Measurements

Jayant Murthy
Indian Institute of Astrophysics
jmurthy@yahoo.com
murthy@iiap.res.in
http://www.iiap.res.in

Some Resources

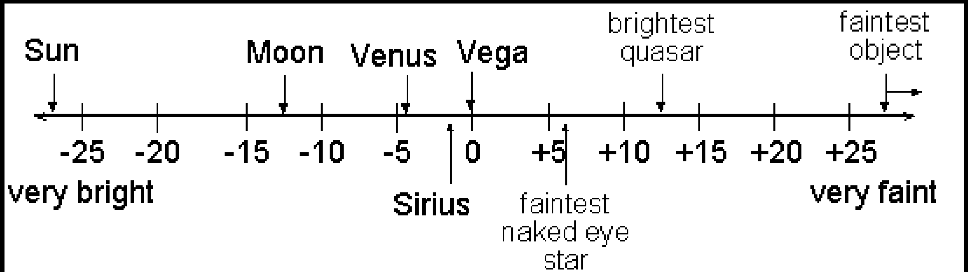
- http://ipag.osug.fr/~philybla/teaching/phy553b.html
- http://www.astro.princeton.edu/~draine/book/index.html
- http://www.physics.sfsu.edu/~lea/
- http://spiff.rit.edu/classes/
- http://home.strw.leidenuniv.nl/~emr/stralingsprocessen/

Cox ARAA 2005, 43, 337

- The interstellar medium (ISM) is a fascinating place to spend one's life. There is ample beauty in the images, abundant challenge in the observations, good company in the fellow travelers, and a high sense of importance attached to the work as a foundation for understanding how galaxies work, along with the ways they may have influenced one another and the intergalactic medium. There is also sufficient uncertainty about what is happening that it presents a huge canvas for the joyous exercise of imagination.

Magnitude Scale

- Greeks classified stars by brightness to eye.
  - Eye responds in a logarithmic scale.
- Brightest stars classified as 0^{th} magnitude.
  - Each magnitude corresponds to a factor of 2.5 in brightness.
- Faintest observable stars about 6^{th} magnitude.



Apparent brightnesses of some objects in the magnitude system.

Magnitude Scale

- Modern magnitude scale:
    - Defined by Vega – zeroth magnitude A0 star.
- $m = -2.5\log(f_{obs}/f_0)$
- Breaks down for UV.
    - A0 stars have no flux below 2000 Å.

Standard photometric systems

Standard U, B, V, R, I and long wavelength systems

Filter band	λ_0[a] (μm)	$\Delta\lambda_0$ (FWHM) (μm)	Absolute spectral irradiance for mag = 0.0: $f_\lambda(0)$ (erg cm^{-2} s^{-1} Å^{-1})	$f_\nu(0)$ (W m^{-2} Hz^{-1})
U	0.365	0.068	4.27×10^{-9}	1.90×10^{-23}
B	0.44	0.098	6.61×10^{-9}	$4.27(4.64)$[b] $\times 10^{-23}$
V	0.55	0.089	3.64×10^{-9}	3.67×10^{-23}
R	0.70	0.22	1.74×10^{-9}	2.84×10^{-23}
I	0.90	0.24	8.32×10^{-10}	2.25×10^{-23}
J	1.25	0.3	3.18×10^{-10}	1.65×10^{-23}
H	1.65	0.4	1.18×10^{-10}	1.07×10^{-23}
K	2.2	0.6	4.17×10^{-11}	6.73×10^{-24}
L	3.6	1.2	6.23×10^{-12}	2.69×10^{-24}
M	4.8	0.8	2.07×10^{-12}	1.58×10^{-24}
N	10.2		1.23×10^{-13}	4.26×10^{-25}

[a] $\lambda_0 = \int \lambda S(\lambda)\,d\lambda / \int S(\lambda)\,d\lambda$, where $S(\lambda)$ is the photometer response function.
[b] From S. Kleinmann.
U, *B*, *R*, *I*, *N* values from Allen, C. W., *Astrophysical Quantities*. The Athlone Press (1973). *V*, *J*, *H*, *K*, *L*, *M* values from Wamsteker, W., *Astron. Astrophys.*, **97**, 329 (1981).

The spectral irradiance for a star of a given magnitude is given either by:

$$\log f_\lambda(m_x) = -0.4 m_x + \log f_\lambda(0),$$

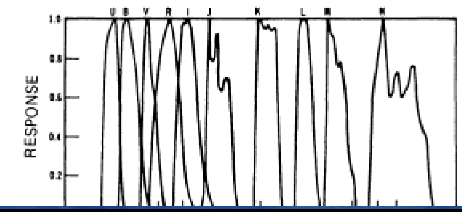
where $f_\lambda(m_x)$ is the spectral irradiance in erg cm^{-2} s^{-1} Å^{-1} of a star of magnitude (m_x) in the x filter band at the mean wavelength $\lambda_0(x)$, or

$$\log f_\nu(m_x) = -0.4 m_x + \log f_\nu(0),$$

where $f_\nu(m_x)$ is the spectral irradiance in W m^{-2} Hz^{-1}.

The relationships above are for the irradiance at the top of the Earth's atmosphere and are valid for *B* through *M* stars.

Photometer response curves for UBVRI and long wavelength systems. (Adapted from Webbink, R. F. & Jeffers, W. Q., *Space Sci. Rev.*, **10**, 191 1969.)



Zombeck: http://ads.harvard.edu/cgi-bin/bbrowse?book=hsaa&page=100

Magnitude Scale

- Better to use SI units:
  - ergs cm^{-2} s^{-1} $\mathring{A}^{-1}$
- Apparent magnitude observed from Earth.
- Absolute magnitude intrinsic to the star.

Standard photometric systems

Standard U, B, V, R, I and long wavelength systems

Filter band	λ_0[a] (μm)	$\Delta\lambda_0$ (FWHM) (μm)	Absolute spectral irradiance for mag = 0.0: $f_\lambda(0)$ (erg cm^{-2} s^{-1} $\mathring{A}^{-1}$)	Absolute spectral irradiance for mag = 0.0: $f_\nu(0)$ (W m^{-2} Hz^{-1})
U	0.365	0.068	4.27×10^{-9}	1.90×10^{-23}
B	0.44	0.098	6.61×10^{-9}	4.27(4.64)[b] $\times 10^{-23}$
V	0.55	0.089	3.64×10^{-9}	3.67×10^{-23}
R	0.70	0.22	1.74×10^{-9}	2.84×10^{-23}
I	0.90	0.24	8.32×10^{-10}	2.25×10^{-23}
J	1.25	0.3	3.18×10^{-10}	1.65×10^{-23}
H	1.65	0.4	1.18×10^{-10}	1.07×10^{-23}
K	2.2	0.6	4.17×10^{-11}	6.73×10^{-24}
L	3.6	1.2	6.23×10^{-12}	2.69×10^{-24}
M	4.8	0.8	2.07×10^{-12}	1.58×10^{-24}
N	10.2		1.23×10^{-13}	4.26×10^{-25}

[a] $\lambda_0 = \int \lambda S(\lambda)\,d\lambda / \int S(\lambda)\,d\lambda$, where $S(\lambda)$ is the photometer response function.
[b] From S. Kleinmann.
U, B, R, I, N values from Allen, C. W., *Astrophysical Quantities*. The Athlone Press (1973). *V, J, H, K, L, M* values from Wamsteker, W., *Astron. Astrophys.*, **97**, 329 (1981).

The spectral irradiance for a star of a given magnitude is given either by:

$$\log f_\lambda(m_x) = -0.4m_x + \log f_\lambda(0),$$

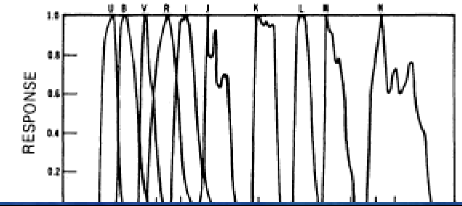
where $f_\lambda(m_x)$ is the spectral irradiance in erg cm^{-2} s^{-1} $\mathring{A}^{-1}$ of a star of magnitude (m_x) in the x filter band at the mean wavelength $\lambda_0(x)$, or

$$\log f_\nu(m_x) = -0.4m_x + \log f_\nu(0),$$

where $f_\nu(m_x)$ is the spectral irradiance in W m^{-2} Hz^{-1}.

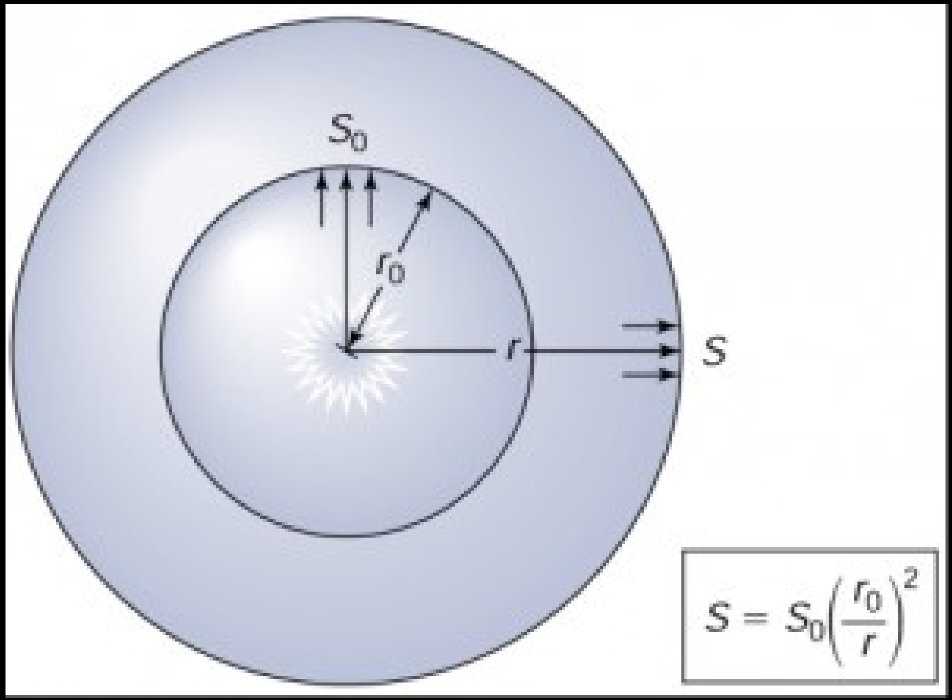
The relationships above are for the irradiance at the top of the Earth's atmosphere and are valid for *B* through *M* stars.

Photometer response curves for UBVRI and long wavelength systems. (Adapted from Webbink, R. F. & Jeffers, W. Q., *Space Sci. Rev.*, **10**, 191 1969.)



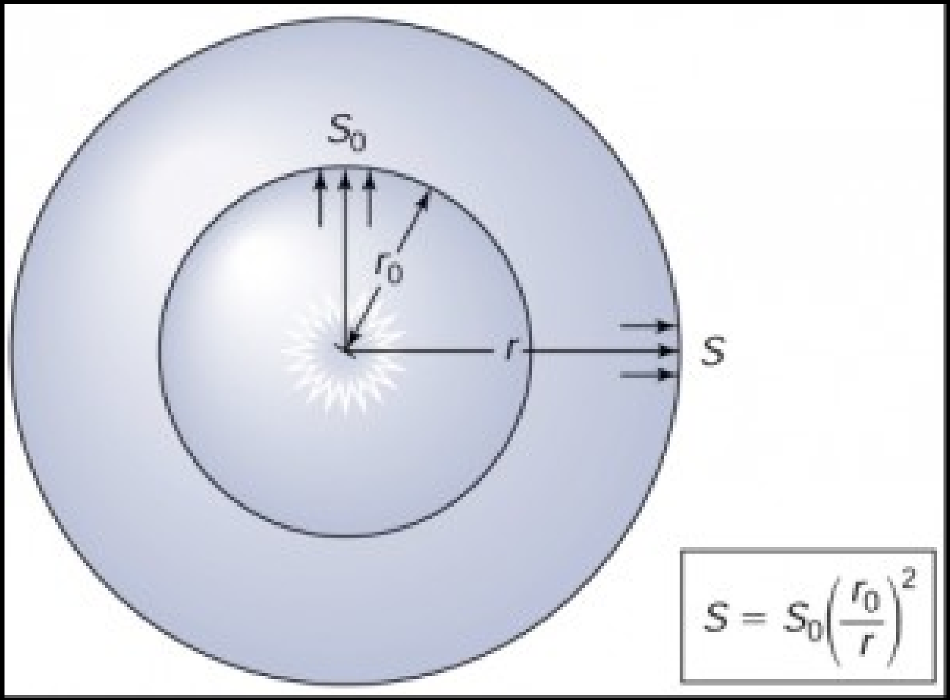
Apparent/Absolute Magnitude

- Absolute magnitude is brightness of star at 10 pc.
- Apparent magnitude is observed brightness.
- $F = L/4\pi d^2$
- $m_1 - m_2 = -2.5\log(F_1/F_2)$
- $m_1 - m_2 = -2.5\log(d_2/d_1)^2 = -5\log(d_2/d_1)$



