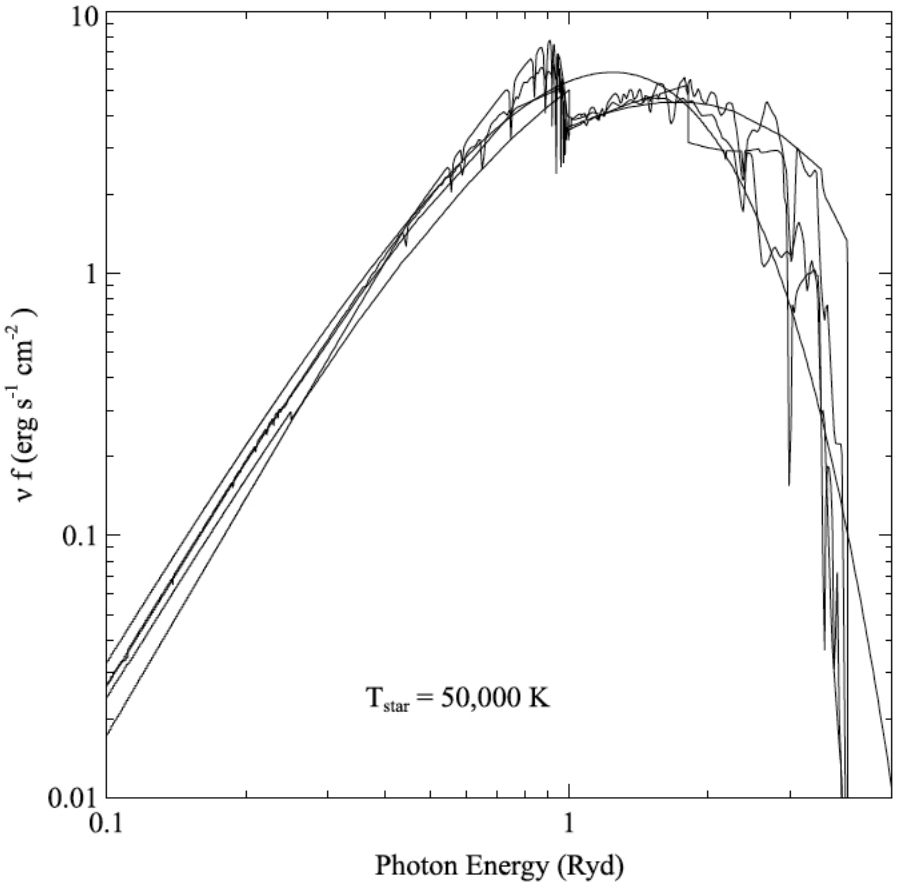
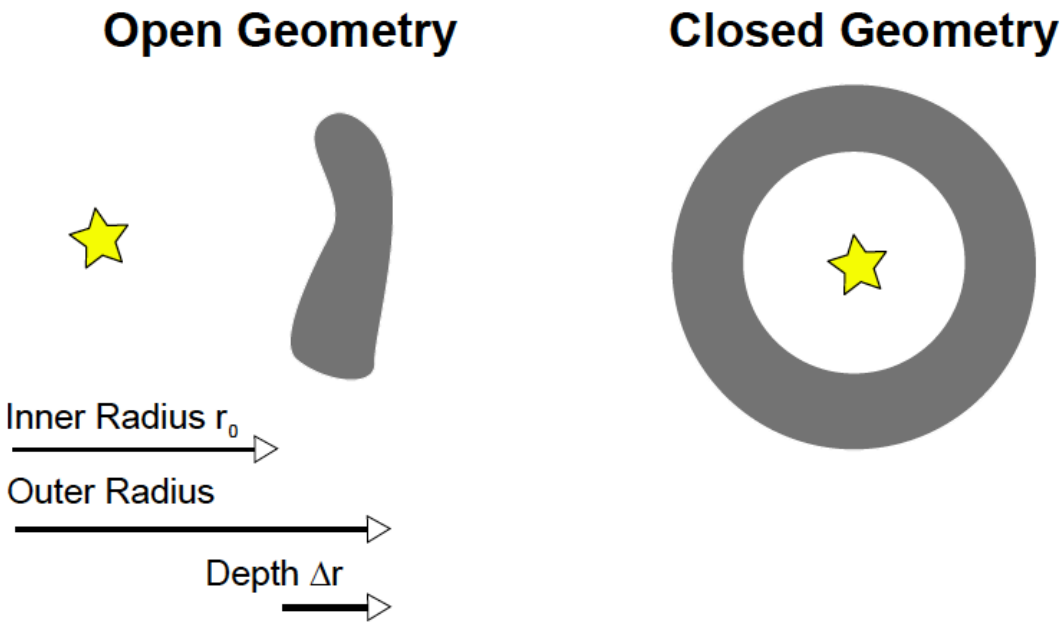
Minimum to run Cloudy

