BASIC PARAMETERS

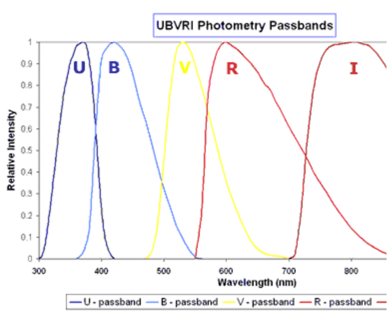
HOW TO DETERMINE/HOW WORKS…

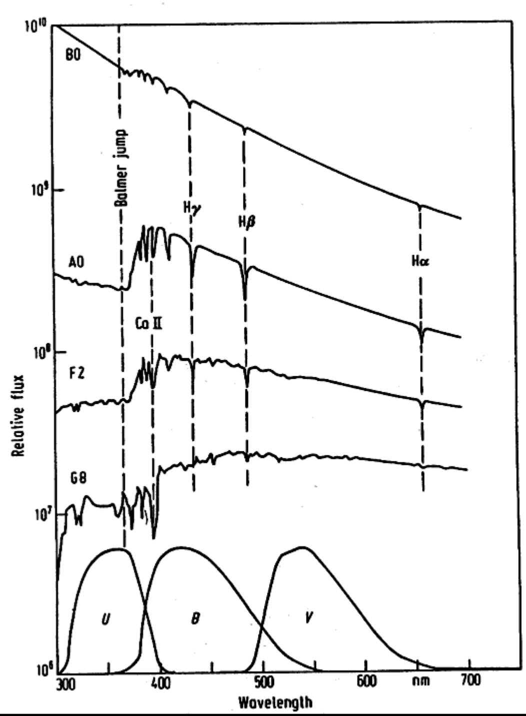
- Effective Temperature (Teff)
- Gravity (logg)
- “Rotation” (Vsini)
- Velocities – micro/macroturbulence velocity (Vmic, Vmac)
- Abundances – do not considered as fundamental parameters

DETERMINATION OF THE EFFECTIVE TEMPERATURE

- photometry
- spectrophotometry
- hydrogen lines
- line spectroscopy
- tips and tricks

DETERMI EFFECTIVI





DETERMINATION OF THE EFFECTIVE TEMPERATURE

photometry

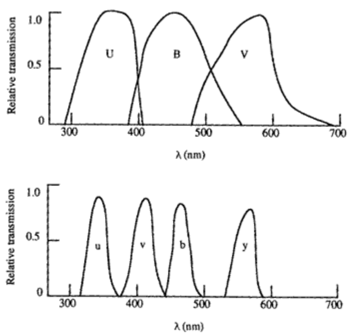


Fig. 10.7. The bandpasses for the broad band UBV system compared to those of the uvby intermediate band system.

Broad band system:

- easy to acquire
- quite inaccurate

Medium/Narrow band:

- more accurate (can also find peculiarities; e.g. Δa photometry)
- not for many objects.

System	Filter	λ_0	$\Delta\lambda_{1/2}$
UBV (Johnson-Morgan)	*U*	3650 Å	700 Å
	B	4400 Å	1000 Å
	V	5500 Å	900 Å
Six-color (Stebbins-Whitford-Kron)	*U*	3550 Å	500 Å
	V	4200 Å	800 Å
	B	4900 Å	800 Å
	G	5700 Å	800 Å
	R	7200 Å	1800 Å
	I	10,300 Å	1800 Å
Infrared (Johnson)	*R*	7000 Å	2200 Å
	I	8800 Å	2400 Å
	J	1.25μ	0.38μ
	K	2.2μ	0.48μ
	L	3.4μ	0.70μ
	M	5.0μ	1.2μ
	N	10.4μ	5.7μ
uvbyβ (Strömgren-Crawford)	*u*	3500 Å	340 Å
	v	4100 Å	200 Å
	b	4700 Å	160 Å
	y	5500 Å	240 Å
	β	4860 Å	30 Å, 150 Å
Washington	C	3910 Å	1100 Å
	M	5085 Å	1050 Å
	T_1	6330 Å	800 Å
	T_2	8050 Å	1400 Å
Thuan-Gunn	u	3530 Å	400 Å
	v	3980 Å	400 Å
	g	4930 Å	700 Å
	r	6550 Å	900 Å