Apparent/Absolute Magnitude

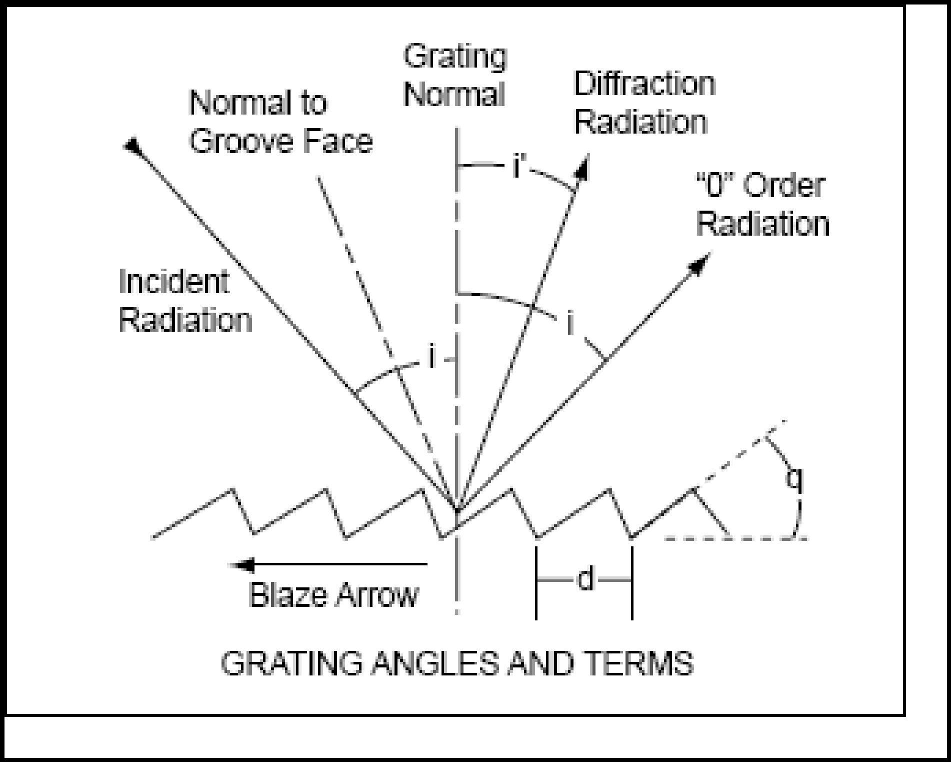
- Absolute magnitude is brightness of star at 10 pc.
- Apparent magnitude is observed brightness.
- $F = L/4\pi d^2$
- $m – M = 5 \Rightarrow F/f = 100.$
  - $d = 10D$
- Distance Modulus:
  - $m – M = 5 \log d - 5$

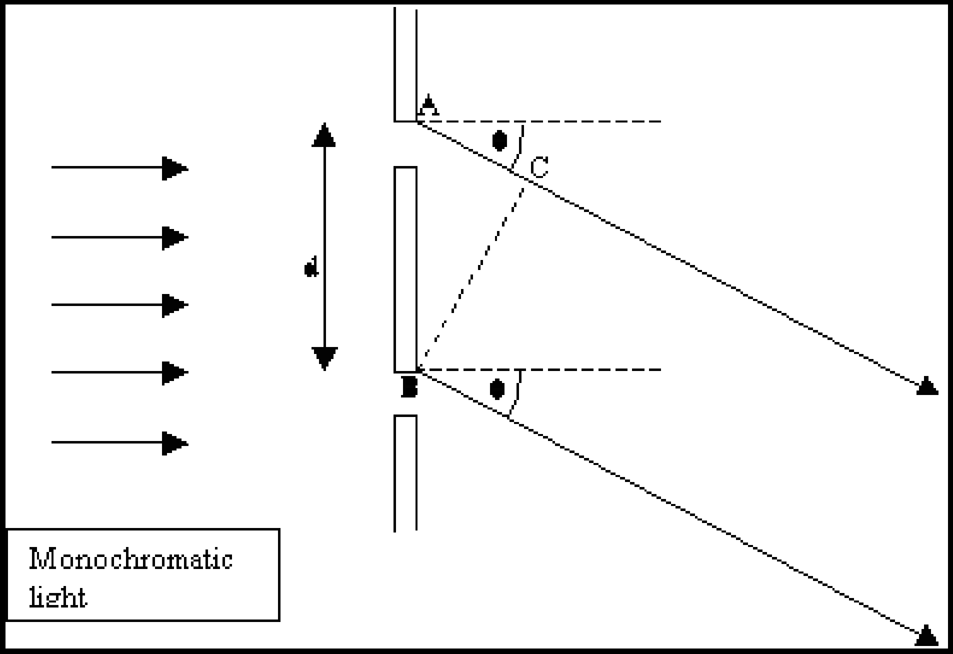


Reddening

- Measure B and V magnitudes.
  - B: 4400 ± 500 Å.
  - V: 5500 ± 500 Å.
- Star has intrinsic (B-V)
  - $(B - V)_I = 0$ for A0 stars.
- $E(B - V) = (B - V)_O - (B - V)_I$.
- $A_V = 3.1\ E(B - V) = 1.086\tau$
- Distance Modulus: $(m_V - A_V) - M_V = 5 \log d - 5$

