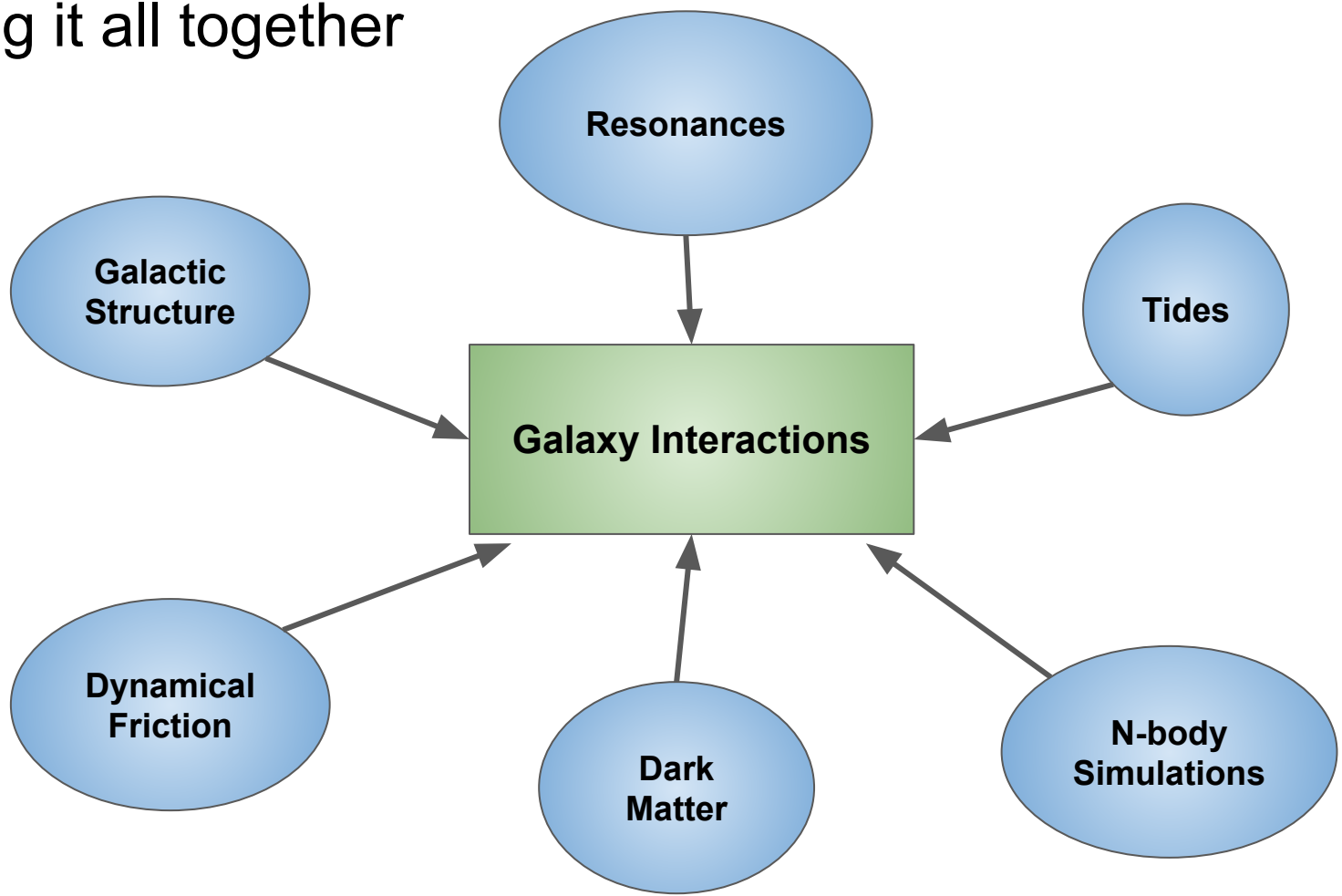
Galaxy Interactions & Mergers

Himansh Rathore

Nov 1, 2024

Putting it all together

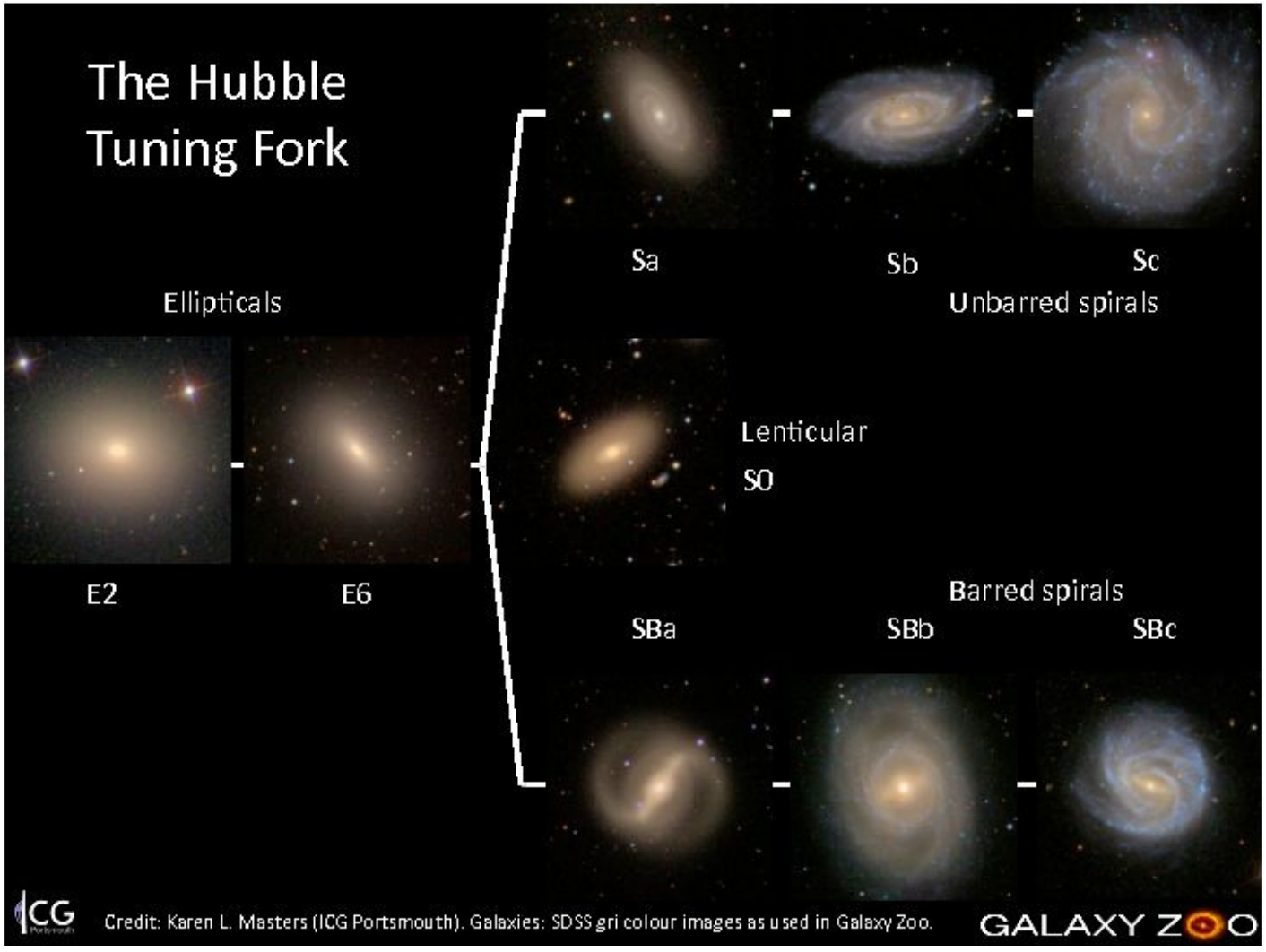


Cosmological Motivation

- We believe that structures in the universe form hierarchically
- Bigger structures are formed out of mergers of smaller structures
- Galaxy interactions are a main driver of the hierarchical formation of the universe !
- What is the main force that drives structure formation ?
    - Gravity !

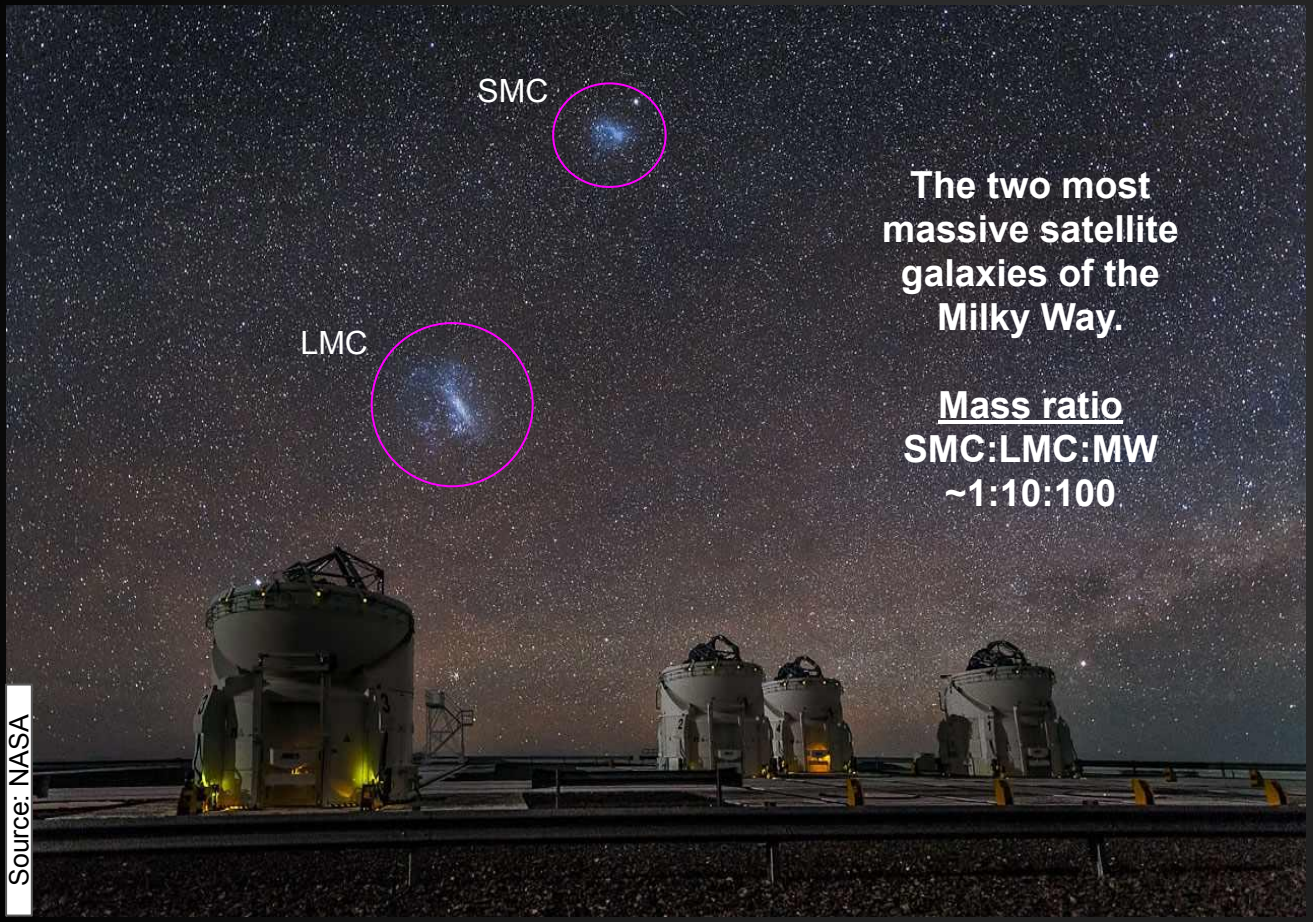
