Observational evidence of star formation stochasticity in the CALIFA dataset

Nicolás Romero Díaz[1]
Advisor: Jaime Forero-Romero[1]

[1]Departamento de Física
Universidad de los Andes

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Stochasticity in star formation

Star formation

- Star forming regions
- Young stars ionize gas clouds
- Spectral quantities: equivalent width

$$\mathrm{EW} \equiv \frac{L_{Ly_\alpha}}{L_{\lambda,UV}} \tag{1}$$

- Low SFR: EW and $\frac{\mathrm{H}_\alpha}{\mathrm{FUV}}$ ratios fluctuate [1], [2]

Stochasticity in star formation

Where does stochasticity arise?

- Star formation
  - Initial Mass Function (IMF)
    - $m_{min} - m_{max}$
    - Relative abundance
    - Less massive stars are more abundant
  - Cluster Mass Function (CMF)

Stochasticity in star formation

Where does stochasticity arise?

- Sampling of mass functions – SFR
- Low SFR:
  - Lowers probability of massive stars — finite sampling in mass [2]
  - Stellar mass and luminosity — highly nonlinear [3]
  - Total mass and luminosity — no longer deterministic [4]
  - Finite sampling in time — stellar phases [2]
  - $m_{max} < M_{ecl}$ [2]
  - Bursts of SFR [2]

Measuring stochasticity

How does stochasticity translate into observable quantities?

- SLUG: Stochastically Light Up Galaxies [5]
- EW, $\frac{\mathrm{H}_\alpha}{\mathrm{FUV}}$ fluctuate [1], [2]
- "We find that stochasticity alone induces a broad distribution in L_α and EW at a fixed SFR, and that the widths of these distributions decrease with increasing SFR" [1]

Double power law

$$P\left(\mathcal{M}|\mathrm{SFR}\right) = P_0\left[\left(\frac{\mathcal{M}}{\mathcal{M}_0}\right)^{-\alpha} + \left(\frac{\mathcal{M}}{\mathcal{M}_0}\right)^{\gamma}\right]^{-1} \quad (2)$$

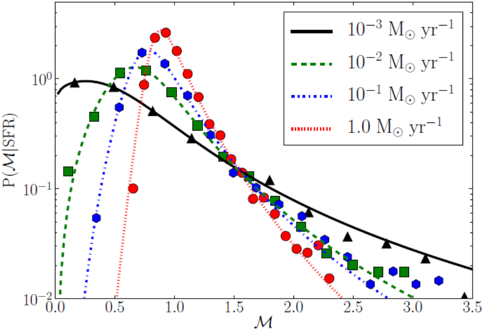

Figure: SFR distributions, $\mathcal{M} = \frac{\mathrm{EW}}{\mathrm{EW}_0}$

Measuring stochasticity

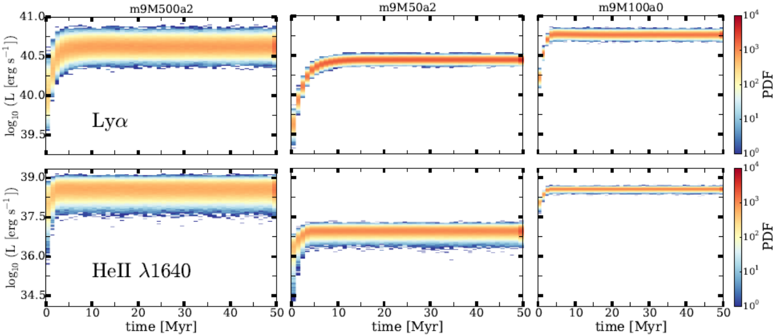

Figure: Mas-Ribas et.al 2016 [6]

Motivation

General objective

"Look for observational evidence of stochasticity in star formation processes in the data published by CALIFA".