- **Must specify**
  - SED – shape of the radiation field
  - Flux of photons per unit area
  - Gas density
- **May specify**
  - Gas composition, grains (grain-free solar by default)
  - Gas equation of state (often constant density)
  - Stopping criterion, often physical thickness

Parameters – the SED

- Quick start guide Chapter 5
- Hazy 1, Chapters 4, 6
- Can be specified as a fundamental shape such as a blackbody
- Generally entered as table of points




Open Geometry
Closed Geometry
Inner Radius r_0
Outer Radius
Depth Δr

SED brightness – the intensity case

- **Specify φ(H) – photons per unit area**
  - The “intensity case”
  - predicts emission per unit area
  - Inner radius of cloud does not need to be specified

SED brightness – the luminosity case

- **Specify Q (H) – photon luminosity**
  - Inner radius of cloud must be specified, since $f(H) = Q(H) / 4\pi r^2$
  - predicts emission line luminosities

The “main output”

- **The *.out file created when code is executed**
  - QSG 7.1 & Hazy 2 Chapter 1
- **Gas & grain composition**
- **Physical conditions in first and last zone**
- **Emission line spectrum**
- **Mean quantities**

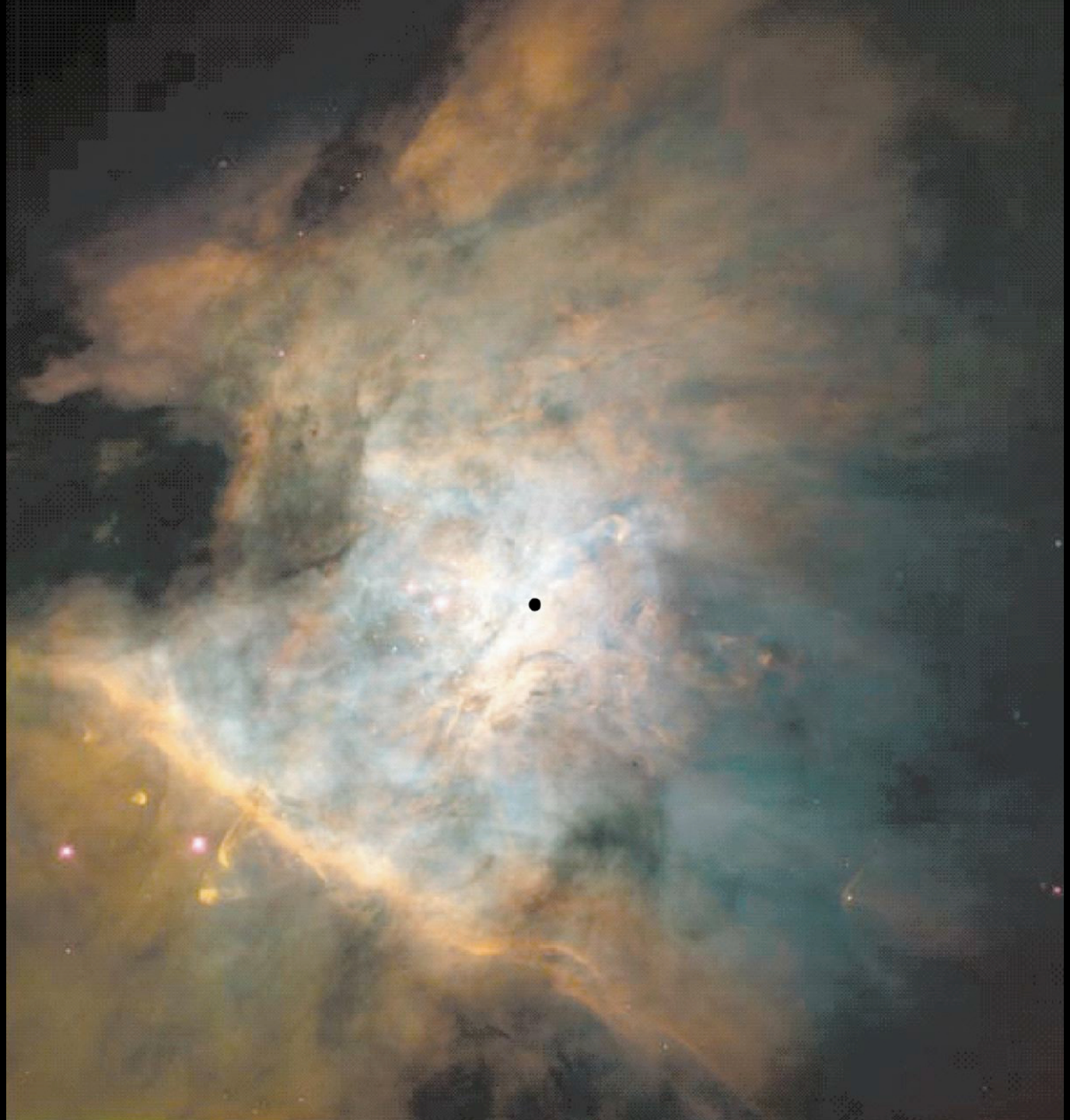
- **Cloudy is designed to be autonomous and self aware**
- **Will generate notes, cautions, or warnings, is conditions are not appropriate.**

