Summer school on the ISM of nearby galaxies

Hands-on 2: Cloudy - emission lines
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Basics of CLOUDY

Microphysics code to predict the thermal, ionization and chemical structure of a cloud
Accurate simulation of physical processes at the atomic and molecular level

How does it work?
Integration of the step-by-step (slabs) absorbed/transmitted and re-emitted photons "kayaking" through a defined medium

- **Incident RF** *(shape T and Q, ionizing photons, & intensity, distance (pc) or Luminosity)*
- **Interacting medium** *(densities/metallicities/abundances)*

- **Cooling (emission)**
- **Heating (absorption) functions**
Project 1: Structure of a PDR

Radial profile for several emission lines of different atoms/molecules for a set of physical conditions in a photon-dominated region (Rollig et al. 2007).

Our case:
Selected lines (H+, H$_2$, C+, C, CO) and Av as stop condition (10) to constrain a PDR

1. Abundance vs Av
2. Comparison with obs (NGC 278 & IC10)

Schematic of a PDR as a function of visual extinction from Wolfire+(22)
Project 1: Results

Schematic of a PDR: abundance of H+, H, H2, C+, CO as a function of visual extinction
Project 1: Comparison with obs

Luminosity ratio, PDR model/obs (NGC 278, top, and IC10, bottom), for 6 selected lines.
Project 2: BPT Diagram of a HII region

Varying:

1. Number density of H \((0 \leq \log n_H \leq 3 \text{ [cm}^{-3}\text{]})\)
2. Ionisation parameter \((-4 \leq \log u \leq -1\)\)
3. Metallicity \((-3 \leq \log Z \leq 0 \text{ in steps of 0.25 } [Z_\odot])\)
Project 3: Modelling AGN with CLOUDY

- Radiation field: SED

Varied parameters
- Ionisation parameter U
- Metallicity Z
- Hydrogen density $n_H$
Varying the Ionisation Parameter

$n_H = 10^4 cm^{-3}, \ Z = Z_\odot$
Varying the Metallicity

AGN \( n_H = 10^3 \, \text{cm}^{-3} \)

\( \log U = -2 \)

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- observation
- SKIRTOR, \( \delta = 0.1 \)
- Schartman, \( \delta = 0.5 \)
- Schartman, \( \delta = -0.5 \)
- Yang20

\[
\log([\text{OIII}]/[\text{H}\beta])
\]

\[
\log([\text{NII}]/[\text{H}\alpha])
\]
Varying the Metallicity

Initial Increase in [OIII]/[Hβ] ratio with metallicity
Varying the Metallicity

Drop in \([\text{OIII}]/[\text{H}\beta]\) ratio at high metallicity

AGN \(n_H = 10^3 \text{ cm}^{-3}\)

\(\log U = -2\)

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SF

\begin{itemize}
  \item observation
  \item SKIRTOR, \(\delta = 0.1\)
  \item Schartman, \(\delta = 0.5\)
  \item Schartman, \(\delta = -0.5\)
  \item Yang20
\end{itemize}
Varying the Metallicity

\[ n_H = 10^3 \text{cm}^{-3} \]
\[ \log U = -2 \]

- Observation
- SKIRTOR, \( \delta = 0.1 \)
- Schartman, \( \delta = 0.5 \)
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- Yang20

\( \log([\text{O}III]/[\text{H} \beta]) \)
\( \log([\text{N}II]/[\text{H} \alpha]) \)

Offset

AGN

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Varying the Hydrogen Density

- $10 \text{ cm}^{-3} < n_H < 10^3 \text{ cm}^{-3}$ - low density regime, almost no effect
- $n_H > 10^4 \text{ cm}^{-3}$ - critical density, collisional de-excitation

More: (Ji et al. 2020)
Summery