Specific objectives

- Develop a simple theoretical model to measure the effects of stochasticity in the EW of the H_α and O_{II} emission lines
- Analize data from the CALIFA survey collaboration
- Compare results between the observed data and the theoretical model
- Conclude if there is enough evidence to claim that stochastic effects have been detected in CALIFA data

Measuring stochasticity

- Balmer decrement
  - Interstellar dust
  - $\frac{H_\alpha}{H_\beta} = 2.85 \rightarrow \frac{H_\alpha}{H_\beta} \geq 2.85$[1]
  - Interstellar reddening

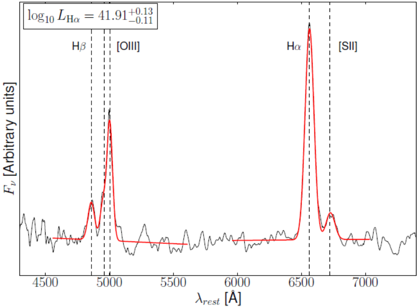

Figure: Domínguez et. al. 2012 [7]

[1] Osterbrock, Astrophysics of Planetary Nebulae and Active Galactic Nuclei, University Science Books, 1989

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The CALIFA survey

- ~ 600 galaxies
- "Largest and most comprehensive wide-field IFU survey of galaxies carried out to date"[8]
- Calar Alto observatory
- Almería, Spain. 2010

The CALIFA survey

- Many spectra per galaxy
- Evolution in mass, brightness of galaxies

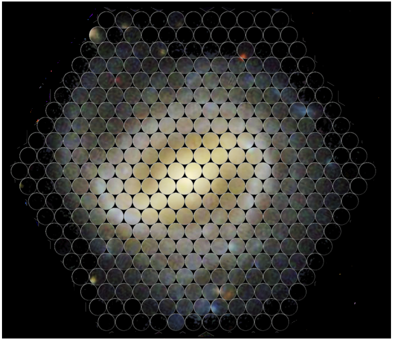

Figure: http://califaserv.caha.es/CALIFA/DATA/Figs/CALIFA_HexDR2.png

The CALIFA datacubes

- 2 setups
- V500
  - 3745 – 7500 Å[9]
  - $^{\lambda}/_{\Delta\lambda} \sim 850$
- V1200
  - 3700 – 4800 Å
  - $^{\lambda}/_{\Delta\lambda} \sim 1650$ [9]

Data analysis

- Fit spectral lines
  - Stellar population
  - Strong emission lines

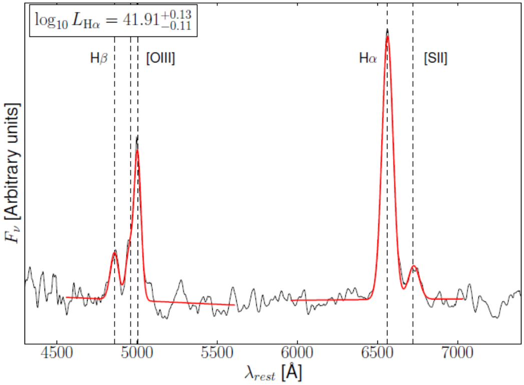

Figure: Spectral fit [7]

Data analysis

- Pipe3D: analysis pipeline [10]
- *"The final product of the data reduction from both surveys is a regular grid datacube, with x and y coordinates that indicate the right ascention and declination of the target, and the z coordinate a common step in wavelength..."*

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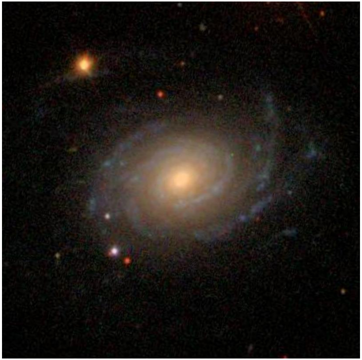
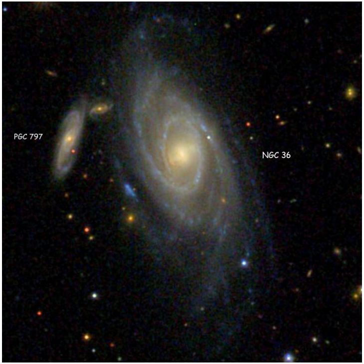
Results

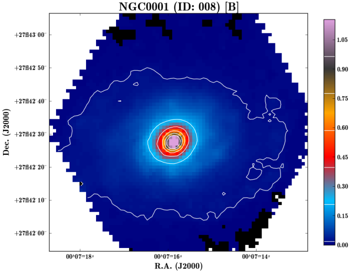


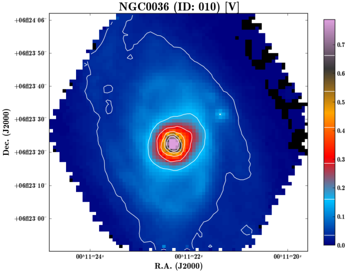
NGC0001
http://www.galaxyzooforum.org/index.php?topic=280028.0