A lot of our knowledge comes from Cosmological simulations. Example:

The Illustris Cosmological Simulation (https://www.youtube.com/watch?v=QSivvdIyeG4)


The Hubble Tuning Fork
Ellipticals
E2
E6
Sa
Sb
Sc
Unbarred spirals
Lenticular
S0
Barred spirals
SBa
SBb
SBc
ICG
Credit: Karen L. Masters (ICG Portsmouth). Galaxies: SDSS gri colour images as used in Galaxy Zoo.
GALAXY ZOO

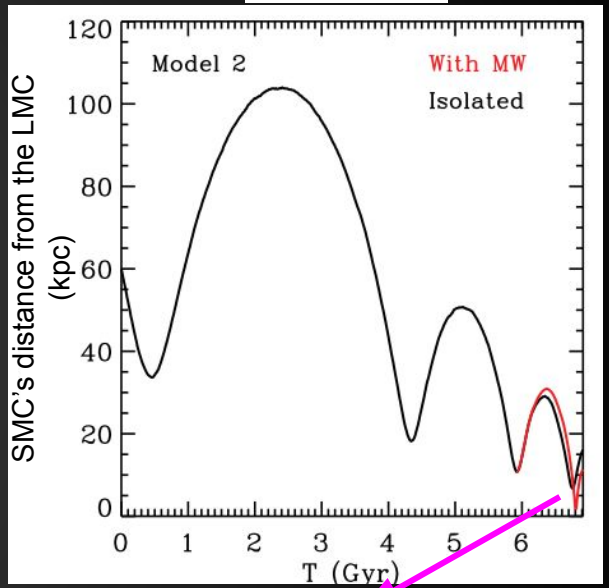
Cosmic crashes are beautiful

The LMC-SMC system: galaxy interactions next door !



