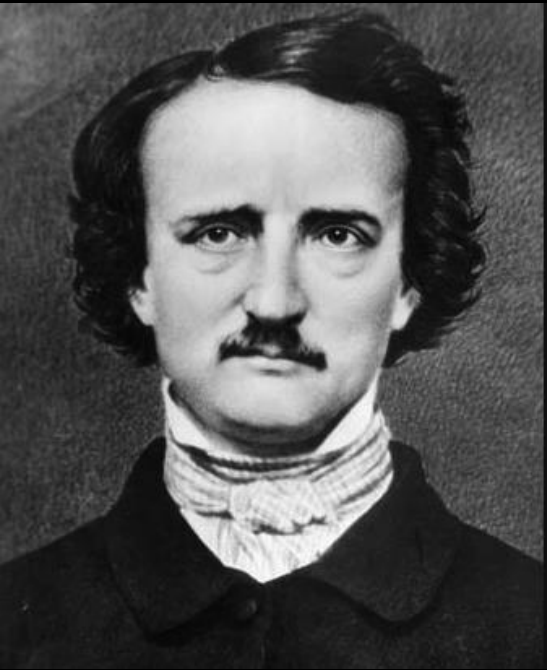


COSMIC ARCHAEOLOGY

Joseph Silk
Dec 2nd 2015

Edgar Allen Poe 1809-1849



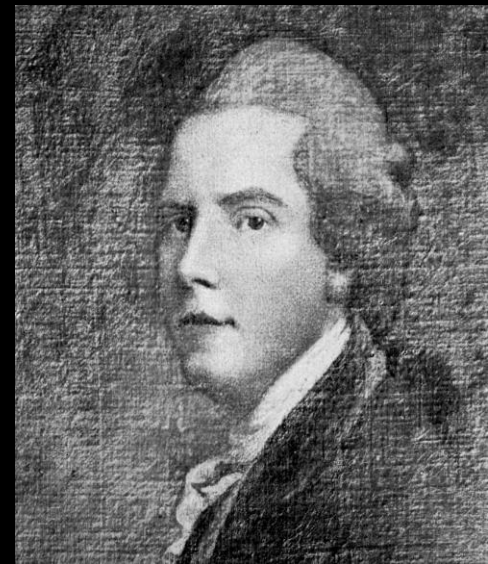
OLBERS' PARADOX: why is the night sky so dark?

Were the succession of stars endless, then the background of the sky would present us a uniform luminosity, like that displayed by the Galaxy – since there could be absolutely no point, in all that background, at which would not exist a star. The only mode, therefore, in which, under such a state of affairs, we could comprehend the voids which our telescopes find in innumerable directions, would be by supposing the distance of the invisible background so immense that no ray from it has yet been able to reach us at all.

Heinrich Olbers 1758-1840



Thomas Digges 1546-1595



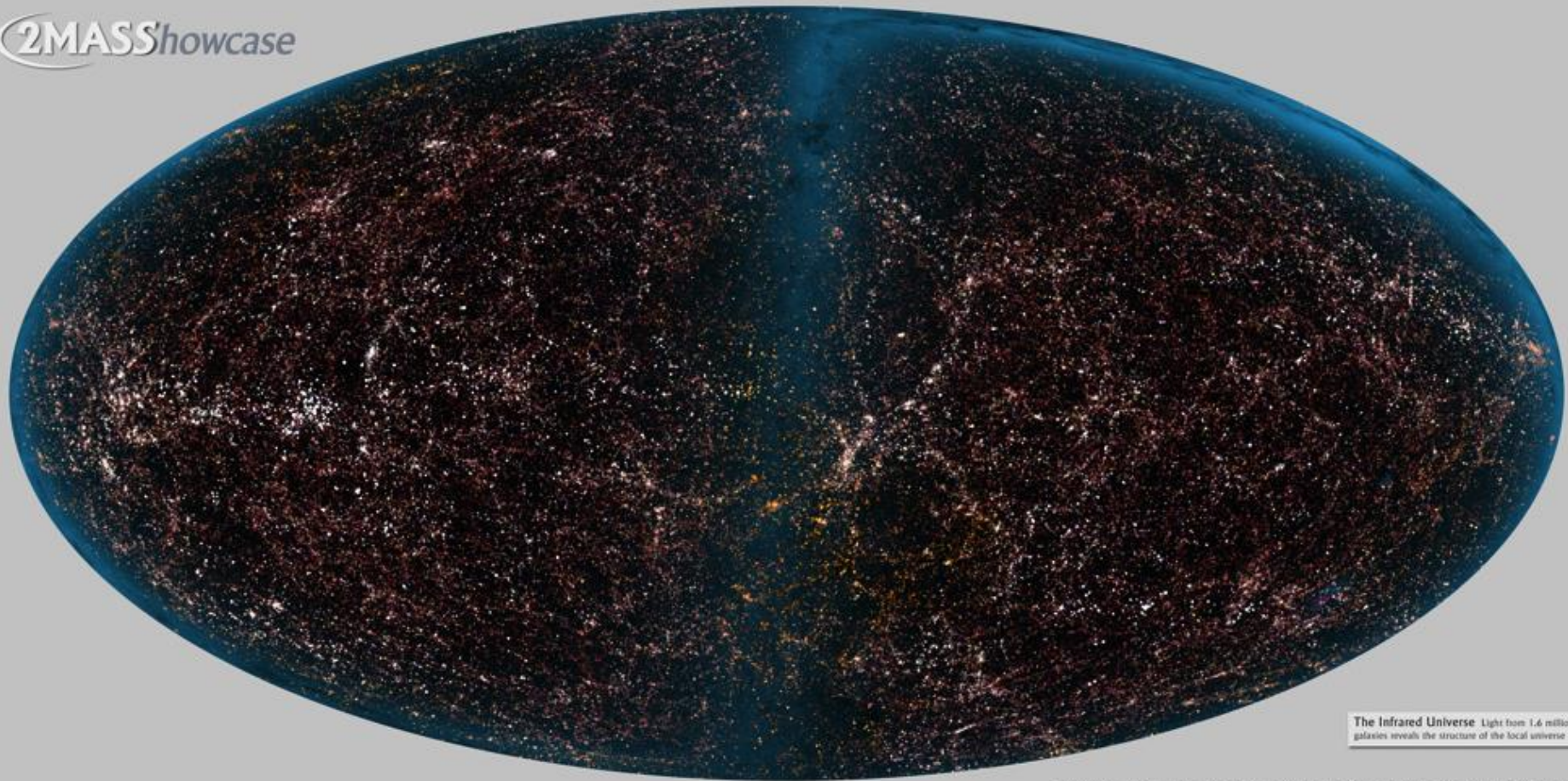




Hubble eXtreme Deep Field (XDF)
Hubble Space Telescope • ACS/WFC • WFC3/IR

The local universe

2MASS Showcase



The Infrared Universe: Light from 1.4 million galaxies reveals the structure of the local universe

Two Micron All Sky Survey Image Mosaic: Infrared Processing and Analysis Center/Caltech & University of Massachusetts

2MASS infrared galaxy survey: 10^6 galaxies

Why the sky is dark at night

Olbers' Paradox

Divide universe into shells of galaxies

Each shell contributes according to its area ($\sim r^2$)
and its contribution decreases as $1/r^2$

So each shell contributes equally

There is no limit if the universe is infinite

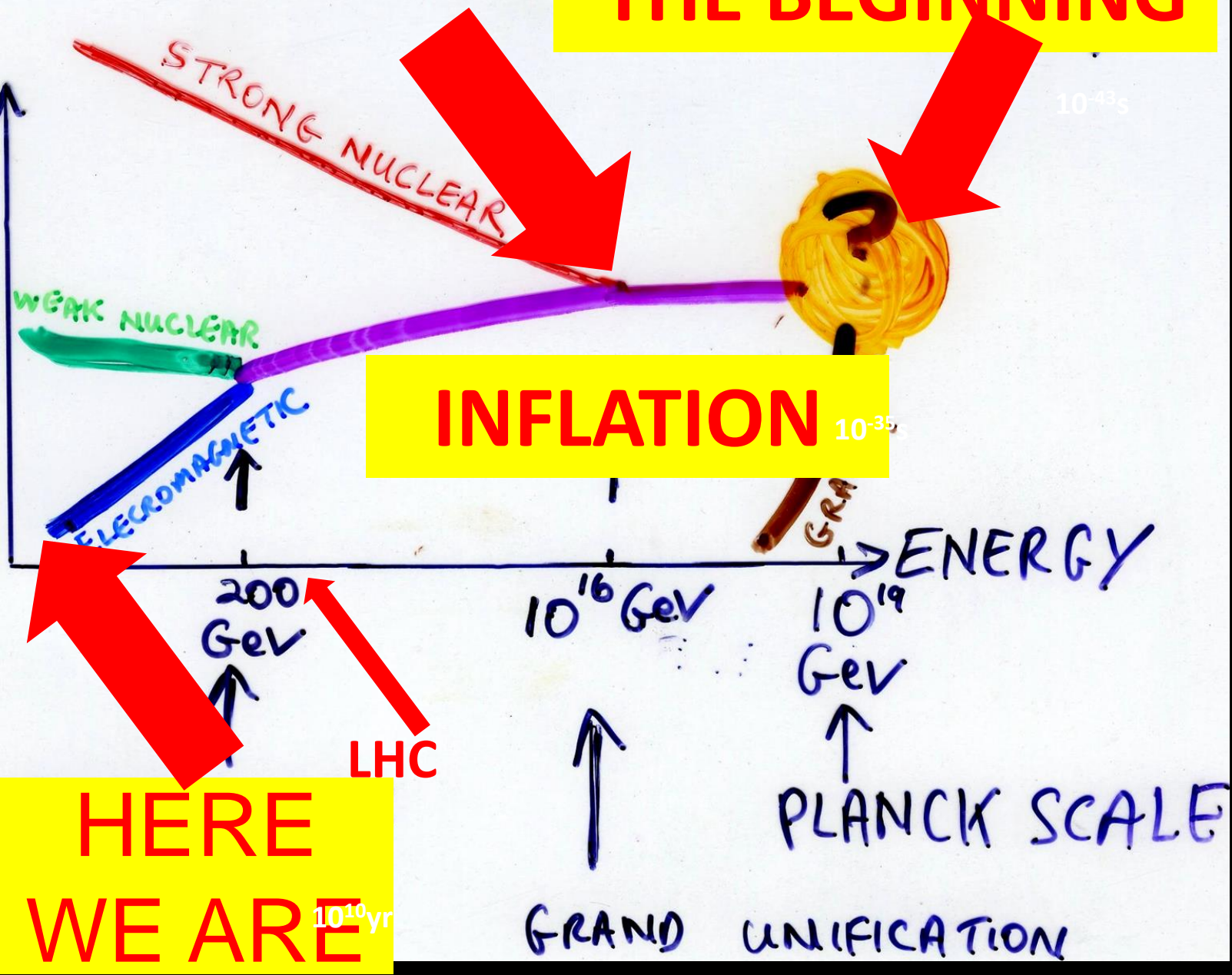
Resolution:

The universe has a finite age,
13.7 billion years otherwise
there would be too many stars

RELICS FROM THE ORIGIN OF SPACE-TIME

- the fundamental forces of nature

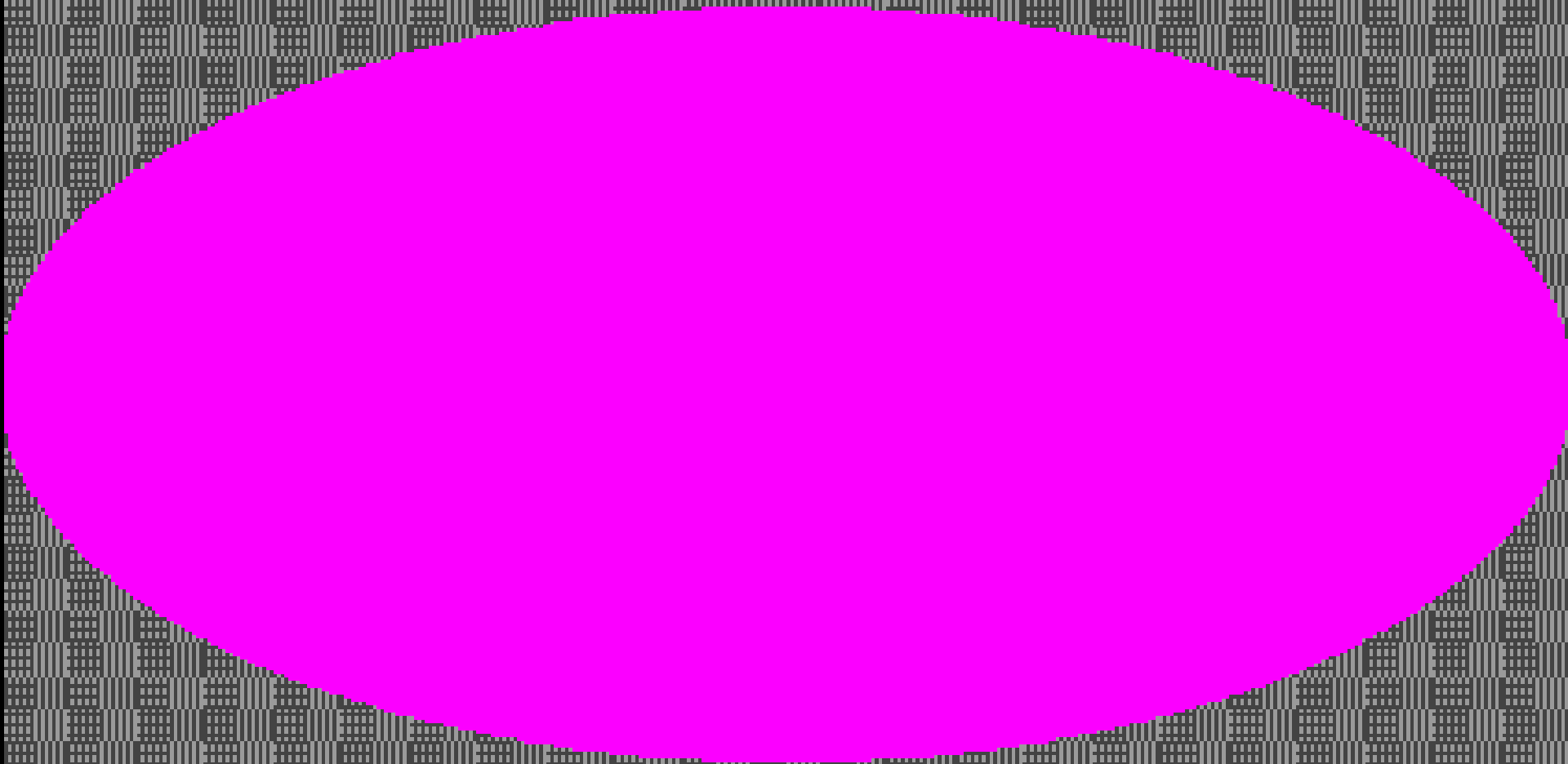
THE BEGINNING



RELIQS FROM 10^{-36} second
AFTER THE BIG BANG

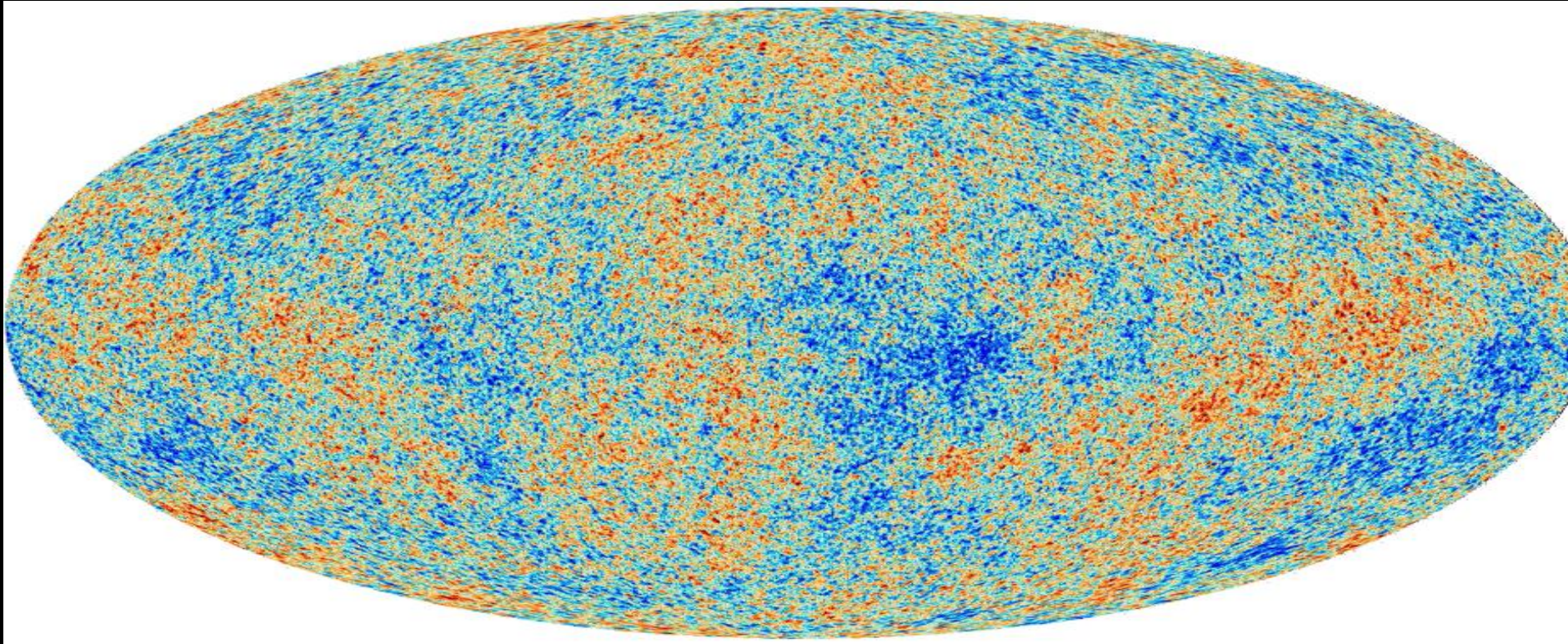
The distant universe

COBE DMR Microwave Sky at 53 GHz



0 3.64 K

The distant universe (ctd)



Planck satellite: cosmic microwave background fluctuations at 1 part in 10^5

- Age of the universe from the expansion

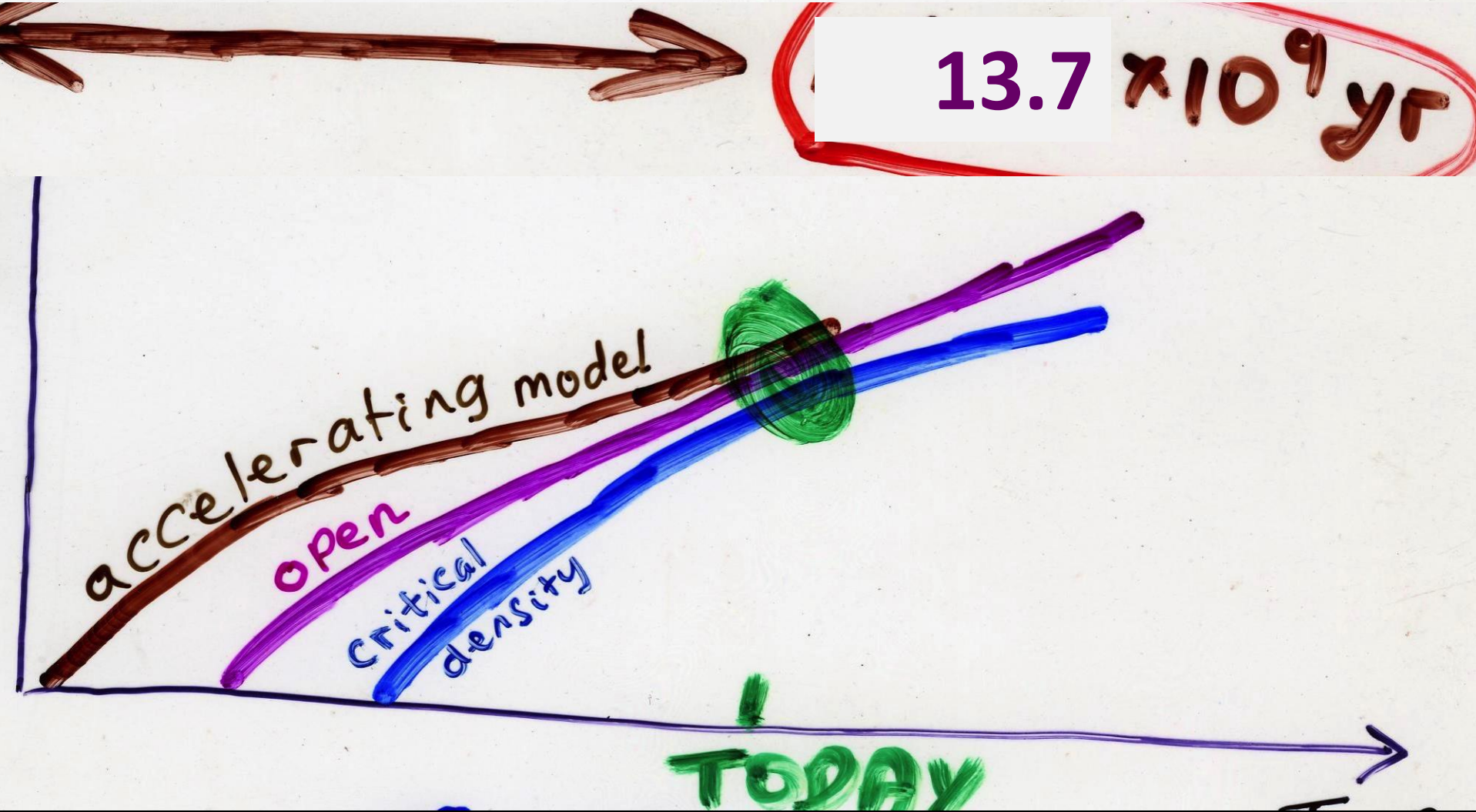
$13.7 \times 10^9 \text{ yr}$

accelerating model

open

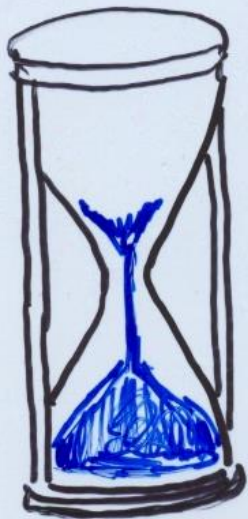
critical density

TODAY

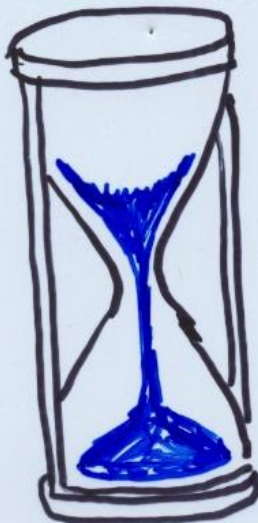


- Age of the universe from the expansion
- Age from radioactive chemistry

OLD



YOUNG



"NEW-BORN"

