AS1001:Extra-Galactic Astronomy

Lecture 4: Galaxy Spectra

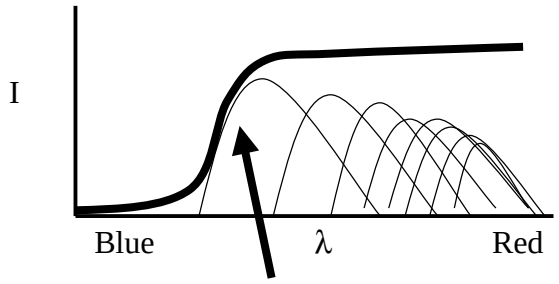
Kenneth Wood 316
kw25@st-andrews.ac.uk
http://www-star.st-and.ac.uk/~kw25

Galaxy Spectra

- The combination of ~50 billion stars plus many molecular clouds and star-forming regions.
- The spectra tell us:
  - The galaxy's relative velocity
  - The star-formation rate
  - The average age of the stellar population
- 3 Aspects:
  - Continuum
  - Absorption Lines
  - Emission Lines

Continuum

- The combination of many Black-Body spectra spanning a range in temperatures
- This produces a fairly flat overall spectrum



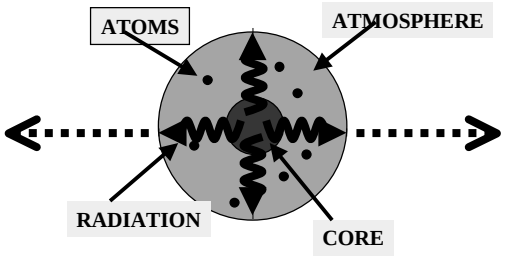
- The main feature is the 4000A-break

The 4000A-break

- Caused by:
  - blanket absorption of high energy radiation from metals in the stellar atmospheres
  - the lack of hot blue stars
- Hence:
  - Ellipticals => A strong 4000A-Break
  - Spirals => A weak 4000A-Break
  - Irregulars => No 4000A-Break

Absorption Lines

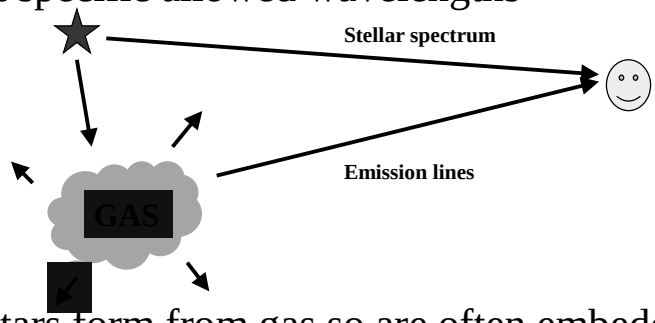
- Caused by Atoms/Molecules in a star's atmosphere that absorb specific wavelengths



- Can also be due to COLD gas in the interstellar medium which can EXTRACT energy from the passing radiation: REDENNING in Ian's course

Emission Lines

- Caused by gas being heated and then re-radiating at specific allowed wavelengths



- Stars form from gas so are often embedded
- Young stars ionise gas which releases radiation at a specific wavelength as it recombines

Orion Nebula

Hydrogen ionized by photons with E > 13.6eV or λ < 912A
1eV = 1.602E-19 J; E = h ν

Four bright O stars emit most of the ionizing photons that produce the Orion Nebula HII region

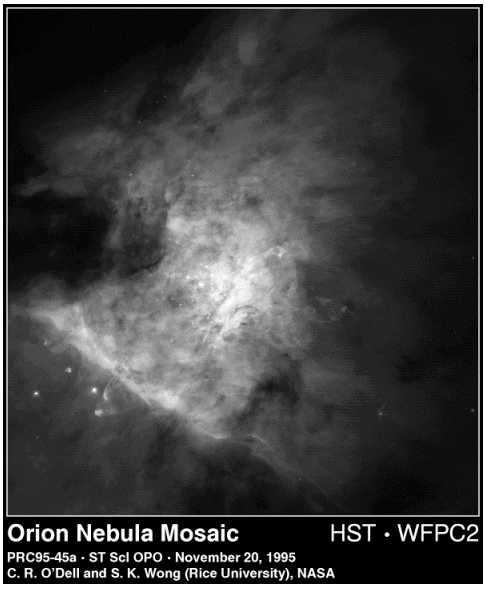
Neutral hydrogen: H^0 = HI
Ionized hydrogen: H^+ = HII

