



# *An educational exploration of Cosmic Rays and Blazars: a PCTO experience*

Introduction to astroparticle physics and data analysis

Gruppo 5

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# Elementary particles

At the base of the world around us are the so-called "elementary particles" that are not composed of other simpler particles, these are:

- quarks;
- leptons;
- bosons.

Standard Model of Elementary Particles											
three generations of matter (elementary fermions)						three generations of antimatter (elementary antifermions)			interactions / force carriers (elementary bosons)		
		I	II	III			I	II	III		
QUARKS	mass	$\approx 2.2 \text{ MeV}/c^2$	$\approx 1.28 \text{ GeV}/c^2$	$\approx 173.1 \text{ GeV}/c^2$	$\approx 2.2 \text{ MeV}/c^2$	$\approx 1.28 \text{ GeV}/c^2$	$\approx 173.1 \text{ GeV}/c^2$			0	$\approx 124.97 \text{ GeV}/c^2$
	charge	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$-\frac{2}{3}$	$-\frac{2}{3}$	$-\frac{2}{3}$			0	0
	spin	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$			1	0
		<b>u</b> up	<b>c</b> charm	<b>t</b> top	<b><math>\bar{u}</math></b> antiup	<b><math>\bar{c}</math></b> anticharm	<b><math>\bar{t}</math></b> antitop			<b>g</b> gluon	<b>H</b> higgs
		$\approx 4.7 \text{ MeV}/c^2$	$\approx 96 \text{ MeV}/c^2$	$\approx 4.18 \text{ GeV}/c^2$	$\approx 4.7 \text{ MeV}/c^2$	$\approx 96 \text{ MeV}/c^2$	$\approx 4.18 \text{ GeV}/c^2$			0	
		$-\frac{1}{3}$	$-\frac{1}{3}$	$-\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$			0	
		$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$			1	
		<b>d</b> down	<b>s</b> strange	<b>b</b> bottom	<b><math>\bar{d}</math></b> antidown	<b><math>\bar{s}</math></b> antistrange	<b><math>\bar{b}</math></b> antibottom			<b><math>\gamma</math></b> photon	
		$\approx 0.511 \text{ MeV}/c^2$	$\approx 105.66 \text{ MeV}/c^2$	$\approx 1.7768 \text{ GeV}/c^2$	$\approx 0.511 \text{ MeV}/c^2$	$\approx 105.66 \text{ MeV}/c^2$	$\approx 1.7768 \text{ GeV}/c^2$			0	$\approx 91.19 \text{ GeV}/c^2$
		-1	-1	-1	1	1	1			0	0
		$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$			1	1
		<b>e</b> electron	<b><math>\mu</math></b> muon	<b><math>\tau</math></b> tau	<b><math>e^+</math></b> positron	<b><math>\bar{\mu}</math></b> antimuon	<b><math>\bar{\tau}</math></b> antitau			<b>Z</b> Z <sup>0</sup> boson	
		$< 2.2 \text{ eV}/c^2$	$< 0.17 \text{ MeV}/c^2$	$< 18.2 \text{ MeV}/c^2$	$< 2.2 \text{ eV}/c^2$	$< 0.17 \text{ MeV}/c^2$	$< 18.2 \text{ MeV}/c^2$			$\approx 80.39 \text{ GeV}/c^2$	$\approx 80.39 \text{ GeV}/c^2$
		0	0	0	0	0	0			1	-1
		$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$			1	1
		<b><math>\nu_e</math></b> electron neutrino	<b><math>\nu_\mu</math></b> muon neutrino	<b><math>\nu_\tau</math></b> tau neutrino	<b><math>\bar{\nu}_e</math></b> electron antineutrino	<b><math>\bar{\nu}_\mu</math></b> muon antineutrino	<b><math>\bar{\nu}_\tau</math></b> tau antineutrino			<b><math>W^+</math></b> W <sup>+</sup> boson	<b><math>W^-</math></b> W <sup>-</sup> boson



# *Cosmic rays*

Cosmic rays are high-energy particles originating from outer space, which provide valuable insights into the high-energy universe.

