

The Life and Death of Galaxies

Cressida Cleland

University of Birmingham



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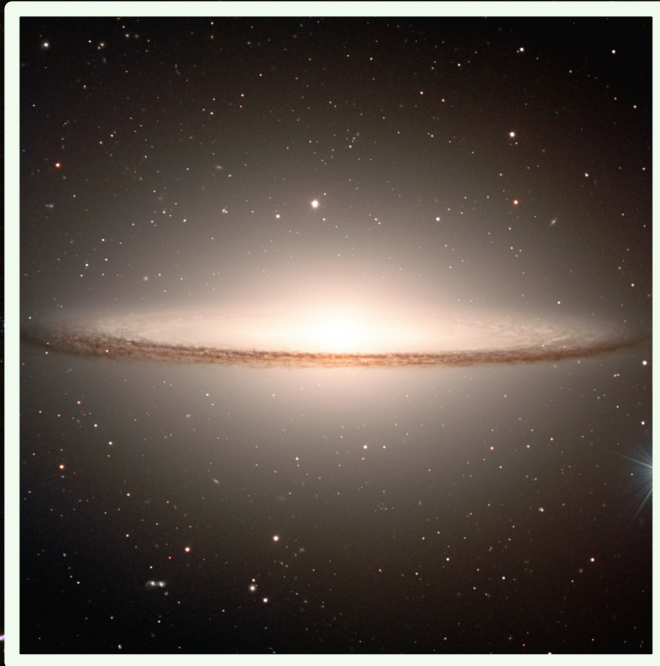
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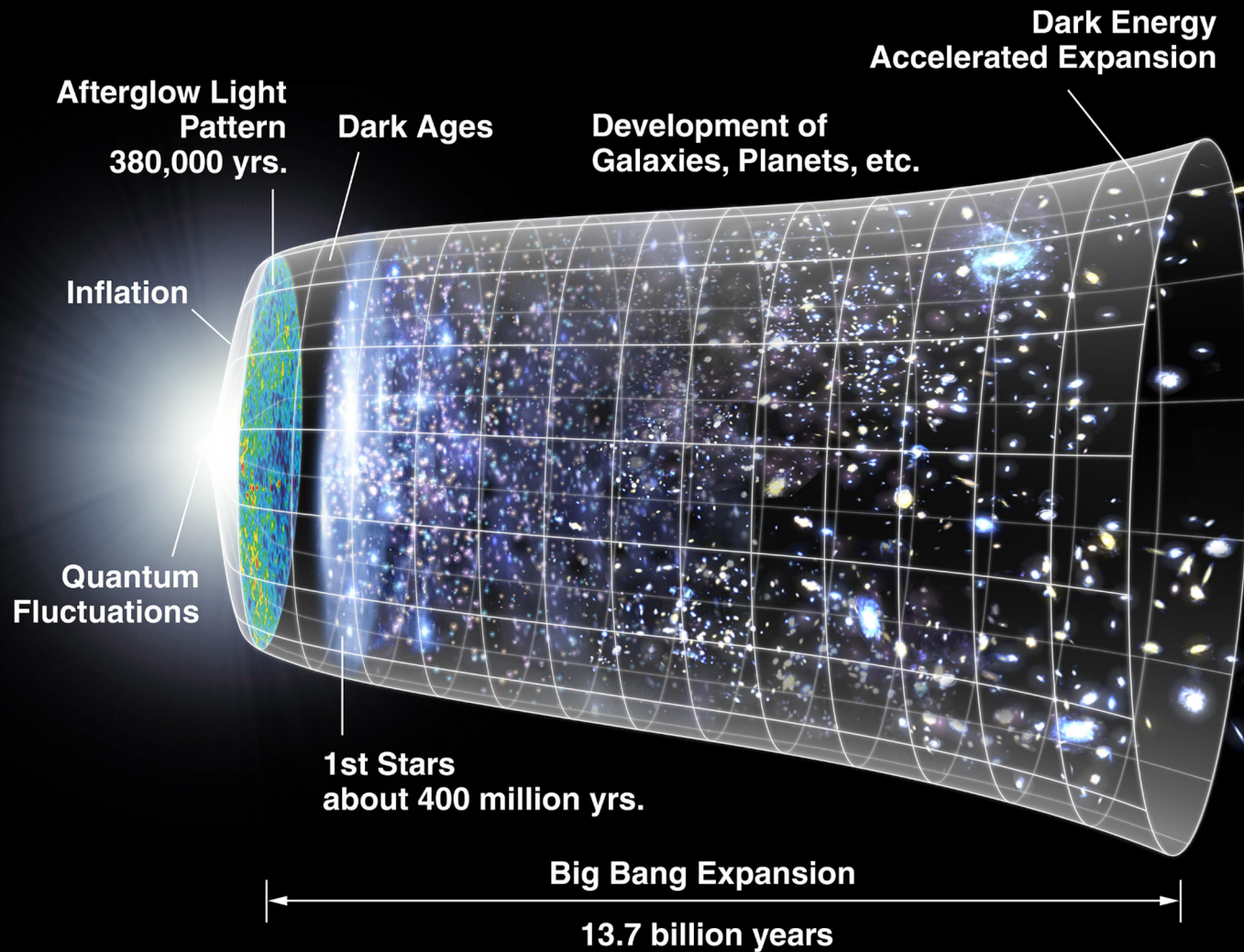