Source: NASA

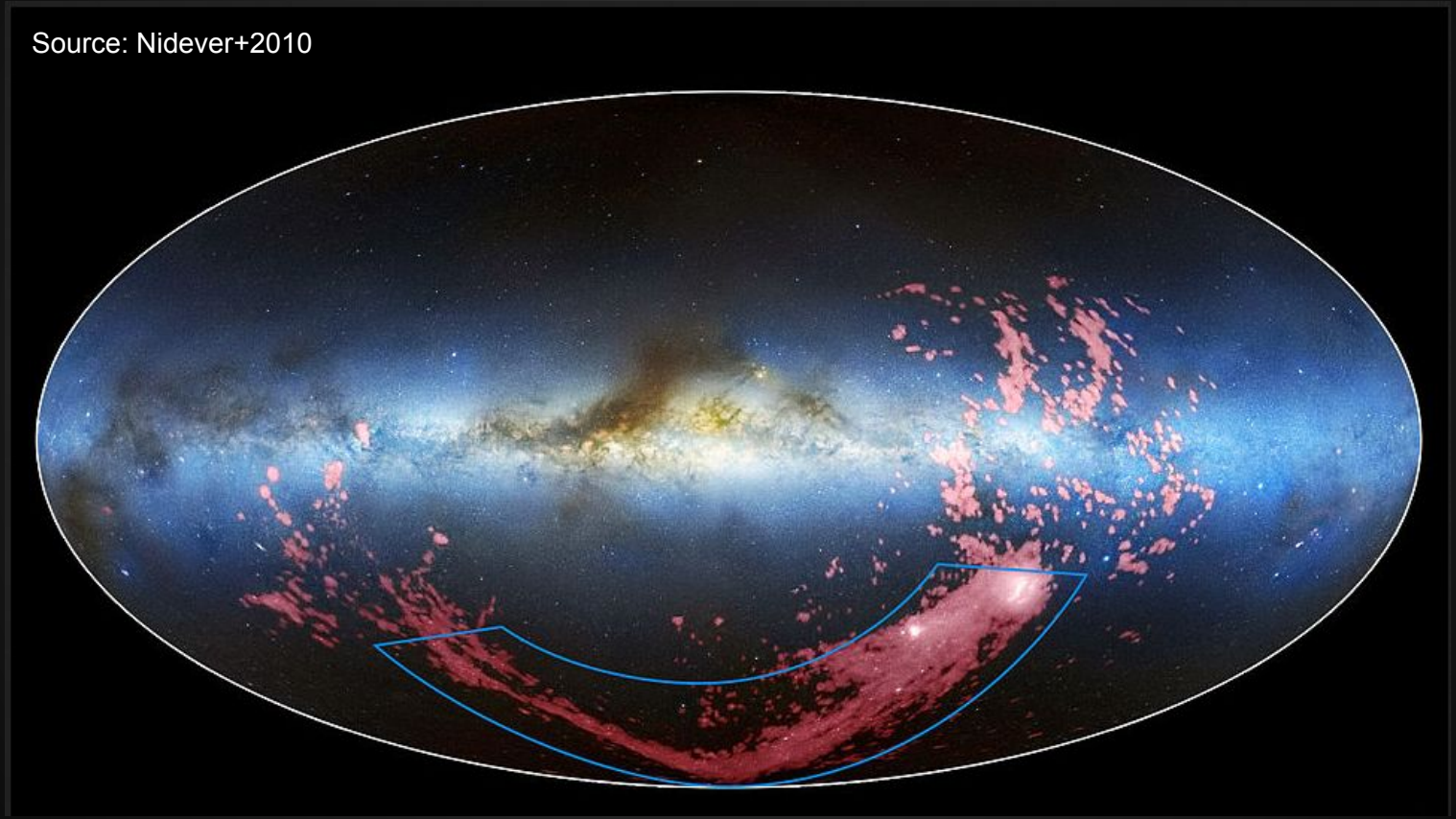
Source: Besla+2012



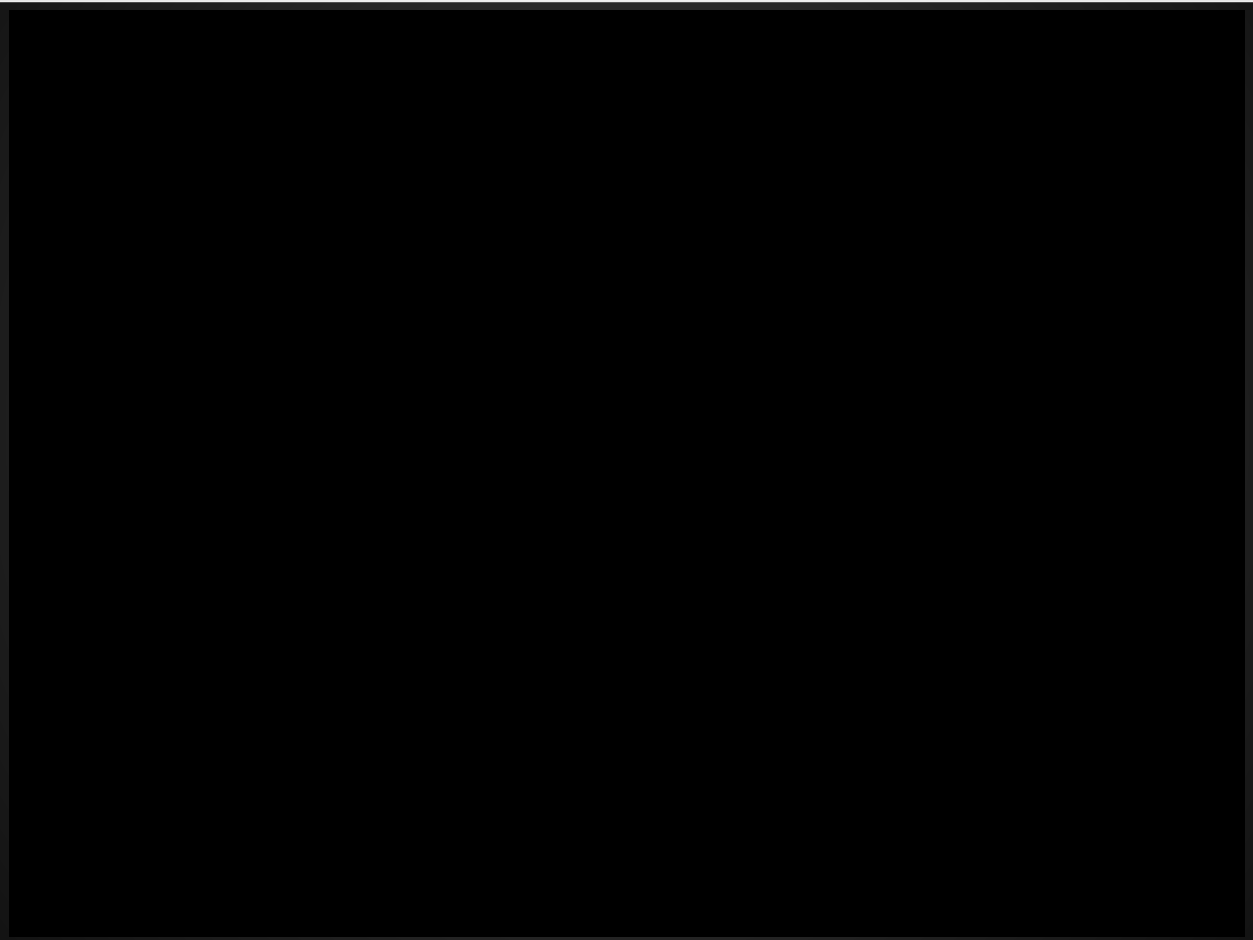
Present day

The LMC and SMC have likely been interacting with each other since the past 6 Gyr

How do we know the LMC and SMC are interacting ?



The MEGHA Simulations - Rathore et al. *in prep*



What drives galaxy interactions ?

- Gravity - causes galaxies to come together !