HST View of Orion Nebula

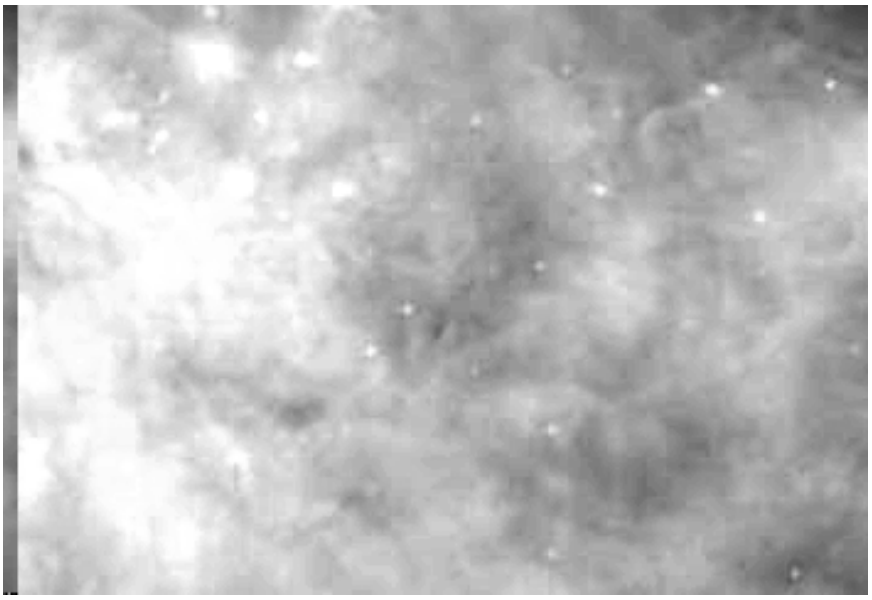
Emission lines of ionized hydrogen and oxygen

Balmer lines in optical Recombinations to n = 2
Hα: 6563A

$$\frac{1}{\lambda} = R\left(\frac{1}{n_l^2} - \frac{1}{n_u^2}\right)$$
$$R = 1.097 \times 10^7 \ m^{-1}$$
$$H\alpha: n_u = 3 \quad n_l = 2$$

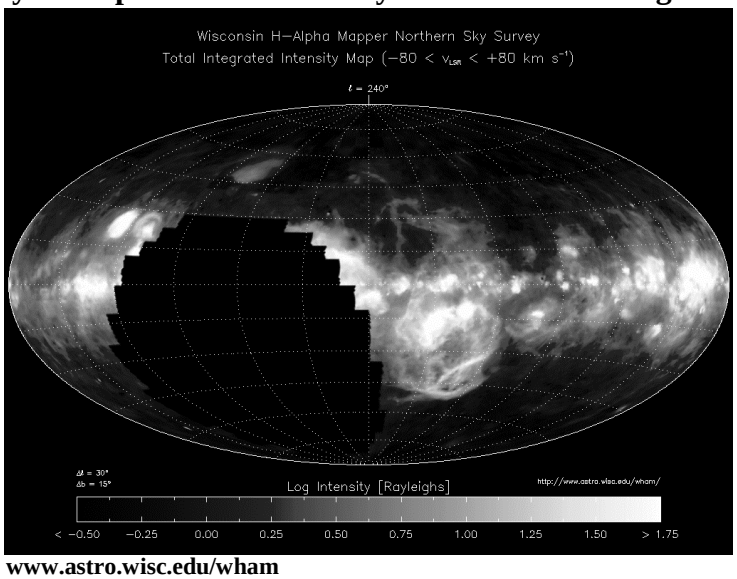


HST View of Orion Nebula



Ionized Gas in the Milky Way

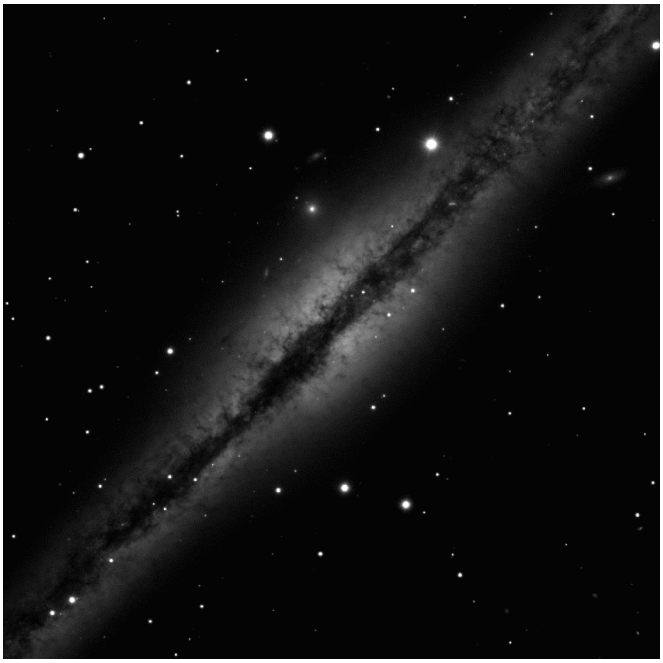
Gas layer ~1kpc thick. Ionized by O & B stars in the galactic disk