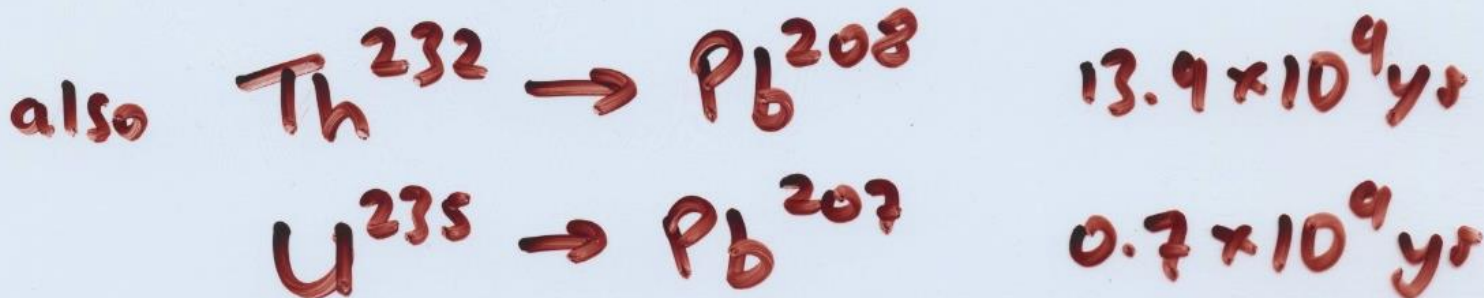


U^{238}
decays
with
half life
 4×10^9 yr

Pb^{205} ←

radiogenic isotope of lead

only formed by this decay process



ORIGIN OF THE LIGHT ELEMENTS

H B		<div style="display: flex; justify-content: space-around; align-items: center;"> <div style="border: 1px solid black; padding: 2px; background-color: #d9ead3;">B</div> <div style="border: 1px solid black; padding: 2px; background-color: #d9ead3;">L</div> <div style="border: 1px solid black; padding: 2px; background-color: #d9ead3;">\$</div> </div> <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="border: 1px solid black; padding: 2px; background-color: #d9ead3;">c</div> <div style="border: 1px solid black; padding: 2px; background-color: #d9ead3;">s</div> <div style="border: 1px solid black; padding: 2px; background-color: #d9ead3;">M</div> </div>										He B														
Li C	Be C											B C	C S L	N S L	O S L	F L	Ne S L									
Na L	Mg L											Al \$ L	Si \$ L	P L	S S L	Cl L	Ar L									
K L	Ca L	Sc L	Ti \$ L	V \$ L	Cr L	Mn L	Fe \$ L	Co \$	Ni \$	Cu L	Zn L	Ga \$	Ge \$	As L	Se \$	Br \$	Kr \$									
Rb \$	Sr L	Y L	Zr L	Nb L	Mo \$ L	Tc L	Ru \$ L	Rh \$	Pd \$ L	Ag \$ L	Cd \$ L	In \$ L	Sn \$ L	Sb \$	Te \$	I \$	Xe \$									
Cs \$	Ba L											Hf \$ L	Ta \$ L	W \$ L	Re \$	Os \$	Ir \$	Pt \$	Au \$	Hg \$ L	Tl \$ L	Pb \$	Bi \$	Po \$	At \$	Rn \$
Fr \$	Ra \$											La L	Ce L	Pr \$ L	Nd \$ L	Pm \$ L	Sm \$ L	Eu \$	Gd \$	Tb \$	Dy \$	Ho \$	Er \$	Tm \$	Yb \$ L	Lu \$
												Ac \$	Th \$	Pa \$	U \$	Np \$	Pu \$	Am M	Cm M	Bk M	Cf M	Es M	Fm M	Md M	No M	Lr M

predicted origin of light elements & fossil radiation in 1949

The Origin of Chemical Elements

R. A. ALPHER*

*Applied Physics Laboratory, The Johns Hopkins University,
Silver Spring, Maryland*

AND

H. BETHE

Cornell University, Ithaca, New York

AND

G. GAMOW

The George Washington University, Washington, D. C.

February 18, 1948



ROBERT HERMAN, GEORGE GAMOW, RALPH ALPHER

*half
an
hour
of
creation...*

PHYSICS TODAY
AUGUST 1950

What happened to place in the first one three

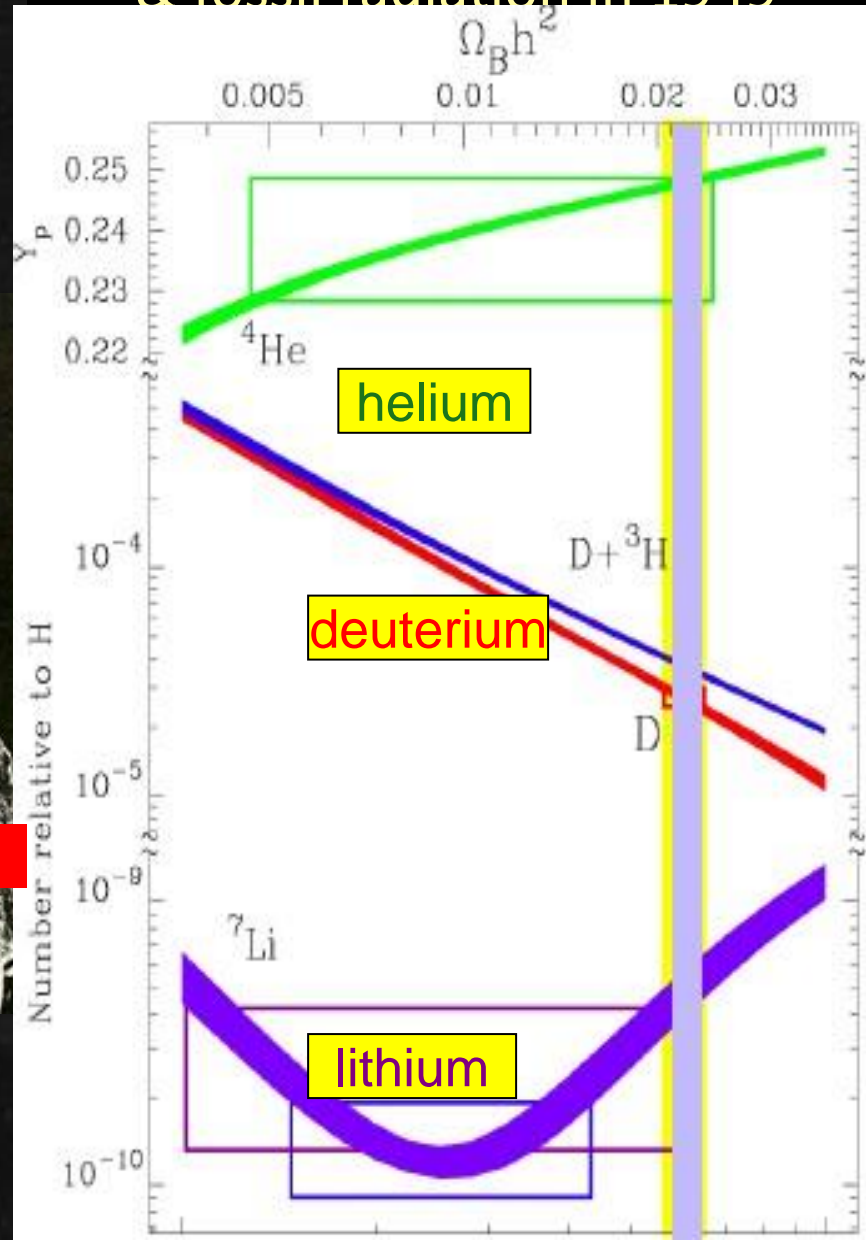
As the present epoch, in which the density of matter in the universe is about 10^{-27} g/cm³, and if temperature is only about 3°K, the density of radiation (according to the Stefan-Boltzmann law) 3×10^{-12} (1/3)°K⁴ or 10^{-12} erg/cm³ or 10^{-12} g/cm³. This even now the mass density of radiation (if total to mass-energy equivalence law) is only an twenty times smaller than that of matter.

