Some astrophysical background

Ivan Milić *(AOB/OCA)*
ivanzmilic@gmail.com

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Galaxies sure are nice...

But let us hear some opinions on the stars:

“You'd look pretty simple from ten parsecs too.”

Fred Hoyle (~ 1955)

“Why in the world would anyone want to study stellar atmospheres? They contain only 10^{-10} of the mass of a typical star; surely such a negligible fraction of a star’s mass cannot affect the overall structure and evolution.”

Edwin Salpeter to Dmitri Mihalas (~1970)

Keep in mind following things:

Stars, in principle, can influence objects on larger scales (reionisation, stellar feedback in galaxy formation/evolution)

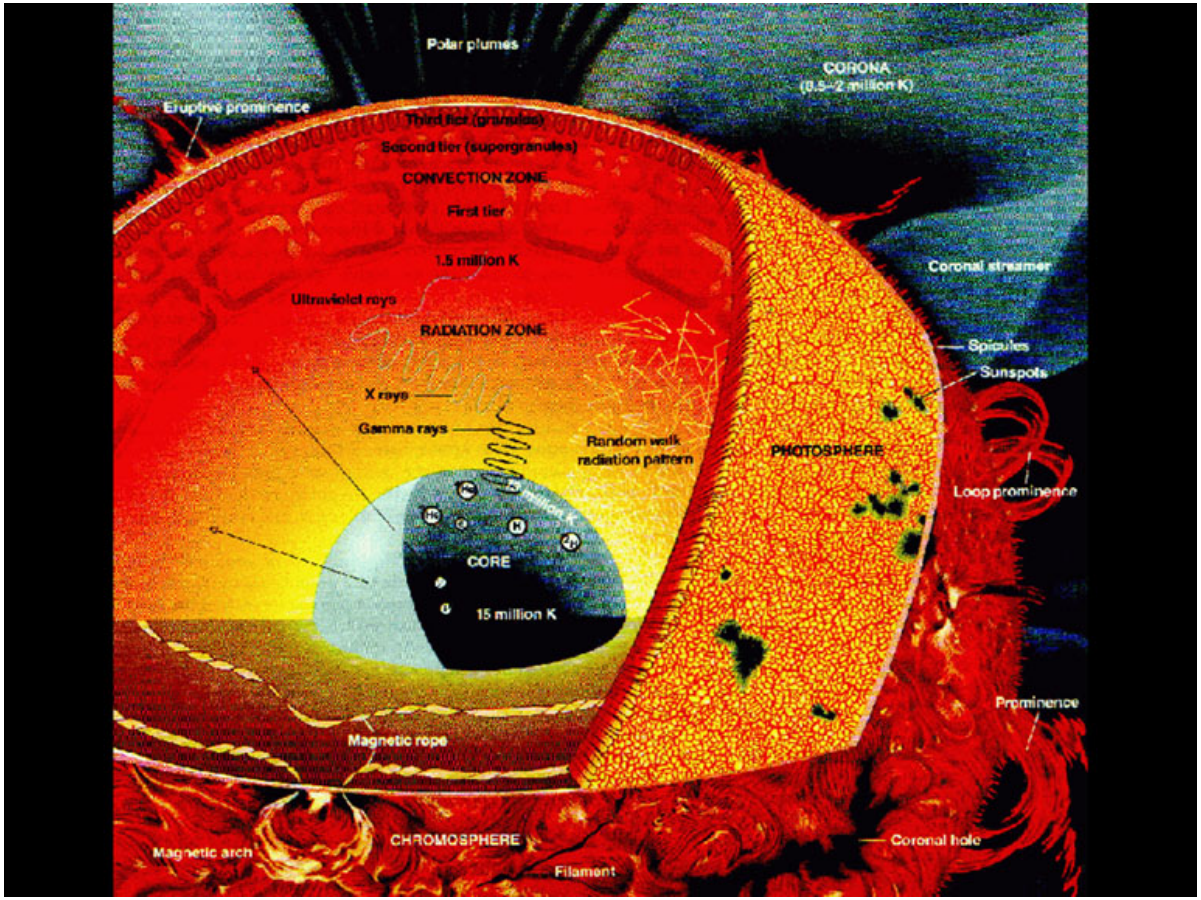
Our knowledge on more “local” objects should not contradict our knowledge on cosmological scales (e.g. ages of objects should not contradict each other)

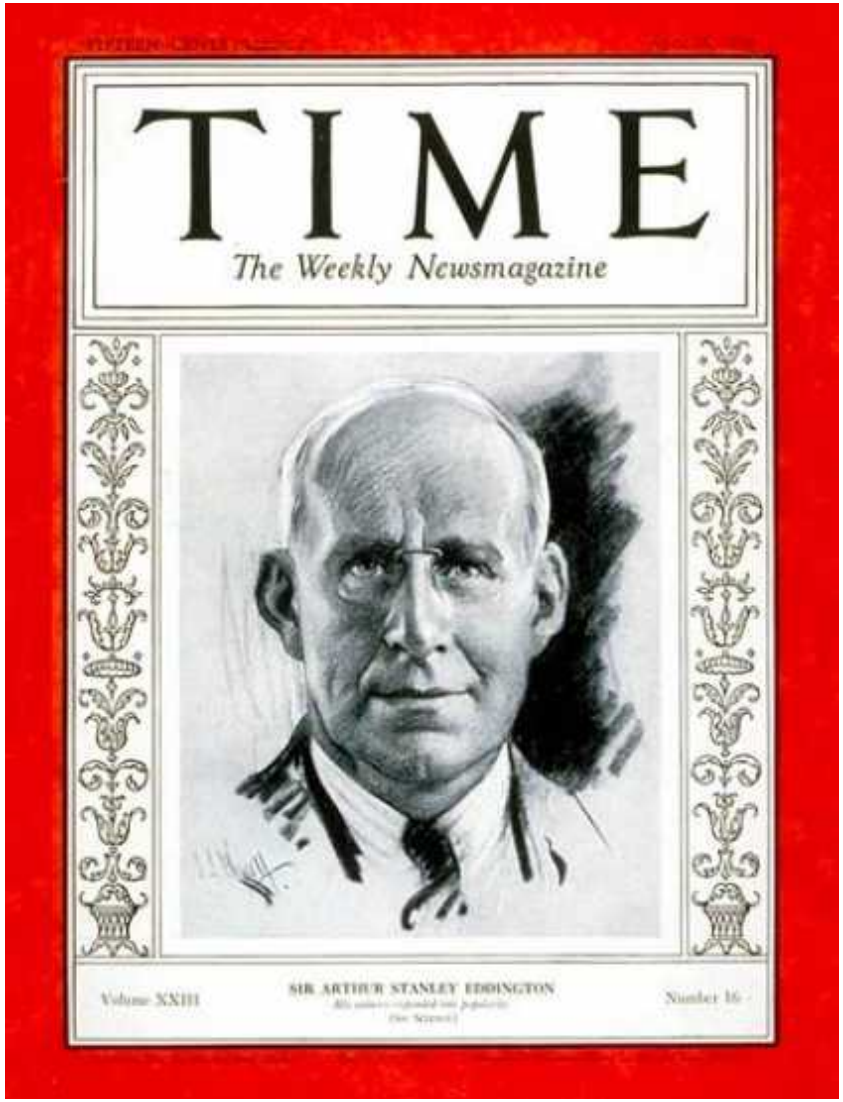
Stars can prove as useful tools in extragalactic astronomy and cosmology (SNe Ia, variable stars...)