- But, the galaxies need to slow down to merge together, otherwise they will just fly by each other !
  - The speeds are ~ 100 km/s !
- What causes them to slow down and stick together ?
- Dynamical Friction !

Another reason why we need Dark Matter to exist !

Galaxy interactions as an astrophysical laboratory !

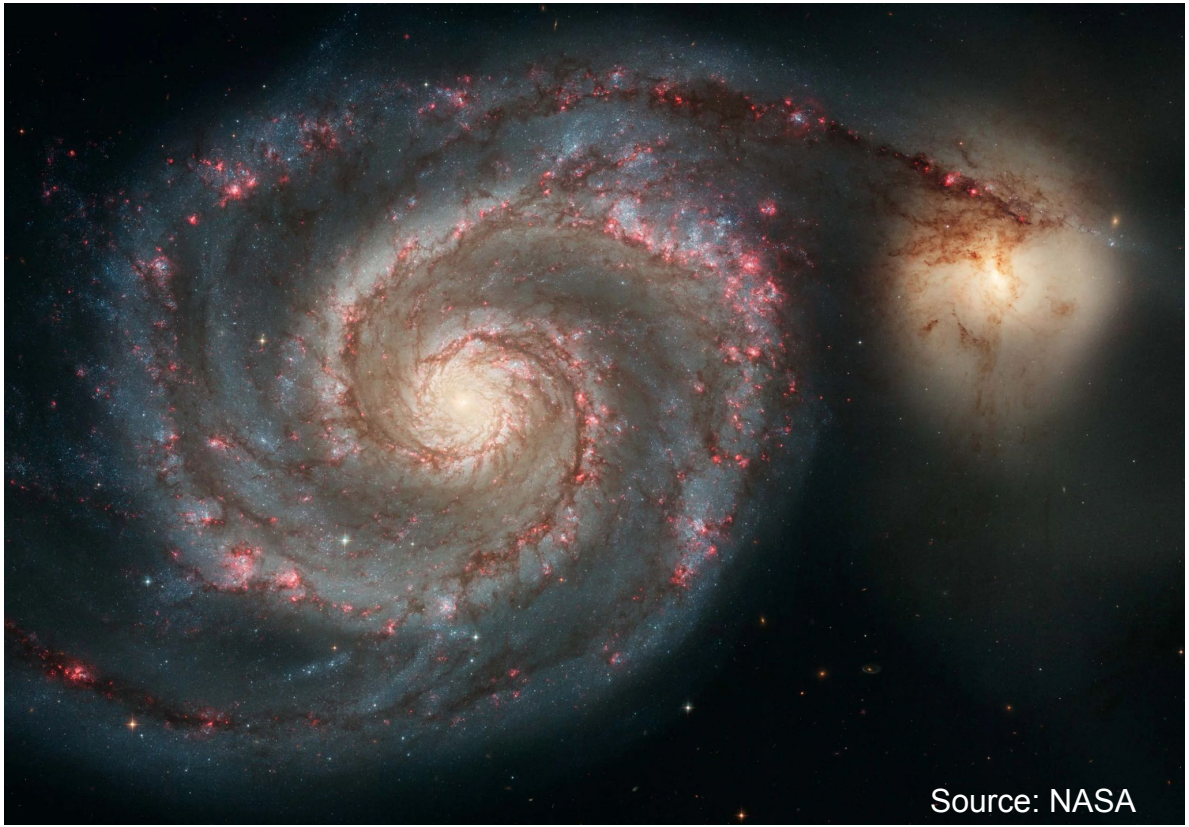
Galaxy interactions affect galaxy evolution !

