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OASES IN THE DARK: GALAXIES AS PROBES OF THE COSMOS

Shane L. Larson
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Yellowstone National Park
10 August 2007

STORYLINE

- What are we talking about?
- Simple facts, some history
- Galaxy clusters, galaxy collisions
- Some galaxies you can see

GALAXIES EVERYWHERE

- Most of us see galaxies every day!

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SIMPLE FACTS

- The largest easily observed structures in the Universe
- There are more than **100 billion** galaxies
- There are about **100,000 per square degree** on the sky
- The nearest galaxy to the Milky Way is the Small Magellanic Cloud 180,000 lightyears away (or the Canis Major Dwarf at 25,000 lightyears)

SIMPLE FACTS

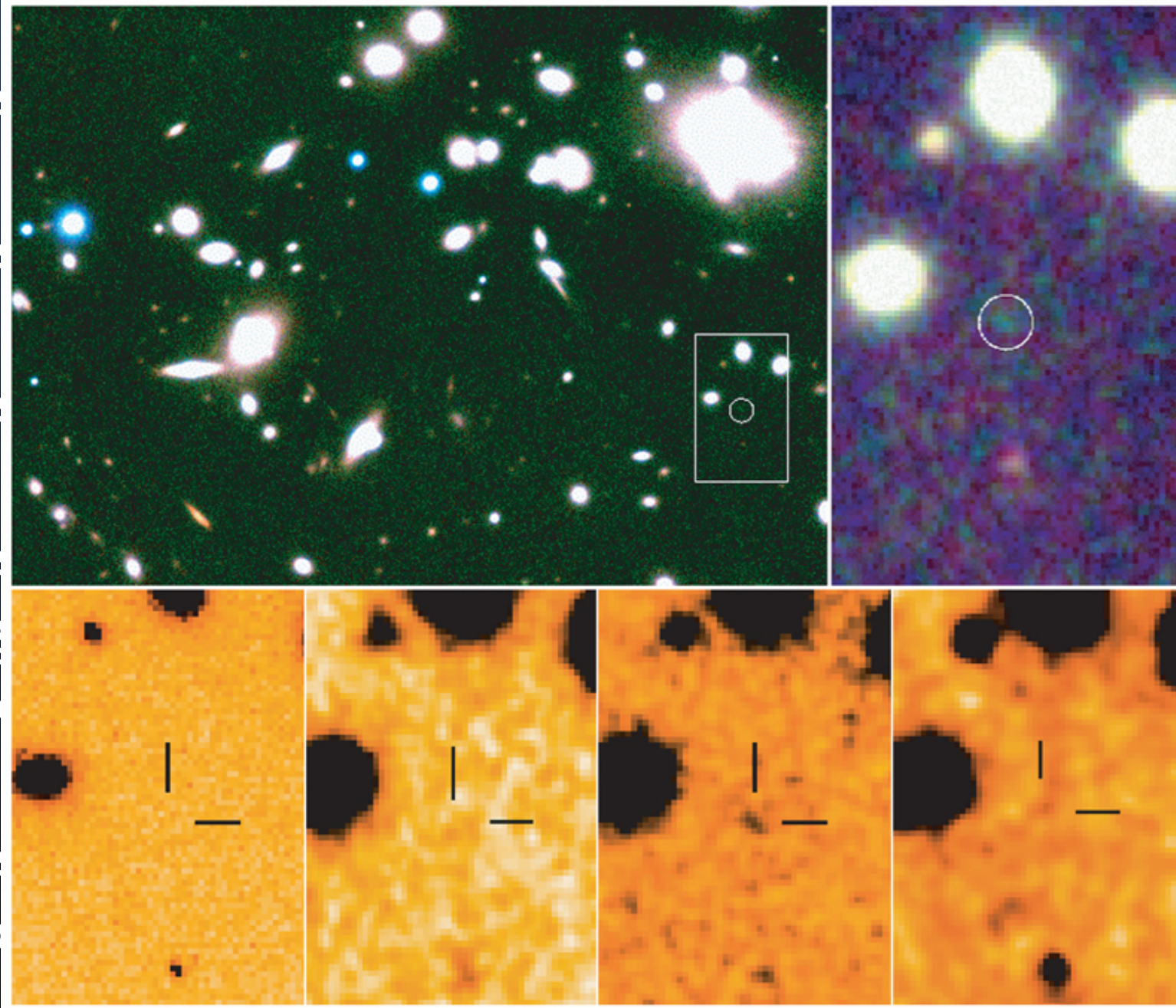


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- The farthest known galaxy is Abell 1835 IR1916, 13.23 billion lightyears distant.

SIMPLE FACTS

- The
- The
- The
- The
- The
Mag
Maj
- The
billi



verse

he sky

e Canis

13.23

SPECULATIONS

- In 1755, Immanuel Kant speculated (on philosophical grounds) that there should exist distant “island universes” of stars (much like the Milky Way)