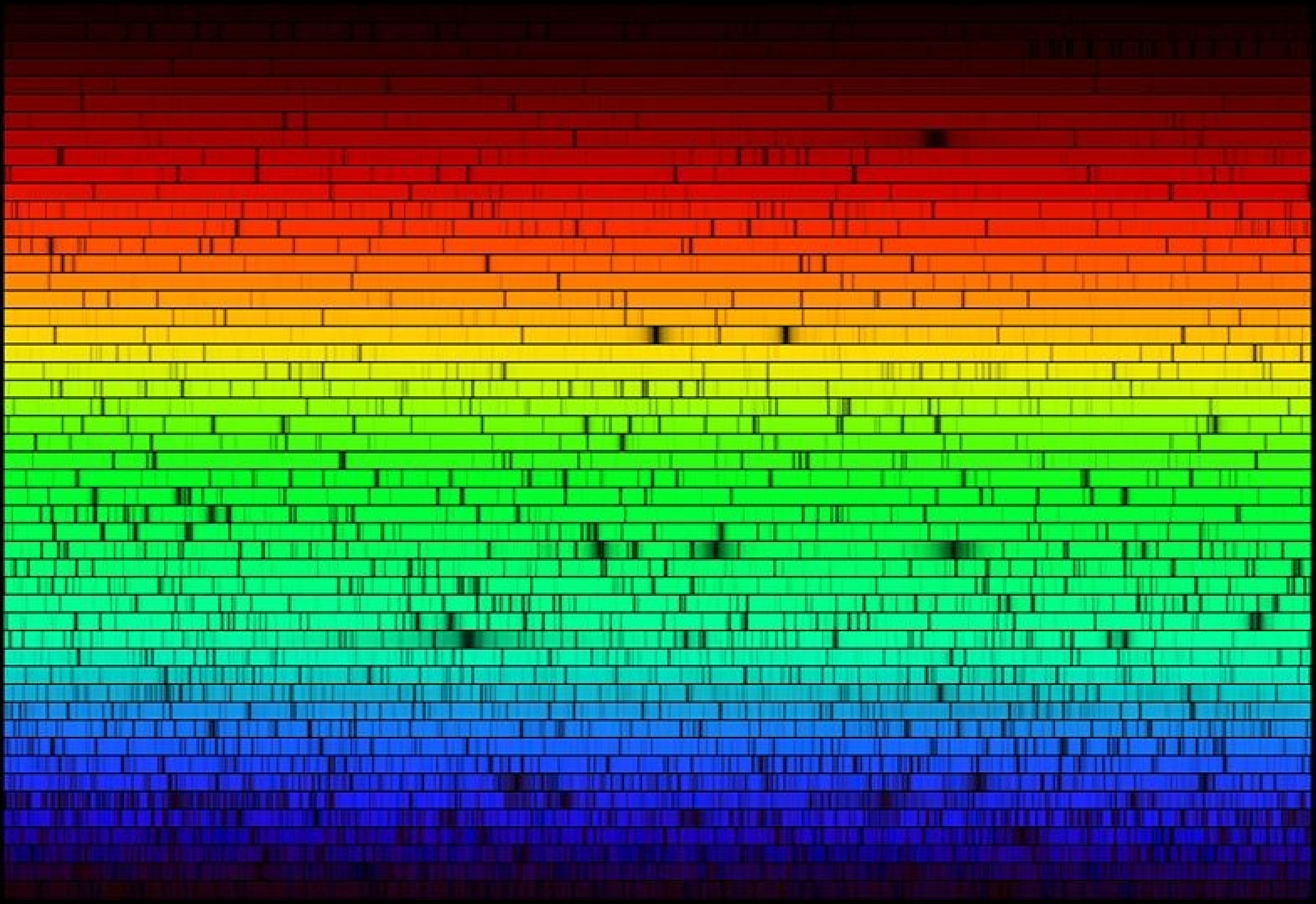
Spectrographs



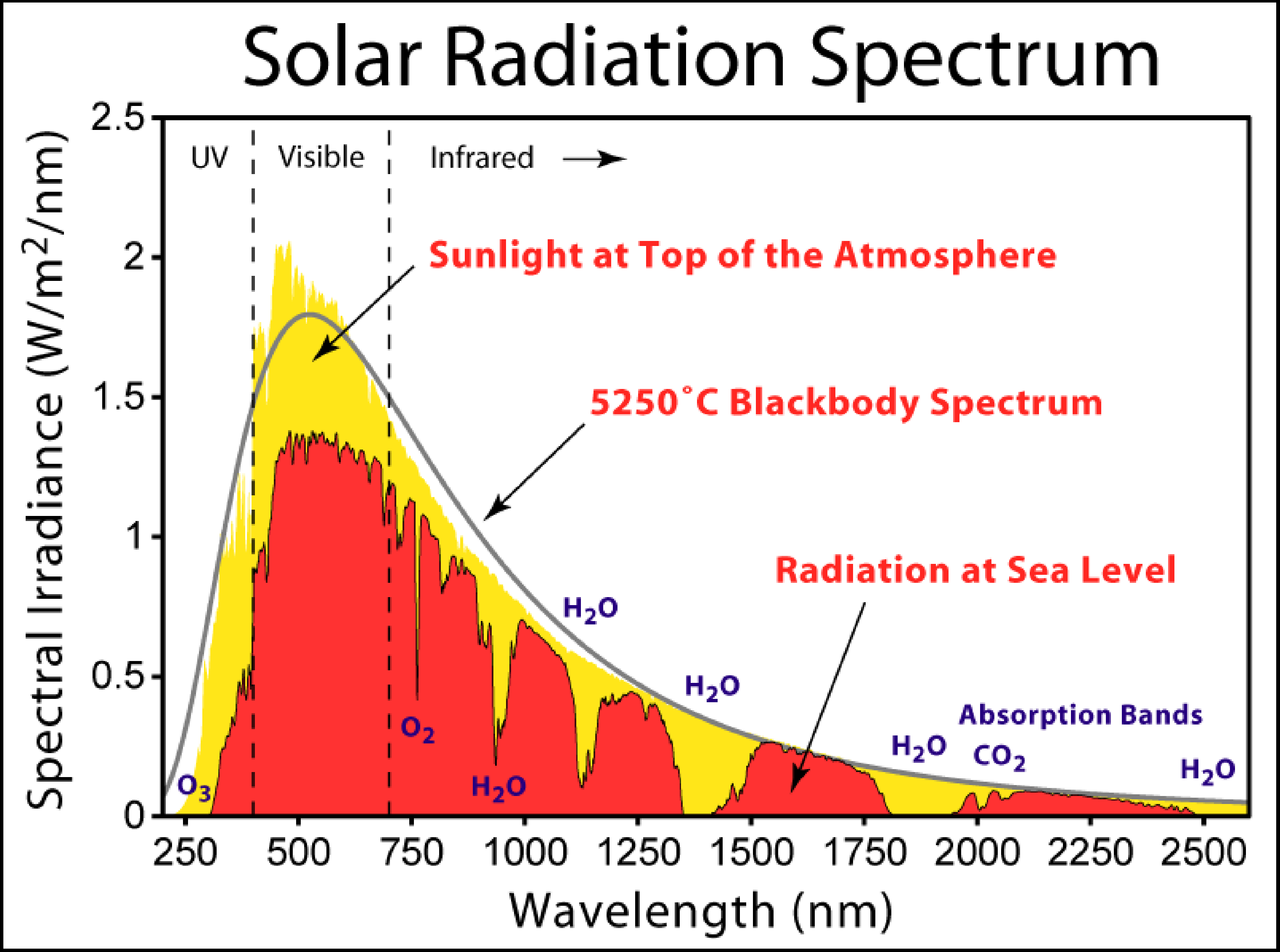


$n\lambda = d\,(\sin(i) + \sin(l))$

Solar Spectrum

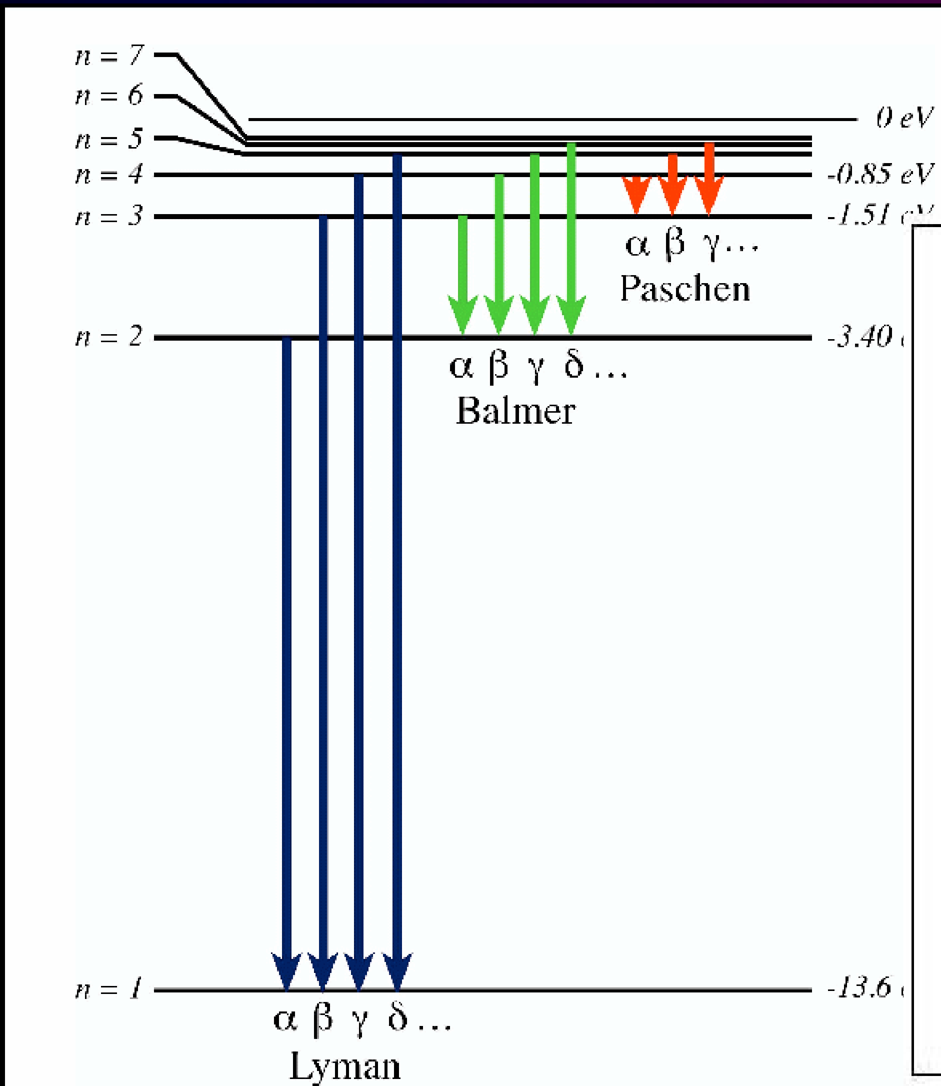


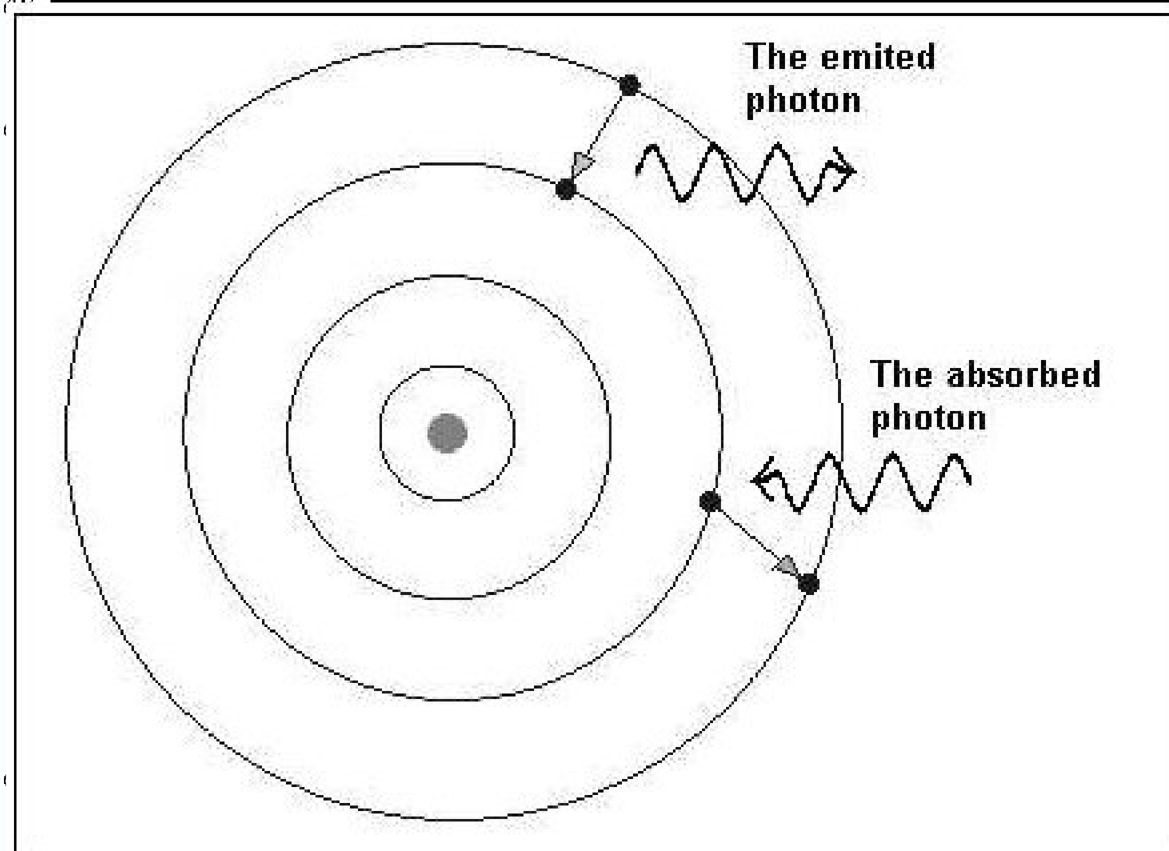
Solar Spectrum



Spectroscopy

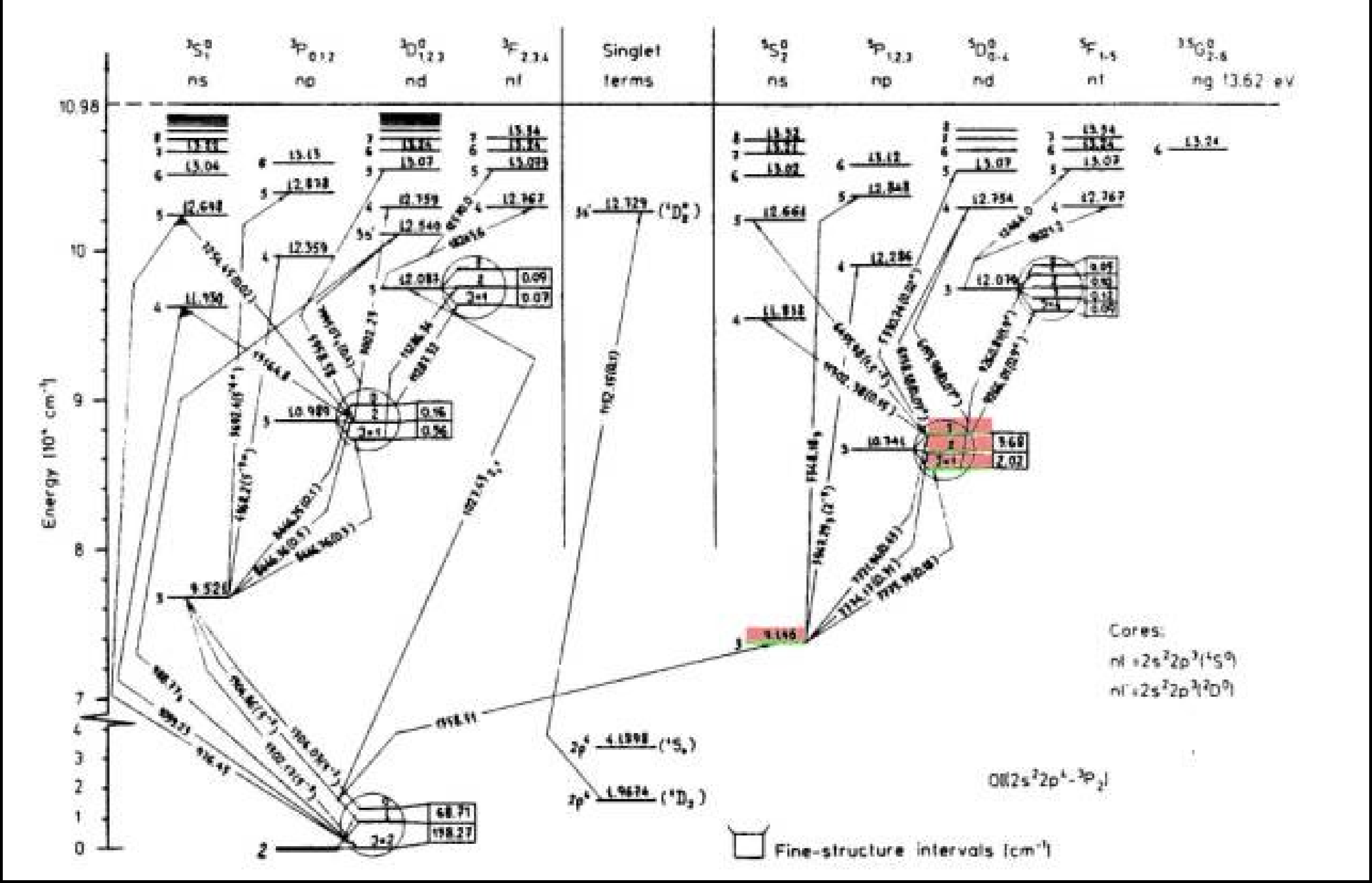
Bohr model of Hydrogen atom.





The electron emits or absorbs the energy changing the orbits.

Grotrian Diagram (Oxygen)



Atomic Basics

- H I is atomic hydrogen.
- H II is ionized hydrogen – not to be confused with H_2.
- O VI is O^{+5} – five times ionized oxygen.
- Atomic energy levels: n, l where $0 \leq l < n$.
  - n: energy; l: angular momentum
  - s, p, d, f for l = 0, 1, 2, 3

Atomic Basics

- Atomic energy levels: n, l where $0 \leq l < n$.
  - n: energy; l: angular momentum
  - s, p, d, f for l = 0, 1, 2, 3
- Degenerate quantum numbers
  - m_z: projection of angular momentum onto z axis.
  - spin of electron.
- Pauli Exclusion Principle.
  - Degeneracy: $2(2l + 1)$.
- C: $1s^2 2s^2 2p^2$.

Periodic Table

Abridged Periodic Table of the Elements

4/17/96 ghw

1A	2A		1B	2B	3A	4A	5A	6A	7A	noble
1 H $1s^1$										2 He $1s^2$
3 Li $1s^2 2s^1$	4 Be $1s^2 2s^2$			$1s^2$	5 B $2s^2 2p^1$	6 C $2s^2 2p^2$	7 N $2s^2 2p^3$	8 O $2s^2 2p^4$	9 F $2s^2 2p^5$	10 Ne $2s^2 2p^6$
11 Na [Ne] $3s^1$	12 Mg [Ne] $3s^2$			[Ne]	13 Al $3s^2 3p^1$	14 Si $3s^2 3p^2$	15 P $3s^2 3p^3$	16 S $3s^2 3p^4$	17 Cl $3s^2 3p^5$	18 Ar $3s^2 3p^6$
19 K [Ar] $4s^1$		[Ar] $3d^{10}$	29 Cu $4s^1$	30 Zn $4s^2$	31 Ga $4s^2 4p^1$	32 Ge $4s^2 4p^2$	33 As $4s^2 4p^3$	34 Se $4s^2 4p^4$	35 Br $4s^2 4p^5$	36 Kr $4s^2 4p^6$
37 Rb [Kr] $5s^1$		[Kr] $4d^{10}$	47 Ag $5s^1$	48 Cd $5s^2$	49 In $5s^2 5p^1$	50 Sn $5s^2 5p^2$	51 Sb $5s^2 5p^3$	52 Te $5s^2 5p^4$	53 I $5s^2 5p^5$	54 Xe $5s^2 5p^6$
55 Cs [Xe] $6s^1$		[Xe] $4f^{14} 5d^{10}$	79 Au $6s^1$	80 Hg $6s^2$	81 Tl $6s^2 6p^1$	82 Pb $6s^2 6p^2$	83 Bi $6s^2 6p^3$	84 Po $6s^2 6p^4$	85 At $6s^2 6p^5$	86 Rn $6s^2 6p^6$

Selection rules

- The selection rules that apply to one-electron systems are:
  - orbital angular momentum: $\Delta l = \pm 1$
  - parity must change between states.
  - magnetic quantum number: $\Delta m = 0, \pm 1$
  - spin does not change: $\Delta s = 0$ (always true for the H atom)
  - total angular momentum: $\Delta j = 0, \pm 1$
- Forbidden transitions violate a selection rule.

