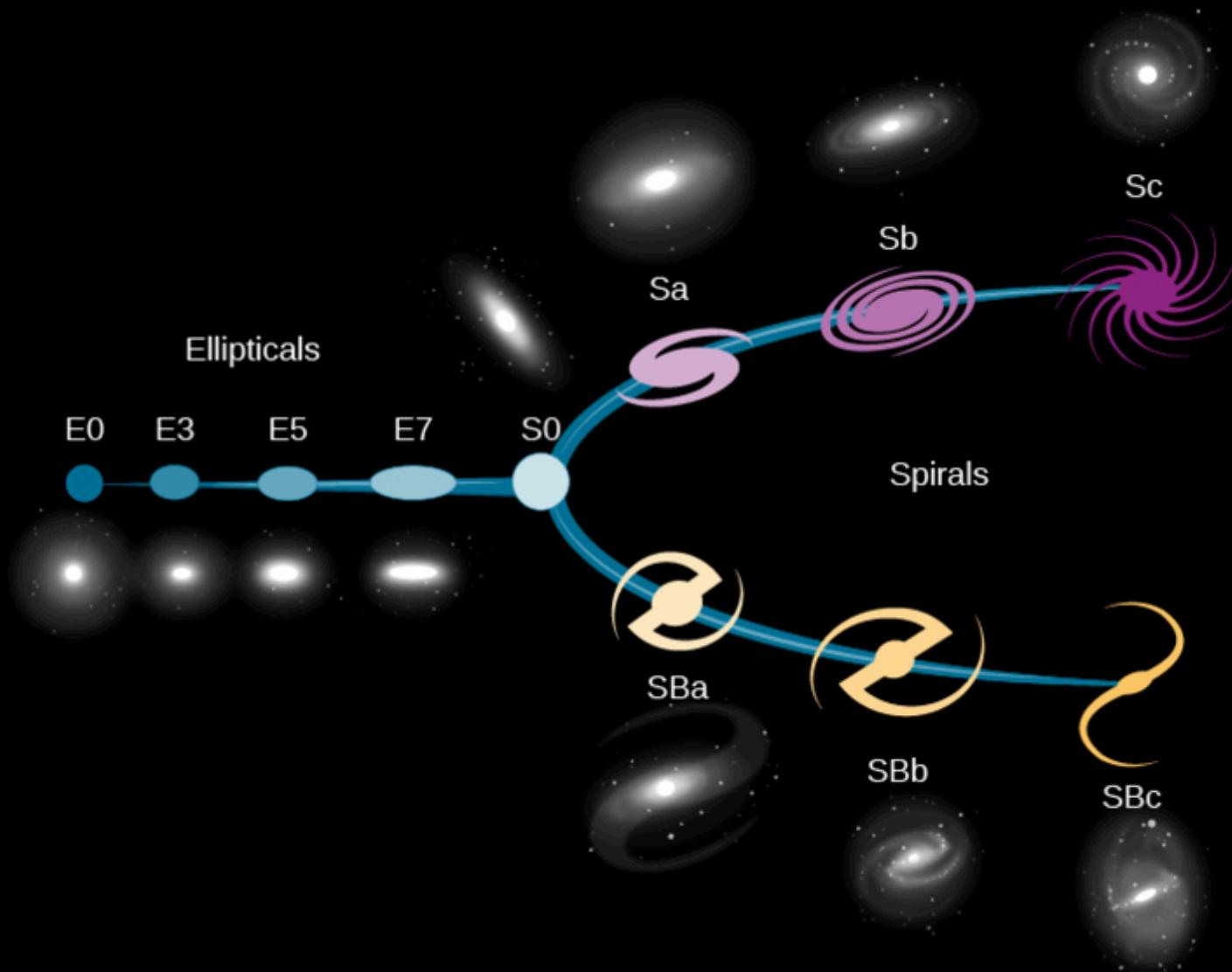


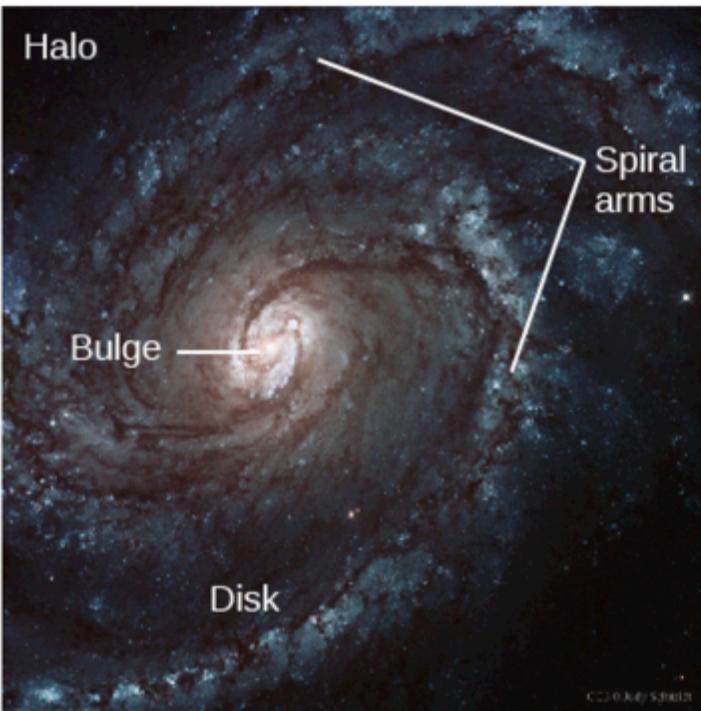
Galaxy keywordss

- **Elliptical galaxy:** ellipse, no star formation
- **Irregular galaxy:** no pattern, merger
- **Spiral galaxy:**
- **Redshift:** lines shifted to longer wavelength from expansion of universe
- **Distance ladder:** steps to calculate distance
- **Galaxy evolution:** changes in galaxies over cosmic time
