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Jumping Through Hoops: An Introduction to Polar Ring Galaxies

Outline

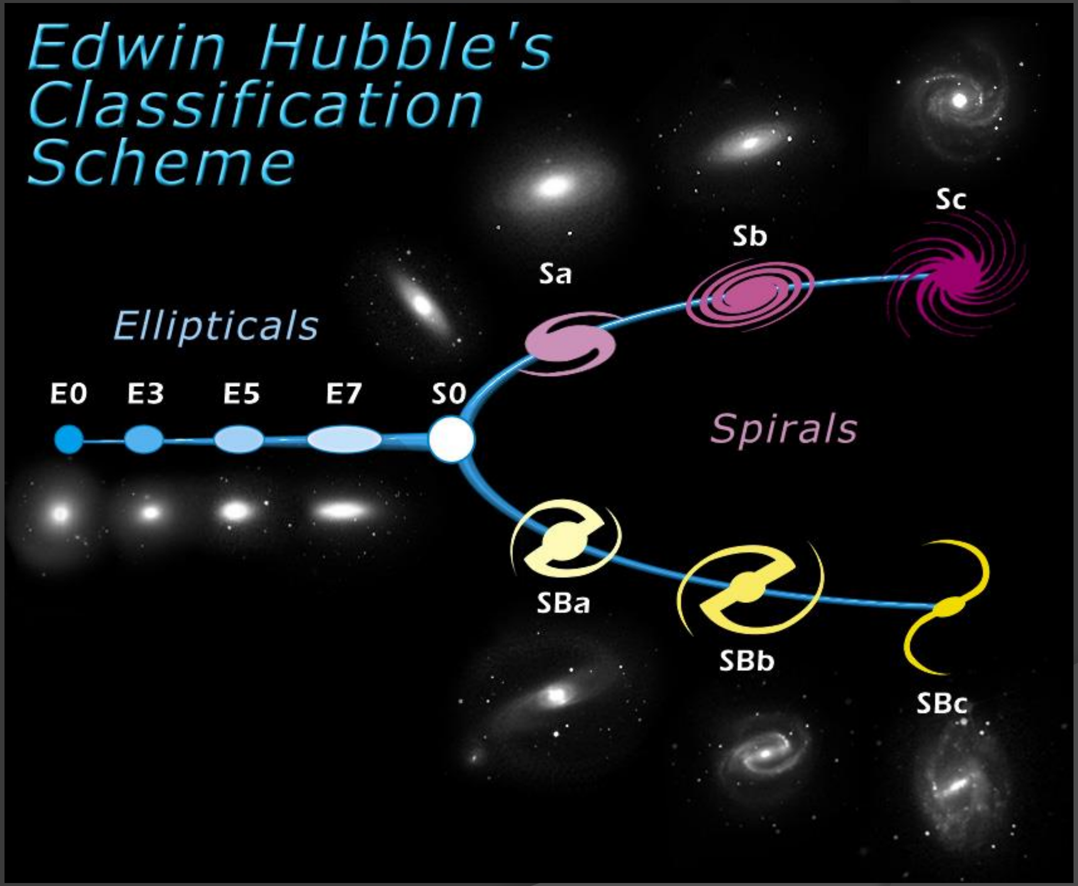
- Familiar Galaxies
- Morphology
- Evolution
- Star Formation
- Polar Ring Galaxies
- Unique Challenges

Galaxies

- Large systems of gas, dust, stars, and dark matter orbiting around a common center of mass.
- We estimate that roughly 185 billion galaxies exist within the observable universe.
- Galaxies come in all sorts of shapes and sizes, containing anywhere from a few billion to hundreds of millions of stars.
- Classification of galaxies is usually based on their morphology. Some are way more eccentric than others.

Galactic Morphology

- Galaxies are largely divided into ellipticals, spirals, and "irregulars."
- Ellipticals: huge, older star populations, little structure.
- Spirals: characteristic spiral arms and dark matter halo, usually quite dusty, high rates of star formation (Williams et al., 2009).
- Special Mention: Lenticular (Hubble type S0) Galaxies have rudimentary spiral arms and elliptical halos, thought to be a transition phase.



Hubble's well-known "tuning fork."