DETERMINATION OF THE EFFECTIVE TEMPERATURE

photometry

Some important remarks:

• in photometry the reddening is of very important, since the parameters are derived using the total flux; in spectroscopy it is not necessary since we normalise the flux

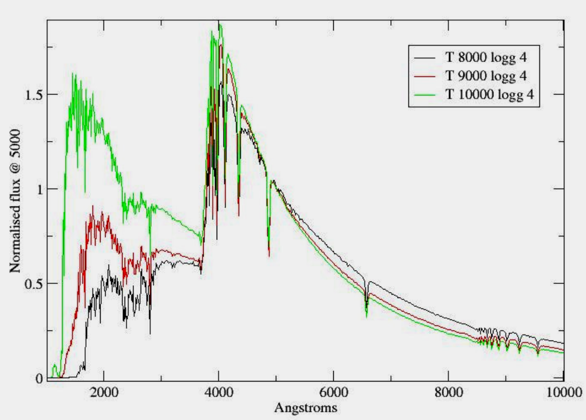
• uncertainties: broad band ~ 10%

narrow band ~ < 5%

• the photometric parameters do not necessary coincide with the spectroscopic parameters; in spectroscopy we derive the parameters that are more suitable for abundance analysis.

DETERMINATION OF THE EFFECTIVE TEMPERATURE

spectrophotometry

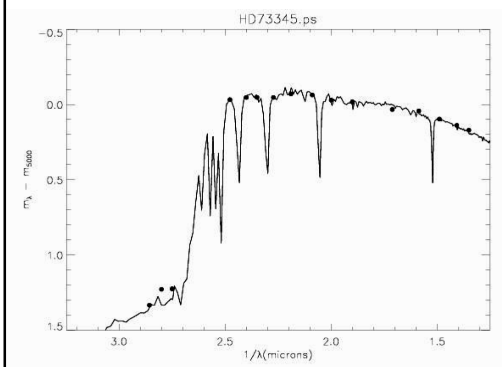


Redistribution of the energy from infrared to ultraviolet with increasing of the temperature

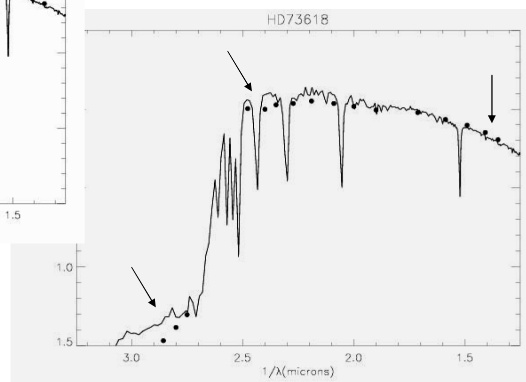
The “pendence” of the energy distribution in the visible is increasing with the temperature

DETERMINATION OF THE EFFECTIVE TEMPERATURE

spectrophotometry



Photometry in very narrow bands calibrated on a big (hopefully) sample of reference star

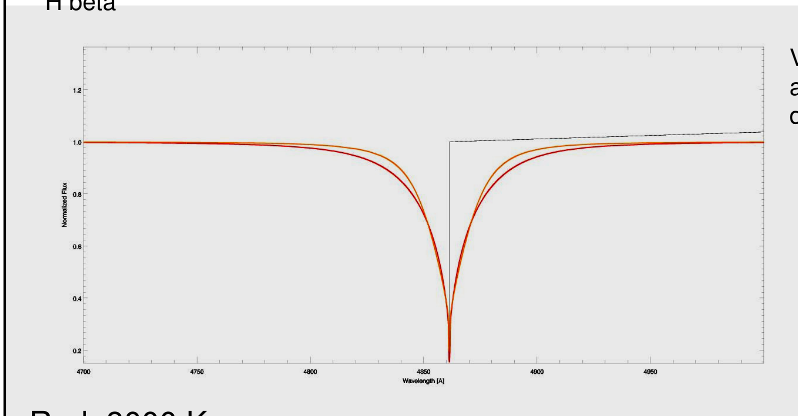


Teff is too high!