- Affect dynamical processes
  - Spirals arms and bars
  - Tidal streams
  - Affect the shape (Morphology) of the galaxies
- Affect gas physics
  - Bring in gas/trigger star-formation
  - Change gas distribution
- Supermassive Black Holes
  - Can fuel Active Galactic Nuclei
  - Supermassive Black Hole Mergers

Galaxy Interactions affecting dynamical processes

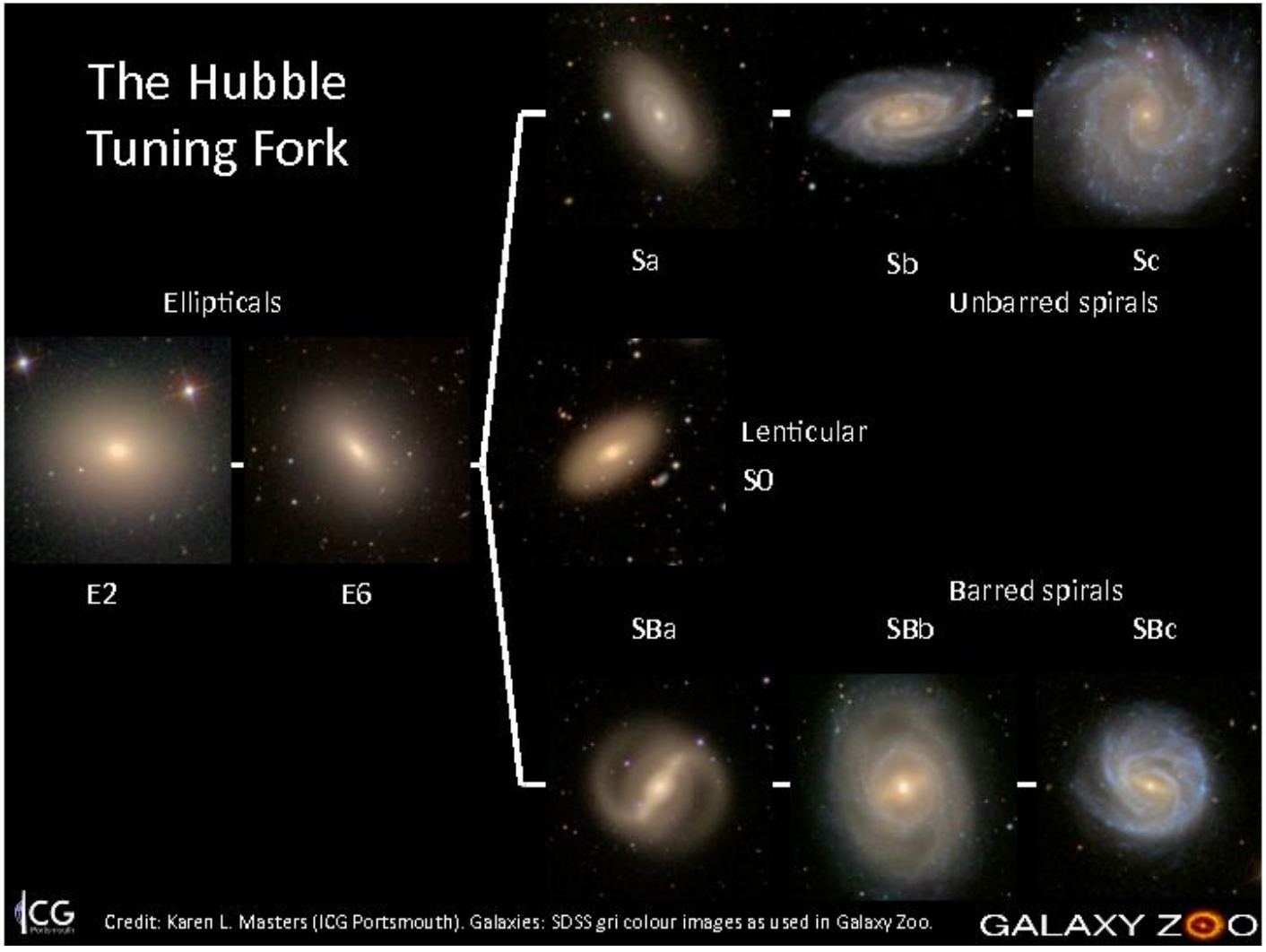
Interactions can trigger spiral arms

M51 - The Whirlpool Galaxy



Stellar streams through tidal interactions

The Mice galaxies - NGC 4676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Credit: Karen L. Masters (ICG Portsmouth). Galaxies: SDSS gri colour images as used in Galaxy Zoo.
GALAXY ZOO

How do you form an Elliptical galaxy ?

Interactions are a dominant pathway to form Elliptical galaxies !

Our home (the Milky Way) is headed on a collision course with our Neighbour - the Andromeda Galaxy.

The resulting product (Milkdromeda) will most likely be an Elliptical galaxy.

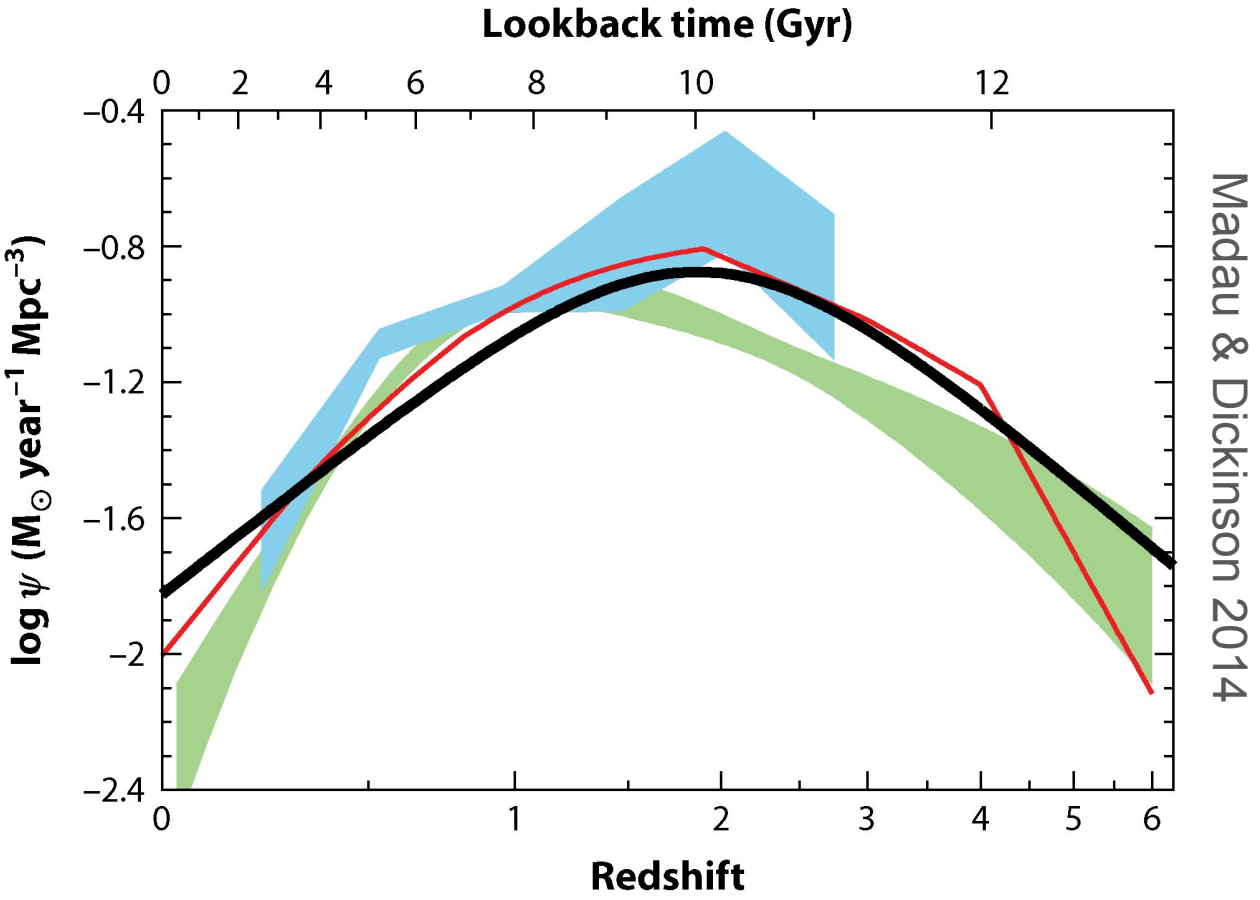
Simulation: https://www.youtube.com/watch?v=-WoLSL3EDEs

