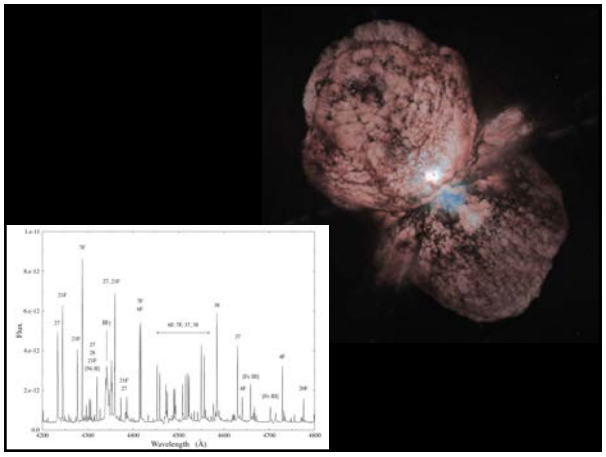
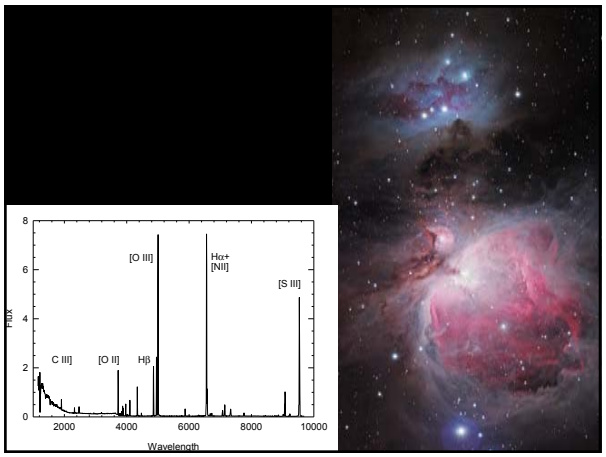
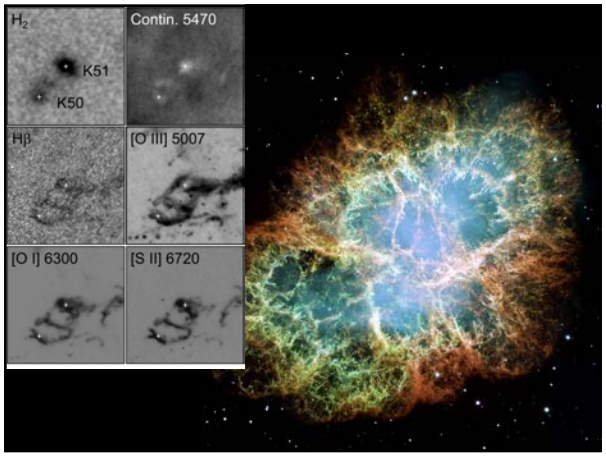


