Dark Matter

By Iraj Vaezzadeh

Contents

- The history of dark matter – from a crazy idea to the standard model
- What actually is dark matter?
- What has it does for us lately?

Fritz Zwicky (1898-1974)

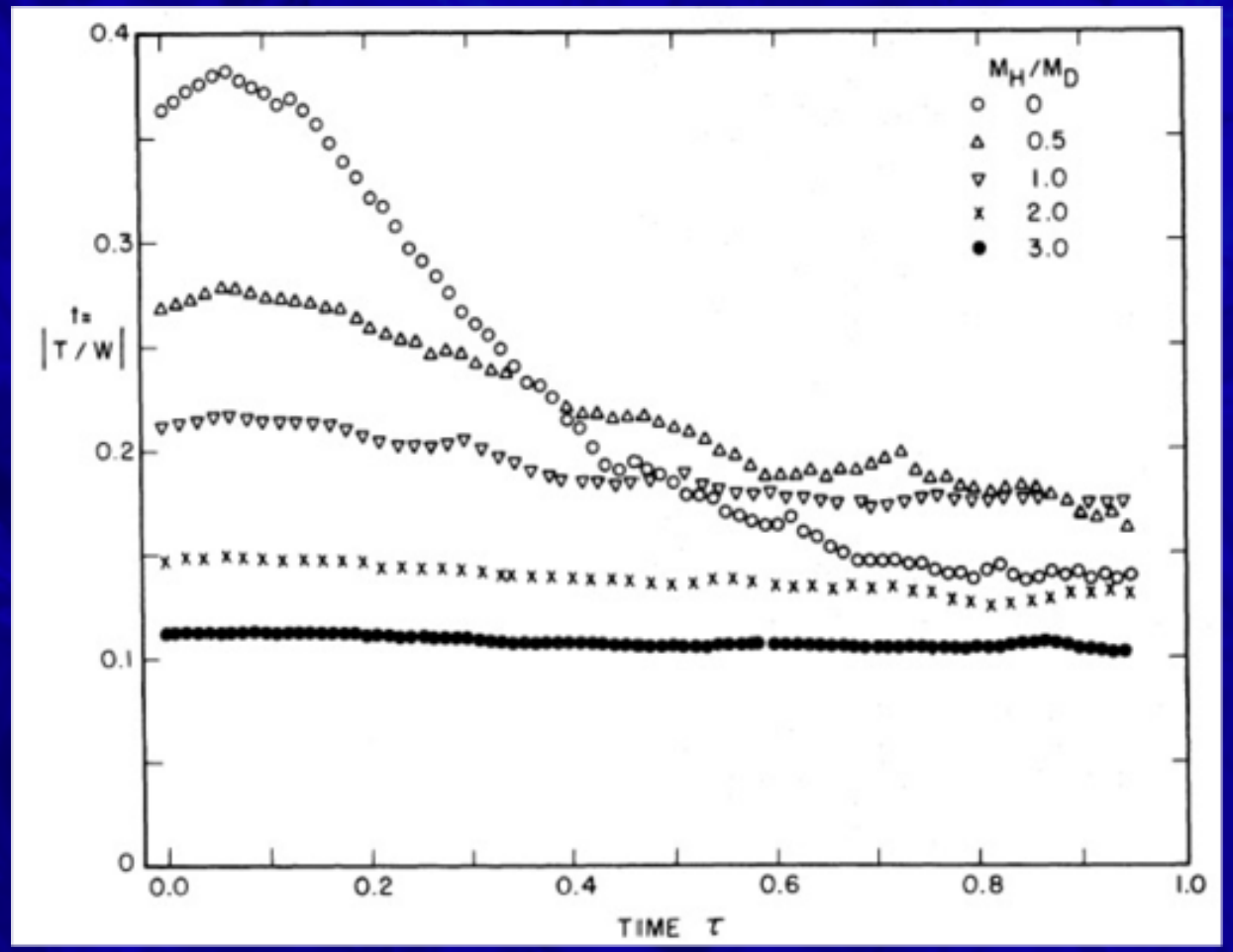
- Measured the mass of the Coma cluster using the *Virial Theorem*
- Measured speeds of galaxies in the Coma Cluster
- Estimated 400 times as much dark matter as visible matter