By George Gamow

predicted origin of light elements
& fossil radiation in 1949



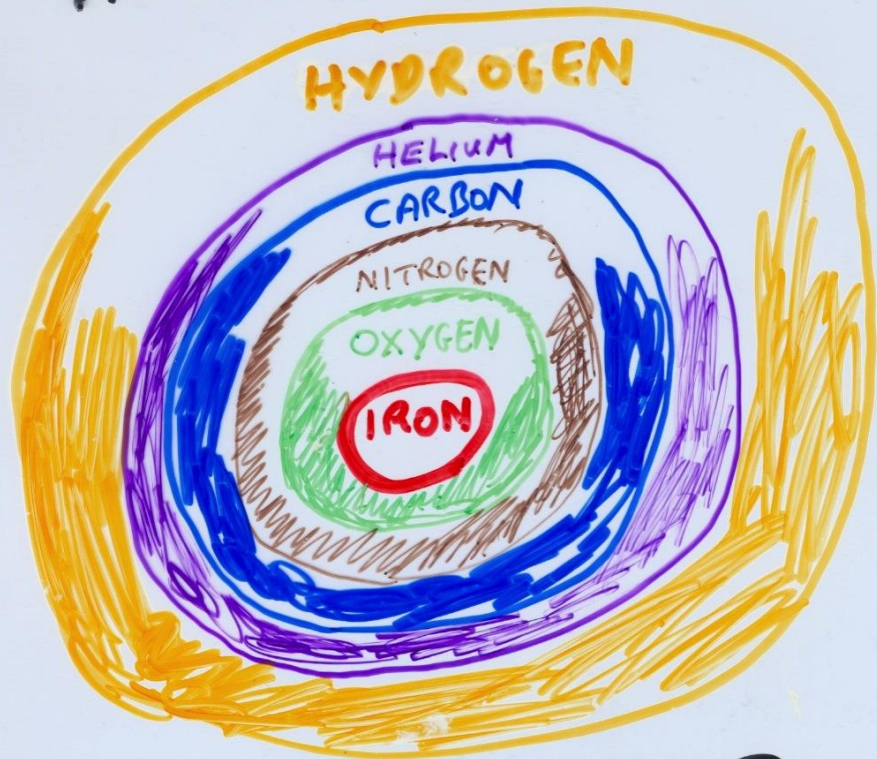
ROBERT HERMAN, GEORGE GAMOW, RALPH ALPHER



ORIGIN OF THE HEAVY ELEMENTS

We are the ashes of stars


A MASSIVE STAR EVOLVES



AND EXPLODES



FROM ITS ASHES OUR SOLAR SYSTEM FORMED

A vintage photograph showing four individuals in an outdoor setting. On the left, a woman in a dark vest over a light-colored shirt is smiling. Next to her, a man in a brown jacket and yellow shirt is looking towards the center. In the center, a man with glasses and a white shirt with a dark tie is looking down at a large, complex piece of scientific equipment on a table. To the right, a man in a light-colored sweater and glasses is leaning forward, looking at the equipment. The background consists of dense green foliage.

Margaret Burbidge

Geoff Burbidge

Willy Fowler

Fred Hoyle

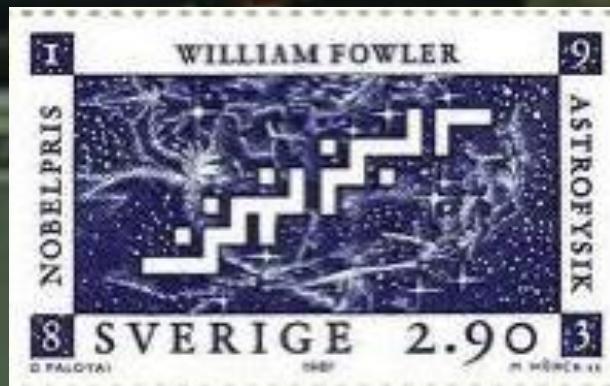


Margaret Burbidge

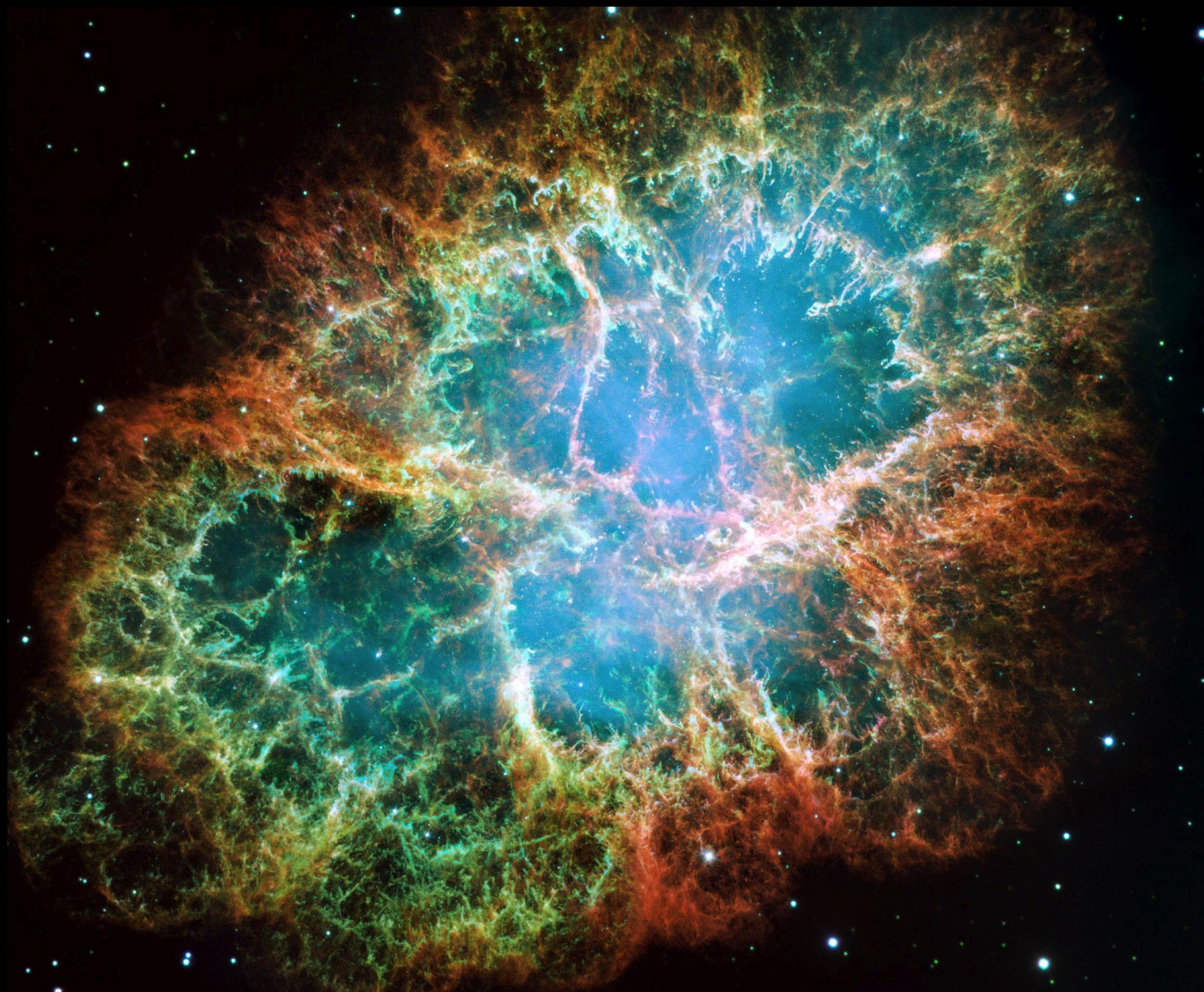
Geoff Burbidge



Fred Hoyle



Willy Fowler



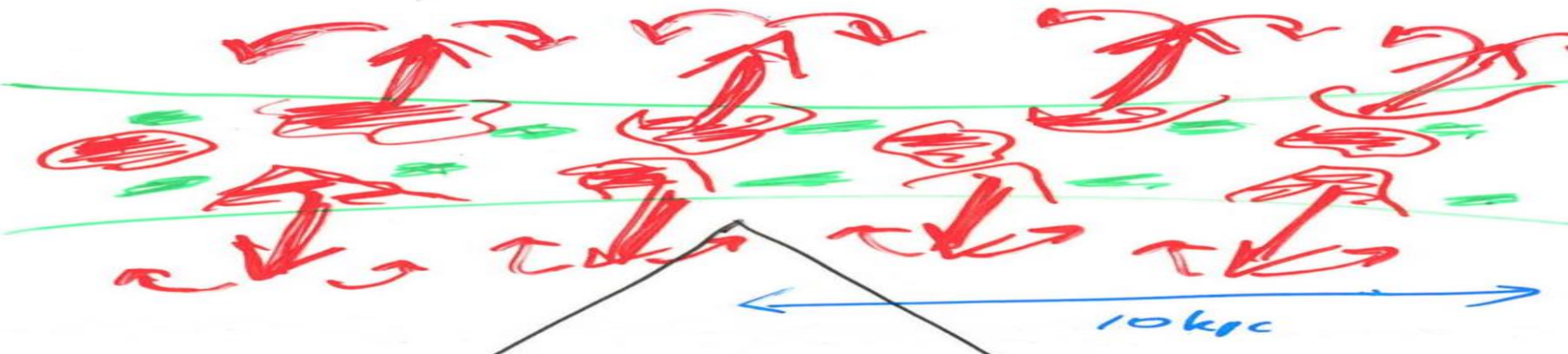
Relic of an exploding star recorded by Chinese astronomers in 1054