Galaxy interactions affecting gas physics

The ring of fire

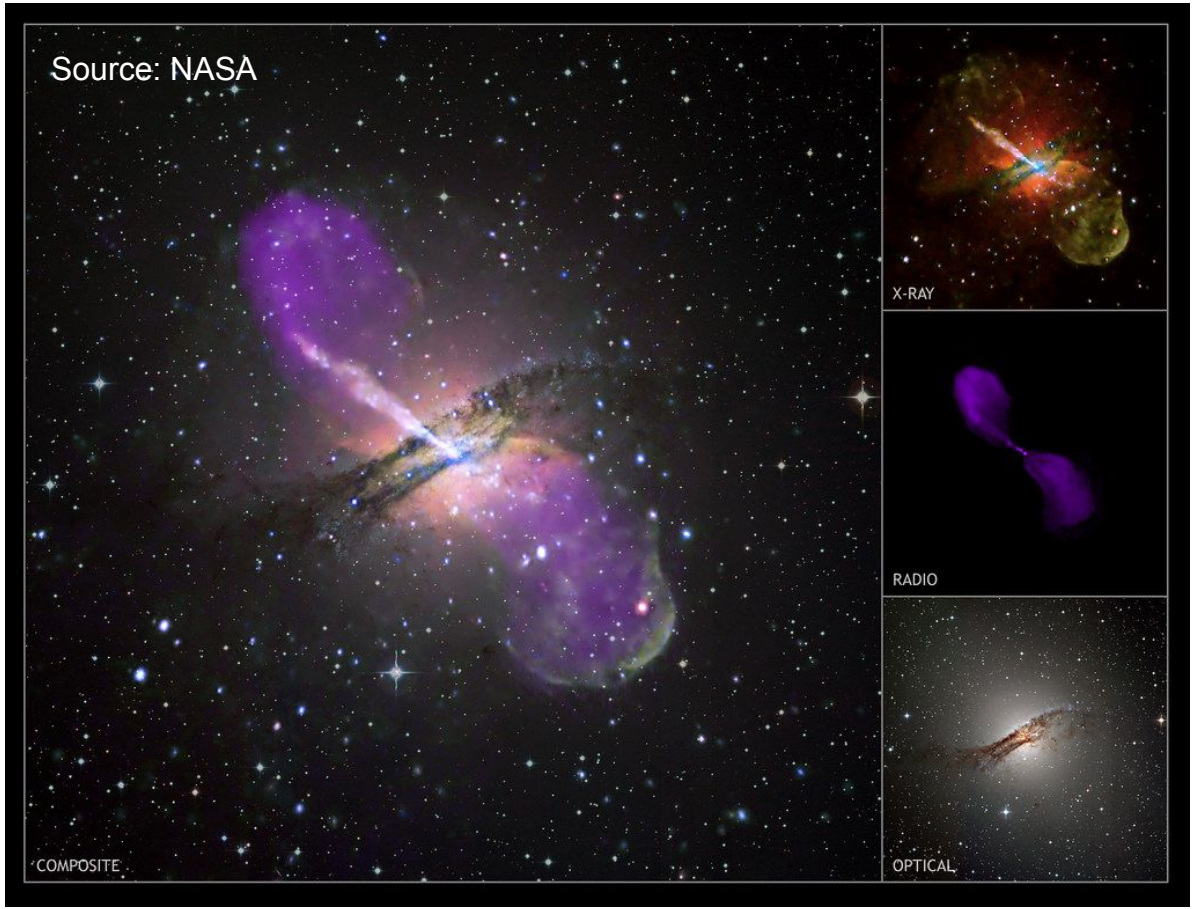
The cartwheel galaxy

The Cosmic Star-formation Rate (CSFR)



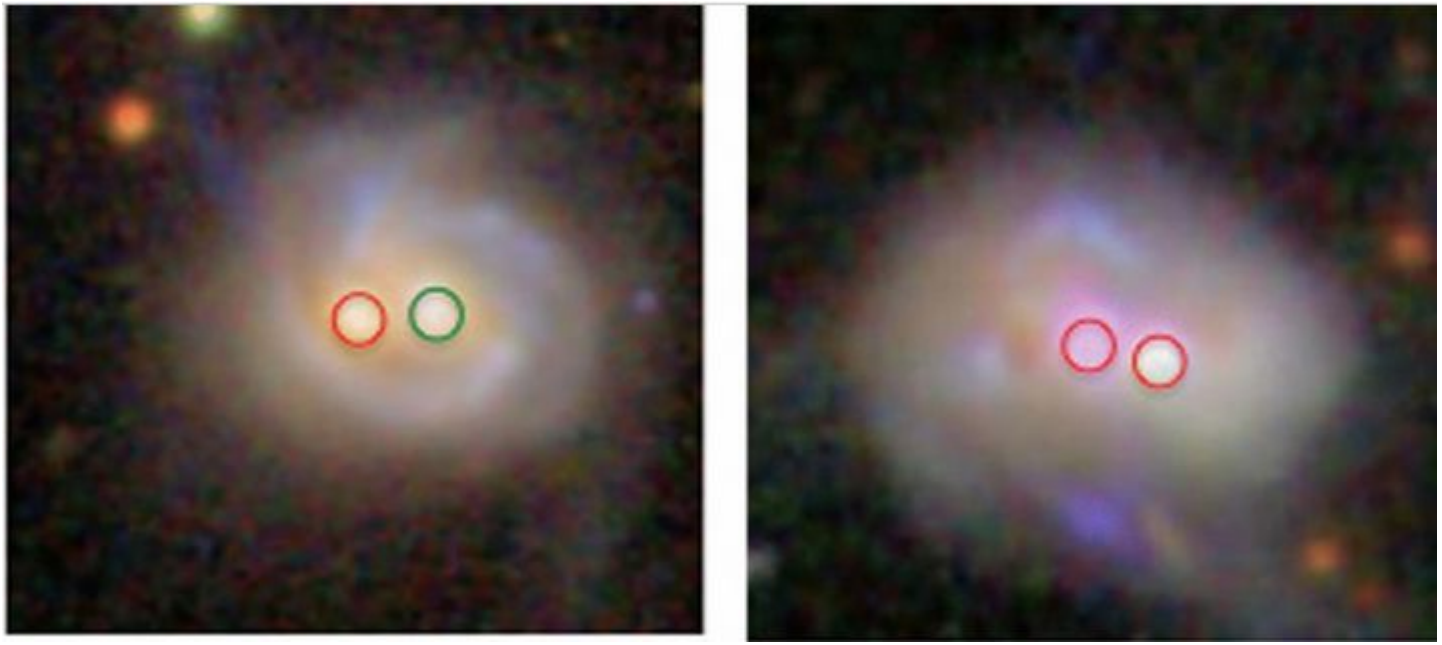
Galaxy interactions affecting the Supermassive Black Holes

