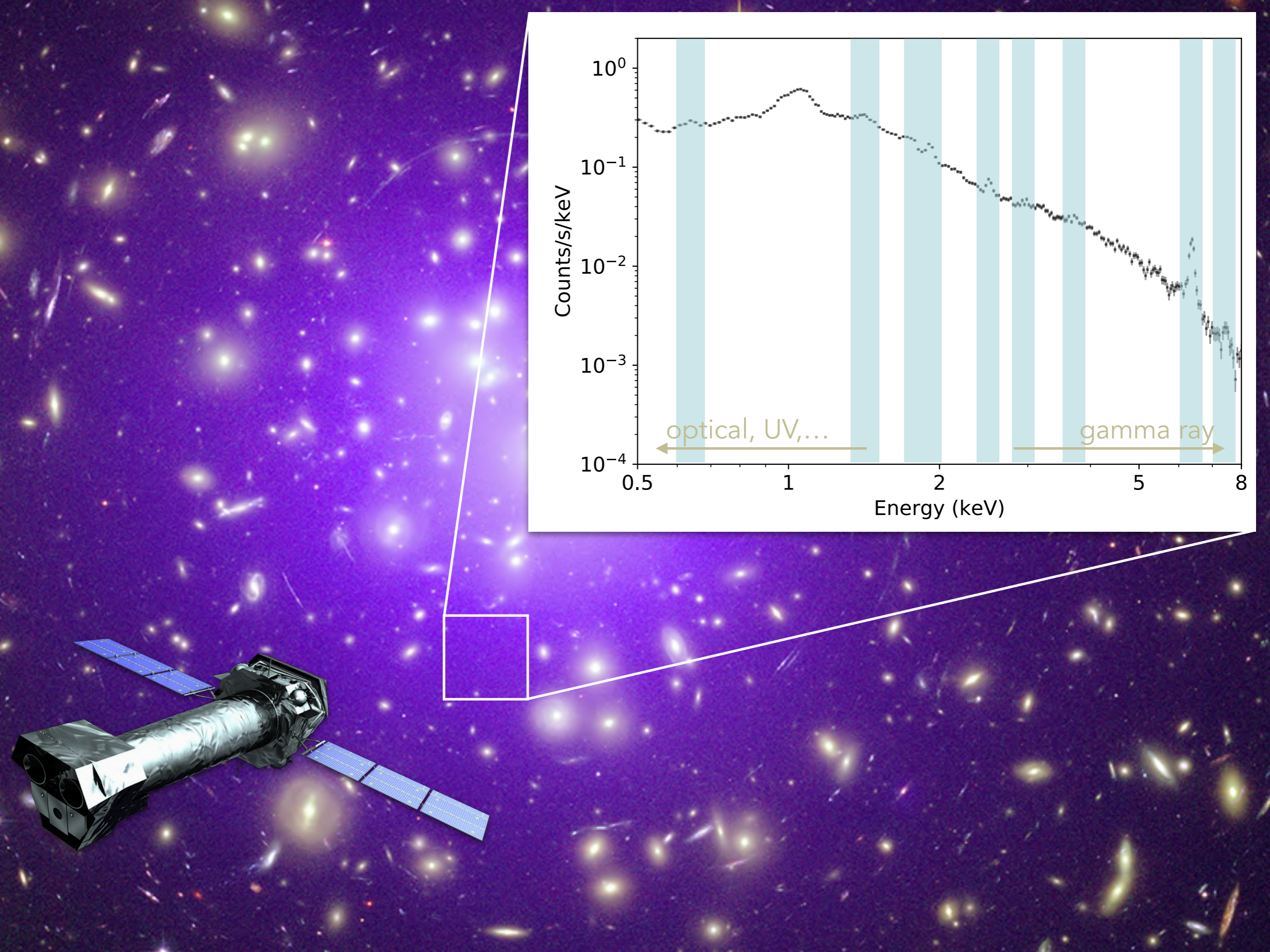
~80%

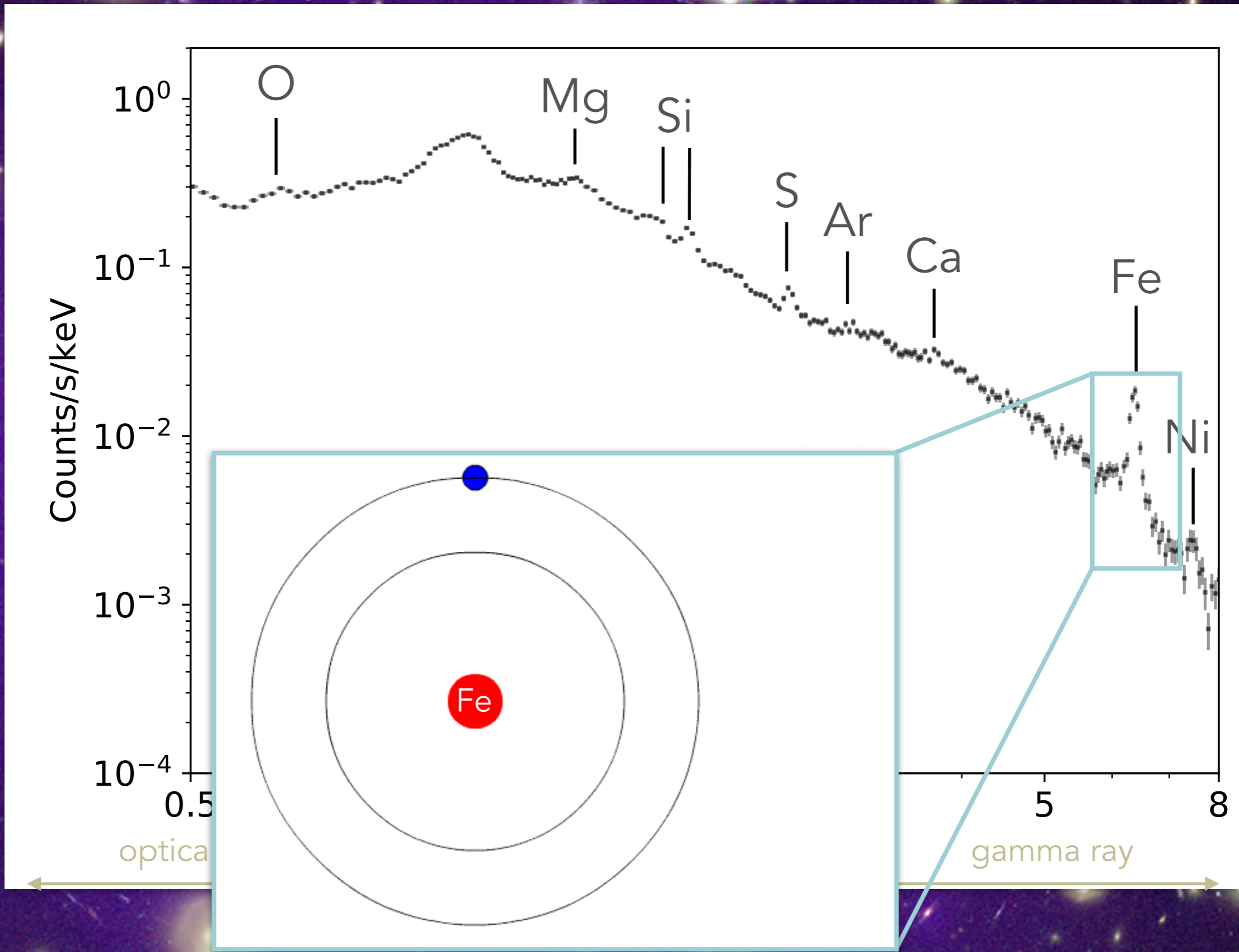
Intracluster medium

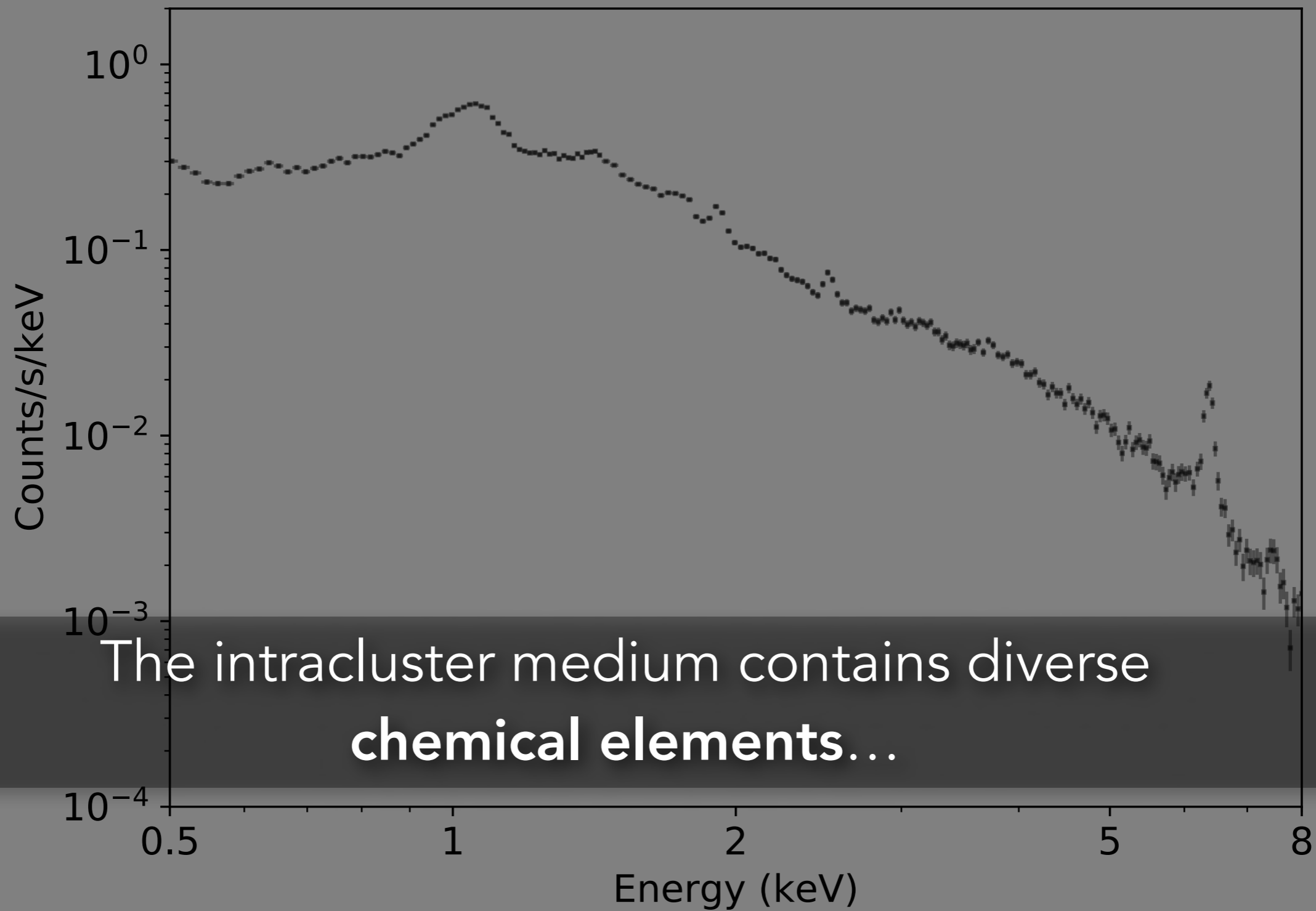


