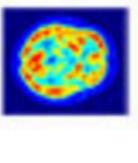


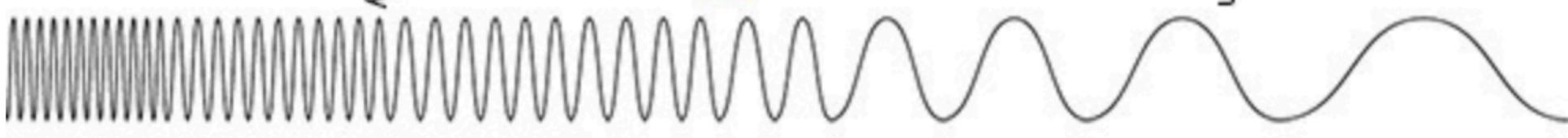
# Mapping the Galaxy, Missing Matter

*The Principal Evidence for Dark Matter*

*Physics 090*

2020-05-13

Gamma-ray	X-ray	Ultraviolet	Visible	Infrared	Microwave	Radio
						
Terrestrial gamma-ray flashes	PET scan	Airport security scanner	UV light from the Sun	Night vision goggles	Microwave oven	Aircraft communication
AM radio	Amateur radio			TV Remote Control		



## Electromagnetic Spectrum

Where is 3K, 0.001mm radiation peaked?

Where is 3000K, 1mm radiation peaked?

What is the wavelength of red? 700nm or 0.0007mm or 0.7μm

What is 21cm radiation?