Stars are one of the major constituents of the visible part of galaxies, thus heavily influencing what we observe in galaxies.

Stars are also pretty fun on their own, but we shall leave that for another school in Petnica for some other year.

As Eddington correctly concluded, stars must be at least as old as the Earth, and there must exist a source of energy powerful enough to fuel these cosmic furnaces for periods of time long enough (few Myr – few hundreds of Gyr) → **nuclear energy!**





FUNDAMENTAL STELLAR STRUCTURE EQUATIONS (FSSE) IN TIME-INDEPENDENT (STATIC) FORM

$$\frac{dP}{dr} = -G\frac{M_r\rho}{r^2}$$ HYDROSTATIC EQUILIBRIUM

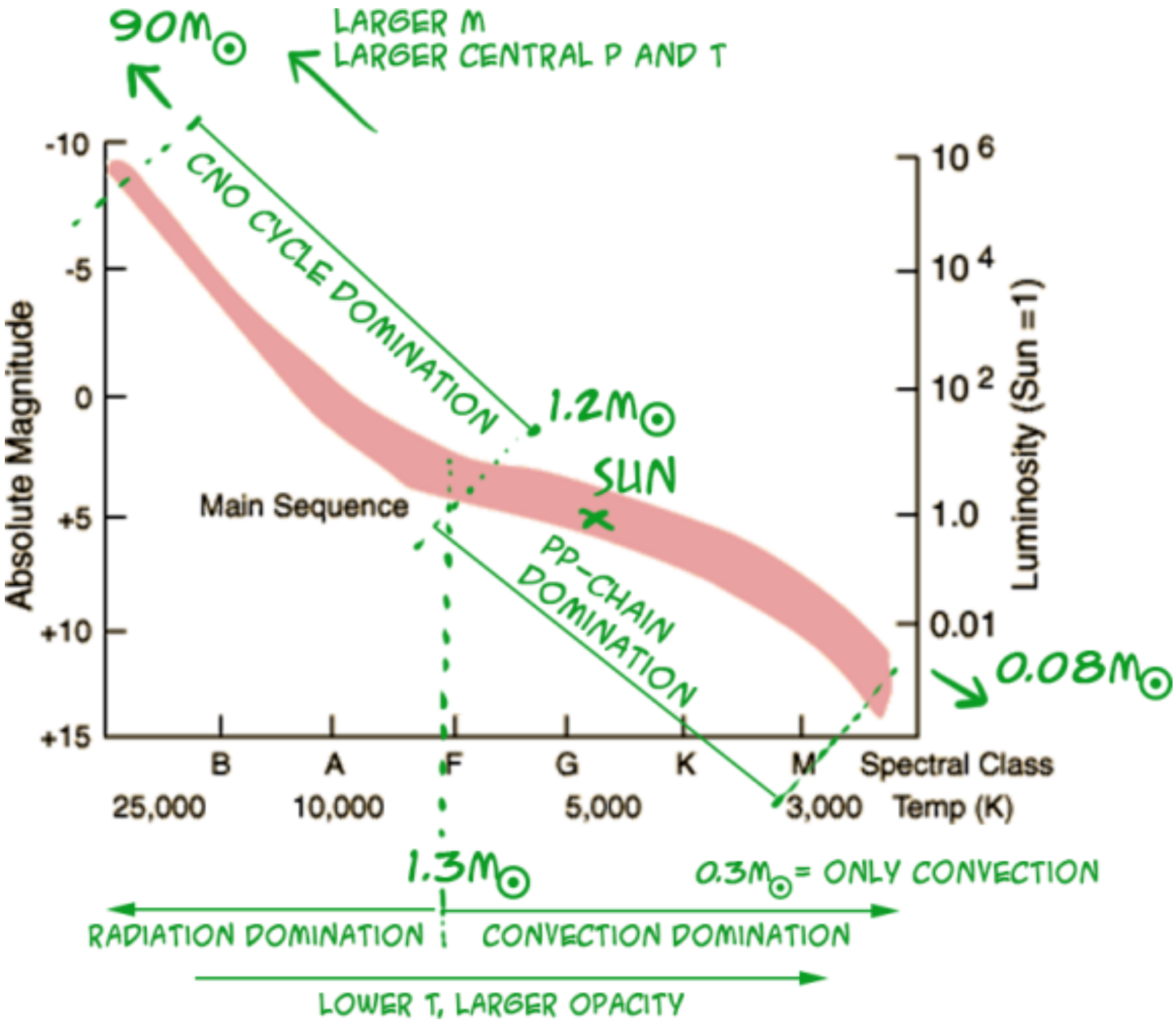
$$\frac{dM_r}{dr} = 4\pi r^2\rho$$ MASS CONSERVATION

$$\frac{dL_r}{dr} = 4\pi r^2\rho\epsilon$$ ENERGY EQUATION

$$\left.\frac{dT}{dr}\right|_{rad} = -\frac{3}{4ac}\frac{\overline{\kappa}\rho}{T^3}\frac{L_r}{4\pi r^2}$$ RADIATIVE TRANSPORT

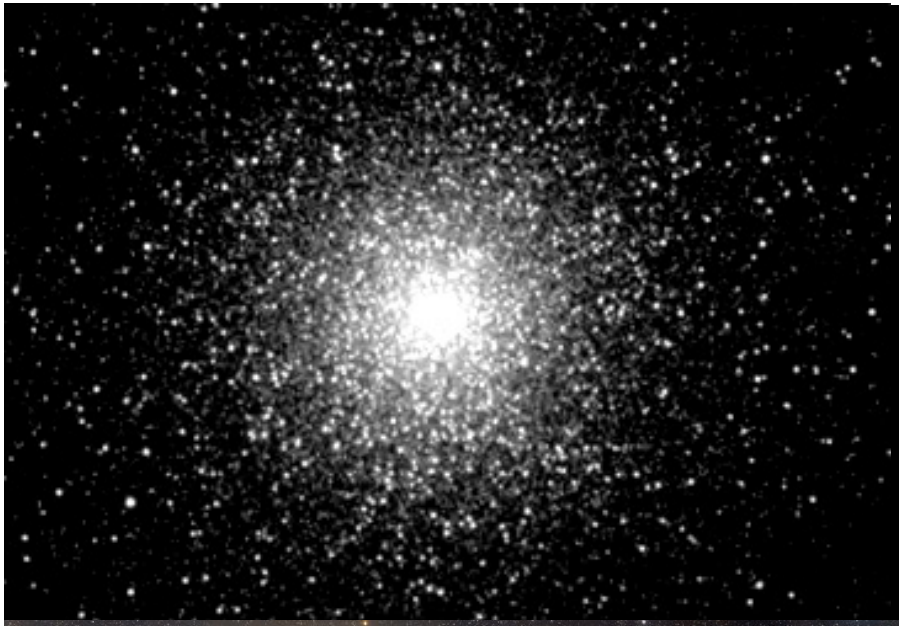
$$\left.\frac{dT}{dr}\right|_{\mathrm{ad}} = -\left(1-\frac{1}{\gamma}\right)\frac{\mu m_H}{k}\frac{GM_r}{r^2}$$ ADIABATIC CONVECTION