Allowed HI Transitions

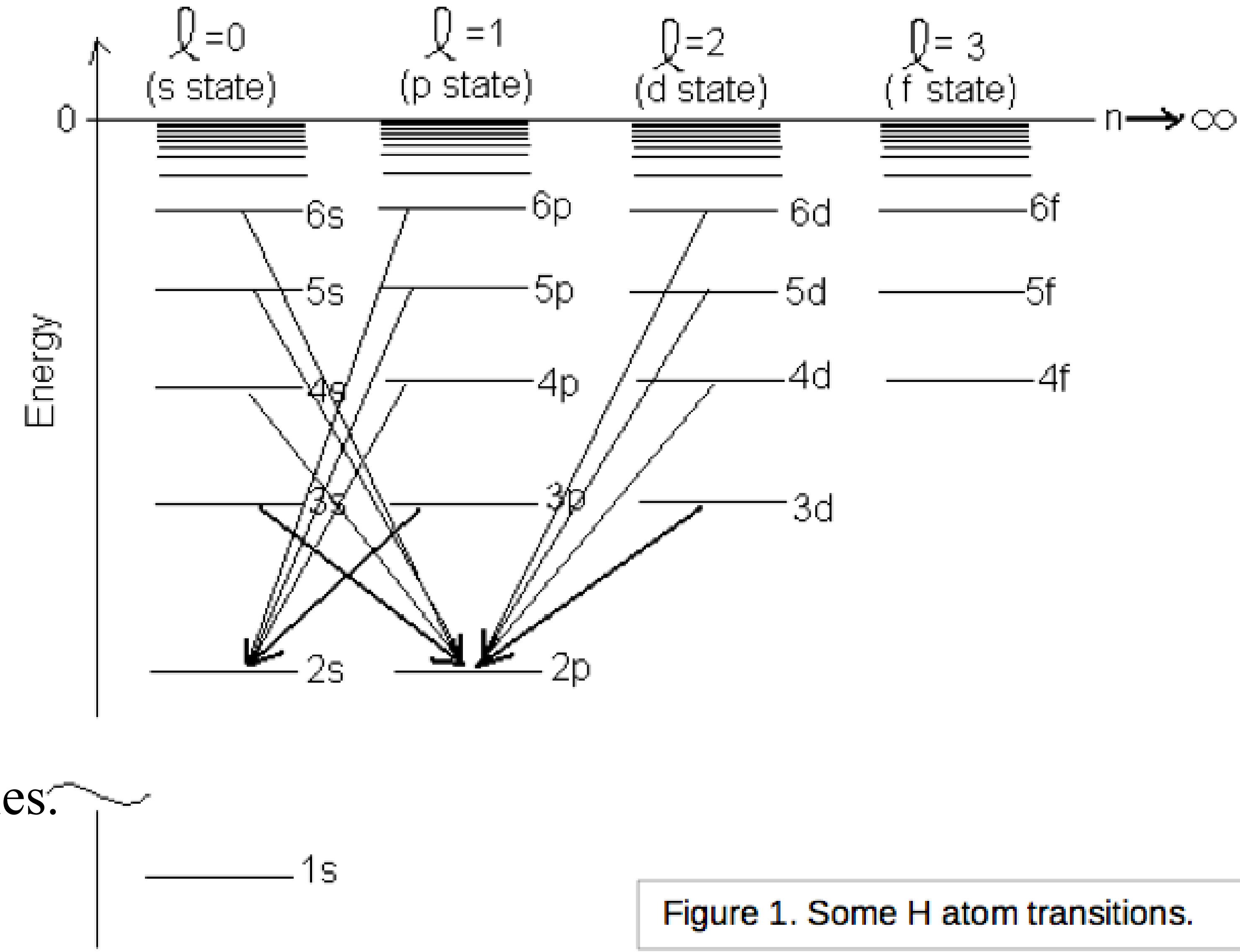


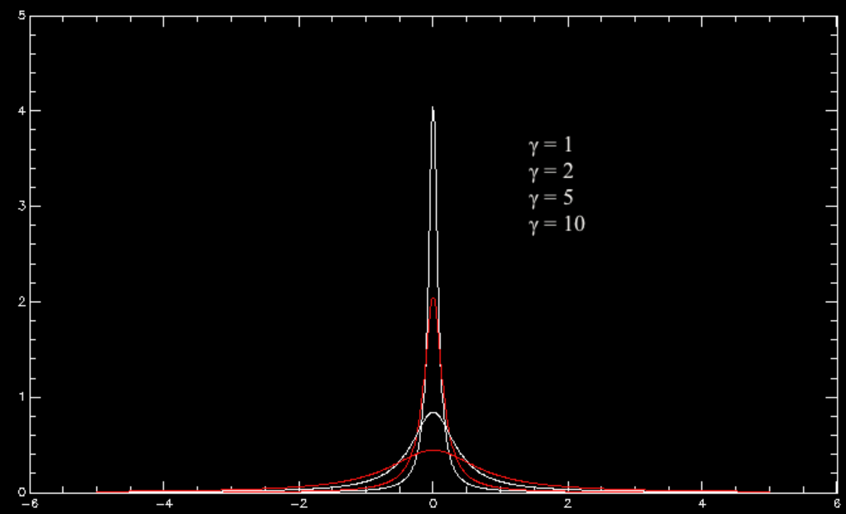
Figure 1. Some H atom transitions.

Note Selection Rules.

Line Broadening

- Uncertainty relationship between E and t.
  - Lorentzian: 2γ is Einstein A coefficient for spontaneous transition.
  - 1/A is the lifetime of the state.

$$I(\nu) = I_0 \gamma \frac{1}{(\nu-\nu_0)^2+(\gamma/4\pi)^2}$$

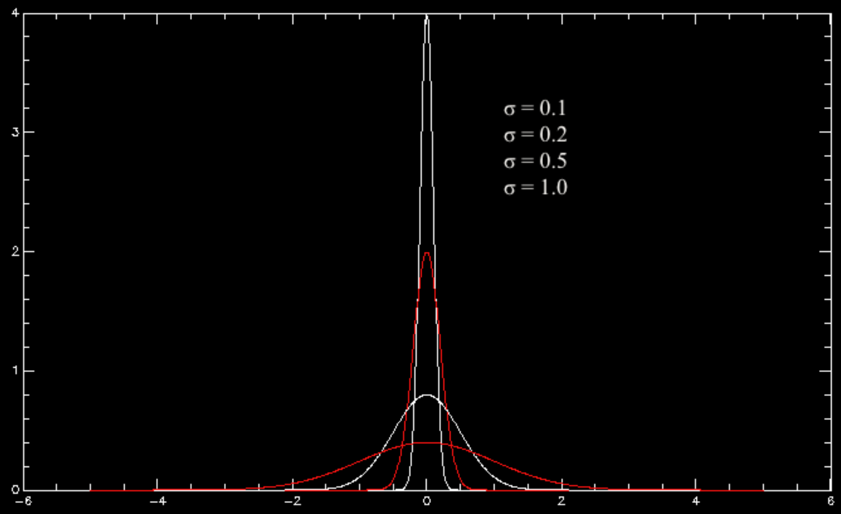


Line Broadening

- Thermal broadening.
  - Gaussian.
- FWHM is 2.3548σ.
- σ is dependent on the Temperature and on turbulence.

$$\varphi_{mn}(\upsilon) = \frac{1}{\sqrt{2\pi}\sigma}\exp\left(-\frac{(\nu-\nu_{mn})^2}{2\sigma^2}\right)$$

$$2\sigma^2 = \frac{\nu_{mn}^2}{c^2}\left(\frac{2kT_k}{M} + V^2\right)$$



Line Broadening

- Uncertainty relationship between E and t.
  - Lorentzian.
- Thermal broadening.
  - Gaussian.
- Convolution.
  - Voigt function.

$$\varphi(\nu) = \frac{2\sqrt{\ln 2}}{\sqrt{\pi}\Delta\nu_D} H(a, b)$$

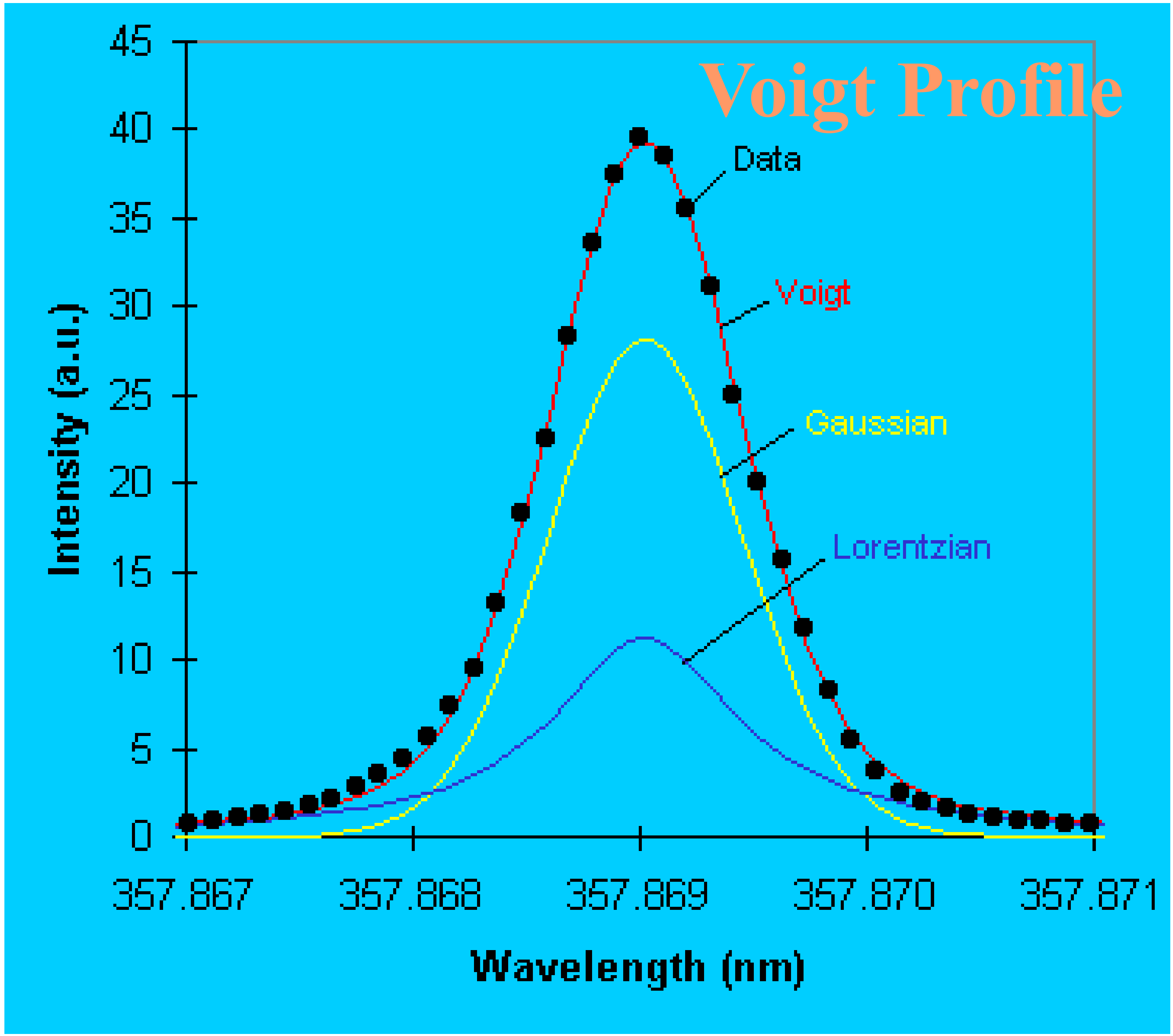
$$a = \sqrt{\ln 2}\Delta\nu_L/(2\Delta\nu_D)$$

$$b = 2\sqrt{\ln 2}(\nu - \nu_0)/\Delta\nu_D$$

$$H(a, b) = \frac{a}{\pi}\int \frac{\exp(-y^2)dy}{(b-y)^2 + a^2}$$

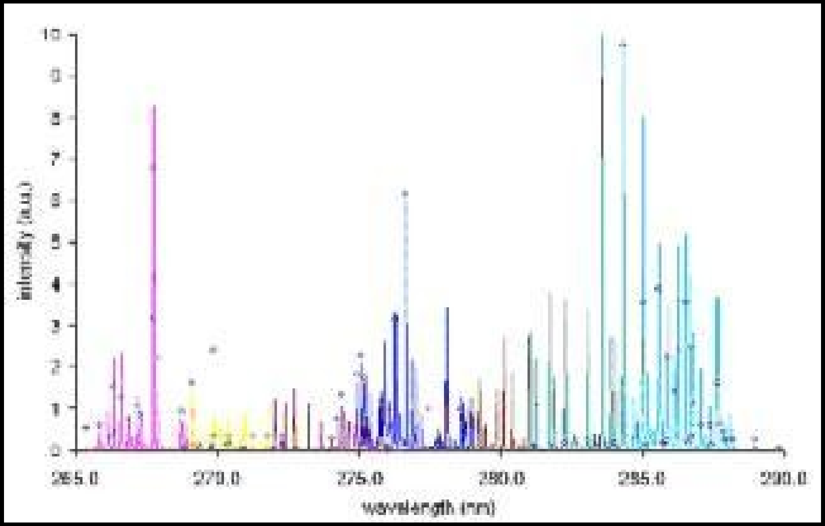
$$\Delta\nu_D \; FWHM - Doppler$$

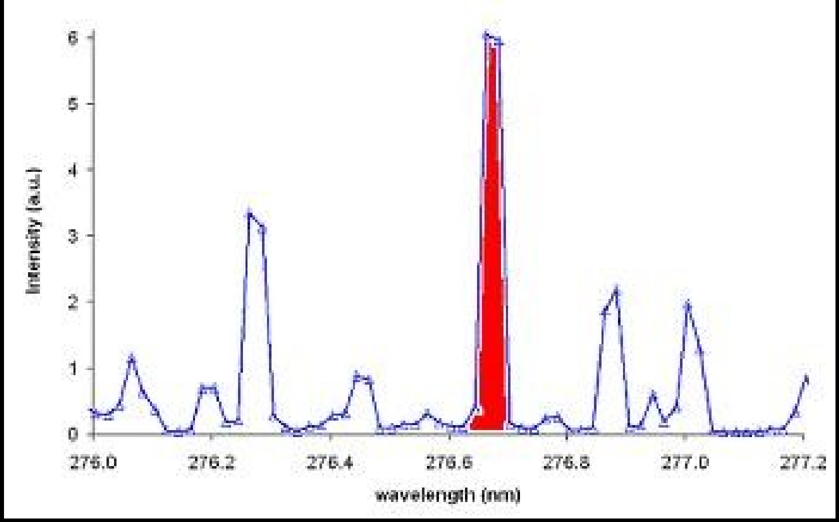
$$\Delta\nu_L \; FWHM - Lorentzian$$



Voigt Profile
Data
Voigt
Gaussian
Lorentzian
Intensity (a.u.)
0
5
10
15
20
25
30
35
40
45
357.867
357.868
357.869
357.870
357.871
Wavelength (nm)

