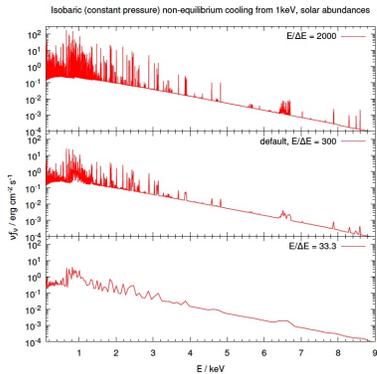


▪ **How to make sense of all these lines**



**Species vs spectra**

- $H^0, C^{3+}, O^{2+}, H_2, CO$  are baryons
- $H\ I, C\ IV, O\ III, H_2,$  and  $CO$  are the spectra they emit / absorb
- $O\ III$  is a permitted line produced by  $O^{2+}$ , while  $[O\ III]$  is a forbidden line
- $C\ III]$  is a semi-forbidden line, often an intercombination line

**Baryons and spectra**

- Hazy 1 Section 2.5
- SpeciesLabels.txt in docs
- Molecules are not ambiguous
  - $H_2$
  - $CO$
  - $O_2$
  - $H_2^+$
  - $C_2^+$
  - Their spectra have the same notation as the baryon

**Baryons and spectra**

- Atomic spectra use number of spectra
    - $H\ 1, C\ 4$
  - The baryon
    - “ $H$ ”, “ $He+$ ”, “ $C+2$ ” ( $C_2+$  is  $C_2^+$  in our notation)
- 2.5 “Species”, how we specify atoms, ions, and molecules, and their spectra

2.5.1 Overview

CLOUDY simulates gas ranging from fully ionized to molecular. Nomenclature varies considerably between chemical, atomic, and plasma physics. We adopted a nomenclature that tries to find a middle ground between these different fields.

We refer to a particular atom, ion, or molecule as a “species”. A species is a baryon. Examples are  $CO, H_2, H^+,$  and  $Fe^{22+}$ . Species are treated using a common approach, as much as possible.

**Finding lines in Cloudy**

- A line is identified by a spectral label & wavelength
- docs/LineLabels.txt has label, wavelength, comment about line
  - Generated with command “Save line labels”
- Pick lines from this file

**Save line list ratio H1 Sec 16.66.7**

The ratio option

If the keyword ratio appears then the ratio of adjacent lines will be output. There must be an even number of lines in the line-list file. The output will have the ratio of the intensity of the first divided by the second, the third divided by the fourth, etc. This provides a quick way to look at line ratios as a function of other parameters. The grid command can produce grids of calculations. Suppose the file linelist.dat contains the following:

```
#
# the [O III] temperature indicator
o 3 5006.84
Blnd 4363
```

The command

```
save line list "o3.lin" ratios from "linelist.dat"
would report the ratio of the [O III] λ5006.84 to the λ4363 line.
```

## The grid command – Hazy1 Chap 18

- Computes a grid of models in parallel on multi-core machines
- Include “vary” keyword on commands with variable parameters (Chapter 17.4)
- “grid” command specifies lower, upper bounds, and step size
  - Radius 13 vary
  - grid 13 23 2

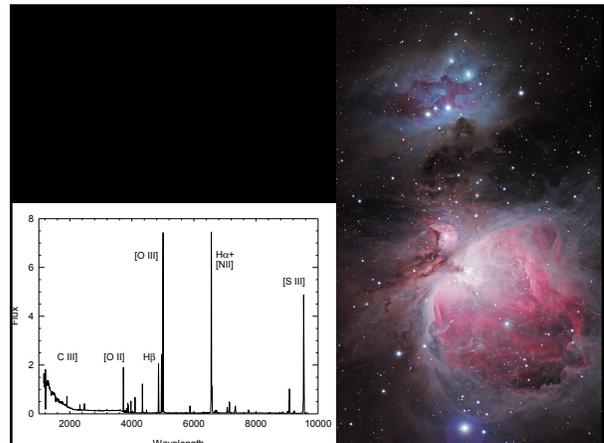
## “Save grid” with grids

- “Save grid” command saves step parameters
  - Summary of error conditions
- Summary of any problems

```
#Index Failure? Warnings? Exit code #rank #seq RADIUS= % grid param
000000000 T F early termination 1 0 10.000000 10.000000
000000001 T F early termination 2 0 11.000000 11.000000
000000002 F T warnings 3 0 12.000000 12.000000
000000003 F T warnings 0 0 13.000000 13.000000
```

## Vary Metals –temperature balance

- Model varyZ.in
  - Z varies by many dex
  - How does O/H and [O III]/H $\beta$  vary with Z?