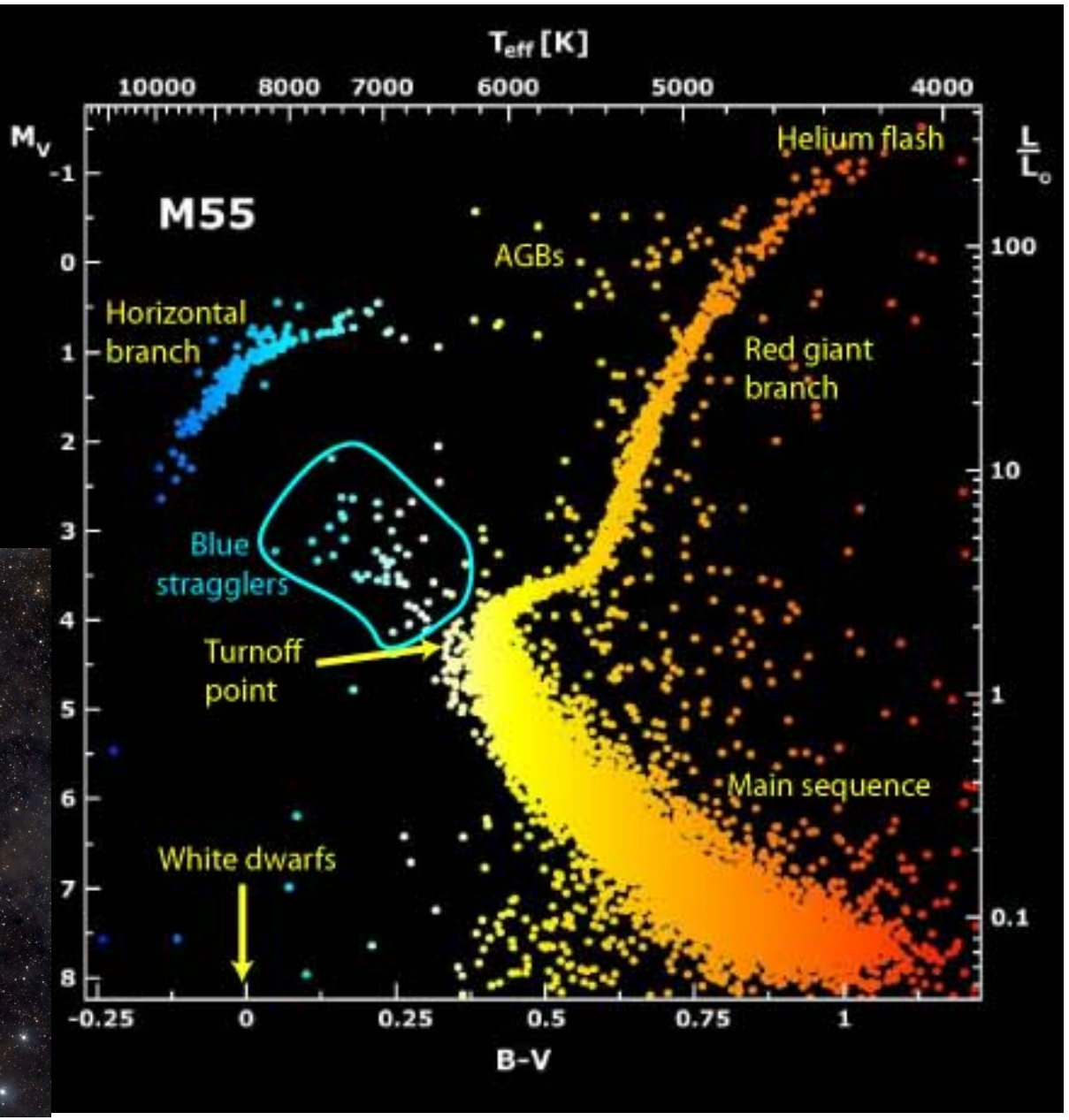
Credit to Quantum Red Pill Blog


90M⊙
LARGER M
LARGER CENTRAL P AND T
CNO CYCLE DOMINATION
1.2M⊙
SUN
Main Sequence
PP-CHAIN DOMINATION
0.08M⊙
Absolute Magnitude
-10
-5
0
+5
+10
+15
Luminosity (Sun =1)
10 6
10 4
10 2
1.0
0.01
B
A
F
G
K
M
Spectral Class
25,000
10,000
5,000
3,000
Temp (K)
1.3M⊙
0.3M⊙ = ONLY CONVECTION
RADIATION DOMINATION
CONVECTION DOMINATION
LOWER T, LARGER OPACITY