THE MILKY WAY

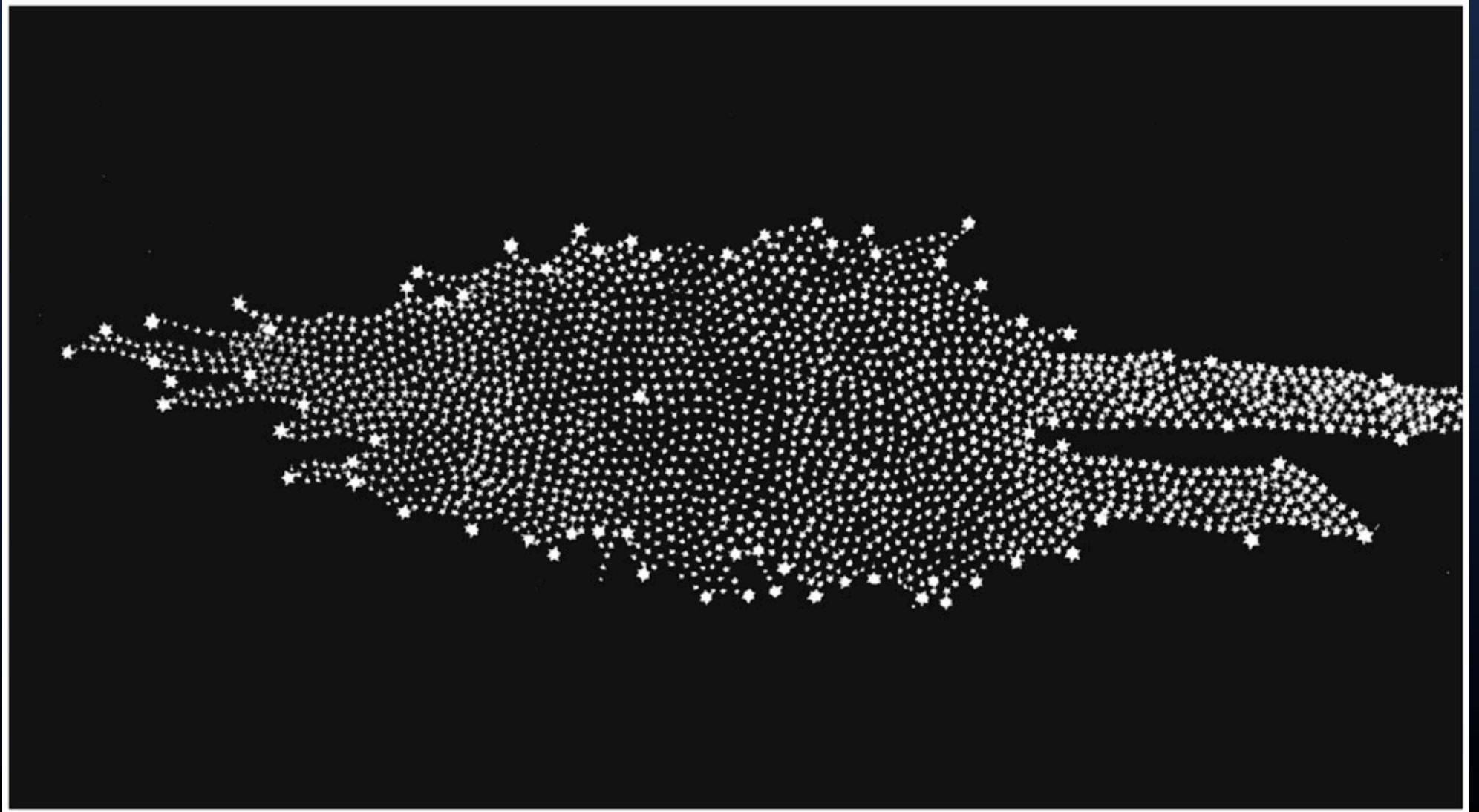


THE MILKY WAY



- In 1785, William Herschel decides to map the Milky Way by counting all the stars he can see in every direction.
- He finds we are near the center of a flattened distribution of stars (a disk)

THE MILKY WAY



IN THE OLDEN DAYS...

- We used to think that galaxies were nebulae
- Through a scope, you might see how this could be



Centaurus A (NGC 5128)



Trifid Nebula (M20)

SPIRAL NEBULAE

- In 1845, William Parsons (the 3rd Earl of Rosse) was observing with his 72-inch Leviathan of Parsonstown
- He detected spiral structure in nebulae, and promptly adopted the name “island universes”