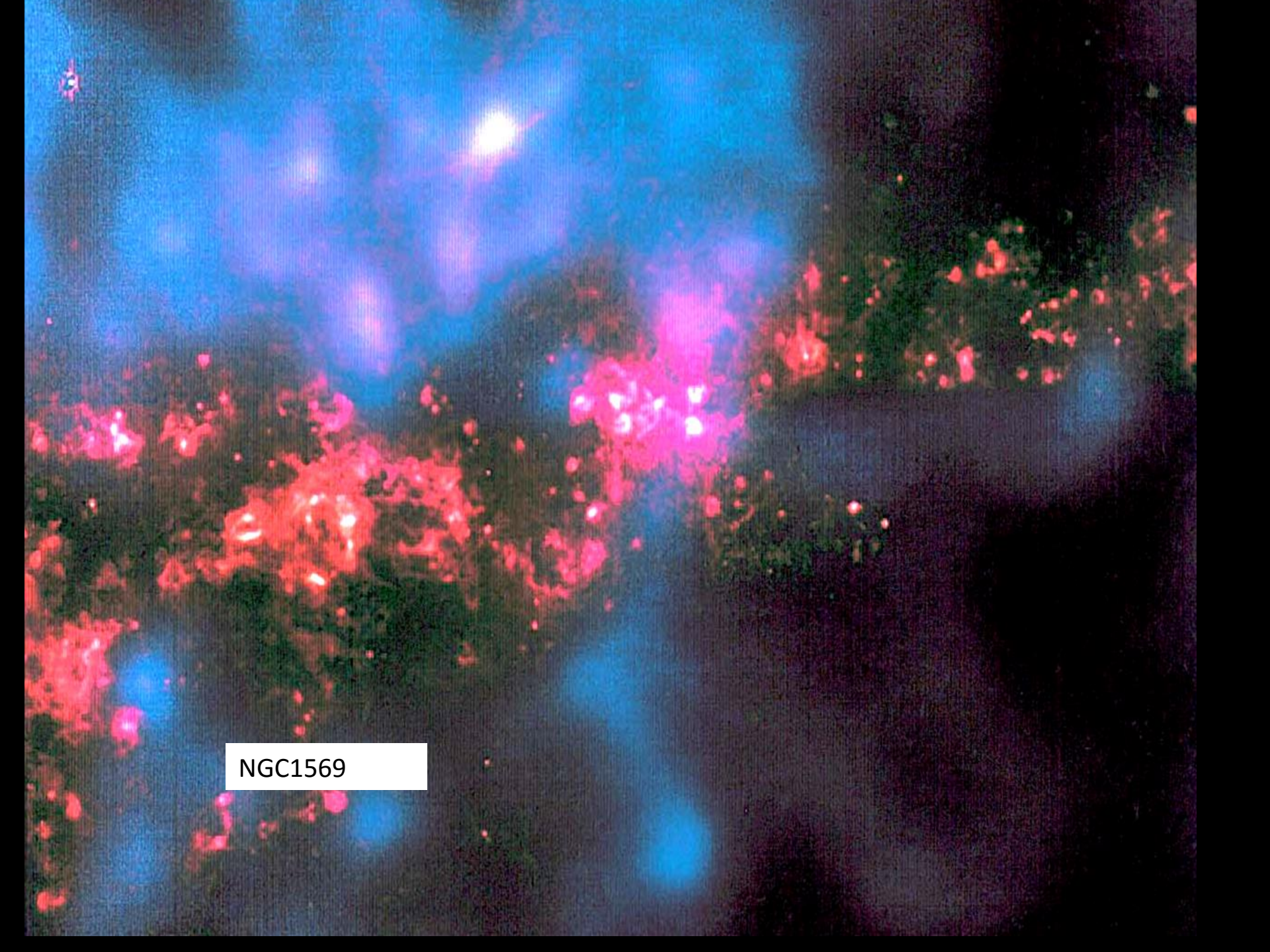


CIRCULATION OF THE DEBRIS



CIRCULATION OF THE DEBRIS

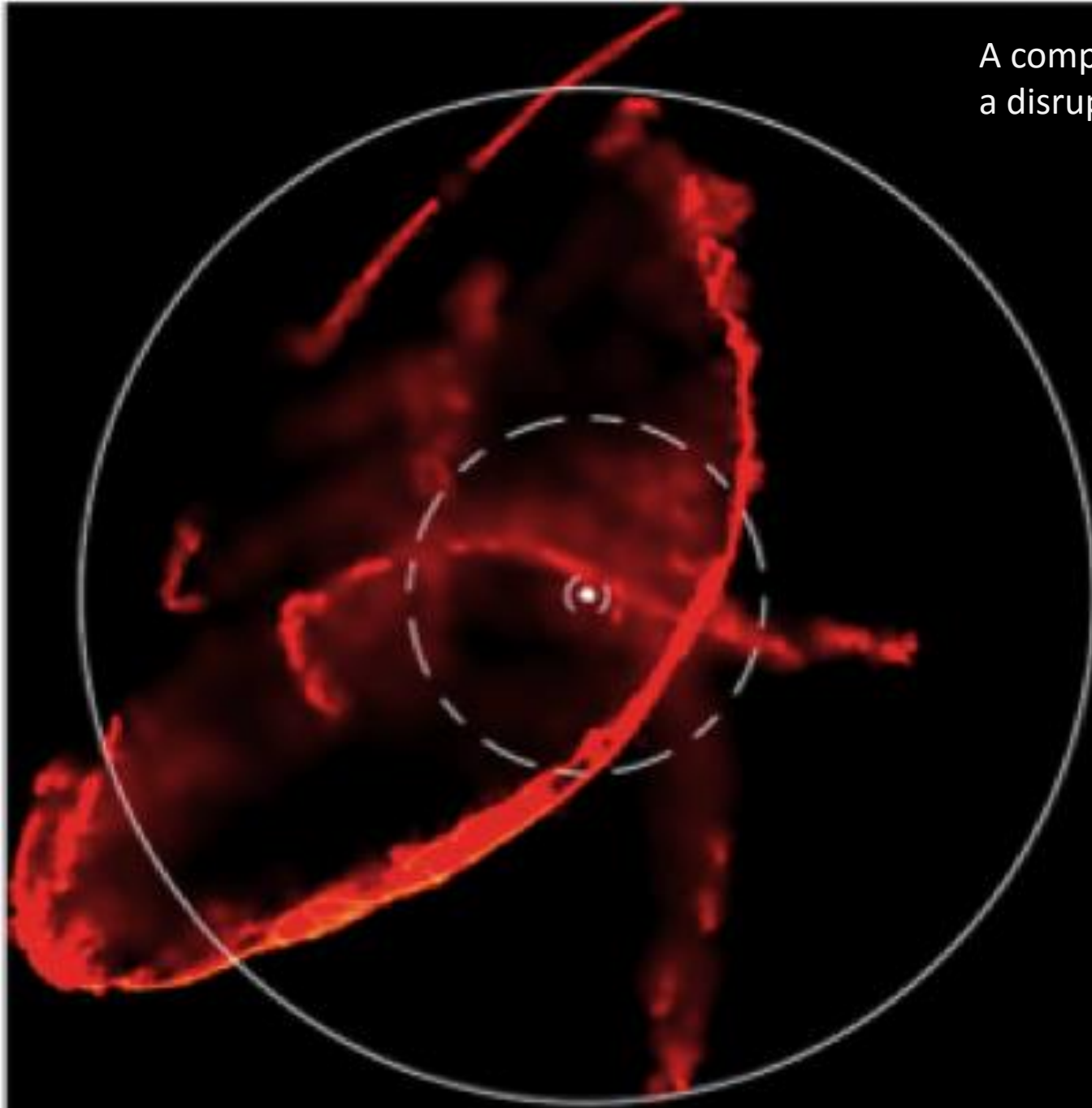


This is a multi-color astronomical image of the galaxy NGC 1569. The image displays a complex structure with a prominent blue region in the upper left and a large, irregular red region in the lower left and center. The background is dark, with scattered blue and red points of light. The overall appearance is that of a star-forming galaxy with distinct color-coded regions.

