Welcome! We are glad you are here!!

- Wifi cloudy
- pw cloudysummerschool

- Tea/coffee breaks are upstairs

- This room cannot be locked – bring your laptops with you

- Group photo Thursday 12:30

Social program

- Kindly organized by nice QUB people (Catherine, Matt, Mattia, Joe, Janet).
- Linked to from agenda page
- Please sign up by tomorrow evening

Benvenuti!

Scalini is an Italian family run pizzeria restaurant in the heart of South Belfast & within walking distance of Queen's University & Botanic Gardens.

Since opening in October 2001 it's popularity has grown to become one of Belfast's favourite Italian eateries.

A Mediterranean glow welcomes you on entering the doors of Scalini – not just in the warm ochre hue of the décor but also in the welcome from our friendly staff.

The word Scalini in Italian means 'steps' which becomes evident on the mini adventure to your table, as the restaurant has been cleverly designed on multiple floor levels* - each one with it's own character.

On one level you may feel as though you're dining 'al fresco' under a Mediterranean sky, stars twinkling above your head, while on others you may feel transported to a traditional rustic Italian family mealtime, but no matter where your eyes turn they are treated to a different picturesque vista of Italian charm!

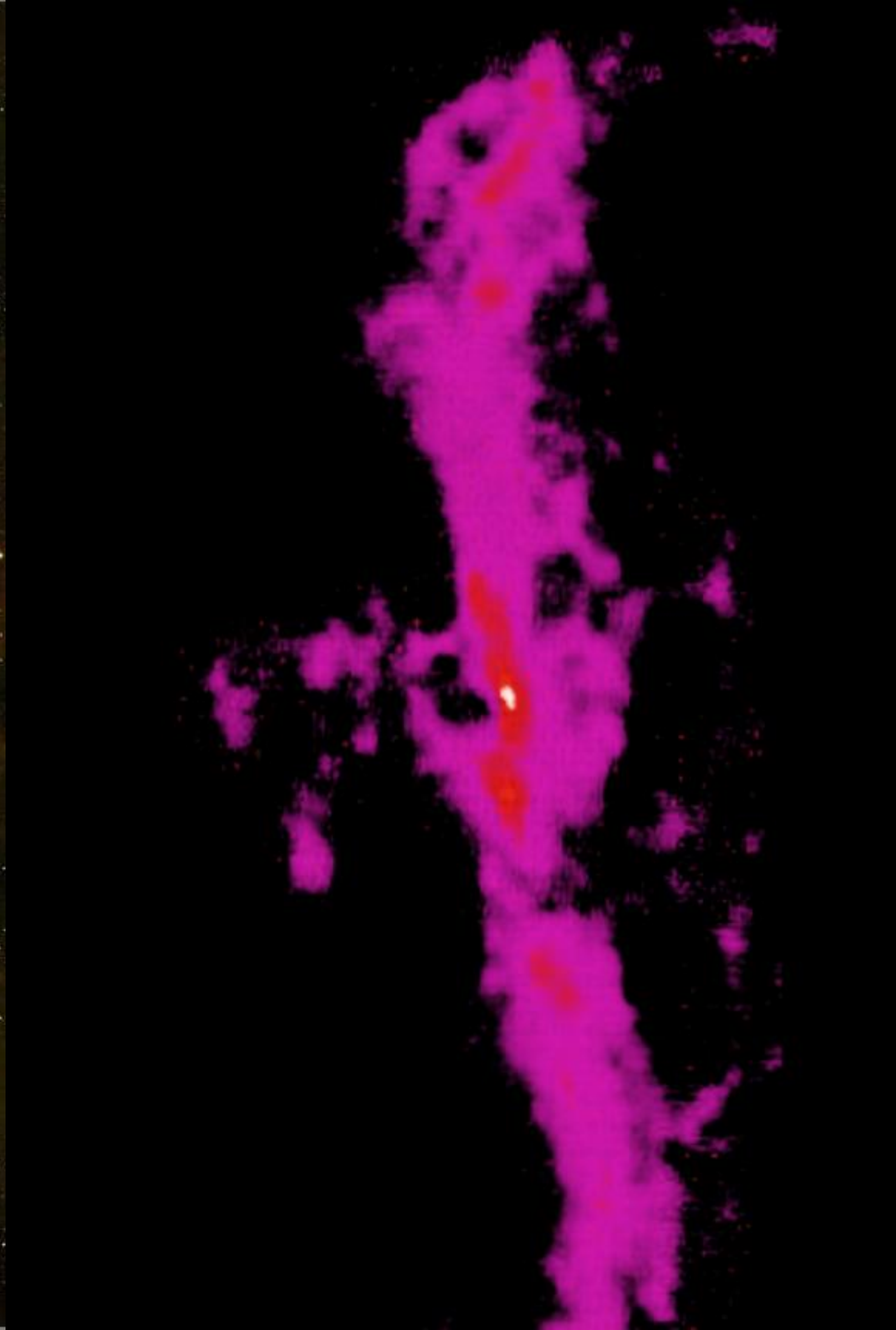
From the relaxed friendly atmosphere, to the fresh delicious food - this is the place to come to in Belfast for a real Italian experience!