Galactic Evolution

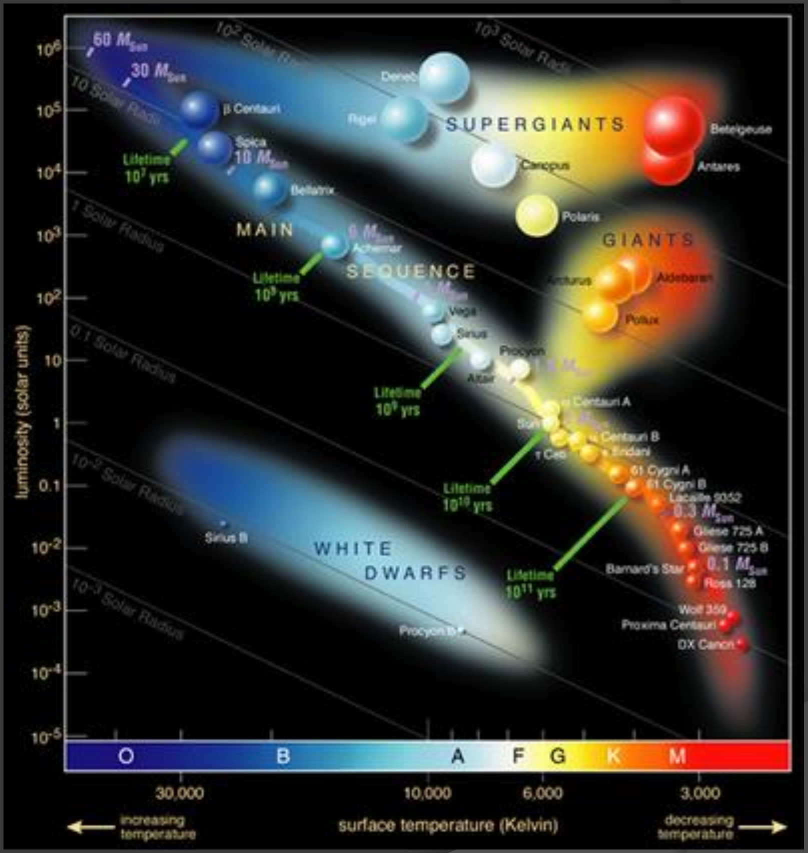
- Just like stars, galaxies age and evolve.
- Elliptical galaxies are huge (over a million light-years across) and have little structure.
- Spiral galaxies are relatively small (usually a few hundred thousand l-y in diameter), and can be considered as large-scale version of our own solar system: matter coagulated into a spinning disk thanks to angular momentum.
- In studying different classes of galaxies, one collects a variety of wavelengths of light.
- Elliptical galaxies are particularly bright in longer wavelengths, whereas spiral arm galaxies give off lots of light across the Electromagnetic Spectrum. Why?
- Two words: Star Formation!

Star Formation

- Elliptical Galaxies shine brightest in the Infrared (IR) wavelengths because their stellar populations are quite old. Very little to no star formation occurs in Ellipticals.
- Spiral Galaxies give off IR light as well, but exhibit a significant amount of the Ultraviolet (UV) light typical of younger stars.
- Conveniently enough, star formation in Spiral Galaxies is most often observed in the spiral arms! These are actually “density waves” in the plane of the galaxy.

Special Note: Starlight and Color

- Galaxies shine because of their stars. As stars age, their spectra change.
- Young, active stars tend to be at their hottest and most energetic, giving off a maximal amount of blue light.
- As they age and cool down, blue light fades and red light begins to dominate.
- Each star has its own story and tendencies, but when lots of “red” stars are apparent in one place, we say that that region is particularly old.
- Not to be confused with Doppler Effect! Stars emit one wavelength, but we observe another.



The Hertzsprung-Russell Diagram. Note the relationship between temperature and color.

Polar Ring Galaxies

HST image of NGC 4650A, a polar ring galaxy. Note the distinct shape of the ring orbiting the S0 galaxy.

- Polar Ring Galaxies, or PRGs, are named for the ring of gas and stars that orbits perpendicular (or nearly perpendicular) to the plane of the central galaxy.
- Most PRGs are S0 lenticular-type galaxies, though research has shown that ellipticals can also host rings of their own (Whitmore et al., 1990).
- About 0.5% of nearby lenticulars have these rings, but up to 5% of these galaxies may have had rings at some point (Whitmore et al., 1990).
- Obvious question: how do PRGs form?

