# Nebular continuum correction in the chemical analysis of HII galaxies

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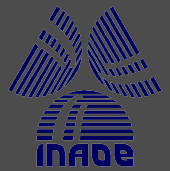
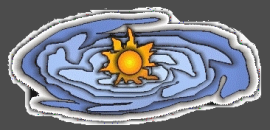
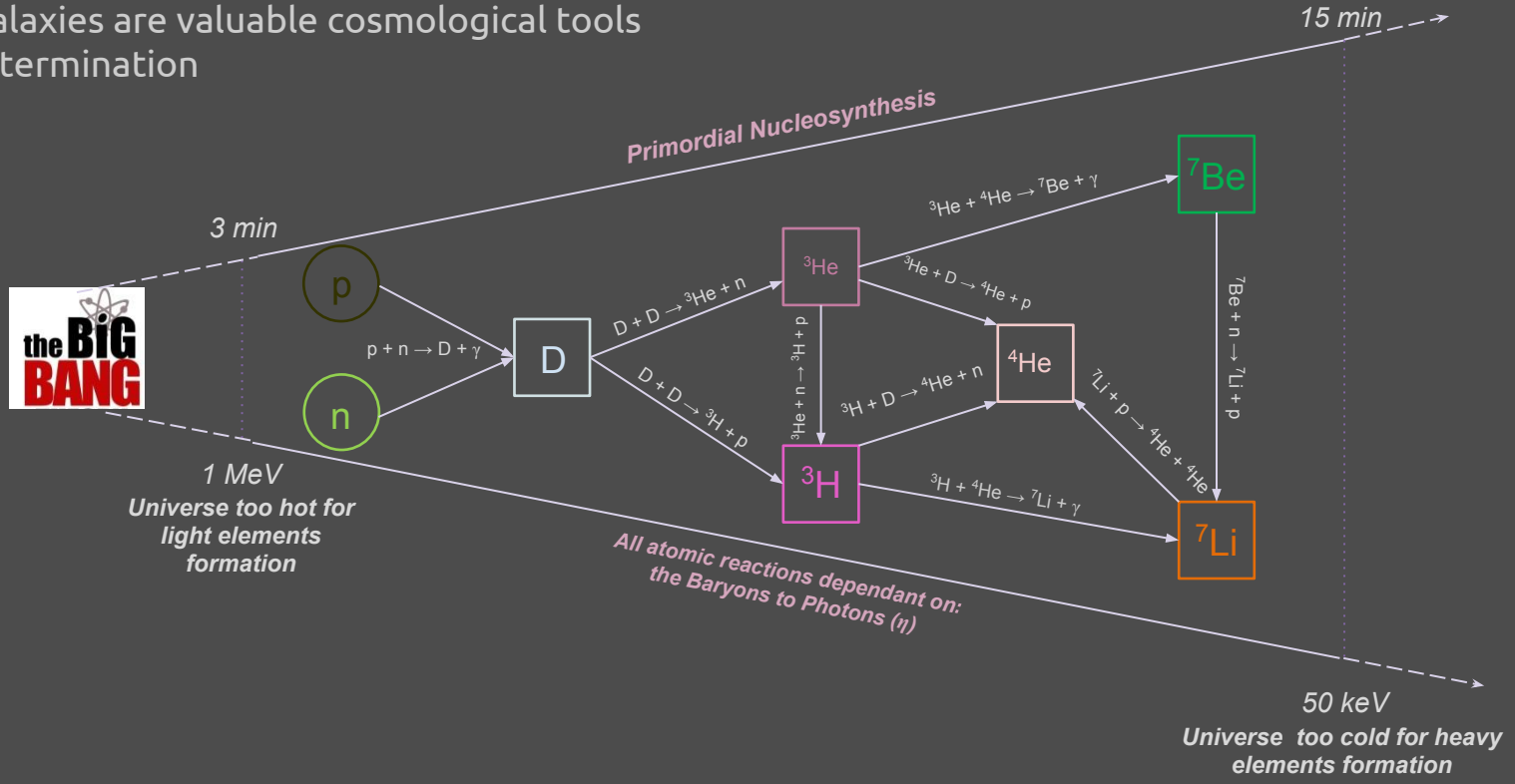