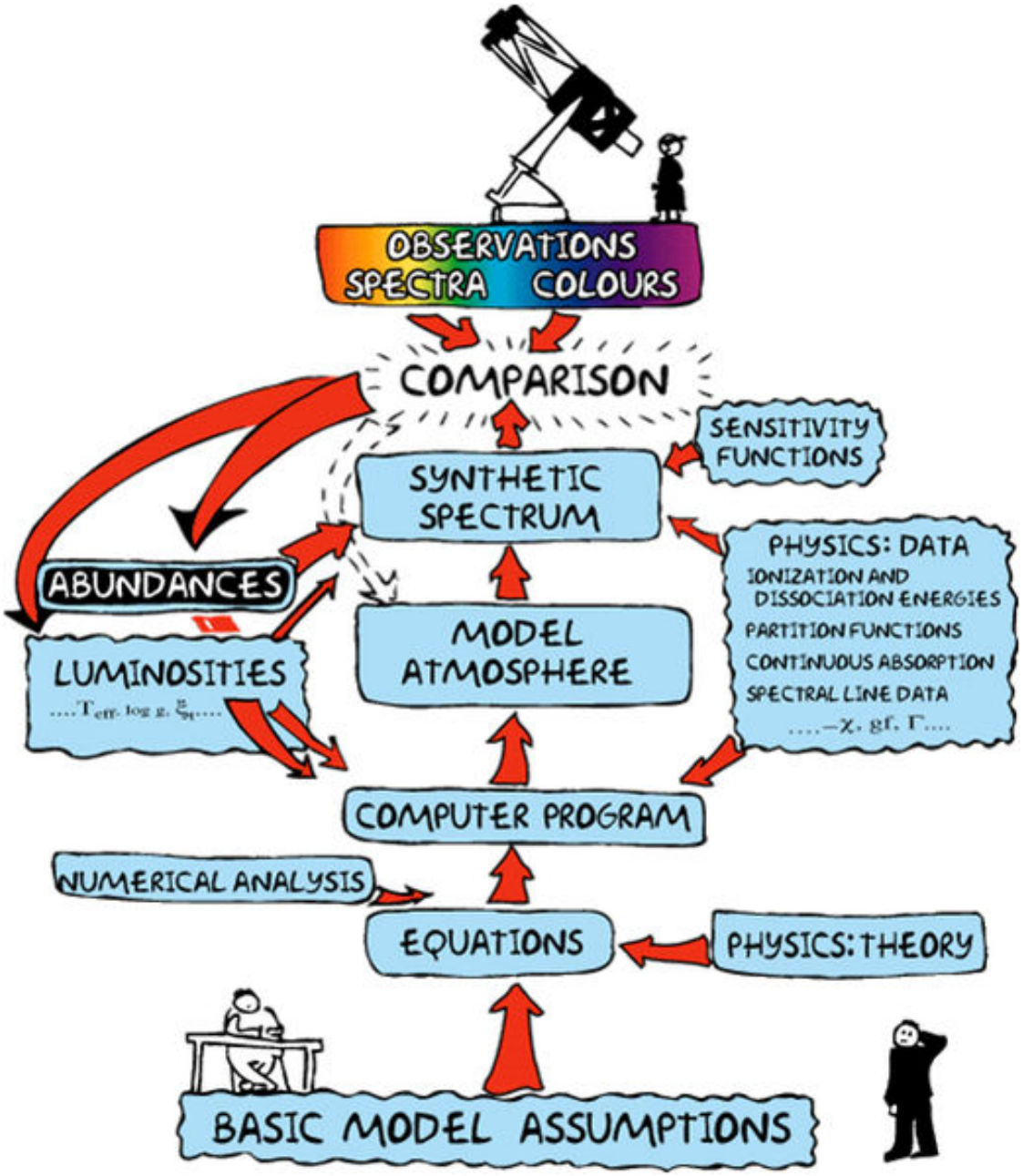
Importance of stellar clusters

(we will come back to these in a bit)





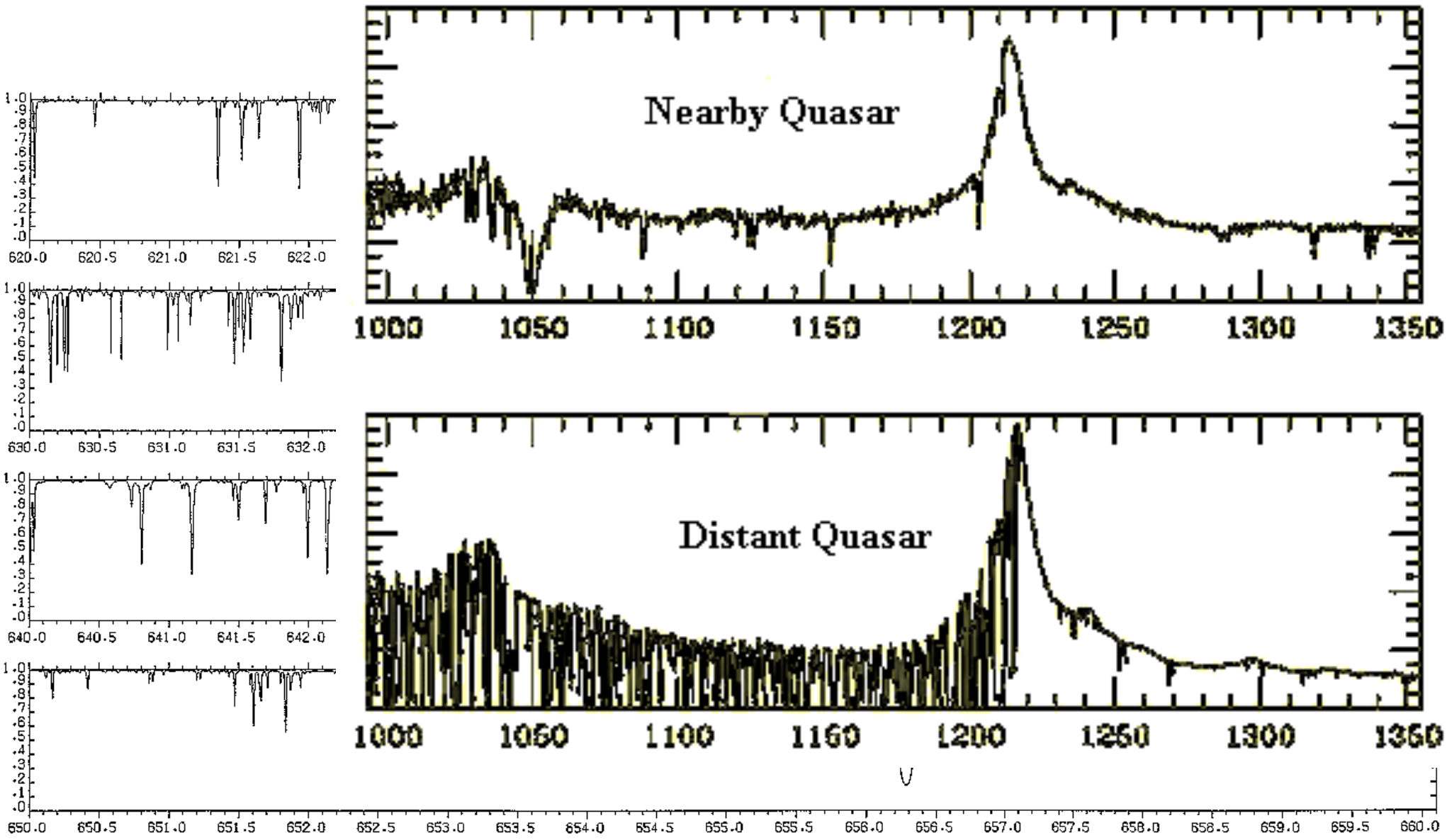
Why are we so sure about this?



Pretty much all our knowledge about stars (and, to be honest, about lot of other celestial objects too) comes from quantitative spectroscopy, that is, analysis of observed:

- Distribution of intensity in the continuum
- Position and intensity (eq. width) of spectral lines
- Spectral line shapes

Let us spend few moments with some spectra



Even without comparison with models spectrum can give us **some** elementary information:

Line **position** gives us information on the objects velocity with respect to us (Doppler shift).