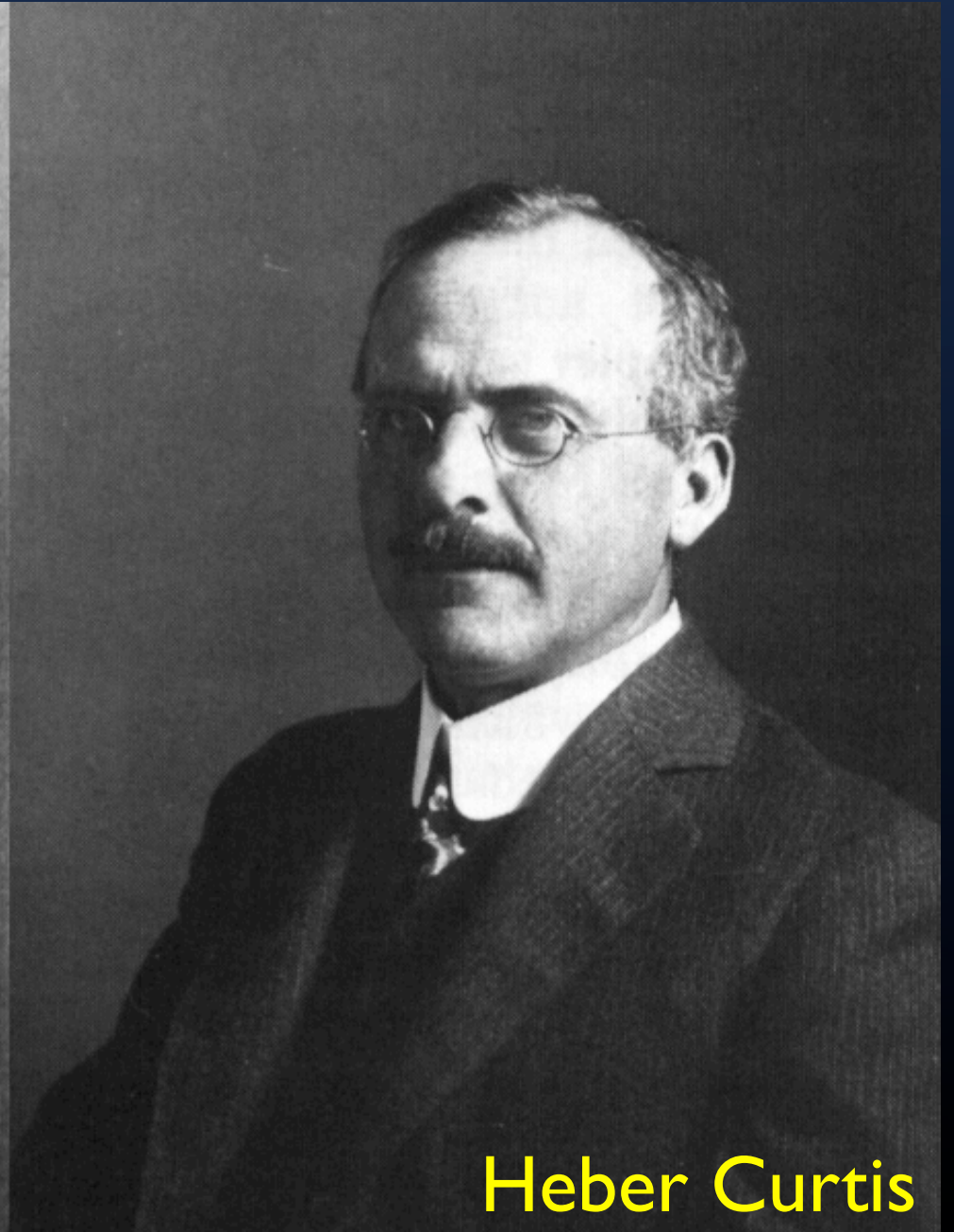
SPIRAL NEBULAE



SHAPLEY-CURTIS DEBATE



Harlow Shapley



Heber Curtis

SHAPLEY-CURTIS DEBATE

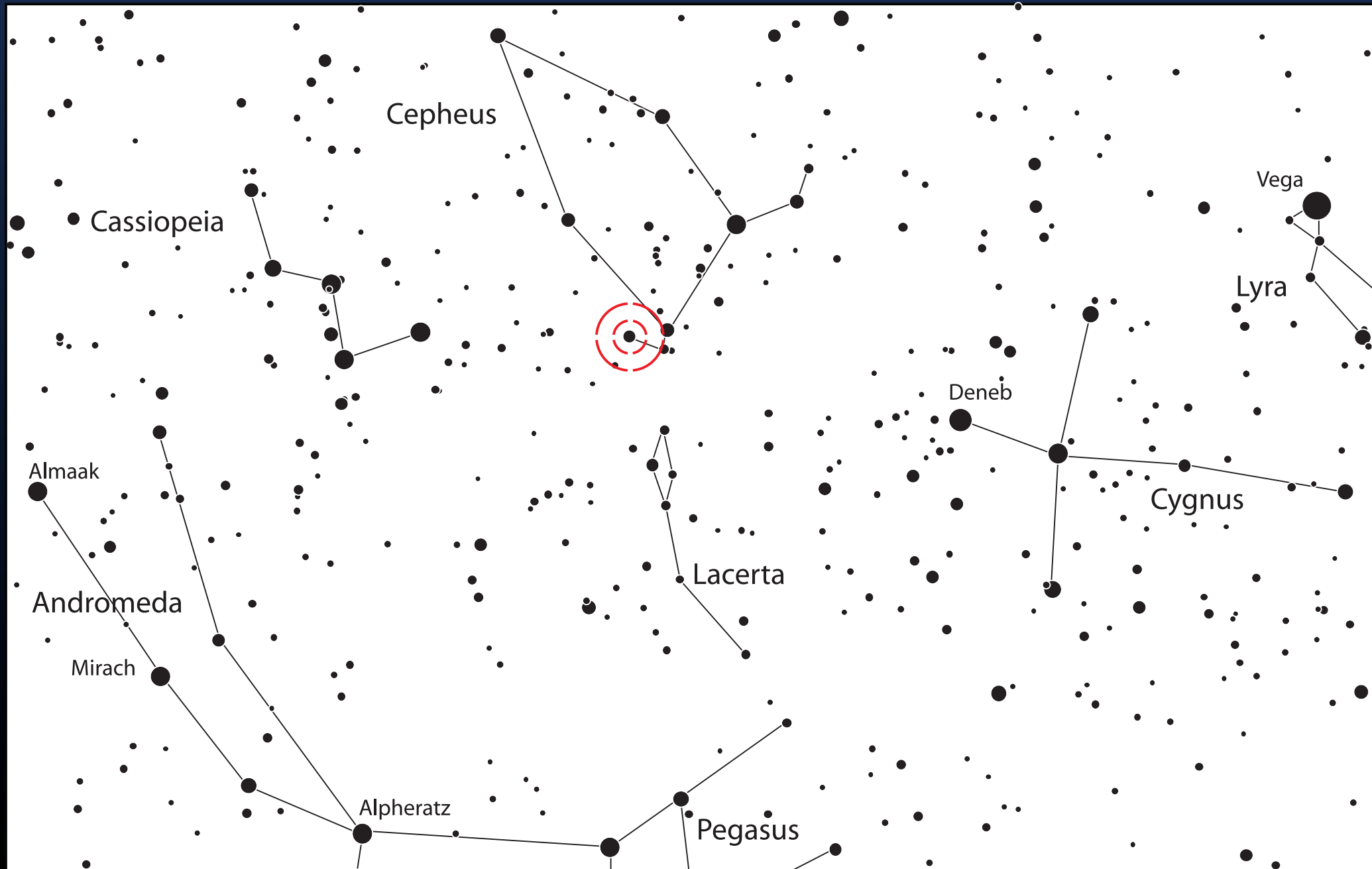
- **Harlow Shapley** (Mt. Wilson Observatory) & **Heber Curtis** (Allegheny Observatory) debated the nature of the spiral nebulae and the size of the Universe
- **26 April 1920**: Smithsonian Museum of Natural History
 - Technical papers about the nature of galaxies were presented all day
 - **Live debate** between Shapley and Curtis that evening
- Open scientific debate; did little to change anyone's mind
 - **Needed more and better observational data!**

CEPHEID VARIABLES...

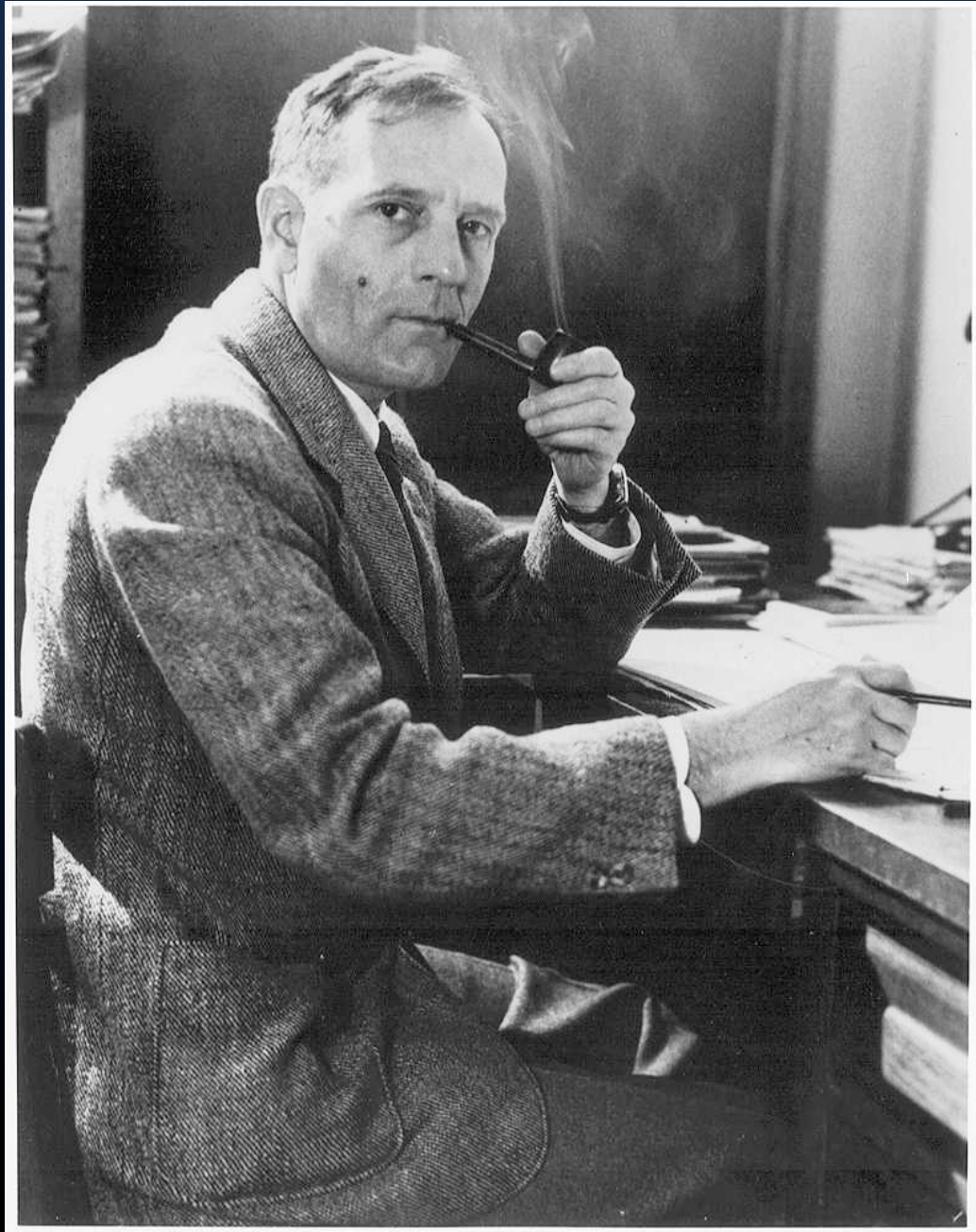
- Resolving the galaxy debate would depend on getting distances
- **Henrietta Swan Leavitt** discovered **Cepheid variables** in 1912 at HCO
- Period of variability and the brightness can be used to determine distance!
(**Period-luminosity relation**)