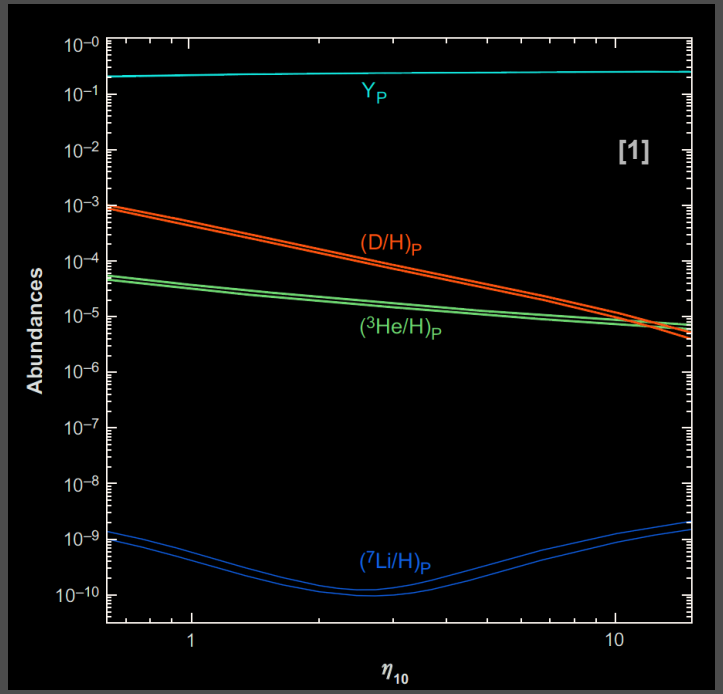

# Introduction:

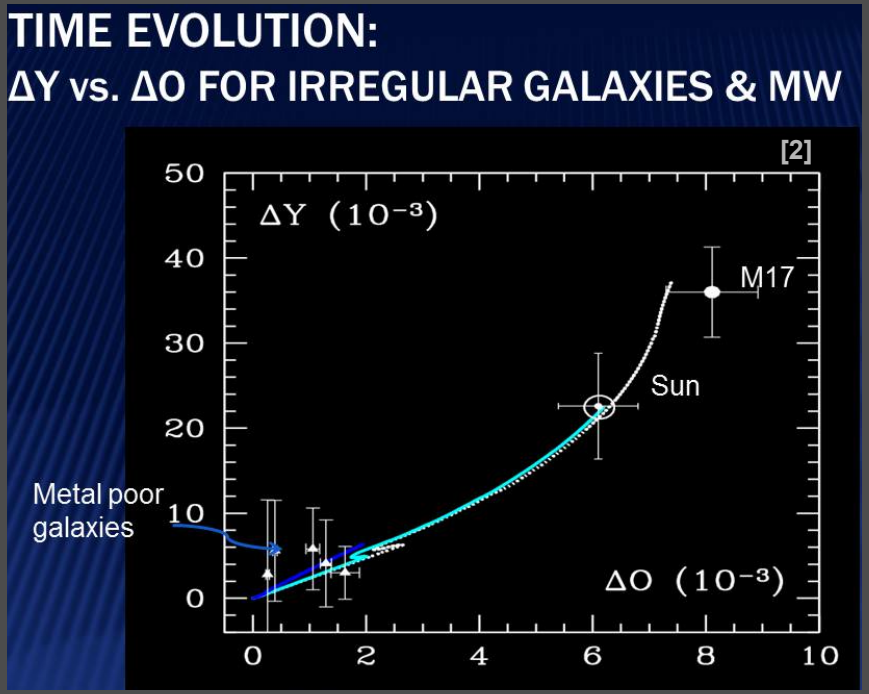
- HII galaxies are valuable cosmological tools
- $Y_P$ determination



# Introduction:

- All primordial abundances are a function of the Baryons to photons ratio:



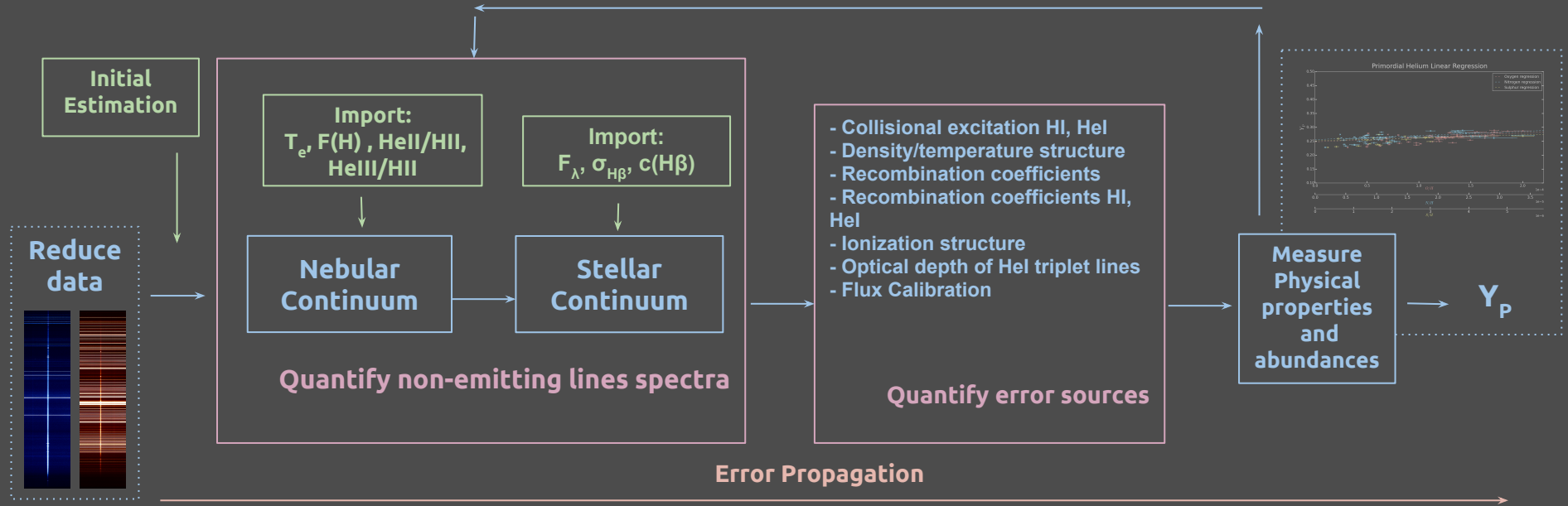




- HII galaxies experience a linear increase in Helium abundance with Z

[1][Carigi, Peimbert (2001)] [2][Steigman et al (2008)]

# Workflow

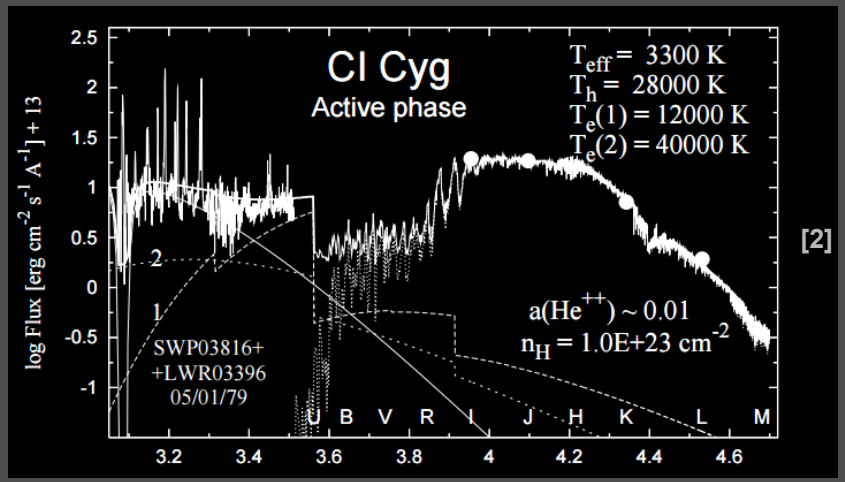
- Start with the data reduction and finish with the linear regression. In between deal with the systematic uncertainties:



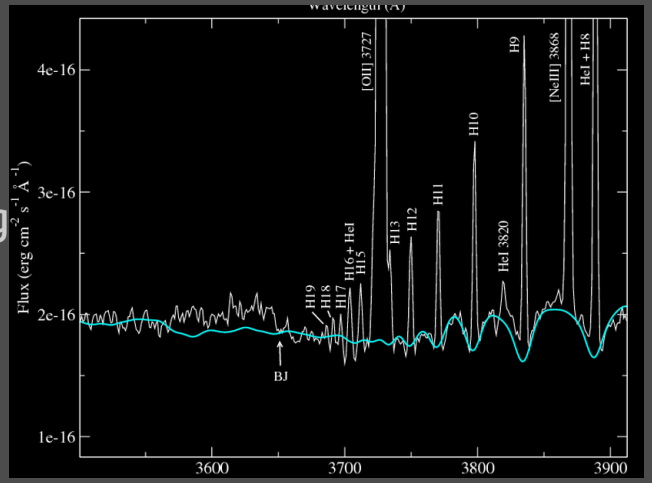

- In this presentation we describe the nebular continuum calculation

# Nebular continuum

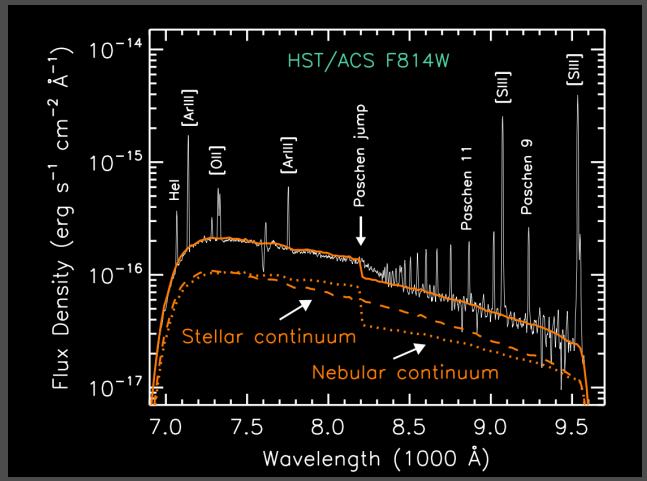
t in very young BCD galaxies, symbiotic stars, young




[2]




[1]




[3]

[1][Perez-Montero, 2010] [2][Skoopal (2005)] [3][Reines et al (2009)]

# Free-free component:

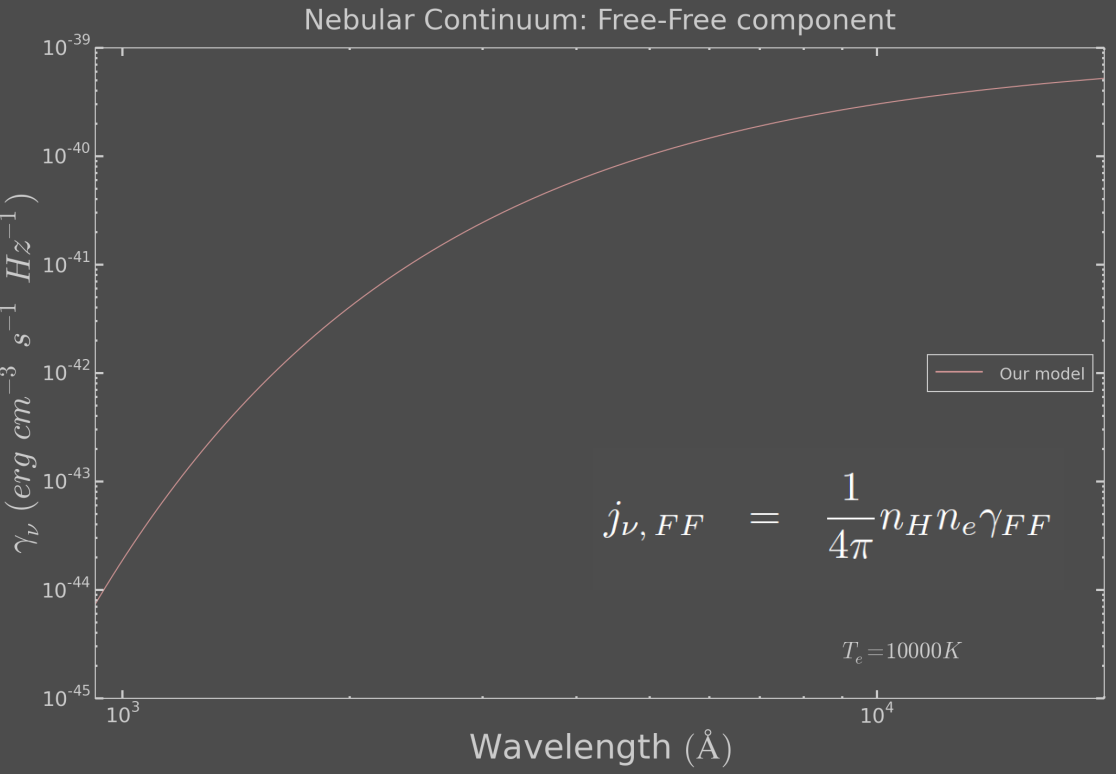
- Produced by the Bremsstrahlung effect

$$\gamma_{\nu,H^+\,FF} = \frac{32Z^2e^4h}{3m^2c^3}\left(\frac{\pi h\nu_0}{3kT}\right)^{1/2} e^{-h\nu/kT} g_{ff}(T,Z,\nu)$$

