













30,000 light-years

Galaxies near and far: a tour through the realm of the nebulae

July 9, 2011

Lick Observatory Music of the Spheres

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The University of Chicago

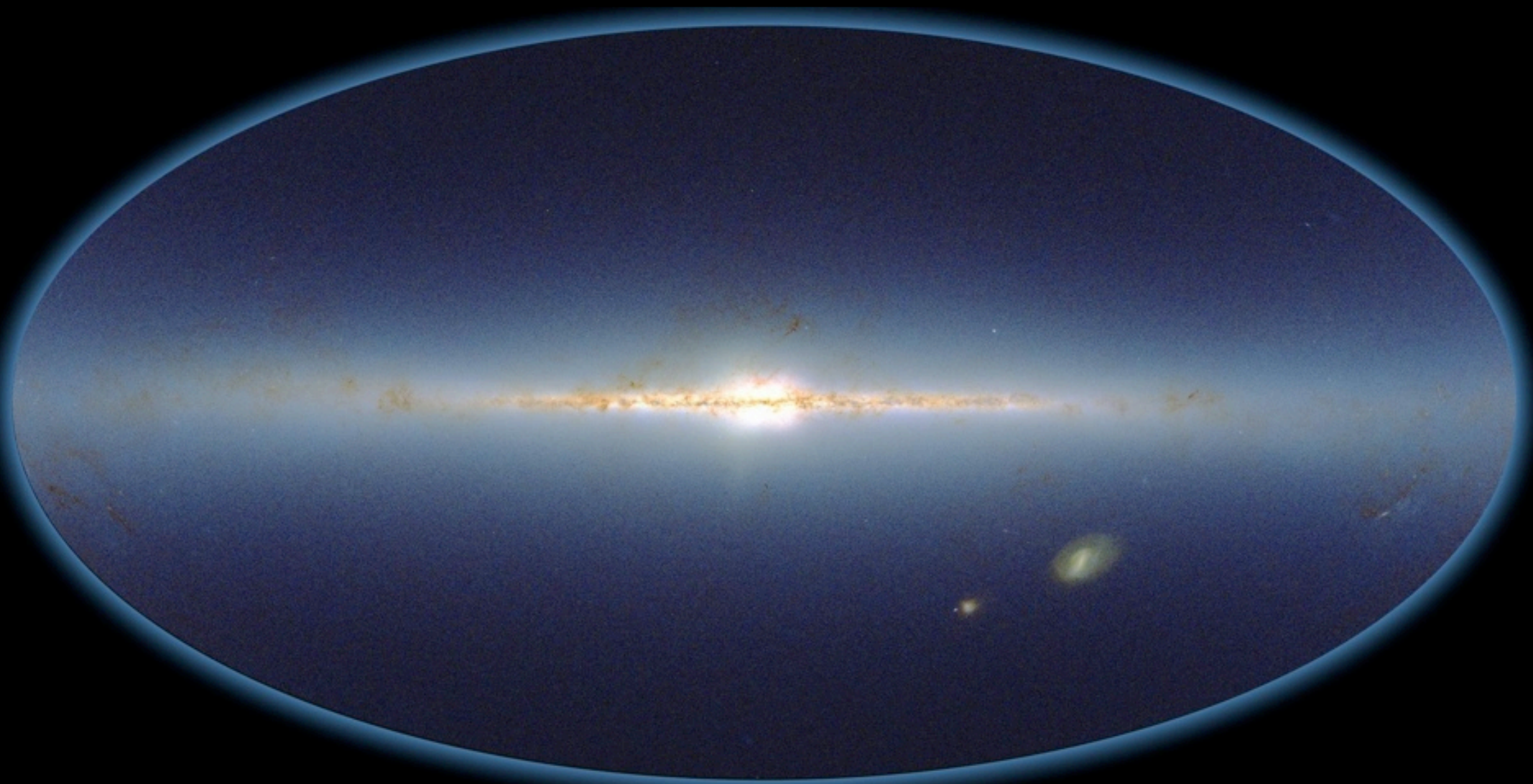
backyard photo of our home galaxy, the Milky Way






the Milky Way in Sagittarius

all-sky view of the Milky Way and the Small and Large Magellanic Clouds



The Two Micron All Sky Survey

Infrared Processing and Analysis Center/Caltech & Univ. of Massachusetts



H.D. Curtis suggested that spiral nebulae were like the Milky Way (“island universes”)





The Milky Way is about 100 thousand light-years across.

A satellite map of the San Francisco Bay Area is shown in the background. Overlaid on the map is a large, semi-transparent circular area filled with a dense field of multi-colored stars, representing the Milky Way galaxy. The stars vary in brightness and color, including yellow, orange, red, blue, and white. The text is overlaid on the left side of the star field.

Scale model: if the Milky Way filled the Bay Area, neighboring stars would be about 10 feet apart (100 billion of them!)

On this scale, the Sun - Neptune separation would be 5 sheets of paper (and Sun - Earth is 30 times smaller than that, a gnat's eyebrow).

group of galaxies in Leo



30,000 light-years

NGC 3384 & NGC 3379

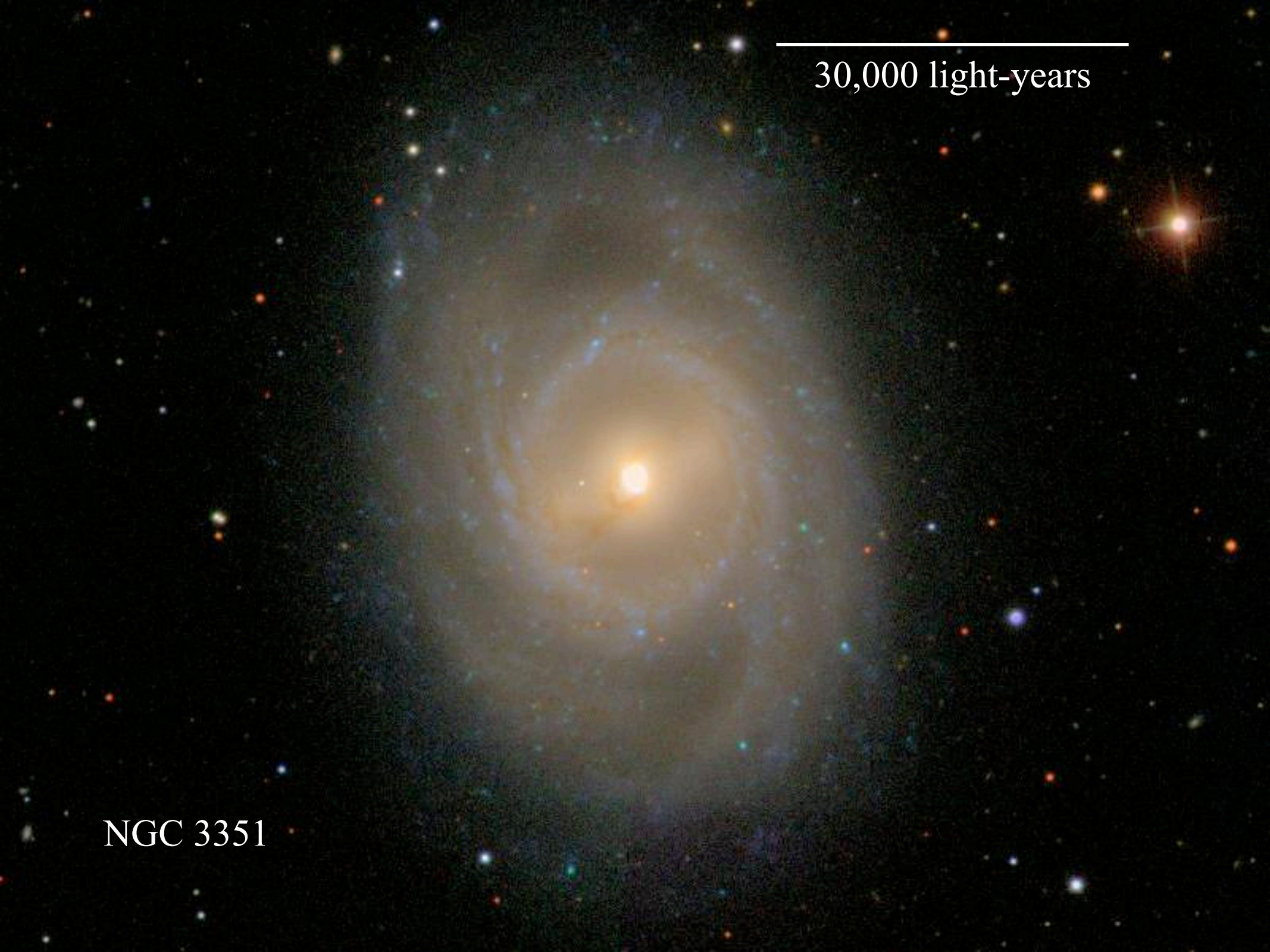
A photograph of the spiral galaxy NGC 3368 (Messier 96) in the constellation Coma Berenices. The galaxy is a face-on, grand design spiral with a bright yellowish-white core and several prominent, well-defined spiral arms. The background is filled with numerous stars of various colors, including blue, orange, and white. A white horizontal scale bar is located in the upper right corner, with the text "30,000 light-years" written below it. A vertical dashed line extends from the bottom of the scale bar down towards the center of the galaxy, indicating a specific distance or scale within the galaxy's structure.