- **Local group:** small cluster of galaxies, including Milky Way
- **Starburst:** galaxy with a burst of star formation, often a result of collisions
- **Quasar and AGN:** accreting supermassive black holes

Galaxies and their supermassive black holes



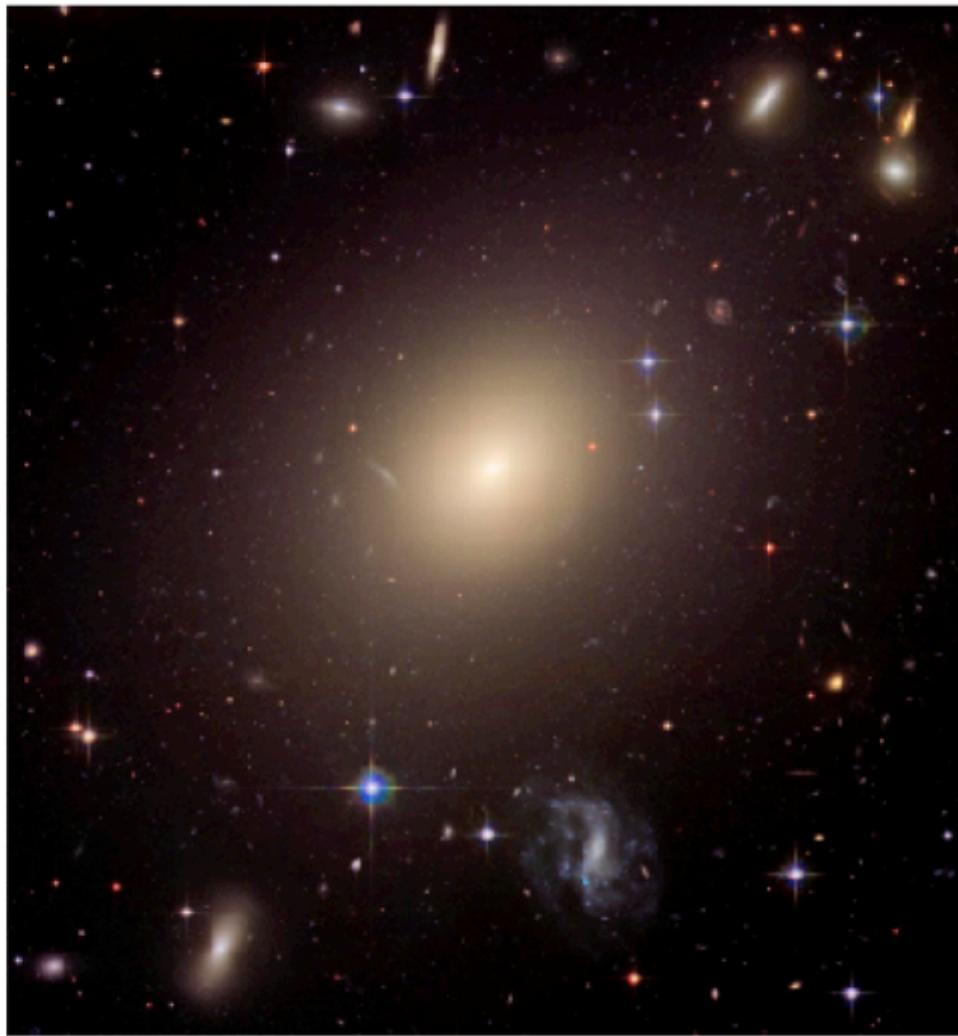
Spiral galaxies



Spirals: dense gas gets clustered, form stars: young, blue, bright



Elliptical galaxy



Irregular galaxy (merger)