[1]

$$\gamma_{Total} = \gamma_{\nu,H^+\,FF} + \gamma_{\nu,He^+\,FF} + \gamma_{\nu,He^{++}\,FF}$$
$$= \left(1 + 4\frac{HeII}{HII} + 4\frac{HeIII}{HII}\right)\cdot \gamma_{\nu,H^+\,FF}$$

- Important in the infrared




[1][Brown, Mathews (1970)]

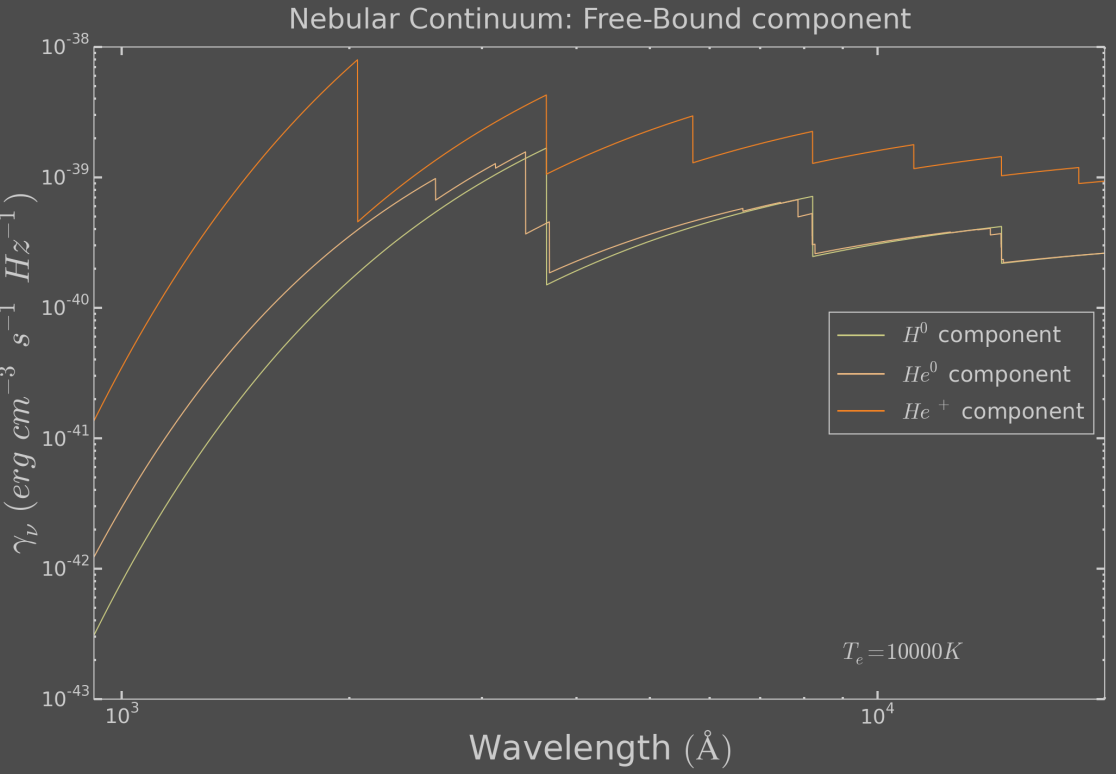
# Free-bound component:

- Important contributions from

$$\gamma_{n,\nu,FB} = \frac{4\pi h}{c^2}\left(\frac{h^2}{2\pi m k T}\right)^{3/2} e^{-\epsilon/kT}\frac{\omega^*}{\omega^+}\nu^3\sigma_\nu\,(X*)$$

- Coefficients can be found tabulated in [Ercolano and Storey (2006)]