Fritz Zwicky (1898-1974)

- Coined the term supernova
- Discovered neutron stars (and thought they were full of exploding goblins)
- Proposed gravitational lensing from clusters

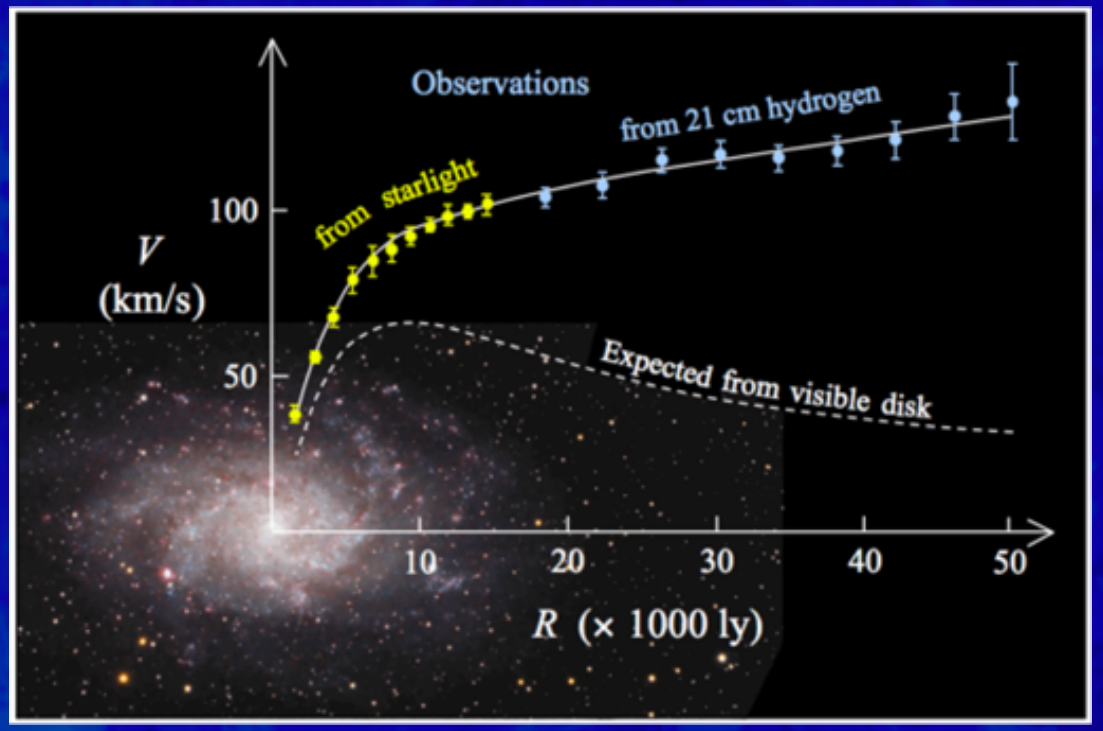
Ostriker (1937-) & Peebles (1935-)