30,000 light-years

NGC 3368 = Messier 96

30,000 light-years

NGC 3351



A wide-field astronomical image of the galaxy Messier 101 (Bode's Galaxy). The galaxy is a face-on spiral, with a bright yellowish-white central core and several distinct spiral arms. The image is colorized, showing blue and cyan spots scattered throughout the galaxy, likely representing young, hot stars. A white horizontal scale bar is located in the upper right corner, with the text "30,000 light-years" written below it. The background is dark, with many individual stars visible.

30,000 light-years

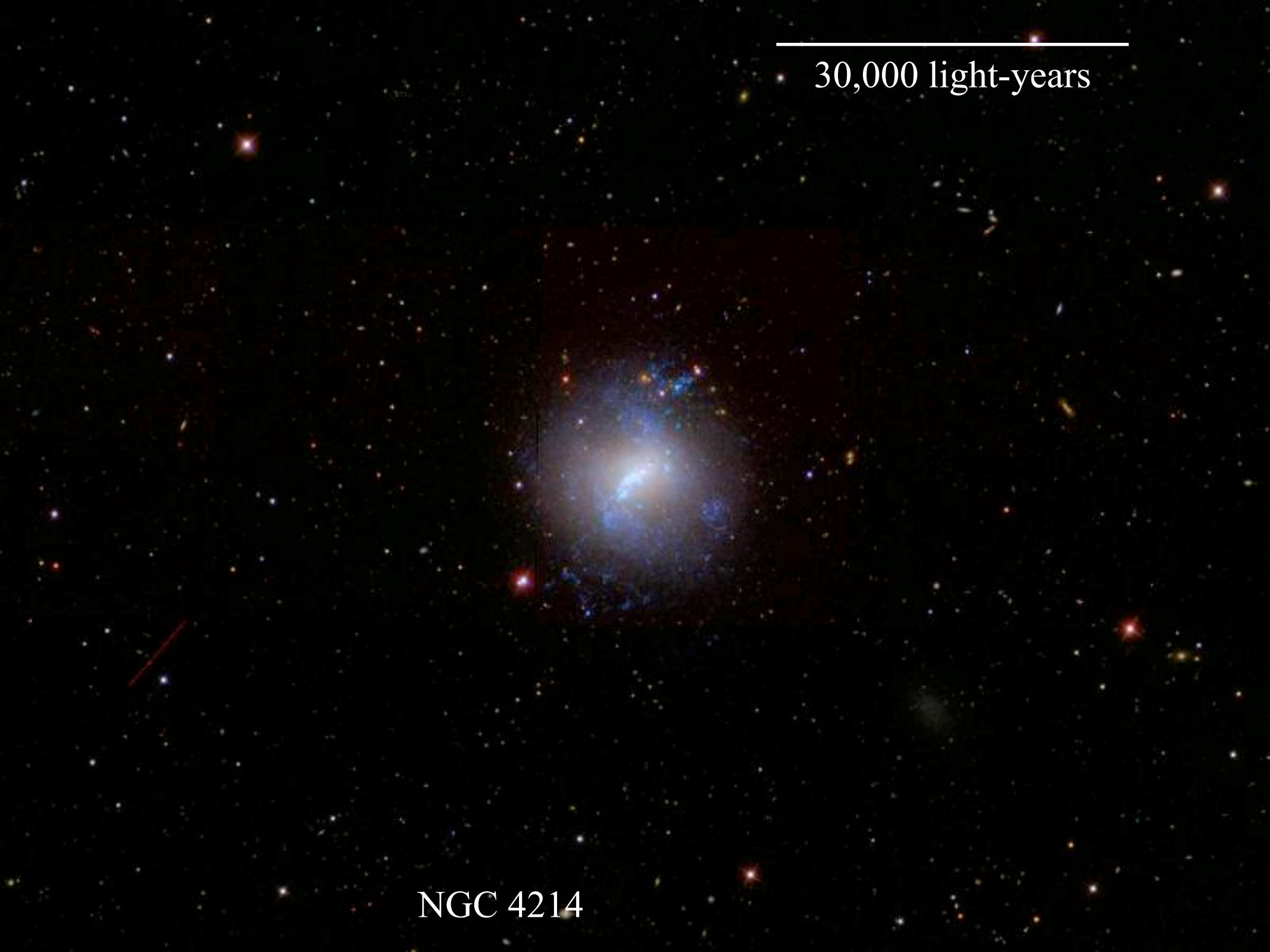
Messier 101

30,000 light-years

NGC 4449

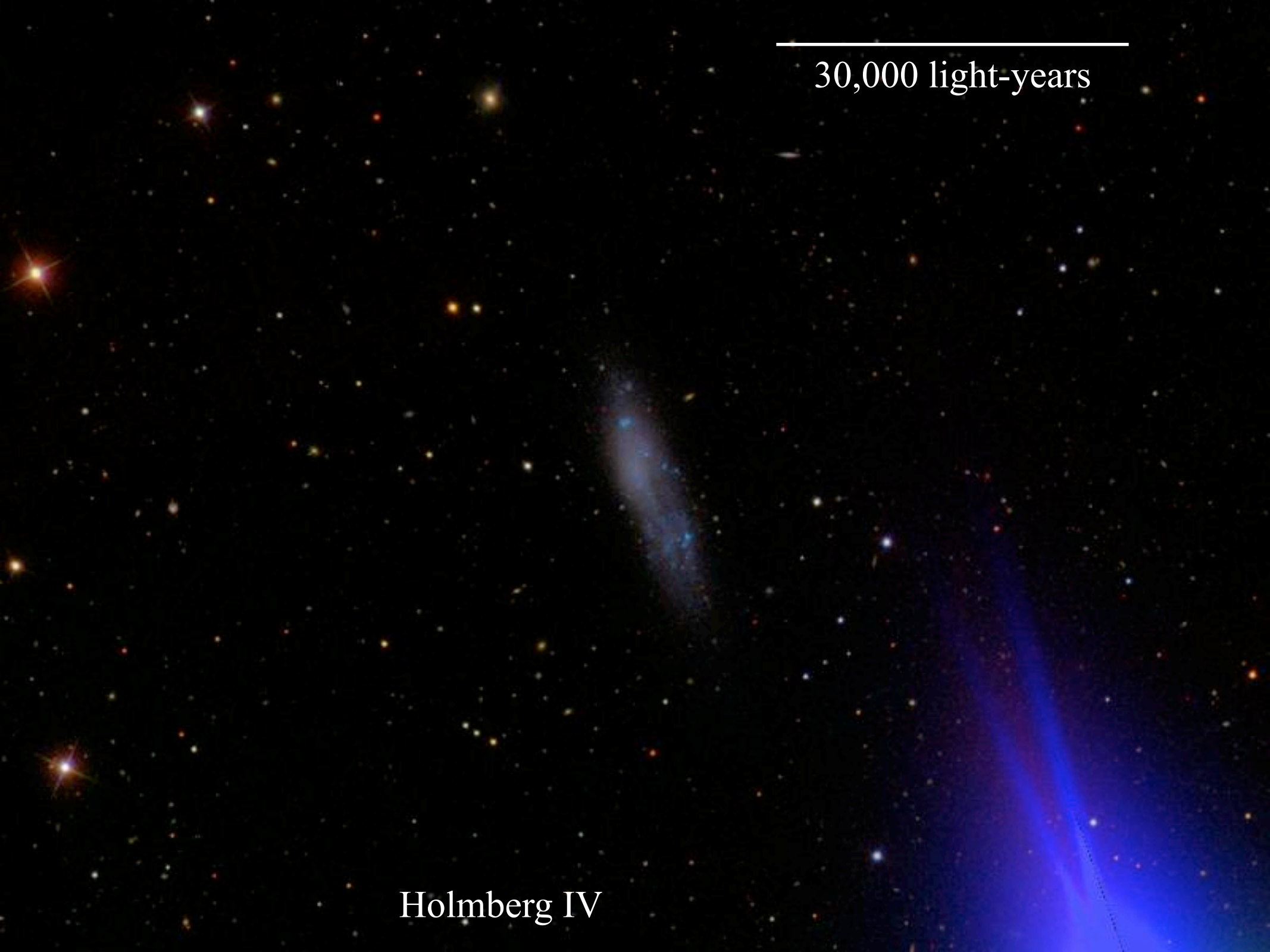
30,000 light-years

NGC 4214



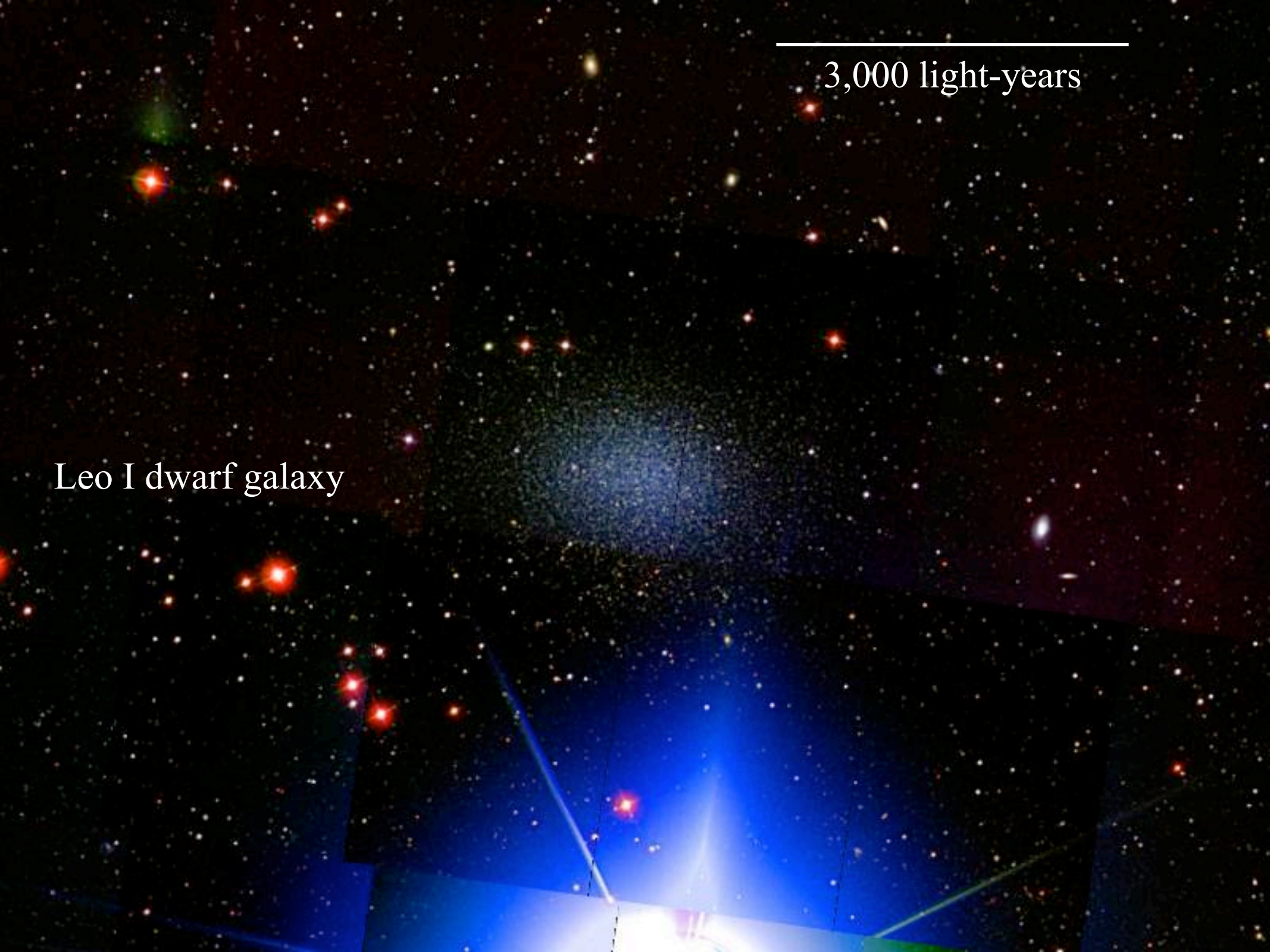
30,000 light-years

Holmberg IV



3,000 light-years

Leo I dwarf galaxy



NGC 5218 & Arp 104

galaxy collisions take a few hundred million years, start to finish

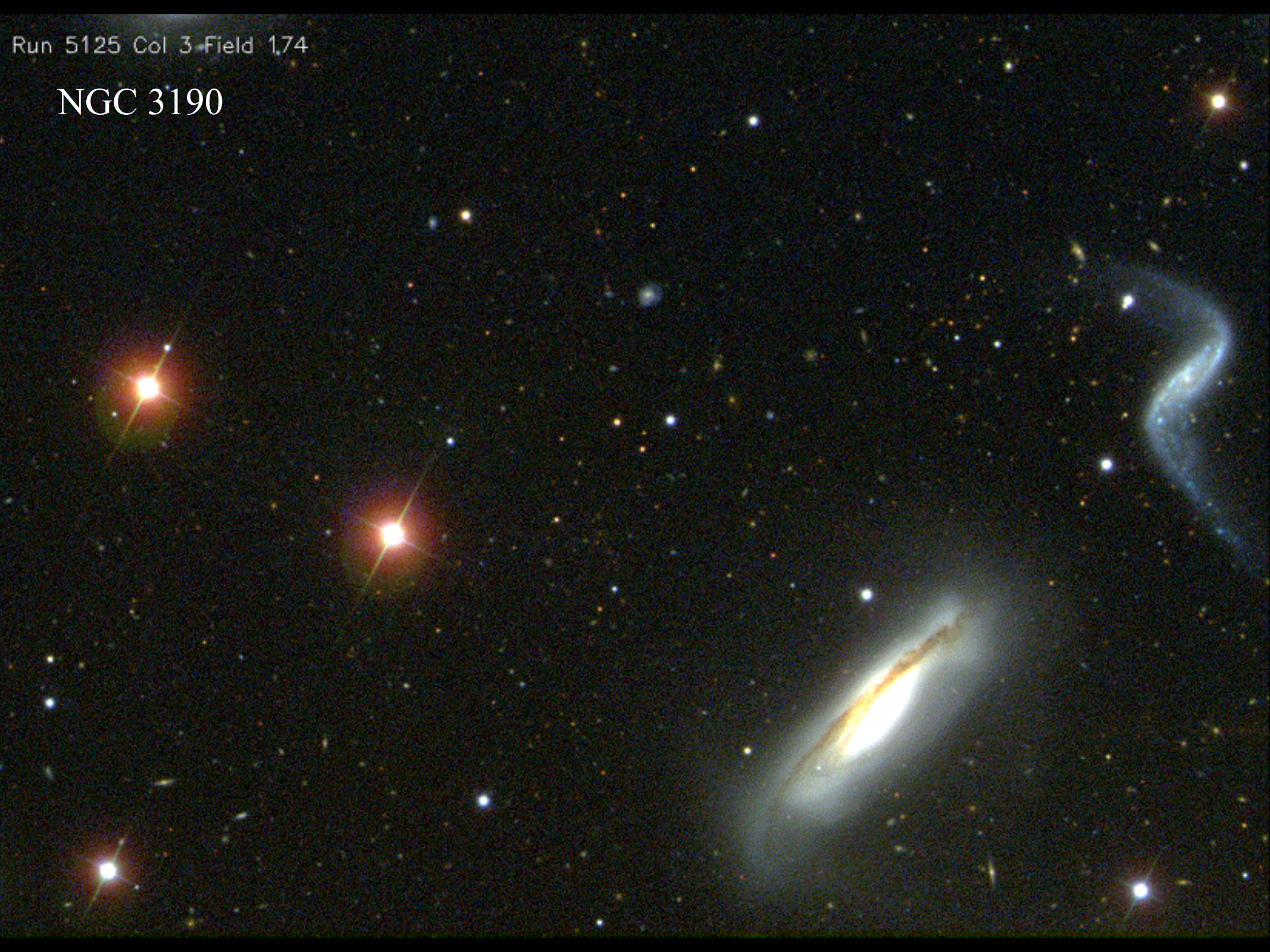


John Dubinski's computer simulation of the future collision
between the Milky Way and Messier 31:

http://www.galaxydynamics.org/spiral_metamorphosis.html

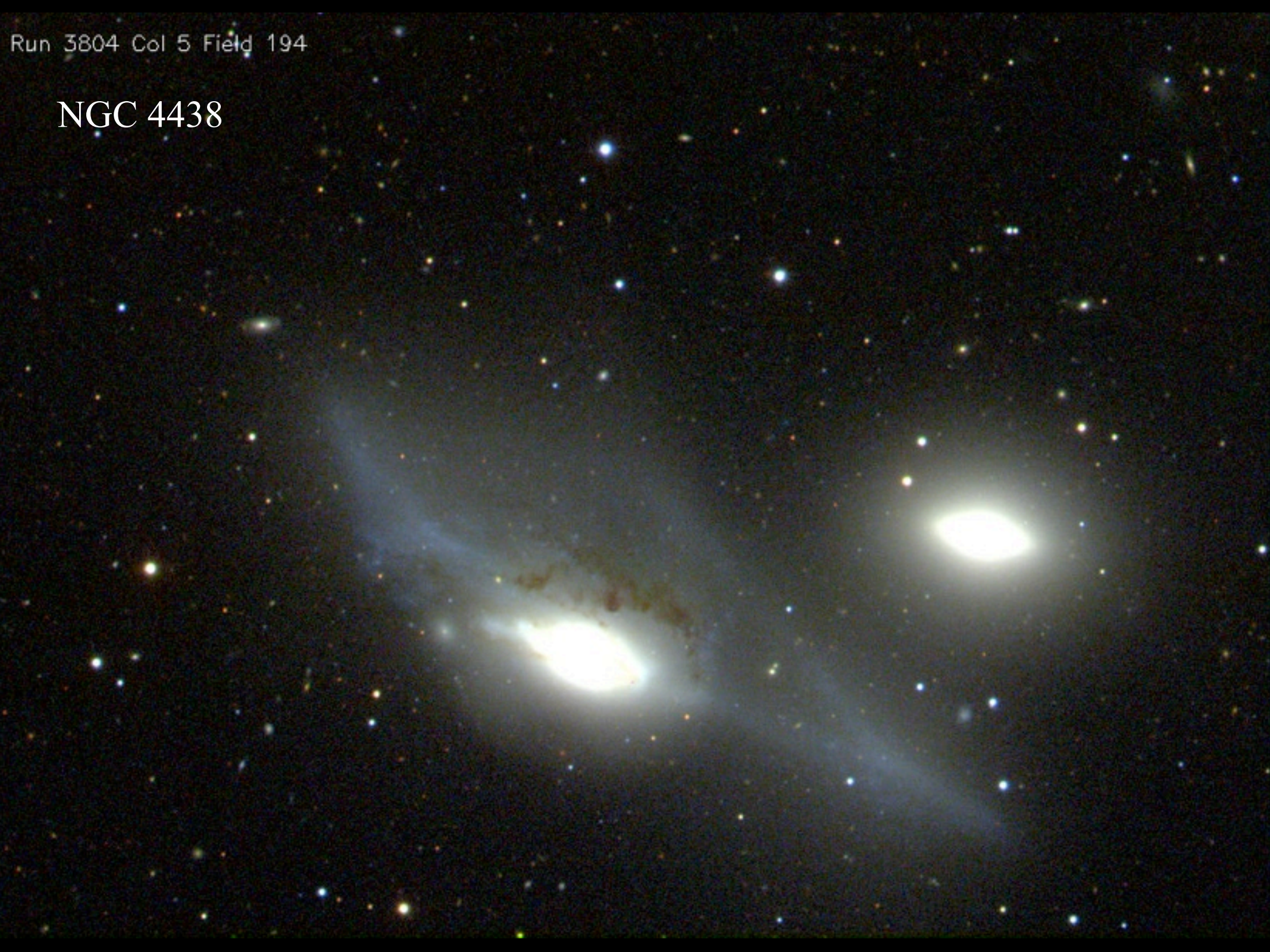
Run 5125 Col 3 Field 1,74

NGC 3190



Run 3804 Col 5 Field 194

NGC 4438



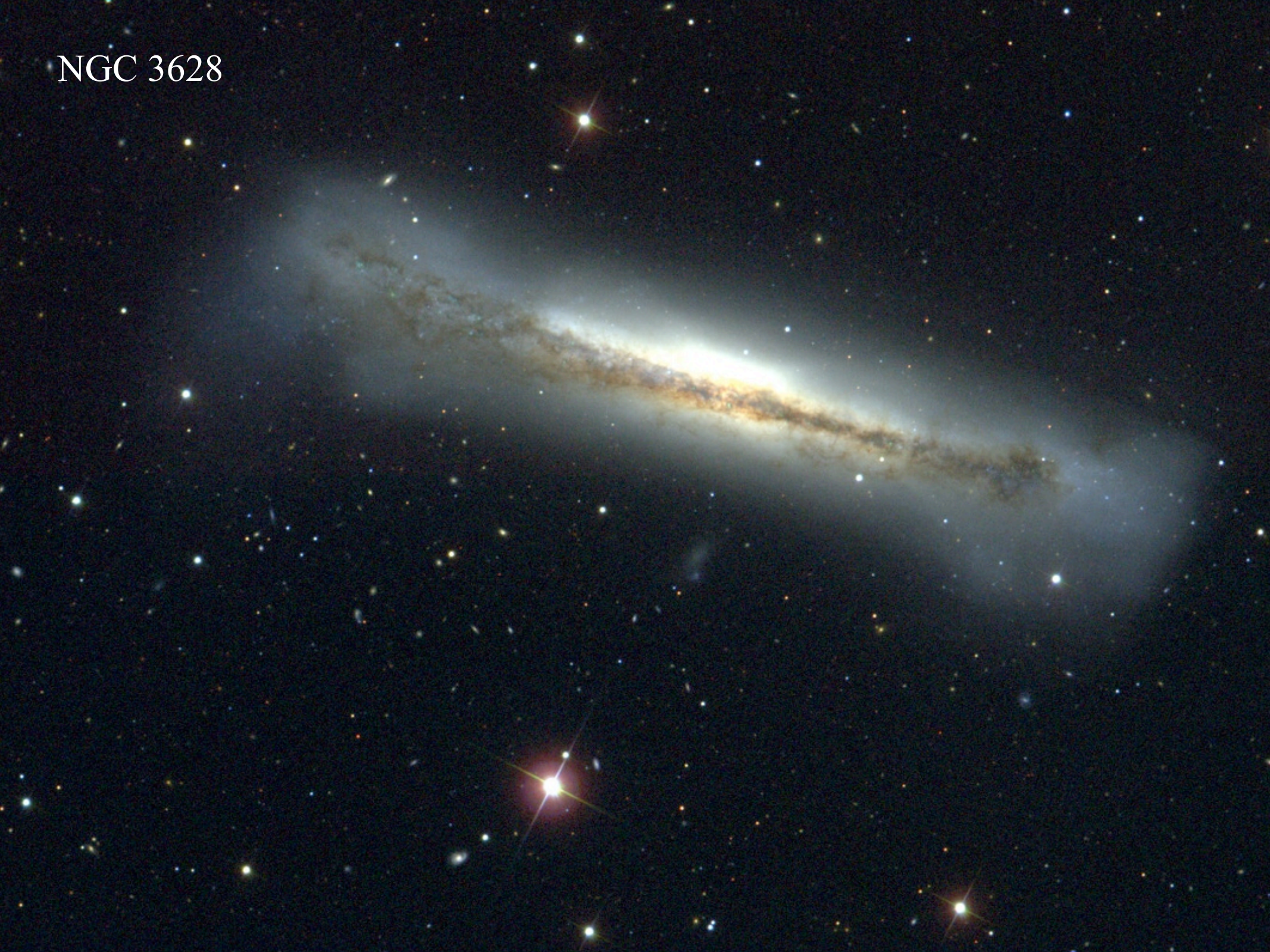
Arp 94



NGC 660

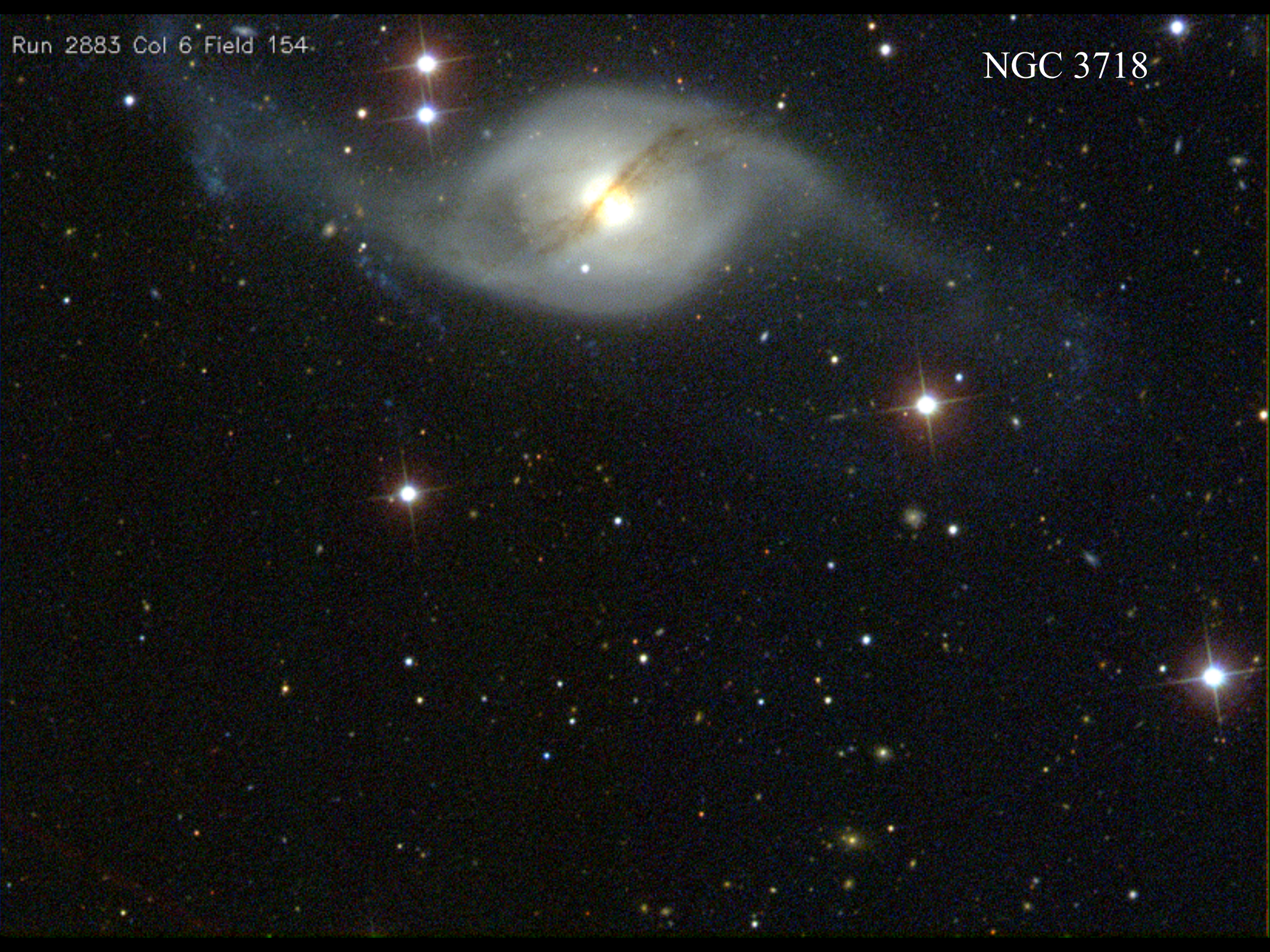
close encounters between galaxies compress gas clouds, which contract and form new stars