Elliptical: red and dead
No dust/gas, no star formation



Mergers: starbursts
Lots of young stars and dust, gas

Characteristics of the Different Types of Galaxies

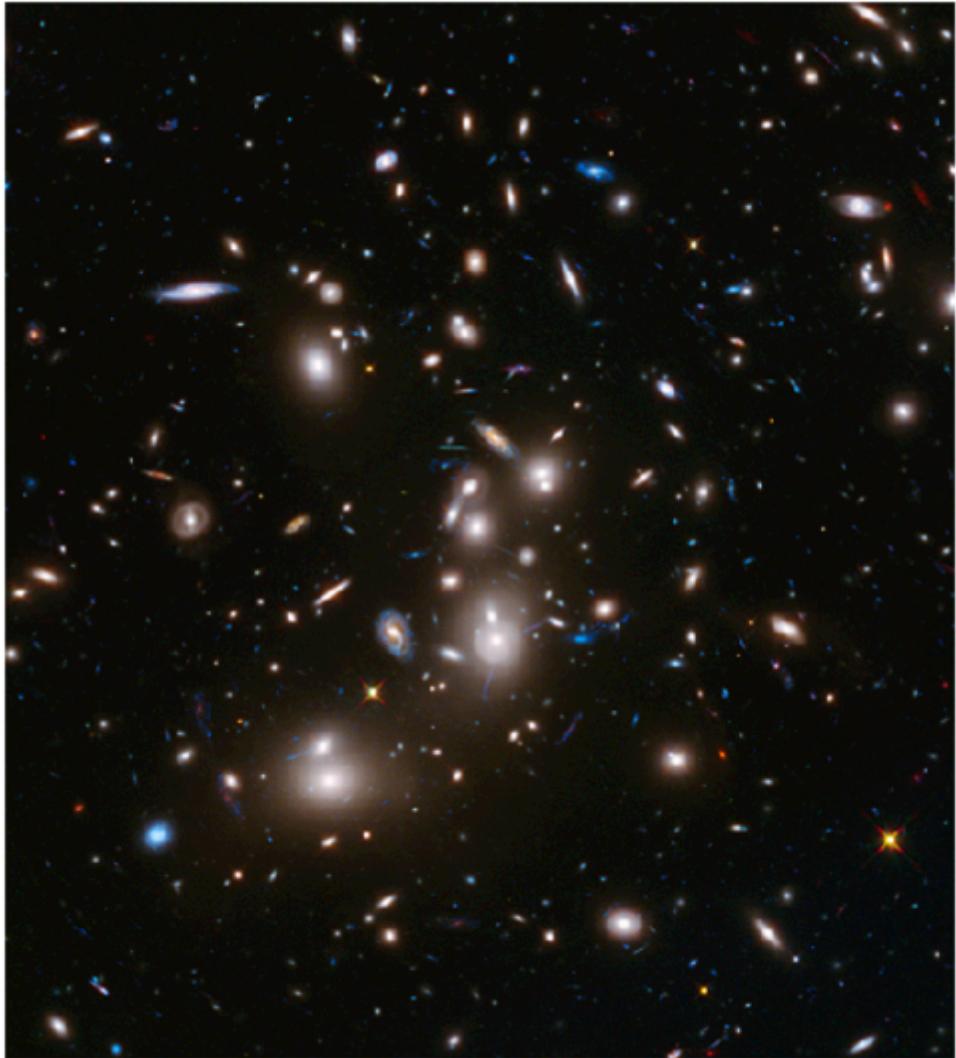
Characteristic	Spirals	Ellipticals	Irregulars
Mass (M_{Sun})	10^9 to 10^{12}	10^5 to 10^{13}	10^8 to 10^{11}
Diameter (thousands of light-years)	15 to 150	3 to >700	3 to 30
Luminosity (L_{Sun})	10^8 to 10^{11}	10^6 to 10^{11}	10^7 to 2×10^9
Populations of stars	Old and young	Old	Old and young
Interstellar matter	Gas and dust	Almost no dust; little gas	Much gas; some have little dust, some much dust
Mass-to-light ratio in the visible part	2 to 10	10 to 20	1 to 10
Mass-to-light ratio for total galaxy	100	100	?