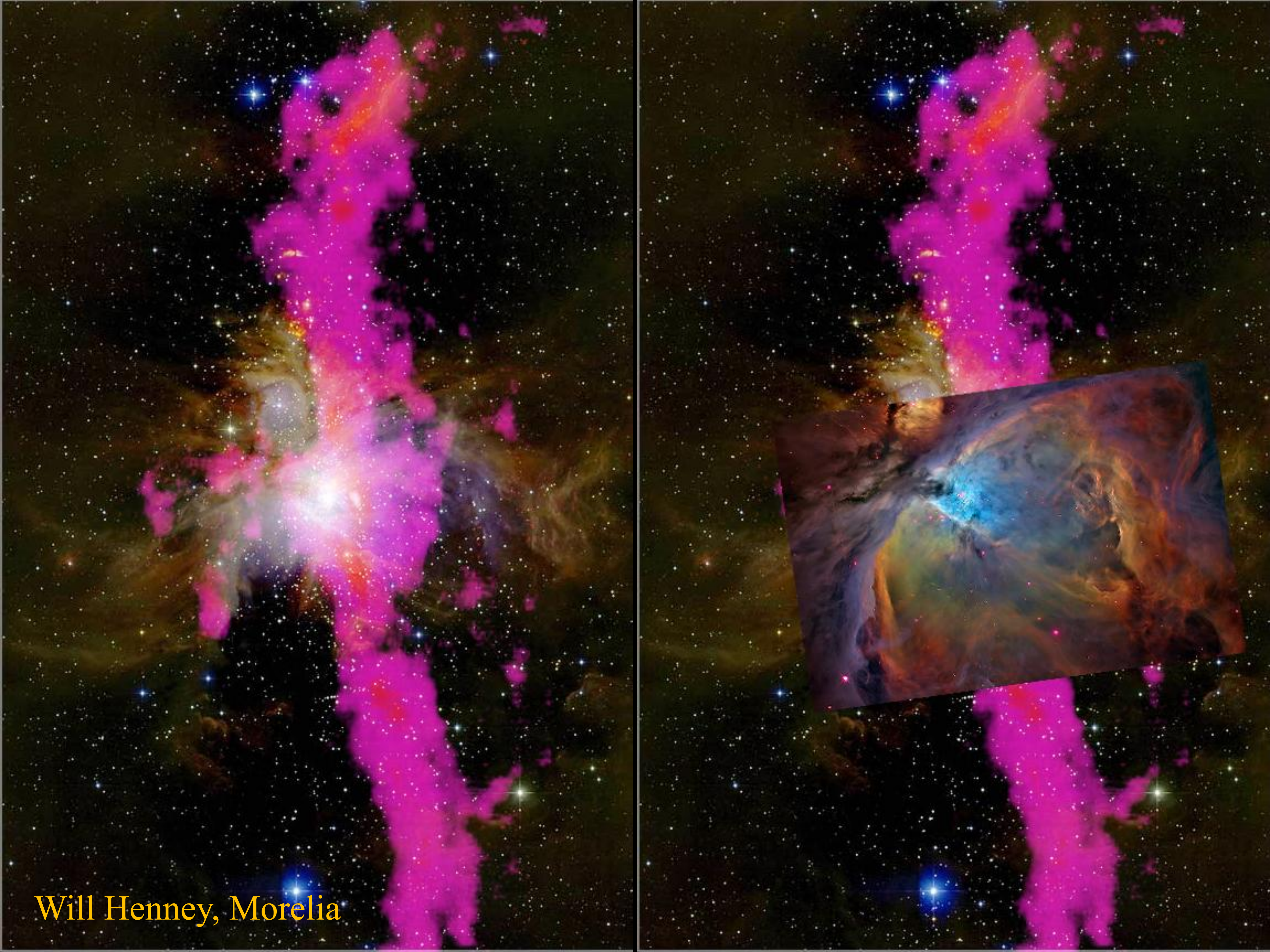
Buon Appetito!

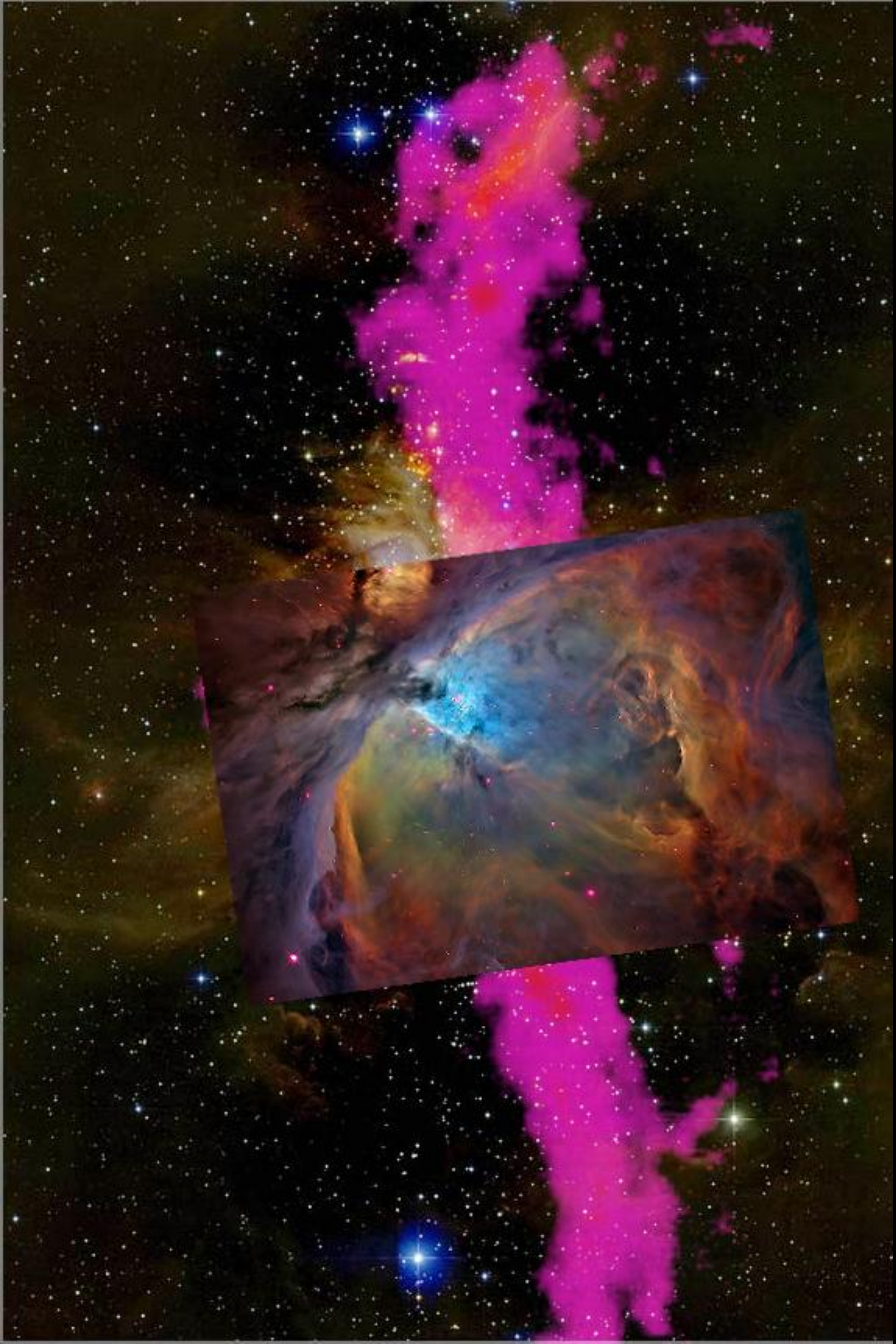
Cloudy workshop school
Welcome!!