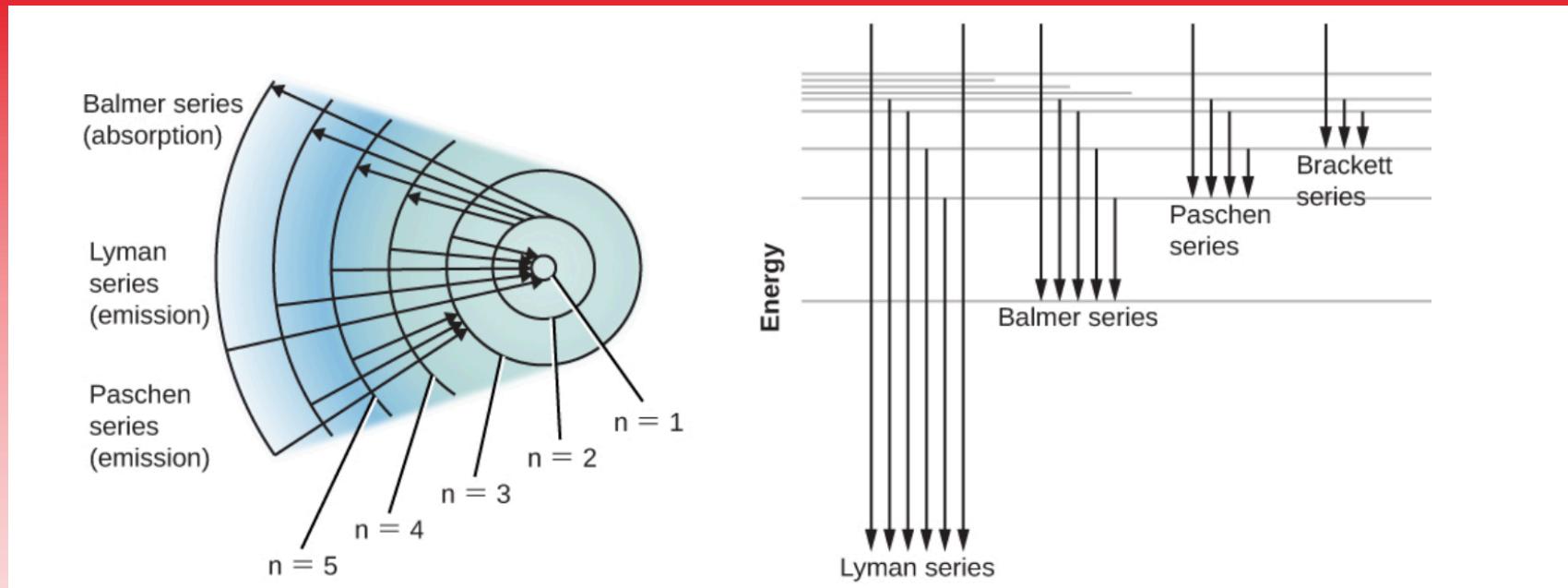
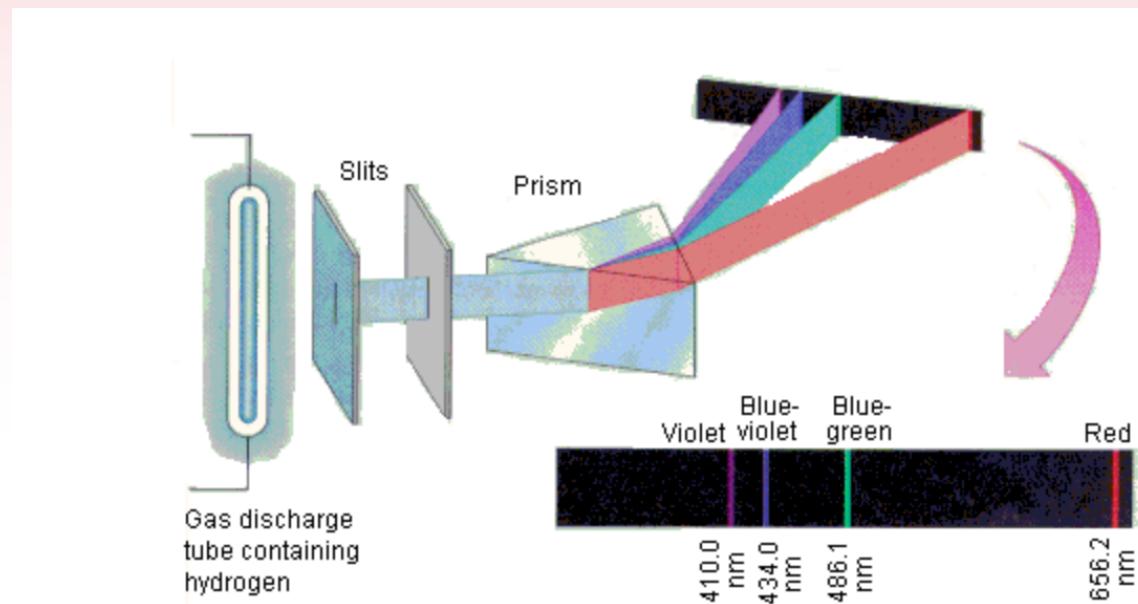
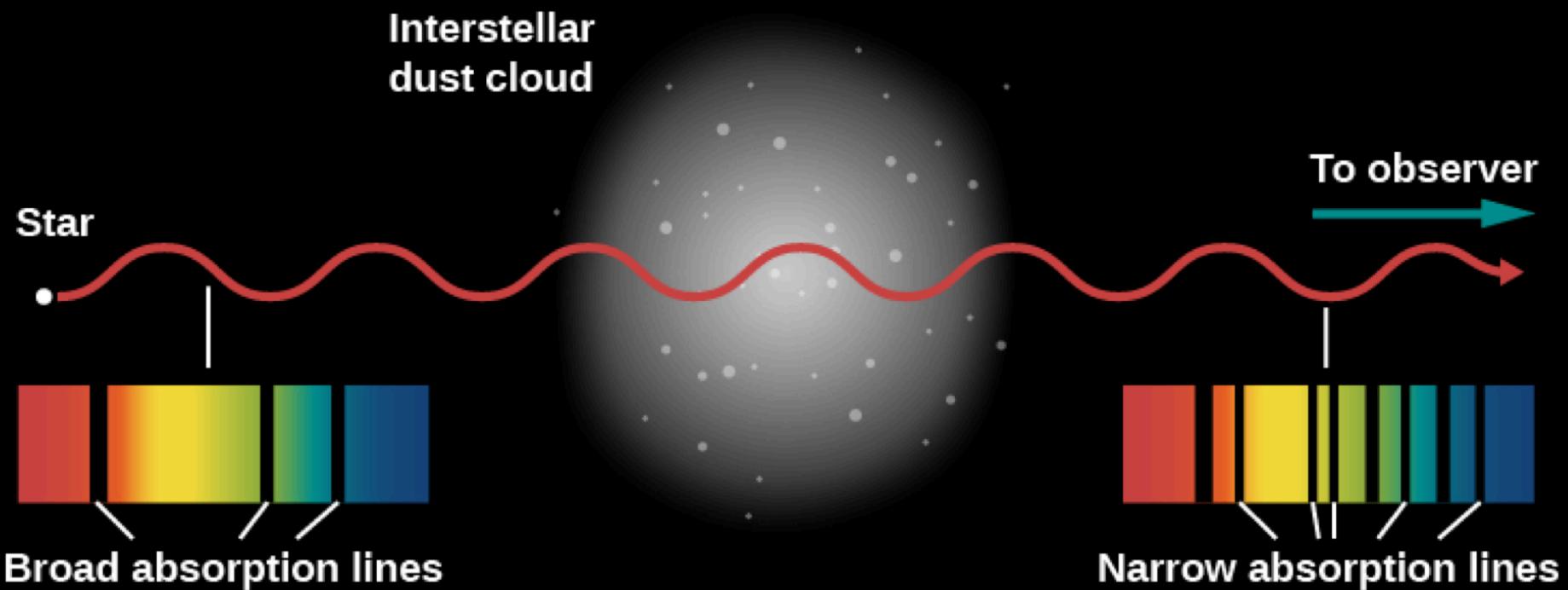