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Galaxies evolve and change?

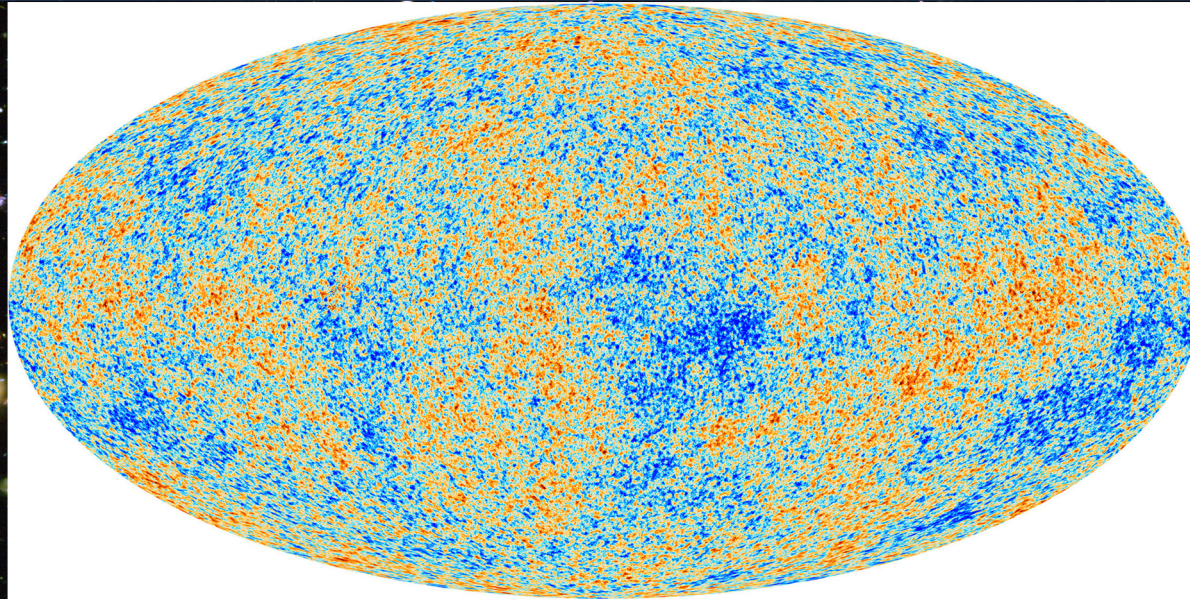


Expansion of universe



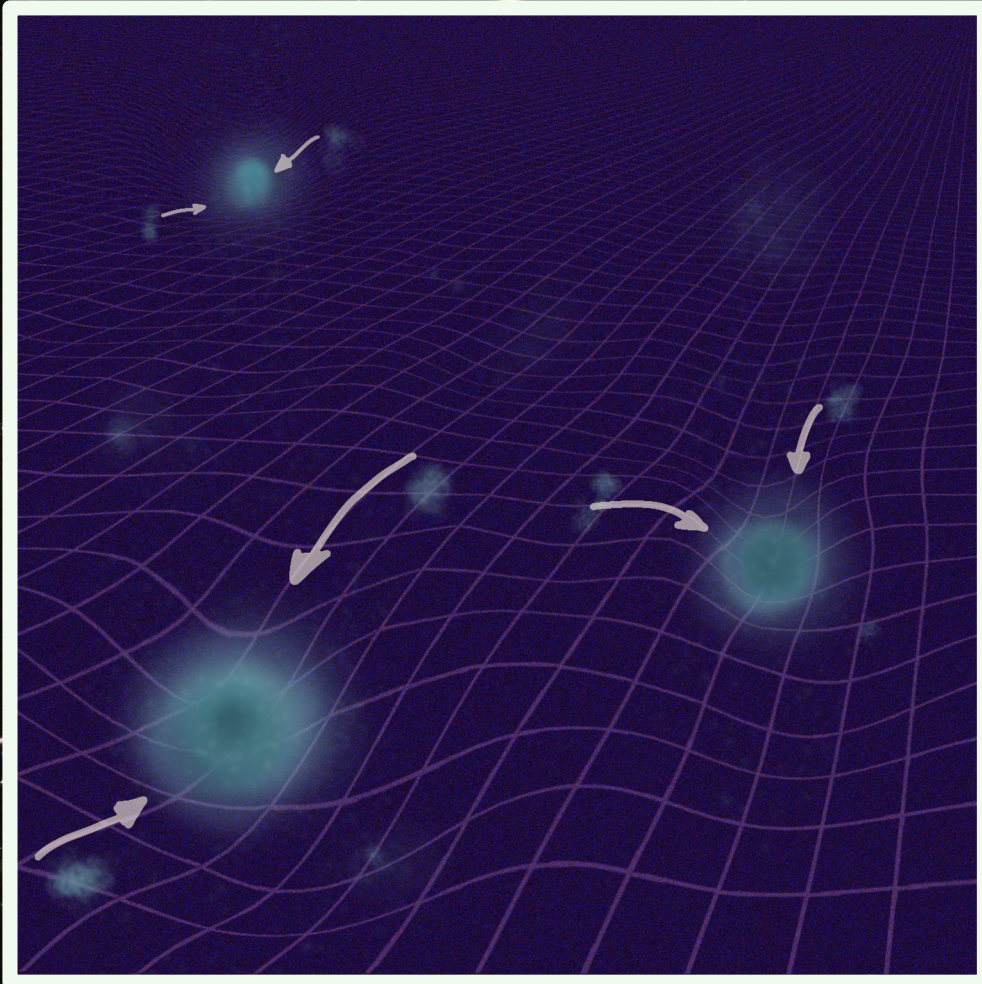
The formation of galaxies

- Early Universe composed of particles and cold dark matter
- Perturbations in the density of the dark matter causes gravitational 'wells'