DELTA CEPHEI

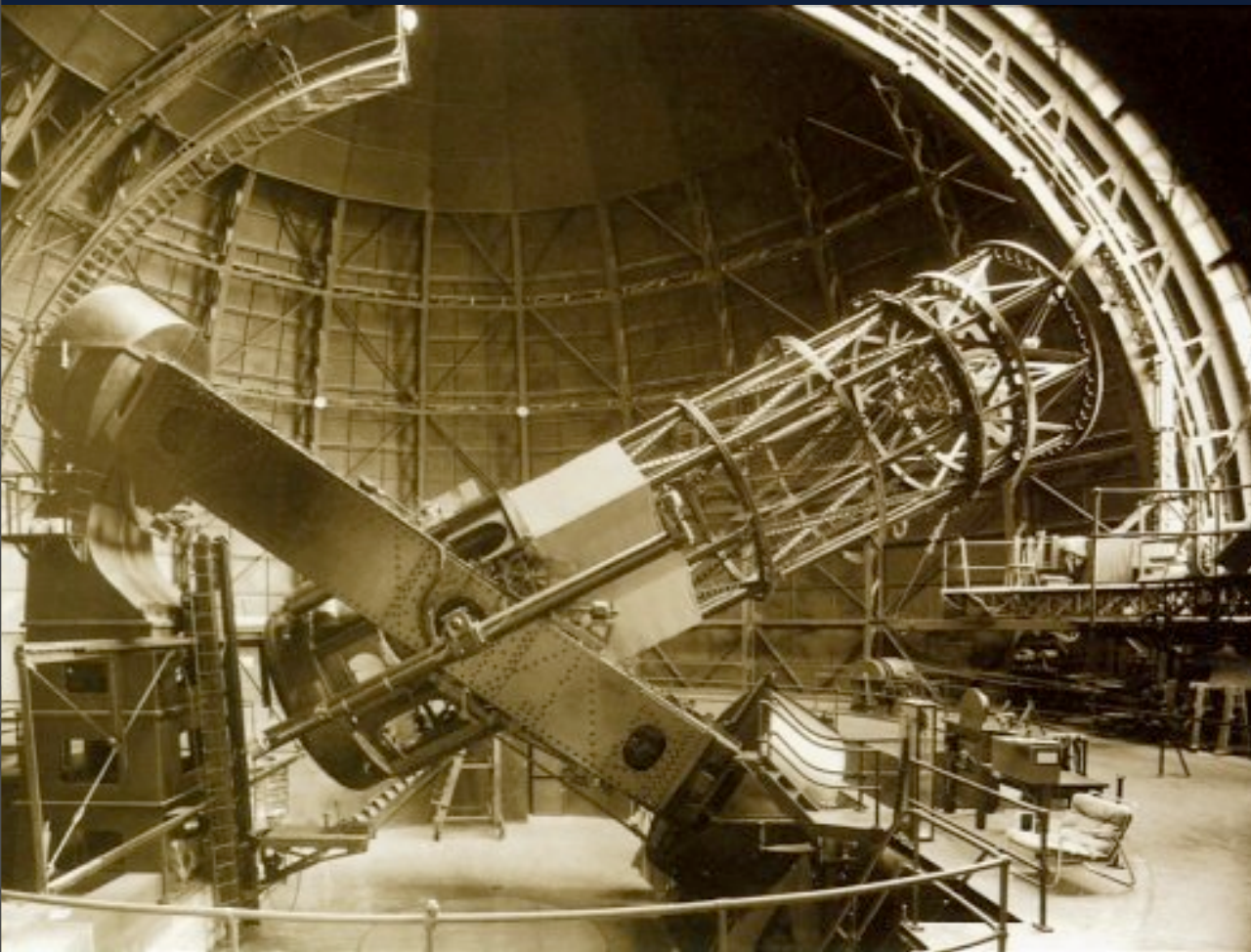


ENTER HUBBLE...

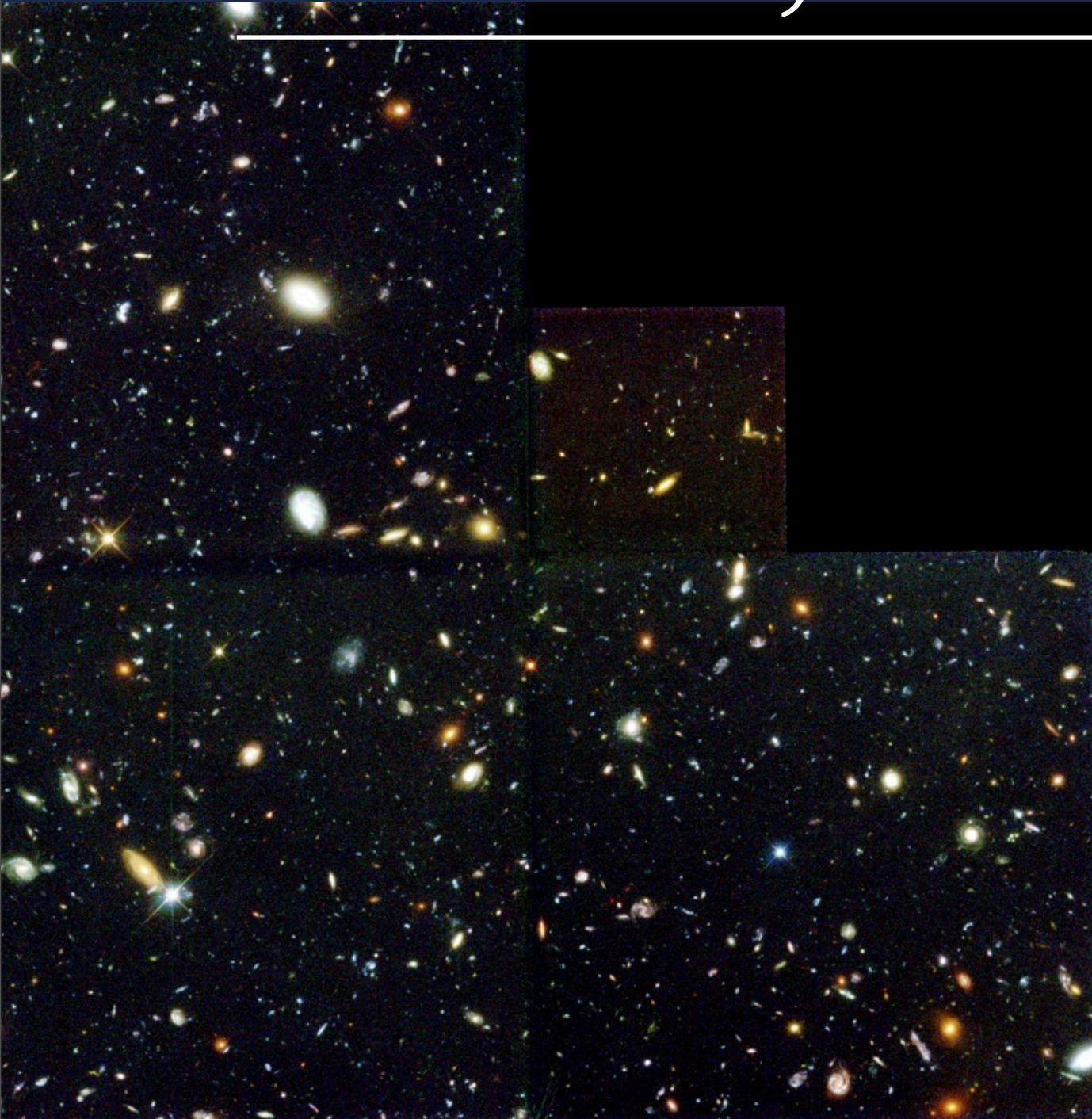


ENTER HUBBLE...