DETERMINATION OF THE EFFECTIVE TEMPERATURE

hydrogen lines

H beta



Very useful also for error determination

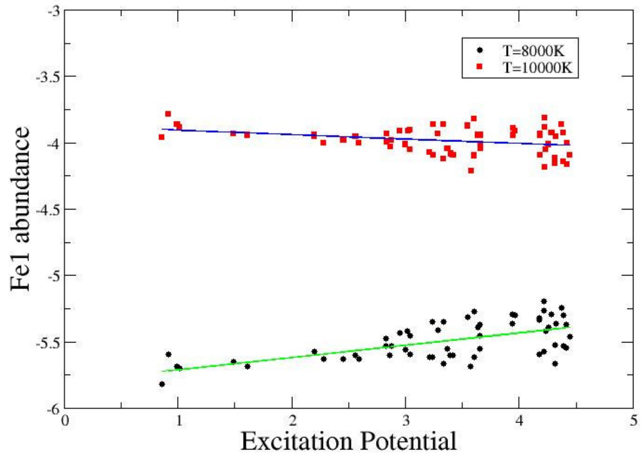
Red: 8000 K

Orange: 10000 K

NORMALISATION!

DETERMINATION OF THE EFFECTIVE TEMPERATURE

line spectroscopy

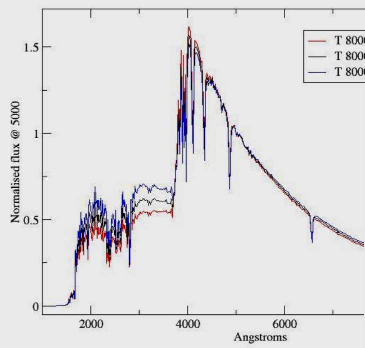


DETERMINATION OF THE GRAVITY (log G)

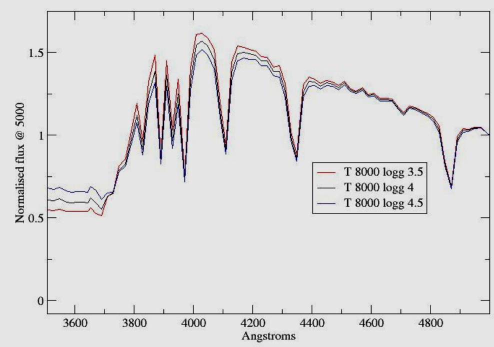
- photometry (see the part on the effective temperature)
- spectrophotometry
- hydrogen lines + but not only
- line spectroscopy
- tips and tricks

DETERMINATION OF THE GRAVITY

spectrophotometry



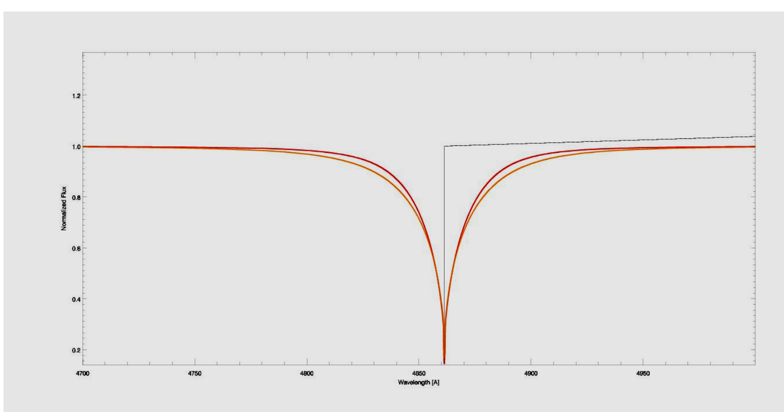
The Balmer jump is increasing or decreasing with logg variations – the direction depends upon the temperature