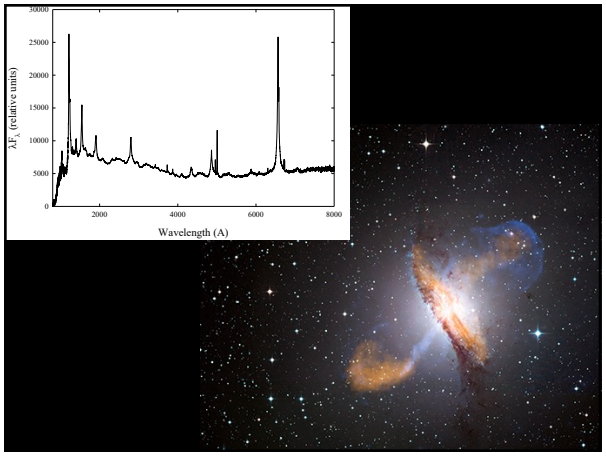
1


[O III]
Hα+
[NII]
[S III]
C III]
[O II]
Hβ
Flux
Wavelength

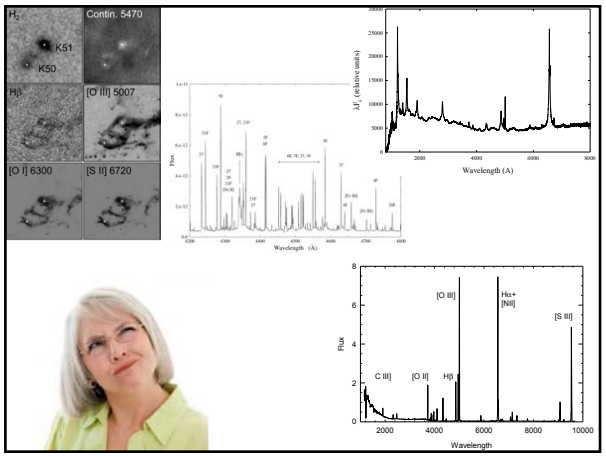
2


H2
K51
K50
Contin. 5470
Hβ
[O III] 5007
[O I] 6300
[S II] 6720

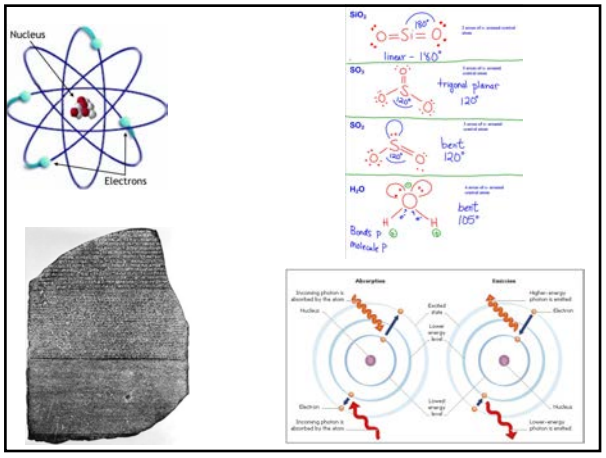
3


λF_λ (relative units)
Wavelength (A)

4


H2
Contin. 5470
K51
K50
Hβ
[O III] 5007
[O I] 6300
[S II] 6720
Wavelength (A)
Flux
[O III]
Hα+ [NII]
[S II]
C III]
[O II]
Hβ
Wavelength

5


Nucleus
Electrons
linear - 180°
trigonal planar 120°
bent 120°
bent 105°
Bonds P
molecule P
Absorption
Emission

6

Light is much harder than gravity

$$F = G\frac{m_1 m_2}{d^2}$$

vs

$$\dot{\Psi} = \left(-\frac{\dot{R}}{R^2} + \frac{\mathrm{i}\dot{F}}{R}\sum_{i=1}^{N}\mathbf{x}_i^2 + \frac{\mathrm{i}\dot{\mathbf{G}}}{R}\sum_{i=1}^{N}\mathbf{x}_i + \mathrm{i}\frac{\dot{M}}{R}\right)\mathrm{e}^{\mathrm{i}\phi(\mathbf{x}_i,t)}\Phi(\mathbf{y}_i,\tau)$$
$$+\frac{1}{R}\mathrm{e}^{\mathrm{i}\phi(\mathbf{x}_i,t)}\sum_{i=1}^{N}\frac{\partial\Phi(\mathbf{y}_i;\tau)}{\partial\mathbf{y}_i}\left[\mathbf{x}_i\left(-\frac{\dot{L}}{L^2}\right)+\dot{\mathbf{S}}(t)\right]+\frac{1}{R}\mathrm{e}^{\mathrm{i}\phi(\mathbf{x}_i,t)}\frac{\partial\Phi(\mathbf{y}_i;\tau)}{\partial\tau}\dot{\tau}, \quad \text{(A.2)}$$

&

$$\frac{\delta I_{\mathbf{n}\nu}}{\delta s} = \frac{\partial I}{\partial t}\frac{\partial t}{\partial s} + \sum_{i=1}^{3}\frac{\partial I}{\partial q^i}\frac{\partial q^i}{\partial s} + \frac{\partial I}{\partial\Theta}\frac{\partial\Theta}{\partial s} + \frac{\partial I}{\partial\Phi}\frac{\partial\Phi}{\partial s} + \frac{\partial I}{\partial\nu}\frac{\partial\nu}{\partial s} = \eta_{\mathbf{n}\nu} - \chi_\nu I_{\mathbf{n}\nu}. \quad (11.22)$$