Mass-to-light ratio: why different?

Characteristics of the Different Types of Galaxies

Characteristic	Spirals	Ellipticals	Irregulars
Mass (M_{Sun})	10^9 to 10^{12}	10^5 to 10^{13}	10^8 to 10^{11}
Diameter (thousands of light-years)	15 to 150	3 to >700	3 to 30
Luminosity (L_{Sun})	10^8 to 10^{11}	10^6 to 10^{11}	10^7 to 2×10^9
Populations of stars	Old and young	Old	Old and young
Interstellar matter	Gas and dust	Almost no dust; little gas	Much gas; some have little dust, some much dust
Mass-to-light ratio in the visible part	2 to 10	10 to 20	1 to 10
Mass-to-light ratio for total galaxy	100	100	?

Hubble (Space Telescope) Deep Field:



A lot of galaxies

How far away are
they?

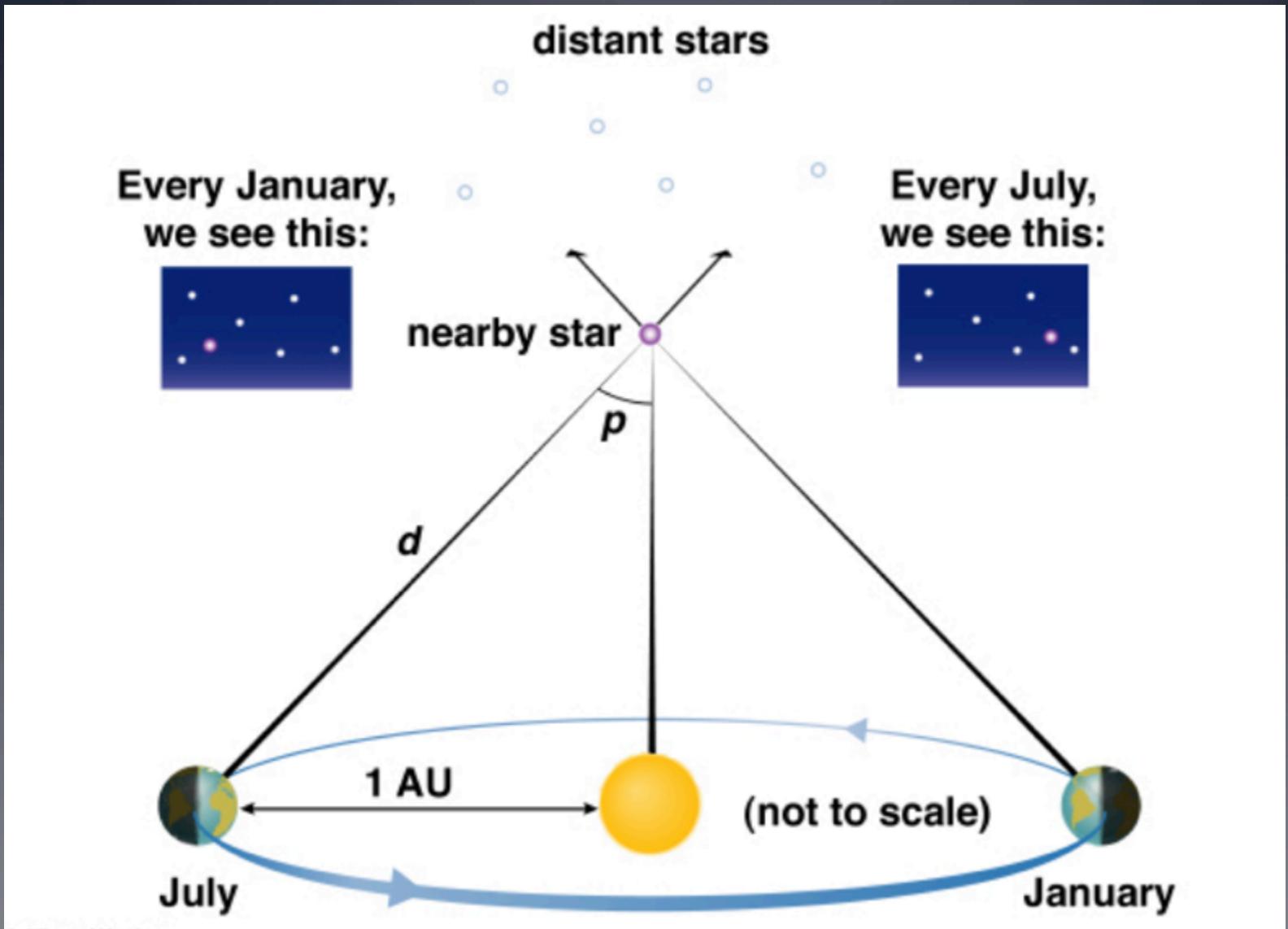
The distance ladder!

