

DARK MATTER

Astrophysical Evidence

DIPARTIMENTO DI FISICA



SAPIENZA
UNIVERSITÀ DI ROMA

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Elementary Particle Physics, Anno Accademico 2015-16

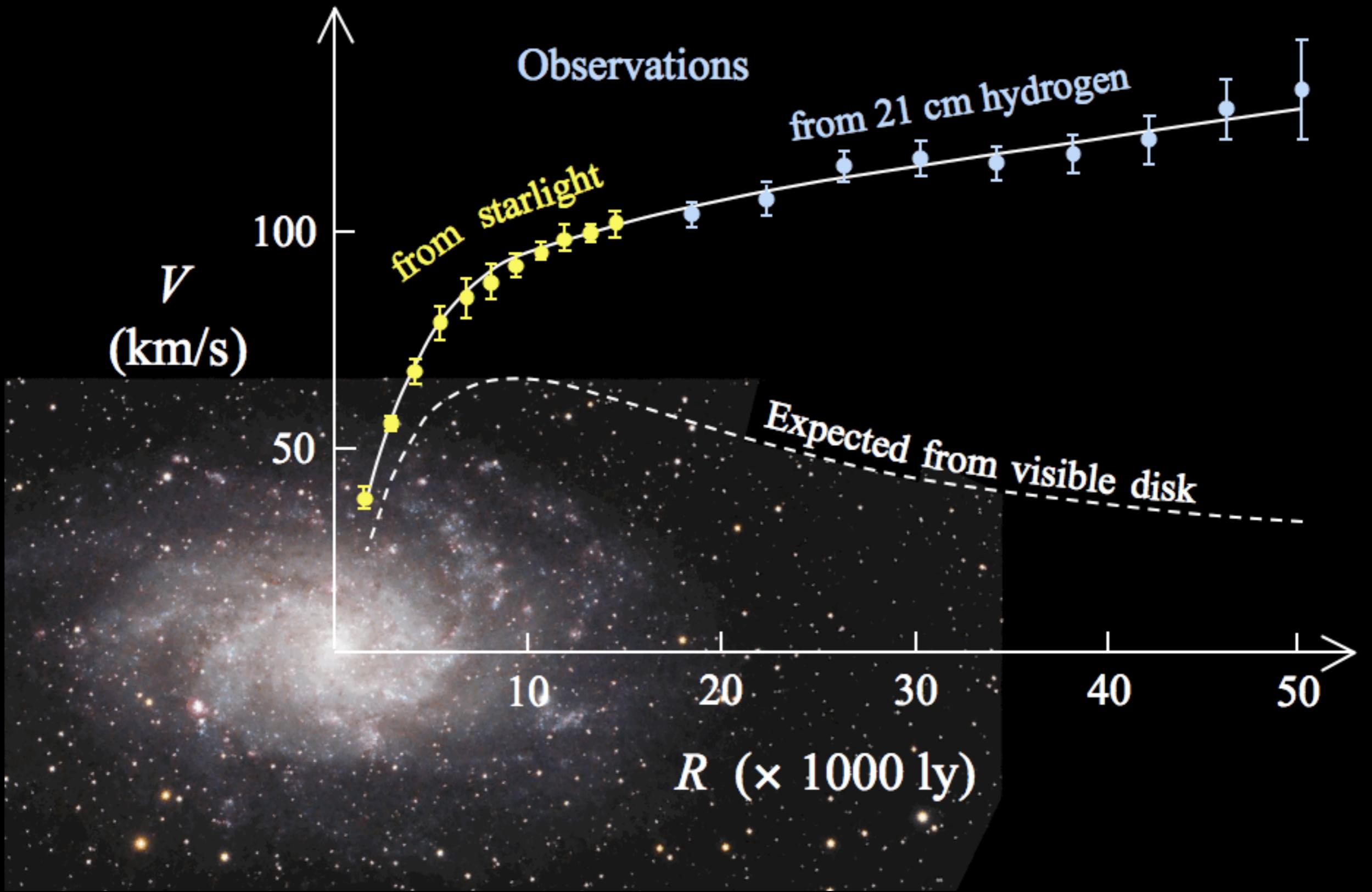
<http://www.roma1.infn.it/people/rahatlou/particelle/>

FIRST INDICATIONS OF DARK MATTER

In 1933, Fritz Zwicky calculated the mass of the Coma cluster using galaxies on the outer edge, and came up with a number 400 times larger than expected.