Cosmic Rays can be revealed thanks to cutting-edge telescopes like the Pierre Auger observatory in western Argentina.

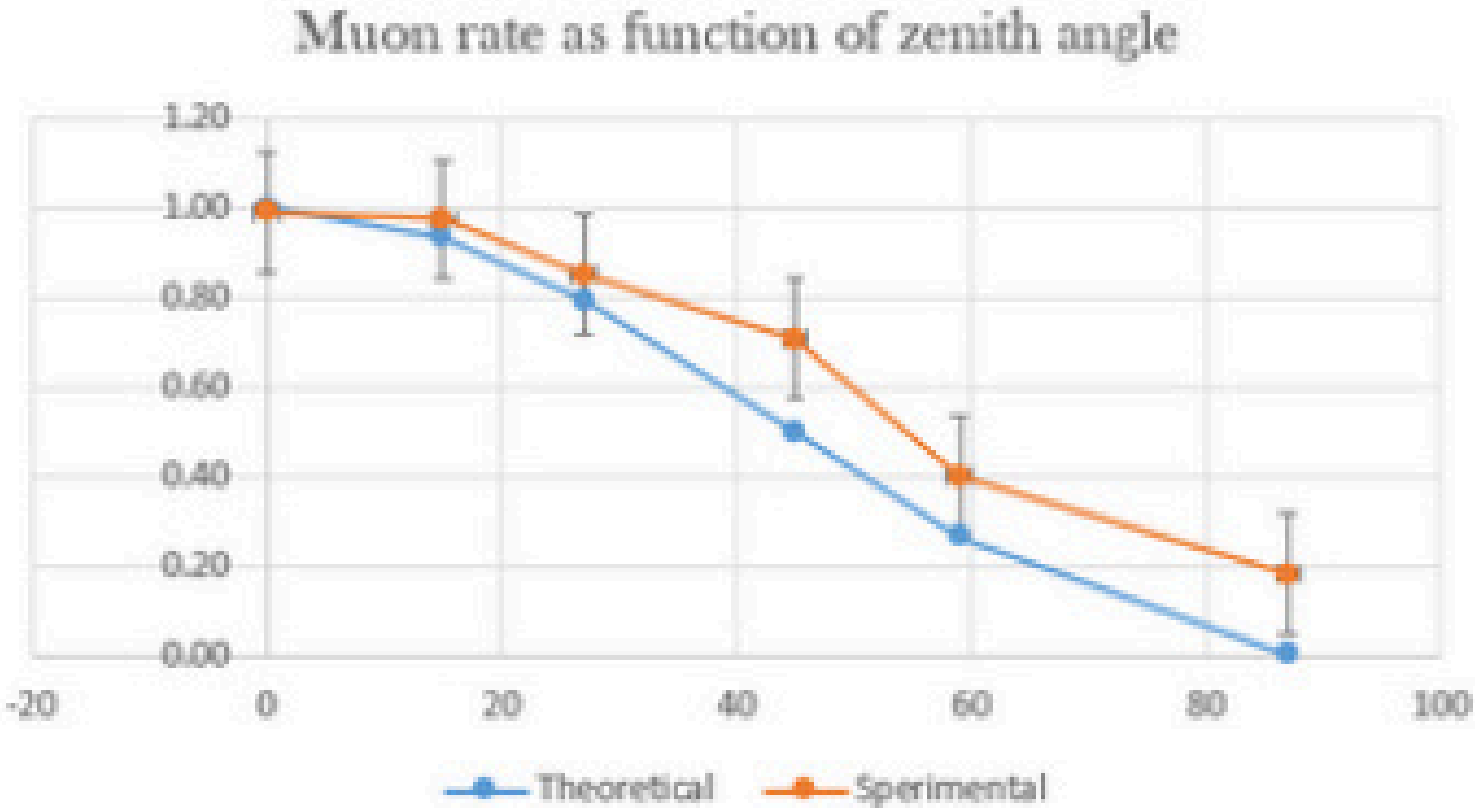


Cosmic Rays Cube

# Cosmic Rays Cube measurements

DEGREES	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	R <sub>4</sub>	R <sub>5</sub>	R <sub>6</sub>	MEDIA	MEDIA/50	ERRORS	DEGREE		COS 1/2 θ
0	50.0	48.0	49.0	51.0			49.5	0.99	0.03	0	0	1.000