Triggering the central Supermassive Black Hole

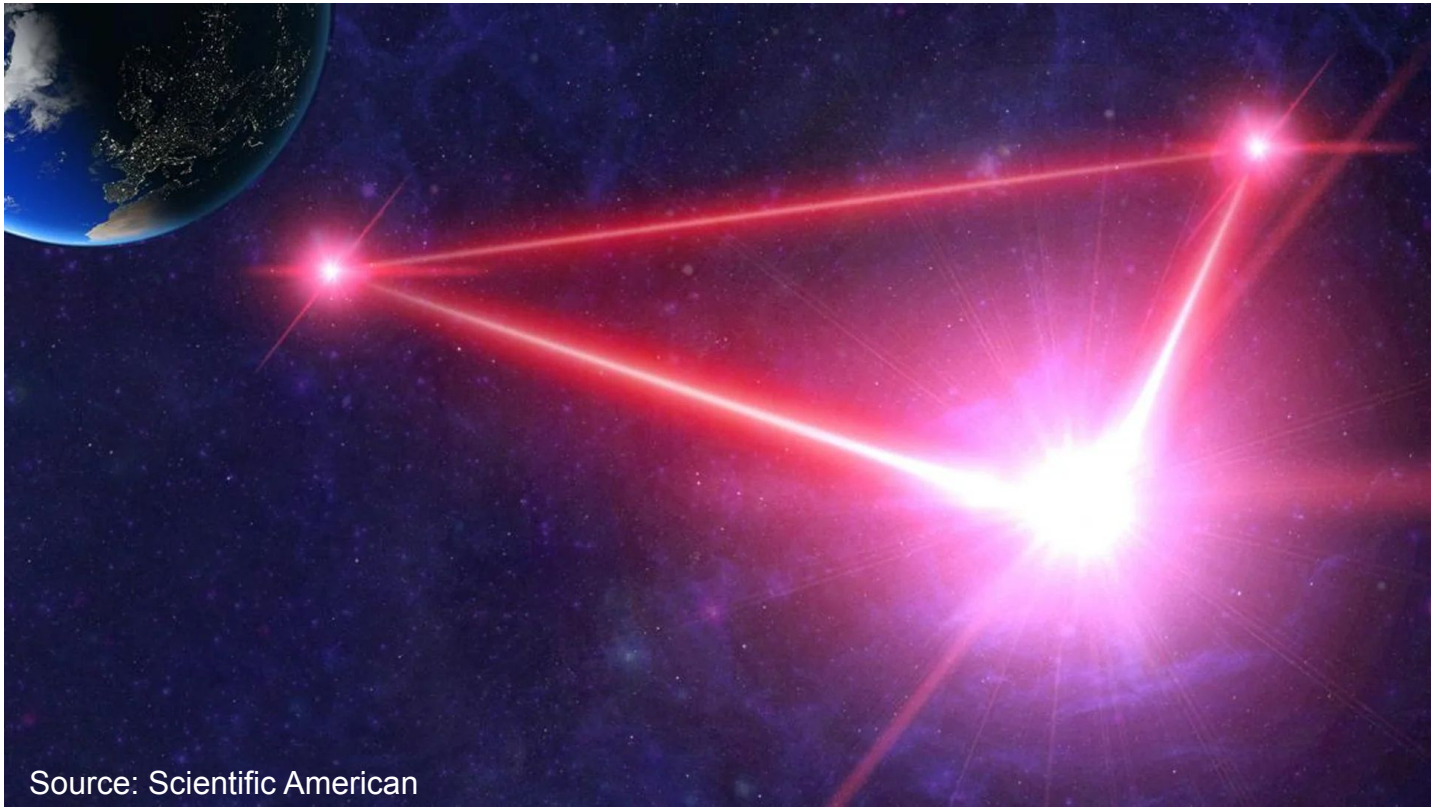


Dual Active Galactic Nuclei (AGNs)

Dual AGNs (Koss et al. 2012)



LISA - the Next Generation Gravitational Wave Observatory



How can we study galaxy interactions ?

- Observations provide only one snapshot of the process
- Timescales involved are much much much longer than human lifespan
- Simulations - both N-body and hydrodynamic !