Cosmic microwave background

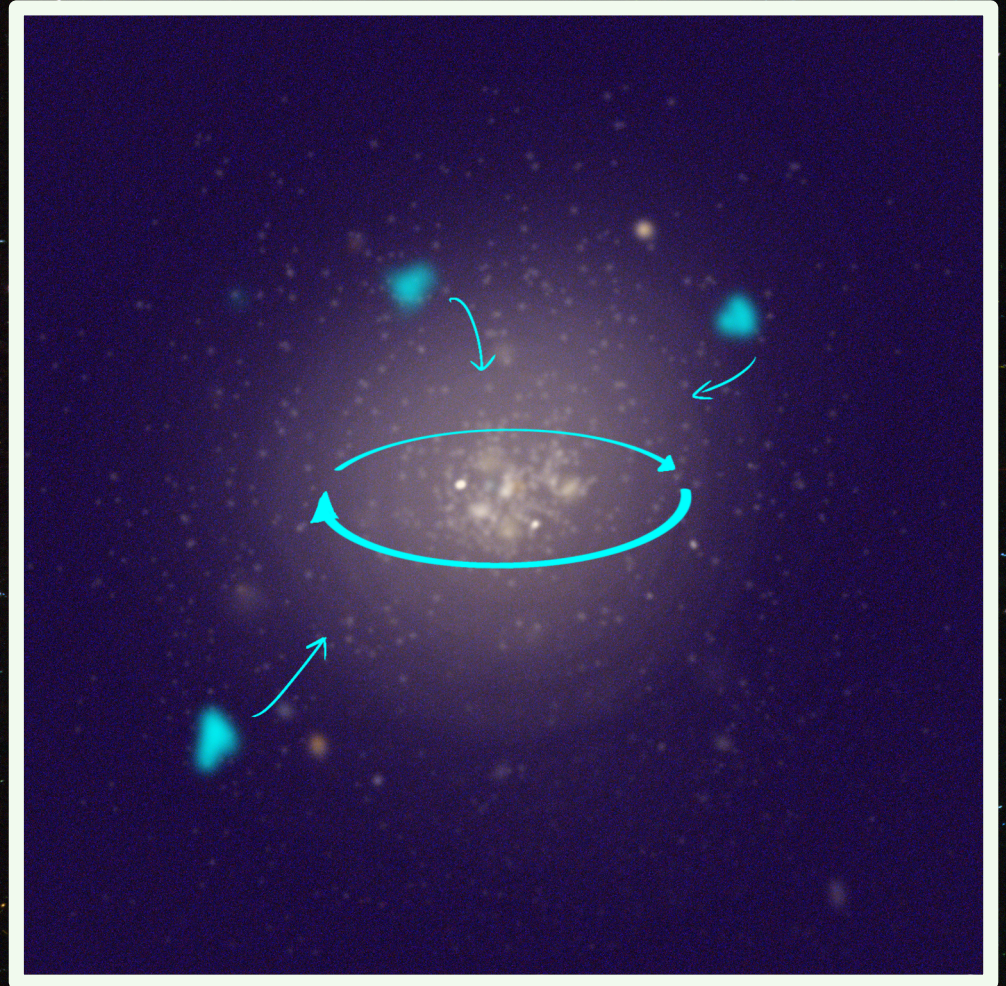
The formation of galaxies



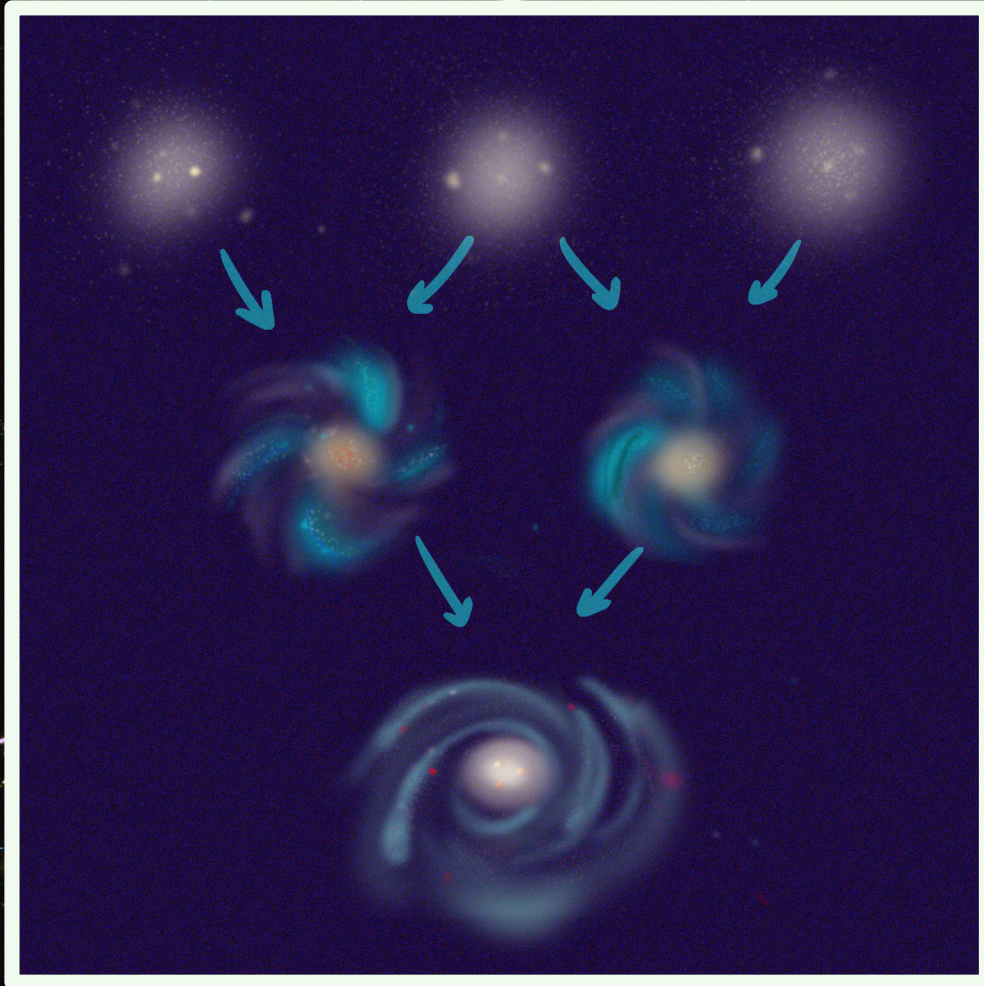
- 1 Over-densities of dark matter collect more and more dark matter, and gas
- 2 Increasing gravitational forces cause gas clouds to condense
- 3 Eventually forms stars