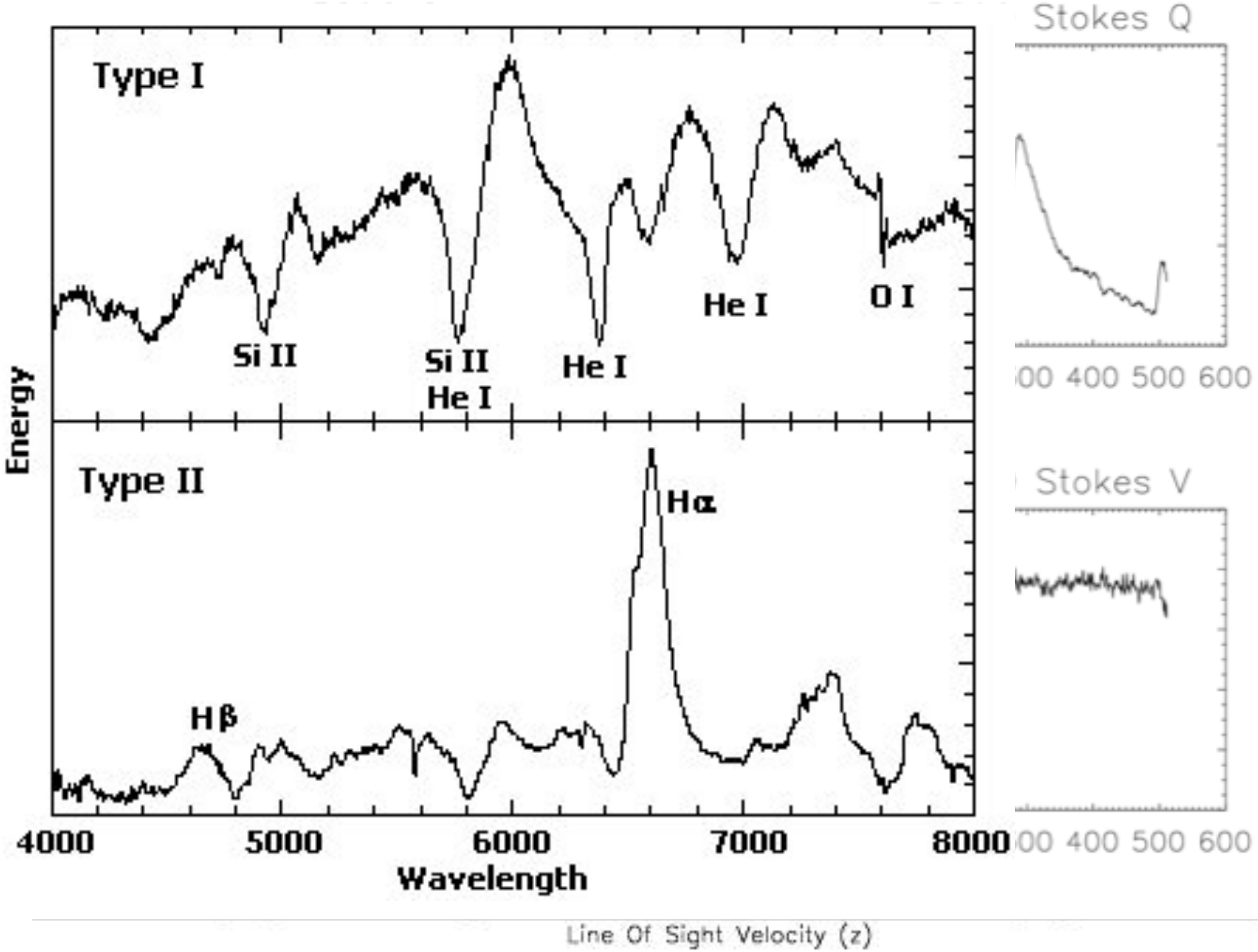
Line **equivalent width (strength)** gives us information on presence/absence of the absorbing material, and, with sophisticated enough tools, allows for abundance determination.

Asymmetries and **broadening** give us information on internal velocity fields and/or stellar rotation.

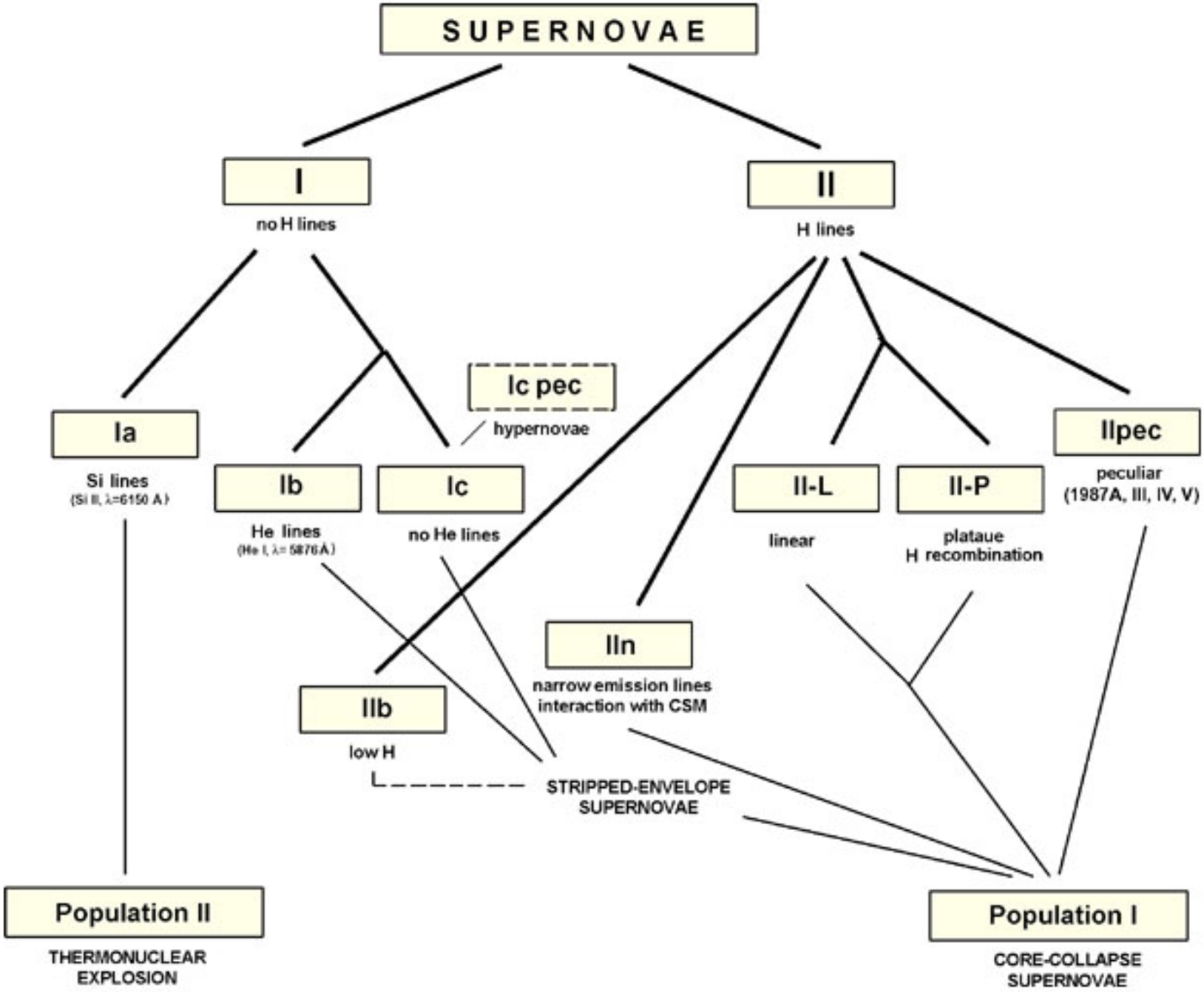
Peculiar shapes and temporal variations are evidence of complicated structures or transient processes in stars.

Line polarization (Full Stokes vector) allows for estimation of strength and orientation of the magnetic field which pervades the object.

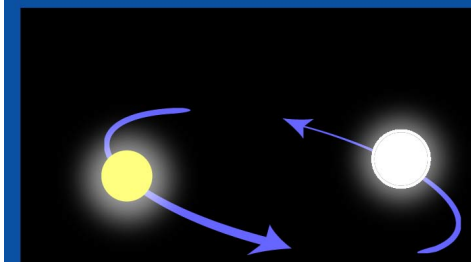
And some examples...