- On 30 Dec 1924, Hubble announced observations of Cepheid variables in other galaxies, firmly establishing that the spiral nebulae were distant star systems.

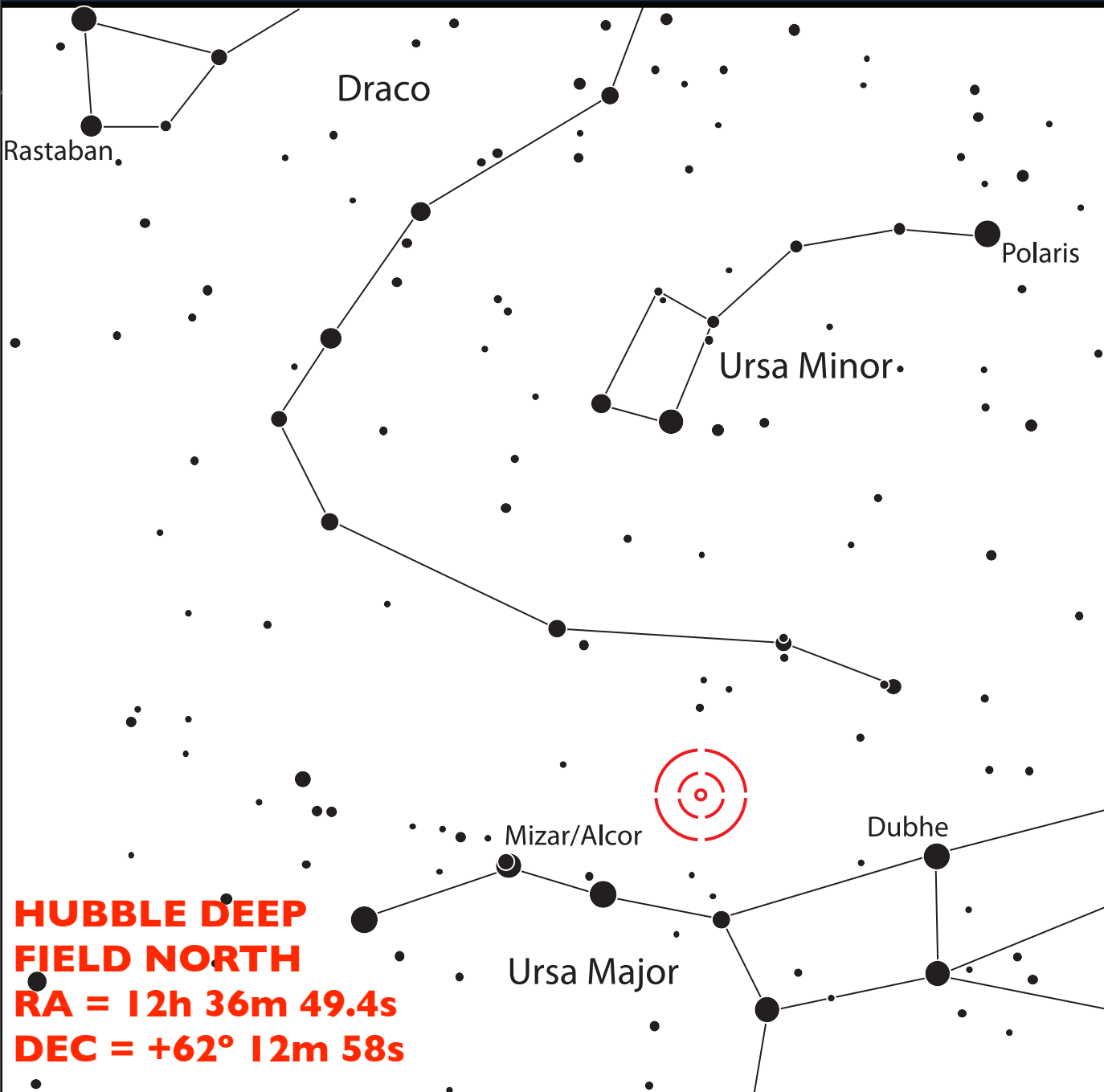


GALAXIES, GALAXIES!



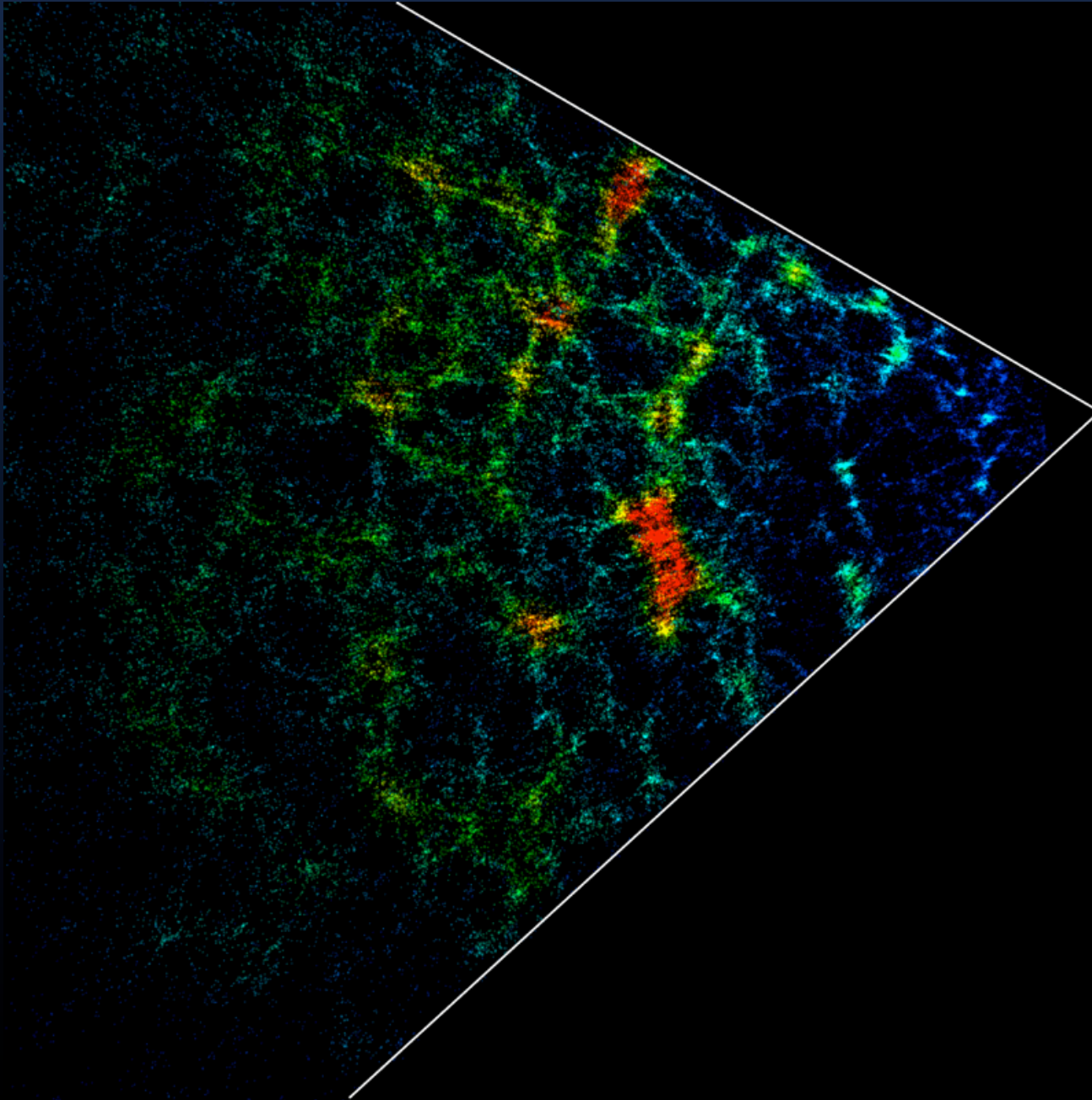
- Over 10 days in 1995, the Hubble Space Telescope looked at the same spot in Ursa Major (an “empty spot”)
- The result was the Hubble Deep Field (North).
- ~3000 galaxies in this single image!