- Mainly optical contribution

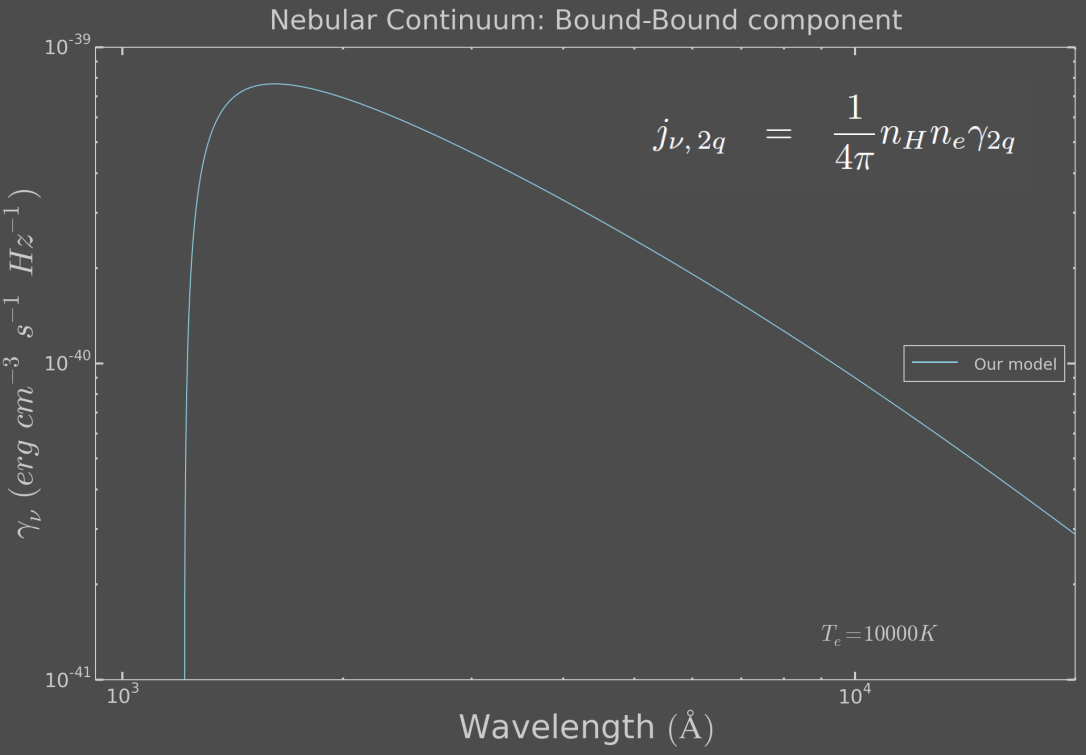


# Bound-bound component:

- Also referred as the two-photon continuum
- Produced by the decay of the $2^2S_{1/2}$ level of H and He+ and also the $2^1S_0$ level of He

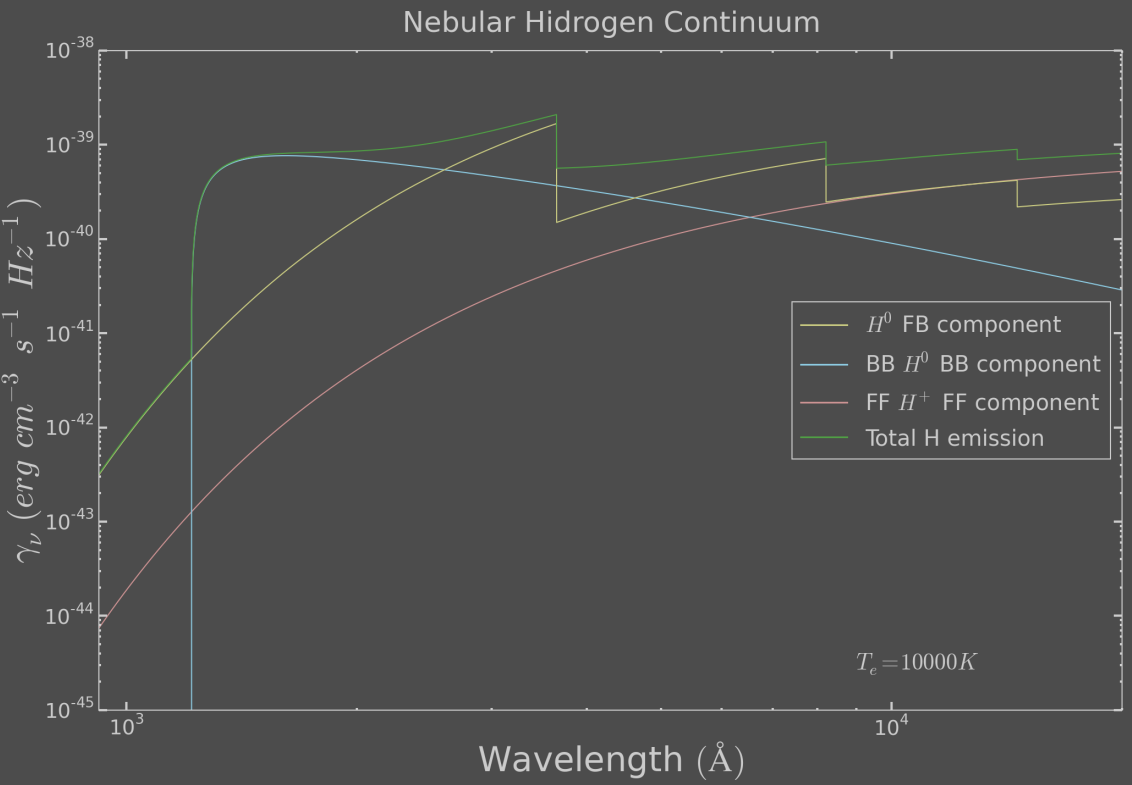
$$\gamma_{2q} = \frac{\alpha_{2\,^2S}\left(H^0, T\right) g_\nu}{1 + \left[\frac{n_p q^P_{2\,^2S,\,2\,^2P} + n_e q^e_{2,\,^2S,2\,^2P}}{A_{2\,^2S,\,1^2S}}\right]}$$ [1]

- Important contribution in the ultraviolet




[1] [Nussbaumer and Schmutz (1984)]

# Total nebular emission:



# Calibration:

- Using nebular features:

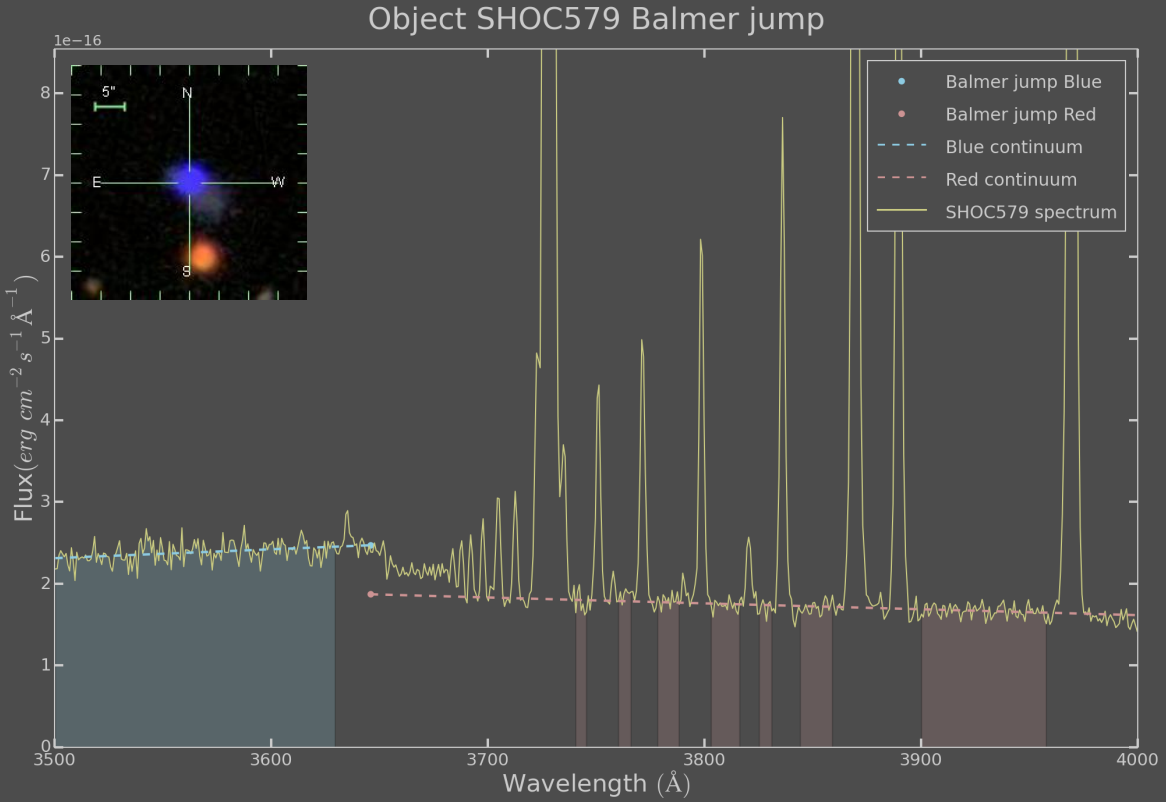
$$j_\nu = \frac{1}{4\pi} n_H n_e \gamma_{\nu,Total}$$

$$\downarrow$$

$$4\pi d^2 F_{Neb,\nu} = \gamma_\nu \int_V n_+ n_e dV$$

$$\downarrow$$

$$F_{Neb,\nu} = \gamma_\nu \frac{\int_V n_+ n_e dV}{4\pi d^2} = \gamma_\nu EM$$




- Calculate electronic temperature from the balmer jump [2] [3]:

$$T_{Bac} = 368 \times \left(1 + 0.259 y^{+} + 3.409 y^{2+}\right) \left(\frac{BJ}{H11}\right) [K]$$

[1][Skopal (2005)] [2][Hägele et al. (2006)] [3][Liu et al. (2001)]

# Calibration:

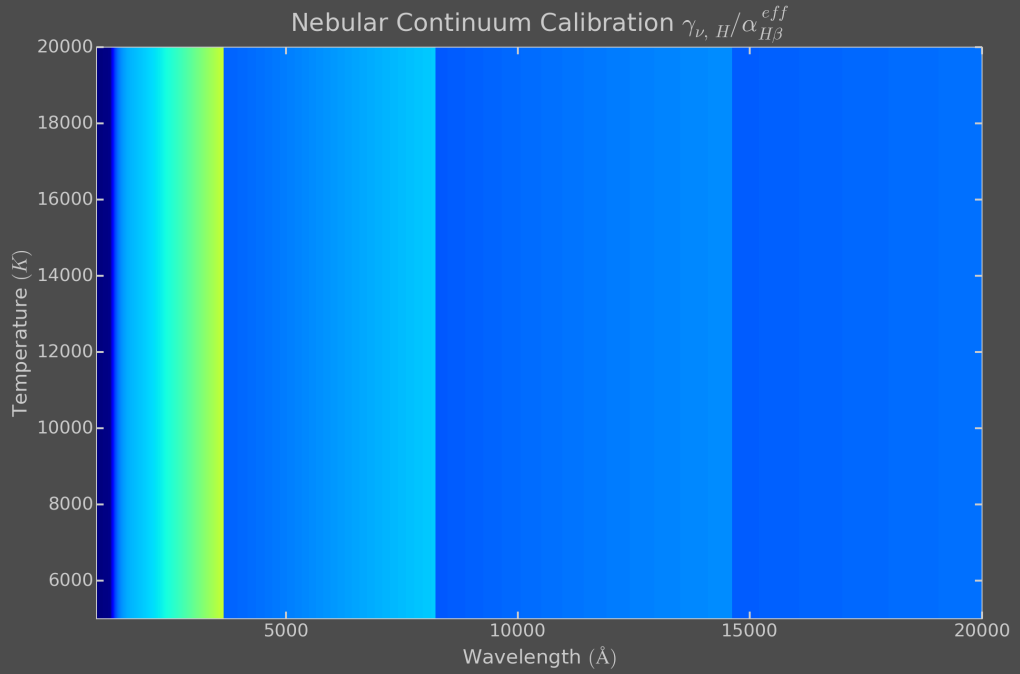
- Using emission line intensity from spectra:

$$4\pi j_{\nu,Neb} = N_{H+} N_e \gamma_\nu (T)$$

$$4\pi j_{\nu,H\beta} = N_{H+} N_e \alpha^{eff}_{H\beta} (T)\, h\nu_\beta$$

$$\frac{L_{\nu,Neb}}{L_{\nu,H\beta}} = \frac{\int_0^{r_0} N_{H+} N_e \gamma_\nu (T)\, dV}{h\nu_\beta \int_0^{r_0} N_{H+} N_e \alpha^{eff}_{H\beta} (T)\, dV} \quad [1]$$