www.astro.wisc.edu/wham

NGC 891

Also displays a thick layer of ionized gas



Absorption / Emission Lines

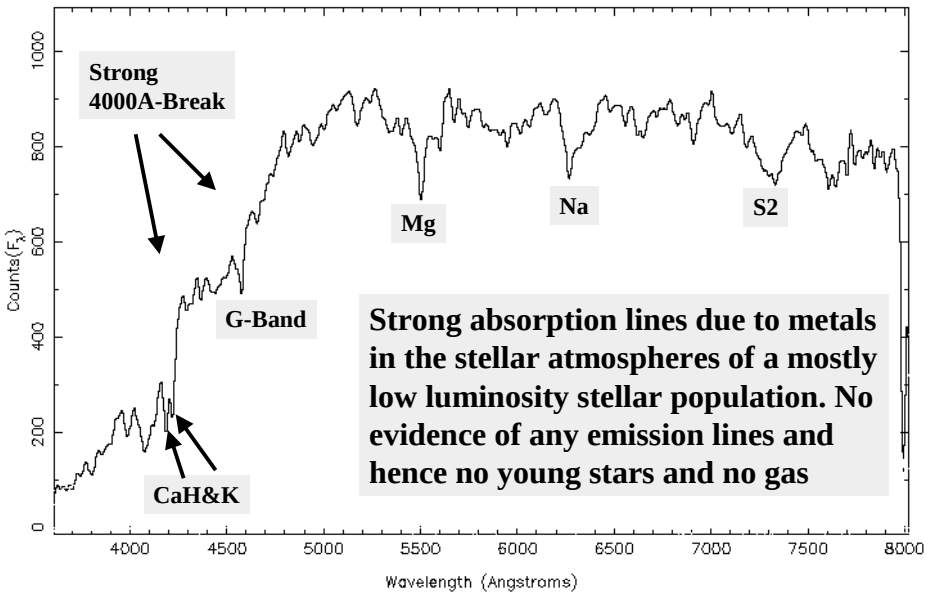
- Absorption Lines
  - Need metals in stellar atmospheres or cold gas in the interstellar medium
- Implies
  - Old stellar population = old galaxy
- From
  - Ellipticals
  - Spiral Bulges

- Emission Lines
  - Need very hot gas and OB type stars
- Implies
  - Newly formed stars = star-forming/young galaxy
- From
  - Spiral Disks
  - Irregulars

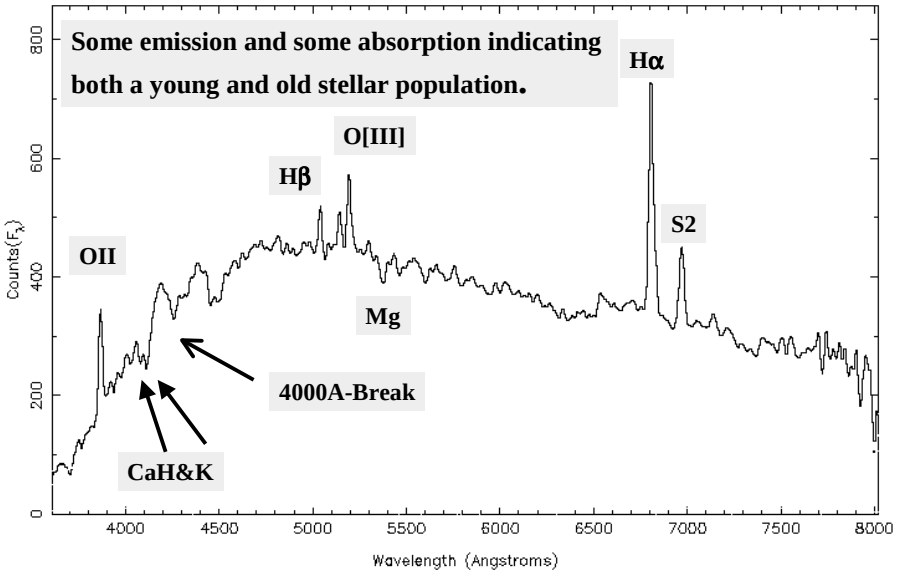
Typical Spectral features

- Absorption
  - Ca(H) = 3933.7A
  - Ca(K) = 3968.5A
  - G-band = 4304.4A
  - Mg = 5175.3A
  - Na = 5894.0 A
- Emission
  - O[II] = 3727.3A
  - Hδ = 4102.8A
  - Hγ = 4340.0A
  - Hβ = 4861.3A
  - O[III] = 4959.0A
  - O[III] = 5006.8A
  - Hα = 6562.8A
  - S2 = 6716.0A