Emission Lines





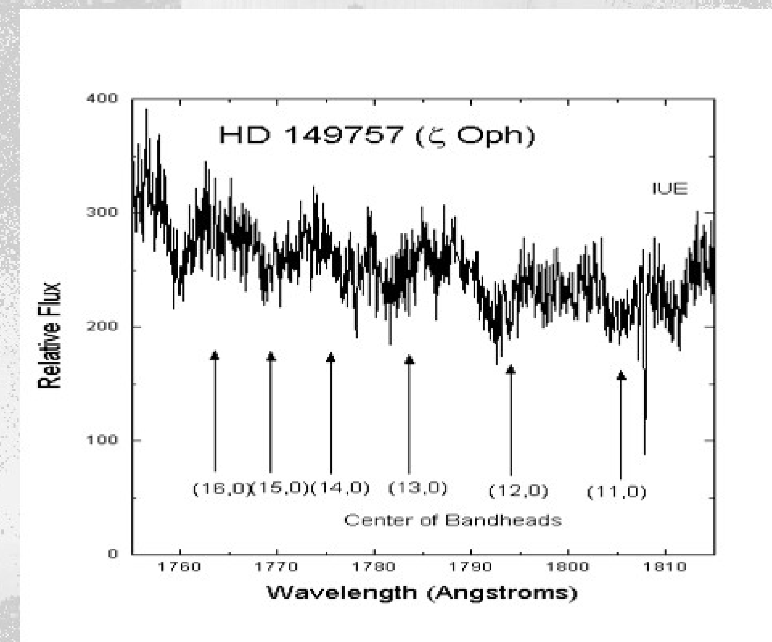
- Instrumental broadening.
- Typically gaussian.
- Limits information from lines.

http://www.thespectroscopynet.com/Index.html?/Lineshapes_1.html

Real Data

MOLECULAR OXYGEN IN THE INTERSTELLAR MEDIUM

International Ultraviolet Explorer Spectrum of Zeta Oph from 1760 to 1810 Angstroms



A new interest of mine is the search for molecular oxygen (O2) in the interstellar medium. The fractional abundance of O2 is an important, but as yet unknown, parameter for models of interstellar clouds. This species likely plays a central role in gas-phase interstellar chemistry. If present in significant abundance, O2 may also function as an important coolant of interstellar clouds and therefore play a role in cloud contraction and star formation.

Oxygen is the third-most abundant nucleon in the universe yet its form in much of the interstellar medium remains a mystery. The presence of ionized oxygen has long been known in HII regions, while [OI] lines have been observed in some photon--dominated regions. In the denser, better-shielded regions where molecules exist, O2 is predicted to be one of the most important

http://www.etsu.edu/physics/mwc/interest.htm#Molecular%20Oxygen%20in%20the%20Interstellar%20Medium

Spectral Resolution

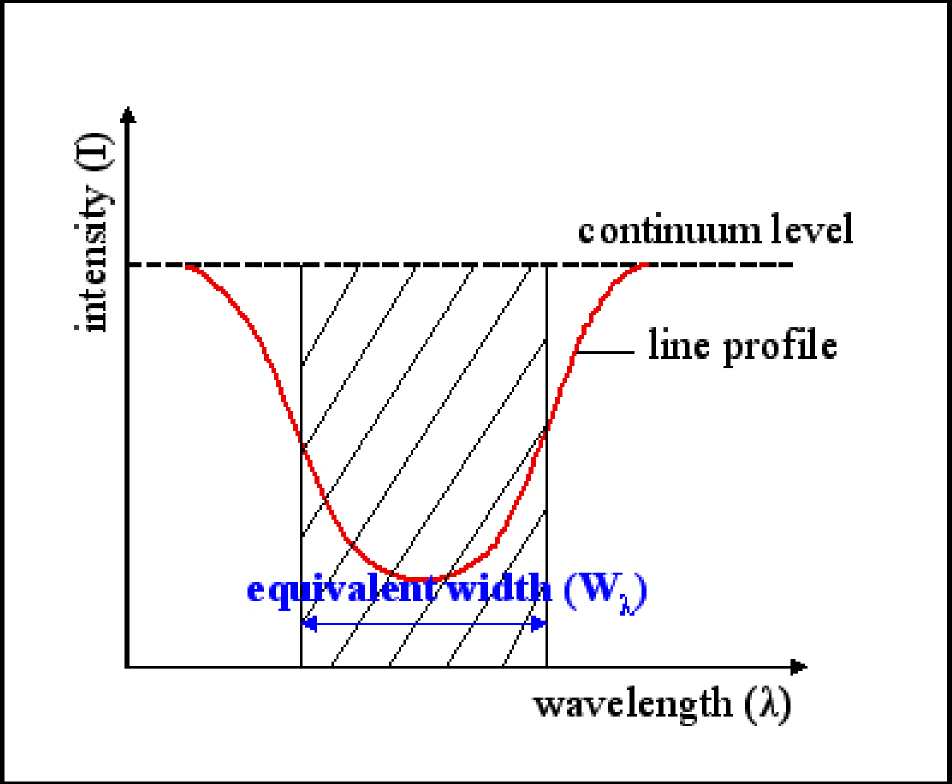
- Resolution = $\lambda/\Delta\lambda$.
  - IUE: Resolution was 0.2 Å at 2000 Å => R = 10,000.
  - FUSE: R = 20,000.
- For small velocities: $\Delta\lambda = \Delta v/c\ \lambda$.
- IUE: $\Delta v = 30$ km s^{-1}.
- Typical interstellar lines may be < 10 km s^{-1}.

Equivalent Width

- Equivalent width.

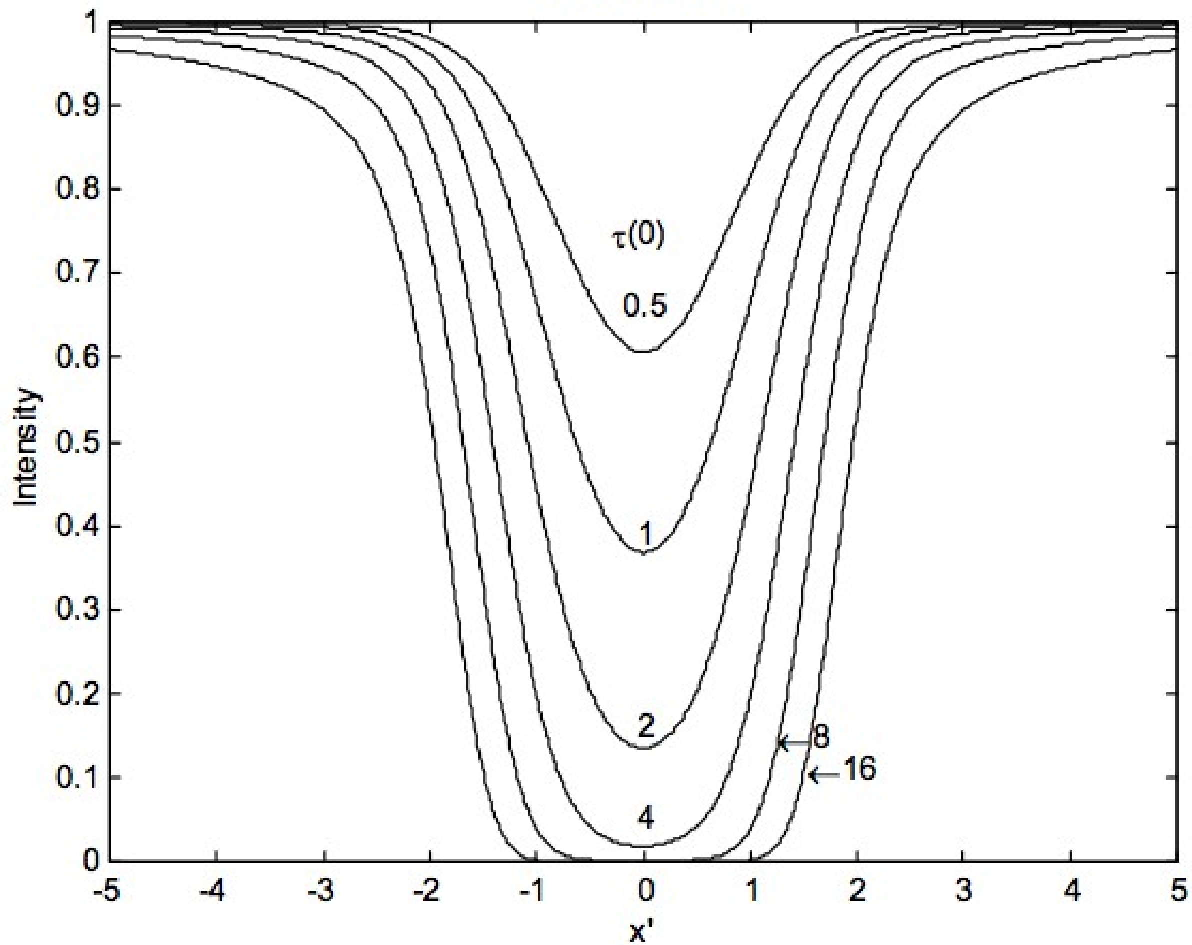
$$W_\lambda = \int (1 - F_\lambda / F_0) d\lambda$$

  - Same area as line.
- Independent of instrumental broadening.



Voigt Profiles

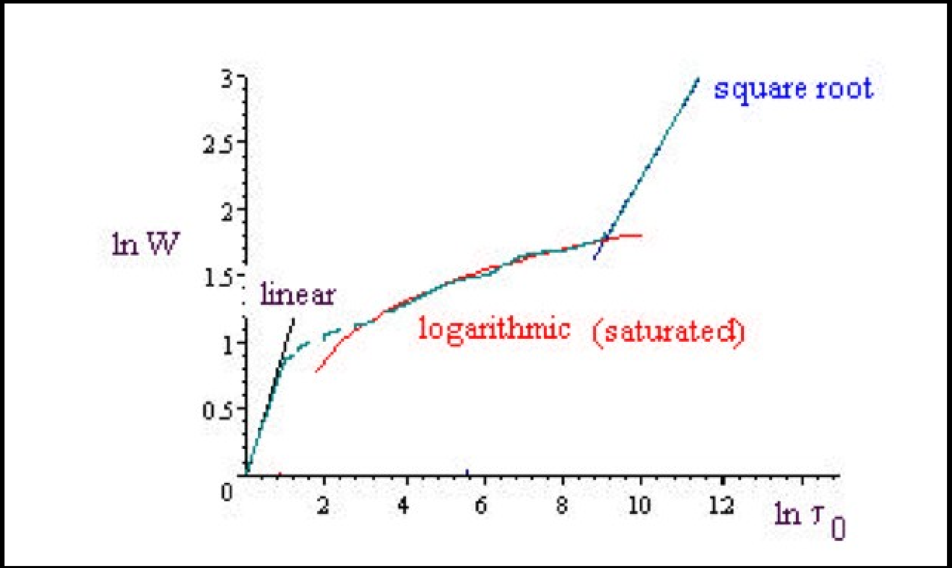
FIGURE XIA.2



The equivalent width (equation 11.A.1) is the area above these curves, and it can be seen again that determining the upper limit for x' is a problem.

Curve of Growth

- Equivalent width more robust than model-fitting.
- Easier to measure.

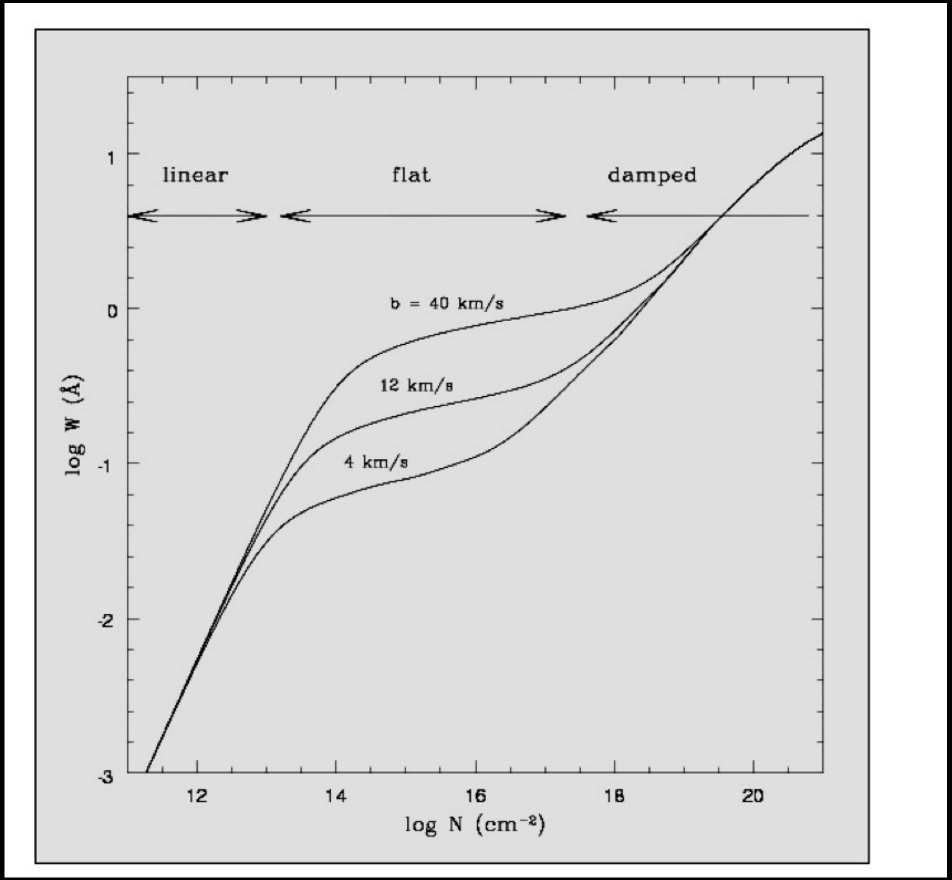


Curve of Growth

- b is the velocity dispersion
- Dimensional check: $(m^2\ kg\ s^{-2}\ K^{-1}\ kg^{-1}\ K + m^2 s^{-2}) m^{-2} s^2$.