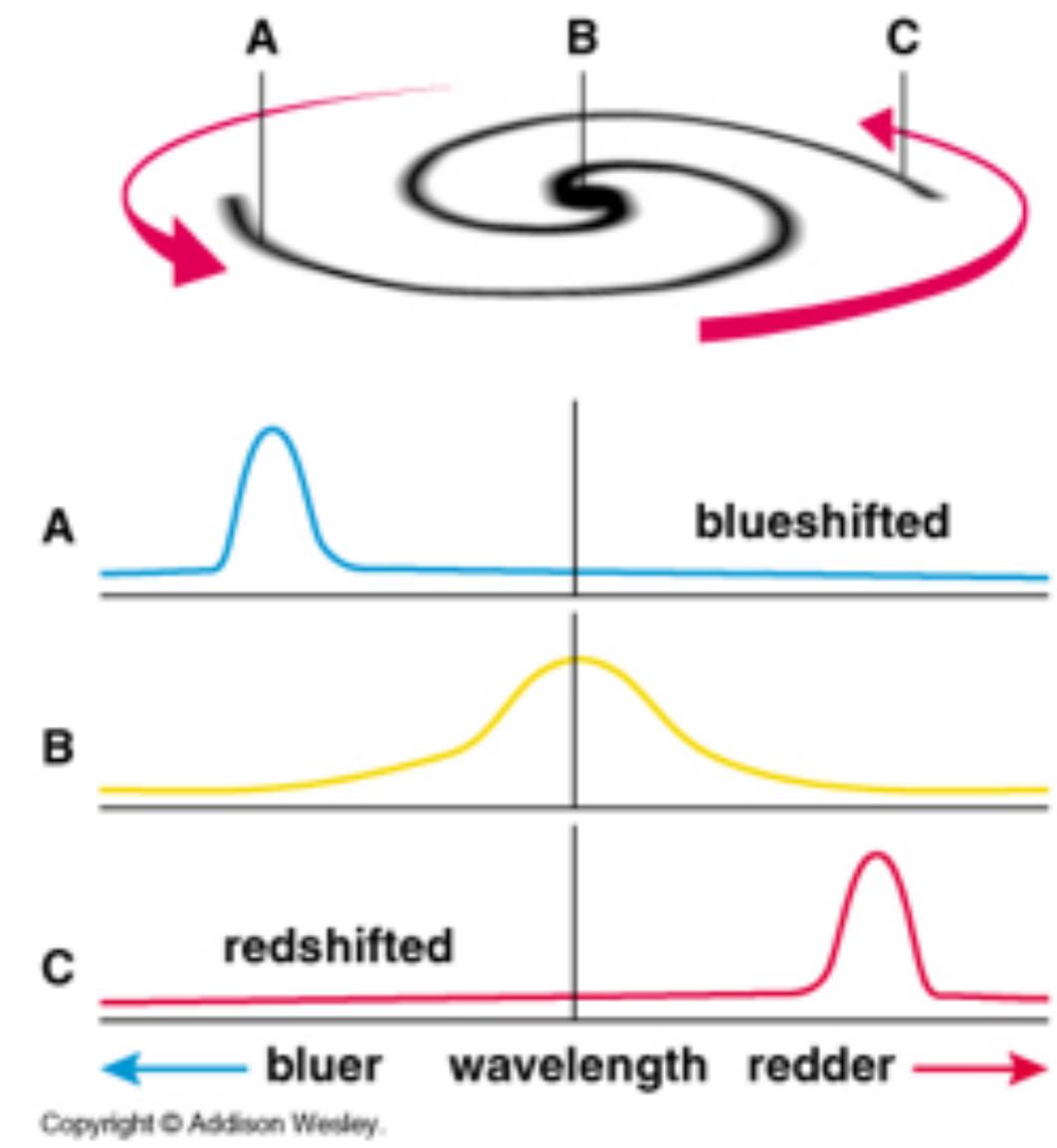
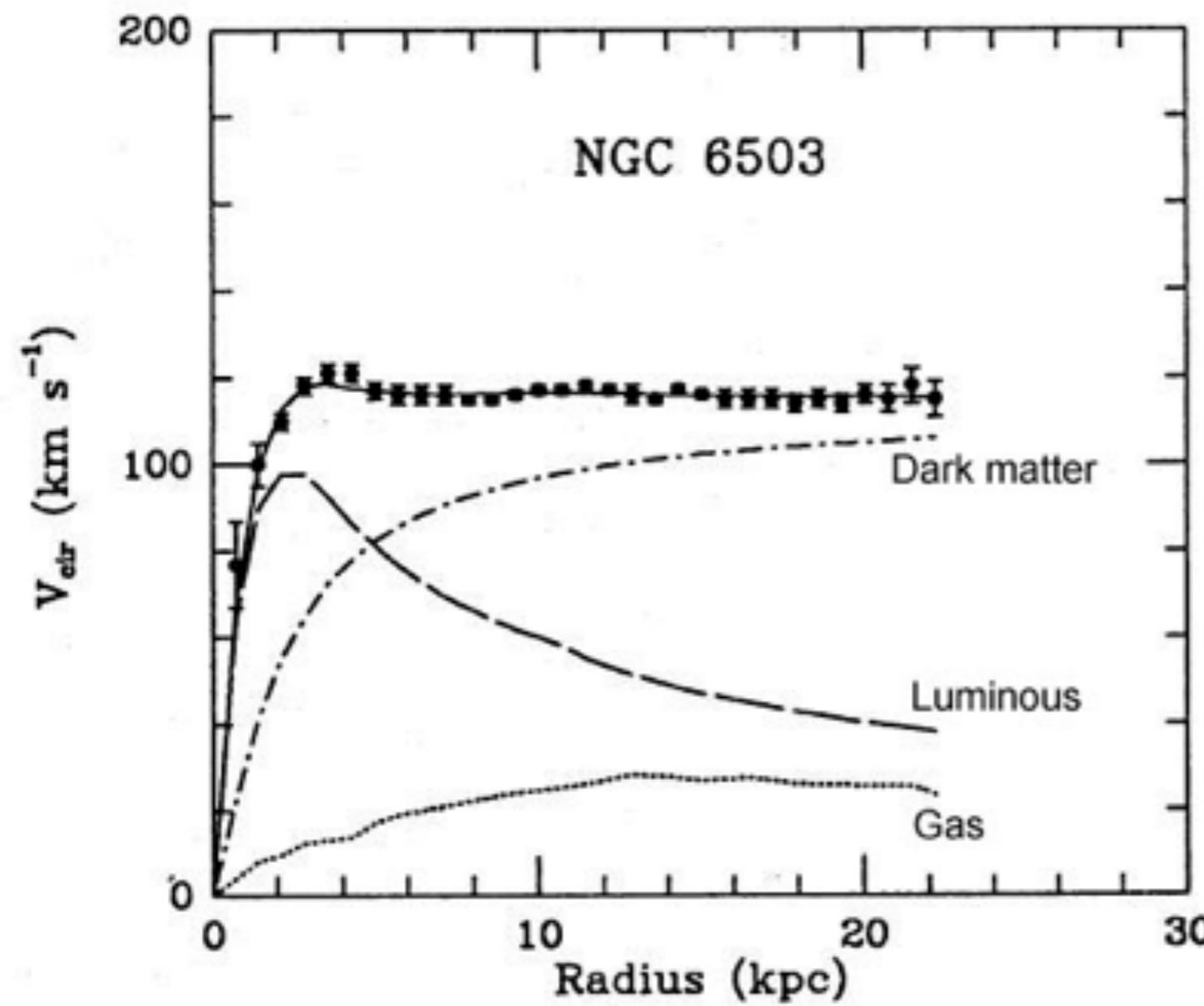
Now we know 90% of its mass due to Dark Matter

