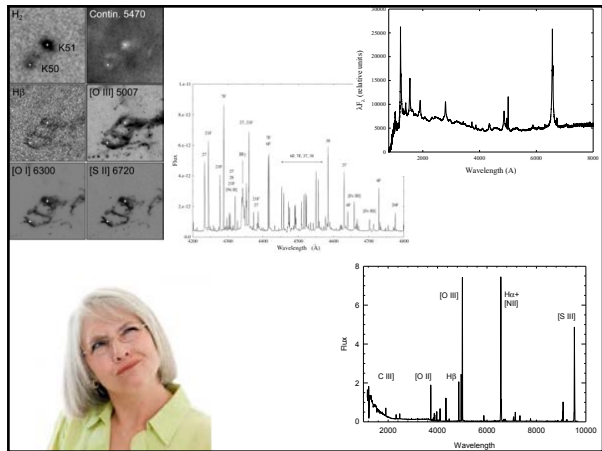
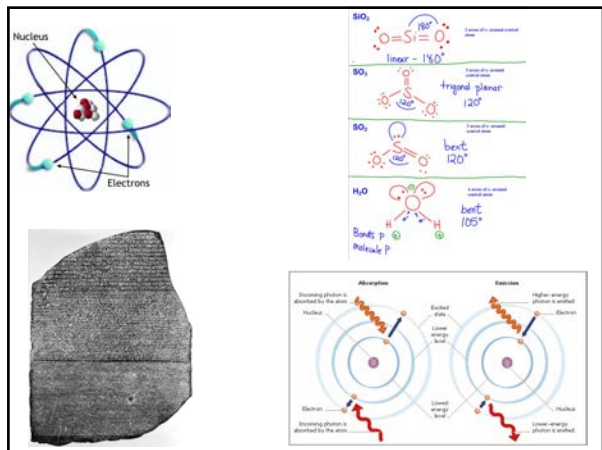


4



5



6

Light is much harder than gravity

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

vs

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

&

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

7



8

Documentation

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

THE 2017 RELEASE OF CLOUDY

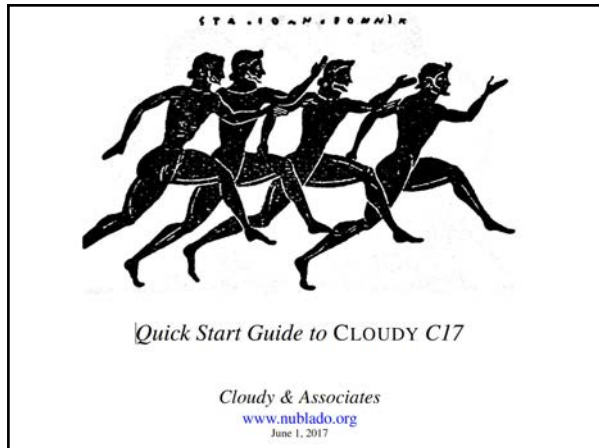
Review

THE 2017 RELEASE OF Cloudy

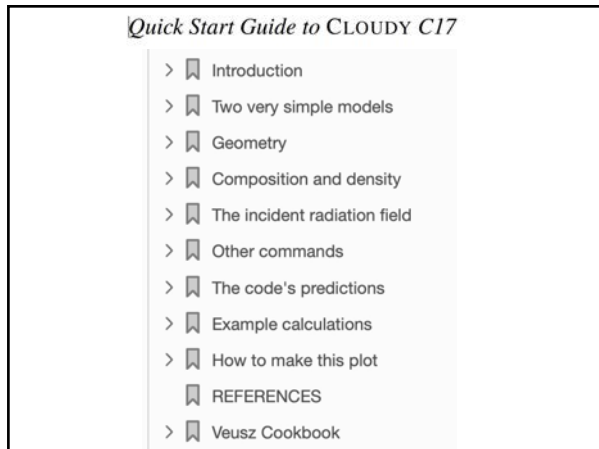
G. J. Ferland¹, M. Chatzikos¹, F. Guzmán¹, M. L. Lykins¹, P. A. M. van Hoof², R. J. R. Williams³, N. P. Abel⁴, N. R. Badnell⁵, F. P. Keenan⁶, R. L. Porter⁷, P. C. Stancil⁷