Stars, planets, galaxies,...
Intracluster medium

Dark matter

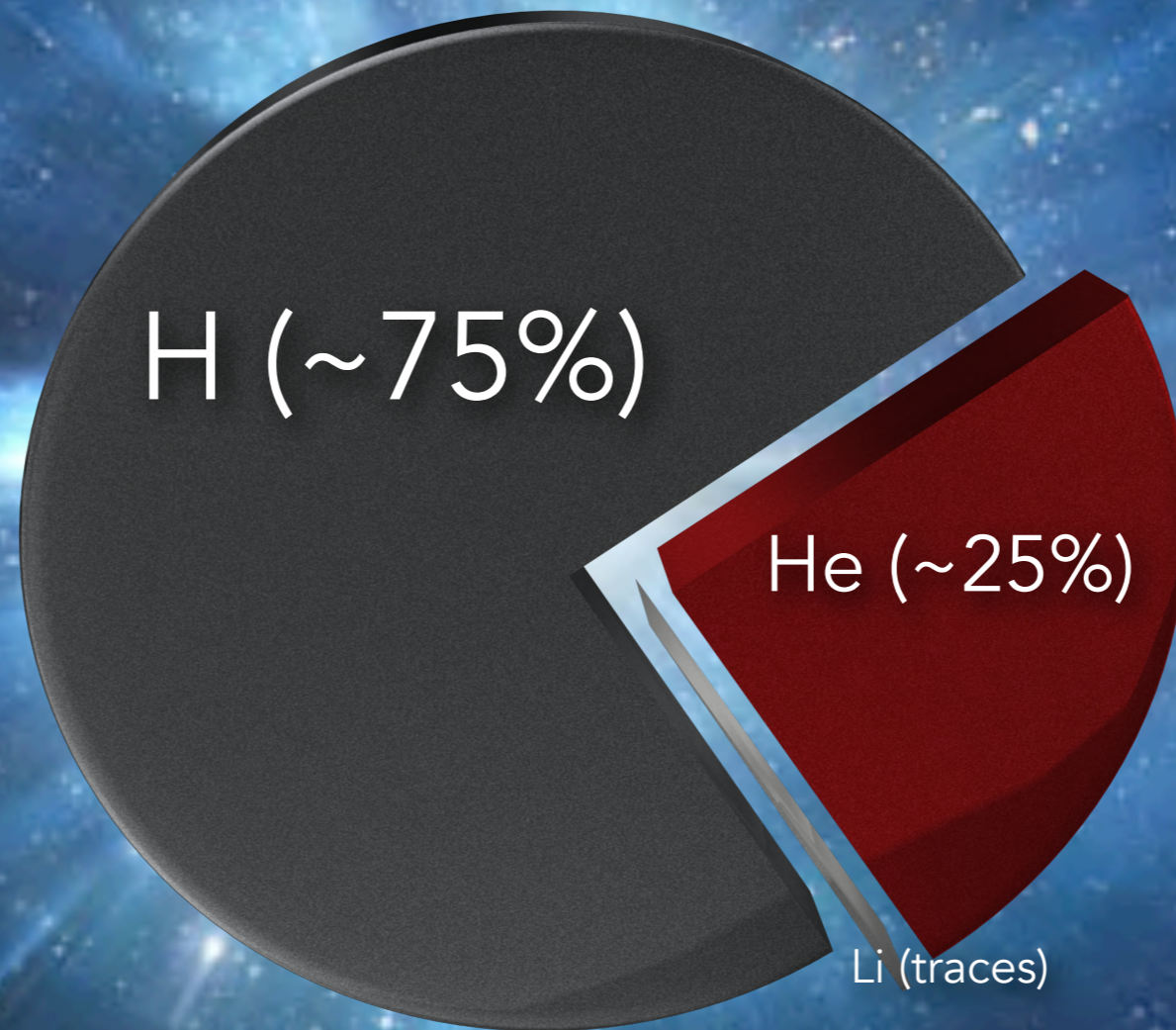






The intracluster medium contains diverse
chemical elements...