DETERMINATION OF THE GRAVITY

H beta

hydrogen lines



Red: logg 3.5

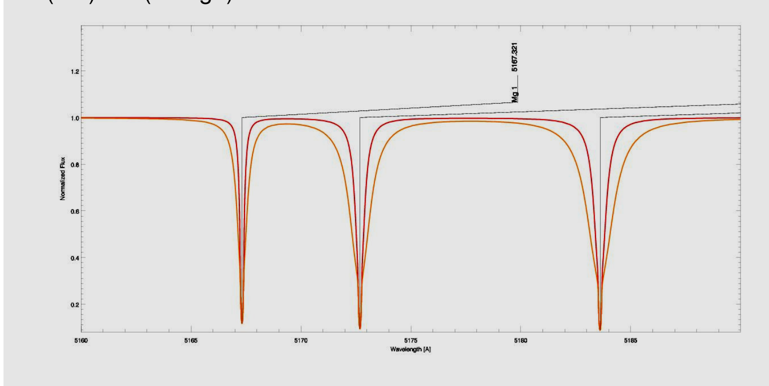
Orange: logg 4.5

NORMALISATION!!

DETERMINATION OF THE GRAVITY

Mg lines for cold stars

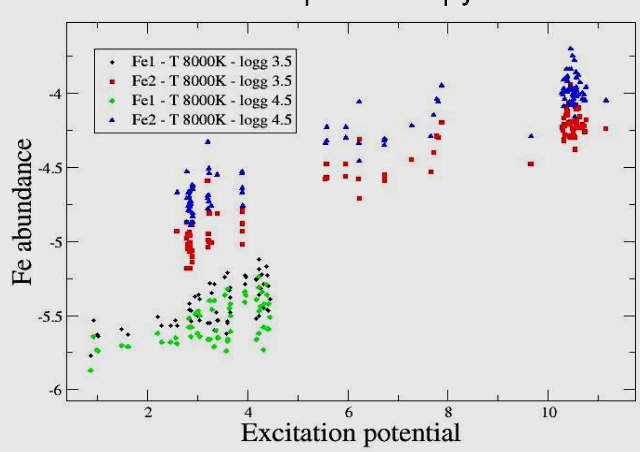
Logg = 3.5 (red) 4.5 (orange)