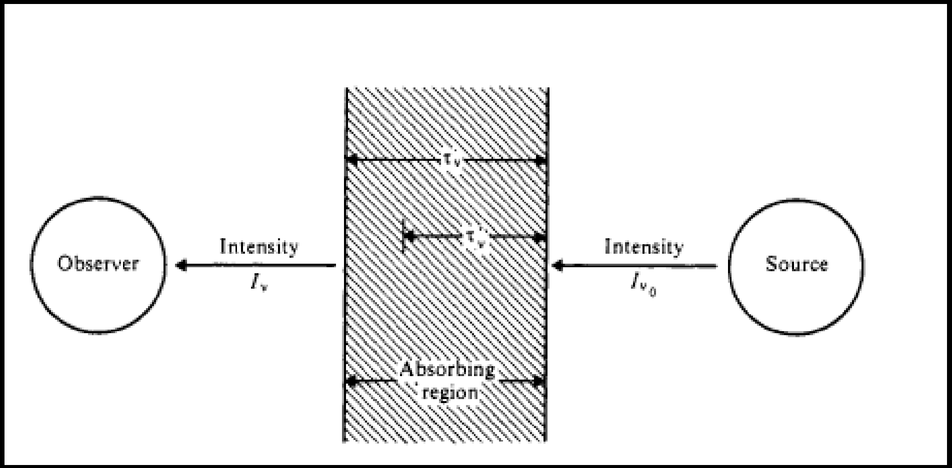
$$\varphi_{mn}(\upsilon) = \frac{1}{\sqrt{2\pi}\sigma} \exp\left(-\frac{(\nu-\nu_{mn})^2}{2\sigma^2}\right)$$

$$2\sigma^2 = \frac{\nu_{mn}^2}{c^2}\left(\frac{2kT_k}{M} + V^2\right)$$



Radiative Transfer

- Intensity defined such that:
- $dE = I_\nu \, dA \, dt \, d\Omega \, d\nu$ where dE is the energy crossing dA in time dt in the frequency range dν
- I_ν units are ergs s^{-1} cm^{-2} sr^{-1} Hz^{-1}



Definitions

- If LTE then $$I_\nu = \frac{2h\nu^3}{c^2}\frac{1}{e^{\frac{h\nu}{kT}}-1}$$
- Brightness temperature
  - $T_B(\nu)$ is temperature at which a blackbody would have the same specific intensity.

Definitions

- Antenna temperature:
  - Linear with intensity and $\sim T_B$ for $kT_A >> h\nu$

$$T_A(\nu) \equiv \frac{c^2}{2k\nu^2} I_\nu$$

- Excitation temperature of u relative to l.
  - where n is number, g is degeneracy and E is energy of upper and lower states.

$$\frac{n_u}{n_l} \equiv \frac{g_u}{g_l} e^{-\frac{E_u - E_l}{kT_{exc}}}$$

Radiative Transfer

$$dE = I_\nu \, dA \, dt \, d\Omega \, d\nu =$$
$$I_\lambda \, dA \, dt \, d\Omega \, d\lambda$$

$$I_\nu \, d\nu = I_\lambda \, d\lambda$$

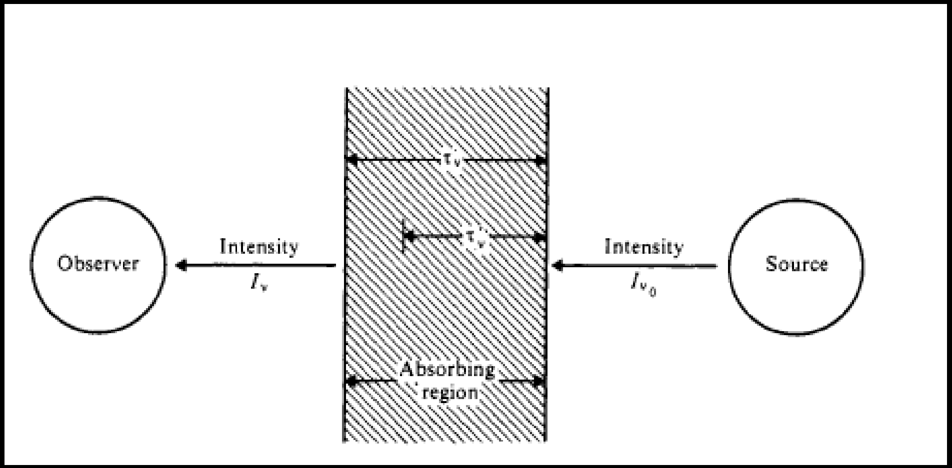
$$\nu = c/\lambda \Rightarrow d\nu = c/\lambda^2 \, d\lambda$$

$$c/\lambda^2 \, I_\nu = I_\lambda$$

dimensional check:

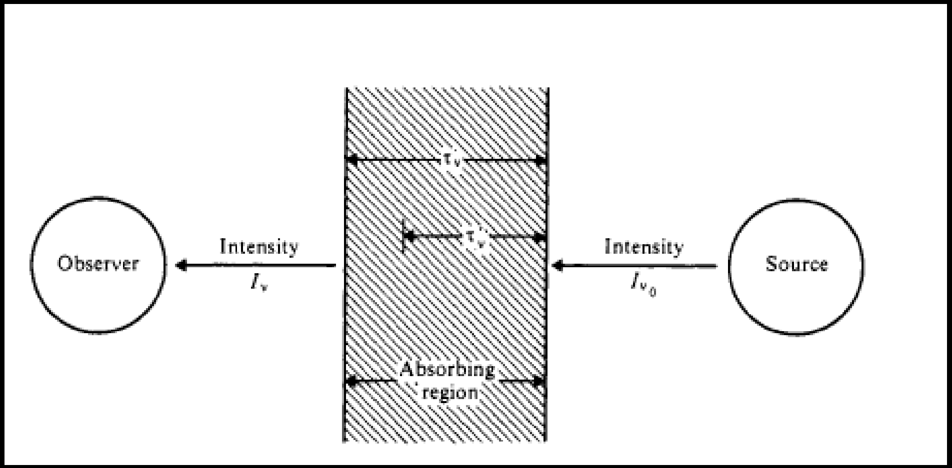
$(\mathrm{m\ s^{-1}})(\mathrm{m^{-2}})(\mathrm{ergs\ s^{-1}\ m^{-2}\ sr^{-1}\ Hz^{-1}}) =$

$\mathrm{ergs\ s^{-1}\ m^{-2}\ sr^{-1}\ m^{-1}}$ 😁



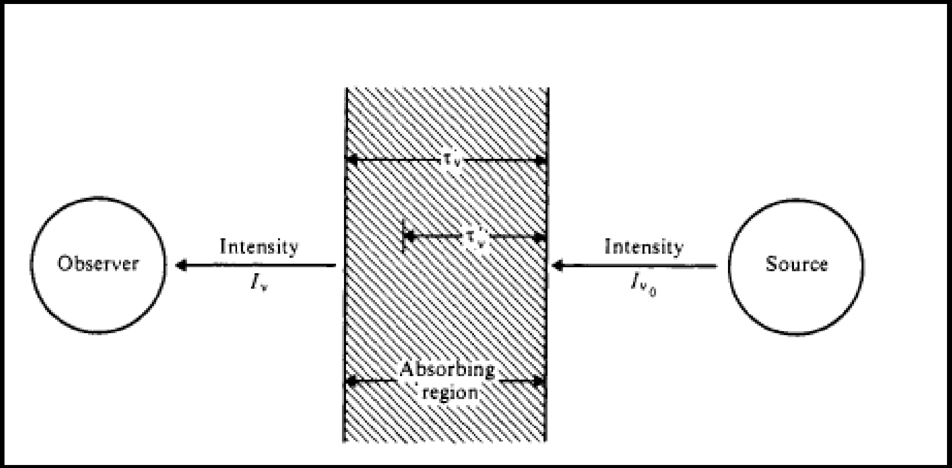
Radiative Transfer

- Spontaneous emission coefficient *j*.
  - *j* is *energy* emitted per unit *time* per unit *solid angle* per unit *volume*.
- $dE = j\, dV\, d\Omega\, dt$
- $dI_\nu = j_\nu\, ds$



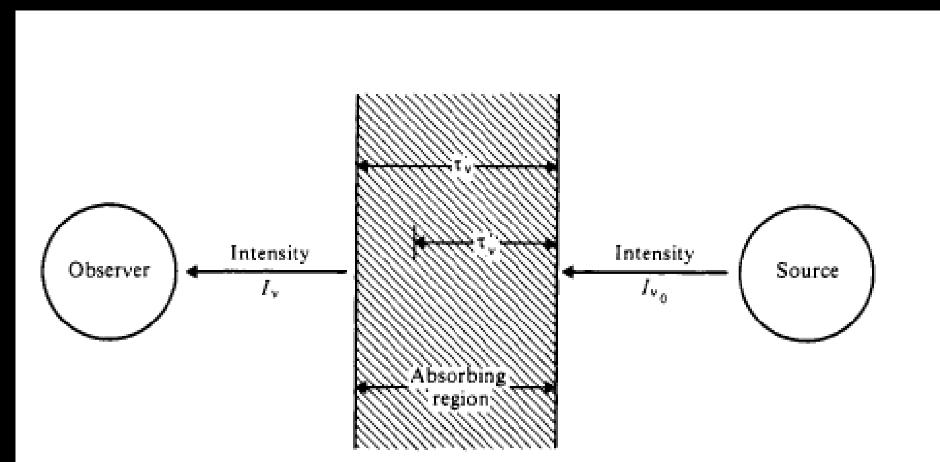
Radiative Transfer

- Absorption coefficient:
  $\alpha_\nu = n\sigma_\nu$
- $dI_\nu = -\alpha_\nu I_\nu \, ds$



Radiative Transfer

- Equation of radiative transfer:
  $dI_\nu/ds = -\alpha_\nu I_\nu + j_\nu$
- Define:
  optical depth: $d\tau_\nu = \alpha_\nu$
  source function: $S_\nu = j_\nu/\alpha_\nu$
- $dI_\nu/d\tau_\nu = -I_\nu + S_\nu$



$$I_\nu = I_{\nu(0)} e^{-\tau_\nu} + \int_0^{\tau_\nu} e^{-(\tau_\nu - \tau_\nu{}')} S_\nu(\tau_\nu') d\tau_\nu'$$

Kirchoff's Law

- Infinite uniform slab: $I_\nu = B_\nu(T)$
- $dI_\nu = 0 = -B_\nu d\tau_\nu + S_\nu d\tau_\nu$.
- Kirchoff's Law: $S_\nu = j_\nu/\alpha_\nu = B_\nu(T)$

$$I_\nu = I_{\nu(0)} e^{-\tau_\nu} + \int_0^{\tau_\nu} e^{-(\tau_\nu - \tau_\nu{}')} S_\nu(\tau_\nu') d\tau_\nu'$$

Limiting Cases

- Optical/UV
- All atoms in ground state so spontaneous emission may be neglected.
  - In ground state because no collisional excitation.

- Radio
- Upper levels are populated and spontaneous emission important.
  - If population inversion, maser occurs.

Transitions

- Spontaneous emission: Energy drops from upper state to lower state.
  - Einstein A coefficient A_{21}: transition probability per unit time.
  - Random process independent of radiation field.

Transitions

- Absorption dependent on the number of absorbers and the strength of the radiation field:

$$\frac{dn_2}{dt} = n_1 B_{12} u_\nu$$

- where n_2 is the number in upper state; u_ν is the radiation density and B_{12} is the Einstein B coefficient.
- For stimulated emission replace B_{12} with B_{21}.