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HOW MANY & HOW FAR?



- Anglo-Australian Observatory galaxy redshift survey
- Can map 2 degrees on the sky at once; covered over 1500 square degrees
- The 2dF Redshift Survey mapped the location of 245,000 galaxies

HOW MANY & HOW FAR?

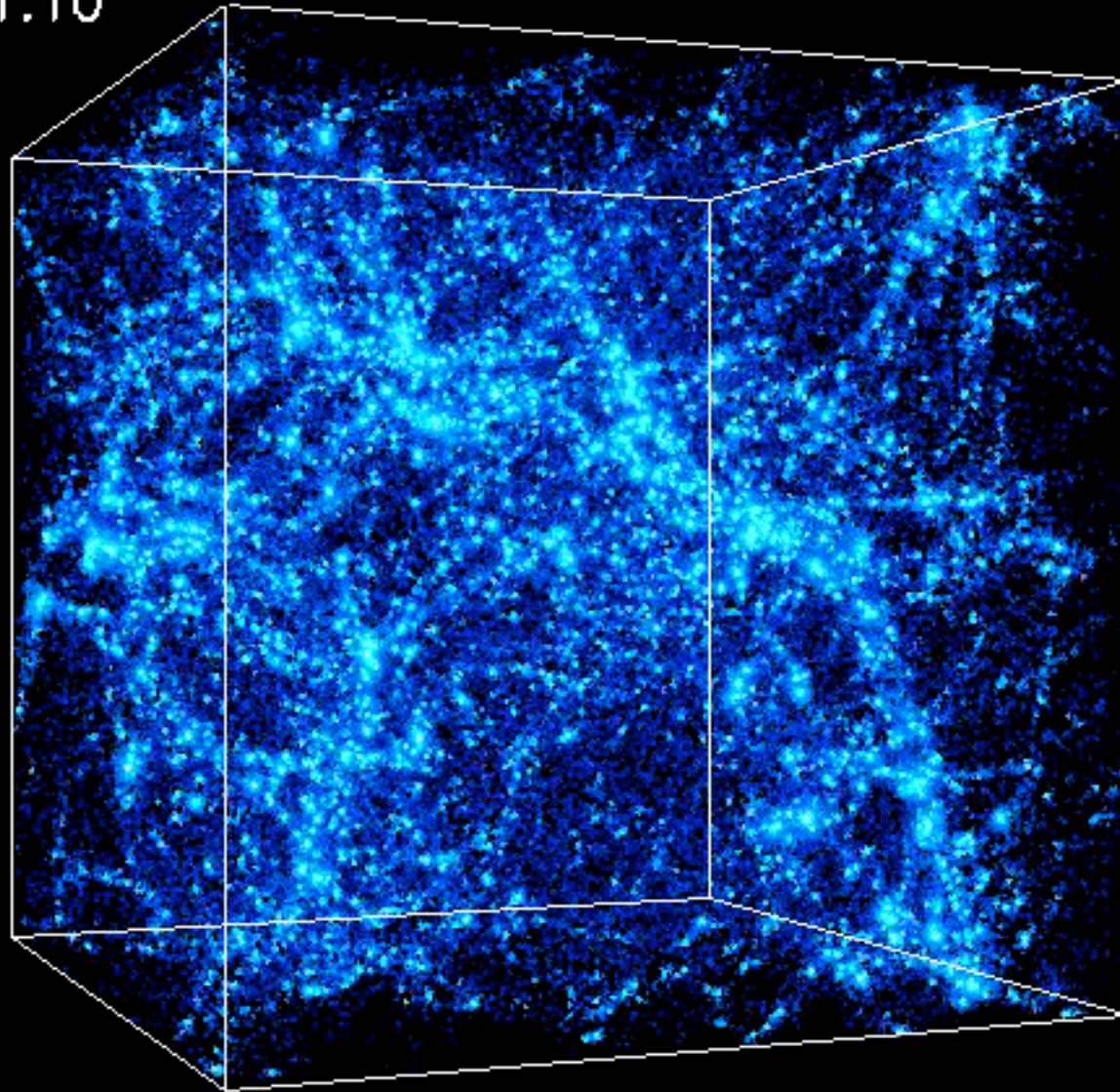


GALAXY CLUSTERS

- It seems galaxies cluster on large scales in the Cosmos
- Supercomputer simulations are attempting to explain this
- Depends on our understanding of cosmology, and the matter content of the Universe