Primordial nucleosynthesis



Big Bang

A vibrant, multi-colored supernova remnant in space, surrounded by a field of yellow stars. The remnant shows complex filamentary structures in shades of blue, green, red, and orange, set against a dark background filled with numerous bright yellow stars.

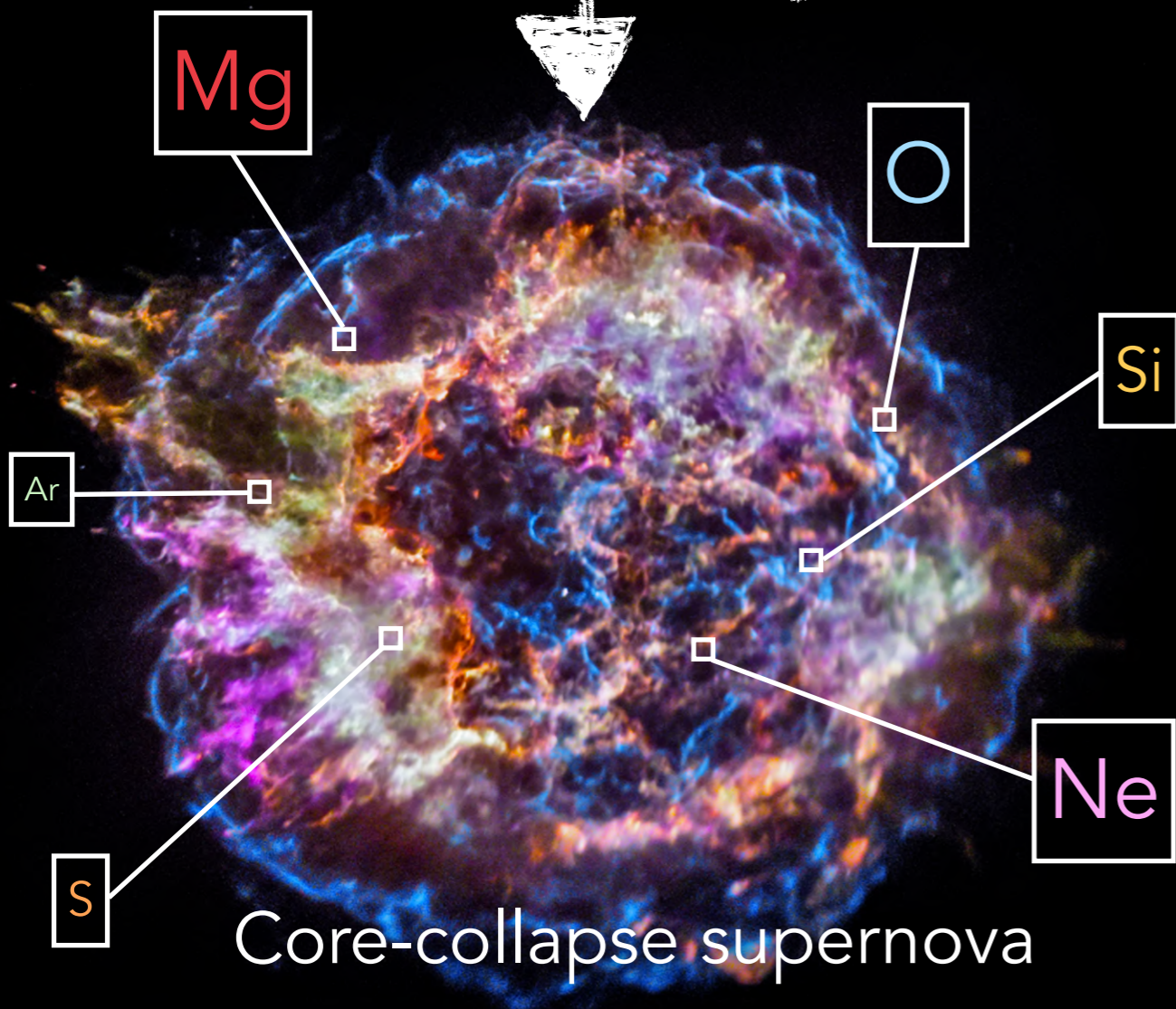
Supernovae are the **only way** to produce metals
(i.e. elements heavier than H and He...)

“We are made of starstuff.” - Carl Sagan

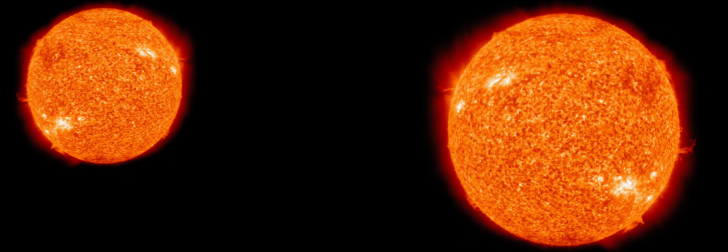
Massive star



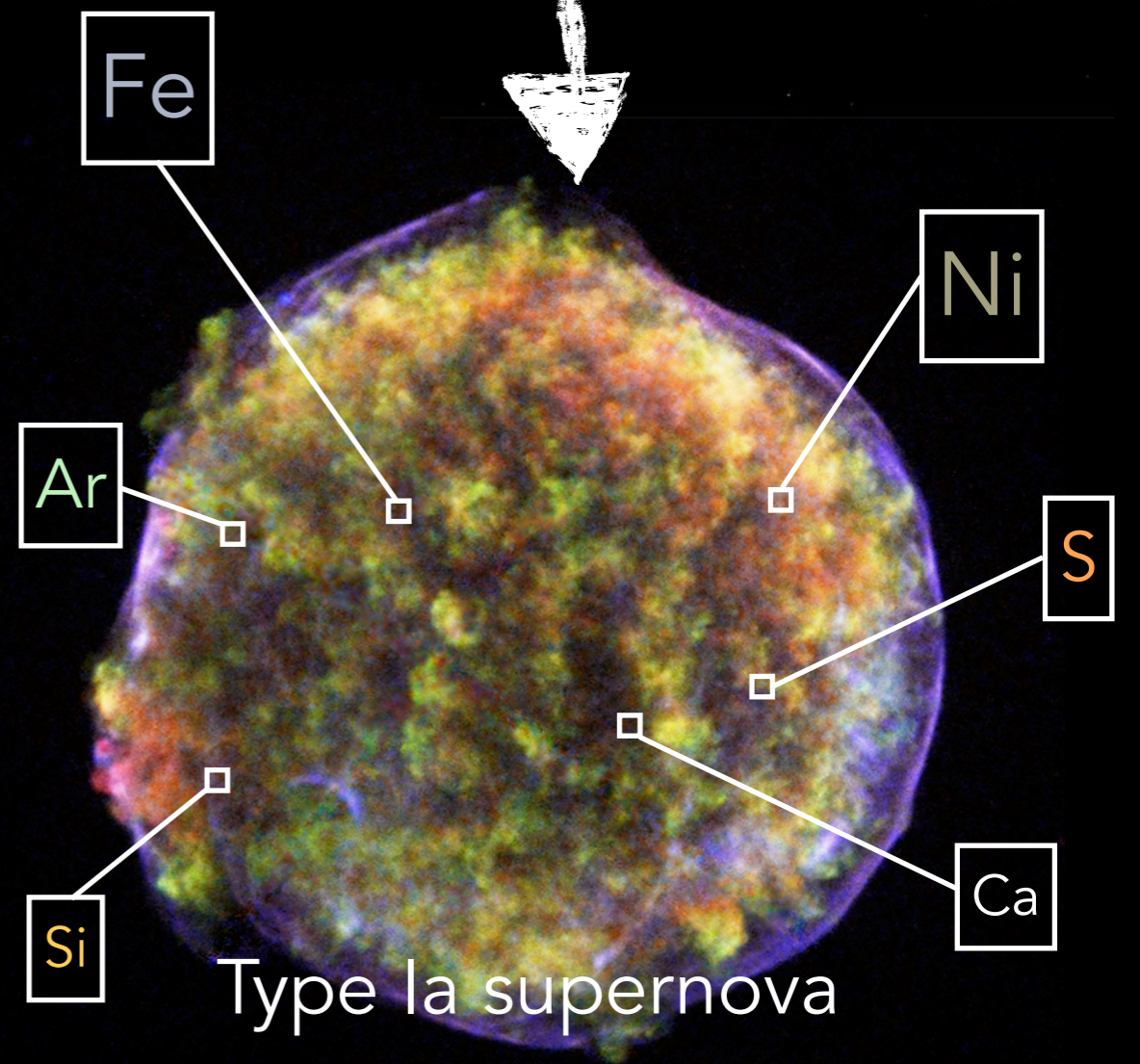
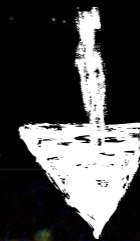
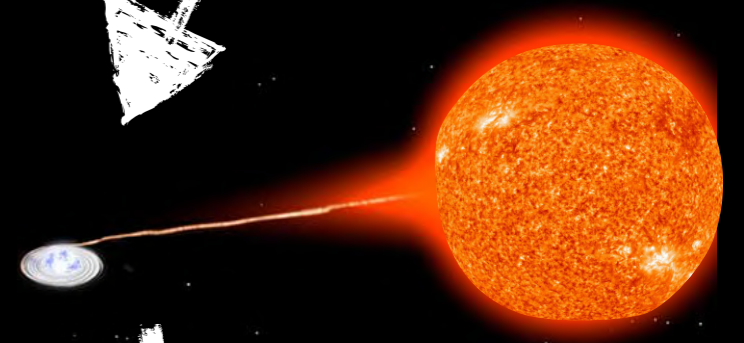
<30 million years