Relation between Einstein coefficients

- In thermodynamic equilibrium:
- $n_1 B_{12} B(T) = n_2 A_{21} + n_2 B_{21} B(T)$
- but $n_1/n_2 = g_1/g_2\, e(h\nu/kT)$ where g is the degeneracy factor.
- After algebra: $$B(T) = \frac{A_{21}/B_{21}}{(g_1 B_{12}/g_2 B_{21}) exp(h\nu/kT) - 1}$$
- *But* for this to be true for all T:
  - $g_1 B_{12} = g_2 B_{21}$
  - $A_{21} = 2h\nu^3/c^2\, B_{21}$

Einstein Coefficients

- $\alpha_\nu = (h\nu/4\pi)\ (n_1B_{12} - n_2B_{21})\varphi(\nu)$ where $\varphi(\nu)$ is the absorption profile
- $j_\nu = (h\nu/4\pi)\ n_2A_{21}$ with the assumption that the emission profile is the same as the absorption profile.
- oscillator strength: $B_{12} = (4\pi^2e^2)/(h\nu_{21}m_ec)f_{12}$
- $g_1f_{12} = -g_2f_{21}$

Curve of Growth

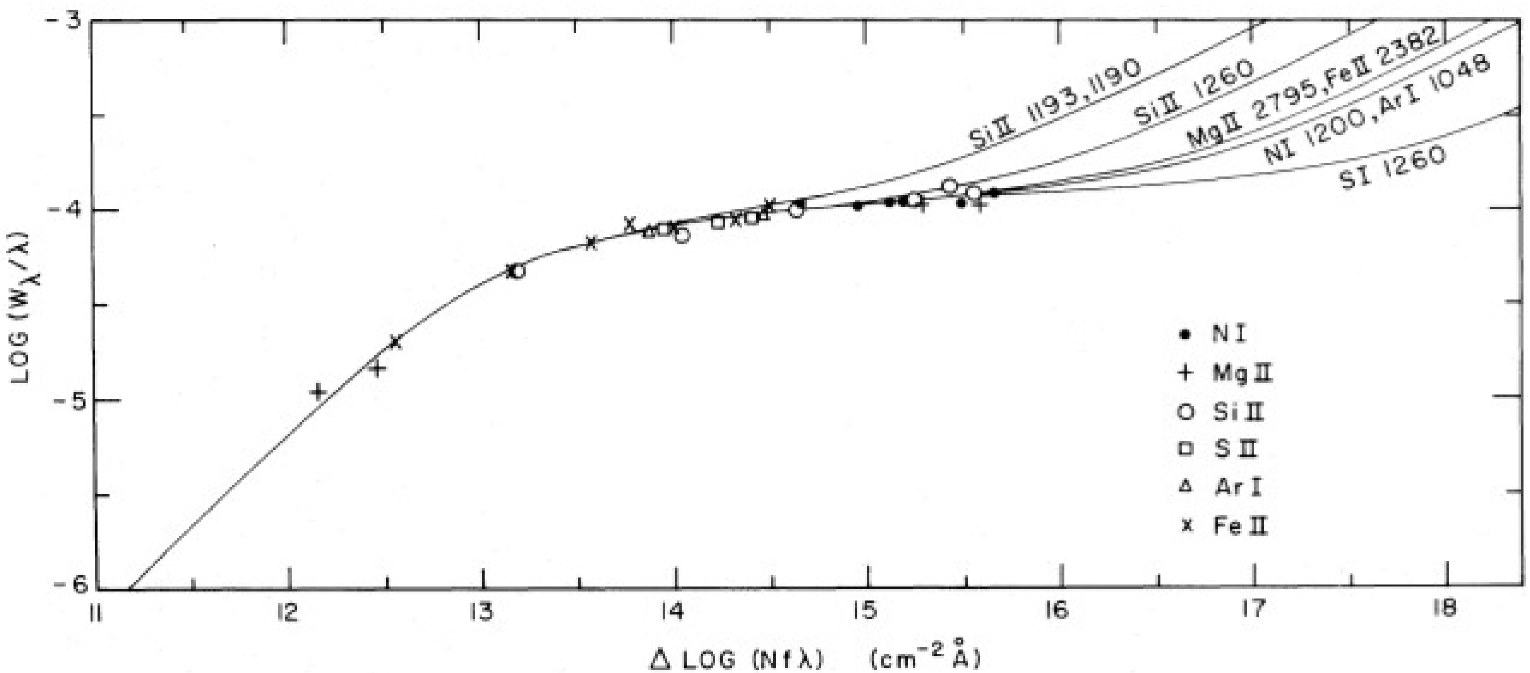


FIG. 5.—Empirical curve of growth for the dominant ion states expected in H I clouds. The solid lines were drawn for a Maxwellian velocity distribution with $b = 6.5$ km s^{-1} and the damping constants appropriate for the lines labeled in the upper right corner. The horizontal scale was labeled to give log N(cm^{-2}) for Fe II λ2382.

Absorption Line Data

- Two components in Fe II line of α Tri.

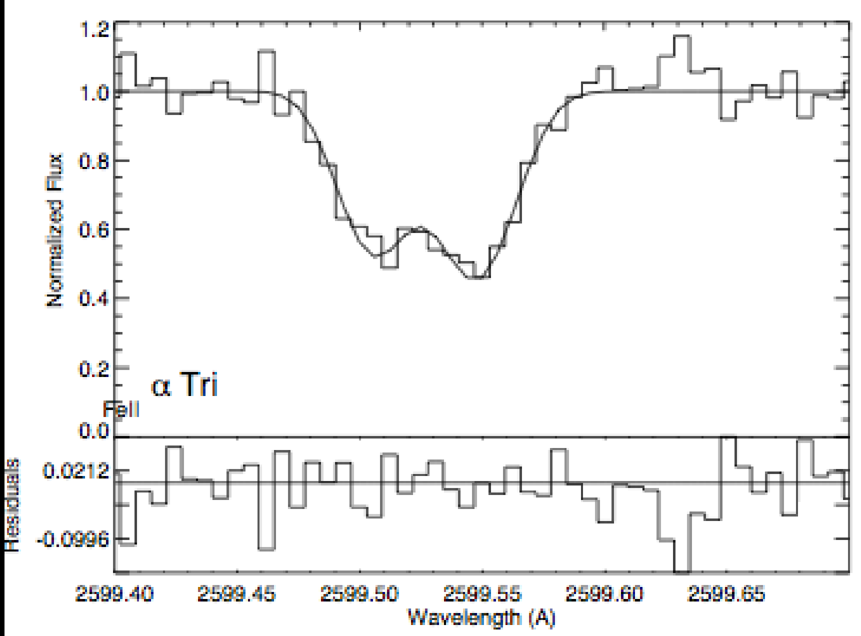
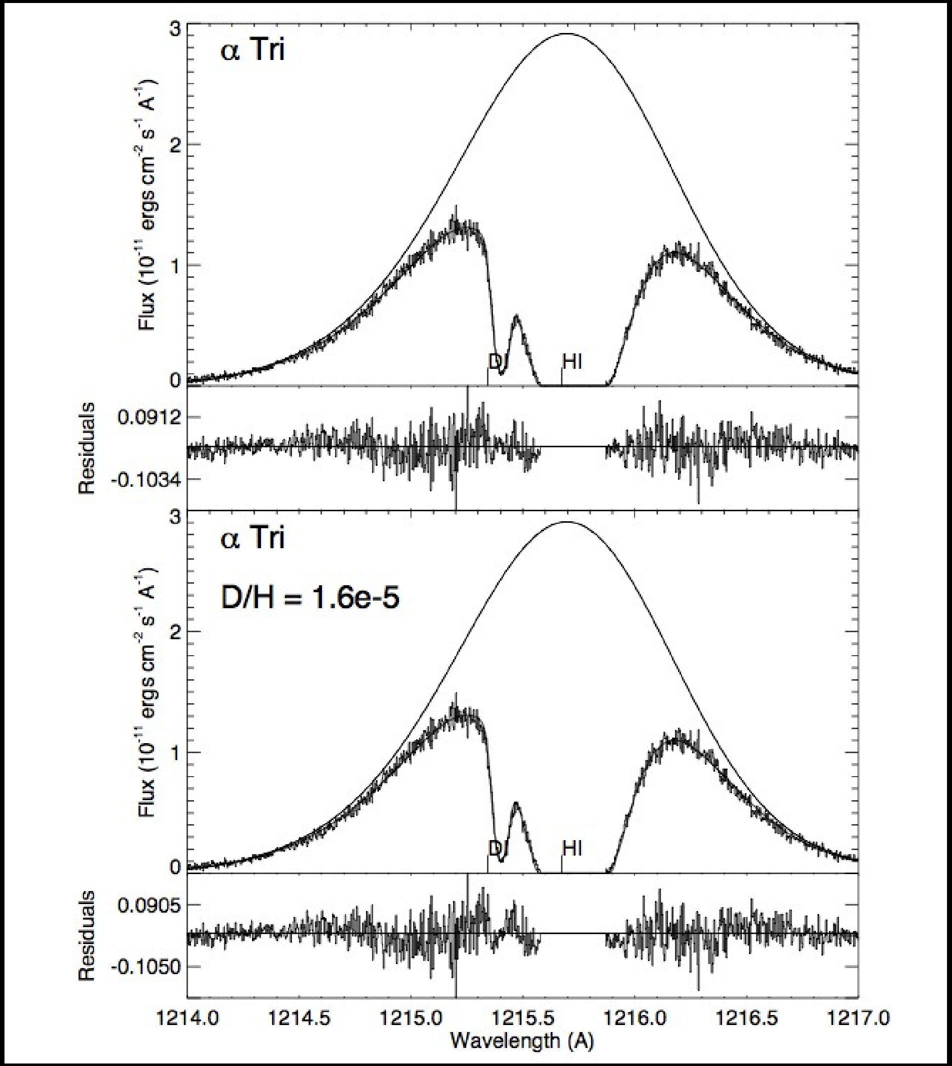


FIG. 4.—Fe II λ2599 region of α Tri showing the observed spectra, the st-fit model ater convolution, and the residuals of the best fit. Two mponents are seen in the opacity profile. The continuum is normalized unity, and the rest wavelength for Fe II is shown by the labeled tick rk.

Absorption Line Data

- Two components in Fe II line of α Tri.
- Fit Ly α line with two components.
- D I next to H I line.



Absorption Line Data

- Two components in Fe II line of α Tri.
- Fit Ly α line with two components.
- D I next to H I line.
- Stellar confusion.

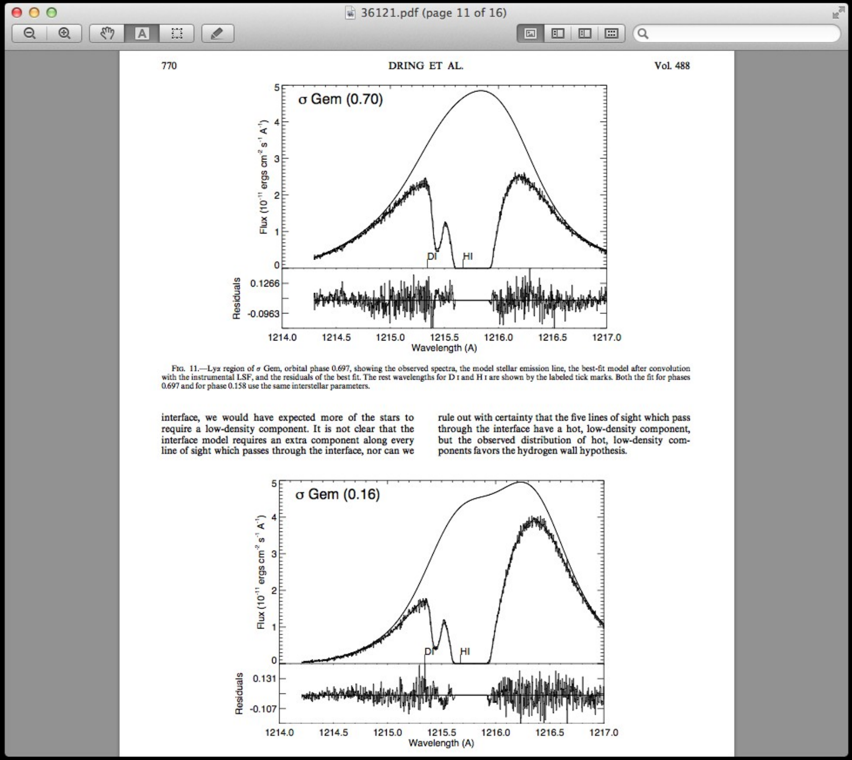
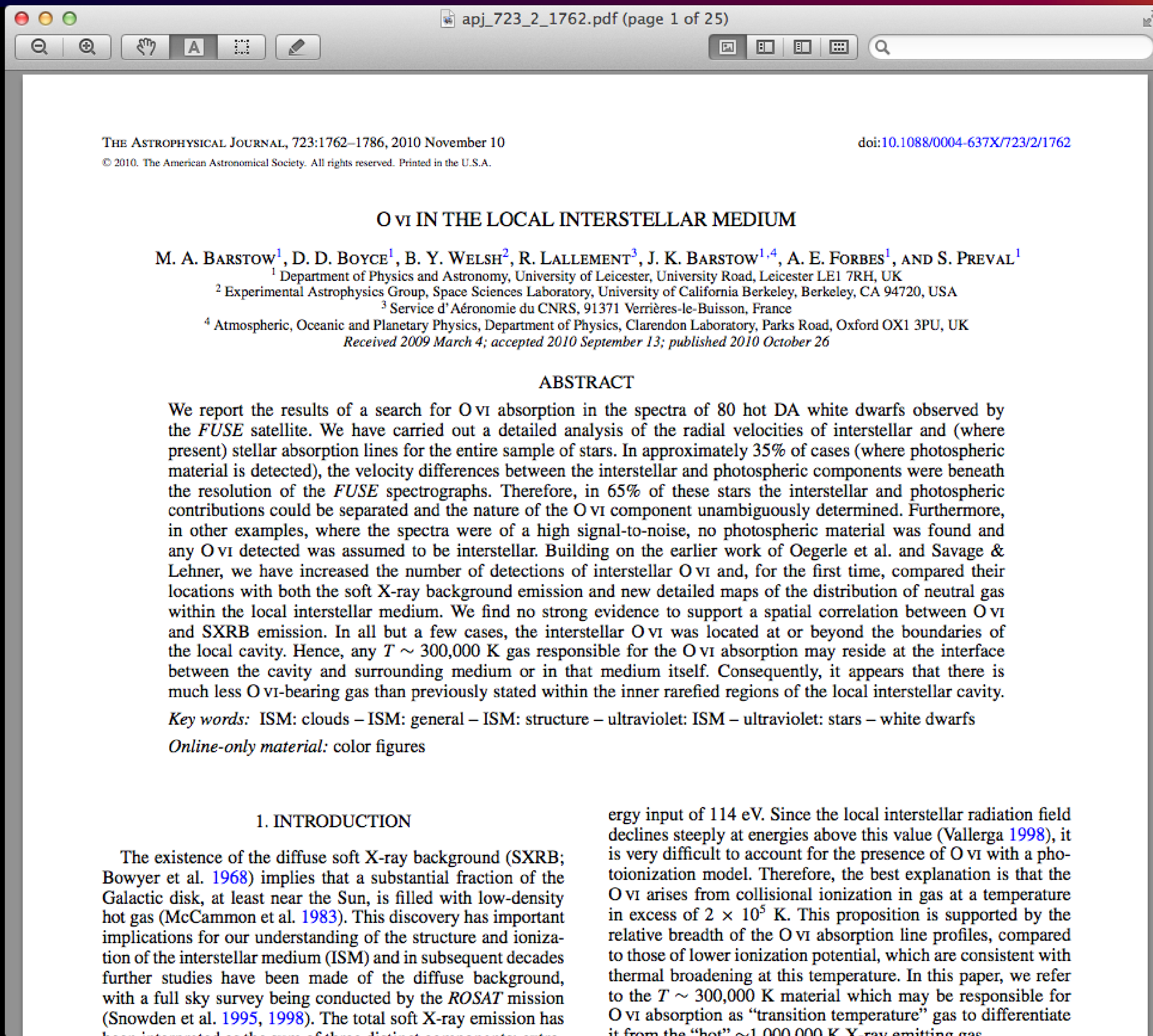


Fig. 11.—Lyα region of σ Gem, orbital phase 0.697, showing the observed spectra, the model stellar emission line, the best-fit model after convolution with the instrumental LSF, and the residuals of the best fit. The rest wavelengths for D I and H I are shown by the labeled tick marks. Both the fit for phases 0.697 and for phase 0.158 use the same interstellar parameters.

interface, we would have expected more of the stars to require a low-density component. It is not clear that the interface model requires an extra component along every line of sight which passes through the interface, nor can we rule out with certainty that the five lines of sight which pass through the interface have a hot, low-density component, but the observed distribution of hot, low-density components favors the hydrogen wall hypothesis.