GALAXY ROTATION



GALACTIC ROTATION

- Starting in 1970's, first measurements of velocity curve of edge-on spiral galaxies
- Velocity found to be flat, consistent with $\sim 10x$ as much "dark" mass for more than one galaxy



GALACTIC ROTATION VELOCITY

- For a star of mass m at distance r from center of the galaxy

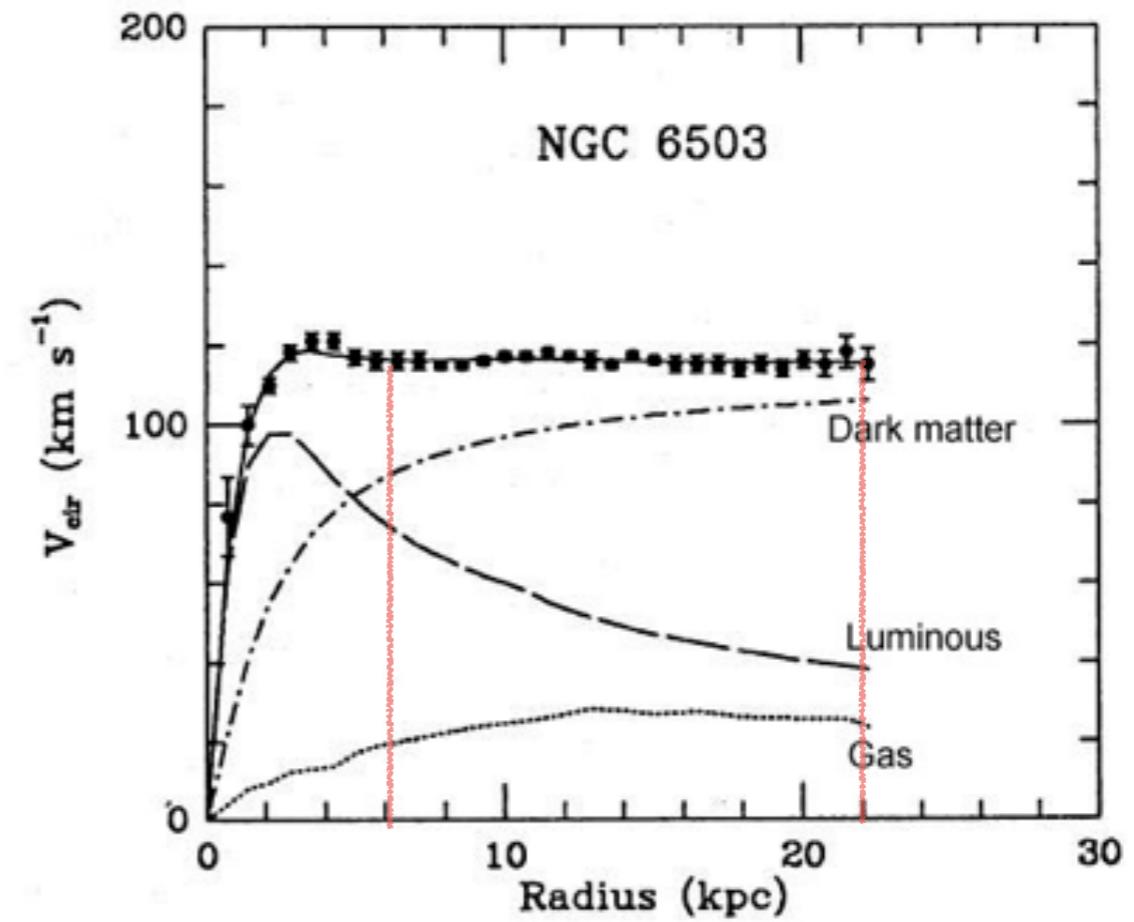
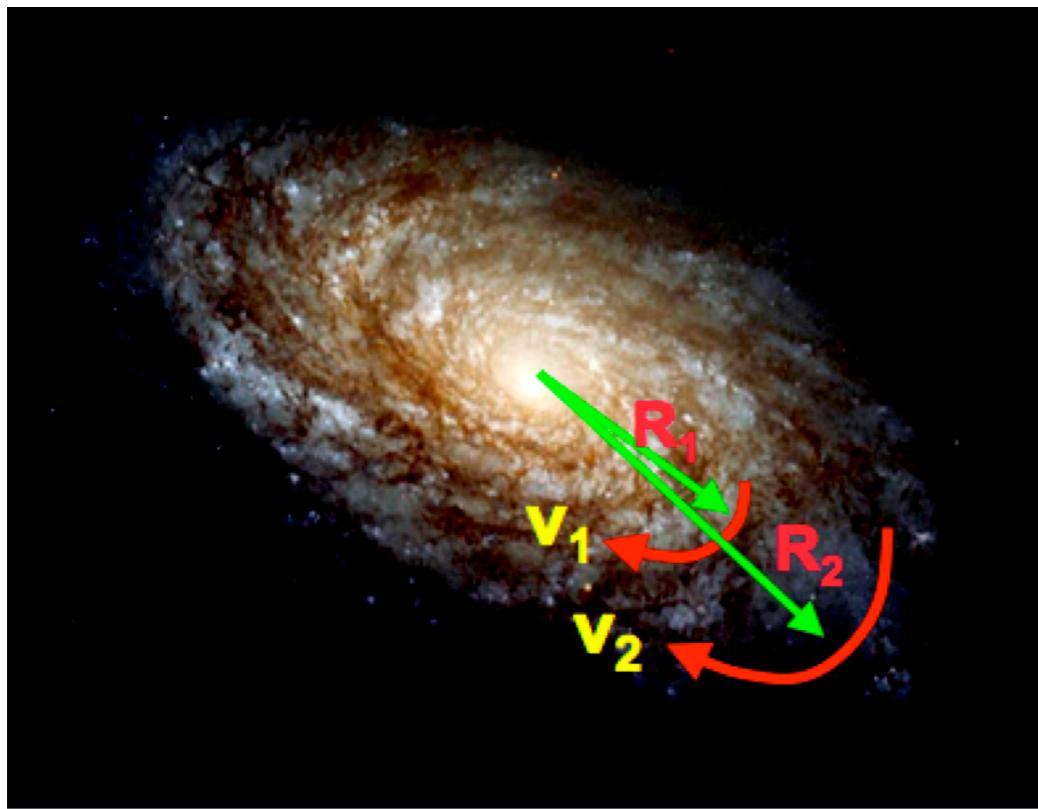
$$\frac{mv^2(r)}{r} = \frac{mM(r)G}{r^2}$$