NGC1569

GALACTIC DISRUPTION

A computer simulation of
a disrupted infalling dwarf galaxy

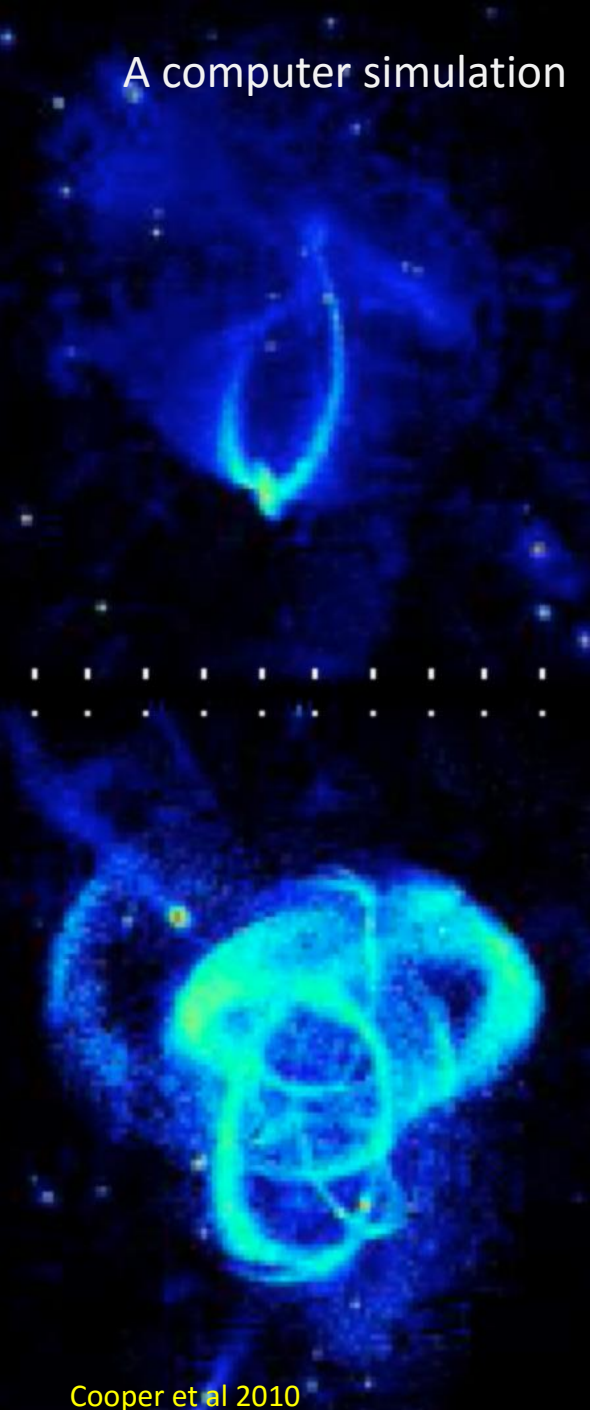


Bonnell 2015



A nearby galaxy

A computer simulation



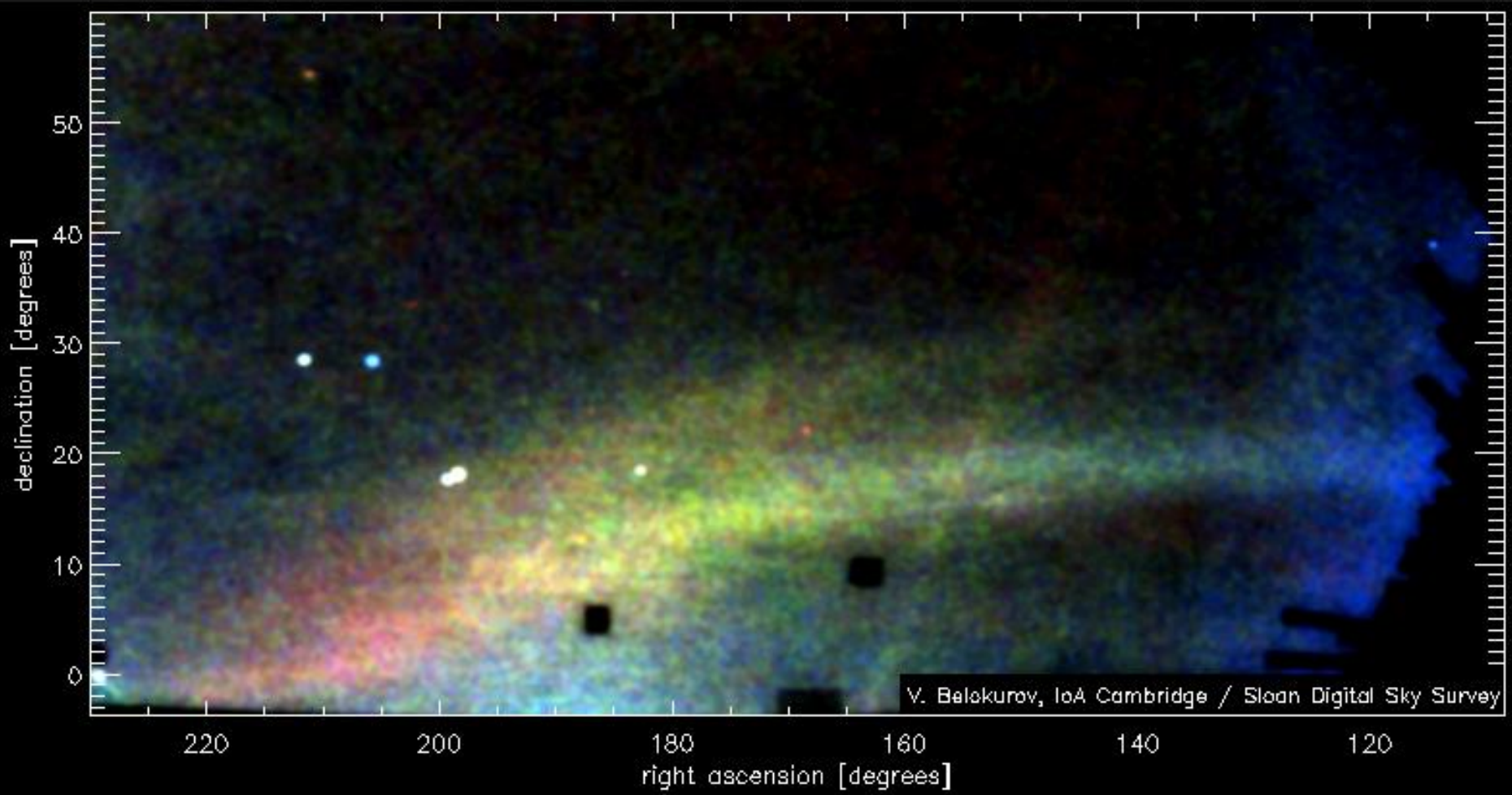
Cooper et al 2010

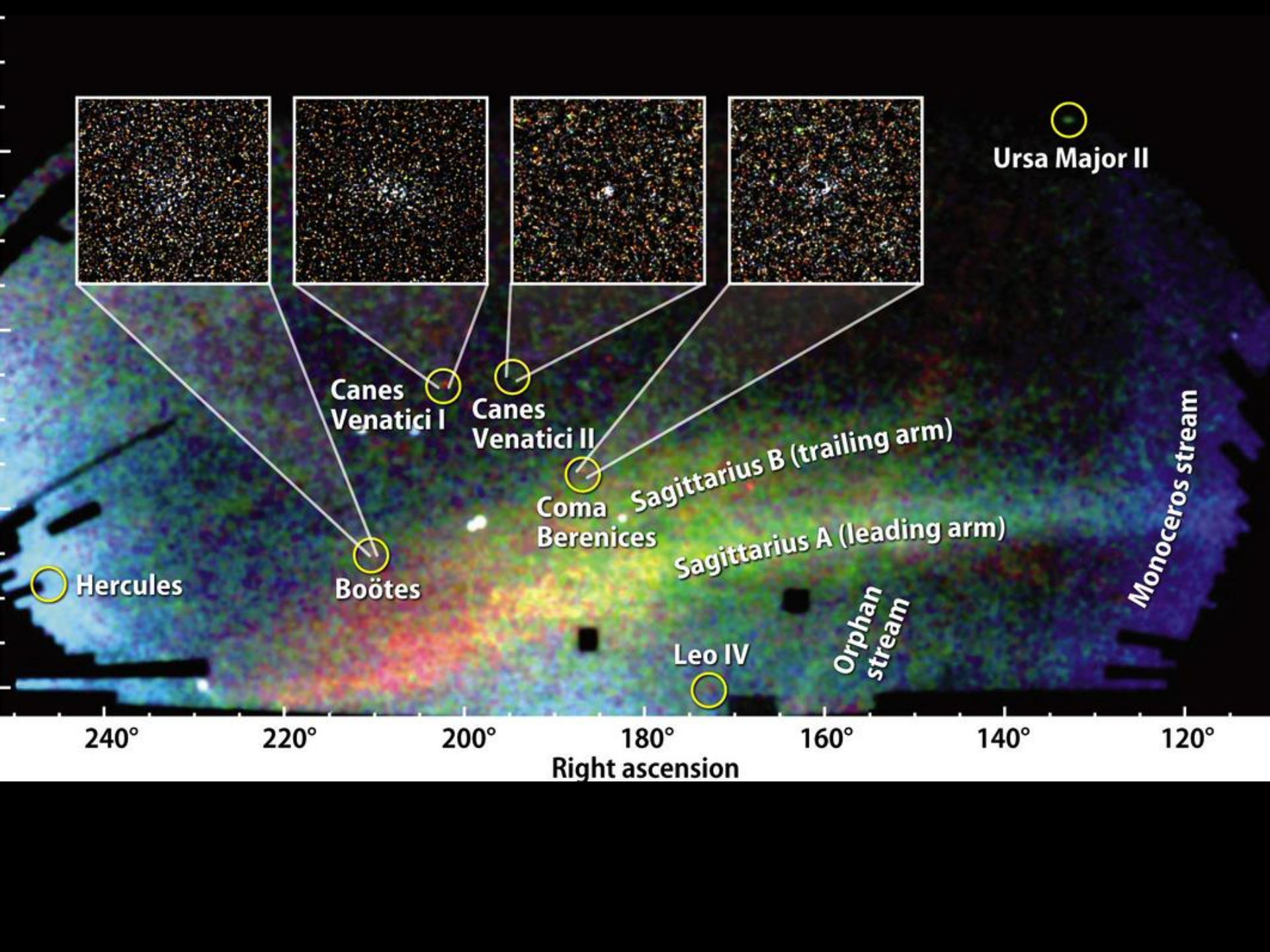
Martinez-Delgado et al 2008



A nearby galaxy

THE FIELD OF STREAMS





ULTRAFAIN T DWARF GALAXIES

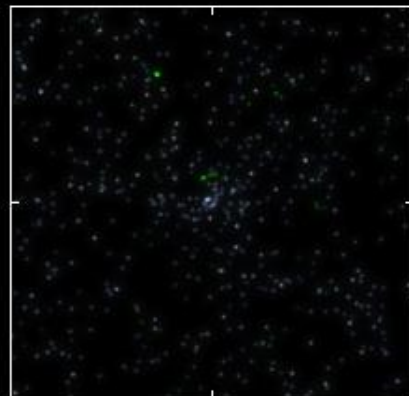
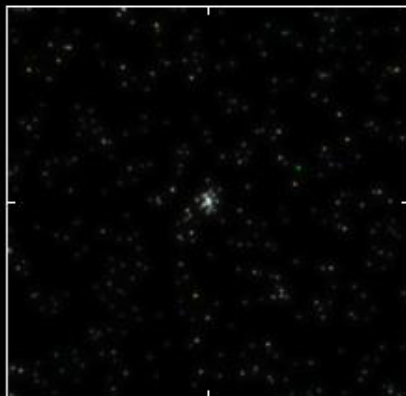
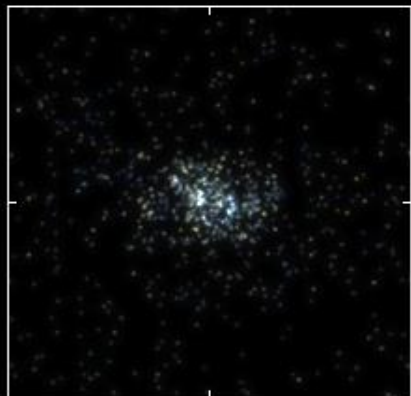
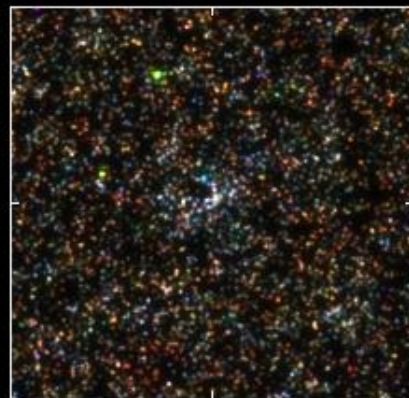
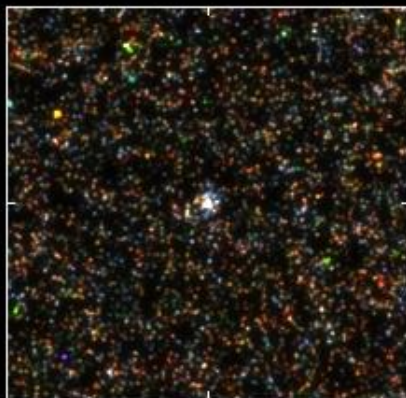
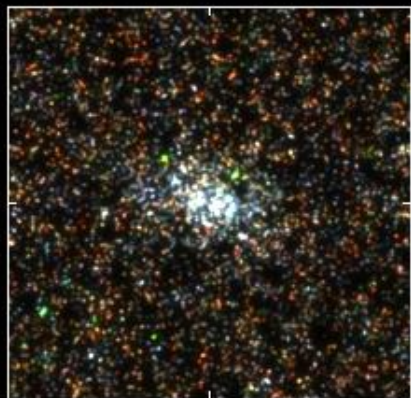
A gallery of SDSS dwarf galaxies