15	48.0	48.0	47.0	48.0	49.0	52.0	48.7	0.97	0.05	15	0.26167	0.933
27	39.0	38.0	50.0	50.0	39.0	39.0	42.5	0.85	0.12	27	0.471	0.794
45	39.0	39.0	34.0	34.0	32.0	34.0	35.3	0.71	0.07	45	0.785	0.500
59	19.0	19.0	19.0	19.0	22.0	22.0	20.0	0.40	0.03	59	1.02922	0.266
87	10.0	10.0	8.0	8.0			9.0	0.18	0.02	87	1.51767	0.003

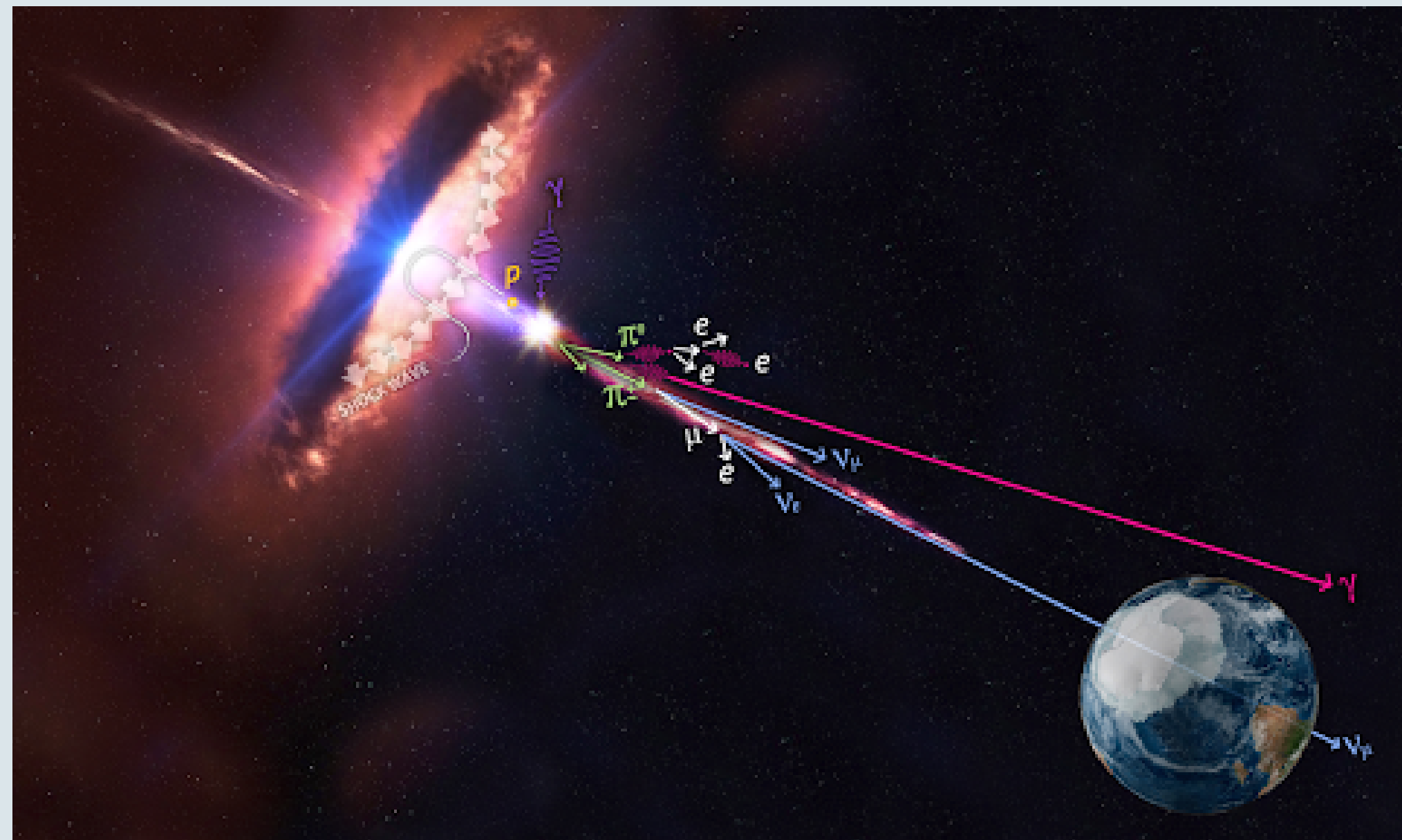
DEGREES	Theoretical	Sperimental
0	1.00	0.99
15	0.93	0.97
27	0.79	0.85
45	0.50	0.71
59	0.27	0.40
87	0.00	0.18