GALAXY CLUSTERS

$Z = 1.10$





NGC 4631



M51



NGC 4656



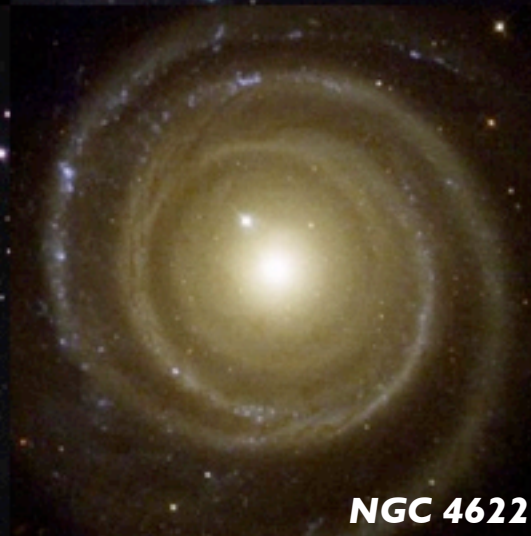
NGC 891



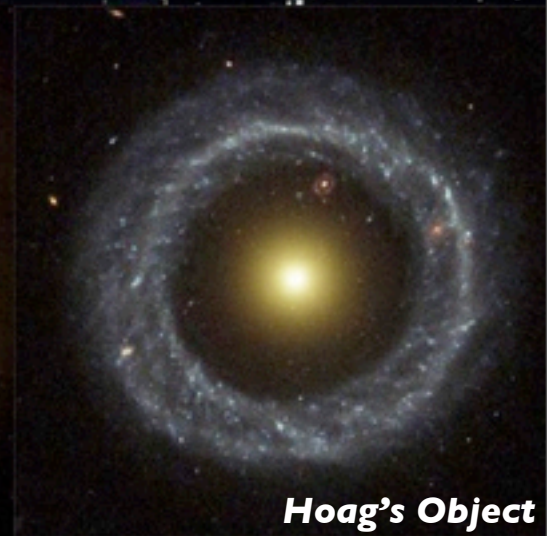
NGC 4414



NGC 4038



NGC 4622



Hoag's Object



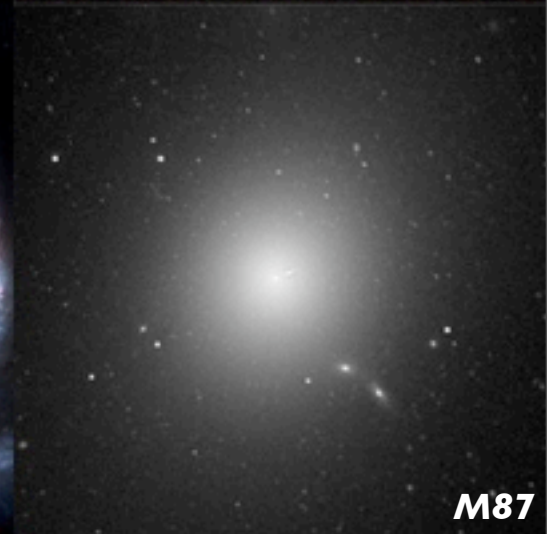
M81 & M82



M104



NGC 1300



M87

GALAXIES YOU CAN SEE



Milky Way (Home)

RA = 17h 45.5m

DEC = -28d 55m

Visible from dark sites, spans the ***entire*** sky!

To the South tonight

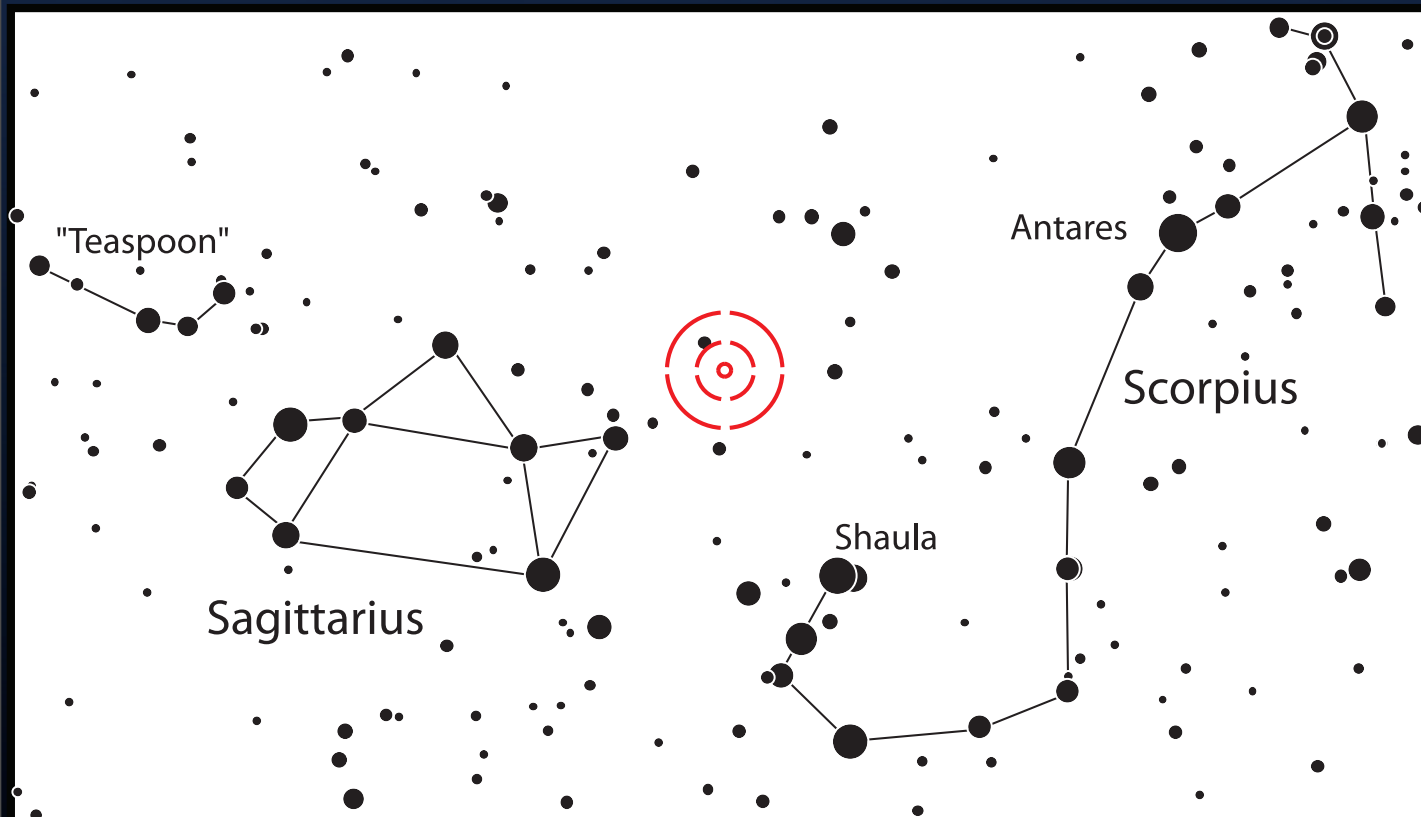
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M31 (Andromeda)