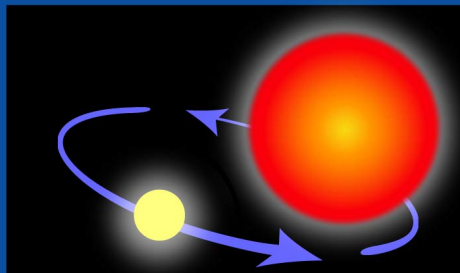
And let us say a few words about supernovae



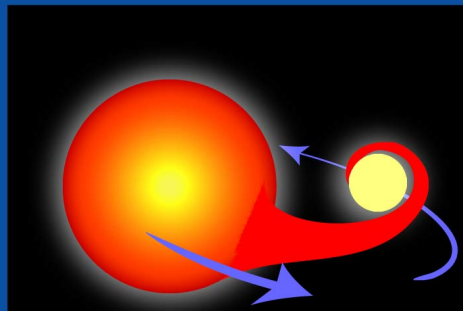
The progenitor of a Type Ia supernova



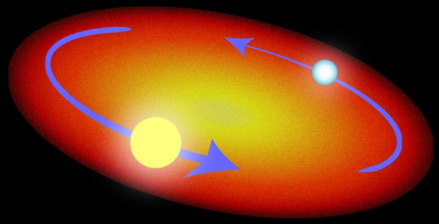
Two normal stars are in a binary pair.



The more massive star becomes a giant...

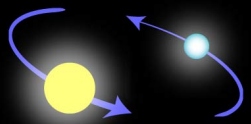


...which spills gas onto the secondary star, causing it to expand and become engulfed.

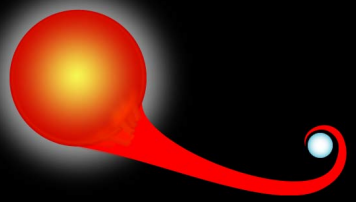


The secondary, lighter star and the core of the giant star spiral inward within a common envelope.

The common envelope is ejected, while the separation between the core and the secondary star decreases.

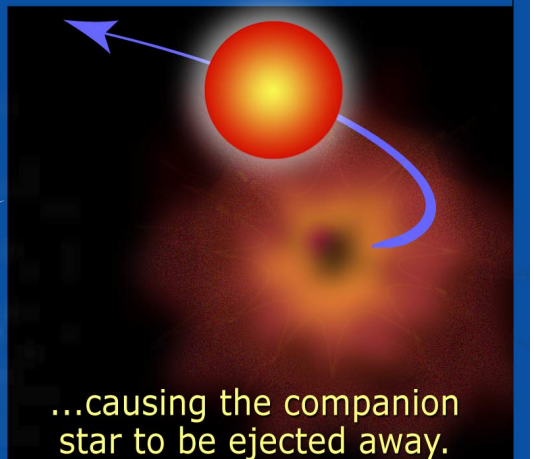


The remaining core of the giant collapses and becomes a white dwarf.



The aging companion star starts swelling, spilling gas onto the white dwarf.

The white dwarf's mass increases until it reaches a critical mass and explodes...



...causing the companion star to be ejected away.

Some other “standard candles”:

Variable stars, Cepheids and RR Lyrae stars → the consequence of stellar evolution is well-defined **period-luminosity relation.**

Sigma-D relation, also a consequence of the “post stellar” evolution (evolution of supernovae remnants).

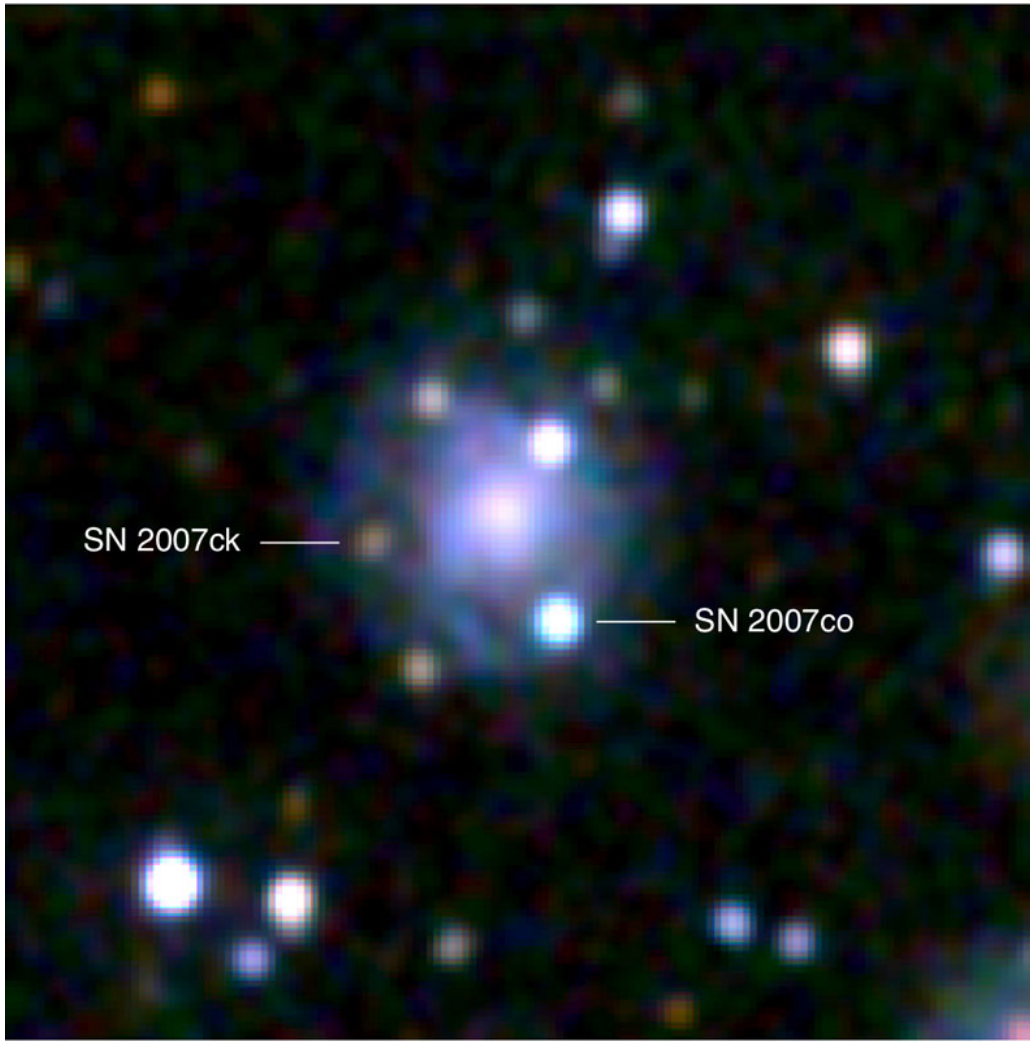
Novae in some cases also have well-defined luminosity which allows distance determination.