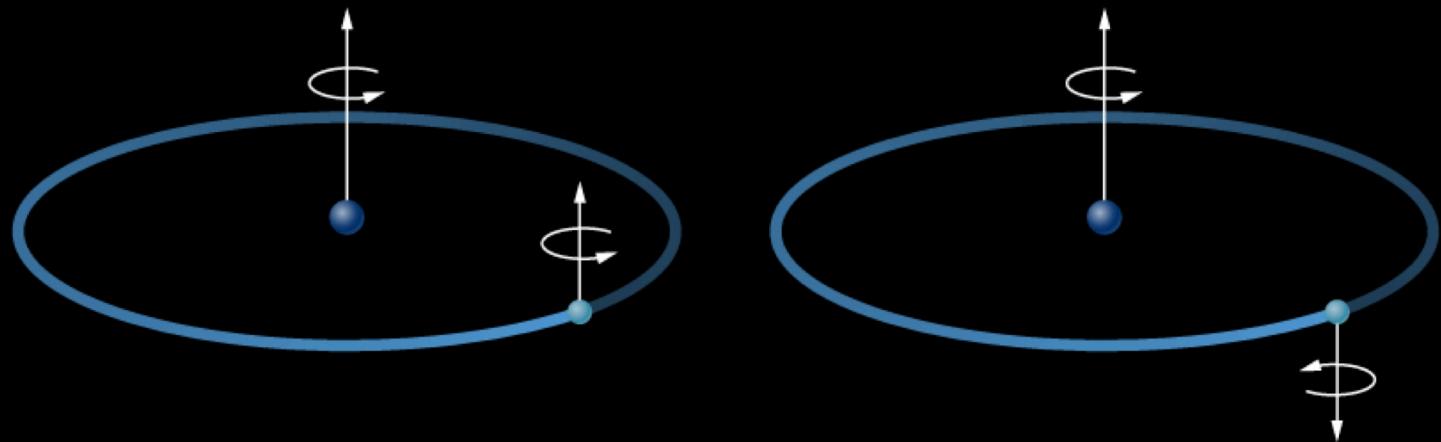
Figure 5.20 from OpenStax: Energy Levels for Hydrogen