NGC0036 http://cseligman.com/text/atlas/ngc36.jpg

Results





http://califaserv.caha.es/CALIFA/DATA/V1200/v2.2/web/NGC0001.B.png http://califaserv.caha.es/CALIFA/DATA/V500/v2.2/web/NGC003

Results

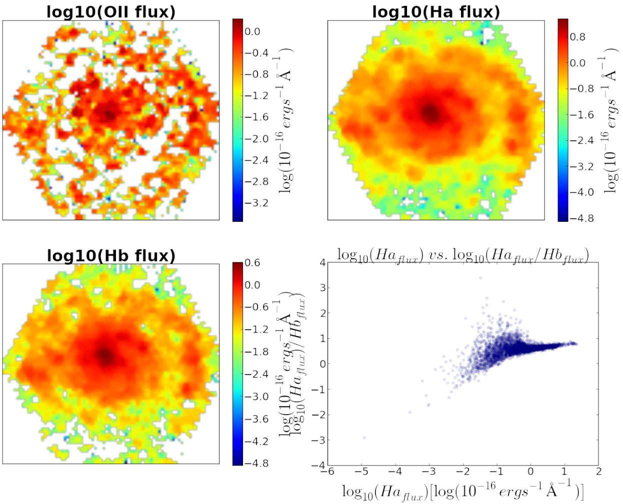


Figure: NGC0001

Results

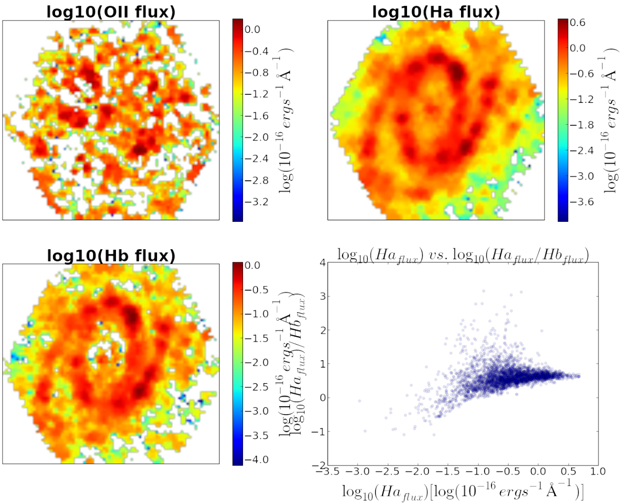


Figure: NGC0036

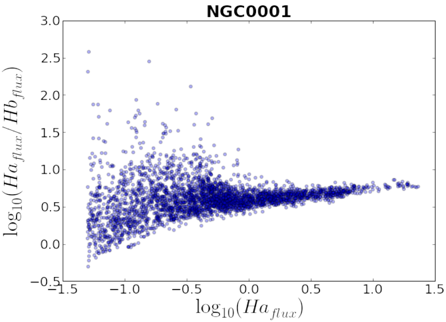


Figure: NGC0001

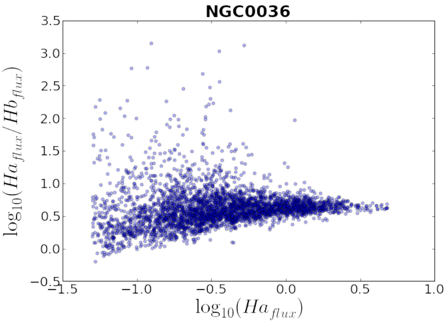


Figure: NGC0036

Results

- H_α luminosity is a direct measure of SFR [11]
- Higher H_α luminosity $\rightarrow$ higher SFR [12]

$$\mathrm{SFR}(\mathrm{M}_\odot \mathrm{yr}^{-1}) = 7.9 \times 10^{-42} L(H_\alpha)(\mathrm{ergs\,s}^{-1}) \tag{3}$$