NGC 3628



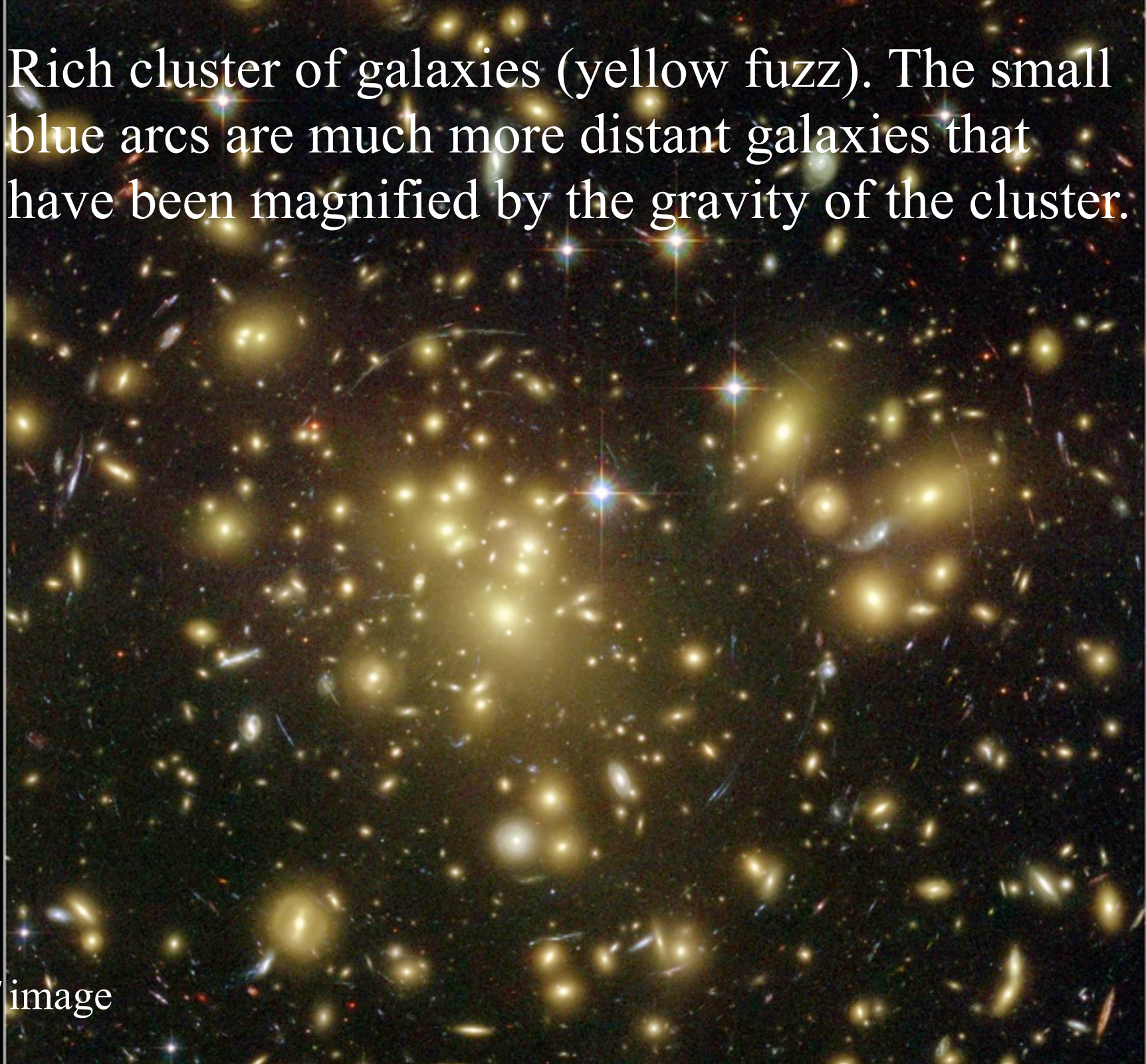
Run 2883 Col 6 Field 154


NGC 3718



Rich cluster of galaxies (yellow fuzz). The small blue arcs are much more distant galaxies that have been magnified by the gravity of the cluster.

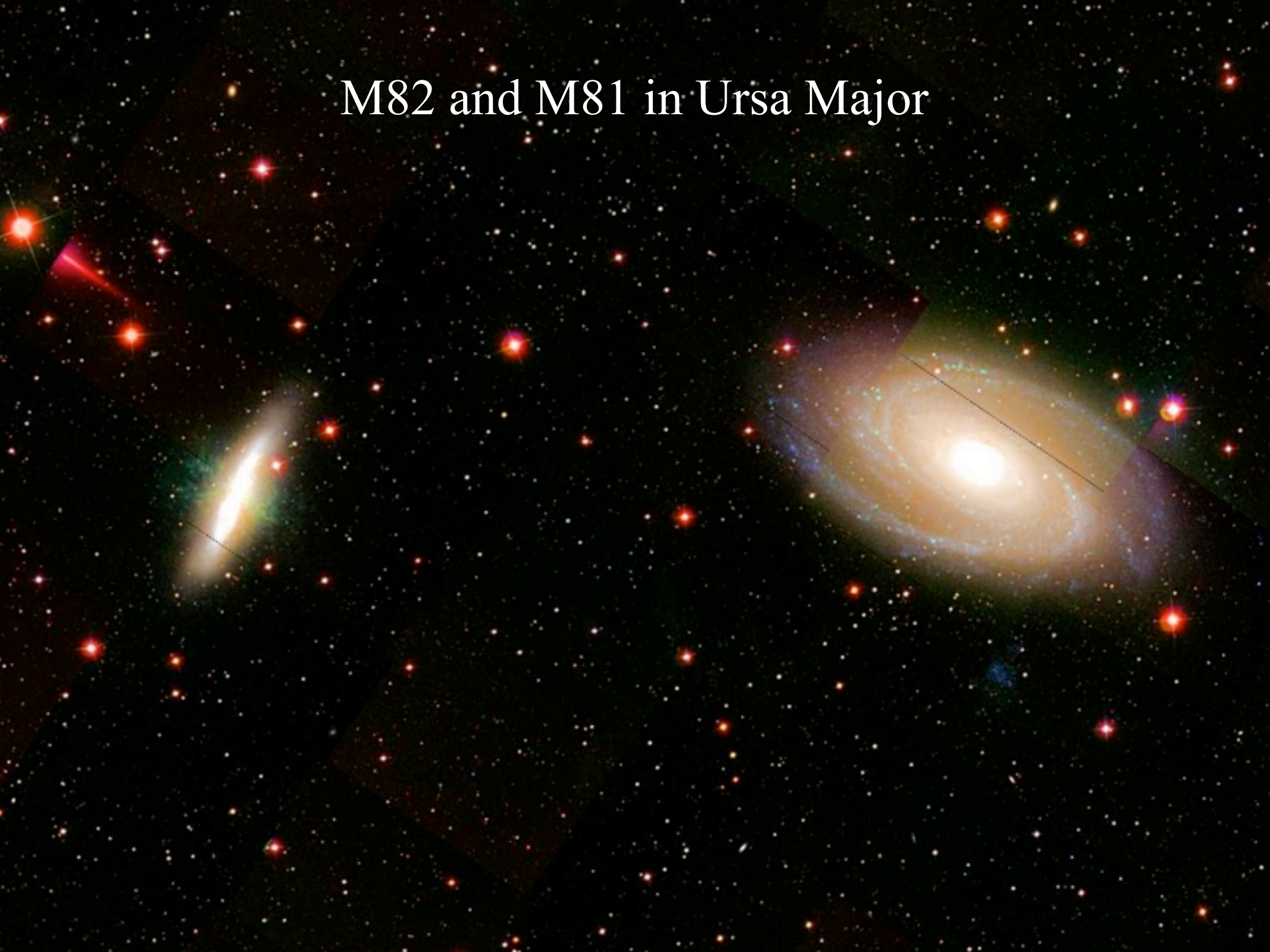
HST image



A field of stars with several bright, distorted spots representing gravitational lenses. The background is dark with numerous small, bright stars. Several larger, more prominent stars are visible, some of which are surrounded by multiple, distorted images of themselves, illustrating the effect of gravitational lensing. The text is overlaid in the bottom right corner.

The more mass, the more magnification:
we can use these “gravitational lenses” to
determine the total mass of the cluster.