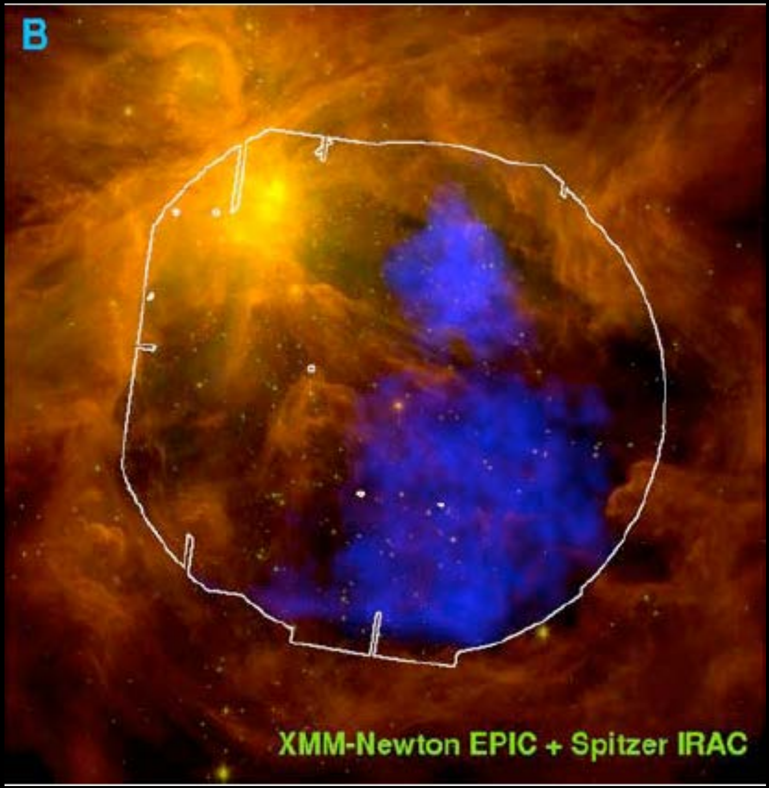
http://cfa-www.harvard.edu/mmw/CO_optical_orion.html