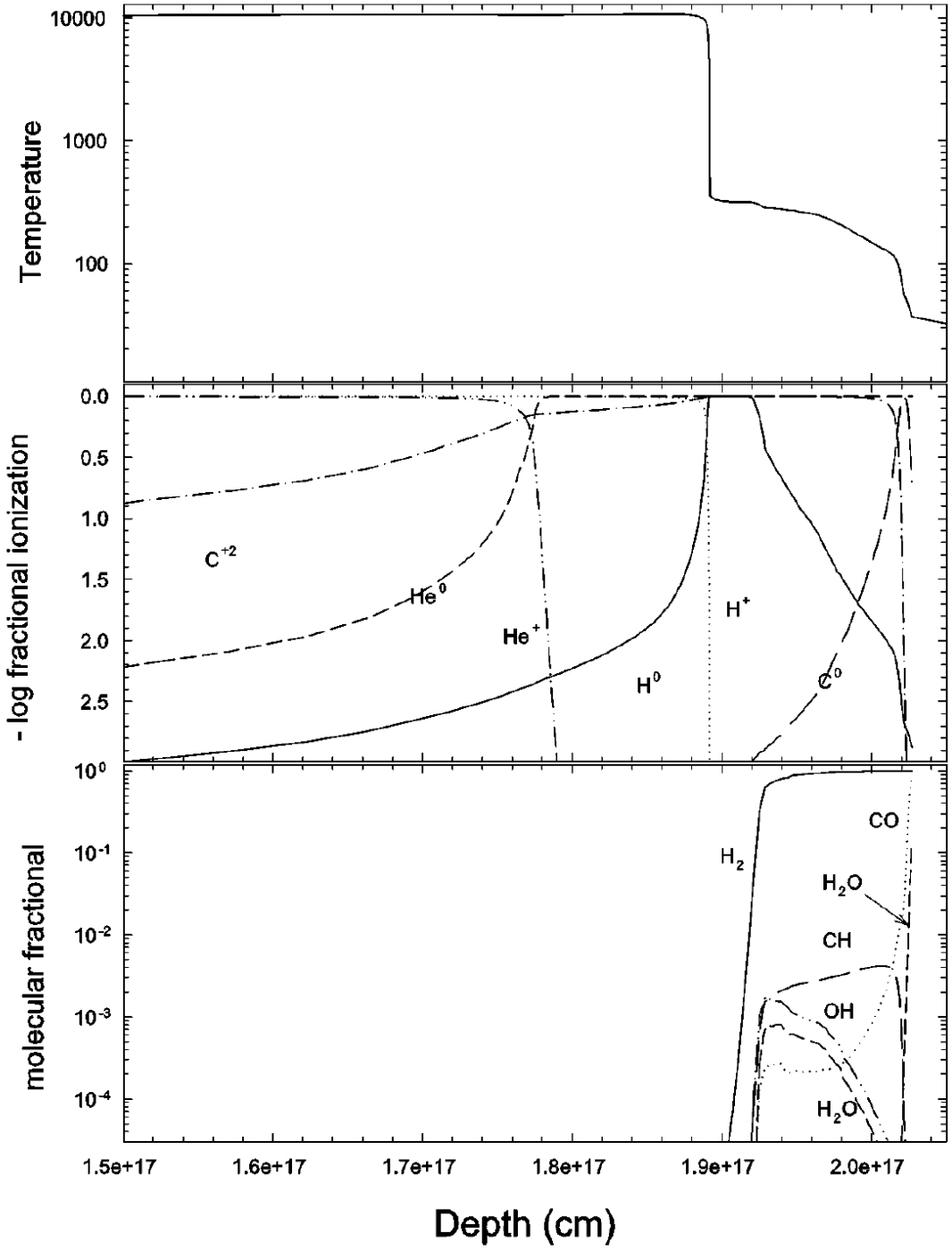
“Save” output

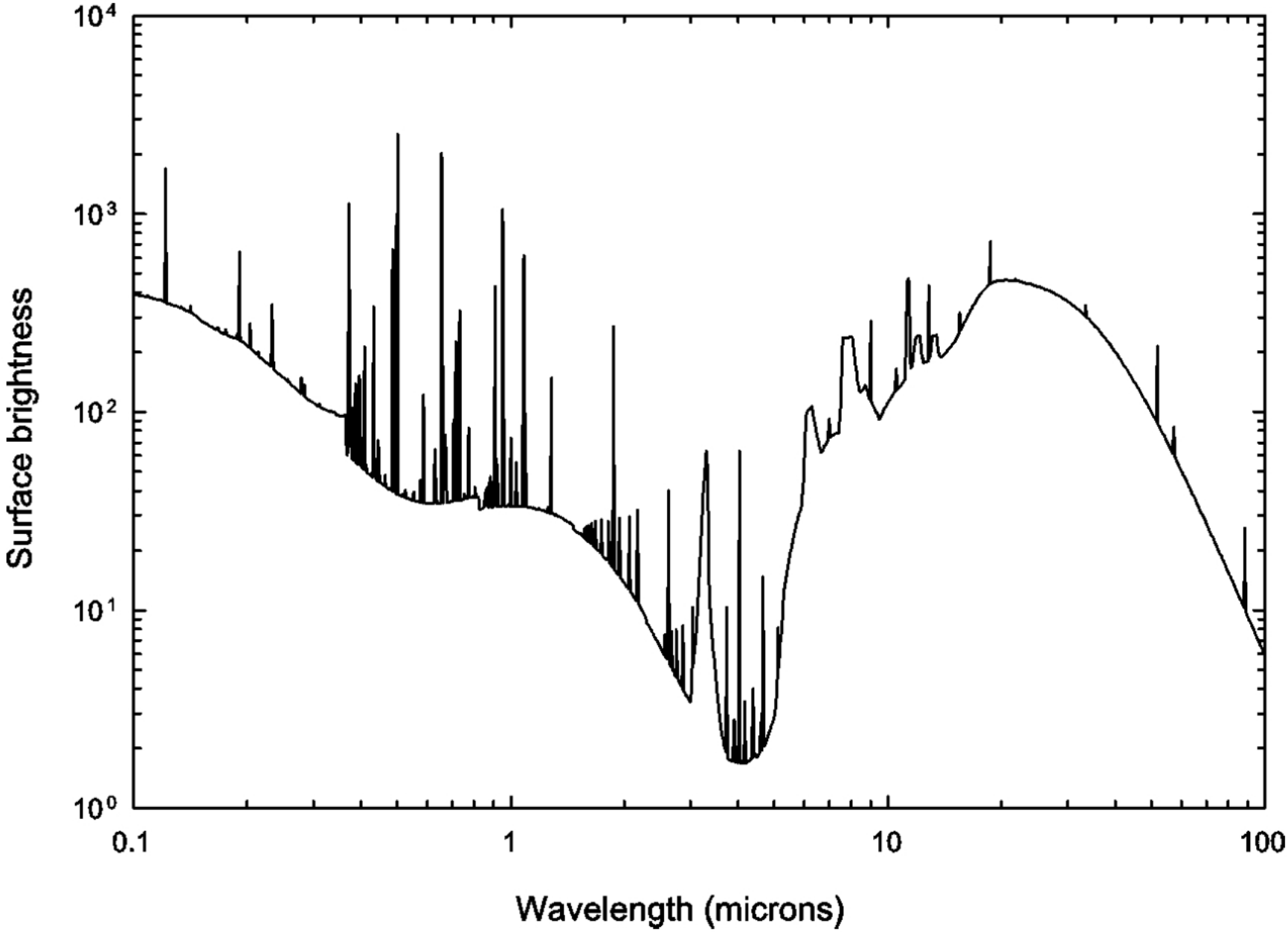
- **Requested with various “save” commands**
  - Hazy 1 Section16.35 and later
- **The main way the code reports its results**