RA = 00h 42.7m

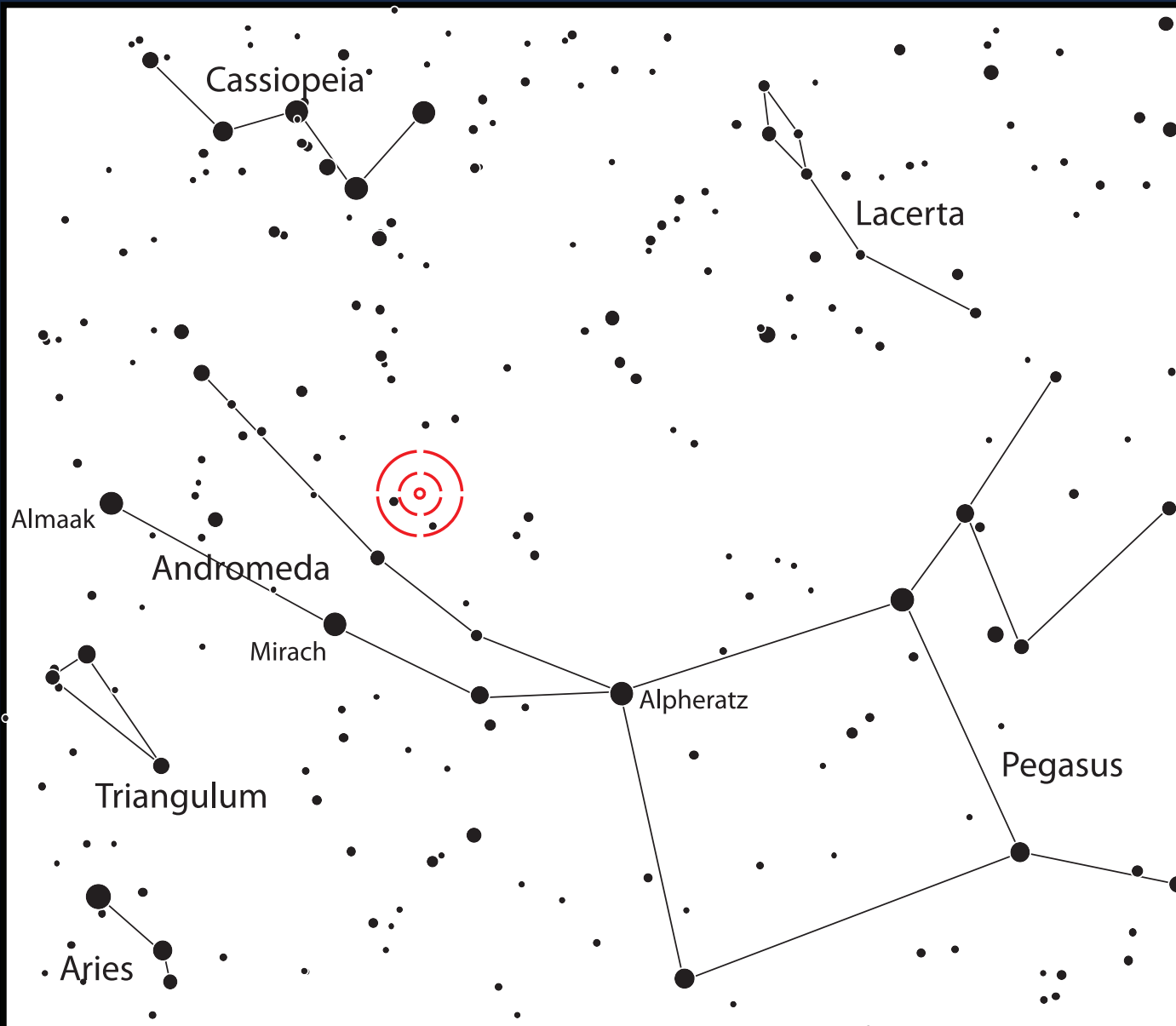
DEC = +41d 16m

Visible to the naked eye, easily seen in binoculars

M32 & M110 nearby!

Rising late, in the East tonight

GALAXIES YOU CAN SEE



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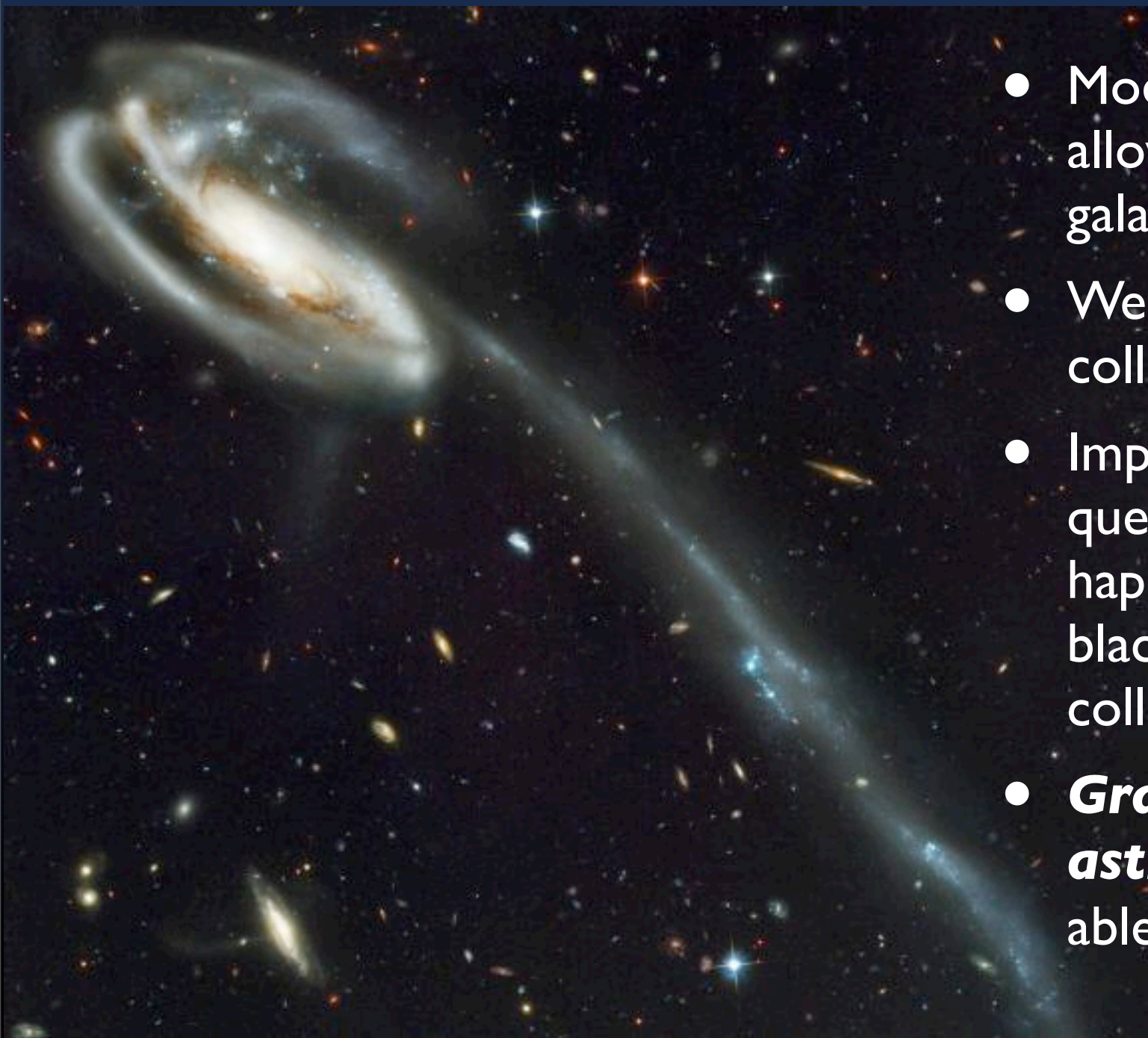
GALACTIC COLLISION

- In 3 billion years, the Milky Way will collide with the Andromeda Galaxy. NOTE: The Sun will not be dead yet!



Simulation by John Dubinski (CITA): www.galaxydynamics.org

GALAXY COLLISIONS



- Modern computers allow us to **simulate** galaxies & collisions
- We see evidence of collisions all the time!
- Important unresolved questions: what happens to the two black holes after a collision?
- **Gravitational wave astronomy** should be able to tell us

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GALAXY MYSTERIES

- The fate of galaxies after mergers is only one mystery
- There is still a **tremendous amount** we don't know
 - What is the dark matter in galaxies?
 - How do different kinds of galaxies form?
 - Which came first, the star or the galaxy?
 - Where do the central black holes come from?
 - What happens in the cores of galaxies?
 - What is the shape and density of the galaxy?

LAST THOUGHTS...

- Galaxies are among the **largest objects** we can see
- Galaxies are **diverse** in their structure and appearance, and still of **great scientific interest** [black holes, formation, dark matter, ...]
- Galaxies cluster and group together, forming the structure of **the skeleton of the Cosmos**
- Many can be seen by average folks like us!

ENJOY OBSERVING!