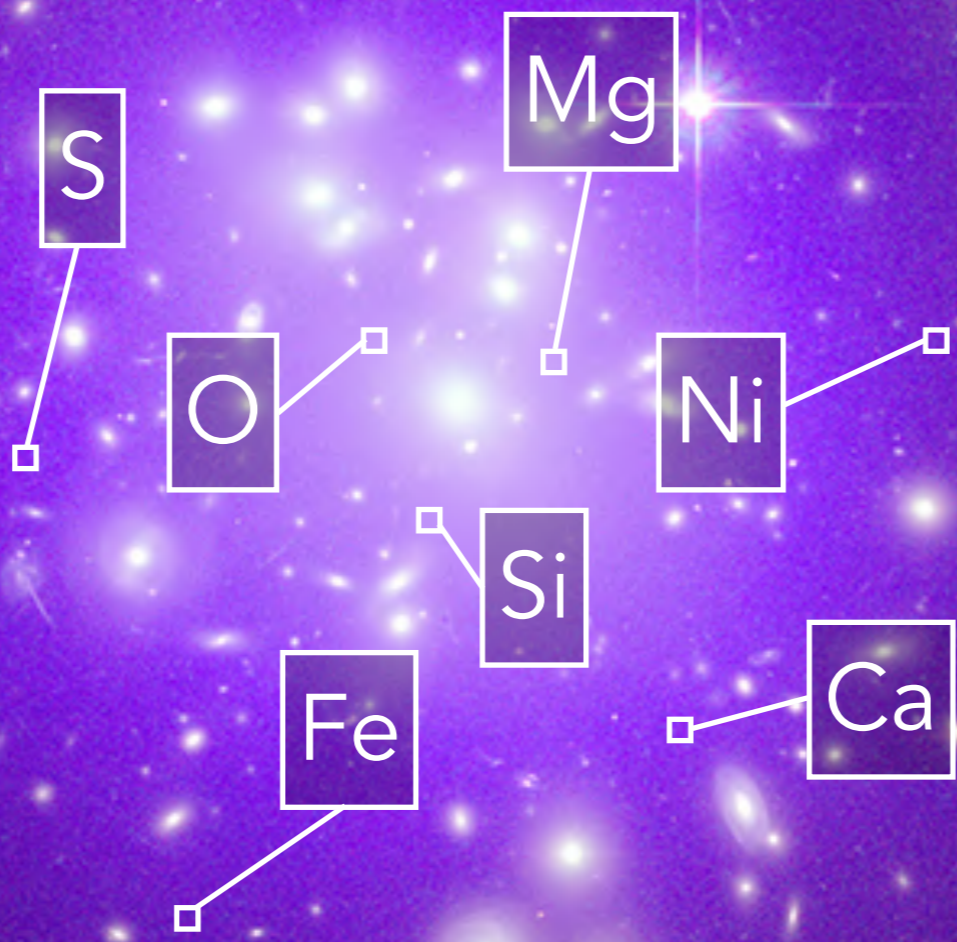


Low-mass stars



>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?