- Galaxy mass mainly within core radius of R_0

$$M(r) = \begin{cases} \rho r^3 & r < R_0 \\ \rho R_0^3 & r \geq R_0 \end{cases}$$

- Galaxy rotation velocity

$$v(r) = \begin{cases} \propto r & r < R_0 \\ \propto r^{-1/2} & r \geq R_0 \end{cases}$$



DARK MATTER HALO

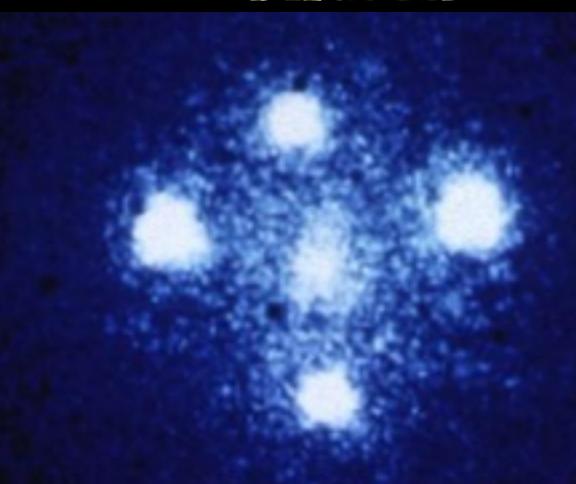


BULLET CLUSTER

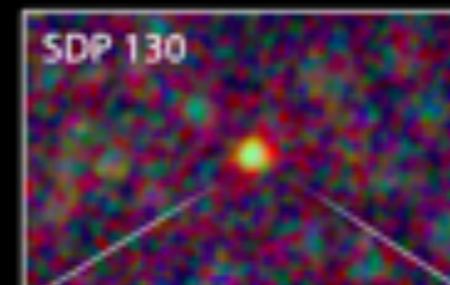
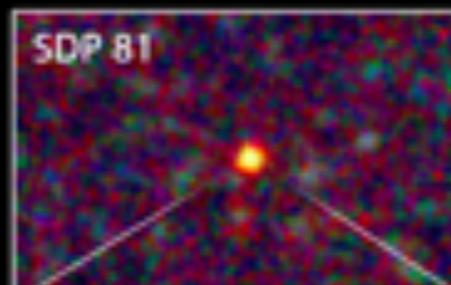