Result



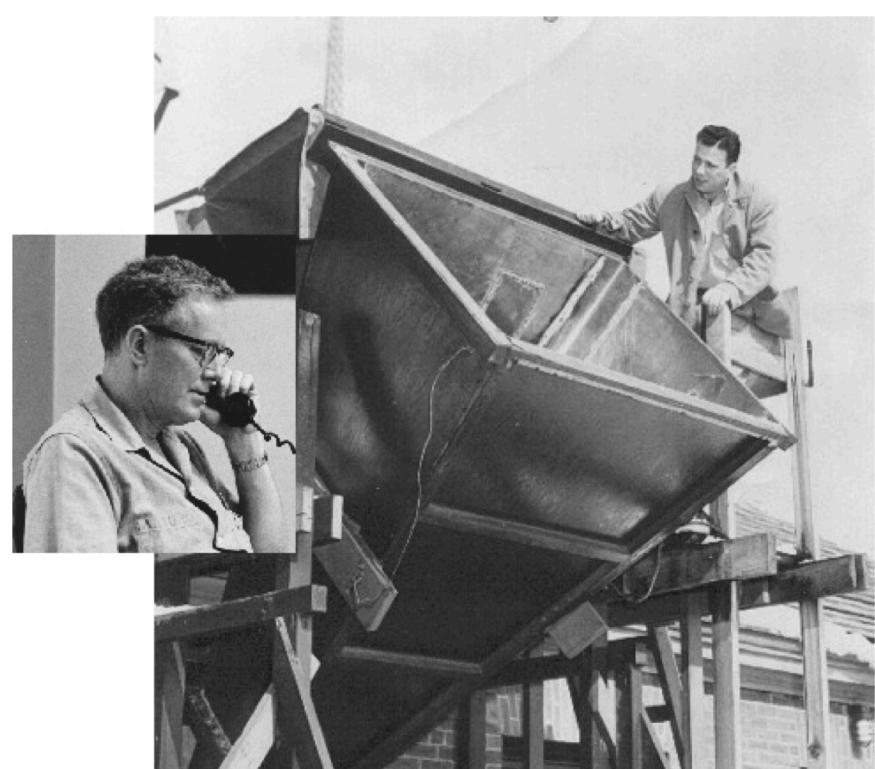


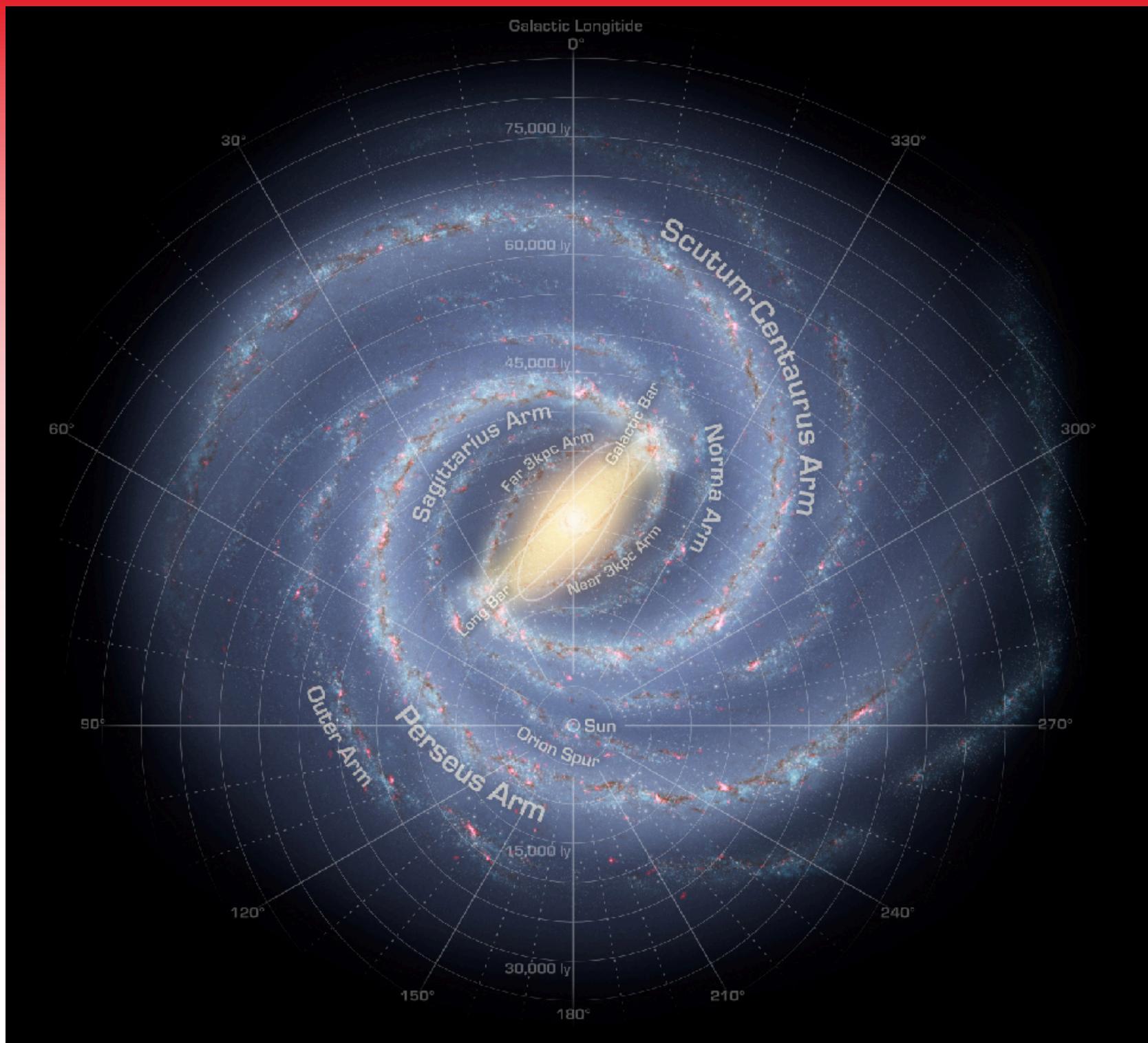
## Absorbtion Lines vs Emission Lines

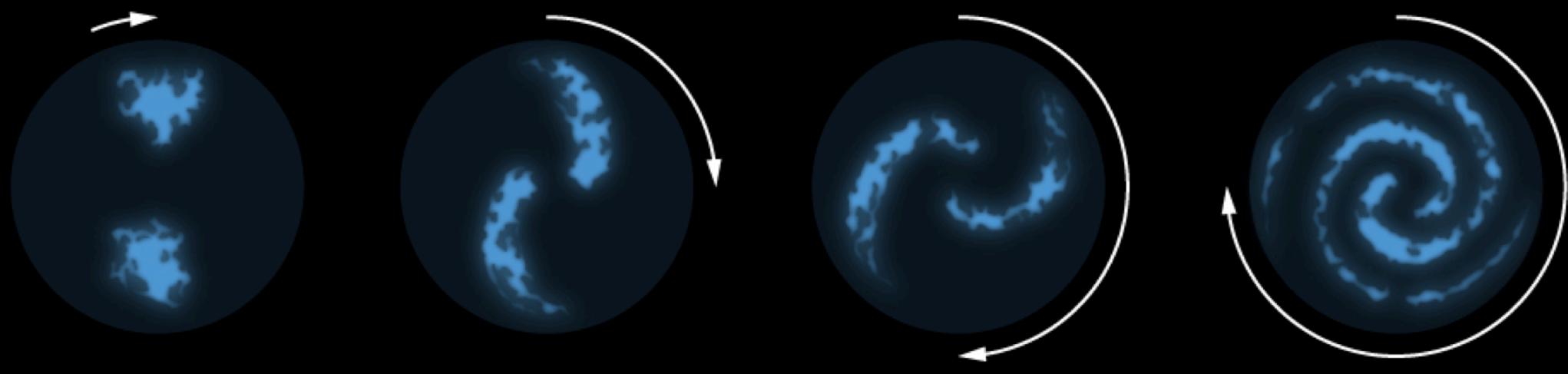


## Explanation of the 21cm Line

Observation of  