The formation of galaxies

- More and more stars form to create a galaxy-like structure
- These objects merge to form larger structures
- Angular momentum from in-falling gas gives disk shape



Galaxy formation – next steps



- Galaxies are formed by the merging together of smaller objects
- Known as bottom-up theory

Gravitationally bound structures

▣ Galaxies gravitate towards each other

▸ Form groups (10s of galaxies), and clusters (100s-1000s of galaxies)

▸ Galaxies merge, creating more massive galaxies

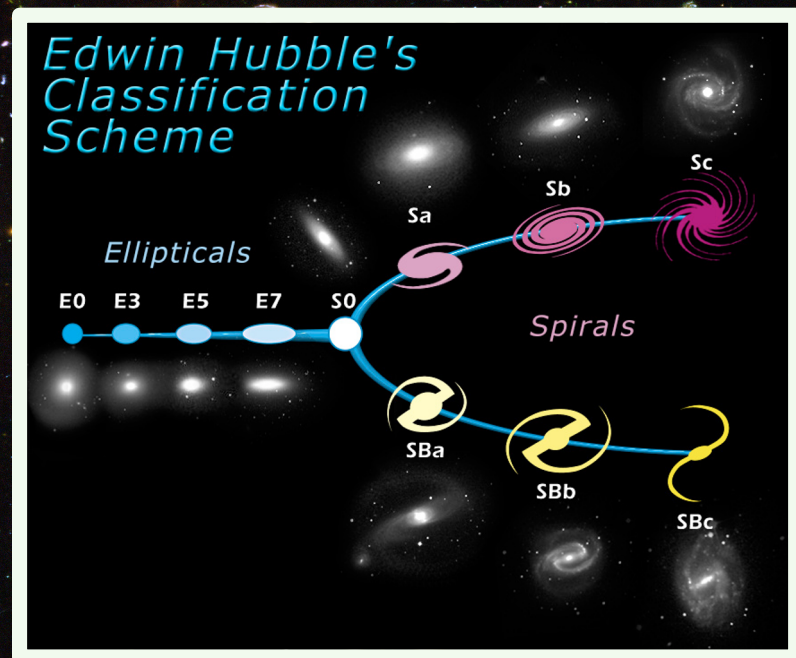
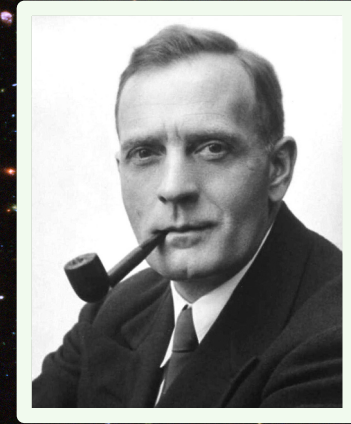
▣ Clusters form along filaments



Characteristics of galaxies

Edwin Hubble came up with classification scheme

Classifies galaxies based on morphology (shape)