RESUMEN

9



10



11

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 $2.7 \text{ K} < T < 10^{10} \text{ K}$
 - No limits to density (low density limit, LTE, STE) for 1 and 2 electron atoms
 - Radiation field 30 m to 100 MeV

12

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

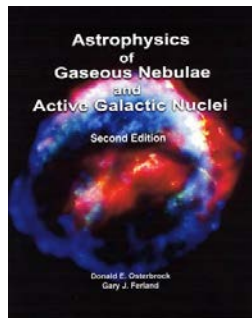
- ◆ **Emphasis is on doing the atomic and molecular physics from first principles**
- ◆ **If we get the microphysics right, the macrophysics will take care of itself**

- ◆ **Many codes have dynamics, shocks, or 3D, as an emphasis, sometimes using Cloudy to get the microphysics**

14

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**



15

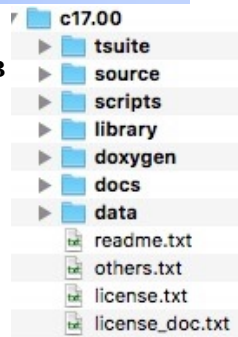
Cloudy version C17.02

- ◆ 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

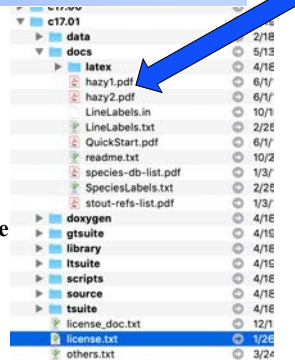
- ◆ 527 MB uncompressed
- ◆ 468 MB of this is data, 9.4 MB is source
- ◆ 88.8% atomic & molecular data



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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 LineLabels.in**

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Cloudy & Associates
Photoionization Simulations for the Discriminating Astrophysicist Since 1978

Welcome to the Cloudy home page!

Cloudy is a spectral synthesis code designed to simulate conditions in interstellar matter under a broad range of conditions. It is provided for general use under an open source License.

Please post question or problems on the Cloudy [discussion board](#). Updates to Cloudy will be announced on that board.

C17.00, is released. [This paper](#) discusses what is new. Follow the [StepByStep](#) instructions for downloading and installing the code, or go straight to the [DownloadLinks](#) page to obtain it. [NewC17](#) explains improvements and changes.

Cloudy -> Workshops Summer 2017

Queen's University Belfast: 31 July - 4 August 2017 We are pleased to announce the Cloudy Workshop 2017, which will be held in the School of Mathematics and Physics at Queen's University Belfast. For more information, or to register, visit [this site](#). **Registration open**

The **Guillermo Haro advanced school** on modelling the ionized universe will be held at INADE (Instituto Nacional de Astrofísica, Óptica y Electrónica, Tonantzintla, Puebla, Mexico) from July 3rd to 14th, 2017. The school will provide a comprehensive, state-of-the-art, hands-on approach to the modelling of ionized gas in different environments, from AGB stars to active galactic nuclei, to an audience of up to 40 young researchers, mainly PhD students and postdocs. The first week will consist of a Cloudy workshop led by Gary Ferland. The second week will delve further into the topics introduced during the first week, with lectures by Gloria Delgado-Inglada (IA-UNAM), Gary Ferland (University of Kentucky), Christophe Morisset (IA-UNAM), Hagai Netzer (Tel Aviv University), Manuel Peimbert (IA-UNAM), and Mónica Rodríguez (INAOE). This website has further details and instructions for applying for the School. **Registration closed**

Getting started with Cloudy

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Or you can go straight to the [DownloadLinks](#) page.

[StellarAtmospheres](#) in Cloudy are now very flexible. They are described on this web site rather than in Hazy.

[KnownProblems](#) are described on this page.

[HotFixes](#) are small corrections to the source that fix problems discovered after the current stable version was released.

<https://www.nublado.org/>

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<https://www.nublado.org/>

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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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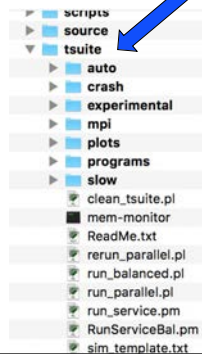
Runtime options

- ◆ **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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