PRGs: Evolution

- Two theories explain the formation of PRGs: collisions and mass accretion (Schweizer et al., 1983).
- Collision: a small galaxy rams into a larger galaxy at a ~perpendicular angle and is ripped apart.
- Mass accretion: two galaxies come near enough to one another to begin interacting gravitationally; the more massive galaxy begins to strip matter from the smaller one through tidal forces, stringing it out into the ring.
- Galaxies are long-lived and any such processes would require a lot of time. But just like we know that supernovae have multiple triggers, so too may PRGs. However, whichever model proves true for a given galaxy will help to explain another issue…

HST image of Interacting Galaxy Pair Arp 87; the two galaxies are NGC 3808A (bottom) and NGC 3808B (top).

PRGs: Star Formation

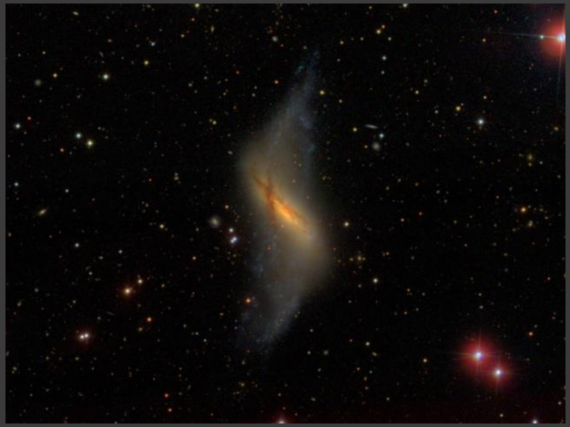
- We CAN and DO observe star formation in the polar rings of these galaxies. But how?
- There are no density waves in the rings, and they are far enough from the central galaxy that the pressure exerted on the ring is fairly low – too low to trigger nuclear fusion (Kulkarni et al., 2011).
- There is still much to learn from PRGs!

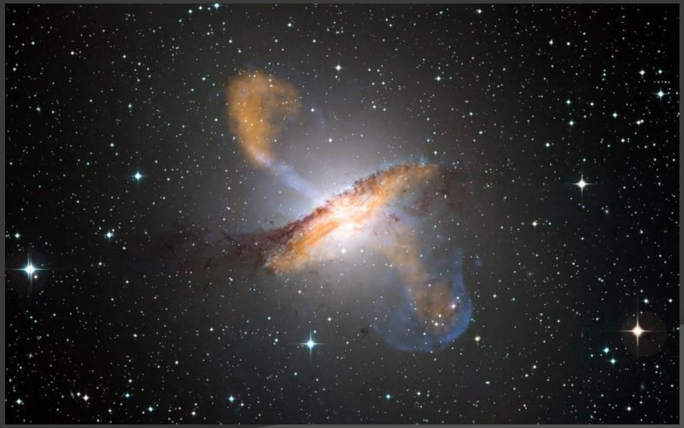
What can PRGs teach us?

- Studying PRGs may reveal more information about dark matter and dark energy. After all, something has to be fueling the formation of stars in the polar rings in the absence of the usual stellar density waves.
- Currently the subject of ongoing research, primarily in infrared wavelengths. These IR observations may reveal new details about the stars forming in the dusty rings – details that were missed in prior, UV studies.

Unique Challenges

- Polar Ring Galaxies tend to be distinct from one another, which can lead to challenges in identification, let alone study:





Upper Left: PRC C-13;
Upper Right: PRC D-18;
Lower Left: PRC A-3;
All SDSS images.

Lower Right: PRC C-45;
Credit to ESO and NASA

Points to Remember

- Polar Ring Galaxies are quite rare, making up less than 1% of all nearby galaxies.
- PRGs likely form through either a galactic merger or mass accretion.
- Stars form in the rings of PRGs, in the absence of the usual triggers (stellar density waves).
- Studying the morphologies of the rings and the star formation within them may lead us to a better understanding of the roles that dark matter plays in the structure of galaxies.

Sources

- Williams, M. J. et al. 2009, *Monthly Notices of the Royal Astronomical Society*. 400,1665.
- Whitmore, B. et al. 1990, *Astronomical Journal.* 100, 1489.
- Schweizer, F. et al. 1983. *Astronomical Journal*. 88, 909.
- Kulkarni, V. et al. 2011. Spitzer Proposal ID #80194.