the 21cm Line,  
Ewen and Purcell







Simple, but Wrong, Explanation of  
Formation of Spiral Arms

## Review Newton's Version of Kepler's Laws

$M$  = mass of center of Galaxy

$m$  = mass of star orbiting center of Galaxy

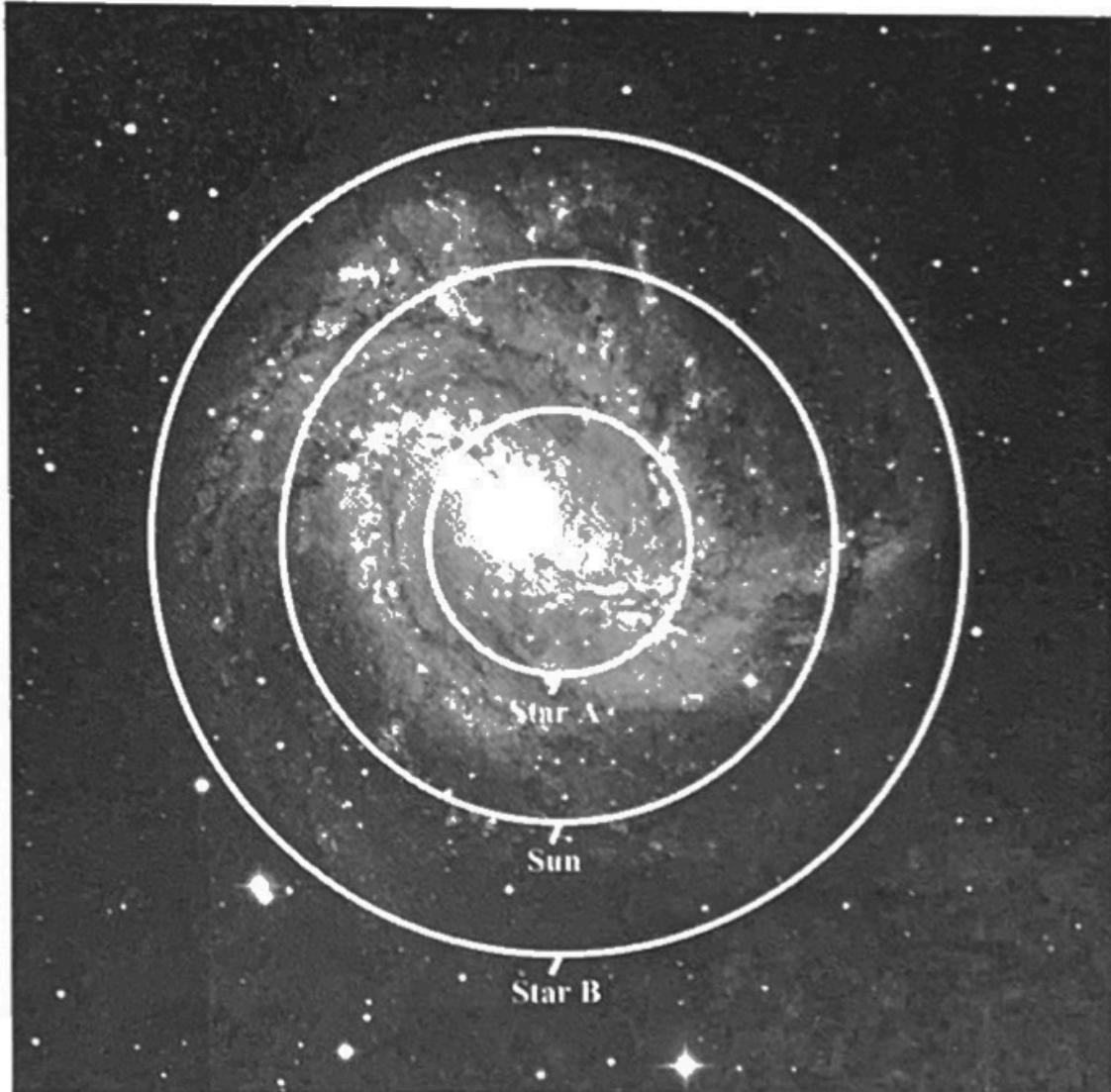
$r$  = distance from center of Galaxy

$v$  = orbital velocity

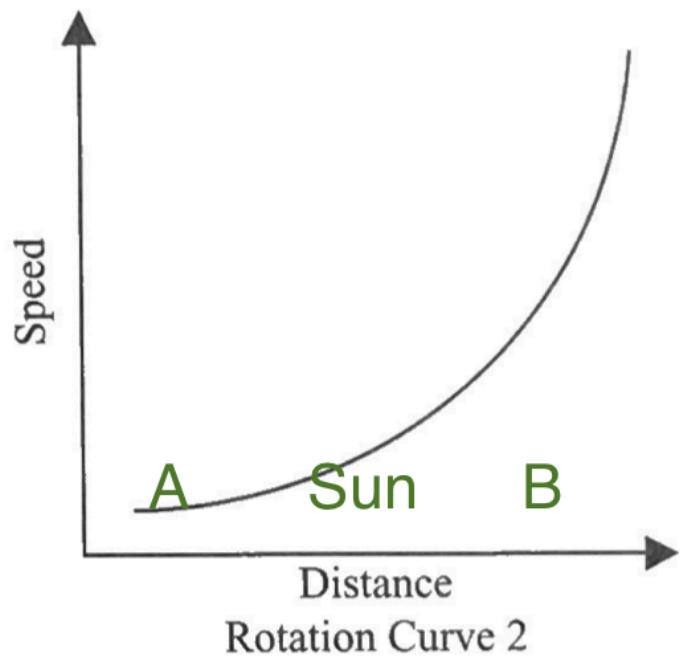