Canes Venatici I

Bootes

Canes Venatici II

Coma Berenices



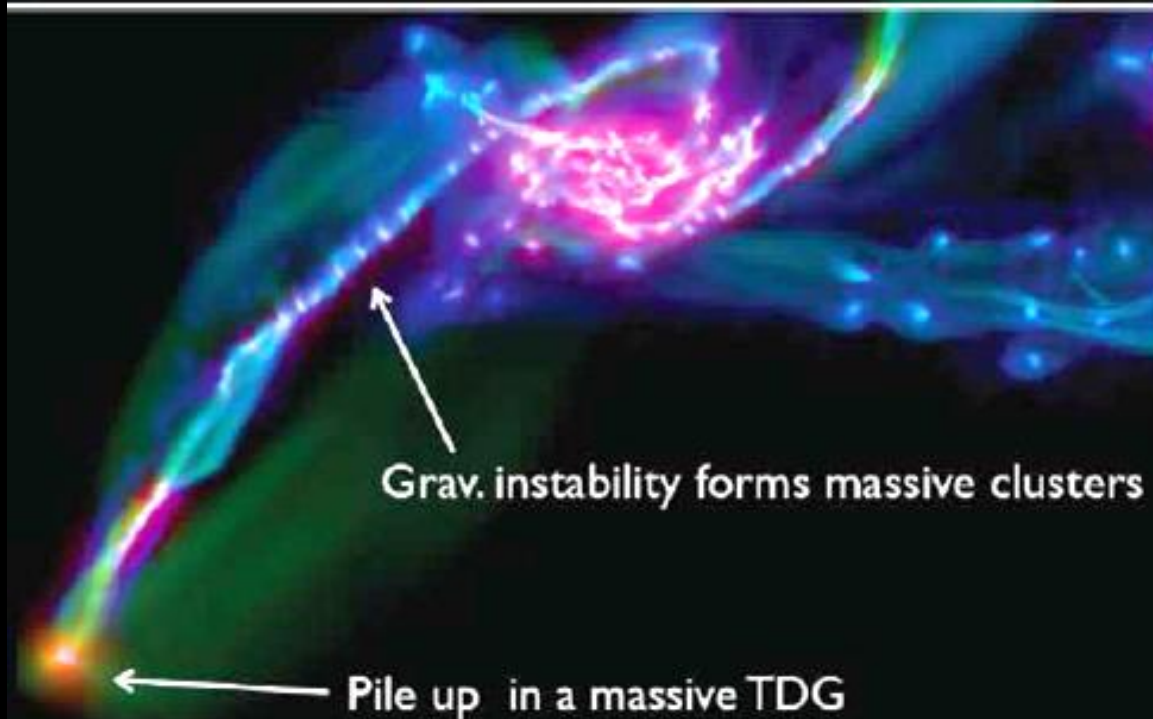
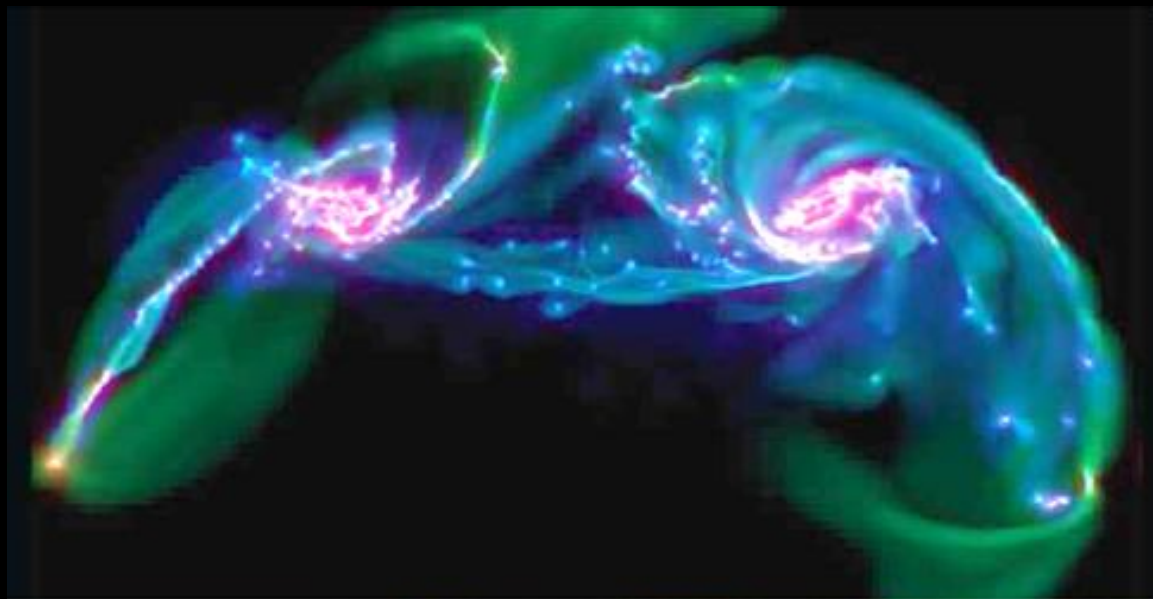
$D = 220$ kpc
 $r_h = 550$ pc
 $M_V = -7.9$ mag