7

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Documentation

- In docs directory in Cloudy download
- Also on web share under “docs” folder

THE 2017 RELEASE OF CLOUDY

Review

THE 2017 RELEASE OF Cloudy

G. J. Ferland[1], M. Chatzikos[1], F. Guzmán[1], M. L. Lykins[1], P. A. M. van Hoof[2], R. J. R. Williams[3], N. P. Abel[4], N. R. Badnell[5], F. P. Keenan[6], R. L. Porter[7], P. C. Stancil[7]

RESUMEN

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Quick Start Guide to CLOUDY *C17*

Cloudy & Associates
www.nublado.org
June 1, 2017

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Quick Start Guide to CLOUDY *C17*

- Introduction
- Two very simple models
- Geometry
- Composition and density
- The incident radiation field
- Other commands
- The code's predictions
- Example calculations
- How to make this plot
- REFERENCES
- Veusz Cookbook

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Cloudy QSG Chapter 1

- **Accurate simulation of physical processes at the atomic & molecular level**
  - Physical processes treated from first principles, not with sub-grid physics or simple fitting formulae
- **Assumptions:**
  - energy is conserved
  - (usually) atomic processes have reached steady state
- **Limits:**
  - Kinetic temperature 2.7 K < T < 10^{10} K
  - No limits to density (low density limit, LTE, STE) for 1 and 2 electron atoms
  - Radiation field 30 m to 100 MeV

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Simultaneous solution of

- **Gas ionization**
  - From ionization balance equations
- **Chemistry**
  - Large chemical network based on UMIST
- **Gas kinetic temperature**
  - Heating and cooling
- **Level populations and emission**
- **Grain physics**
  - Charging, CX, photoejection, quantum heating
- **The observed spectrum**
  - Radiative transport

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Cloudy is a microphysics code

- **Emphasis is on doing the atomic and molecular physics from first principles**
- **If we get the microphysics right, the macrophysics will take care of itself**
- **Many codes have dynamics, shocks, or 3D, as an emphasis, sometimes using Cloudy to get the microphysics**

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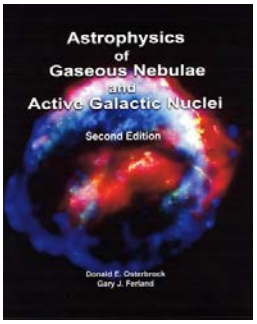
Osterbrock & Ferland Astrophysics of Gaseous Nebulae

- **There were three versions, this is the 3rd**
  - Don called this "AGN3"
- **Any version is OK**
- **PDFs of chapters we will use are in the docs folder of the web share**



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Cloudy version C17.02

- We set this up, ran a model, and created plots, as our homework last week
- The last three major Cloudy reviews are also in the docs folder of the web share

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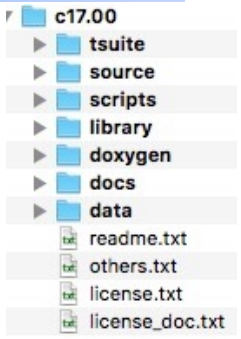
The Cloudy download

- 527 MB uncompressed
- 468 MB of this is data, 9.4 MB is source
- 88.8% atomic & molecular data



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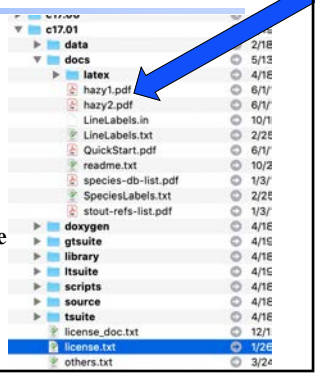
Documentation

- QSG Quick Start Guide
- Hazy 1, all commands
- Hazy 2, description of output, comparison with observations
- Hazy 3, not compiled, badly out of date, some physics is described there



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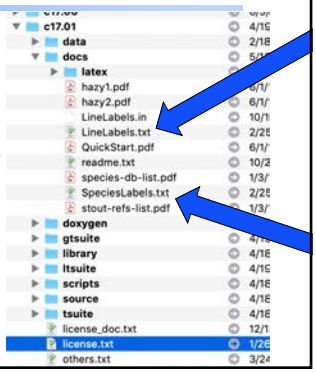
Documentation

