OASES IN THE DARK:
galaxies as probes of the Cosmos

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• What are we talking about?
• Simple facts, some history
• Galaxy clusters, galaxies, black holes
• Galaxies we have known and seen
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)
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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)
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 held that evening

- Open scientific debate
**Shapley’s Arguments**

- Shapley believed the Milky Way was the entire Universe, and the spiral nebulae were simply nearby gas clouds.

- If the Andromeda Nebula were the size of the Milky Way, it would be enormously far away.

- Observations had claimed to measure the Andromeda Nebula’s rotation (would violate the speed of light limit if it were far away).
**Curtis’ Arguments**

- Curtis argued that the spiral nebulae were galaxies much like our own and far away.

- Count the number of novae (a type of stellar explosion) toward the Andromeda Nebula; the density is much higher than elsewhere on the sky.

- Massive Doppler Shifts detected in other galaxies.
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...

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

HUBBLE DEEP FIELD NORTH
RA = 12h 36m 49.4s
DEC = +62° 12m 58s
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?
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
Galaxies You can see

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RA = 17h 45.5m
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Visible from dark sites, spans the entire sky!

To the South tonight
Galaxies You Can See

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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RA = 00h 42.7m
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Galaxies You can see

Splinter Galaxy (NGC 5907)

RA = 15h 16.1m
DEC = +56d 19m

Classic edge on galaxy in Draco, visible in telescope

High in Northwest tonight
Galaxies You can see

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GALAXIES YOU CAN SEE
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Galaxies You can see

NGC 6207

RA = 16h 43.1m
DEC = +36d 50m

Nearby M13 in Hercules; easily seen with a telescope

High overhead tonight
Galaxies & Black Holes

- It seems to be true that galaxies with “round bulges” (spheroids) have black holes in their cores.
- The bigger the round bulge, the bigger the black hole.
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*M33 (Triangulum Galaxy, Pinwheel Galaxy)*
Galaxy Mysteries

- We see galaxies all the time, but 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?
  - What happens when galaxies collide?
  - What is in the galactic halo?
  - 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 skeleton of the structure of the Cosmos.
- Many can be seen by average folks like us!
- Enjoy observing!