Will Henney, Morelia




Will Henney, Morelia





Guedel+ 2008 Science 319, 309

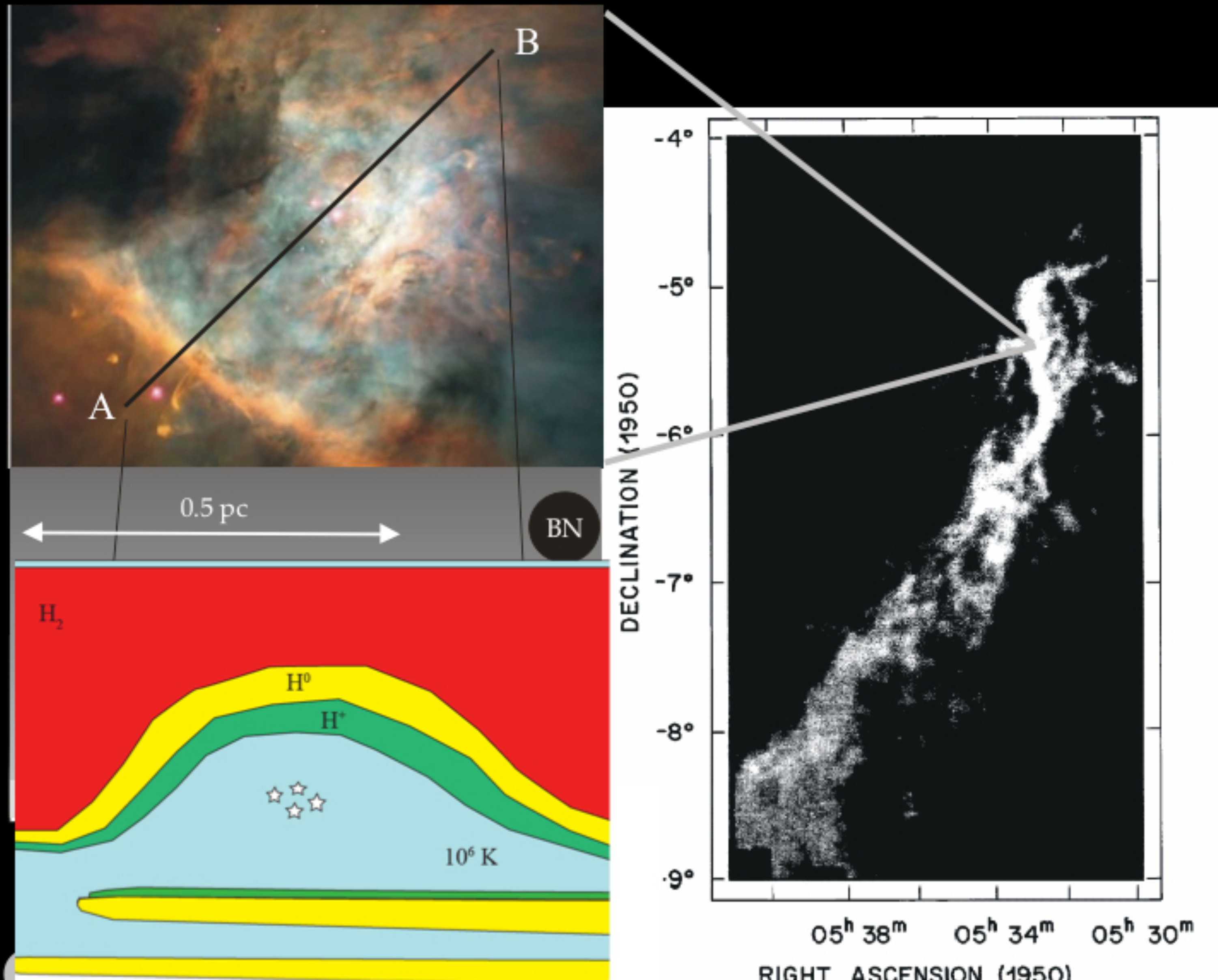
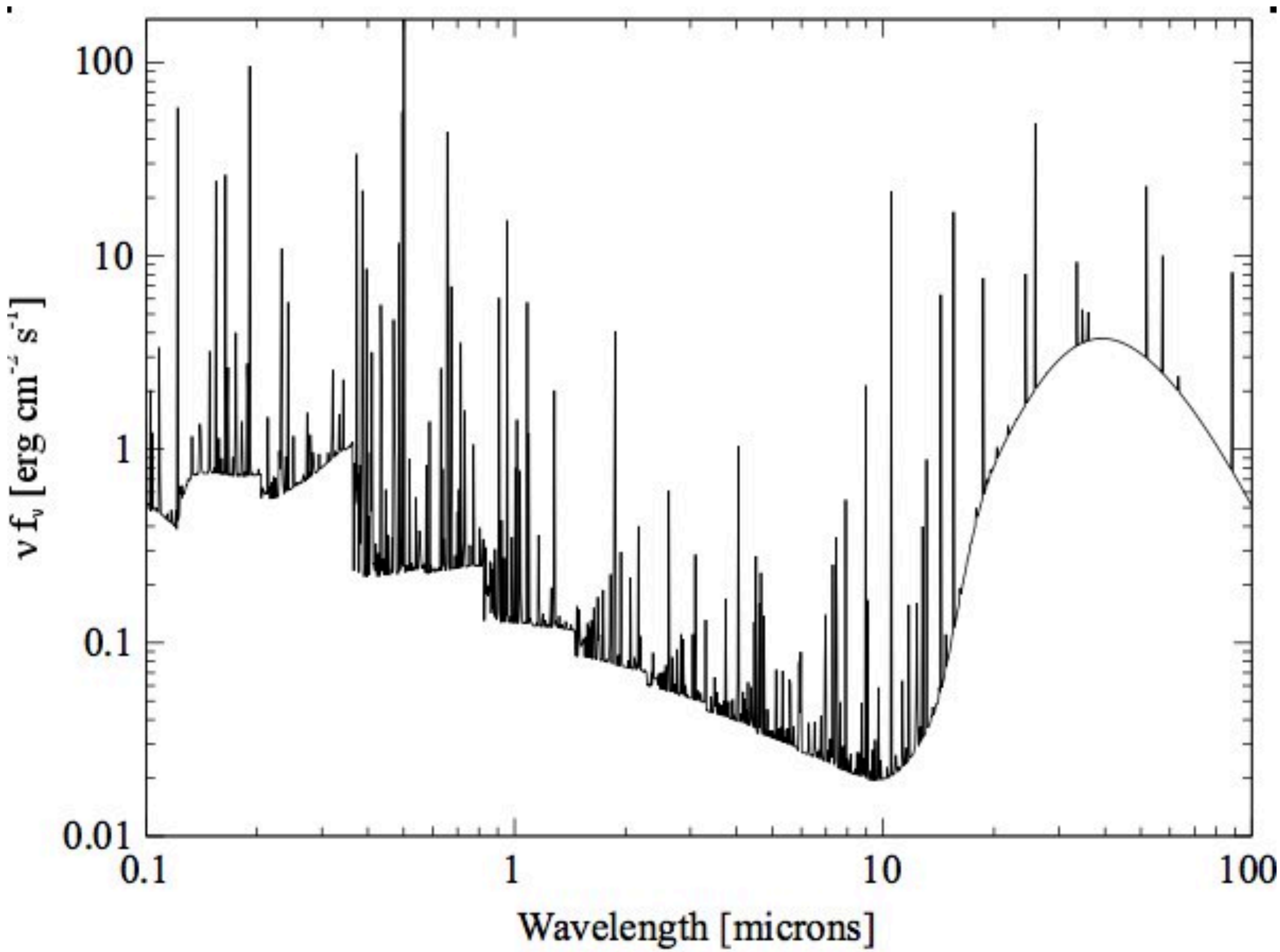
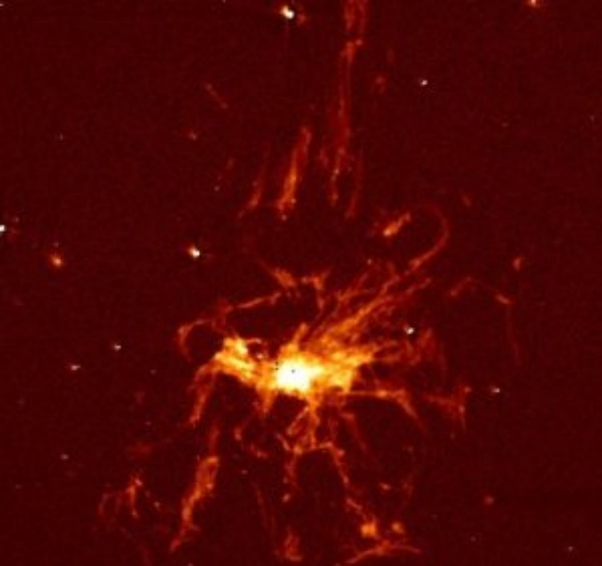
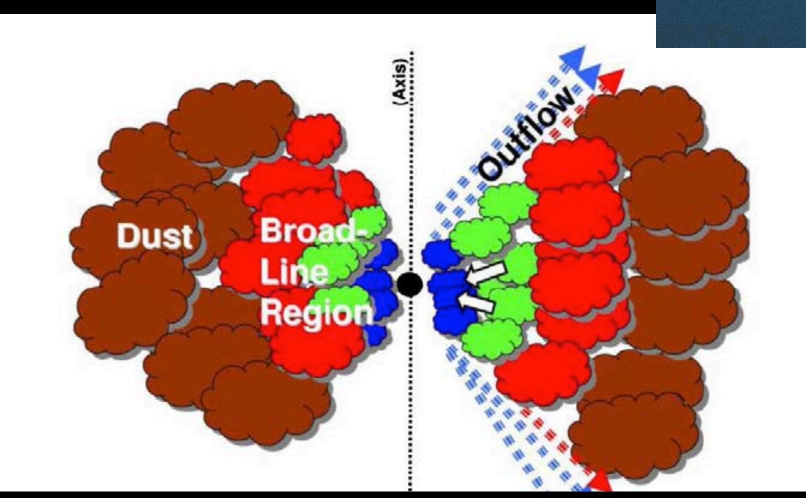