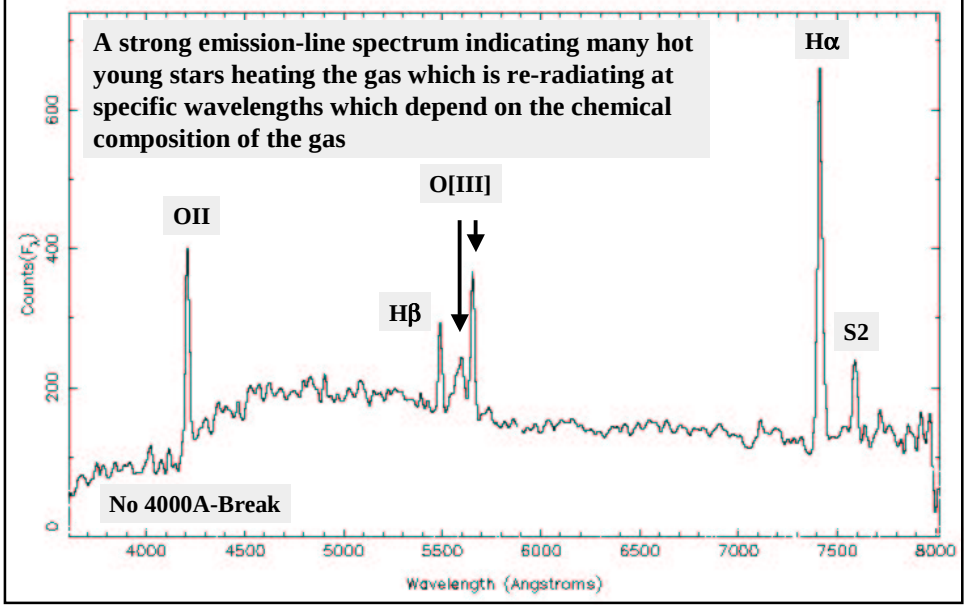
Example Spectrum: Elliptical



Example Spectrum: Spiral



Example Spectrum: Irregular

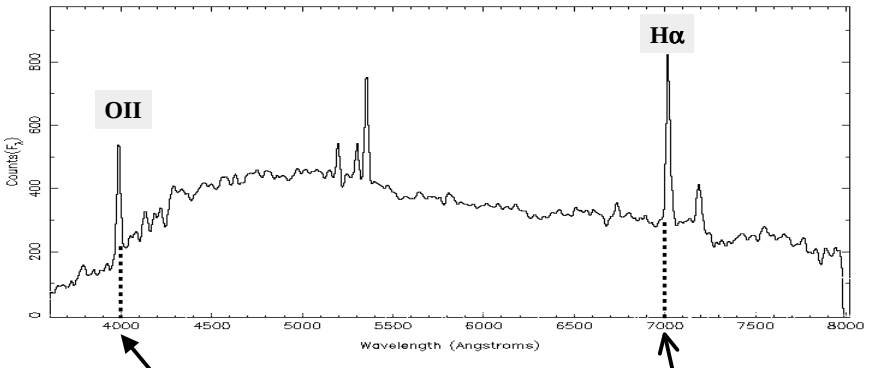


Radial Velocities

- Most galaxy spectra are REDSHIFTED, which means their spectral features are offset compared to those measured for gasses in the lab
- i.e., characteristic combinations of lines are systematically offset to longer wavelengths
- This is interpreted as a DOPPLER shift and implies that galaxies are moving away
- Positive velocities: RECEDING
- Negative velocities: APPROACHING

$$\frac{\Delta\lambda}{\lambda} = \frac{\Delta v}{c} \quad \text{or} \quad \frac{\lambda_{OBSERVED}}{\lambda_{CALIBRATION}} = \frac{v + c}{c}$$

Example Radial Velocity



OII is at 4000A

Hα is at 7030A

$$v = c\left(\frac{\lambda_{OBS} - \lambda_{CAL}}{\lambda_{CAL}}\right) = c\left(\frac{4000 - 3727}{3727}\right) = 21{,}974 \text{km/s} \qquad v = c\left(\frac{467}{6563}\right) = 21{,}500 \text{km/s}$$

GALAXY IS MOVING AWAY AT ABOUT 21,750 km/s