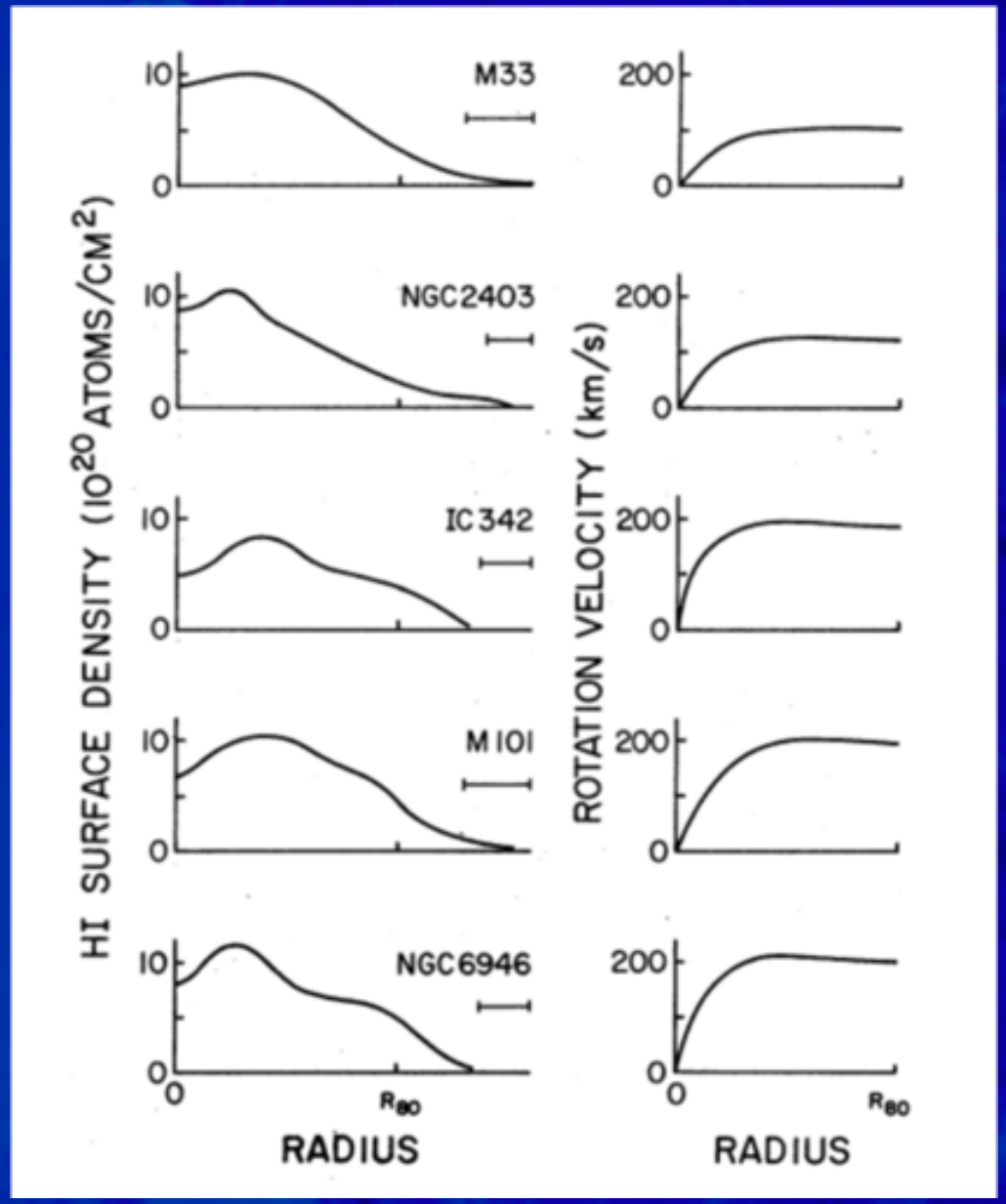
- N-body simulations of galaxies that needed a lot (3 to 10 times) of extra mass to be stable



Vera Rubin (1928-2016)

- Stars on the edge of the Andromeda galaxy are moving as fast as the galaxies at the centre!





How luminosity changes at increasing radius is shown on the left.

How the rotational velocity changes with radius is shown on the right.

You can see the rotation curve stays flat while the visible matter drops off.

What could Dark Matter be made of?