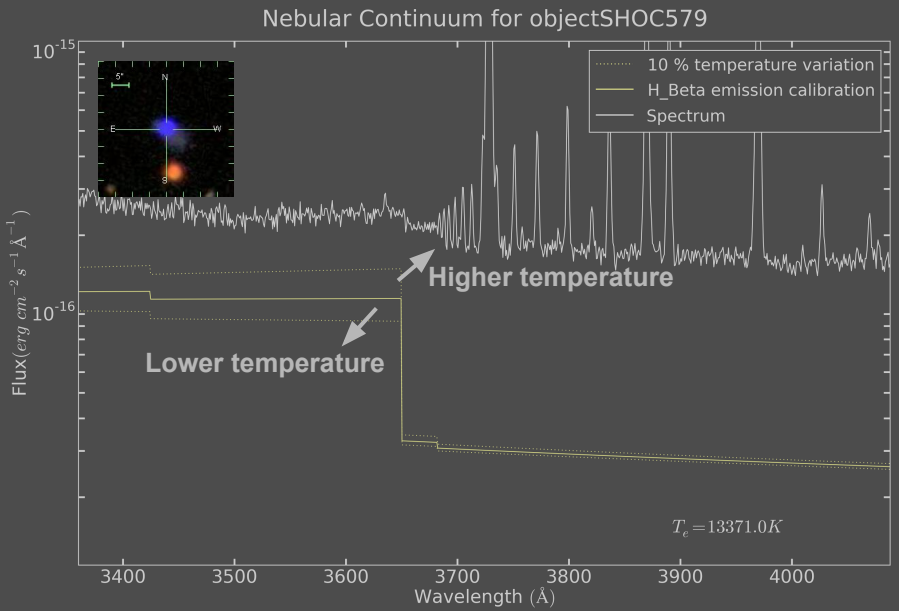
$$F_{\lambda,\,Neb} \approx \frac{\gamma_\nu}{\alpha^{eff}_{H\beta}(T)} \frac{\lambda_{H\beta}}{h \cdot \lambda^2} F_{\lambda,H\beta}$$

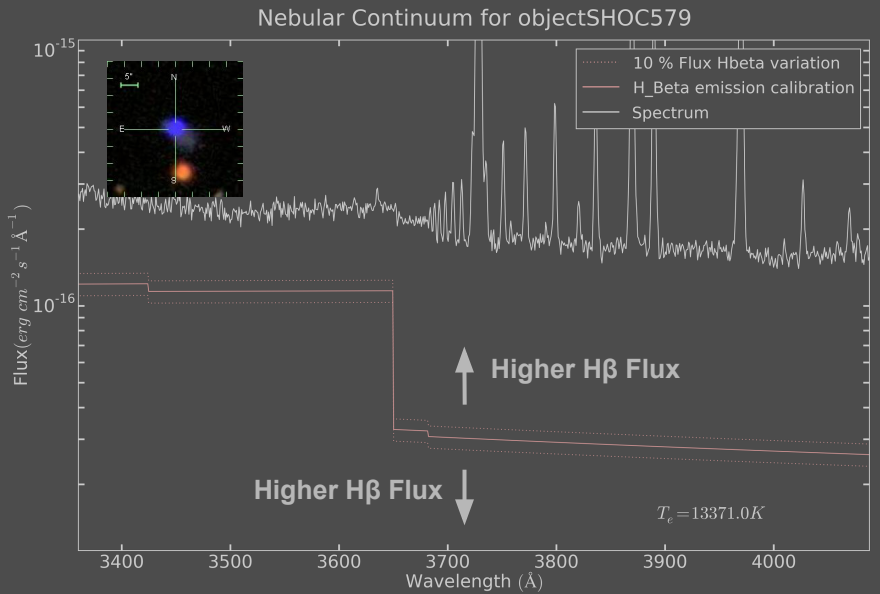



[1][Zanstra (1927)]

# Evolution with $T_e$ and $F(H_\beta)$:

- Calibration using "Zanstra" method:




- In the optical and near infrared regions, for HII galaxies, the error in the nebular continuum will be weakly dependant on the Temperature. Stronger dependence on the recombination line flux.

# Conclusions

- The literature offers a great work on this continuum, which is important in young stellar bursts.

- The calibration can be accomplished using different approaches

- The methodology accounts for:
  - Electron temperature
  - $He^{+}$, $He^{++}$ fractions
  - $FF_{H+, He+, He++}$,, $FB_{H, He, He+}$, $BB_{H}$ I fractions

- The methodology doesn't account for:
  - Escaping photons
  - Neutral hydrogen fraction
  - State of the art atomic coefficients
  - $BB_{He, He+}$ emission

# Share the methodology

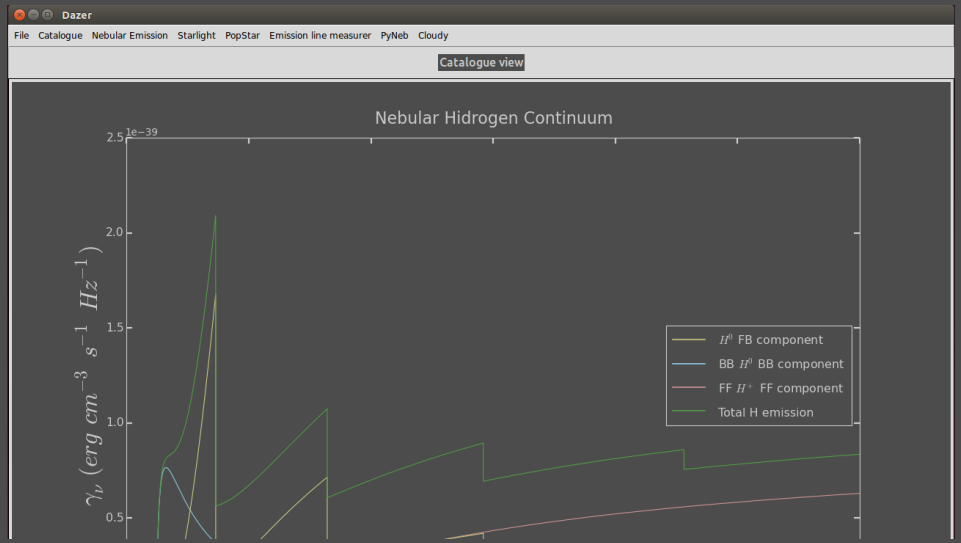
- IRAF video tutorials (9): Longslit spectra reduction