- **LineLabels.txt**
  - List of all lines known to the code
- **SpeciesLabels.txt**
  - List of all species (atoms, ions, and molecules) known to the code
- **Can be recreated by running LineLables.in**



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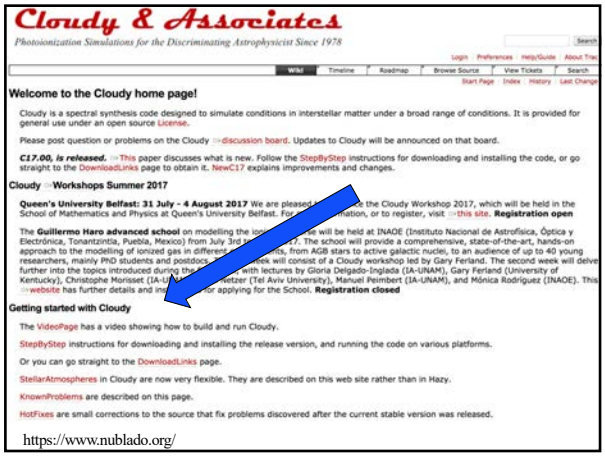

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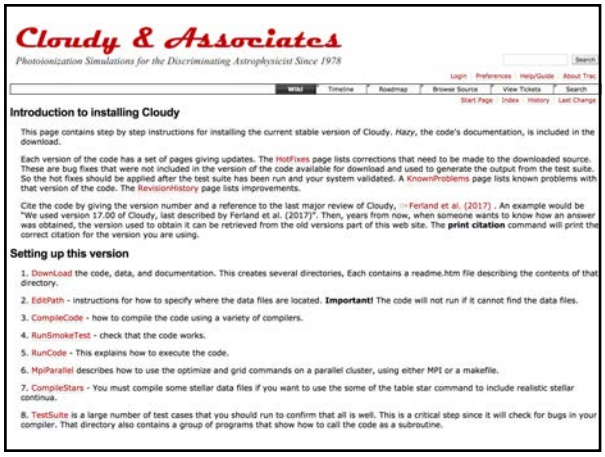

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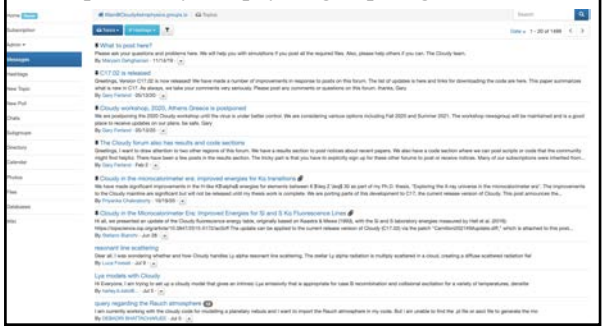
Where to go for help

- **https://cloudyastrophysics.groups.io/g/Main**



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Running cloudy

- **"run" file contains /Users/gary/cloudy/trunk/source/sys_llvm/cloudy.exe -r $1 2> $1.err**
- **If file "model.in" contains input, then**
  - run model &
  - Produces output "model.out"
  - The model will run in the "background" when the line ends with &

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Runtime options

- **Appear after cloudy.exe**
- **Described at http://trac.nublado.org/wiki/RunningC17**
- **-r**
  - I use this in my workflow
  - Required for grids to work
  - Study the options and consider what is best for your workflow
- **Cloudy.exe –h**
  - Will show all options

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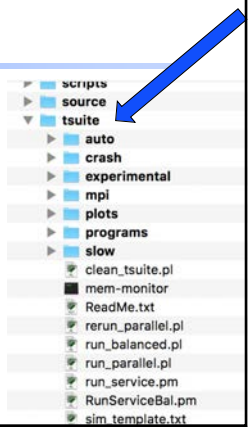
The test suite

- **Fully tests the code after any change**
  - "Monitors" allow automatic comparison of current with previous results
- **Provides examples of how to use Cloudy**
  - But may include extraneous commands for testing
  - Or backwards compatible
- **Useful examples of how to set up a simulation**



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