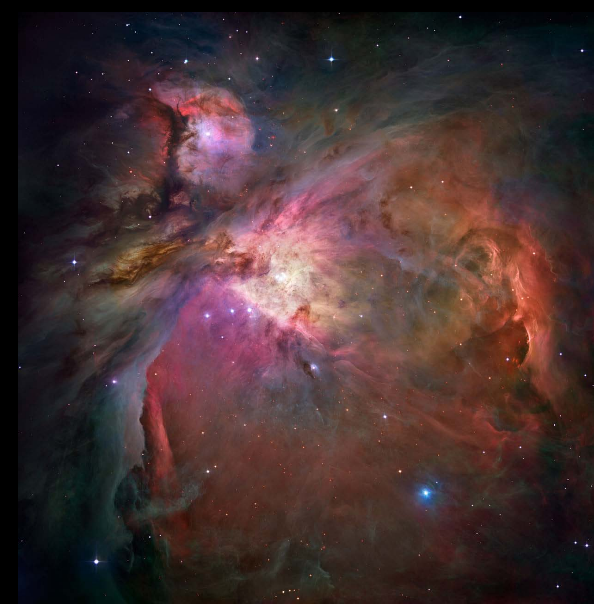
Figure 8.4 AGN3

How to read a spectrum

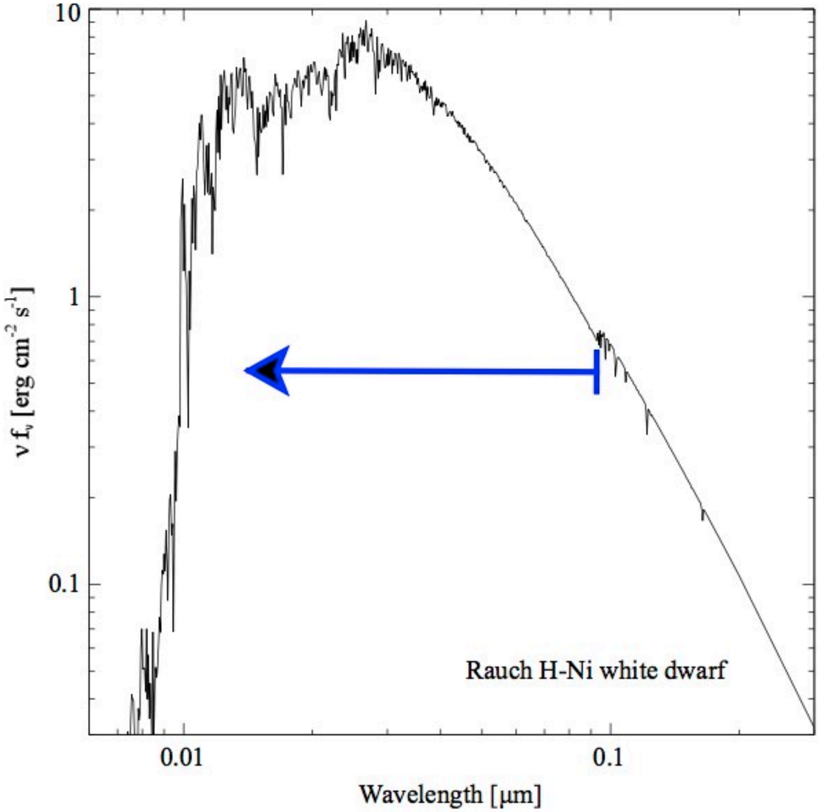




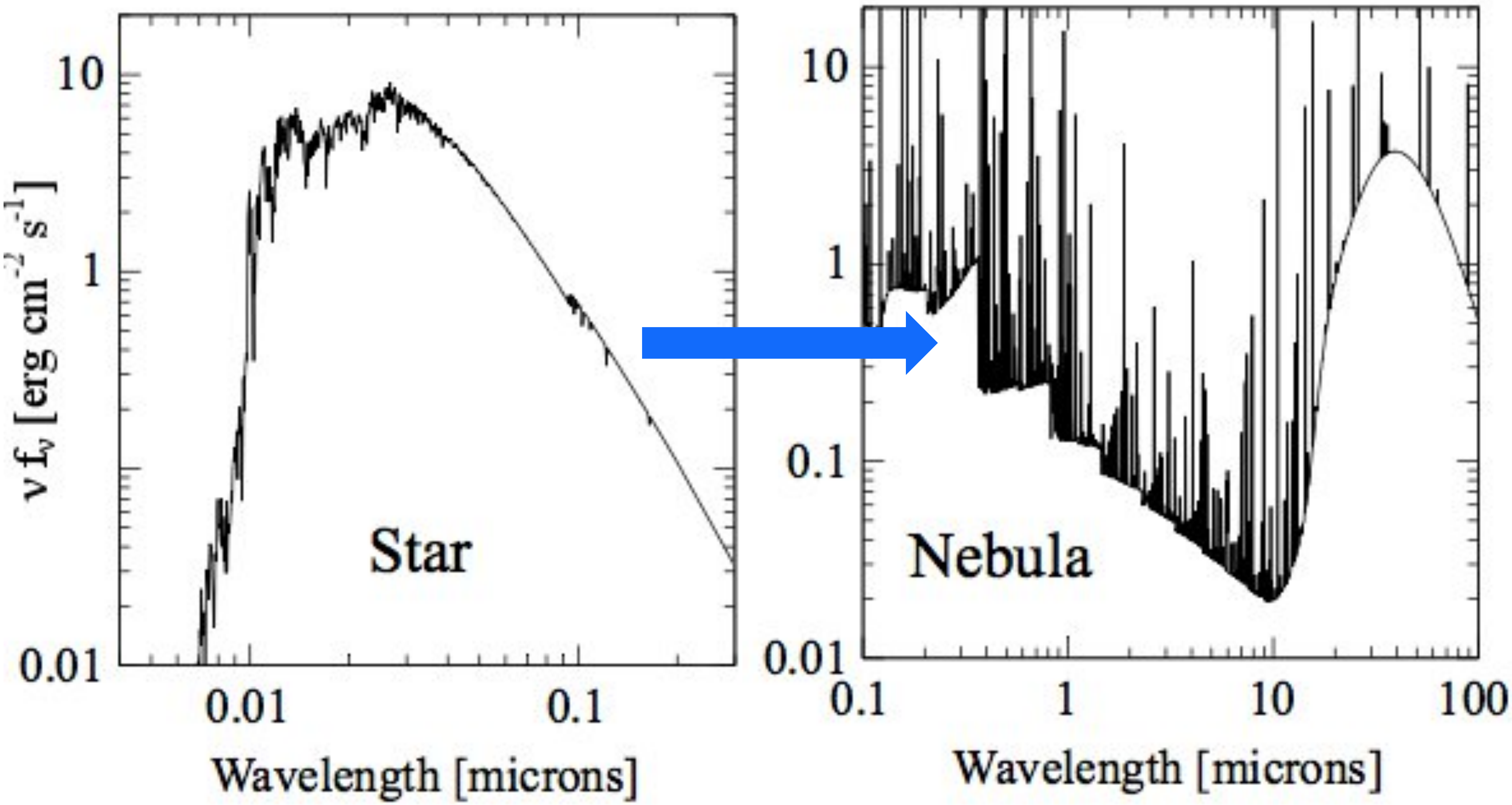

(Axis)
Outflow
Dust
Broad-
Line
Region

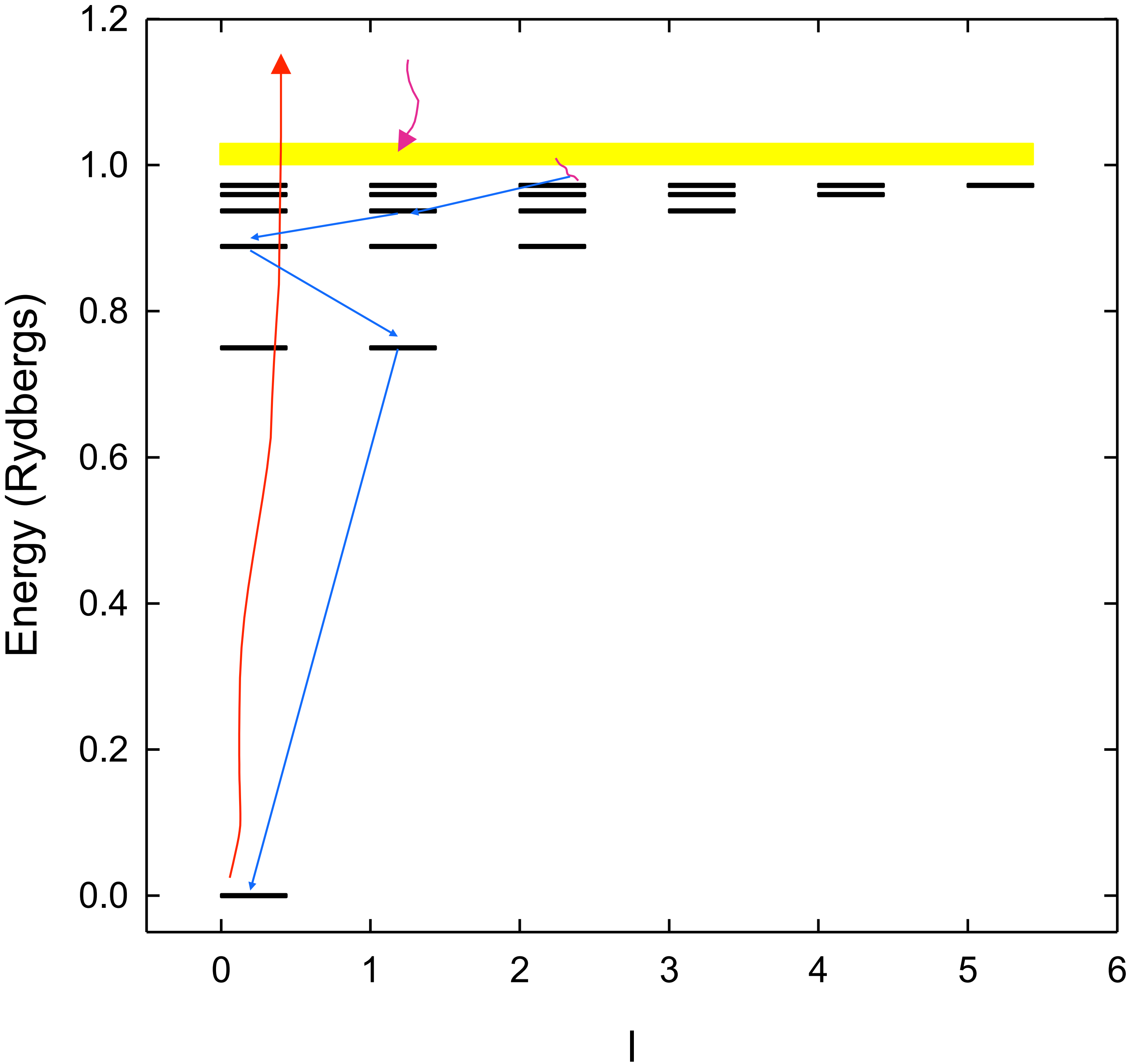


The primary mechanism



Energy is conserved

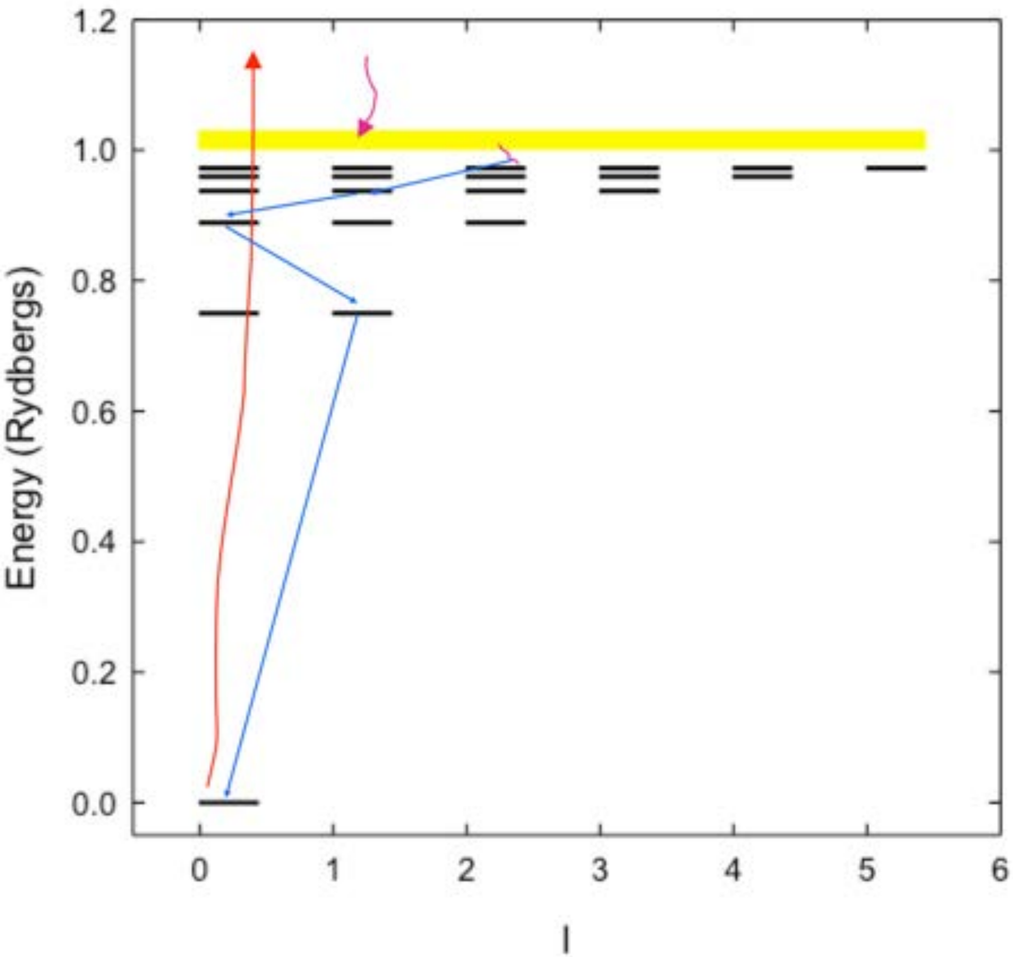




Energy (Rydbergs)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
6
l

Life history of an Orion electron

- H^0 ground state
  - 1 day
- Suprathermal
  - 1 second
- Thermal
  - 1 yr
- H^0 excited states
  - 10^{-7} s
- H^0 ground state



Some jargon – AGN3, Appendix 1

- **Mean intensity *J* (AGN3 eq A1.5)**
  - Mostly deal with $4\pi J$, [erg s^{-1} cm^{-2}]
- **Emissivity *j* (AGN3 Sec A1.7)**
  - Emission per unit volume, [erg s^{-1} sr^{-1} cm^{-3}]
- **Luminosity L**
  - $L = 4\pi j \times$ Volume (if optically thin) [erg s^{-1}]
- **Opacity κ**
  - Absorption per unit length [cm^{-1}]
- **Optical depth τ**
  - $\kappa \times$ Length, with attenuation $\exp(-\tau)$

More jargon – H I vs H^0