- Collision of galaxies in bullet cluster
 - lensing of background objects suggest at least 10x more Dark matter than visible mass

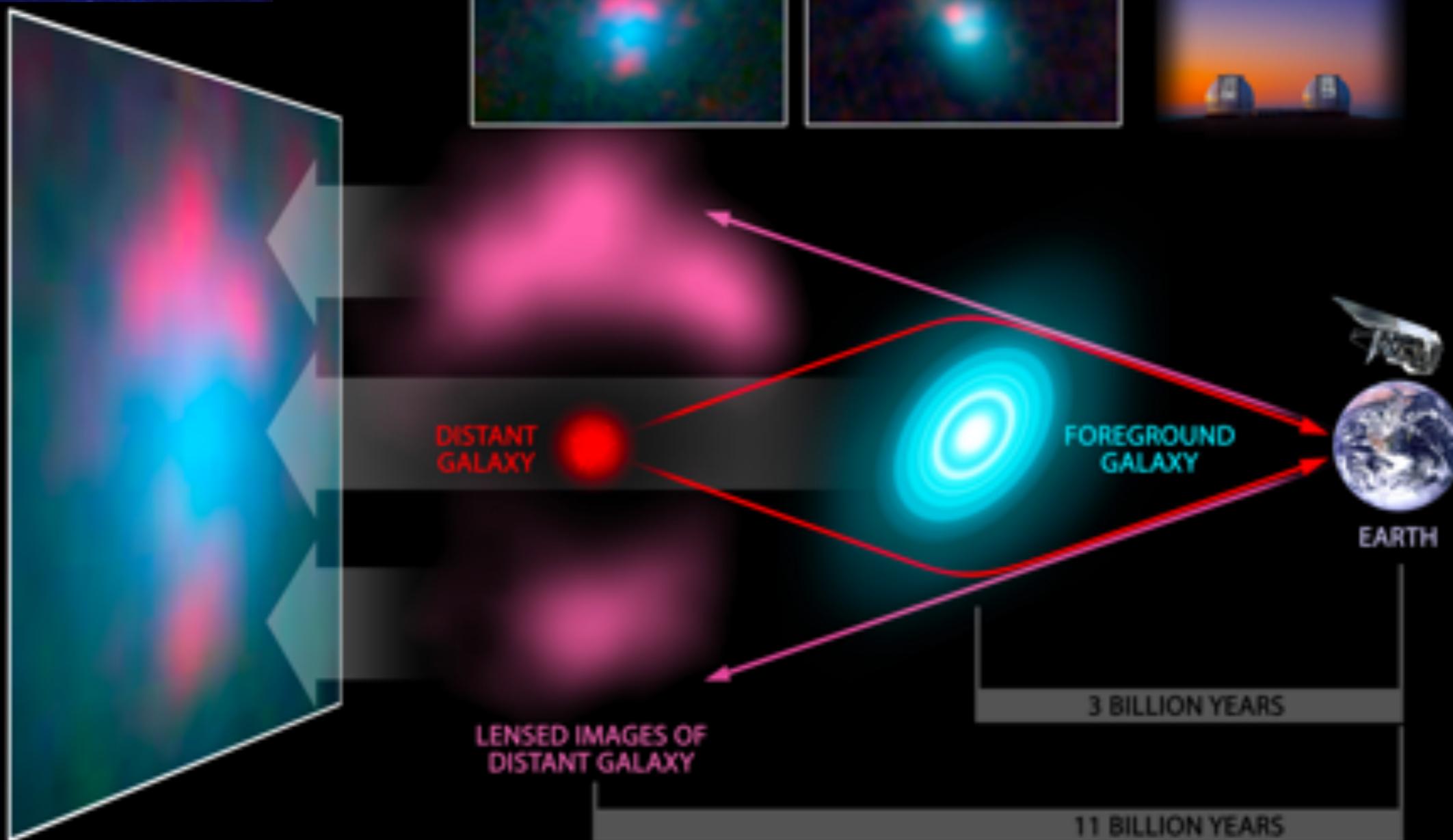
GRAVITATIONAL LENSING



Herschel:

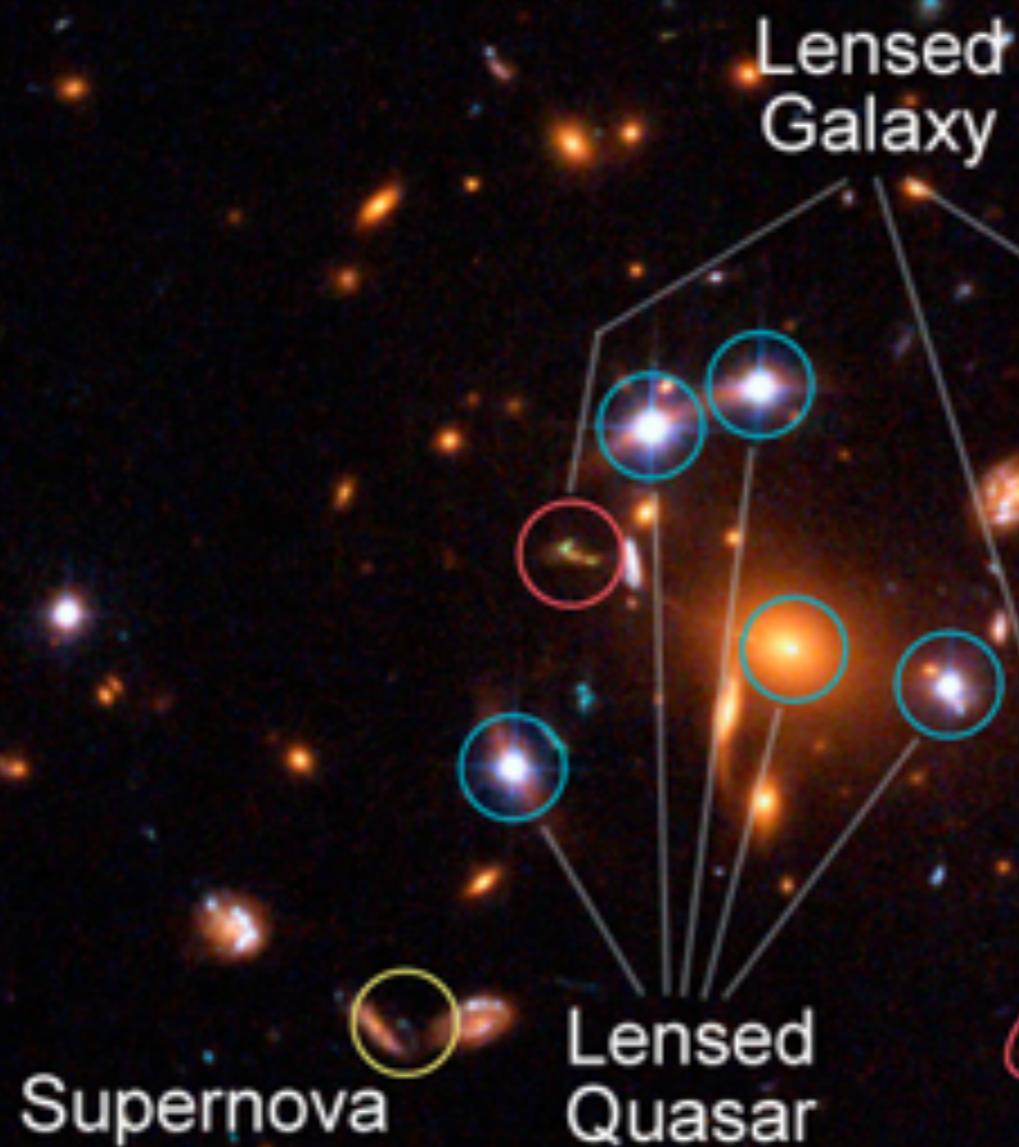


Keck & SMA:

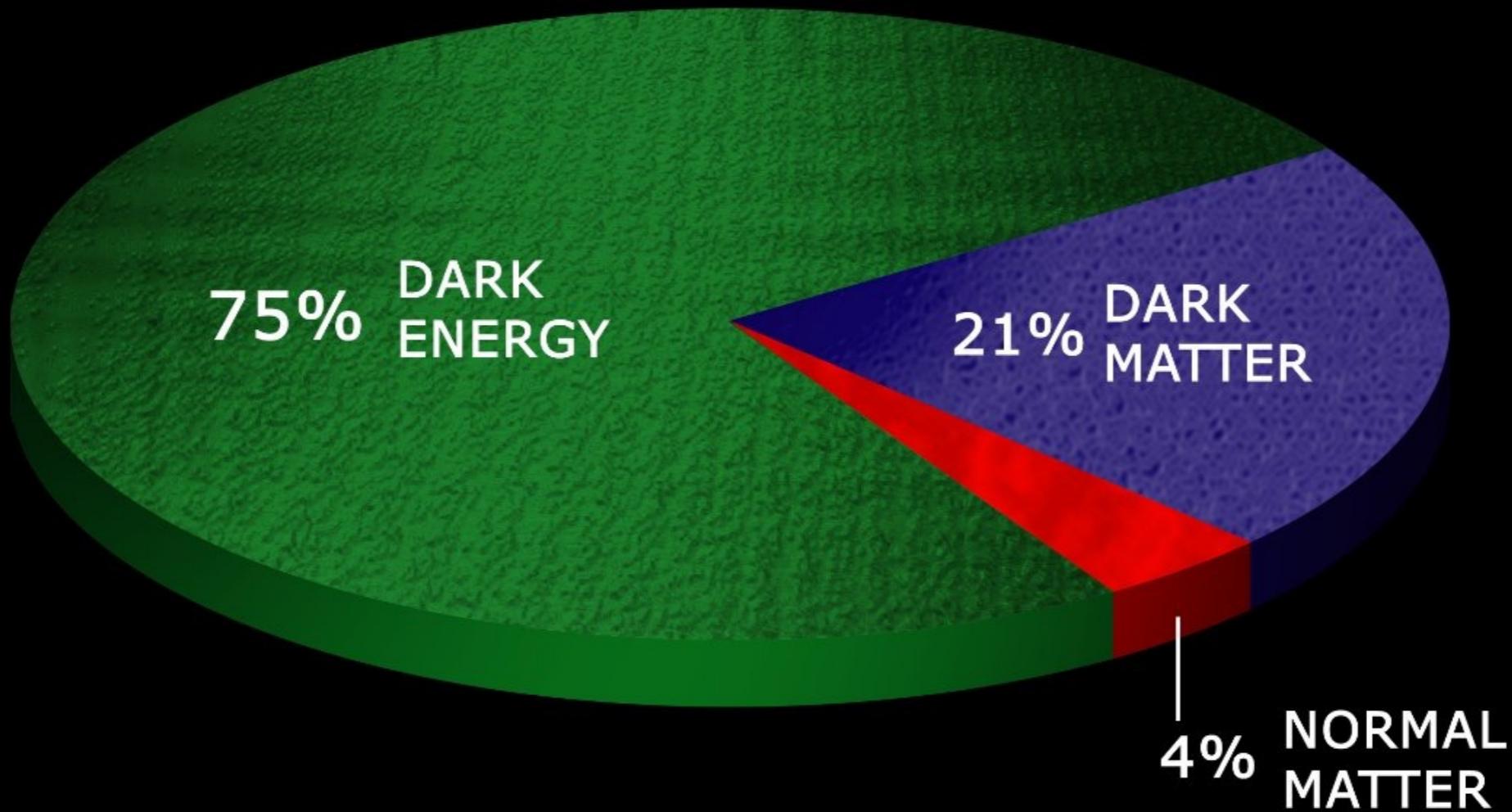


GRAVITATIONAL LENSING

Galaxy Cluster SDSS J1004+4112
HST ACS/WFC



UNIVERSE COMPOSITION



- Strong astrophysical evidence for the existence of dark matter
 - Evidence from bullet cluster, gravitational lensing, rotation curves
 - Dark Matter 5 times more abundant than baryons
 - Contributes $\sim 1/4$ of the total energy budget!