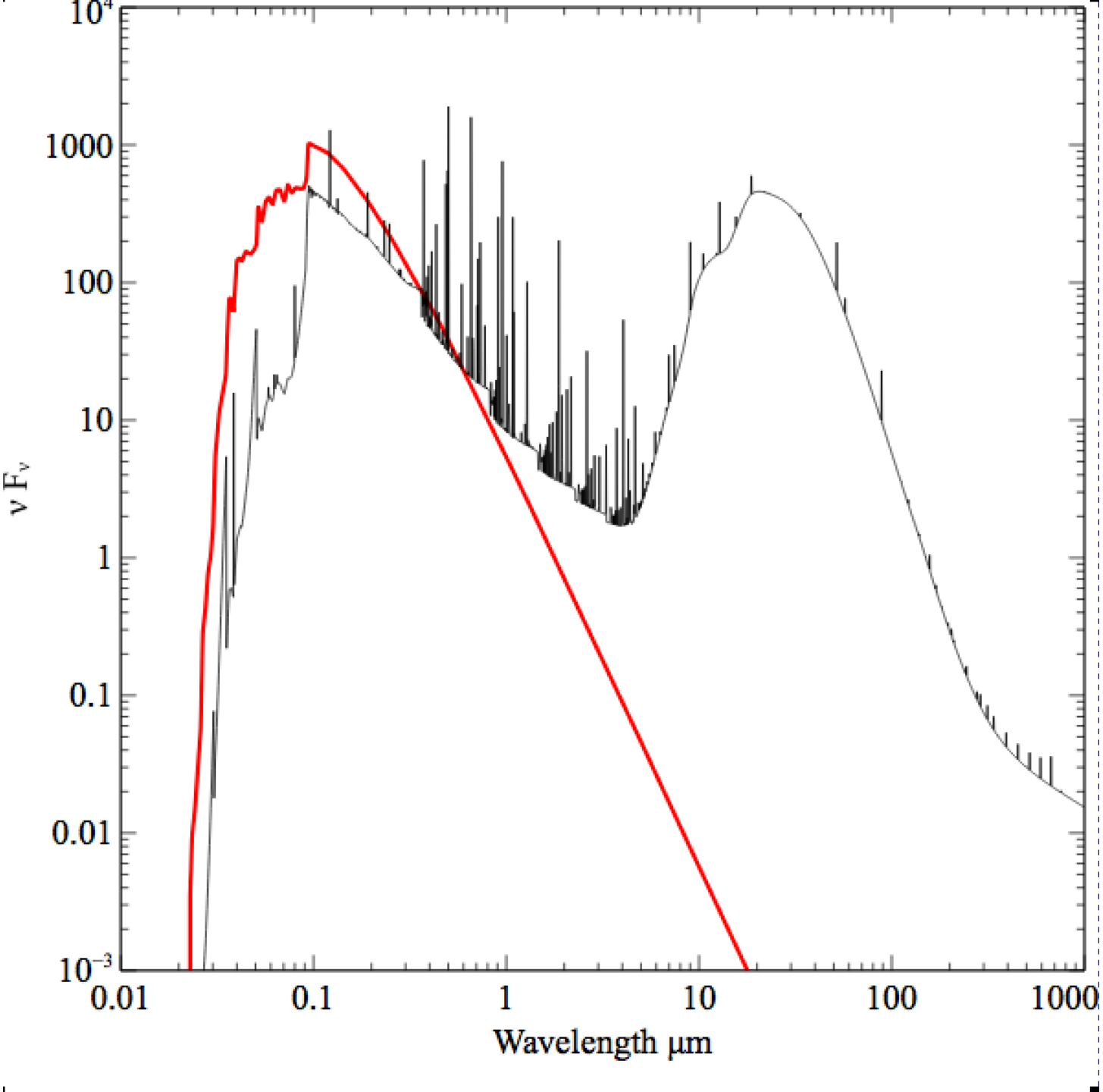
The Orion H II Region

- Based on Baldwin, Ferland, Martin+91 model
- Layer in hydrostatic equilibrium
- Only the H II region (so faster)
- Cloudy / tsuite / auto / orion_hii_open.in




Temperature
10000
1000
100
- log fractional ionization
0.0
0.5
1.0
1.5
2.0
2.5
C+2
He0
He+
H0
H+
C0
molecular fractional
10^0
10^-1
10^-2
10^-3
10^-4
H2
CO
H2O
CH
OH
H2O
1.5e+17
1.6e+17
1.7e+17
1.8e+17
1.9e+17
2.0e+17
Depth (cm)


10^4
10^3
10^2
10^1
10^0
Surface brightness
0.1
1
10
100
Wavelength (microns)


10^4
1000
100
10
1
0.1
0.01
10^{-3}
νF_ν
0.01
0.1
1
10
100
1000
Wavelength μm

Parameters – the SED

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SED brightness – the intensity case

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SED brightness – the luminosity case

- **Specify Q (H) – photon luminosity**
  - Inner radius of cloud must be specified, since $\varphi(H) = Q(H) / 4\pi r^2$
  - predicts emission line luminosities