- H^0 is atomic hydrogen, a proton and an electron, H^+ is its ion, H_2 its molecule
- H I is the spectrum emitted by H^0. H I is a collection of photons
- It is not correct to speak of the H I column density, although an H I absorption line does measure the H^0 column density
- In an ionized gas recombining H^+ also makes H I lines, so an H I emission line indicates the H^+ column density
- There is no such thing as H II

“Species” in Cloudy

- **Hazy 1, Section 2.5**

Species label	Baryon	Spectrum	Line
H	H^0	H I	H 1 1215.68A
C+	C^+	C II	C 2 2323.50A
Fe+22	Fe^{22+}	Fe XXIII	Fe2 11.1600A
H2	H_2	H_2	H2 17.0300m
CO	CO	CO	CO 2600.05m
C2+	C_2^+	C_2^+	-

Line blends

Line
C 2 2323.50A
C 2 2324.69A
C 2 2325.40A
Blnd 2326.00A

Photoionization balance

- **AGN3 eq 2.1**

$$\text{recombination} = \text{ionization}$$

$$n_e n_p \alpha_B(T) = n(H^0)\int_{\nu_0}^{\infty} \frac{4\pi J_\nu}{h\nu} a_\nu d\nu = n(H^0)\varphi(H)\bar{a}[\text{cm}^{-3}\text{s}^{-1}],$$

Number of ionizing photons

- **Total emitted into 4π**

5.14 Q(H) = 56.789 [range...]