- Neutrinos – no
- Brown dwarfs – no
- Black holes – no
- Neutron stars – no
- Axions – no
- neutralinos – no
- Red dwarfs – no
- Pyrgons – no
- Quark matter nuggets – no
- Monopoles – no
- Cosmic strings – no
- Gravatinos – no
- Sneutrinos – no
- Axinos – no
- Other MACHOs – no
- MOND – no

The Gang of Four (Late 1970s)

- Simon White (1951-)

- George Efstathiou (1955-)

- Marc Davis (1947-)

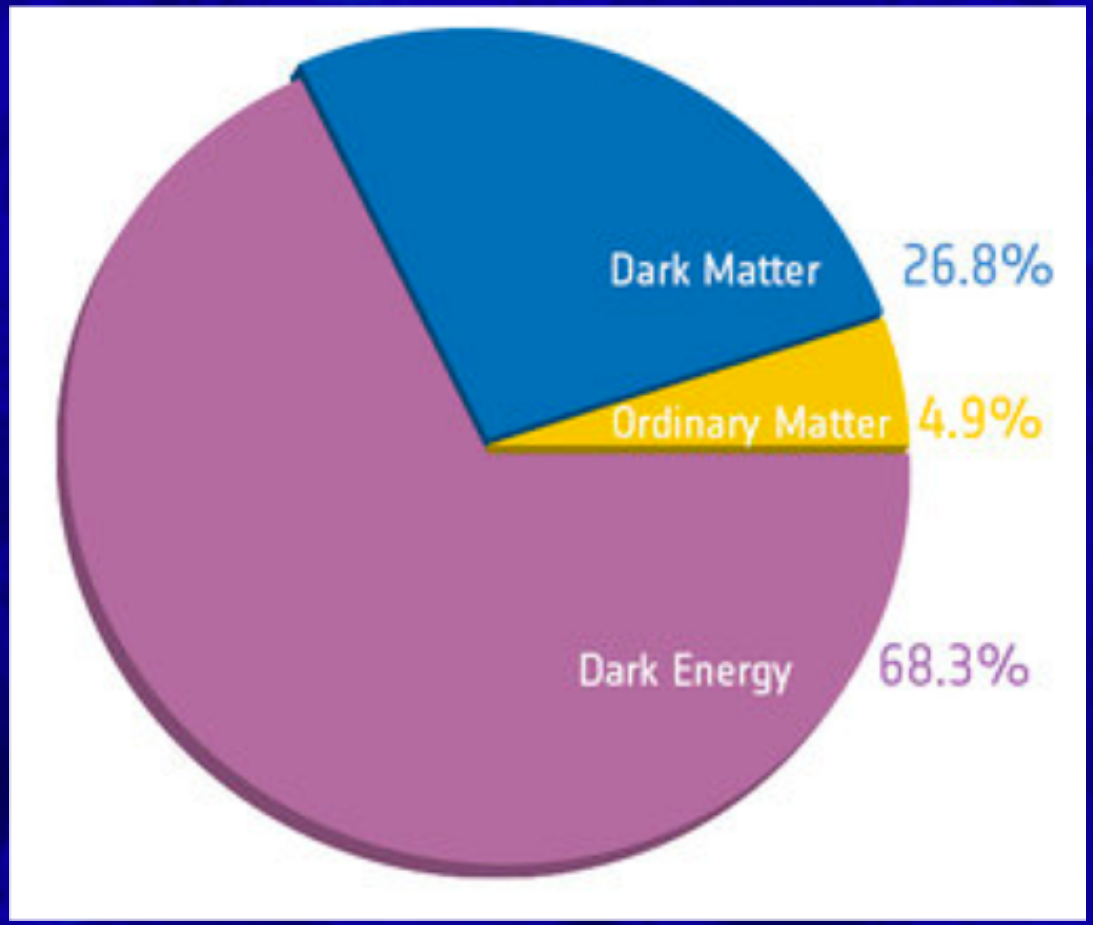
- Carlos Frenk (1951-)

- Cosmological N-body simulations to probe the nature of dark matter
- Warm Dark Matter (fast neutrinos) produced Universes that look nothing like ours
- Dark Matter is best modelled as a Weakly Interacting Massive Particle (WIMP)