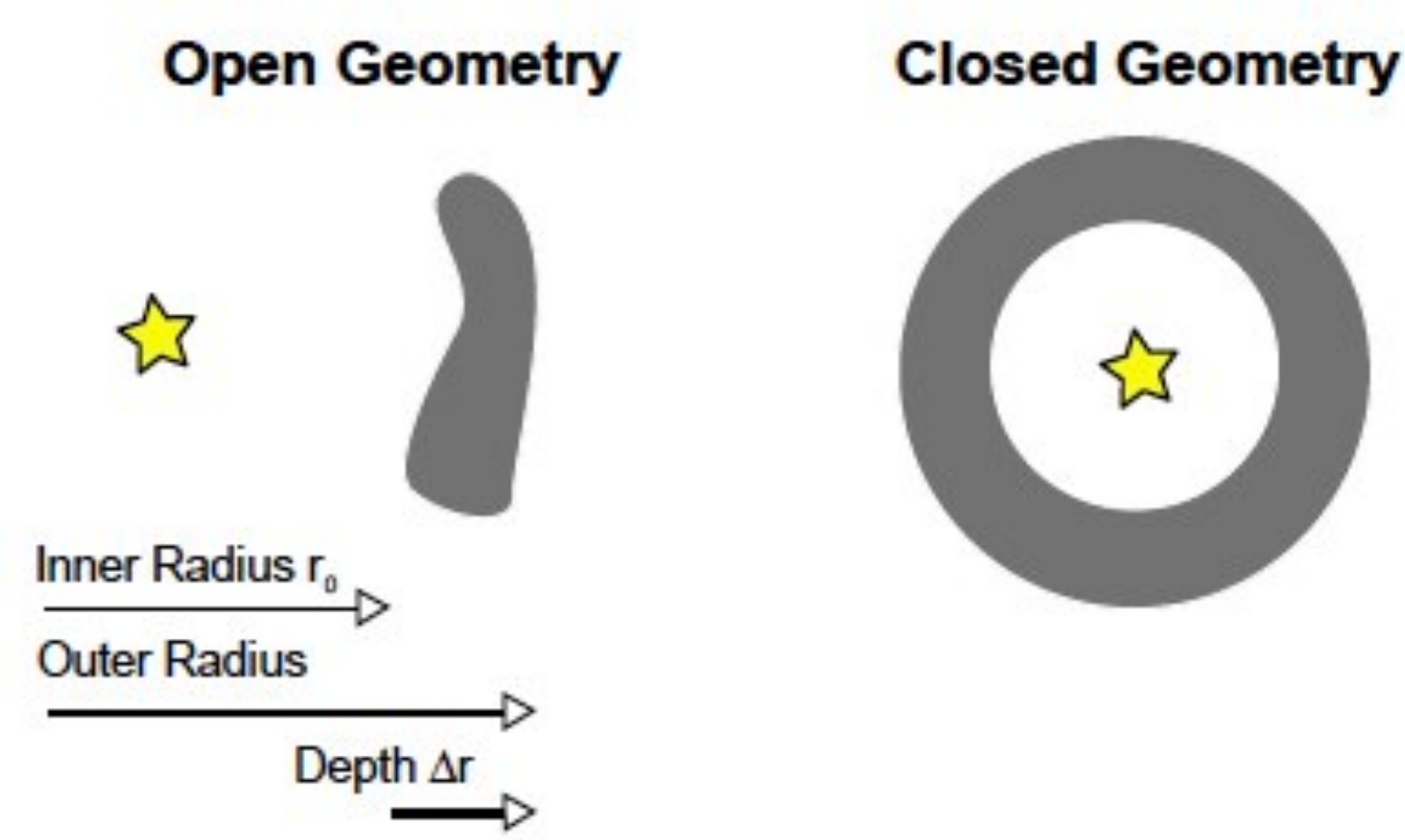
Cloud density

- “hden” command
- Constant density by default
- Other equations of state possible