This is the log of the total number of ionizing photons emitted by the central object [s^{-1}]

$$Q(\mathrm{H}) = 4\pi\, R_{star}^2 \int_{\nu_1}^{\nu_2} \frac{\pi F_\nu}{h\nu}\, d\nu. \qquad (5.7)$$

The default energy range is 1 Ryd to 7.354×10^6 Ryd and the **range** option can be used to change the energy bounds ν_1 and ν_2. The photon flux (the number of photons per unit area of cloud surface) can be specified with the **phi(H)** command[3].

- **Photons per sq cm**

5.13 phi(H) = 12.867 [range...]

This command specifies the log of Φ(H), the surface flux of hydrogen-ionizing photons [$cm^{-2}\ s^{-1}$] striking the illuminated face of the cloud. It is defined as

$$\Phi(\mathrm{H}) \equiv \frac{Q(\mathrm{H})}{4\pi\, r_0^2} \equiv \frac{R_{star}^2}{r_0^2} \int_{\nu_1}^{\nu_2} \frac{\pi F_\nu}{h\nu}\, d\nu\,[\mathrm{cm^{-2}\ s^{-1}}] \qquad (5.6)$$

and is proportional to the optical depth in excited lines, such as the Balmer lines (Ferland et al., 1979; AGN3). The range option can be used to change the default energy range, given by the values of ν_1 and ν_2.