Lambda-CDM

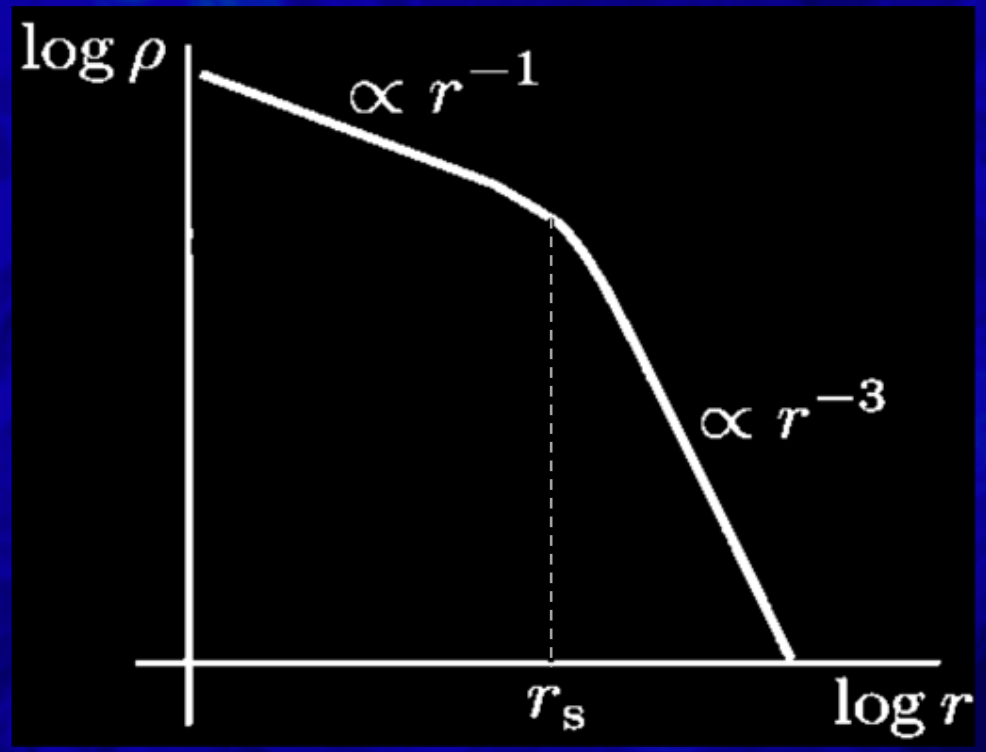
- Cold dark matter is now part of the *Standard Model of Cosmology* in addition to Dark Energy.

- Everything we can see around us and everything we can see in space makes up just 4.9% of the Universe!



Navarro - Frenk - White Profile (1997)

$$\rho(r) = \frac{\rho_0}{\frac{r}{R_s}\left(1+\frac{r}{R_s}\right)^2}$$



$$M = \int_0^{R_{max}} 4\pi r^2 \rho(r)\, dr$$

The Hunt For Dark Matter

- Lab created dark matter: no success so far
- Dark matter interactions: dark matter in the centre of galaxies might be closely packed enough that it could annihilate and produce gamma rays (NASA's Fermi is searching for these signals): no success so far and looking like a dead end
- Detection on earth (deep inside mines): no success so far

Lensing Observations (90s+)