Composition

- Solar, no grains, by default
- Other standard mixes possible

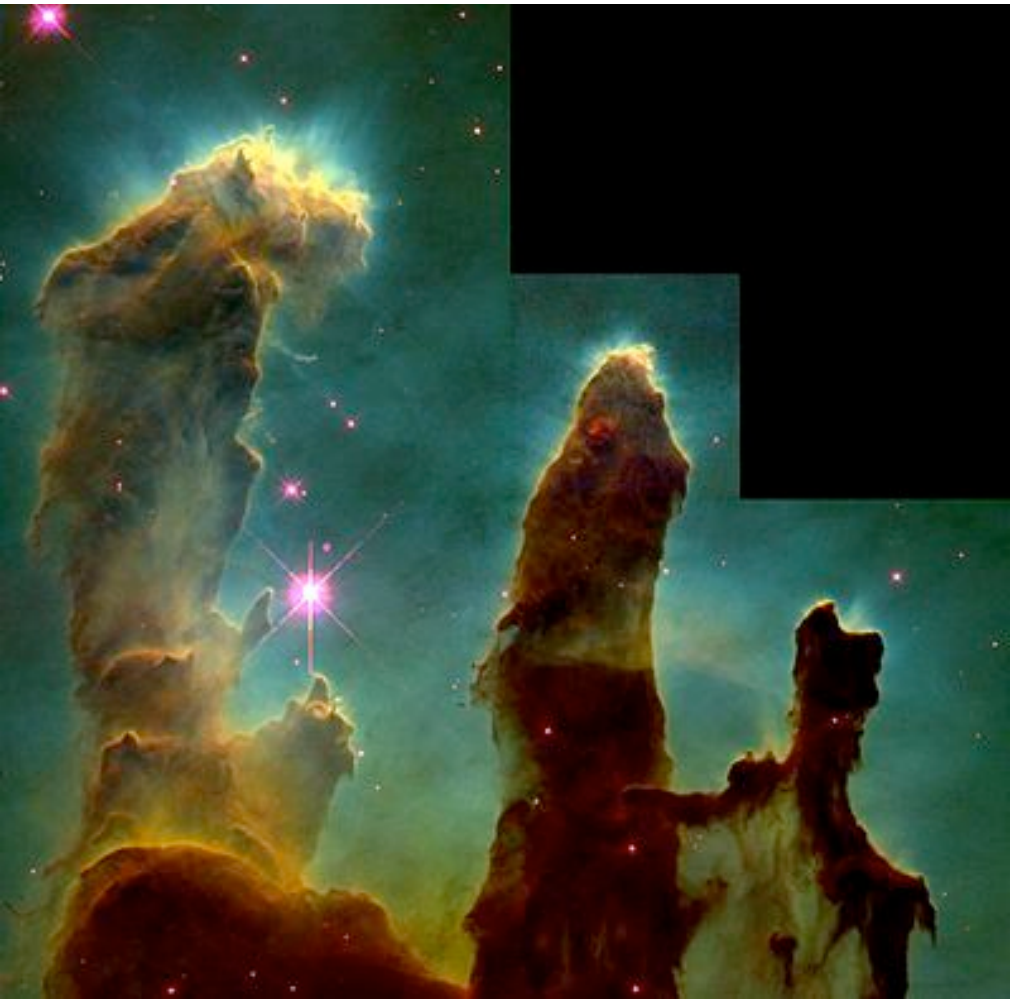
Open vs closed geometry Hazy 2.3



Covering and filling factors

- **Covering factor**
  - AGN3 …
- **Filling factor, how to do clumps**
  - AGN3, hazy1

Strömgren length



Strömgren length

- **Number of ionizing photons entering layer is balance by number of recombinations along it**

$$\varphi(H) = n_e n_p \alpha \; L$$

$$L \propto \frac{\varphi(H)}{n_e n_p \alpha}$$

Matter vs radiation bounded

- SL is for radiation bounded, there is an I front
- Show Abell sphere – matter bounded,
- So phi(H) > SL equation
- Show pics, give section in AGN3

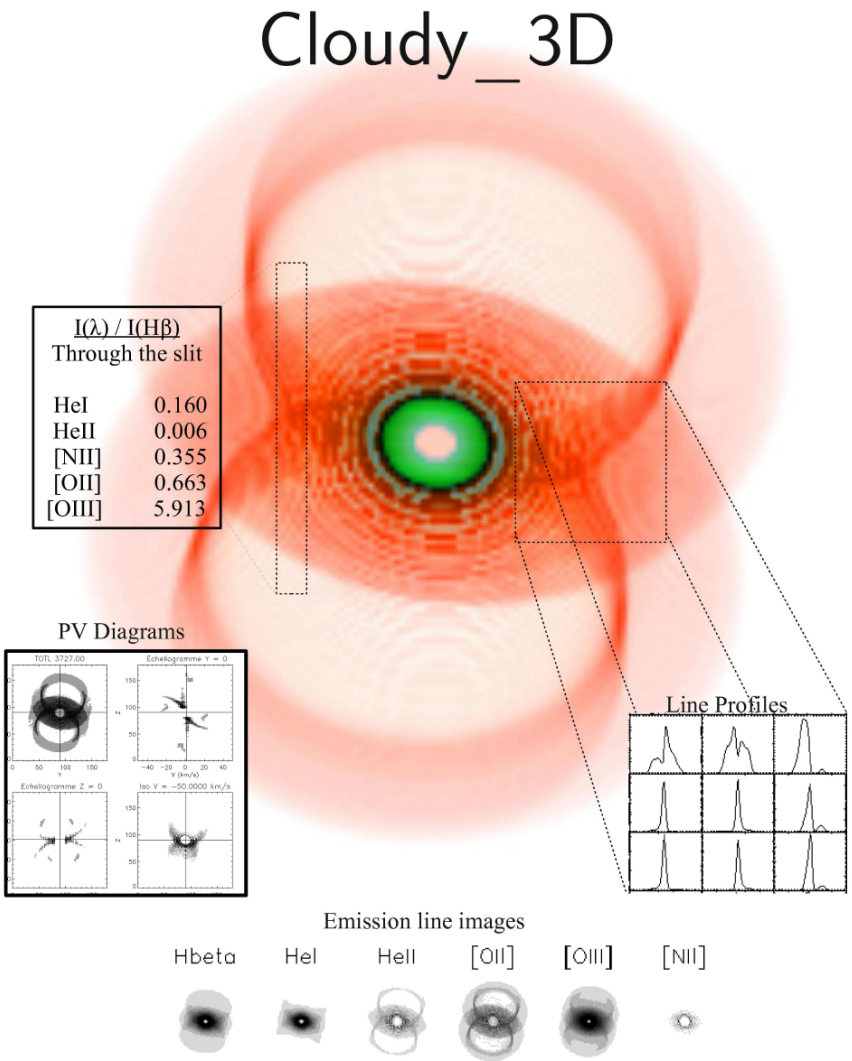
Beyond the H^+ layer

- Little H^+ ionizing radiation gets past the H^+ layer
- Deeper regions are atomic or molecular
- Also cold and produce little visible light
- Large extinction due to dust