Photoionization balance

- **Photoionization rate set by radiation field, not related to temperature**
- **Recombination depends on temperature, $\alpha \sim T^{-1}$**
  - Tables in Ch 2, Appendix 5; discussed in Appendix 4

Photoionization balance

- **AGN3 eq 2.1**

$$\varphi(H)\, n(H^0)\, \langle \sigma \rangle = n_p\, n_p\, \alpha$$

$$\frac{n_p}{n(H^0)} = \frac{\varphi(H)}{n_e}\; \frac{\langle \sigma \rangle}{\alpha}$$

$$\langle \sigma \rangle \sim 10^{-18}\ \mathrm{cm}^{-2}$$

$$\langle \sigma \rangle \sim 10^{-13}\ \mathrm{cm}^{3}\, \mathrm{s}^{-1}$$

Ionization parameter

- **AGN eq 14.7**

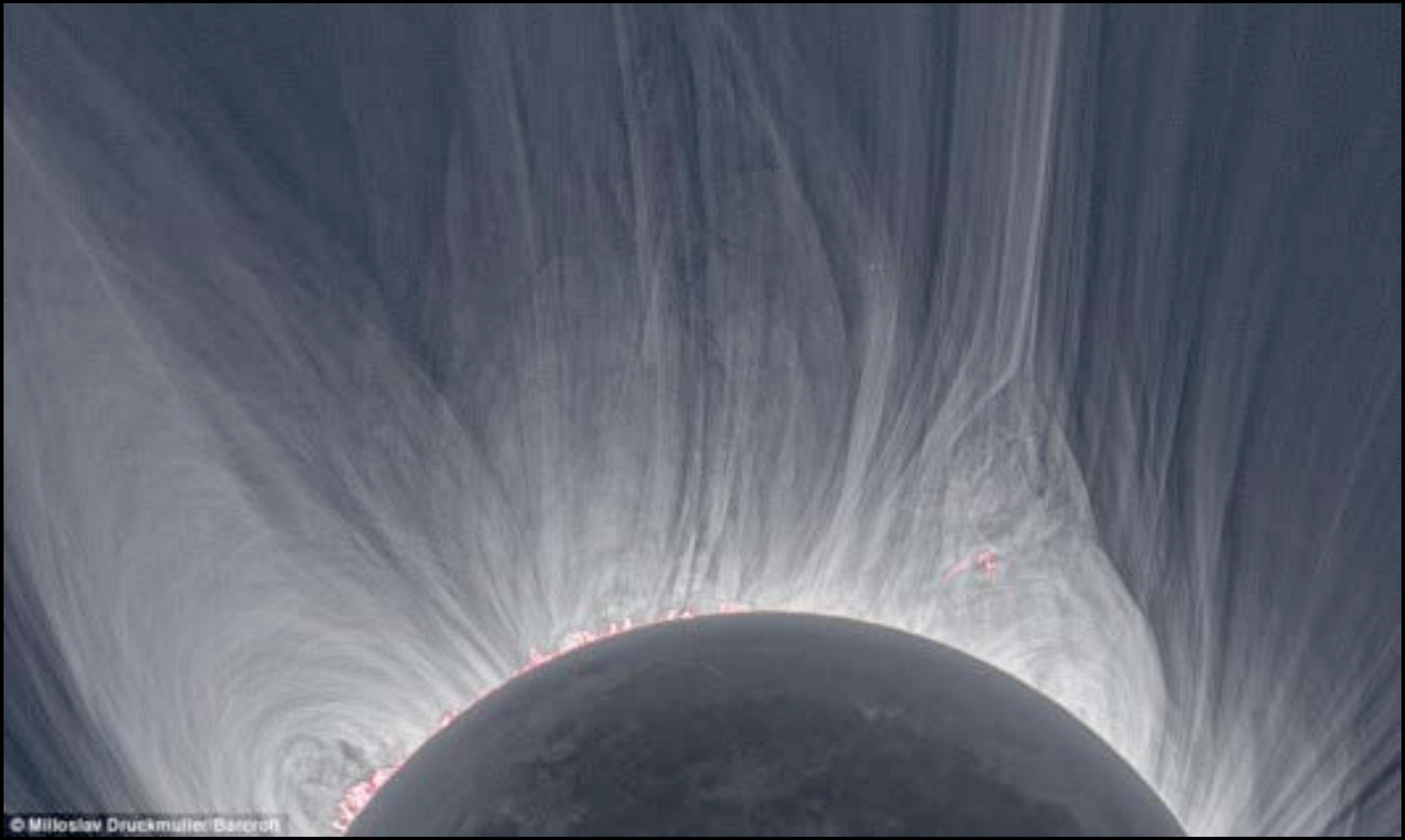
5.8 ionization parameter $= -1.984$

The ionization parameter is the dimensionless ratio of hydrogen-ionizing photon to total-hydrogen densities. It is defined as

$$U \equiv \frac{Q(\mathrm{H})}{4\pi r_0^2 n(\mathrm{H})\, c} \equiv \frac{\Phi(\mathrm{H})}{n(\mathrm{H})\, c} \qquad (5.4)$$

(AGN3, equation 14.7, page 357). Here r_o is the separation [cm] between the center of the source of ionizing radiation and the illuminated face of the cloud, n(H) [cm^{-3}] is the total[1] hydrogen density (ionized, neutral, and molecular), c is the speed of light, Q(H) [s^{-1}] is the number of hydrogen-ionizing photons emitted by the central object, and Φ(H) [$\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$] is the surface flux of ionizing photons. The number is interpreted as the log of U unless the keyword **linear** appears. The ionization parameter is a useful quantity in plane-parallel, low-density, constant-density, models, because of homology relations between models with different photon and gas densities but the same ionization parameter (see Davidson, 1977).

Coronal equilibrium



www.funzug.com

Coronal (Collisional) ionization

- **q_{ion} – collisional ionization rate coefficient [cm^3 s^{-1}]**
- **Rate set by gas temperature & ionization potential of a species**
  - Radiation field does not matter
- **AGN3 eq 12.6, 12.7**

$$n(H^0)\, n_e\, q_{ion} = n_p\, n_e\, \alpha$$

$$q_{ion} \sim k \exp\left(-T_{ion}/T_{gas}\right)$$