Characteristics of galaxies

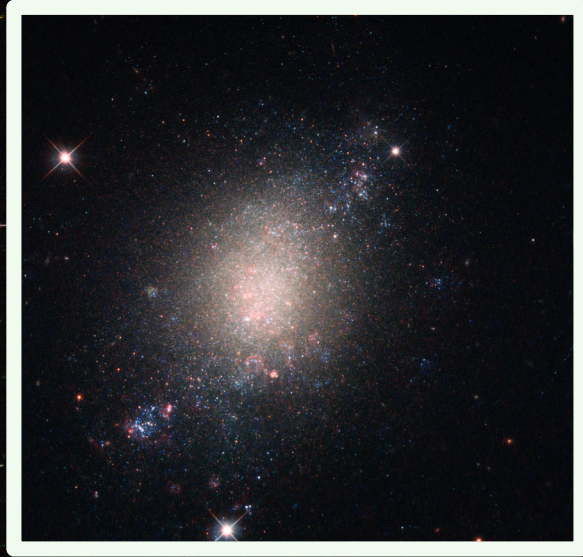


- Major difference in colour; spirals are blue and ellipticals are red
- Blue \rightarrow star formation; red \rightarrow no longer forming stars (quenched)

Characteristics of galaxies

- We know blue light means star formation because young stars emit light at the blue end of the spectrum
- Older stars give off more red light
- If a galaxy has little or no blue light, it means it has stopped forming new stars

Irregular / other galaxies



- Irregular galaxies lack a defined shape or structure

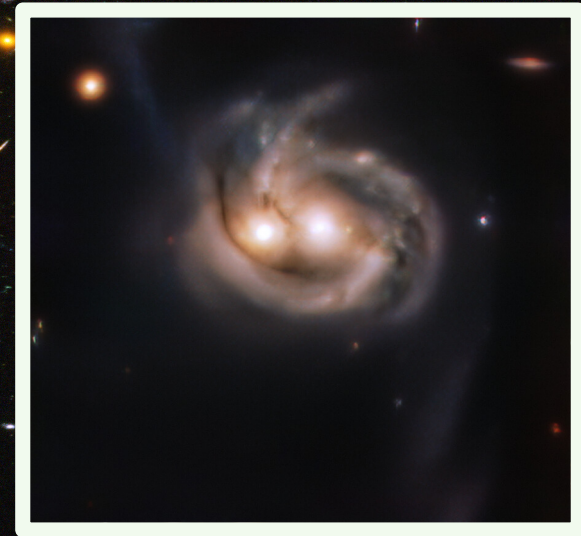
- Are often low in mass

- Dwarf irregular galaxies are thought to be similar to the earliest galaxies

- Some irregular galaxies are the result of strong gravitational forces from other galaxies

Mergers as a quenching mechanism

- Galaxies sometimes collide in a violent event called a merger
- This can disrupt structure, and expel cool star forming gas
- Can lead to quenching...



Quenching mechanisms

Internal/Slow

- Mass quenching
- Morphology
- Gas consumption

External/Slow

- Suppression of cosmic accretion
- Thermal evaporation

Internal/Fast

- Active galactic nucleus feedback
- Post star-burst

External/Fast

- Ram-pressure stripping
- Mergers

Quenching mechanisms

Internal/Slow

- Mass quenching
- Morphology
- Gas consumption

Internal/Fast

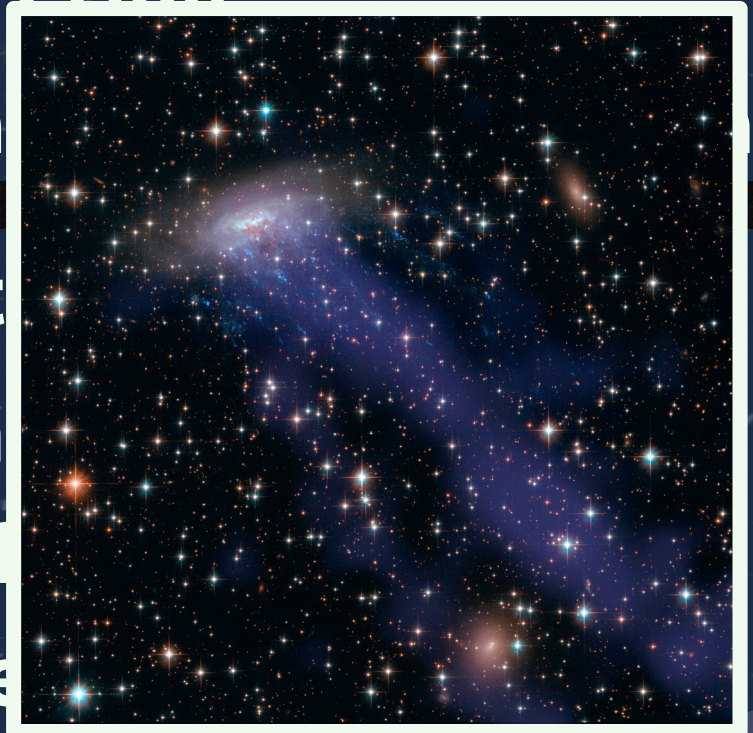
- Active galactic nucleus feedback
- Post star-burst