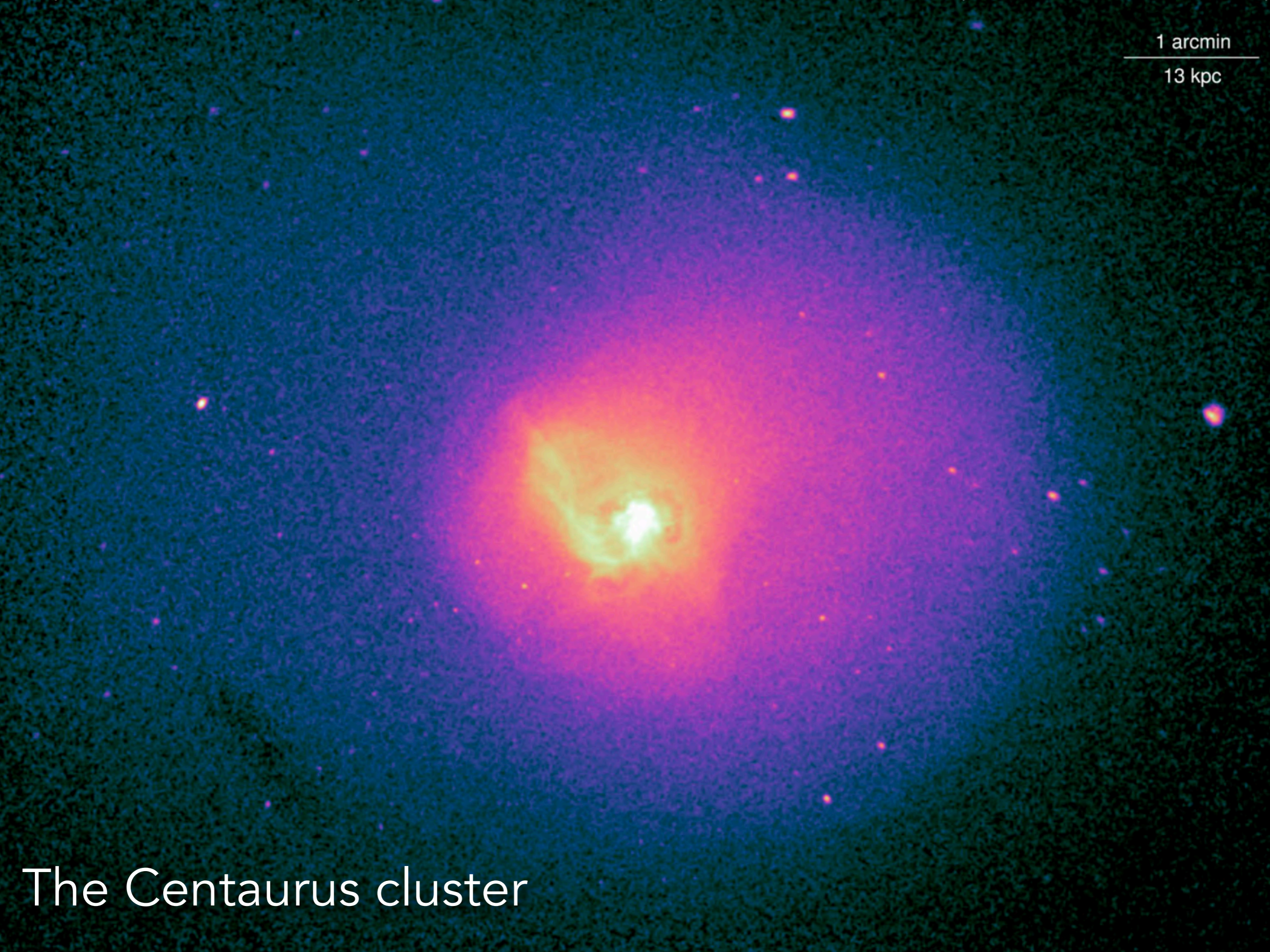


The Centaurus cluster

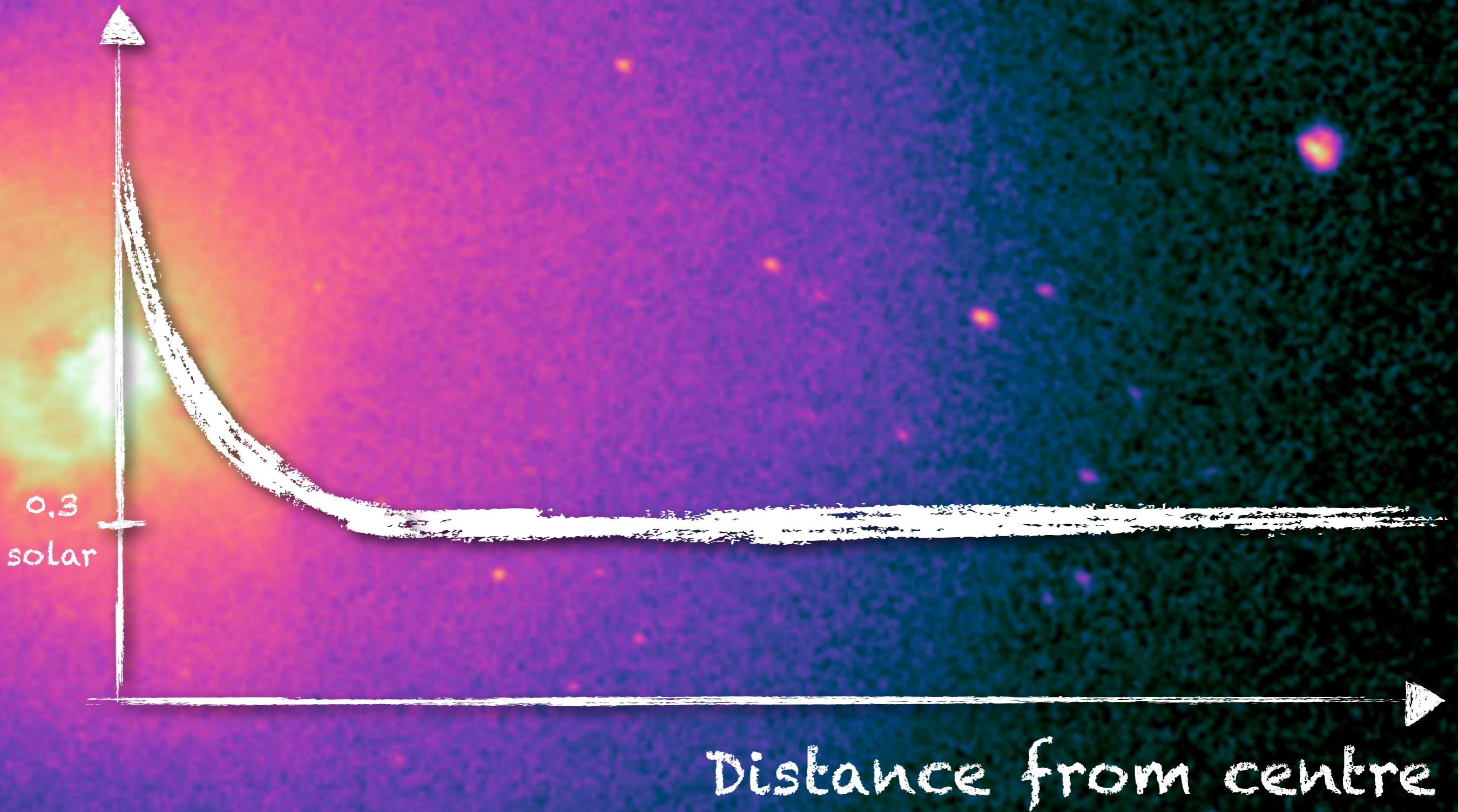
1 arcmin

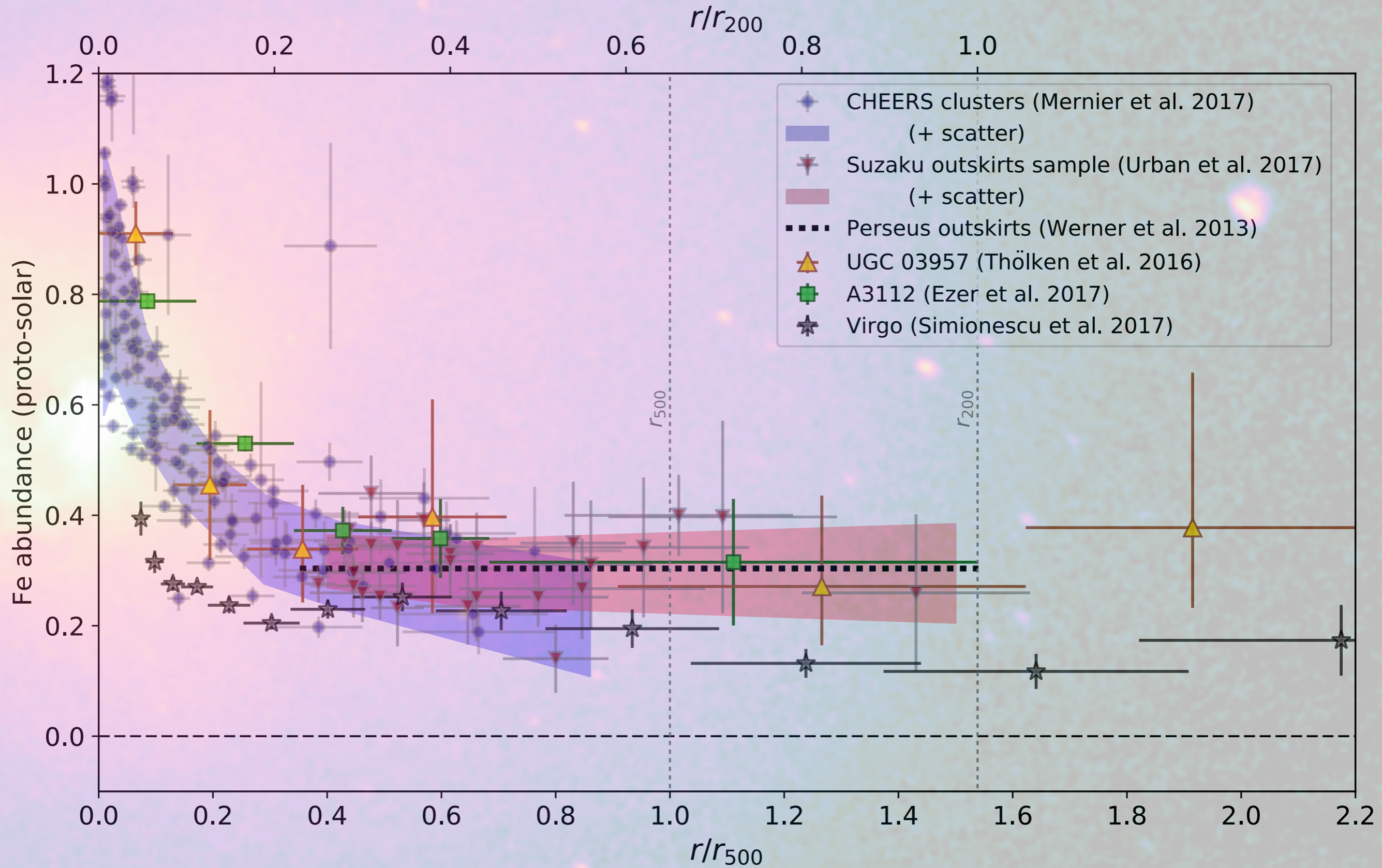
