Distances - effect on luminosity

apparent luminosity \sim \frac{\text{intrinsic luminosity}}{\text{area light is spread over}}

\ell \sim \frac{L}{r^2}

Observe \ell
- if we know r we can calculate L
- if we know L we can calculate r
Distances - compare two star clusters

All stars in the Pleiades star cluster are at one distance and all stars in the Hyades star cluster are at a nearer distance.

The stars lie along a band where stars spend most of their lives converting Hydrogen into Helium - the main-sequence.

The locations of analogs of the Sun are indicated.

Figure 15.10
Comparison of the apparent brightness of stars in the Hyades Cluster with those in the Pleiades Cluster shows that the Pleiades are about 2.75 times farther away because they are $2.75^2 \approx 7.5$ times dimmer.
Distances - compare galaxies

nearer

farther

14+12
1.33 Mpc
N3109
1.37 Mpc
Antlia

17+6
5.25 Mpc
N0784
5.15 Mpc
U1281

1.40 Mpc
SexA
1.39 Mpc
SexB

5.73 Mpc
KK 16
5.18 Mpc
KK 17
**Distances** - Hubble’s Law

velocity / distance = constant

\( \frac{V}{d} = H_0 = \text{Hubble Constant} \)

\( 1/H_0 \) ~ age of universe

= if constant expansion
> if slowing down
< if speeding up
Distances – the distance ladder

near

techniques change with distance

far
**Distances - parallax**

We know the distance of the Earth from the Sun

We measure the wobble of a near star against the backdrop of distant stars

Using trigonometry we get the distance to the star

\[ d = \frac{1 \text{AU}}{\sin \rho} \]
Distances
- Cepheid variable stars

Cepheid stars pulsate bright - faint with periods of days to months

Fig 15.12 shows the mean brightness of Cepheids in a neighbor galaxy; ie, they are all at the same distance. We see that the stars that pulsate with a long period are brighter than the stars that pulsate with a short period.

\[ l \sim \frac{L}{d^2} \] observe \( l \), know \( L \) => get \( d \)
Distances - “Tully-Fisher” method

Big galaxies rotate fast because they are massive

Hence the integrated emission profile is broad

Little galaxies with modest mass rotate slow

Integrated emission profiles are narrow
Distances - TF method

\[ L \sim W^4 \]

\[ \ell \sim L/d^2 \]

observe \( \ell \)

know \( L \)

get \( d \)

Each point represents a single galaxy.

Slow \( W \)  

Fast
Each of these points represents a galaxy in a relatively nearby cluster.

These points represent galaxies in a relatively more distant cluster.

The rate of rotation $W$ is determined by the intrinsic mass of the galaxy (the measured $W$ is independent of distance).

The Apparent Magnitude (or luminosity) depends on distance $D$ (more distant galaxies are fainter).
Absolute TF Calibration

$\text{L} \sim W^4$

 linewidth $W$
Type Ia Supernova

Gas from binary companion attracted onto a white dwarf. If the mass of the white dwarf grows to exceed the Chandrasekhar limit of $1.4 \times$ the mass of the Sun then the white dwarf will no longer be stable against collapse and the shock of the implosion will give a supernova. Since the mass is precise, the luminosity of the supernova is always almost the same.
Distances - supernovae

Supernovae of type Ia are caused by mass exchange from a companion onto a white dwarf. Once the white dwarf has $1.4 \times$ the mass of the Sun it’s gravity causes the star to implode (becomes a neutron star). Shock waves cause the expulsion of the outer shell => supernova!

Since the mass of the collapsing star is precisely defined, the luminosity of the explosion is well defined => know $L$, get $d$