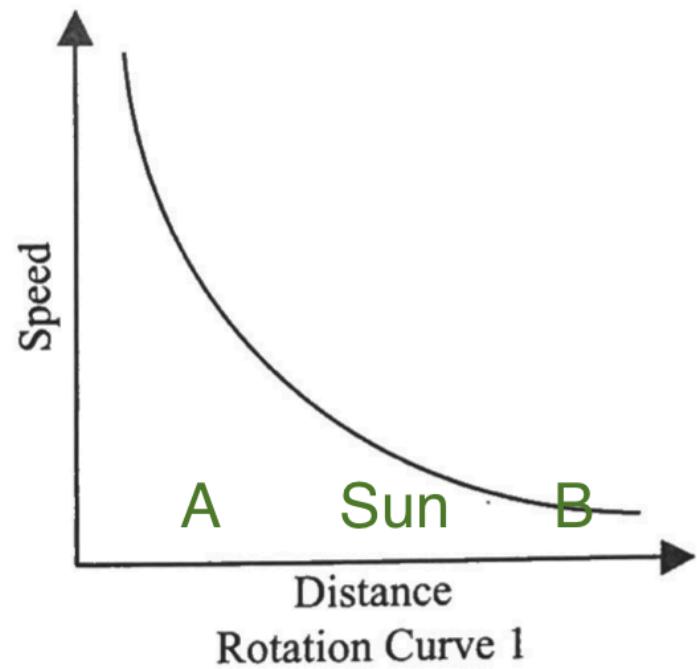
$$G M m / r^{**2} = m v^{**2} / r$$

$$G M / r = v^{**2}$$

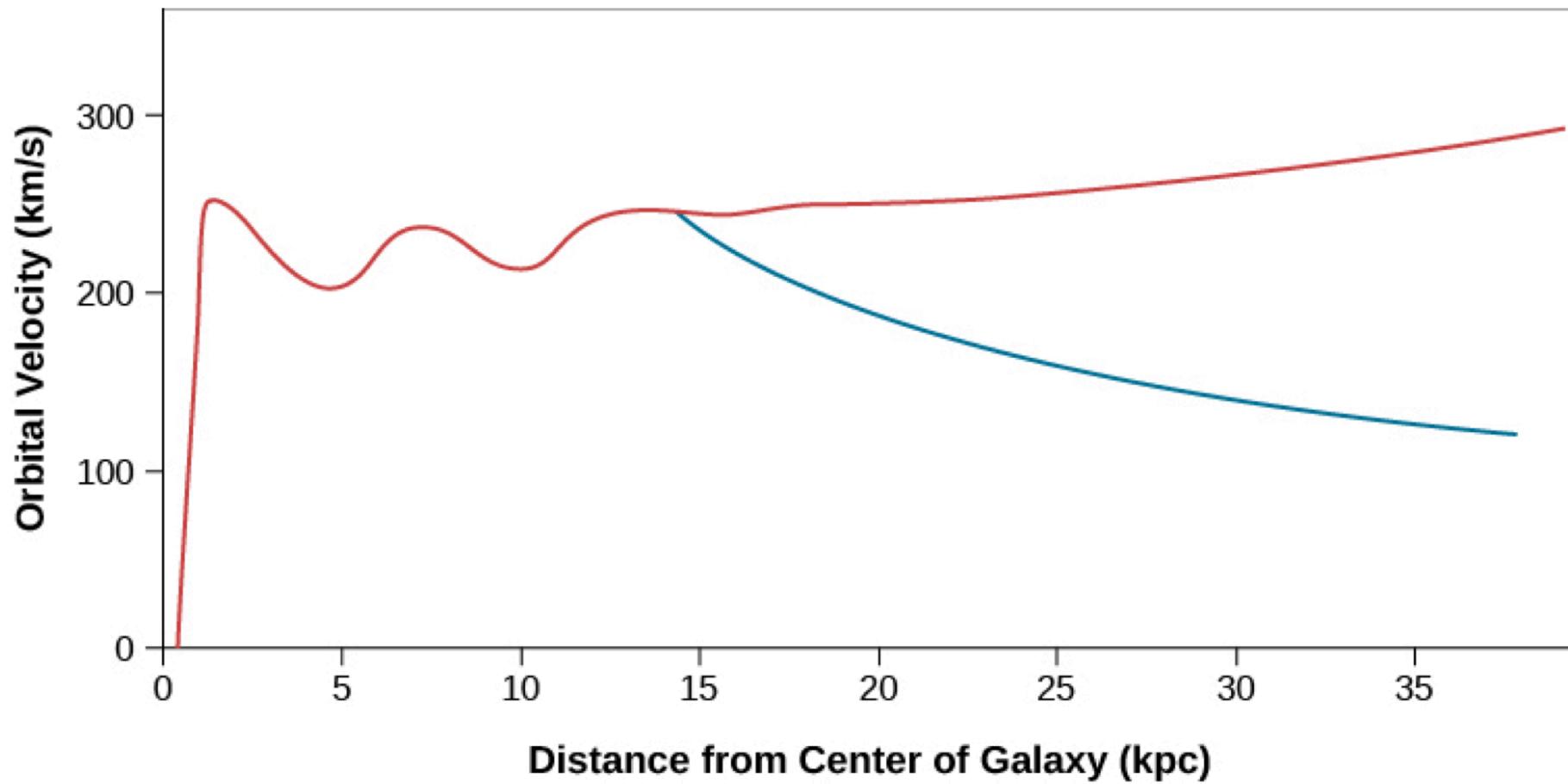
$$v = \text{SQRT}(G M / r) = \text{const} * \text{SQRT}(1/r)$$