GALACTIC BRIDGES AND TAILS

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JURI TOOMRE*
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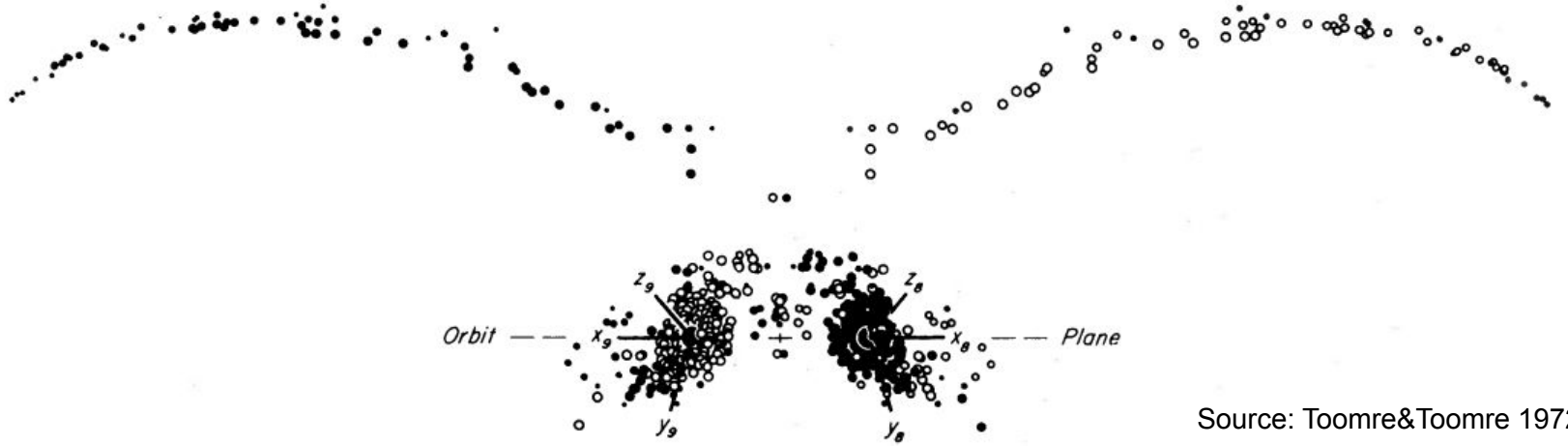
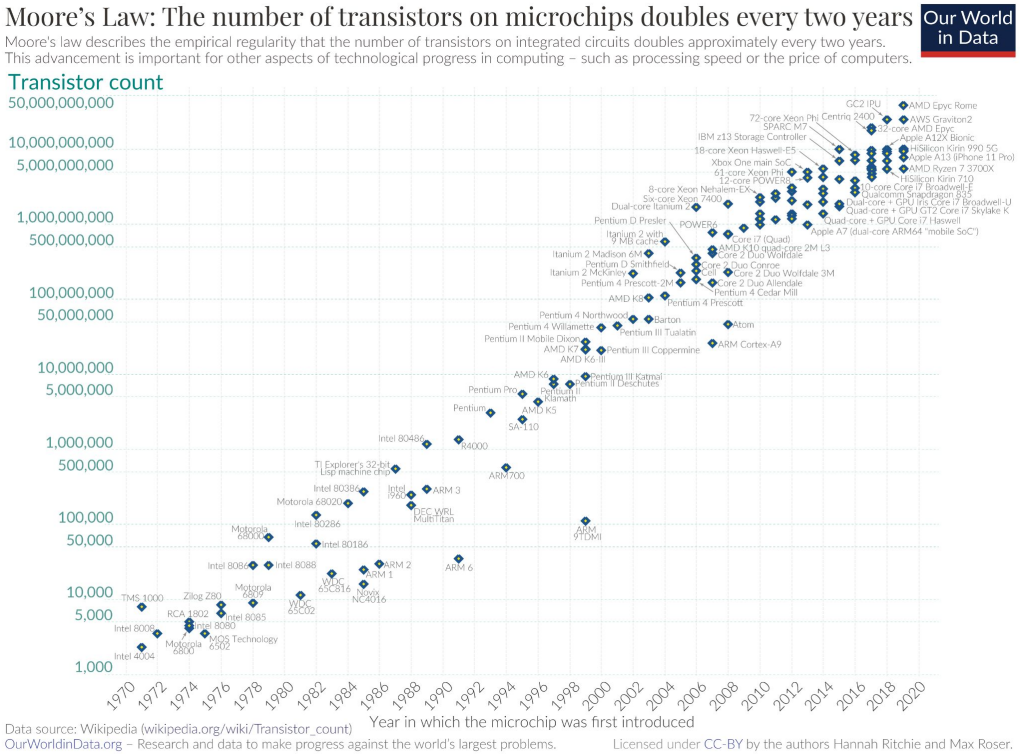
Goddard Institute for Space Studies, New York
Received 1972 May 19

Remarkable success in reproducing the observations !

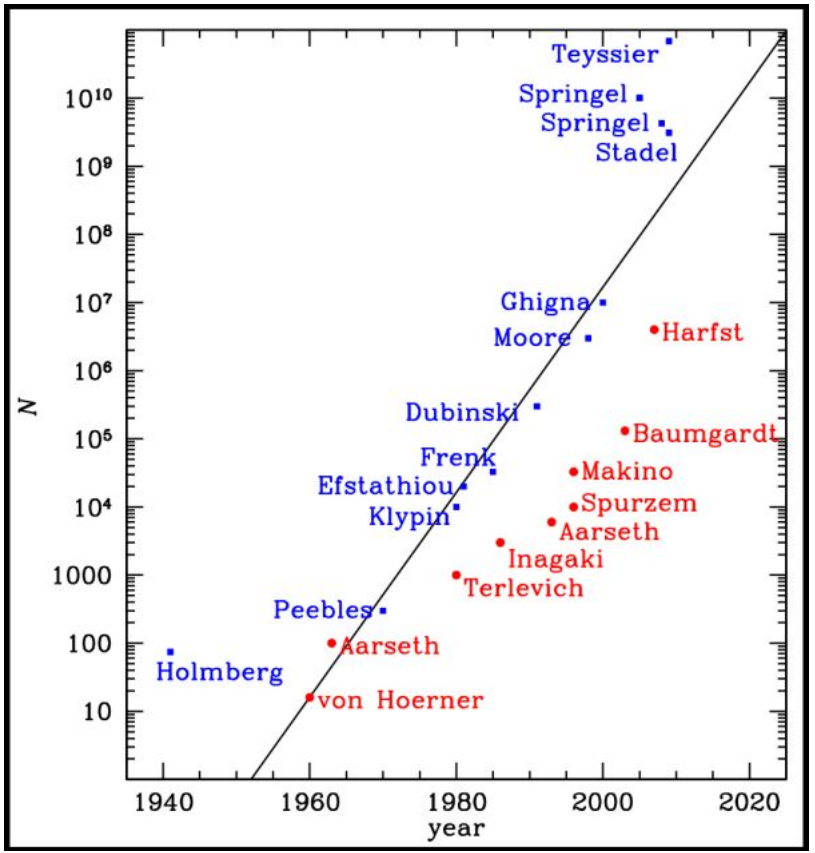


Source: Toomre&Toomre 1972

Modern times



Source: Wiki



Source: Dehnen 2011

Good reference