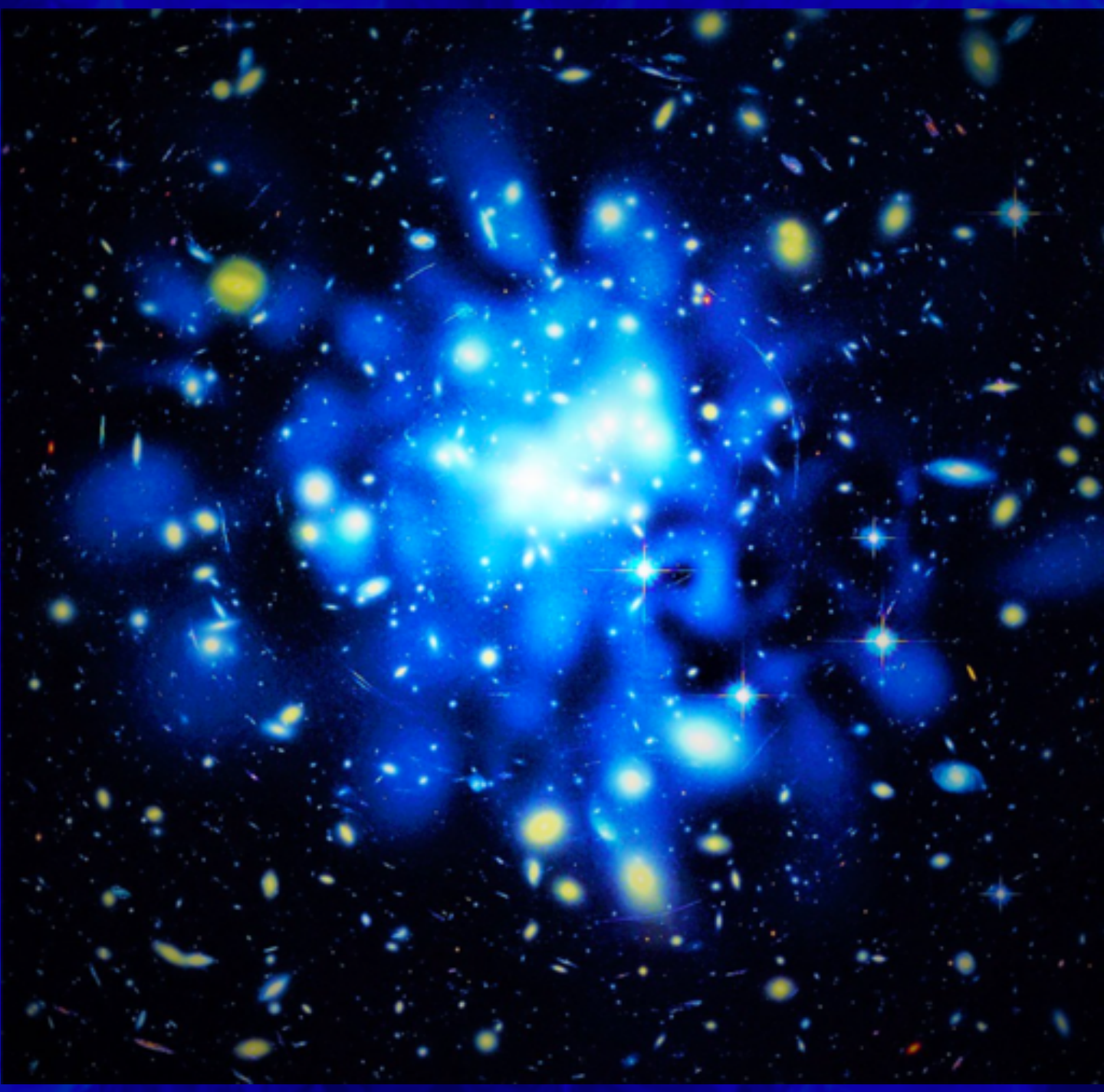
Abell 1689 Image from Hubble

- Mapping mass distribution- where is all the mass in a galaxy cluster?
- Dissociative mergers – dark matter and gas separate

NASA/STScI; ESO WFI; Magellan/U.Arizona/D.Clowe et al.

X-ray: NASA/CXC/UCDavis/W.Dawson et al; Optical: NASA/STScI/UCDavis/W.Dawson etal.