OVI



apj_723_2_1762.pdf (page 1 of 25)

The Astrophysical Journal, 723:1762–1786, 2010 November 10
doi:10.1088/0004-637X/723/2/1762

O VI IN THE LOCAL INTERSTELLAR MEDIUM

M. A. Barstow[1], D. D. Boyce[1], B. Y. Welsh[2], R. Lallement[3], J. K. Barstow[1,4], A. E. Forbes[1], and S. Preval[1]
[1] Department of Physics and Astronomy, University of Leicester, University Road, Leicester LE1 7RH, UK
[2] Experimental Astrophysics Group, Space Sciences Laboratory, University of California Berkeley, Berkeley, CA 94720, USA
[3] Service d'Aéronomie du CNRS, 91371 Verrières-le-Buisson, France
[4] Atmospheric, Oceanic and Planetary Physics, Department of Physics, Clarendon Laboratory, Parks Road, Oxford OX1 3PU, UK
Received 2009 March 4; accepted 2010 September 13; published 2010 October 26

ABSTRACT

We report the results of a search for O VI absorption in the spectra of 80 hot DA white dwarfs observed by the *FUSE* satellite. We have carried out a detailed analysis of the radial velocities of interstellar and (where present) stellar absorption lines for the entire sample of stars. In approximately 35% of cases (where photospheric material is detected), the velocity differences between the interstellar and photospheric components were beneath the resolution of the *FUSE* spectrographs. Therefore, in 65% of these stars the interstellar and photospheric contributions could be separated and the nature of the O VI component unambiguously determined. Furthermore, in other examples, where the spectra were of a high signal-to-noise, no photospheric material was found and any O VI detected was assumed to be interstellar. Building on the earlier work of Oegerle et al. and Savage & Lehner, we have increased the number of detections of interstellar O VI and, for the first time, compared their locations with both the soft X-ray background emission and new detailed maps of the distribution of neutral gas within the local interstellar medium. We find no strong evidence to support a spatial correlation between O VI and SXRB emission. In all but a few cases, the interstellar O VI was located at or beyond the boundaries of the local cavity. Hence, any $T \sim 300{,}000$ K gas responsible for the O VI absorption may reside at the interface between the cavity and surrounding medium or in that medium itself. Consequently, it appears that there is much less O VI-bearing gas than previously stated within the inner rarefied regions of the local interstellar cavity.

Key words: ISM: clouds – ISM: general – ISM: structure – ultraviolet: ISM – ultraviolet: stars – white dwarfs

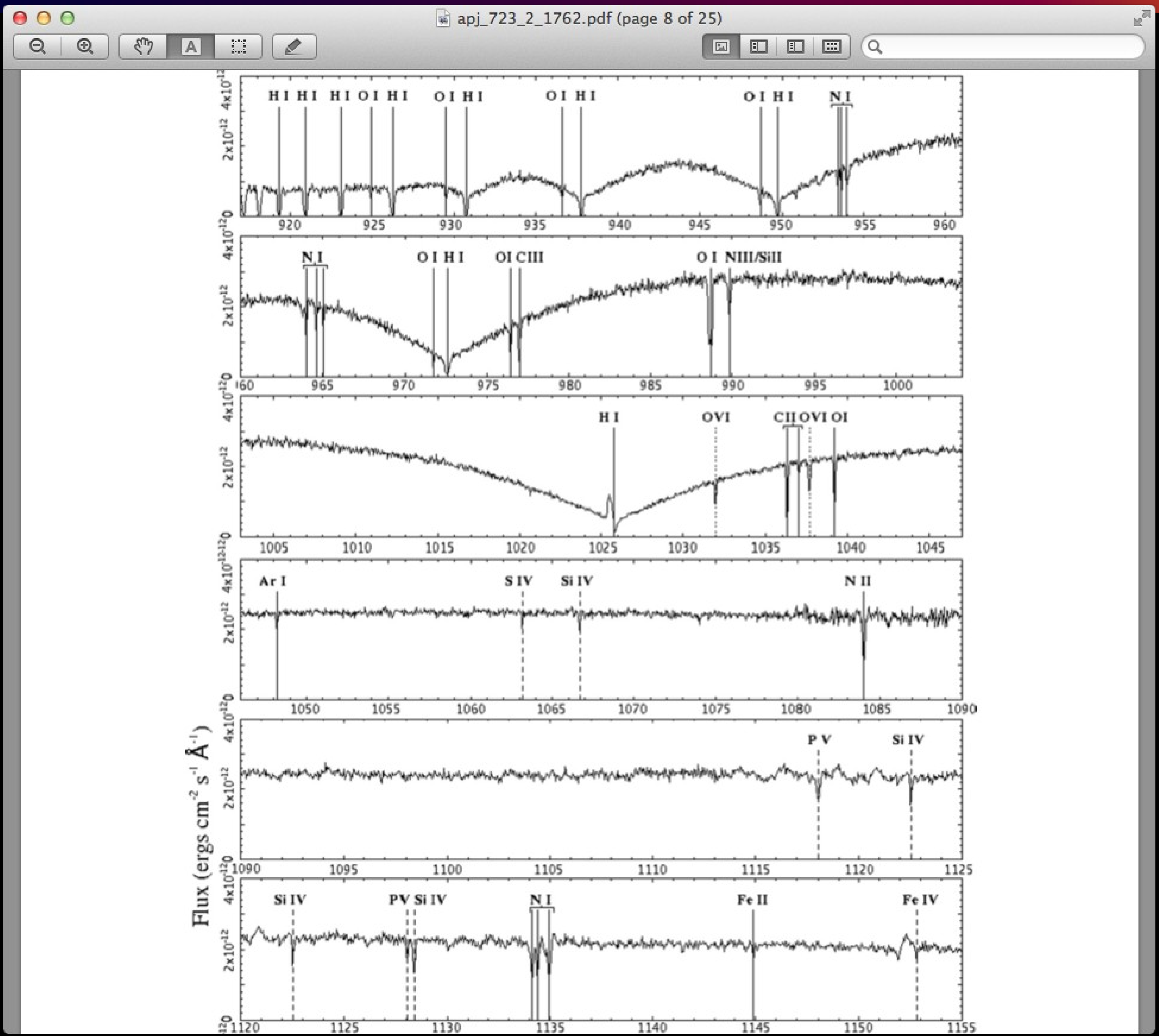
Online-only material: color figures

1. INTRODUCTION

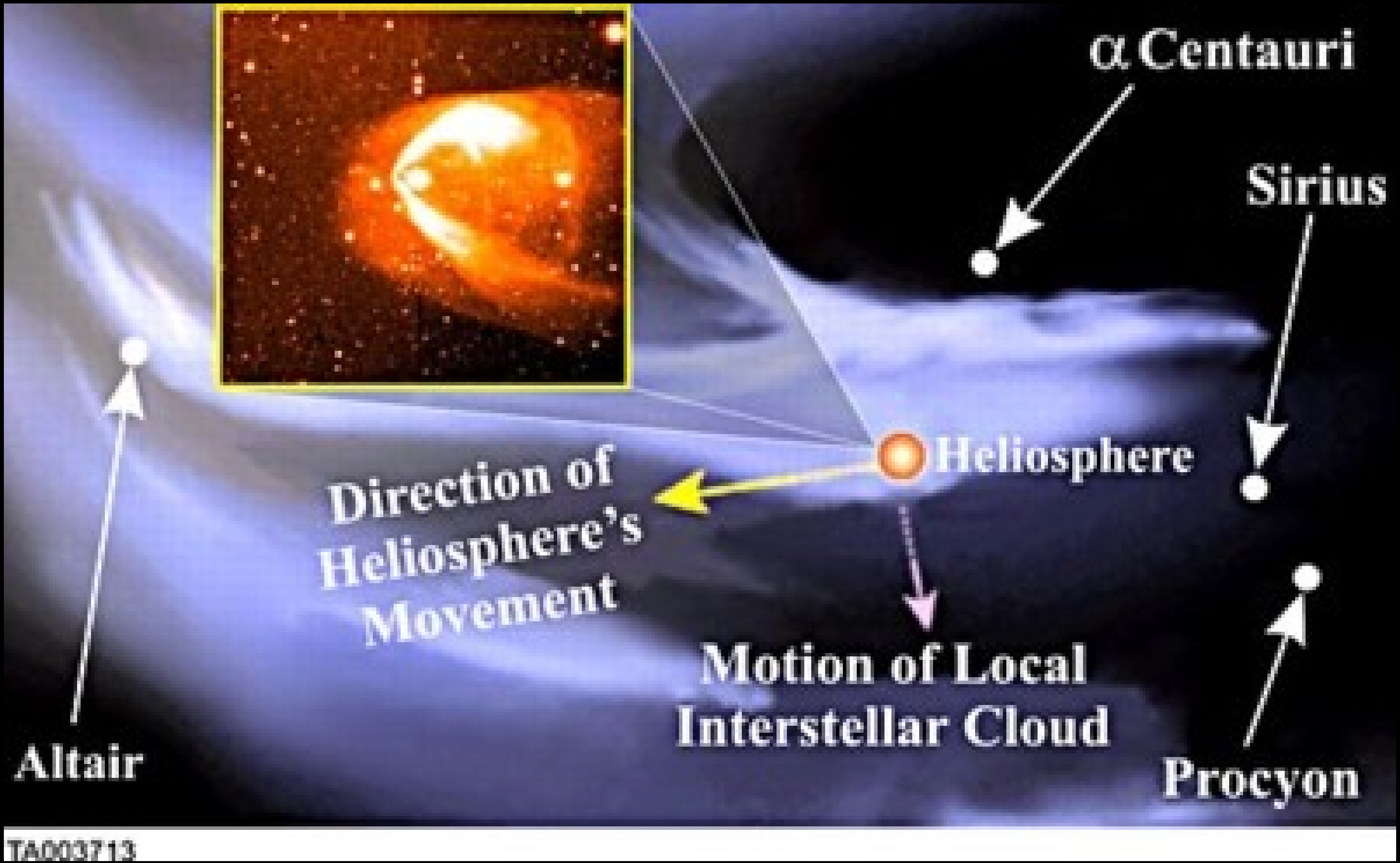
The existence of the diffuse soft X-ray background (SXRB; Bowyer et al. 1968) implies that a substantial fraction of the Galactic disk, at least near the Sun, is filled with low-density hot gas (McCammon et al. 1983). This discovery has important implications for our understanding of the structure and ionization of the interstellar medium (ISM) and in subsequent decades further studies have been made of the diffuse background, with a full sky survey being conducted by the *ROSAT* mission (Snowden et al. 1995, 1998). The total soft X-ray emission has

ergy input of 114 eV. Since the local interstellar radiation field declines steeply at energies above this value (Vallerga 1998), it is very difficult to account for the presence of O VI with a photoionization model. Therefore, the best explanation is that the O VI arises from collisional ionization in gas at a temperature in excess of 2×10^5 K. This proposition is supported by the relative breadth of the O VI absorption line profiles, compared to those of lower ionization potential, which are consistent with thermal broadening at this temperature. In this paper, we refer to the $T \sim 300{,}000$ K material which may be responsible for O VI absorption as "transition temperature" gas to differentiate

OVI


apj_723_2_1762.pdf (page 8 of 25)
H I H I H I O I H I O I H I O I H I O I H I N I
N I O I H I OI CIII O I NIII/SiII
H I OVI CII OVI OI
Ar I S IV Si IV N II
P V Si IV
Si IV PV Si IV N I Fe II Fe IV
Flux (ergs cm^{-2} s^{-1} Å^{-1})

VLISM


α Centauri
Sirius
Heliosphere
Direction of Heliosphere's Movement
Motion of Local Interstellar Cloud
Altair
Procyon
TA003713