M82 and M81 in Ursa Major

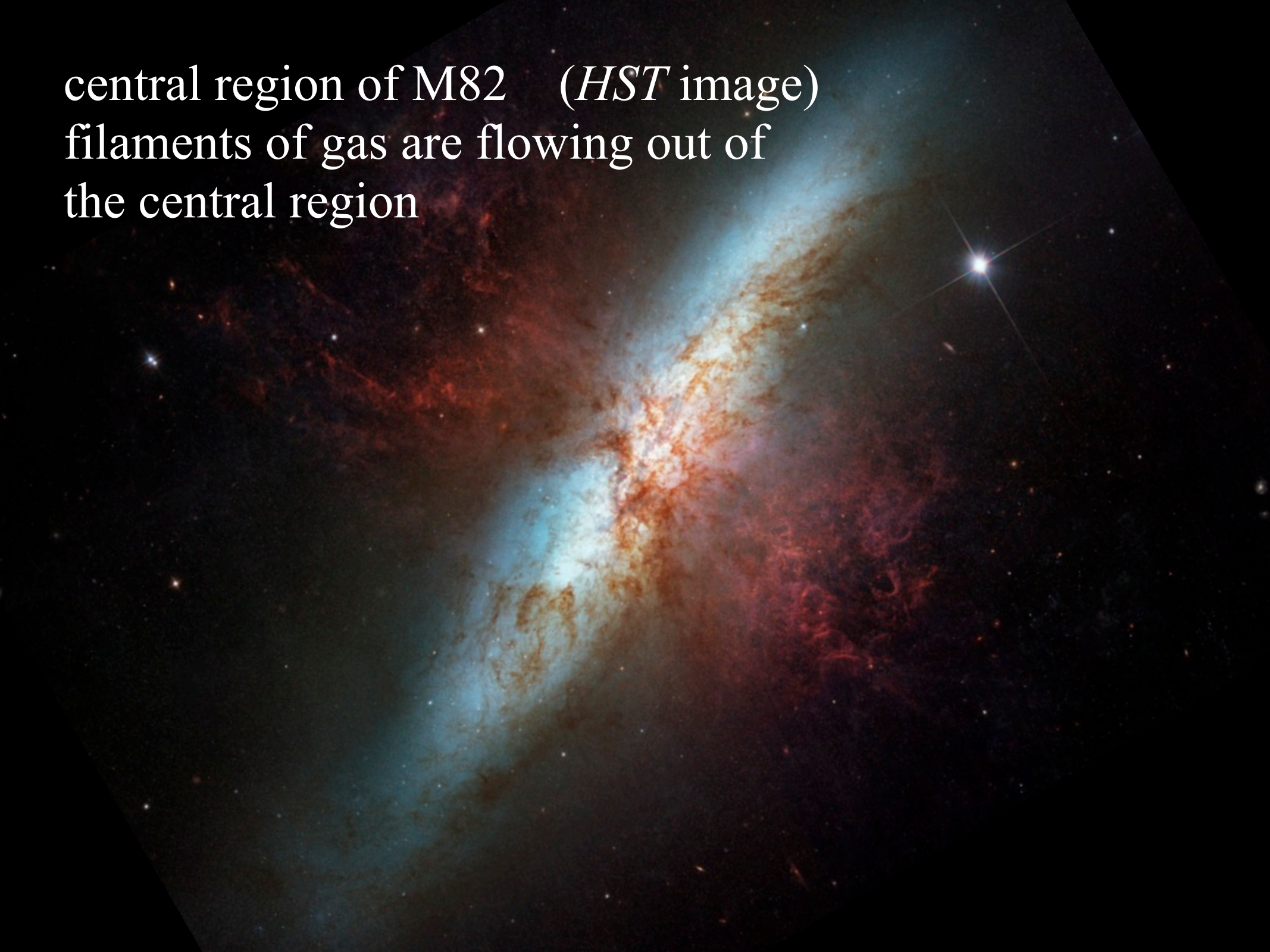


nucleus of M81 (*HST* image)

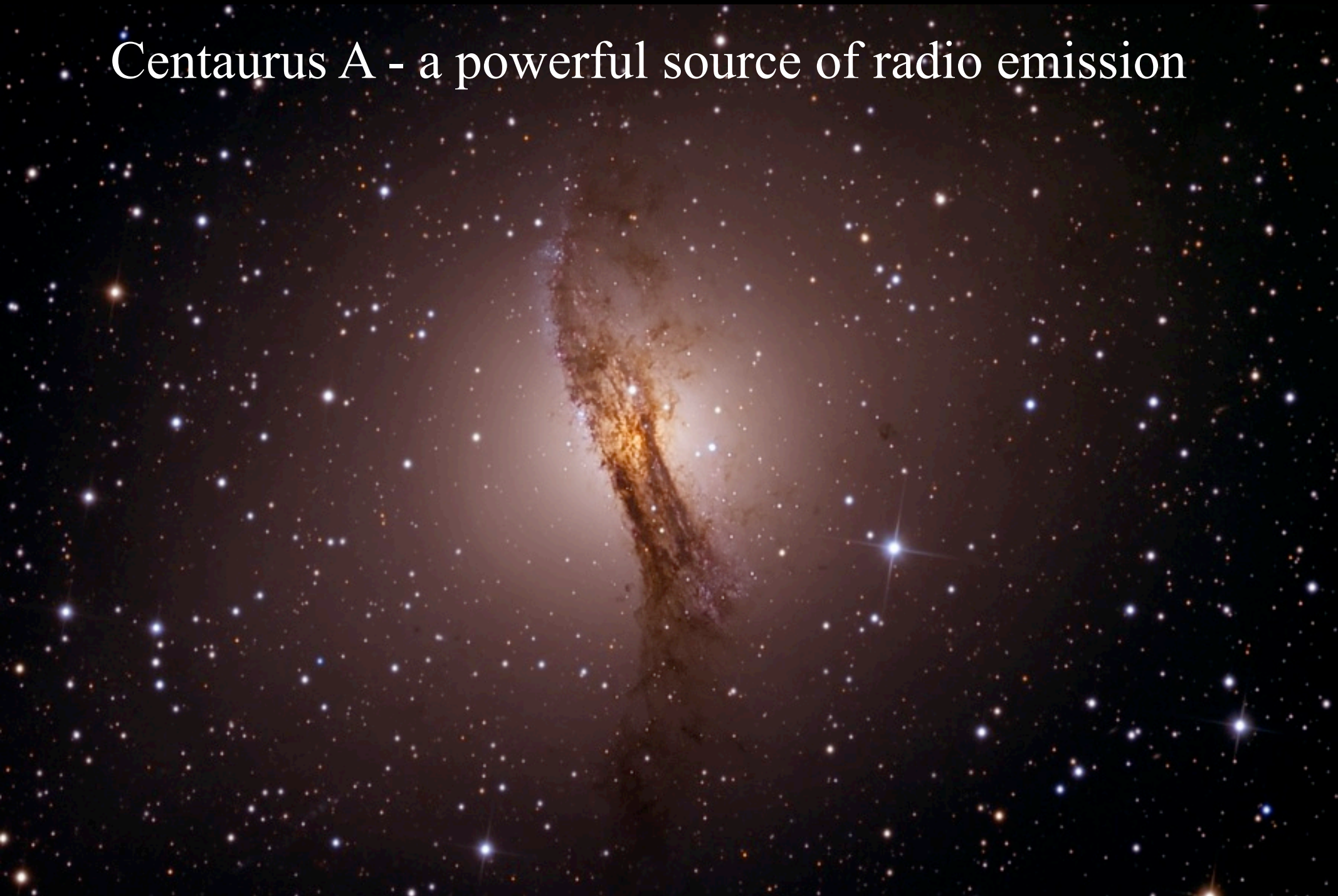
such regions harbor *supermassive black holes*



central region of M82 (*HST* image)
filaments of gas are flowing out of
the central region



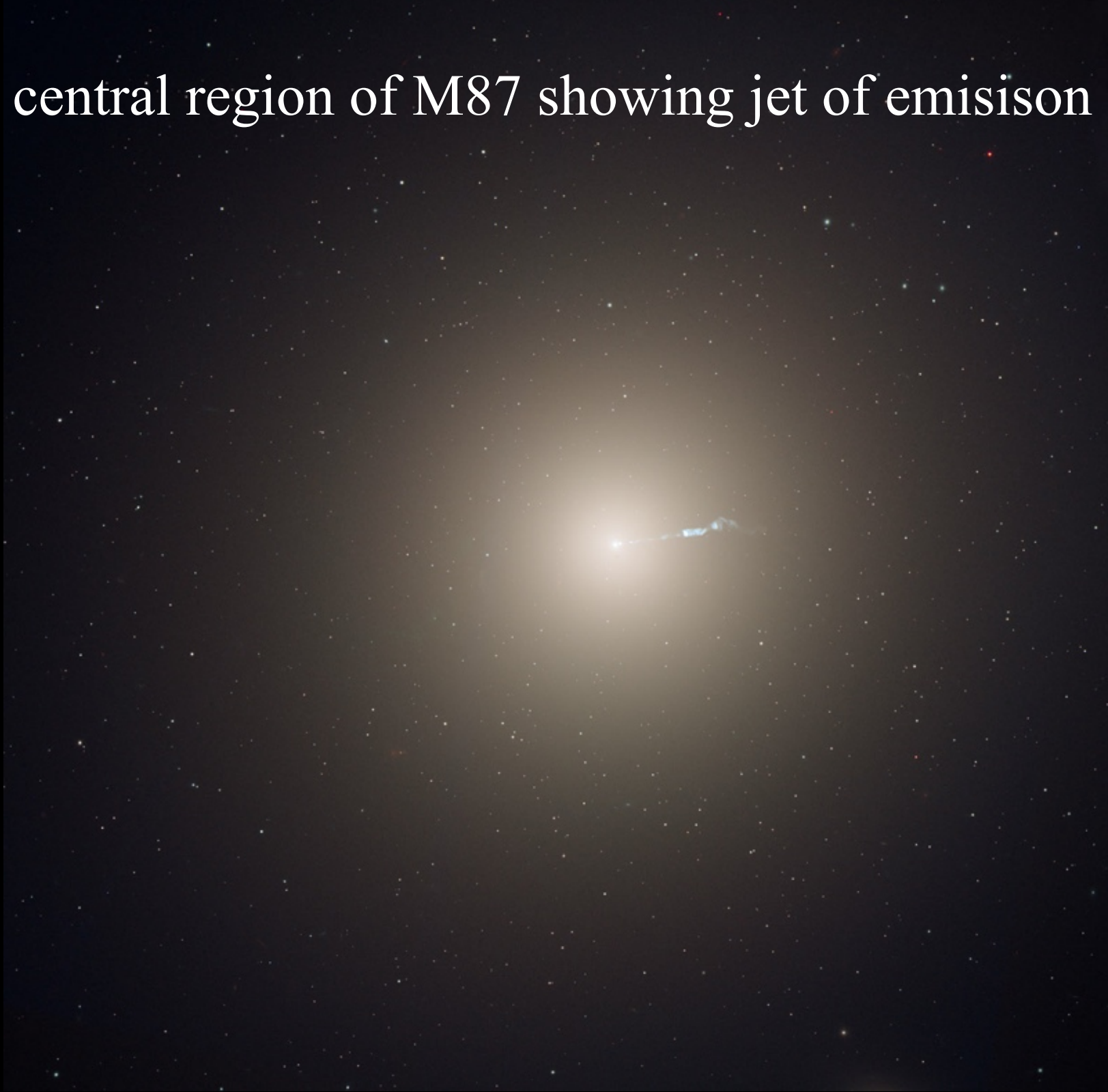
Centaurus A - a powerful source of radio emission