External/Slow

- Suppression of cosmic accretion
- The

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Quenching mechanisms

Internal/Slow

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External/Slow

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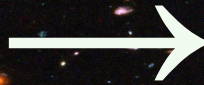
Internal/Fast

- Active galactic nucleus feedback
- Post star-burst

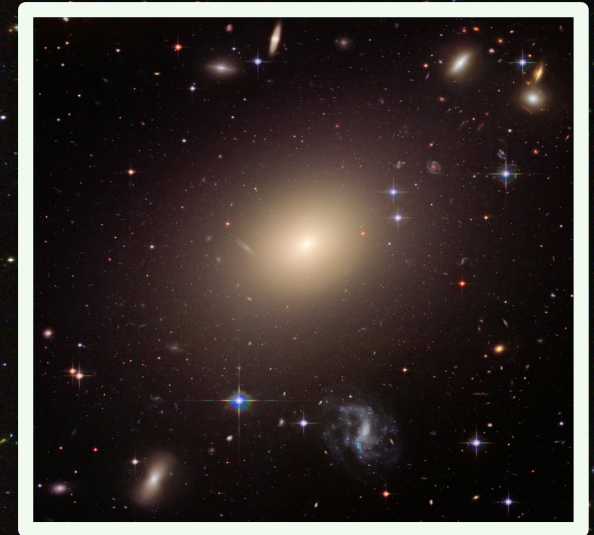
External/Fast

- Ram pressure stripping
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Quenching mechanisms

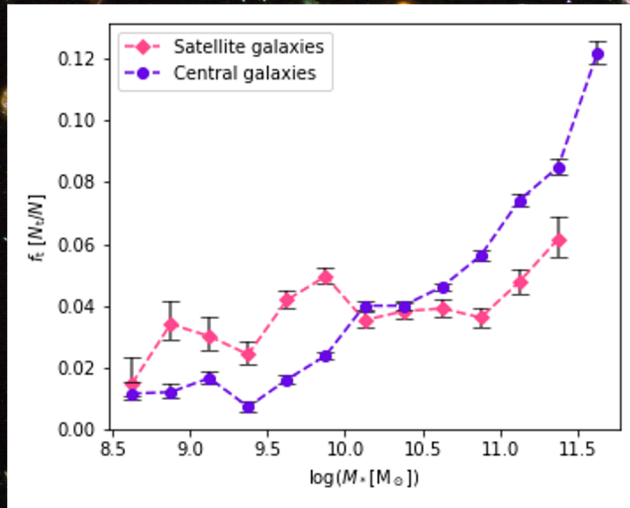


???



Not many galaxies seen in between (sometimes called 'Green Valley')

Recently quenched galaxies (transients)



arxiv.org/abs/2006.16307

- We combined 2 star formation tracers which act on different timescales to identify galaxies which had recently (<100 Myr) quenched
- We see transient fraction increases with mass but is more significant at low-mass for satellite galaxies
- Transient fraction increases with decreasing radial position of galaxy

Recently quenched galaxies (transients)

Results imply recently quenched galaxies occur as a strong function of both stellar mass and halo mass of the group