Stars at Three Distances, Orbital Velocity



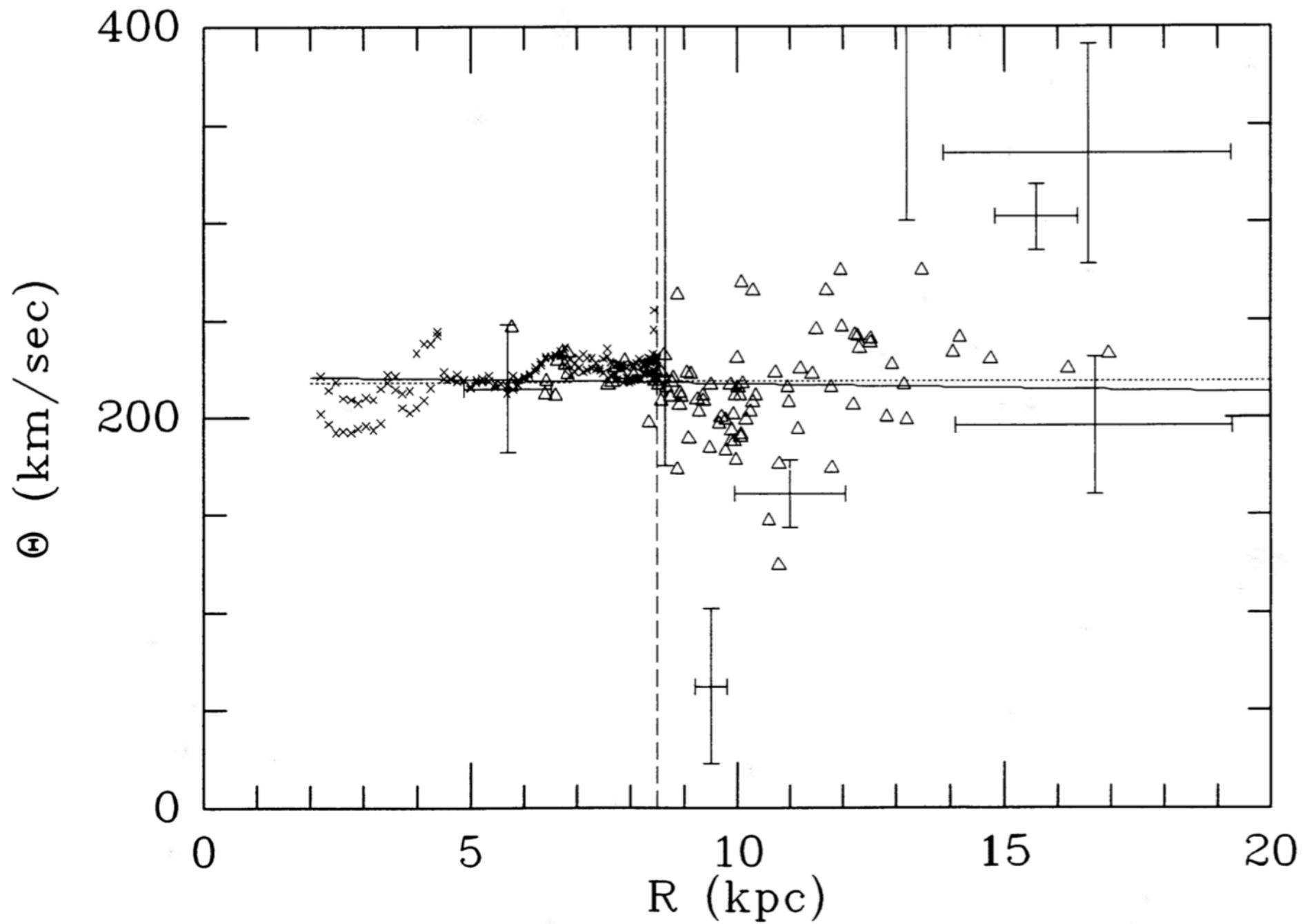
# Actual Rotation Curve For Milky Way

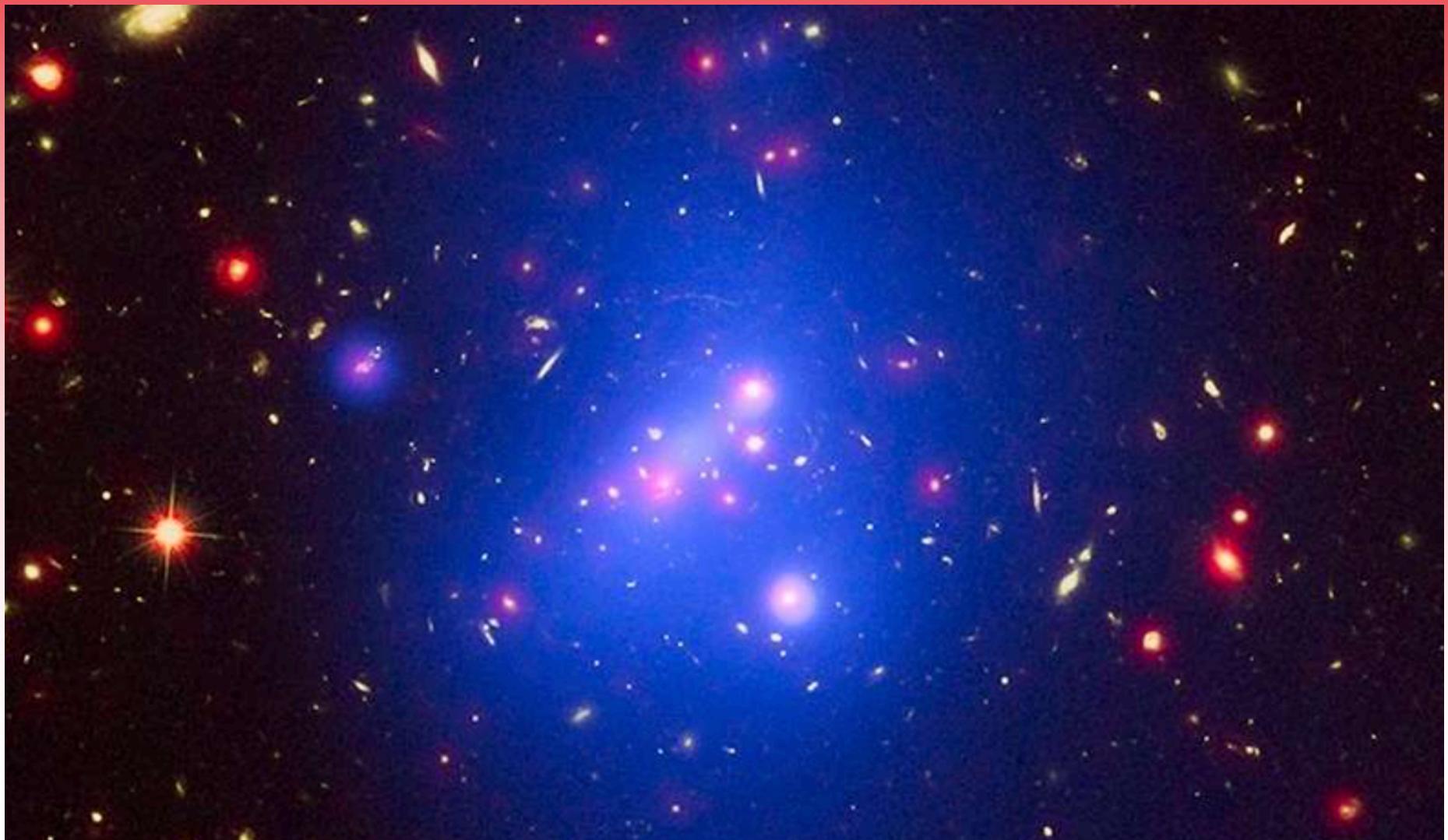


Red, Hydrogen — Blue, Carbon Monoxide

***95% of Milky Way is Dark***

# Fich, et al, 1989, Milky Way Rotation Curve





Friday, Dark Matter and Dark Energy