13 kpc

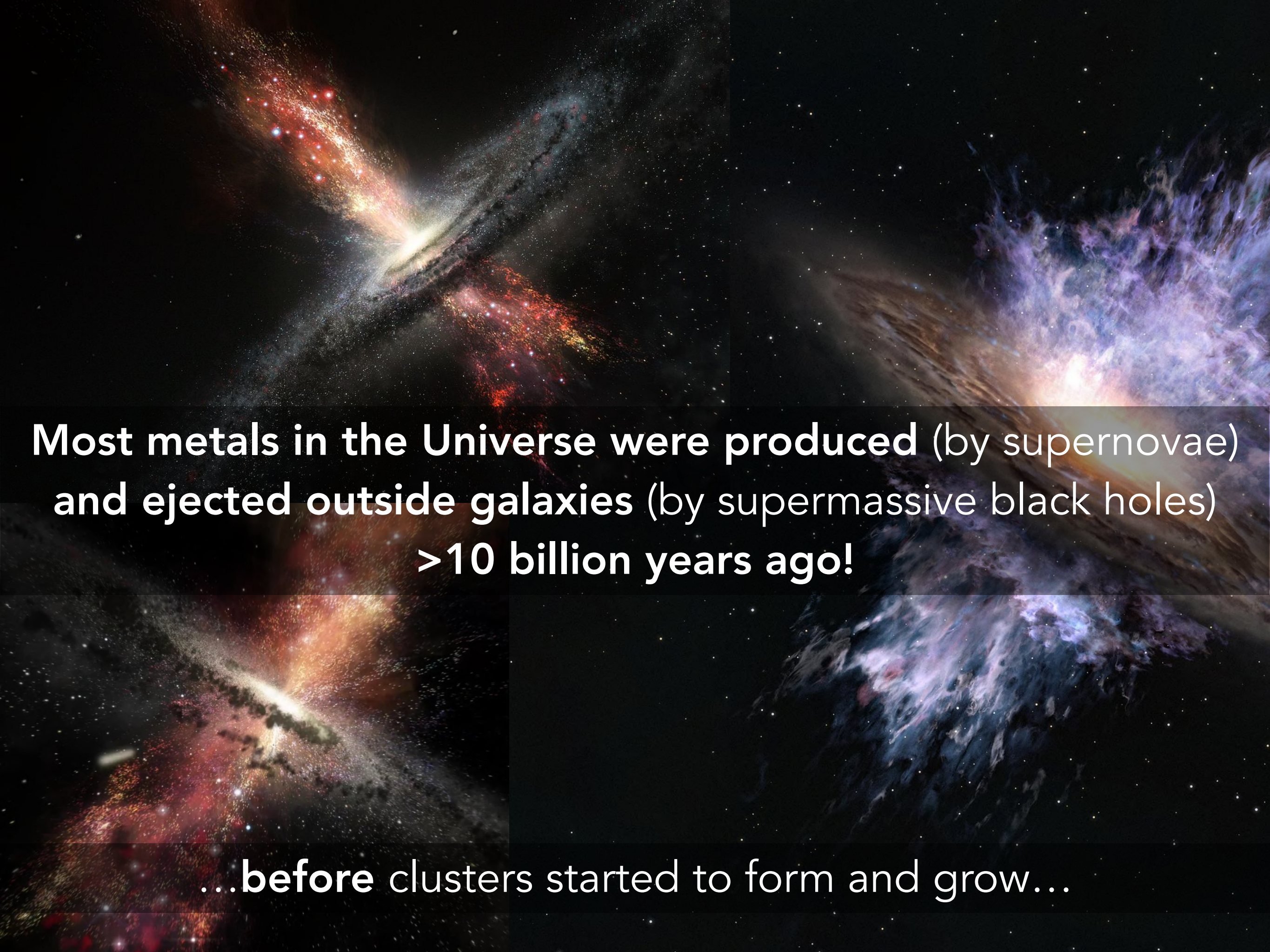
The Centaurus cluster



Metal
abundance



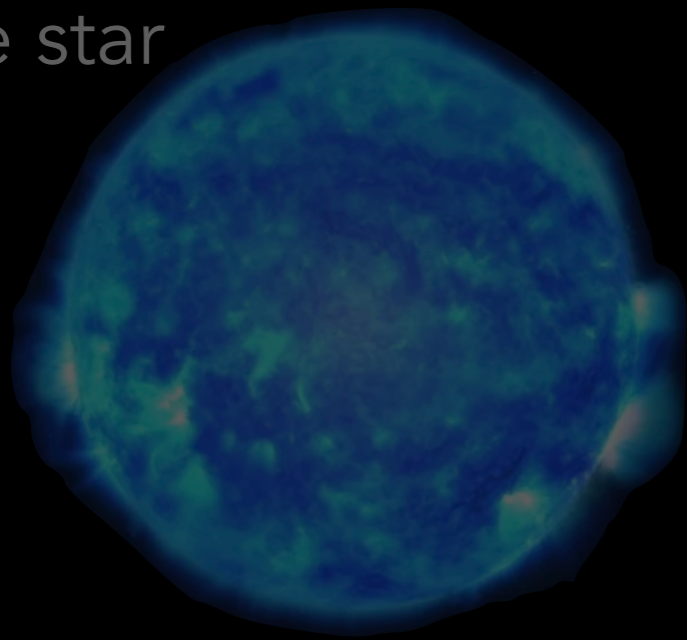




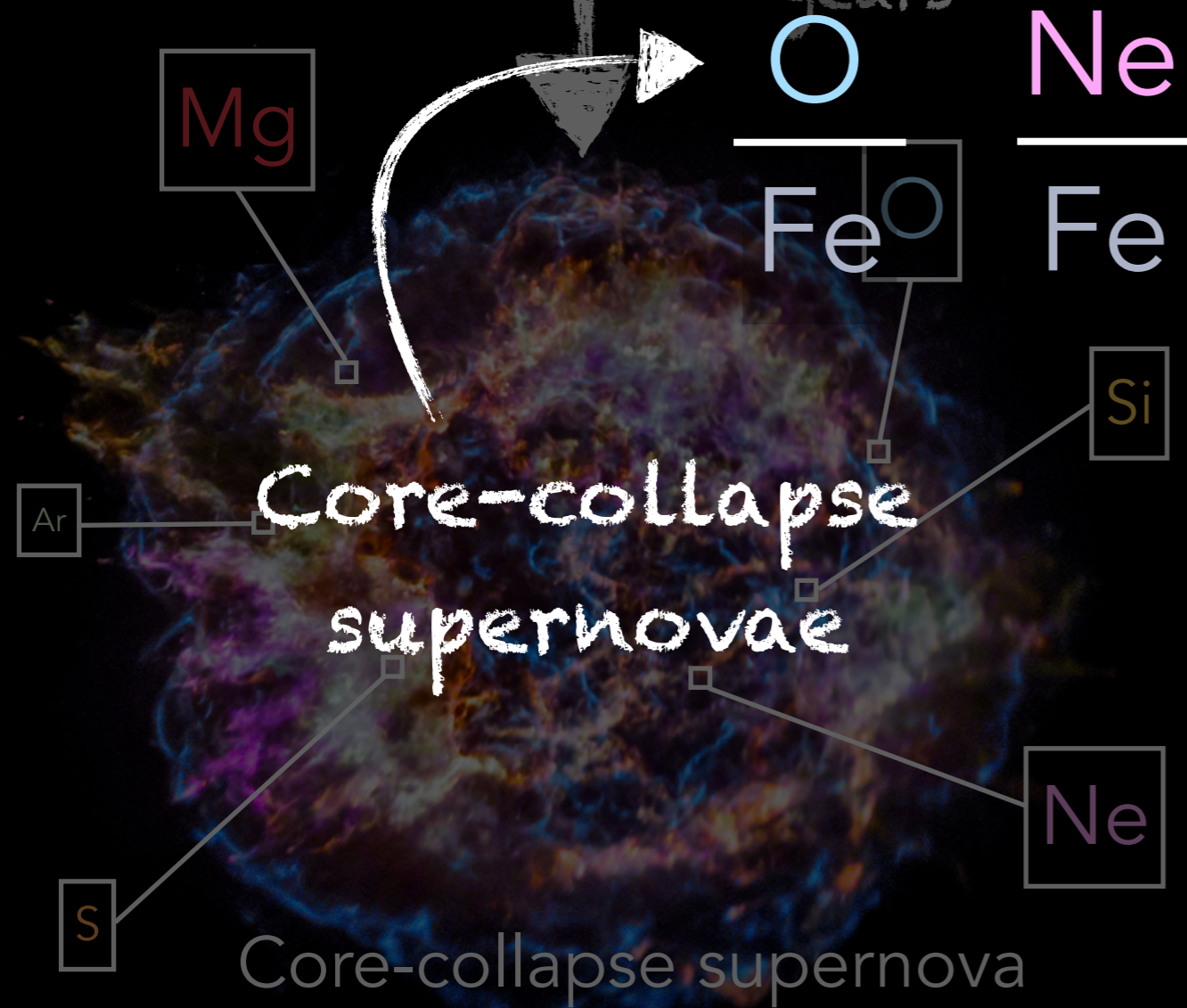
**Most metals in the Universe were produced (by supernovae)
and ejected outside galaxies (by supermassive black holes)
>10 billion years ago!**