Low-mass galaxies are more susceptible to high-mass group gravitational forces

This work supports 'delayed-then-rapid' model of quenching

However, it's still difficult to disentangle interdependent factors

AGN Variability



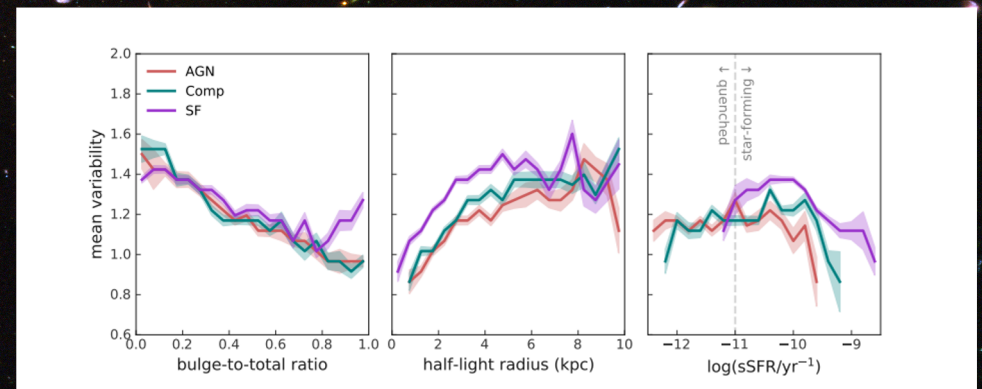
- Active galactic nuclei are compact objects found in the central regions of massive (usually quenched) galaxies
- A supermassive black hole accretes gas and dust, causing heat and release of energy
- AGN activity can vary on different timescales

AGN Variability

- ▣ We use the measurements of the brightness of the galaxy over time
- ▣ Reduced chi-squared to measure variability

AGN Variability

- We found some correlations between variability and other galactic properties
- Surprisingly we find objects labelled as star-forming have higher mean variabilities
- In particular we see increase in variability in intermediate star formation rate



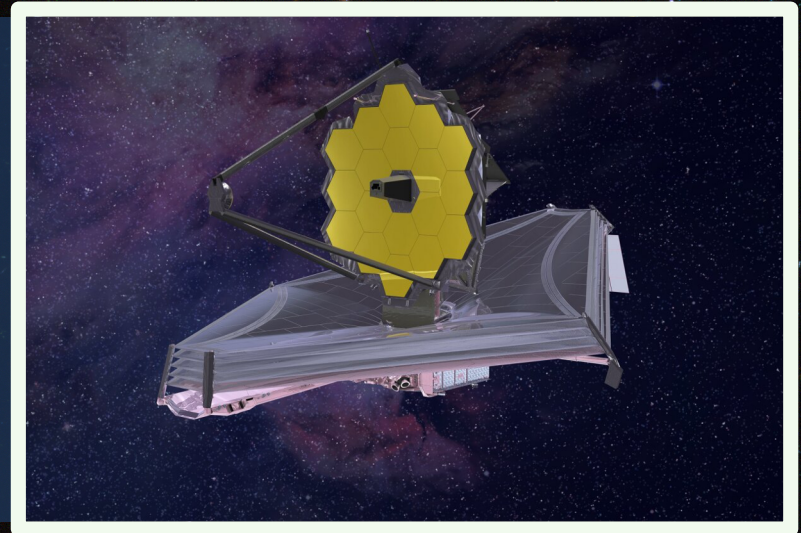
AGN Variability

- **Results imply that variability of this nature can uncover low-mass AGN precluded by star formation**
- **The trends suggest that increased variability can act as a precursor for reduced star-formation and eventual quenching**
- **Future telescopes and datasets will help strengthen results**

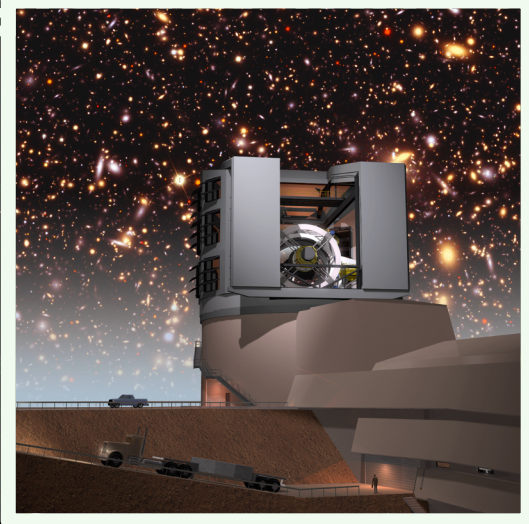
Future of galaxy evolution

James Webb Space Telescope

- Will observe deep into the early Universe
- What did the first



galaxies look like?



Vera Rubin / LSST

- All-sky high-cadence observations
- Will be able to closely monitor galaxies and AGN through time



Thank you!

Image credits: Hubble, ESO, NASA/JPL

28/02/2022

27