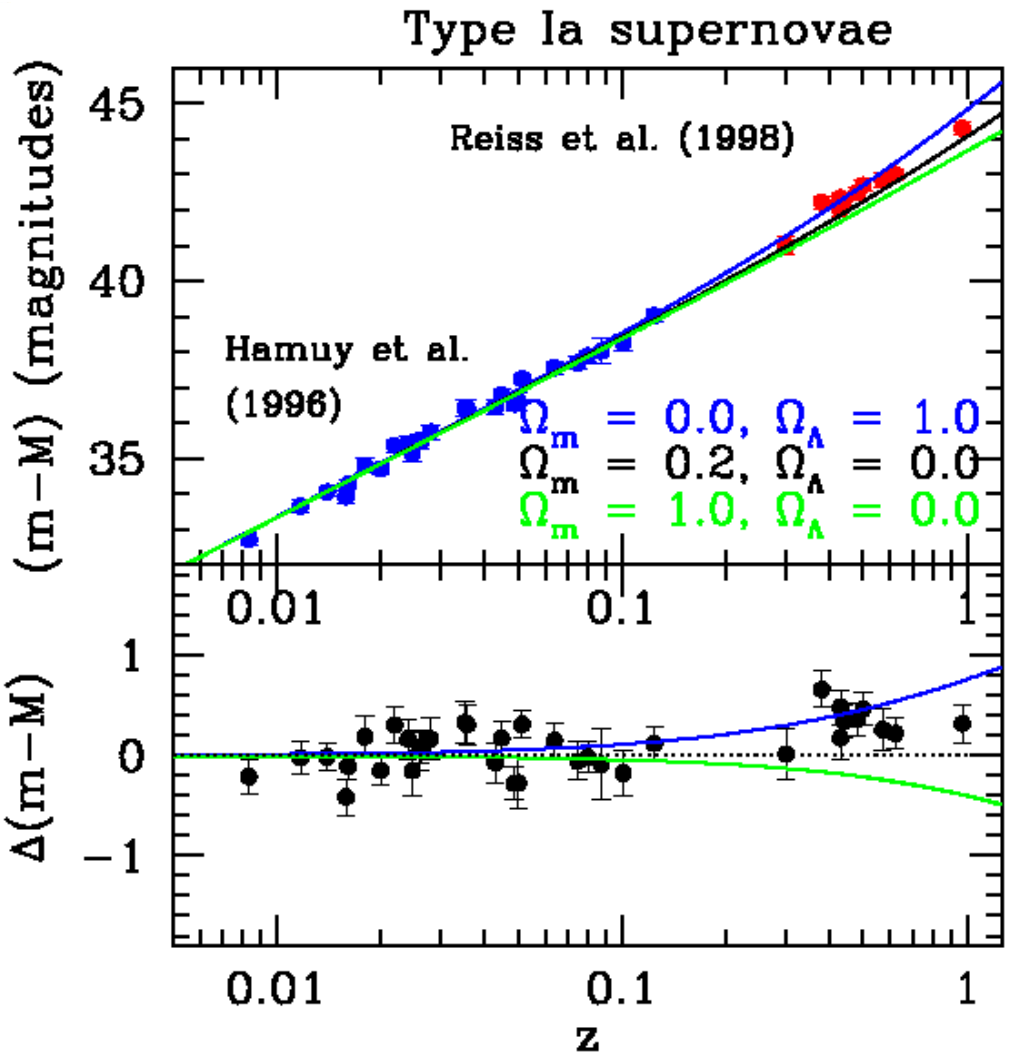
Globular cluster luminosity function → luminosity distribution of globular clusters in a galaxy allows for distance determination.

Tully-Fischer relation → using spiral galaxies as standard candles.

Faber-Jackson relation → similar but for elliptical galaxies, and with velocity dispersion instead of rotational velocity

Supernovae + redshift = ...





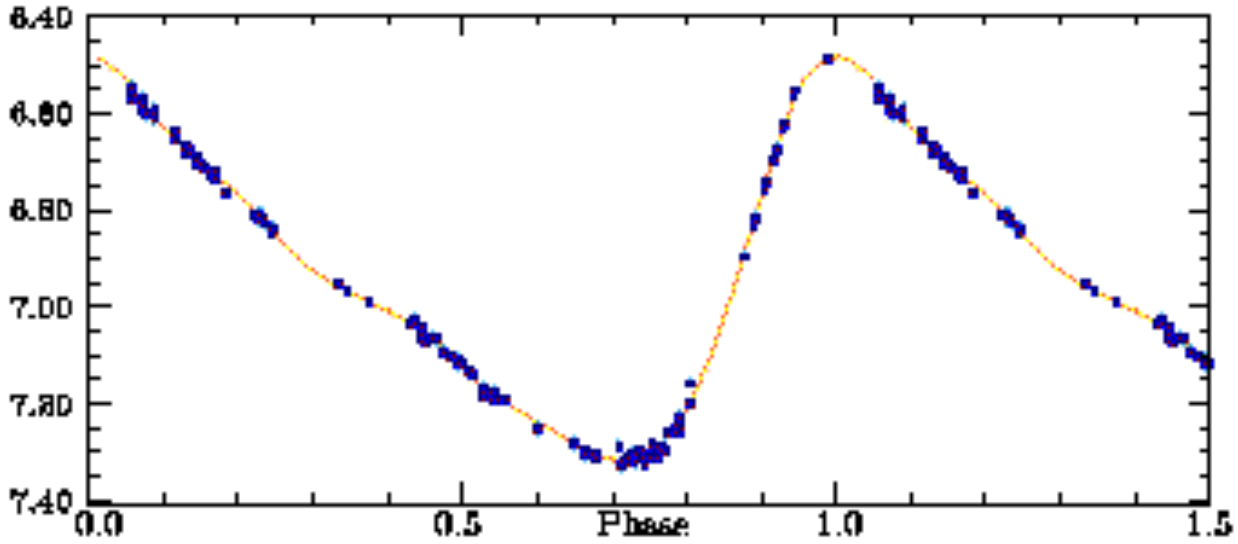
Great Debate (1920)

Are there other stellar systems except the Milky Way?

Harlow Shapley : **NO,** if there were systems as big as our ones, they would be tooo far away (+ van Maanens problematic observations)

Heber Curtis: **YES,** red shift proves this as well as the rates of occurrences of nova stars do.

Debate “settled” later by Hubble who used Henrietta Leavitt's discovery of period-luminosity relation for Cepheid stars to find distance of galaxies