How to measure distances?

Some Methods for Estimating Distance to Galaxies

Method	Galaxy Type	Approximate Distance Range (millions of light-years)
Planetary nebulae	All	0-70
Cepheid variables	Spiral, irregulars	0-110
Tully-Fisher relation	Spiral	0-300
Type Ia supernovae	All	0-11,000
Redshifts (Hubble's law)	All	300-13,000

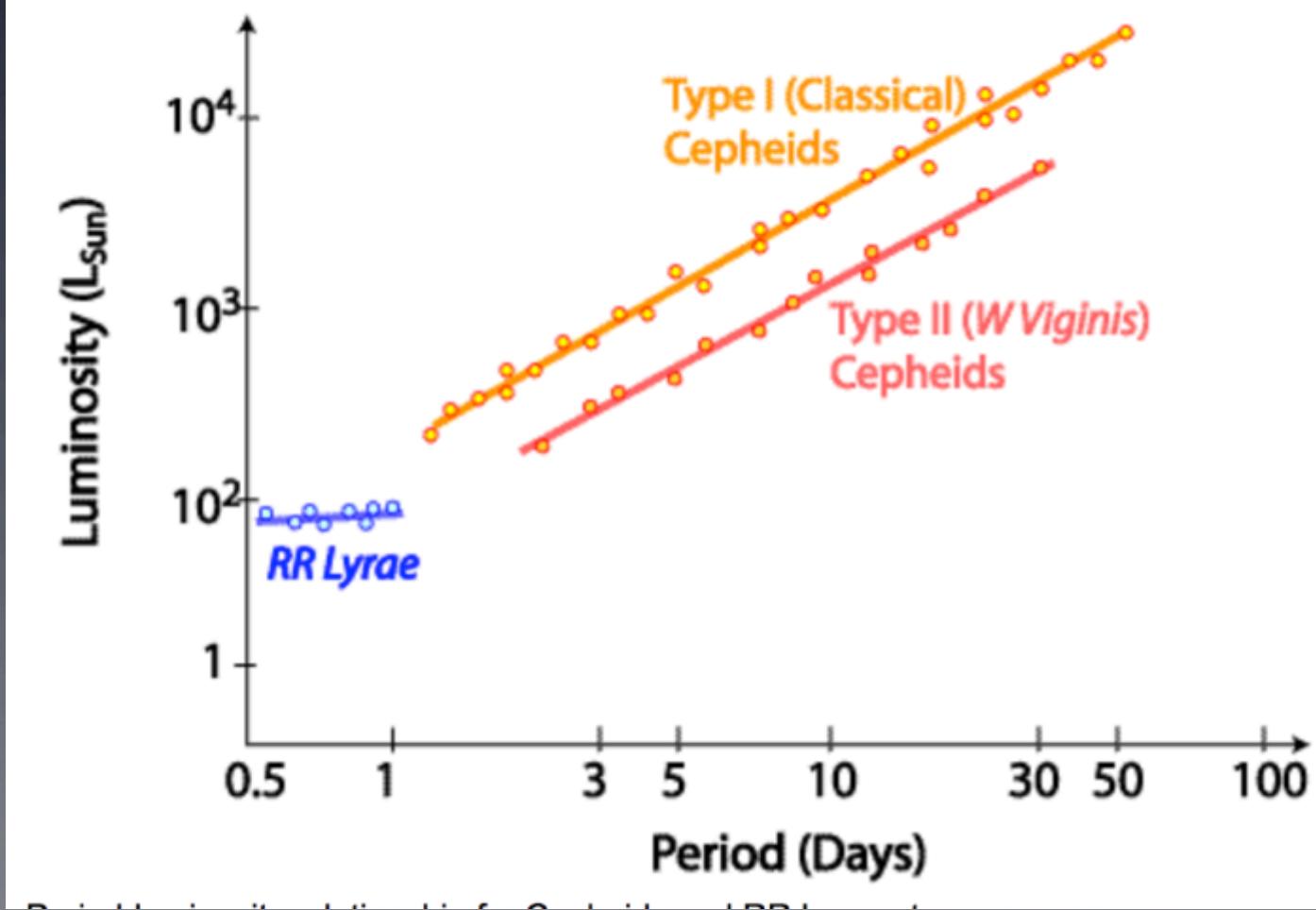
Parallax: galaxies are way too far away

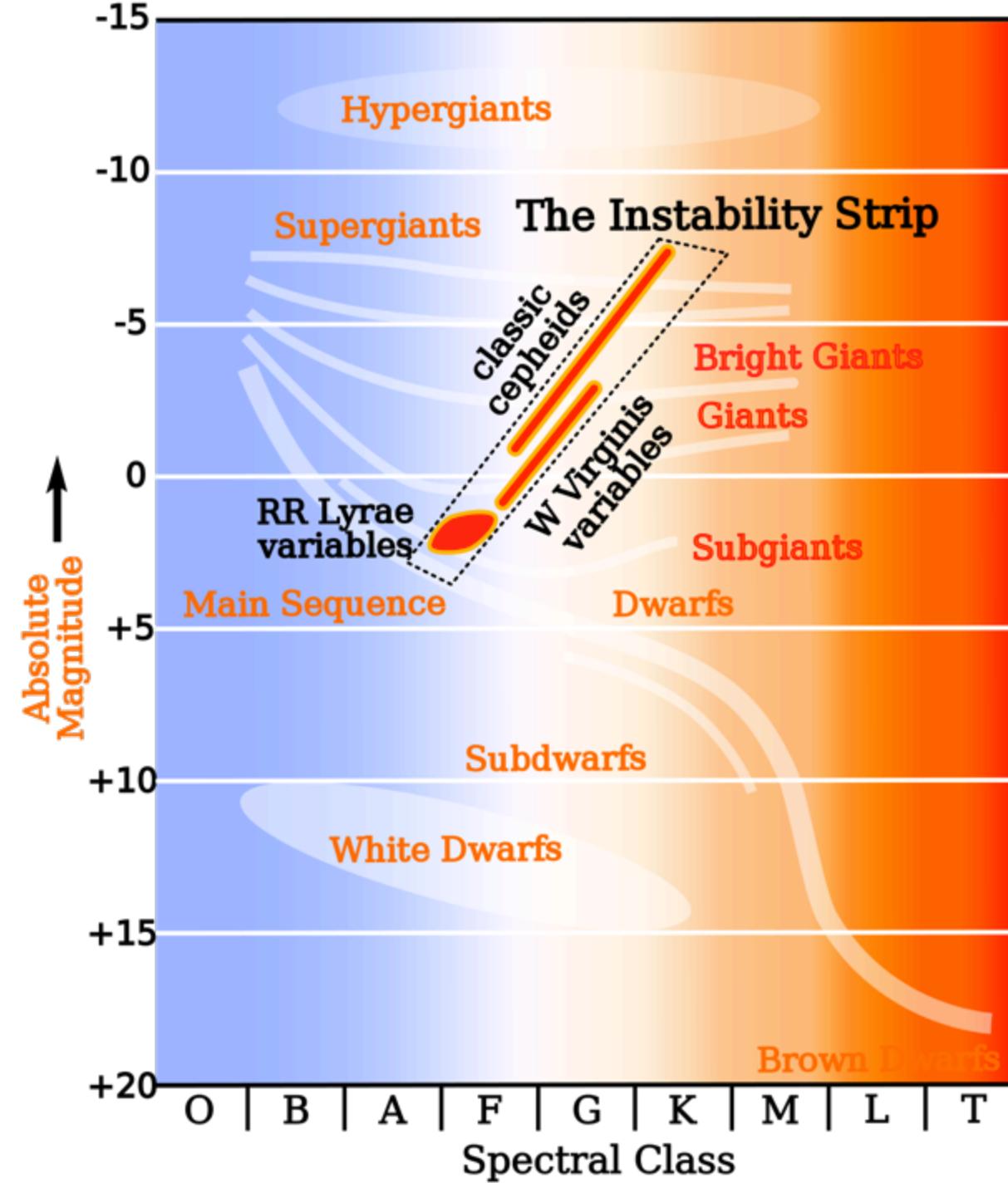


Nearby galaxies: use variable stars!



PERIOD - LUMINOSITY RELATIONSHIP





Period => absolute magnitude => distance