Results

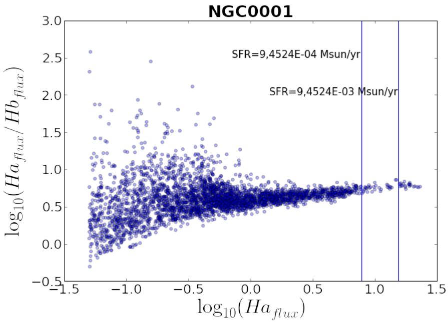


Figure: NGC0001

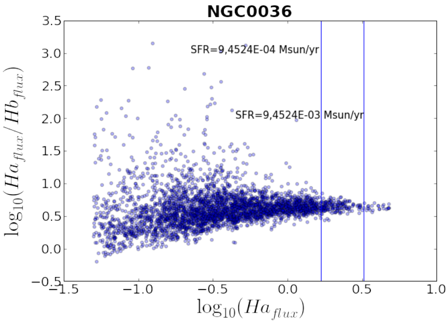


Figure: NGC0036

Results

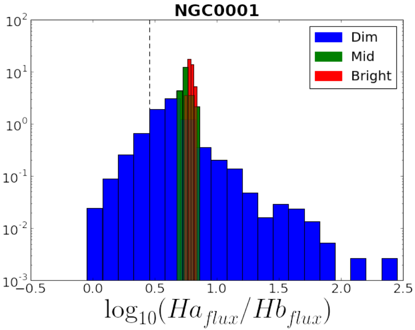


Figure: NGC0001

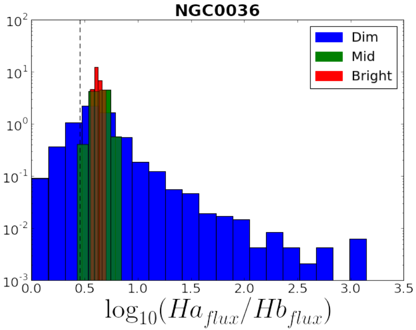


Figure: NGC0036

Results

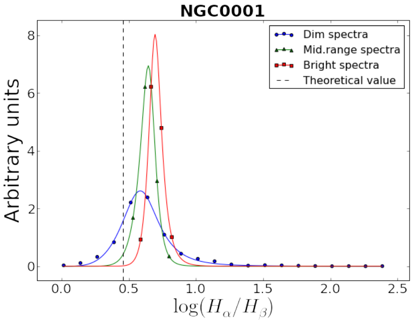


Figure: NGC0001

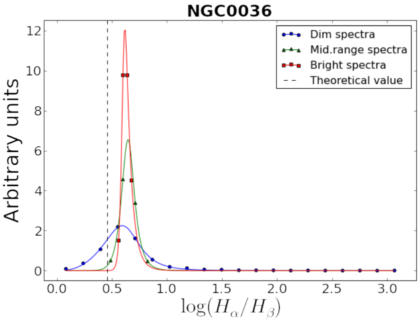


Figure: NGC0036

- OII EW distribution

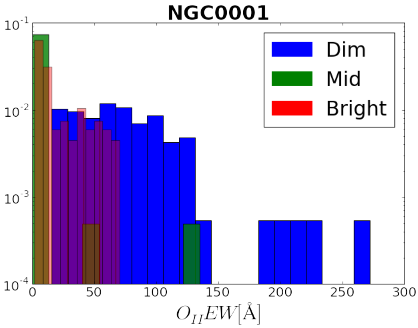


Figure: NGC0001

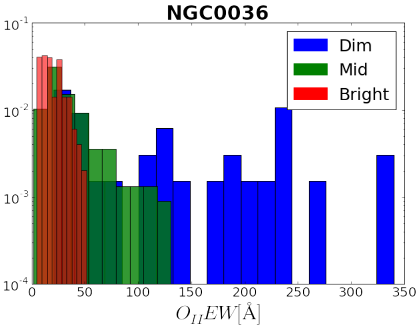


Figure: NGC0036

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Conclusions

- Fluctuation of $\frac{H_\alpha}{H_\beta}$, O_{II} EW was detected.
- Distribution of values follows the double power law (eq. 2)
- We propose stochasticity as a candidate that explains fluctuation of spectral parameters.
- **Further work:** Theoretical work on what is expected of distributions
- Quantify the impact of interstellar dust effects on our results
- Determine if stochasticity is observed
- Expand data sample (MaNGA [13])

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