http://nublado.org/wiki/VideoPage

- Cloudy (1): Installation

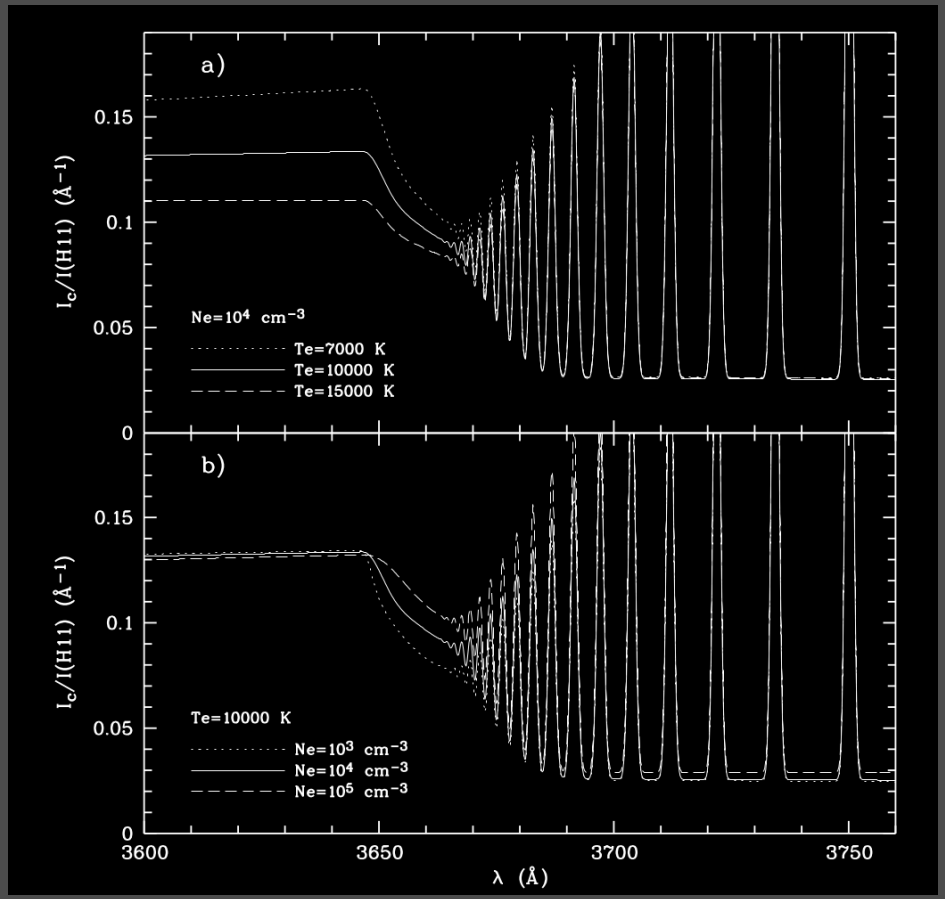
To be uploaded...

- PyNeb (1): Installation



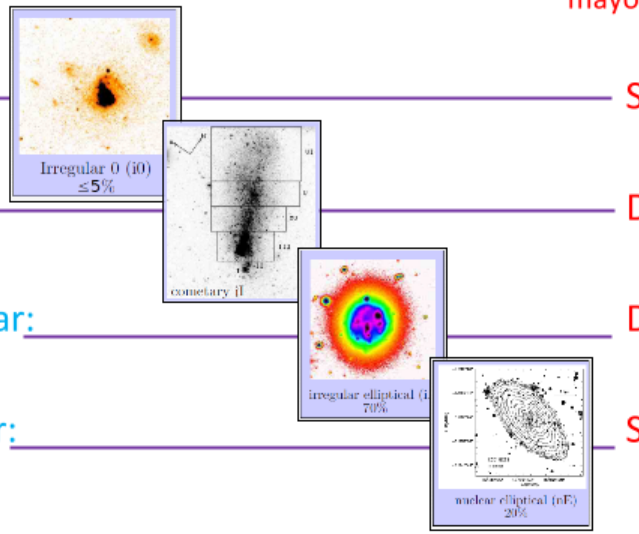

- Program written in python which will become available with all the methodology used in this project: Measure emission lines, calculate physical properties and calculate continuum...

# THANK YOU!


a)
b)
$I_c/I(H11)$ (Å$^{-1}$)
λ (Å)
0
0.05
0.1
0.15
3600
3650
3700
3750
Ne=10$^4$ cm$^{-3}$
Te=7000 K
Te=10000 K
Te=15000 K
Te=10000 K
Ne=10$^3$ cm$^{-3}$
Ne=10$^4$ cm$^{-3}$
Ne=10$^5$ cm$^{-3}$

# Morfología

- Galaxias Enanas:
  - Enanas elípticas
  - Enanas irregulares
  - BCDs :
    - Clasificación morfológica (menor a mayor luminosidad) [1]
    - Clasificación por espectro (menor a mayor luminosidad [2]





*[1]* H.-H. Loose and T. X. Thuan. Surface brightness and color distributions in blue compact dwarf galaxies. I - Haro 2, an extreme example of a star-forming young elliptical galaxy. apj, 309:59–69, October 1986

*[2]*. J. Salzer, Observations of a complete sample of emission-line galaxies. I - CCD imaging and spectroscopy of galaxies in UM lists IV and V. II - Properties of the UM survey galaxies. apjs, 70:447–477, July 1989.