Abell 1689 Image from Hubble



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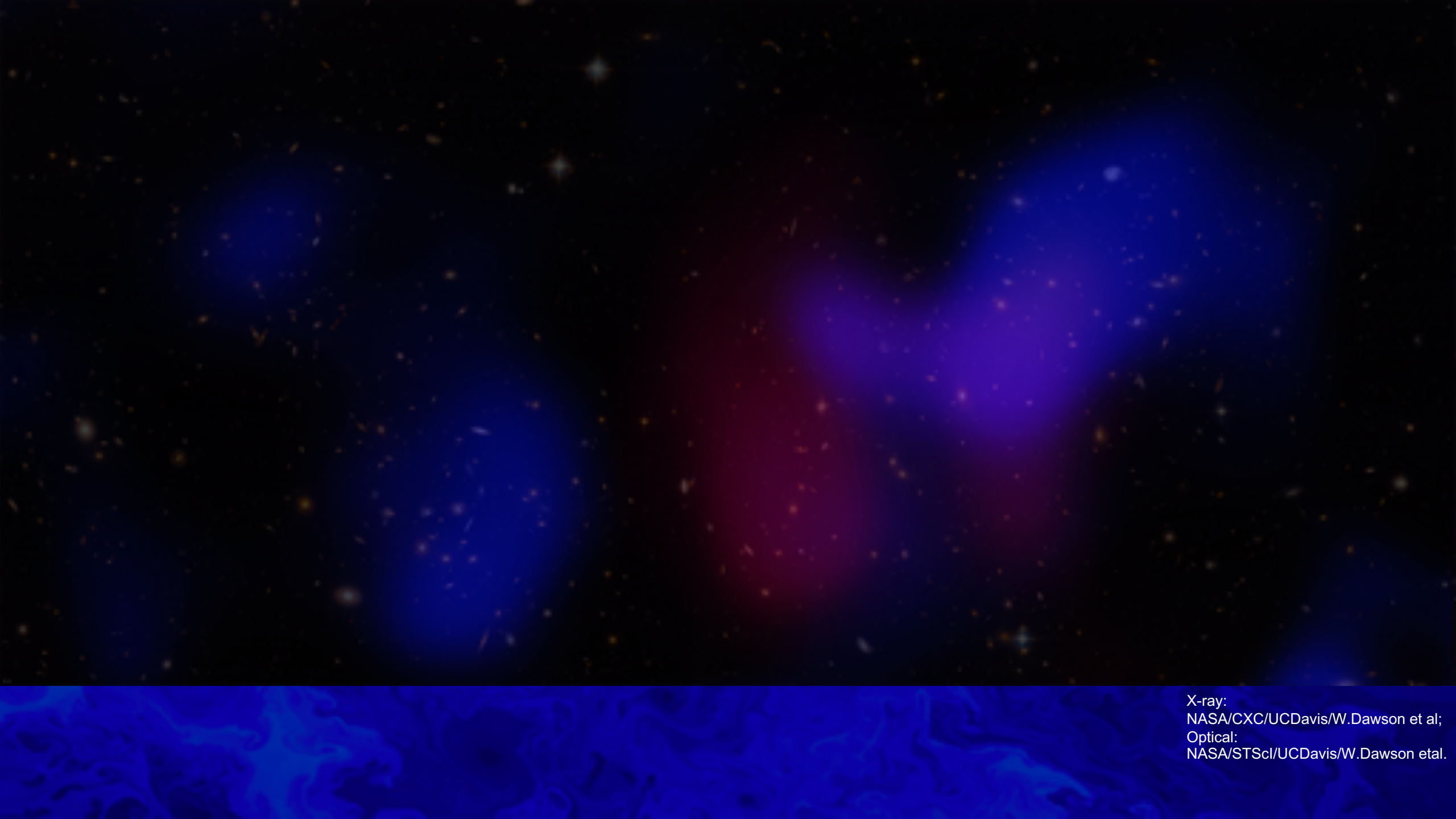
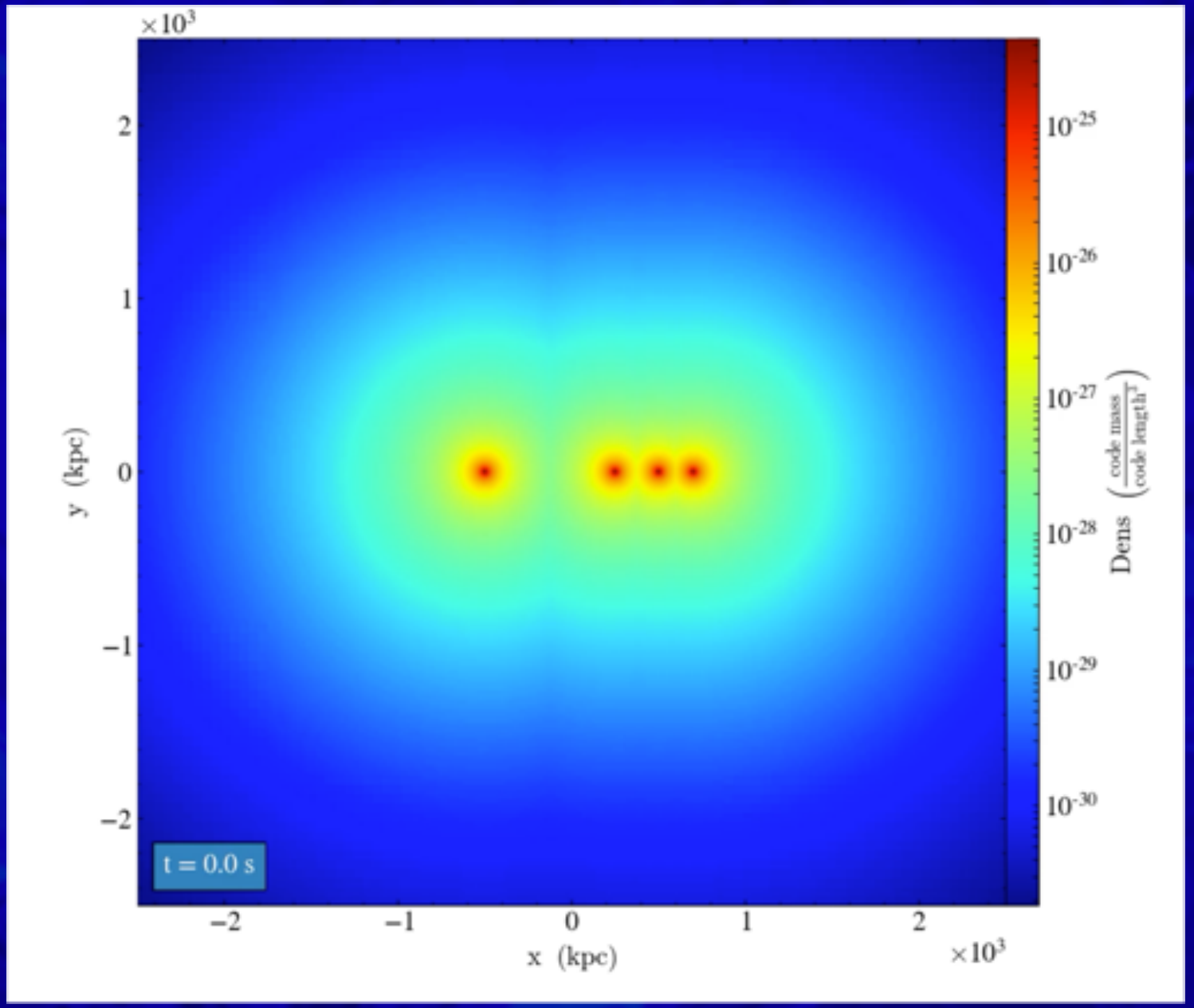


X-ray:
NASA/CXC/UCDavis/W.Dawson et al;
Optical:
NASA/STScI/UCDavis/W.Dawson etal.

How do we use Dark Matter in Hull?

- FLASH code (University of Chicago)
- Hydrodynamic ICM + N-body Dark Matter
- Dark matter makes our clusters behave



ขอบคุณสำหรับการฟัง

Thank you for listening!