Valid only for cool stars – Teff < 7000 K

DETERMINATION OF THE GRAVITY

line spectroscopy

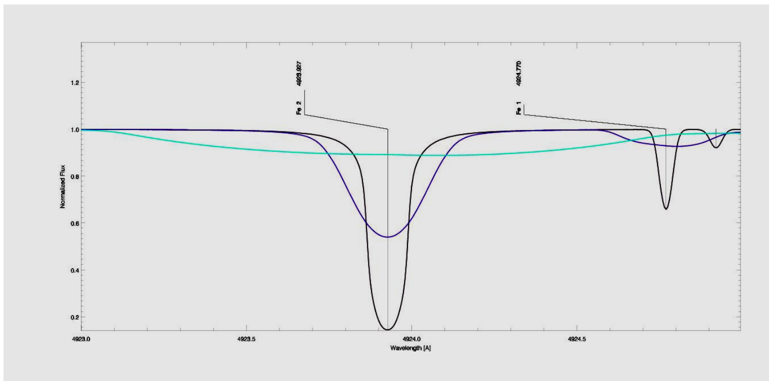


Abn(Fe2-Fe1) → logg   from the Saha equation

STELLAR ROTATION

Vsini

Vsini = 0 – 10 – 100 Km/s

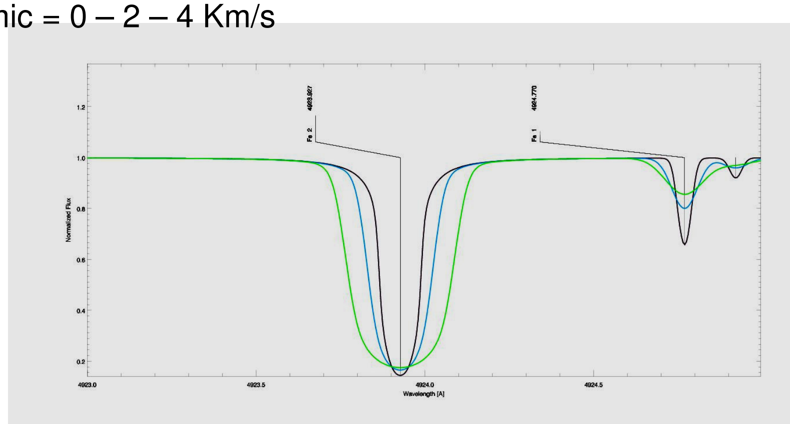


!! Equivalenth widths are not changing with Vsini → it's possible to use equivalenth widths without knowing the Vsini a priori!!

VELOCITY FIELDS

Vmic

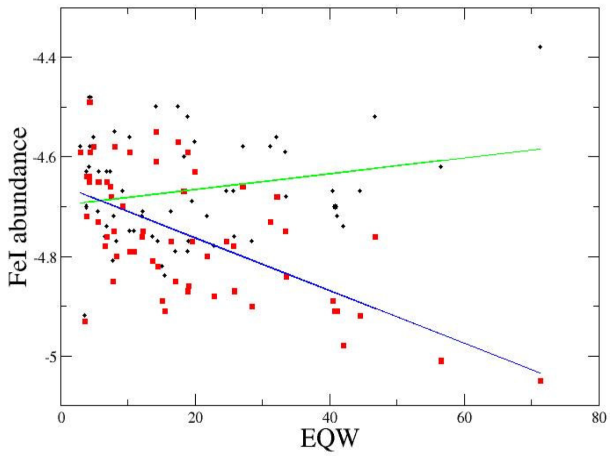
Vmic = 0 – 2 – 4 Km/s



!!Equivalenth widths are heavily changing with Vmic!! → it's possible to use equivalenth widths to derive the correct Vmic

VELOCITY FIELDS

Vmic – line spectroscopy



Black & green:

Vmic 1 Km/s

Red & blue:

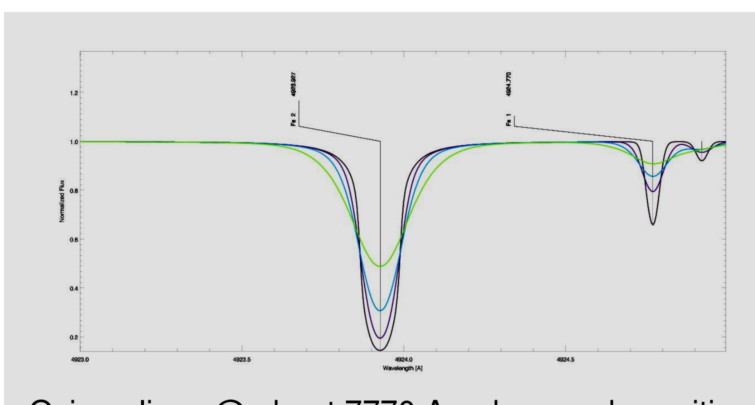
Vmic 4 Km/s

!!Vmic could be depth dependent!!