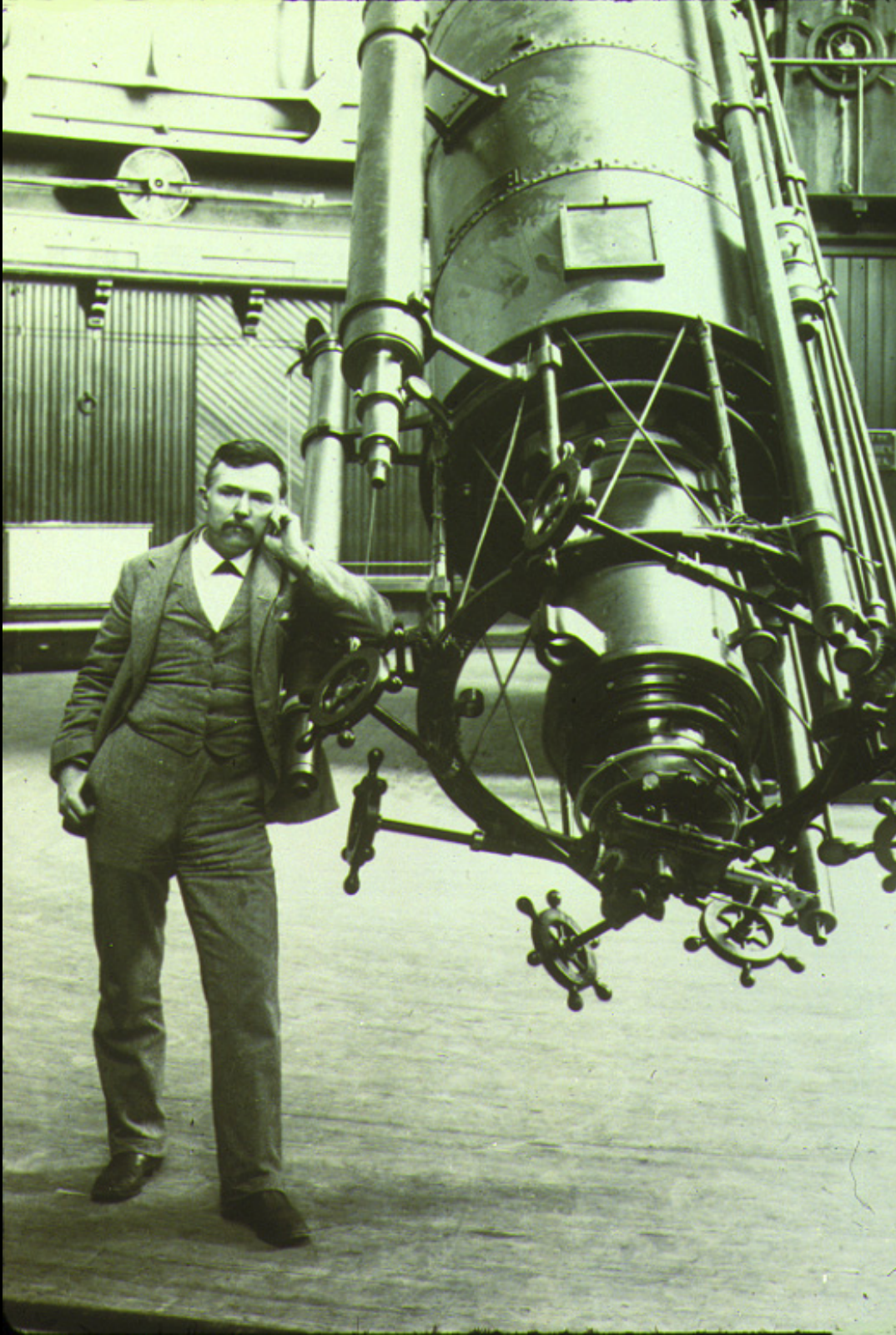


M87 - central giant in the Virgo cluster of galaxies



central region of M87 showing jet of emission

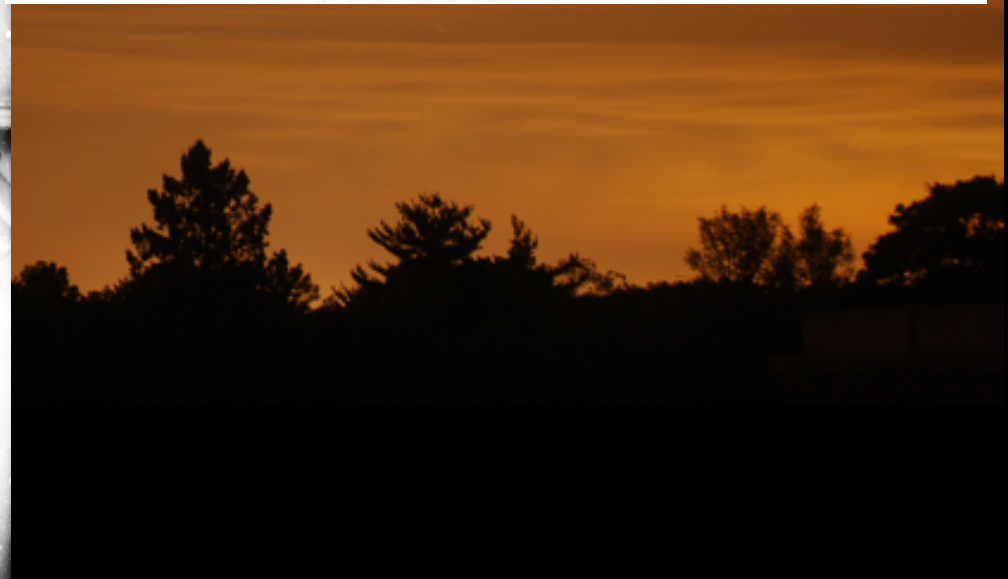
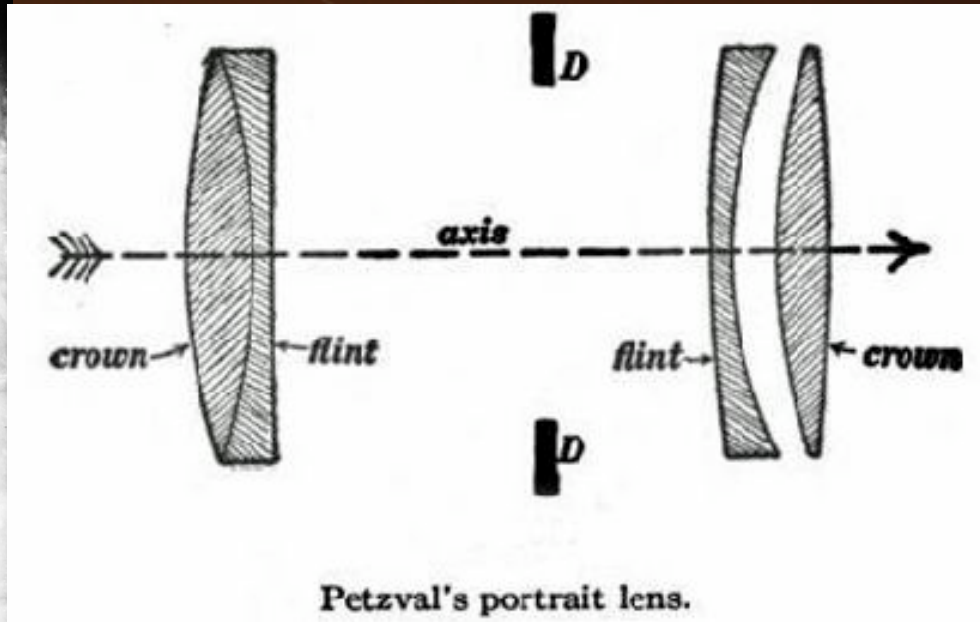
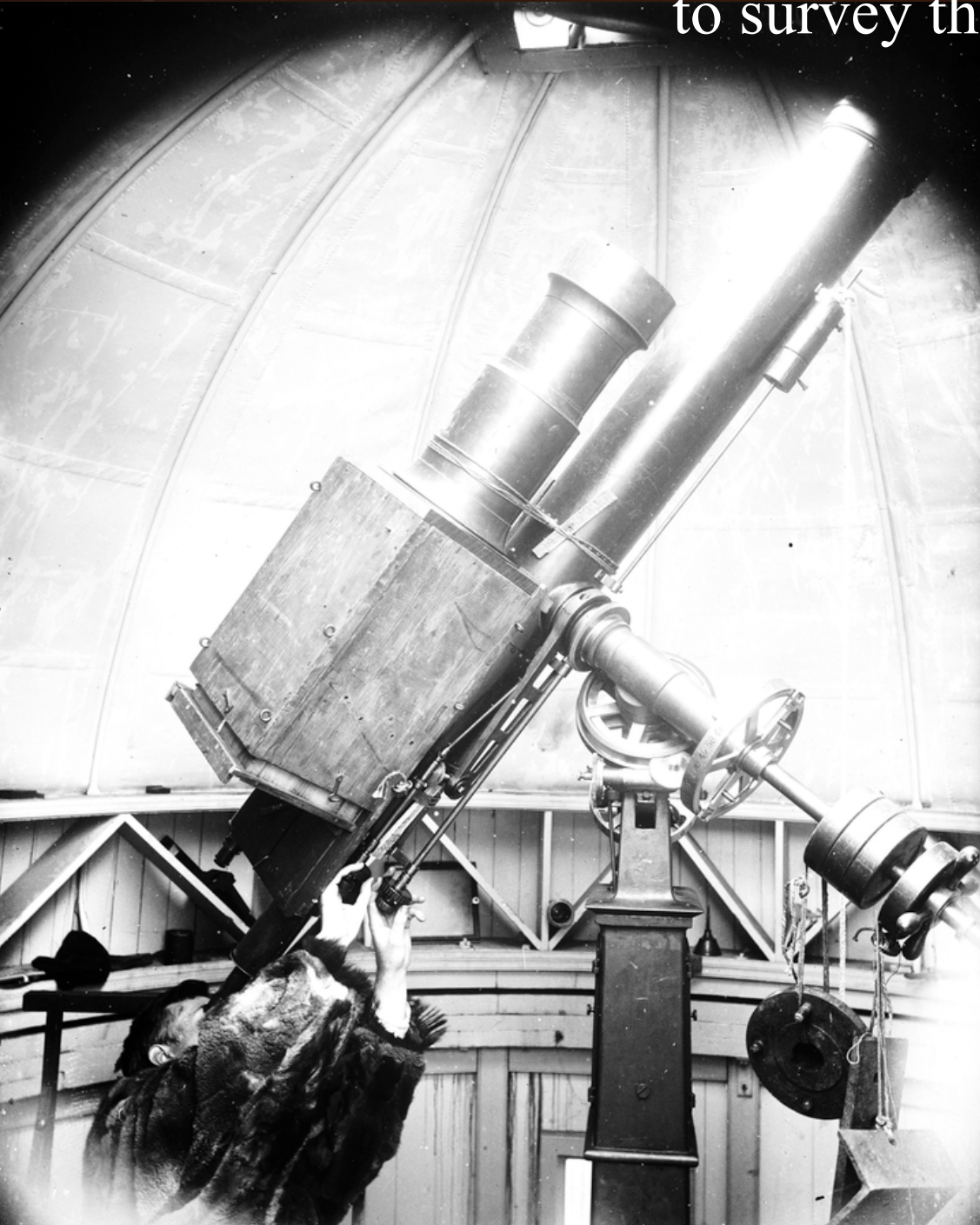