Edw
Cla
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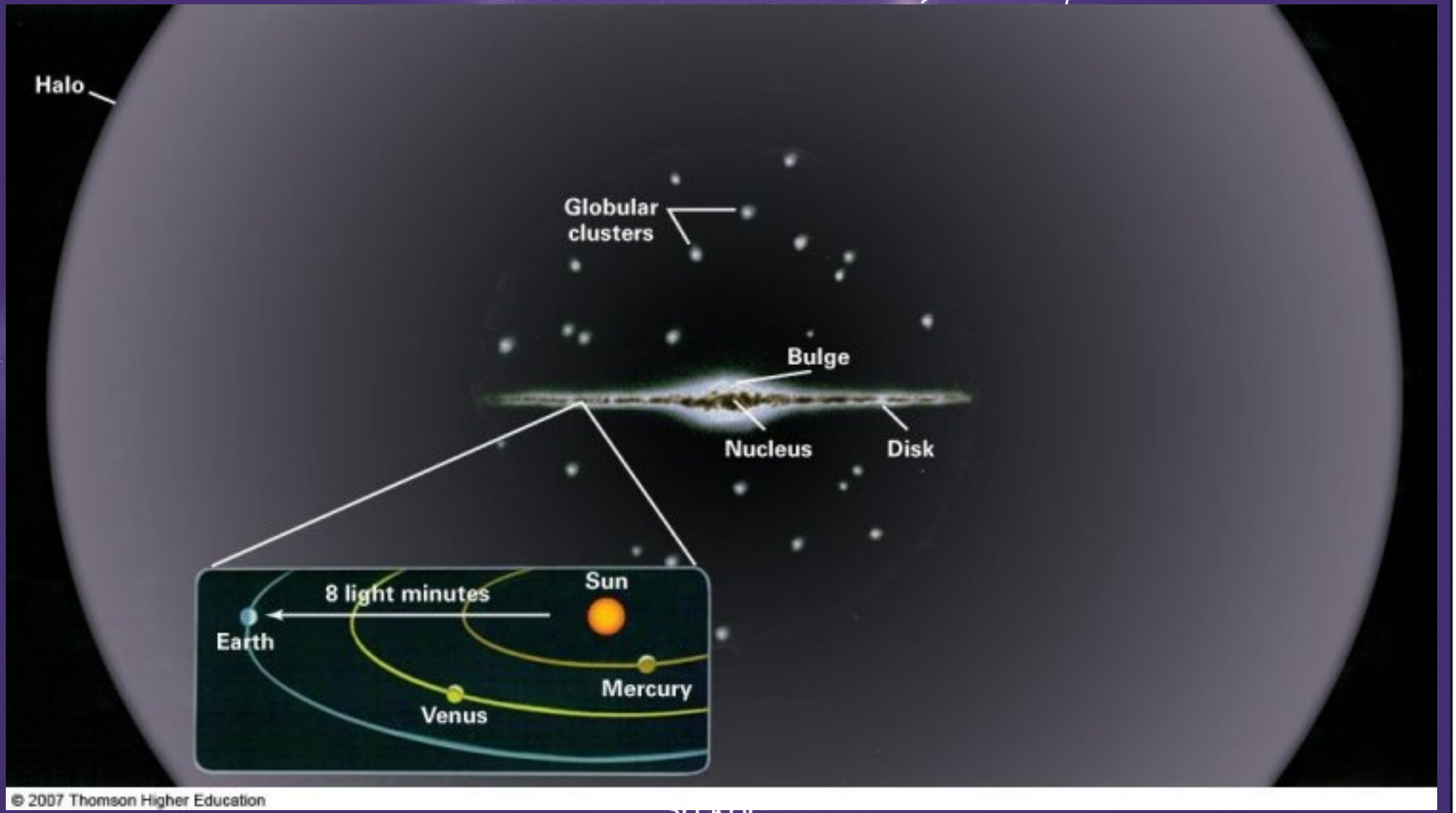
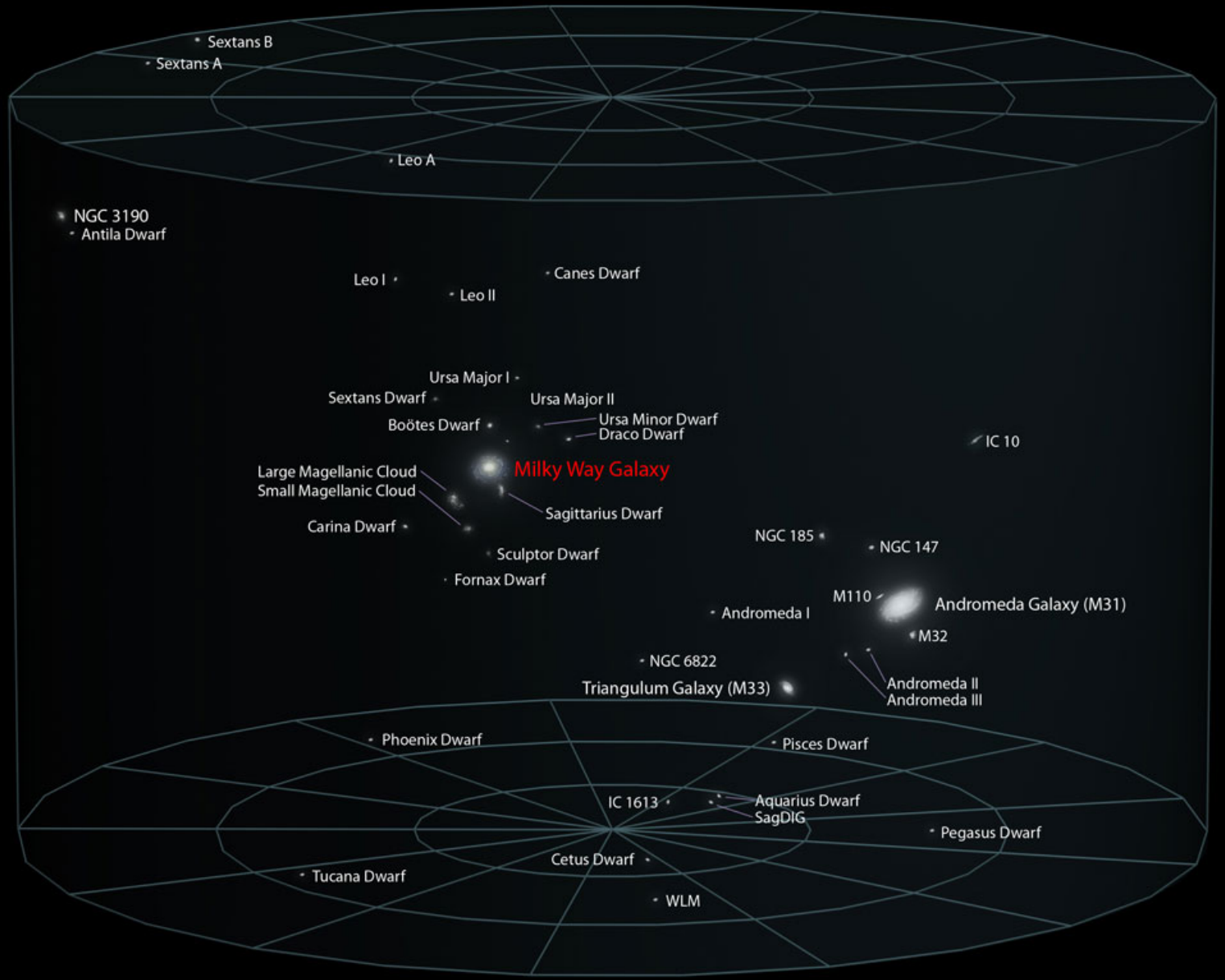
Galactic halo

Globular clusters



30 kpc

Local Galactic Group



What should we try to remember from this

Stellar and galactic astrophysics brings us some useful tools for cosmological research (e.g. supernovae)

Observational techniques in cosmology have naturally evolved for corresponding observational (and modeling) techniques in “classic” astrophysics (photometric and spectroscopic diagnostics)

Also, in order to understand what we see, we often must first understand what happens on much smaller scales: **stars, stellar systems, interstellar gas...**