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

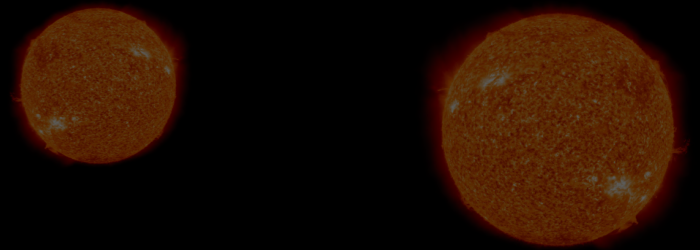
Massive star



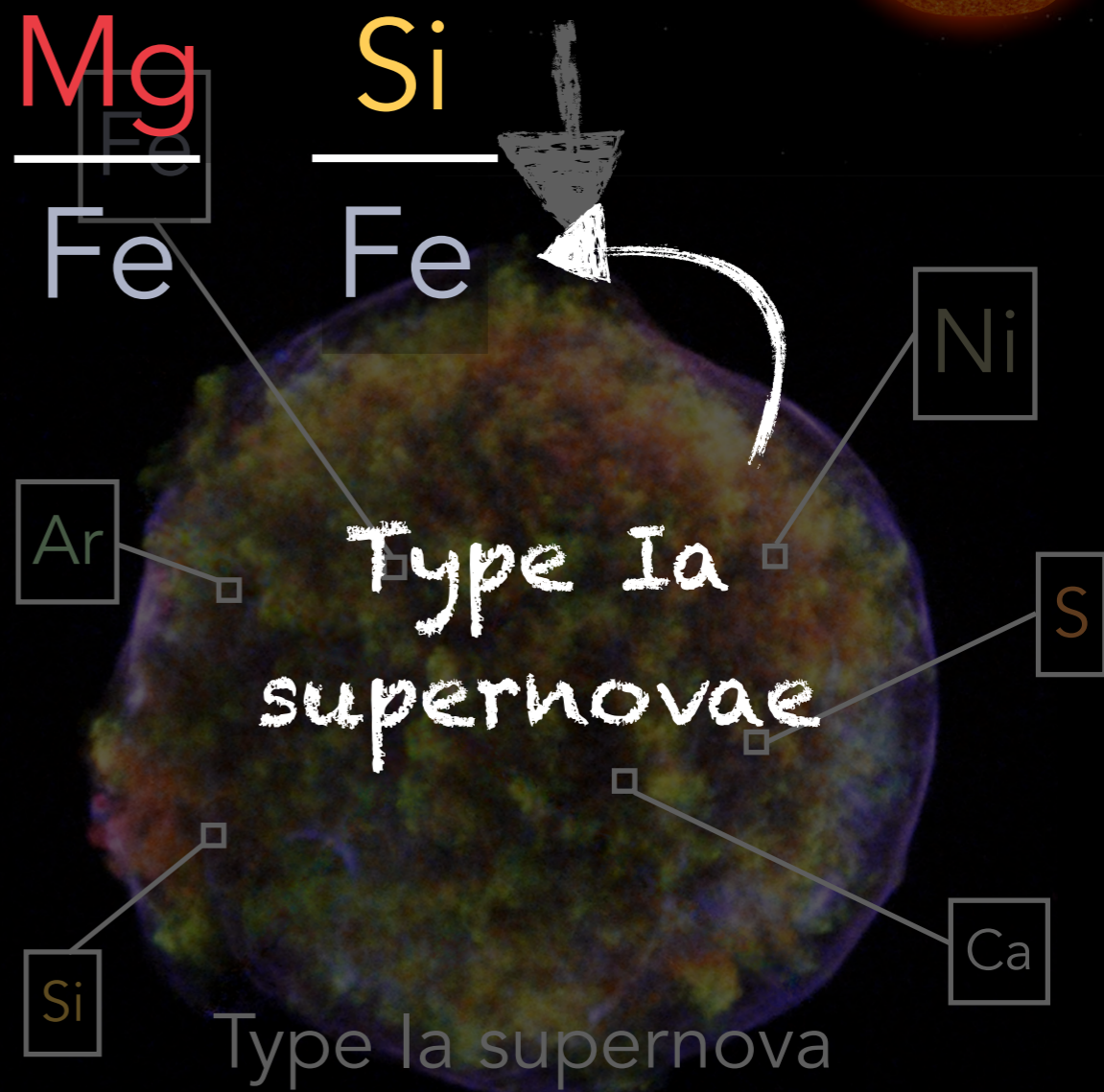
<30 million years

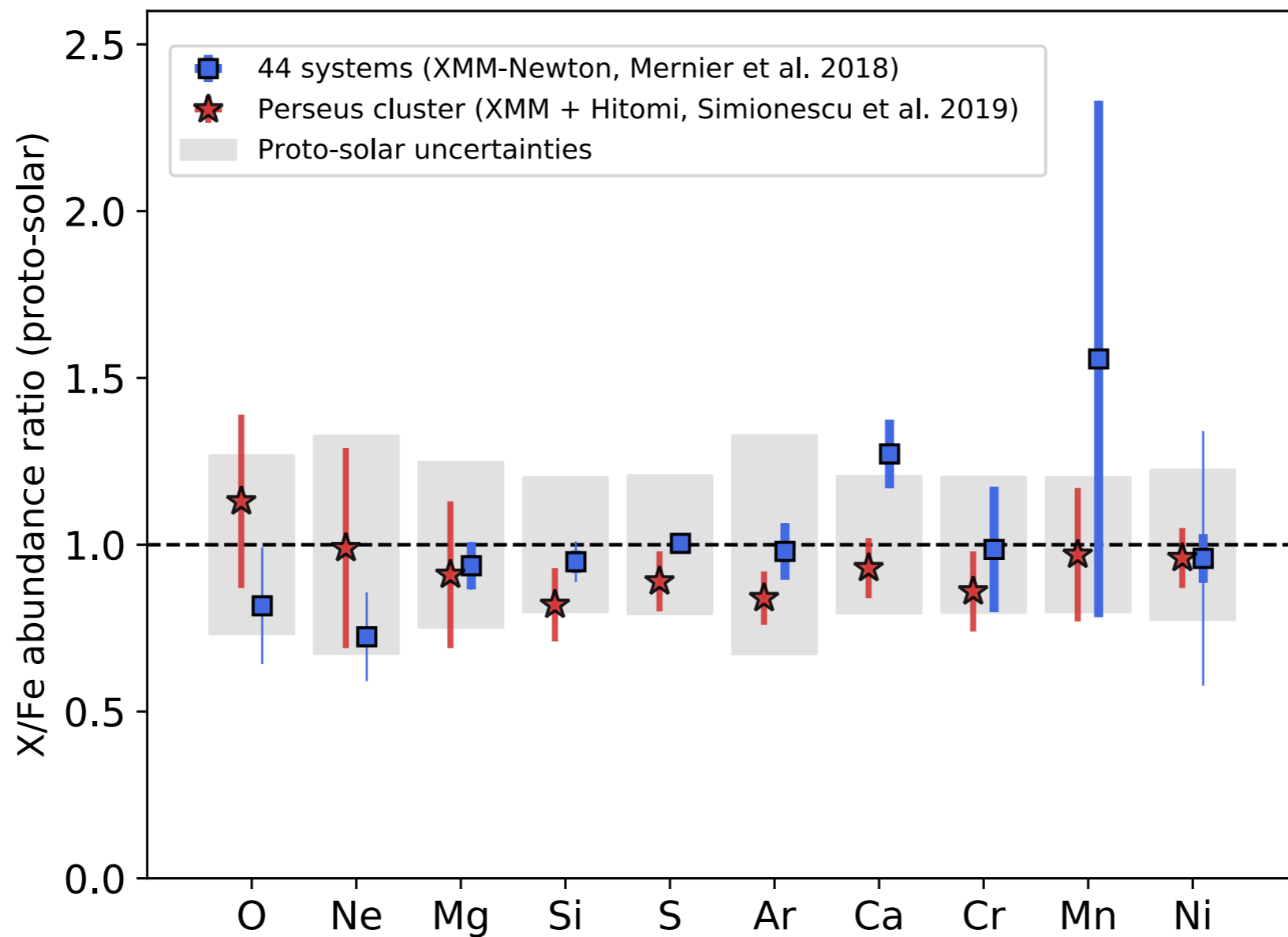


Low-mass stars



>1 billion years

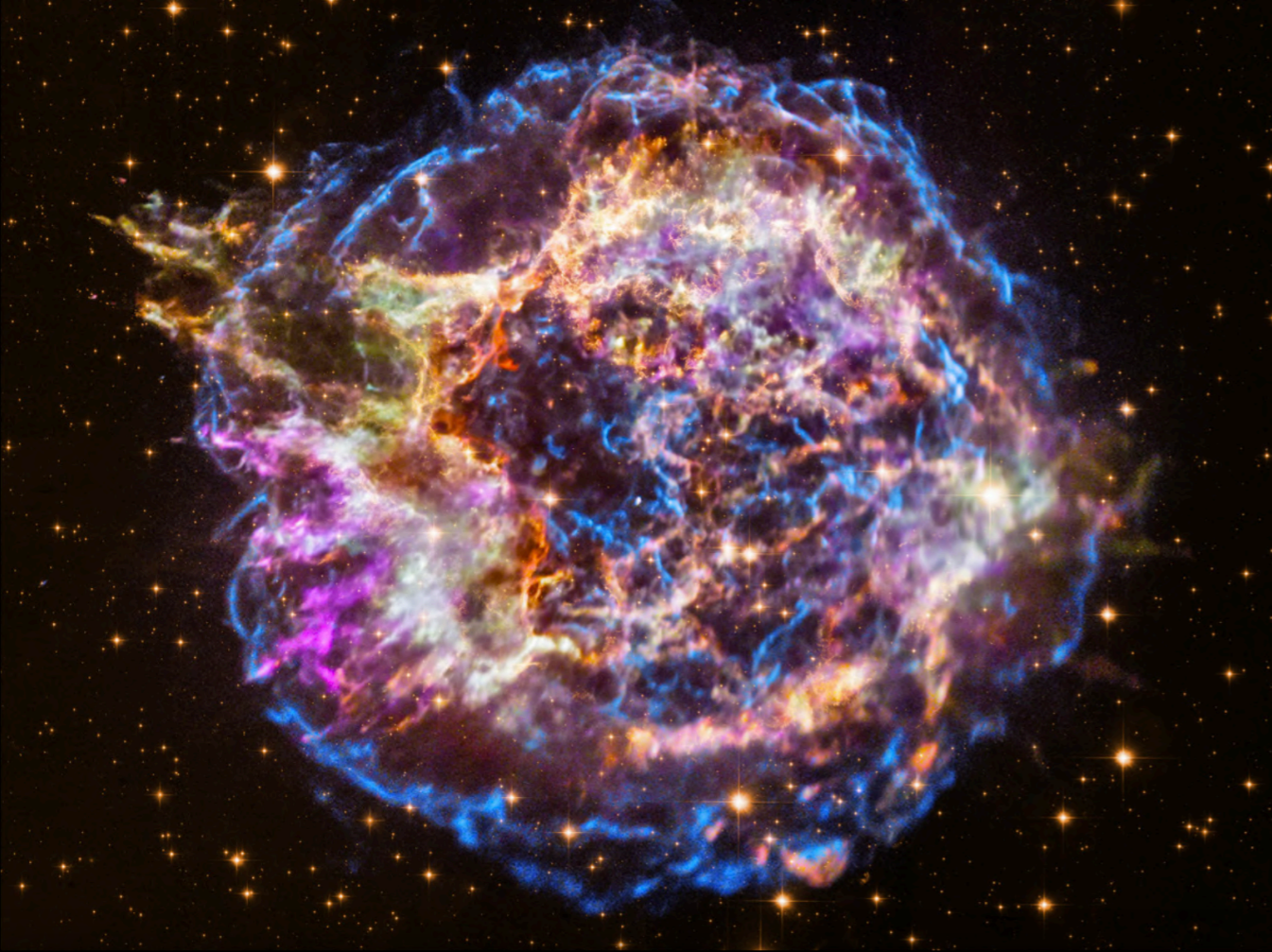




Norma Arm

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

<- Our Solar System



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!