Edward Emerson Barnard 1857 - 1923

- discovered Amalthea, fifth satellite of Jupiter
- numerous comets
- Barnard's star
- map of the Milky Way

Barnard used a photographer's portrait lens to survey the Milky Way in the 1890's



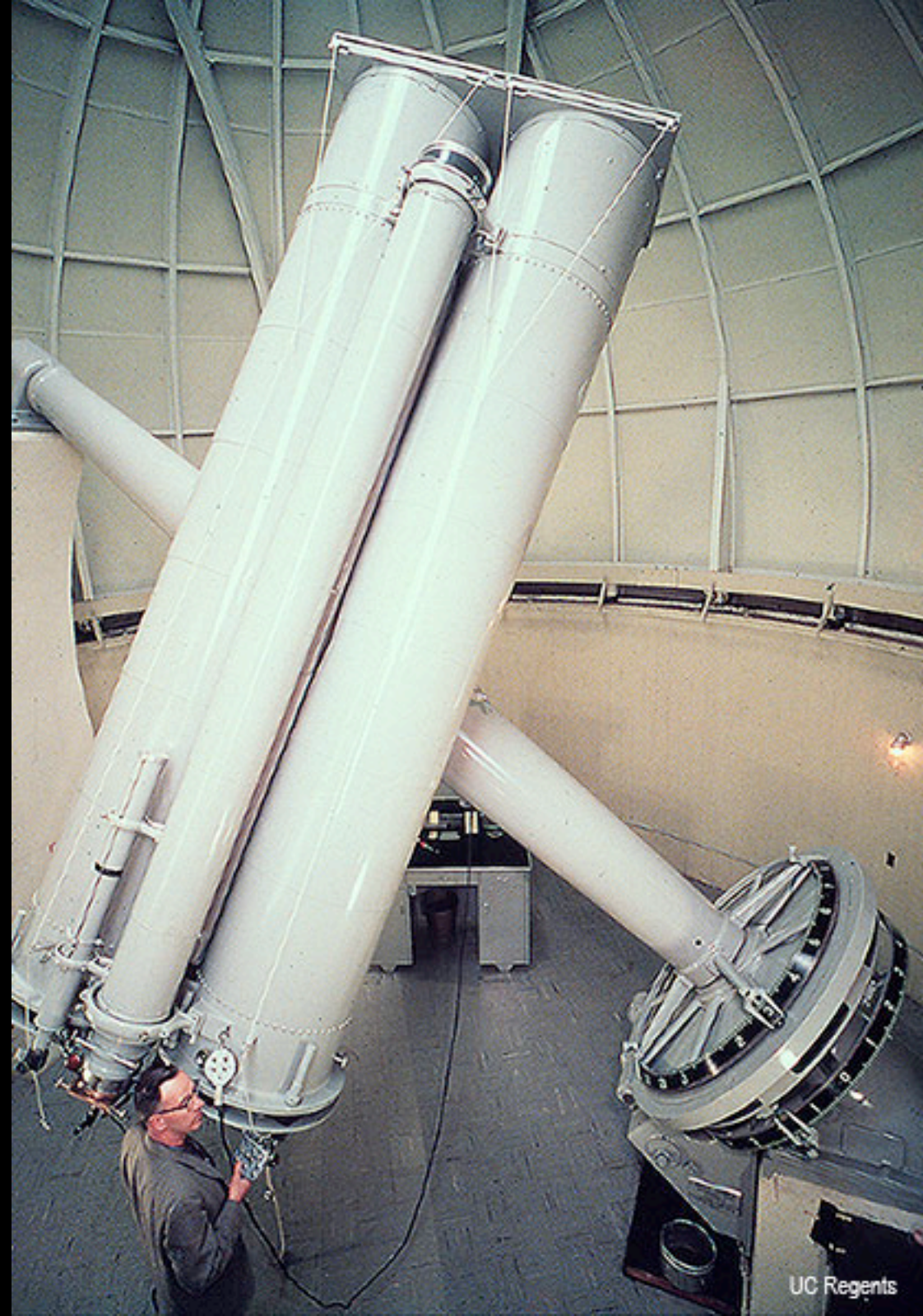
An Atlas of the Milky Way
Publ. Lick Obs. vol XI 1913





The Carnegie 20-inch double astrograph also made an atlas of the sky.

Carl Wirtanen and Donald Shane counted galaxies on the glass plates - one million galaxies in total.





Scanned at the American
Institute of Physics

Carl Wirtanen
Kate Gordon
Edith Wirtanen
(about 1946)

Charles Donald Shane
Mary Lea Shane
(about 1976)



A circular map of the universe showing the distribution of galaxies. The map is filled with numerous small white dots representing galaxies, which are more densely packed in some areas and more sparse in others. A white horizontal line is drawn across the top right of the map, indicating a scale of 1 billion light-years.

1 billion light-years

The Shane-Wirtanen galaxy map provided us with the first view of the clustering of galaxies over a significant volume of the Universe.



1 billion light-years

supercomputer simulation by the Millennium group: [http://
www.mpa-garching.mpg.de/galform/virgo/millennium/](http://www.mpa-garching.mpg.de/galform/virgo/millennium/)

1941 Sky & Telescope: “Progress in Extragalactic Research” by Kate Gordon

maps of the distribution of galaxies show clustering up to large scales

elliptical galaxies are more frequently found in dense clusters

the observed colors of galaxies are diagnostic of the stars within them

there are two main types of supernovae (exploding stars)

galaxies move through space with random speeds of 200 miles per second

there is a velocity-distance relation, suggesting an origin 2 billion years ago

1941 Sky & Telescope: “Progress in Extragalactic Research” by Kate Gordon

velocities of galaxies inside clusters tell us about the origin and mass of clusters

the mass of a galaxy can be determined from its rotation speed (10 to 100 billion times the mass of the Sun)

galaxies rotate in the sense that spiral arms trail

can we understand the variety of forms of galaxies by some kind of evolutionary process? do galaxies undergo some kind of internal instability? what are the effects of encounters between galaxies? permanent captures? spiral arms?