VELOCITY FIELDS

Vmac

Vmac = 0 – 2 – 5 – 10 Km/s



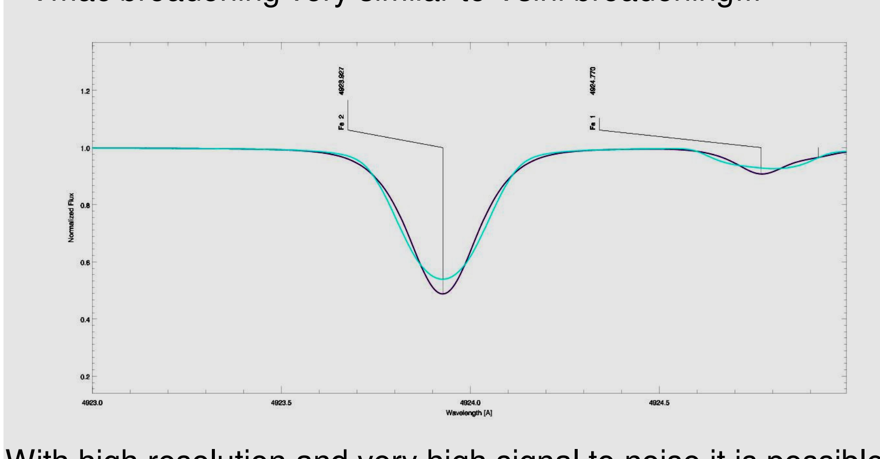
Often Oxigen lines @ about 7770 A – deep and sensitive, but…

Vmac broadening very similar to Vsini broadening!!!

VELOCITY FIELDS

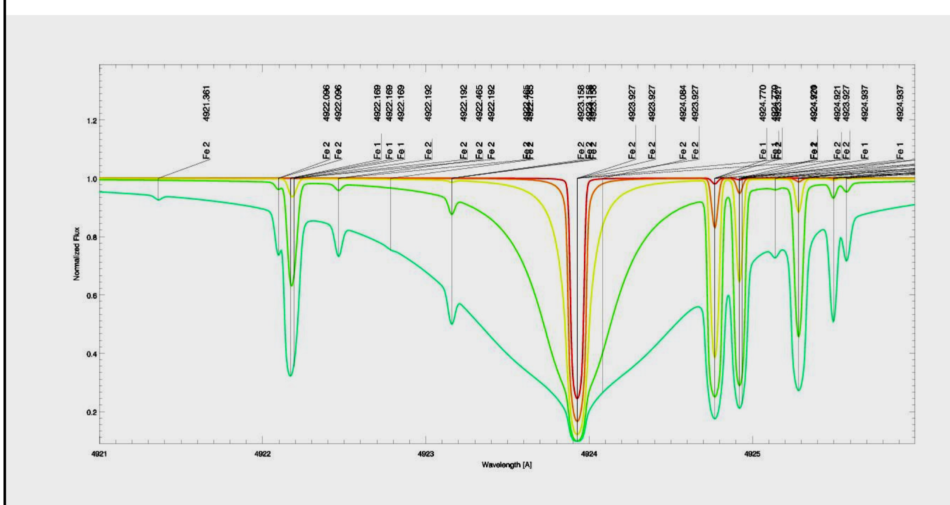
Vmac

Vmac broadening very similar to Vsini broadening!!!



With high resolution and very high signal to noise it is possible to distinguish between them

ABUNDANCES

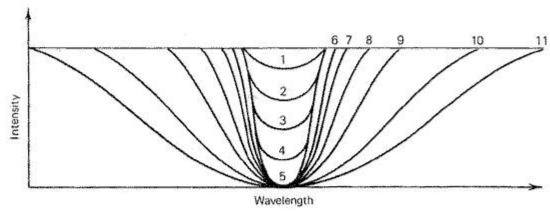


Fe abundance: -6.00, -5.00, -4.00, -3.00, -2.00

ABUNDANCES

Let *W* be the equivalent width of a line and *N* be the number of absorbing atoms for that line.

- When a line grows in strength, it first gets deeper at a rate that is proportional to the number of atoms that can produce the line (see lines 1-4 in the figure below).