$D = 60$ kpc
 $r_h = 220$ pc
 $M_V = -5.8$ mag

$D = 150$ kpc
 $r_h = 140$ pc
 $M_V = -4.8$ mag

$D = 44$ kpc
 $r_h = 70$ pc
 $M_V = -3.7$ mag

GALAXY COLLISIONS



Grav. instability forms massive clusters

Pile up in a massive TDG

Interacting Galaxies Arp 273



Whirlpool Galaxy · M51





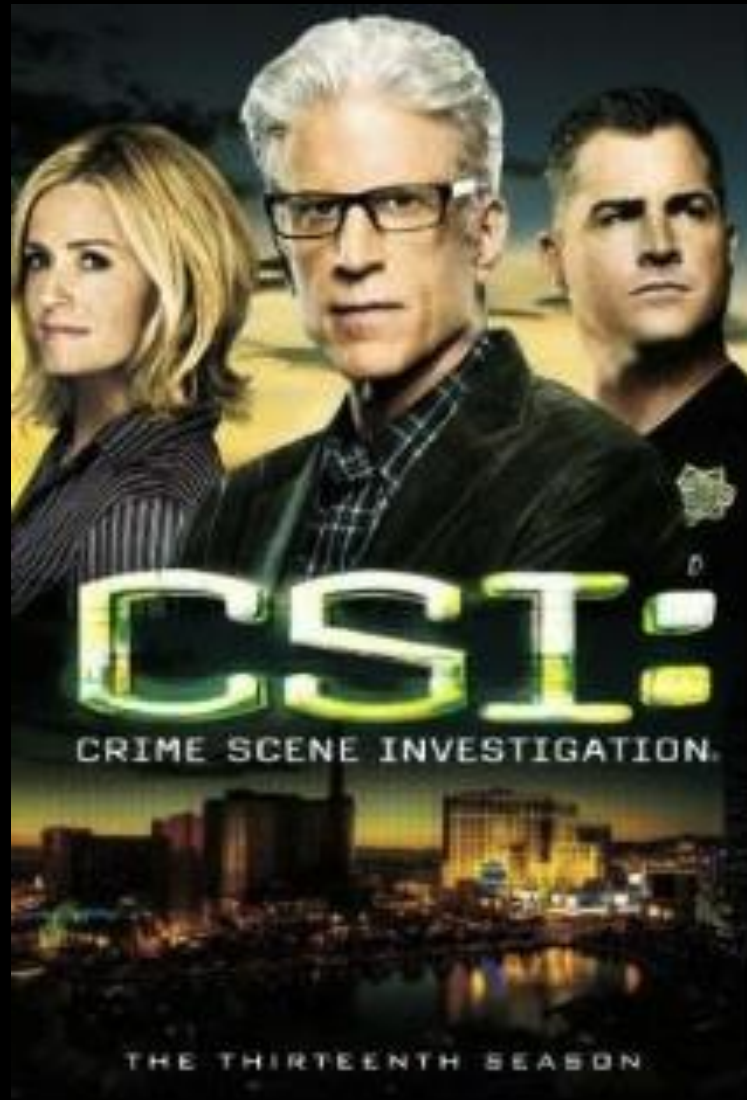
NGC 4038-4039 • Antennae Galaxies



some typical galaxies

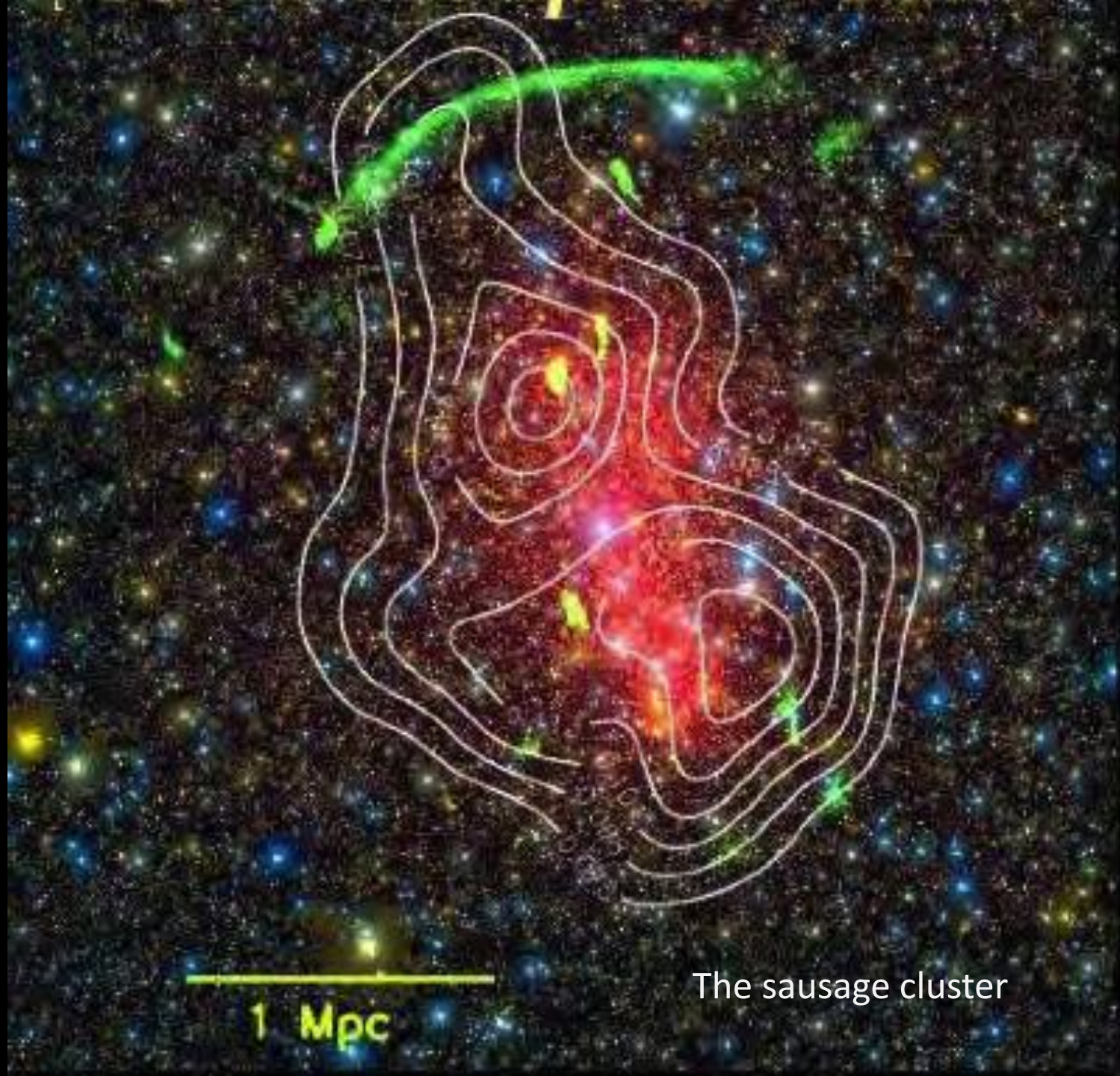


Searching for evidence of a collision
between galaxies...its like a crime scene



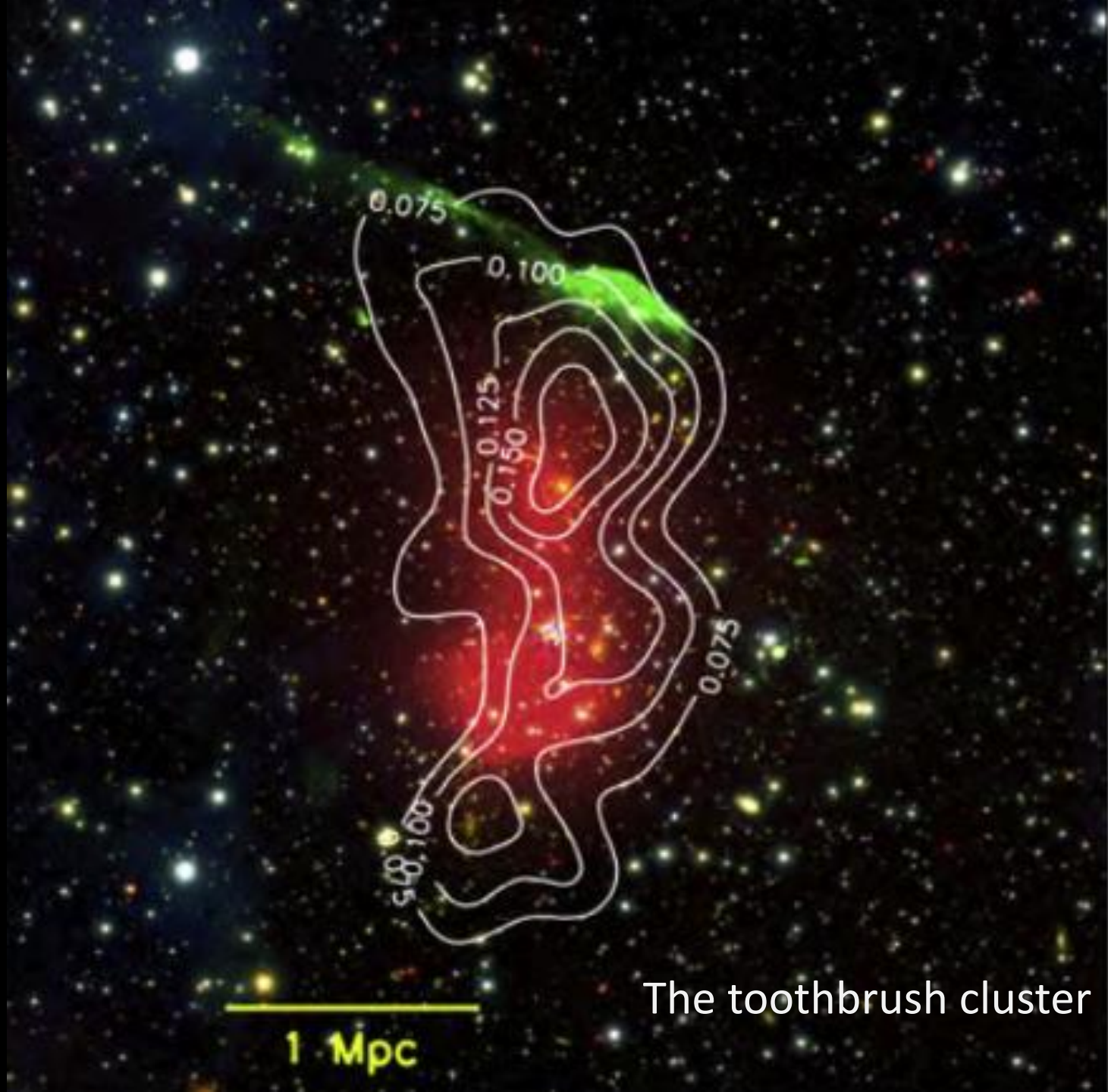


RADIO FOSSILS



The sausage cluster

1 Mpc

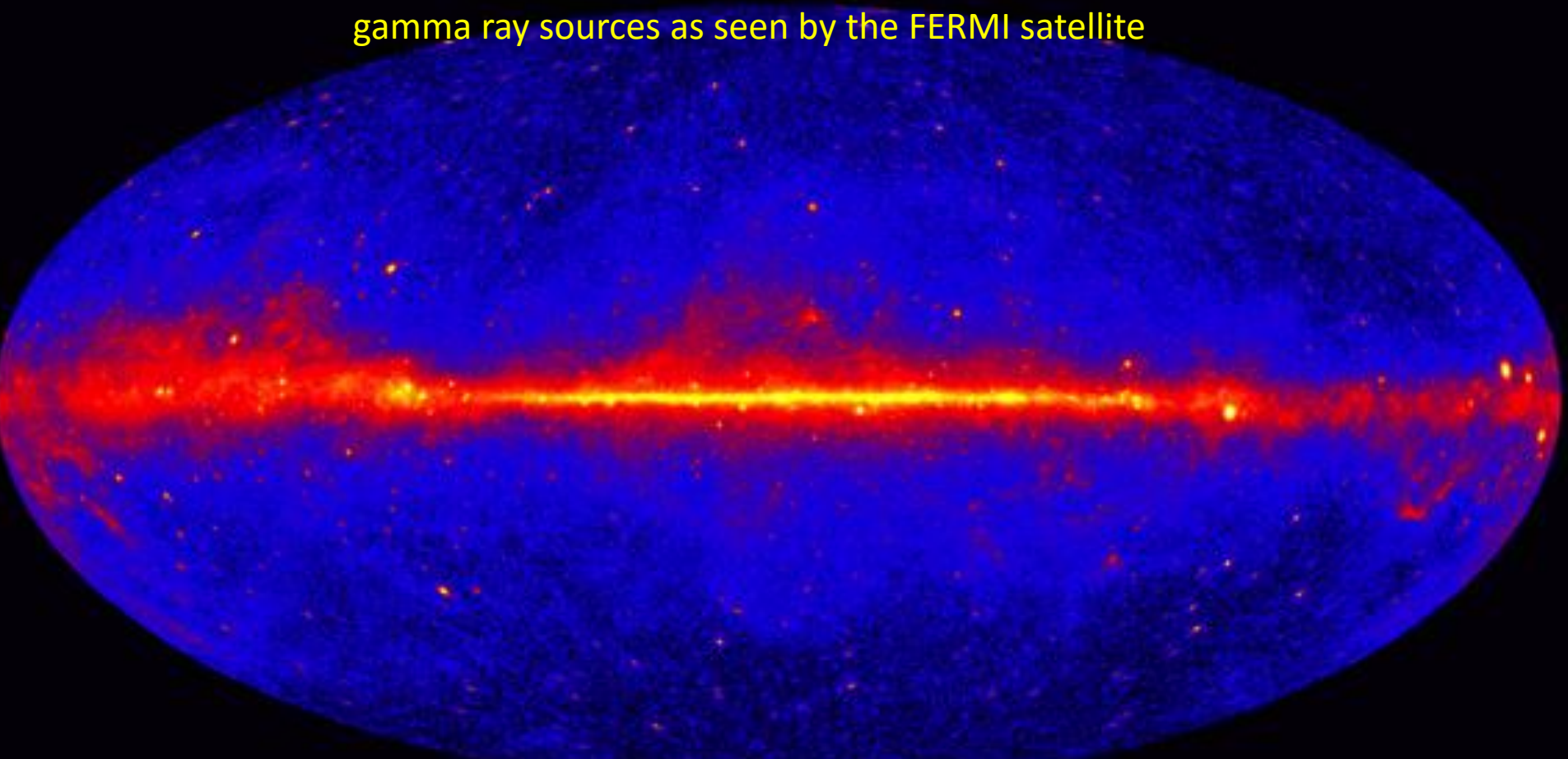


The toothbrush cluster

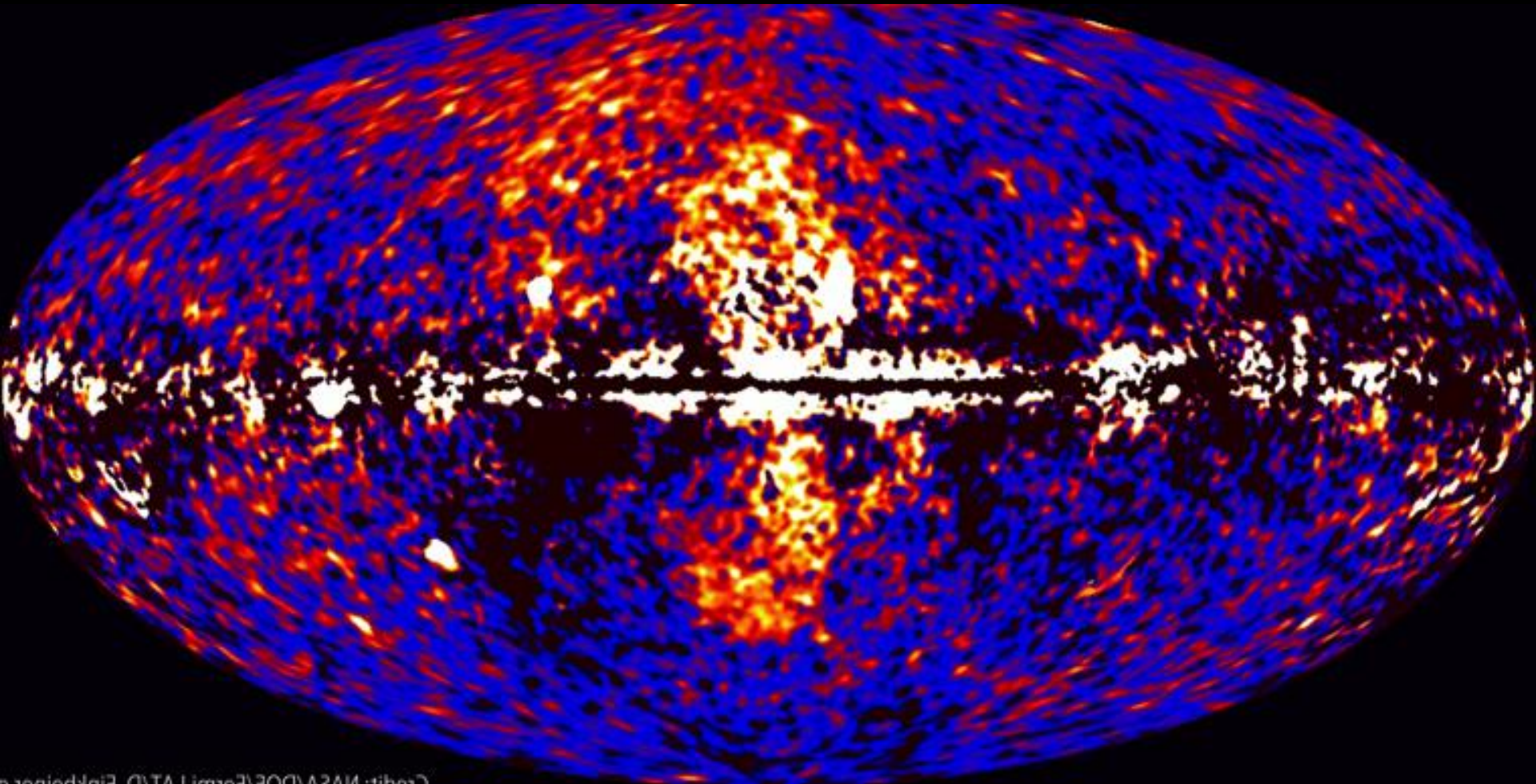
GAMMA RAY FOSSIL CLOSE TO HOME

GAMMA RAY FOSSIL CLOSE TO HOME

gamma ray sources as seen by the FERMI satellite



The diffuse gamma ray background



© 2000 NASA, ESA, and the European Space Agency

A GIGANTIC EXPLOSION OCCURRED A MILLION YEARS AGO AT THE CENTRE OF THE MILKY WAY

How we do cosmology

By looking far away, into the remote past

By searching for nearby fossils

How we do cosmology

By looking far away, into the remote past

By searching for nearby fossils

The questions we pose

Where do we come from?

What is the universe made of?

Where are we going?

How we do cosmology

By looking far away, into the remote past

By searching for nearby fossils

The questions we pose

Where do we come from?

What is the universe made of?

Where are we going?

We are still searching...