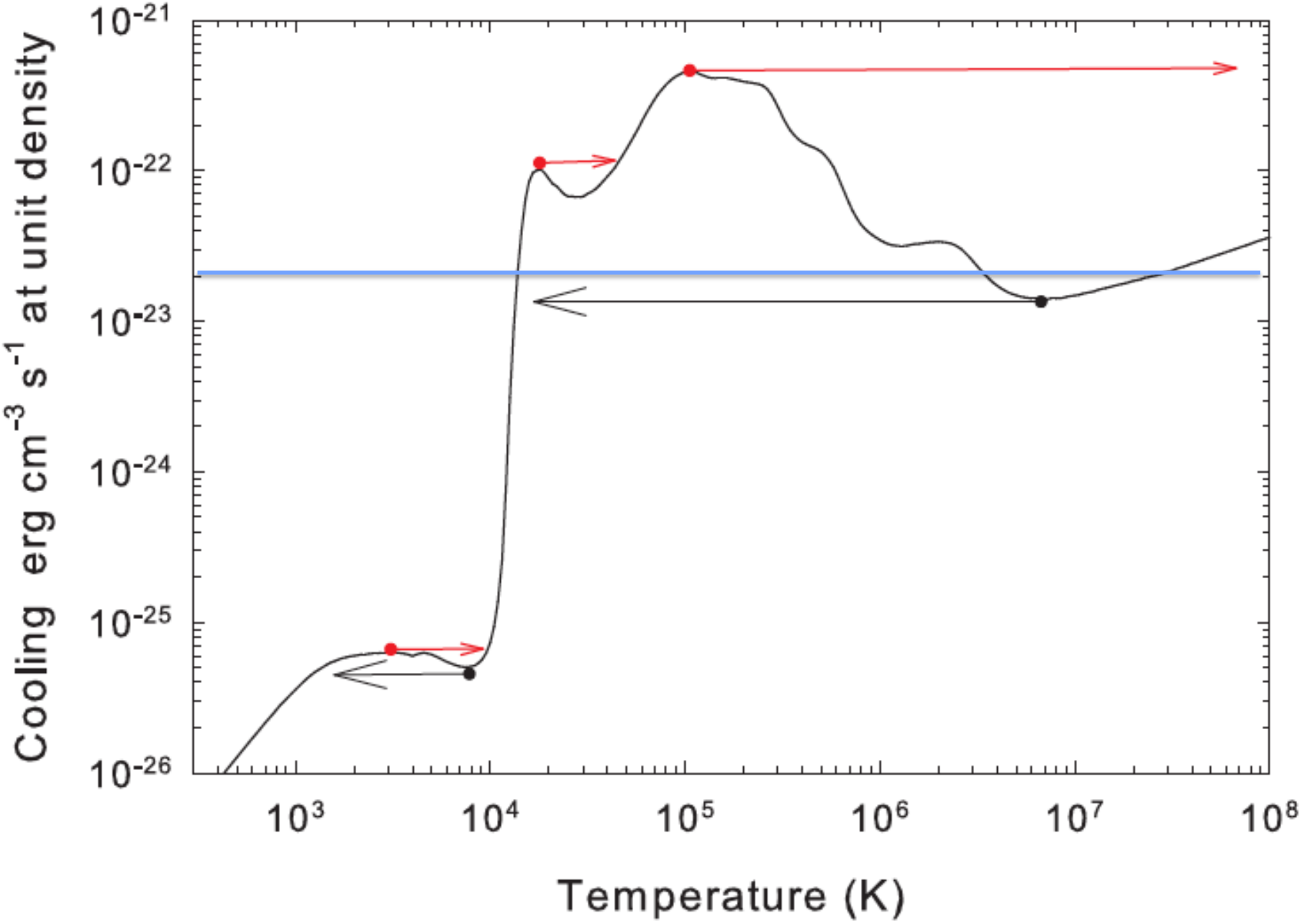
Clumping

- **Filling factors, when clumps smaller than photon scale length**
  - Osterbrock & Flather 1957
- **Add together distinct clouds, when clumps larger than photon scale length**
  - Balwin+ 1995 ApJ **455,** L119+

Volume elements in larger structures



http://sites.google.com/site/cloudy3d/


Cooling erg cm^{-3} s^{-1} at unit density
10^{-21}
10^{-22}
10^{-23}
10^{-24}
10^{-25}
10^{-26}
10^{3}
10^{4}
10^{5}
10^{6}
10^{7}
10^{8}
Temperature (K)