From Abell's *Exploration of the Universe, Fourth Edition.*

Thus, when there are few absorbers, the strength of the line is linearly related to the number of atoms (optically thin regime):

$$W \propto N$$

ABUNDANCES

- For a great enough abundance of atoms, the line *saturates* (completely removes all of the light at the center of the line -- see line 5 in the figure above).
- With the addition of more atoms the strength of the line increases only moderately, and only by growing the wings (see lines 6-11 in the figure above).

Growing the wings means *broadening the lines*, but this can only happen if the corresponding energies of the slightly shifted wavelengths can cause the transition. There are several ways that can happen:

- *natural broadening* -- Energy levels are not perfectly sharp and there is a small range of energies allowed for a transition to occur (a result of the Heisenberg Uncertainty Principle, $h = \delta E \, \delta t$, the amount of time δt an atom spends in an energy level and the mean range of energy δE in an energy level are related).
- *Doppler broadening* -- Because atoms are moving rapidly, they ``see'' wavelengths of photons they encounter at different wavelengths than we do on Earth.
- *collisional broadening* -- Perturbing the energy levels slightly so that the transitions can occur through the absorption of photons of slightly different energy from normal. The perturbing occurs when one atom/ion passes near or collides with another one (recall our discussion of *bands* in solids). This is perhaps the most important source of broadening in strong lines.
- *Zeeman effect* -- Another source of perturbation that allows photons of different energy to be absorbed.

ABUNDANCES

- Thus, as the line is becoming optically thick and saturates, the equivalent width no longer grows as fast as linear with *N*, and can only grow by expanding the wings through the above processes. At first, Doppler broadening dominates the increase in line strength and to a fair approximation:

$$W \propto (\ln N)^{1/2}$$

- However, eventually, as the density of atoms increases even more, collisional broadening takes over the growth of the wings and then:

$$W \propto (N)^{1/2}$$

- These three regimes give rise to the complcated *curve of growth* of a spectral line:

ABUNDANCES

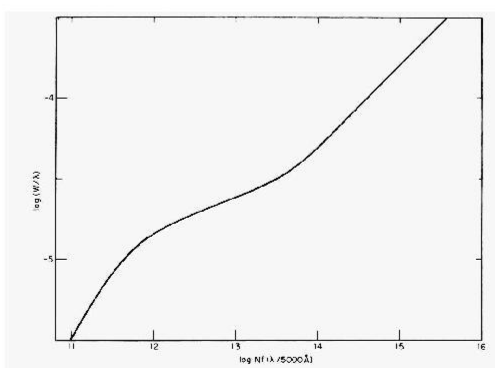


Figure 9.22 A general curve of growth for the Sun. (Figure from Aller, *Atoms, Stars, and Nebulae*, Revised Edition, Harvard University Press, Cambridge, MA, 1971.)

The optically thin, optically thick (saturated) and very optically thick (very saturated) regimes are visible here in this curve of growth. From Carroll and Ostlie, "An Introduction to Modern Astrophysics" (Addison-Wesley 1996).

ABUNDANCES

There are different notations for the abundances:

- H12 – in this notation the H abundance is 12 dex
- N/H
- N/Ntot

Example:

Fe abundance for

the Sun

H12 → 7.45

N/H → -4.59

N/Ntot → -4.55

N/Ntot = H12-12

Log(N/Ntot)=log(N/H)-12-d

d=log (1 + Sum_i[log(Ni/H)-12])

d is mostly influenced by He (most abundant after H) and for the usual He abundance d=0.036

ABUNDANCES

Normalisation to the Sun abundances

The two most common "versions" of the solar abundances:

Grevesse, N, Sauval, A.J. 1998 → abundances in LTE

Asplund, M., Grevesse, N., Sauval, A.J. 2005 → abundances in NLTE

The abundances from Asplund differ mainly in C,N and O where the NLTE effects are more important.

Always know which are the Sun abundances used for the normalisetion.

References

In addition to what is mentioned for the other lessons:

Balona, L. 1994, MNRAS, 268, 119

Karatas, Y. & Schuster, W.J. 2006, MNRAS, 371, 1793