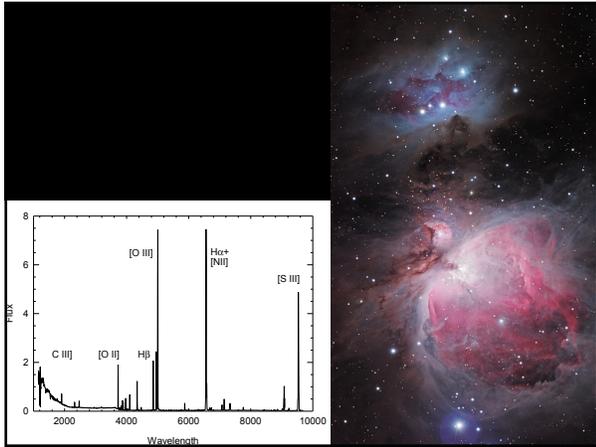


## Thermostat effect AGN3 S9.5

- Vary metals with temperature balance
  - varyZ.in
- Look at line ratios, temperature vs Z
- Cooling and heating vs Z
- Thermostat effect – line spectrum does not change dramatically when Z changes
  - Heating and cooling are equal
  - Cooling is mainly O III lines
  - So they are constant when they are the main coolant

## BPT Diagram & Strong-lined methods

- What can we do if we cannot detect the faint lines needed to measure ratios described in AGN3 Chapter 4 & 5?
- Because object too faint, or
- Telescope not big enough?



**BPT**

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CLASSIFICATION PARAMETERS FOR THE EMISSION-LINE SPECTRA  
OF EXTRAGALACTIC OBJECTS

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▪ <http://adsabs.harvard.edu/abs/1981PASP...93....5B>

**BPT paper on ADS**

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References in the article

- Citations to the Article (2928) (Citation History)
- Referred Citations to the Article
- SIMBAD Objects (47)
- NED Objects (46)
- Also-Read Articles (Reads History)
- Translate This Page

Title: Classification parameters for the emission-line spectra of extragalactic objects

Authors: [Baldwin, J. A.](#); [Phillips, M. M.](#); [Terlevich, R.](#)

**Veilleux & Osterbrock 1987**

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SPECTRAL CLASSIFICATION OF EMISSION-LINE GALAXIES<sup>1</sup>

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*Received 1986 June 4; accepted 1986 August 12*

▪ <http://adsabs.harvard.edu/abs/1987ApJS...63..295V>

**Don's version of BPT**

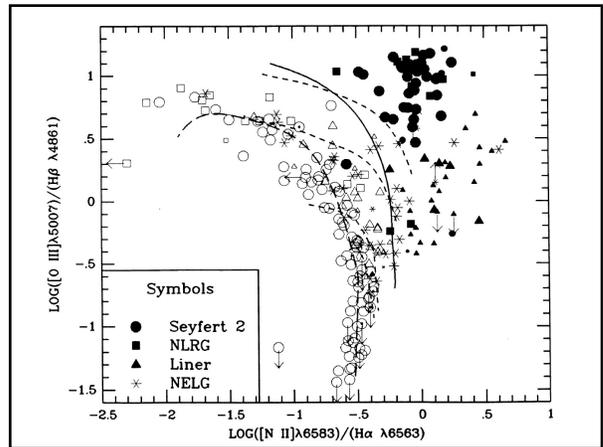
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References in the article

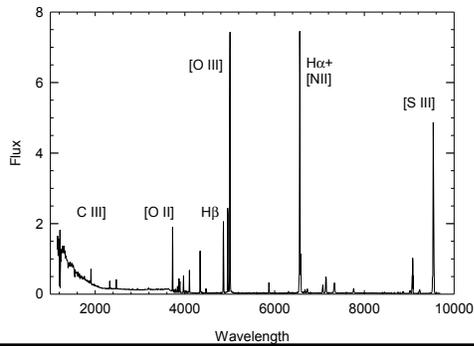
- Citations to the Article (1734) (Citation History)
- Referred Citations to the Article
- SIMBAD Objects (63)
- NED Objects (70)
- Also-Read Articles (Reads History)
- HEP/Spices Information
- Translate This Page

Title: Spectral classification of emission-line galaxies

Authors: [Veilleux, Sylvain](#); [Osterbrock, Donald E.](#)



## Strong lines, close together



## Purpose of BPT diagram

- BPT and VO use ratios of strong lines to classify the emission-line region
  - HII region, PN, AGN, shock,
  - Quasar, Starburst galaxy, NLRG, Seyfert
- Others try to measure chemical composition, metallicity, or ionization parameter