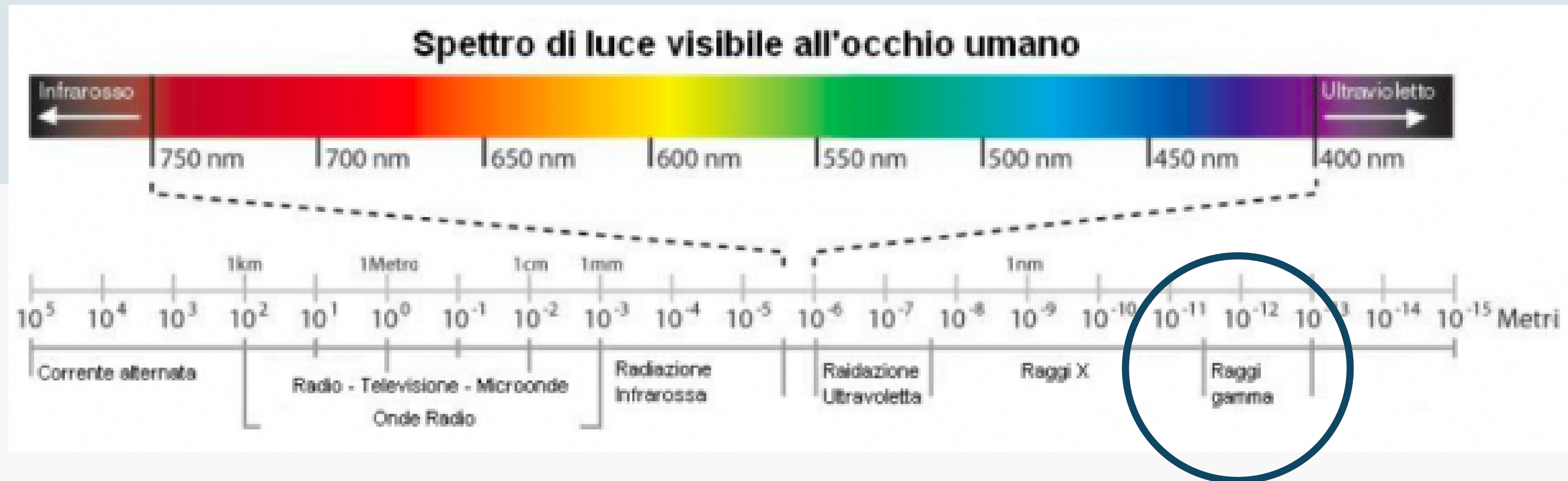
# SOURCES

They are divided into:

- GALACTIC: stars (neutron, PULSAR), supernova, star interactions;
- EXTRAGALACTIC: stars, galaxy clusters, gamma-ray bursts



# *Blazar emission spectrum*

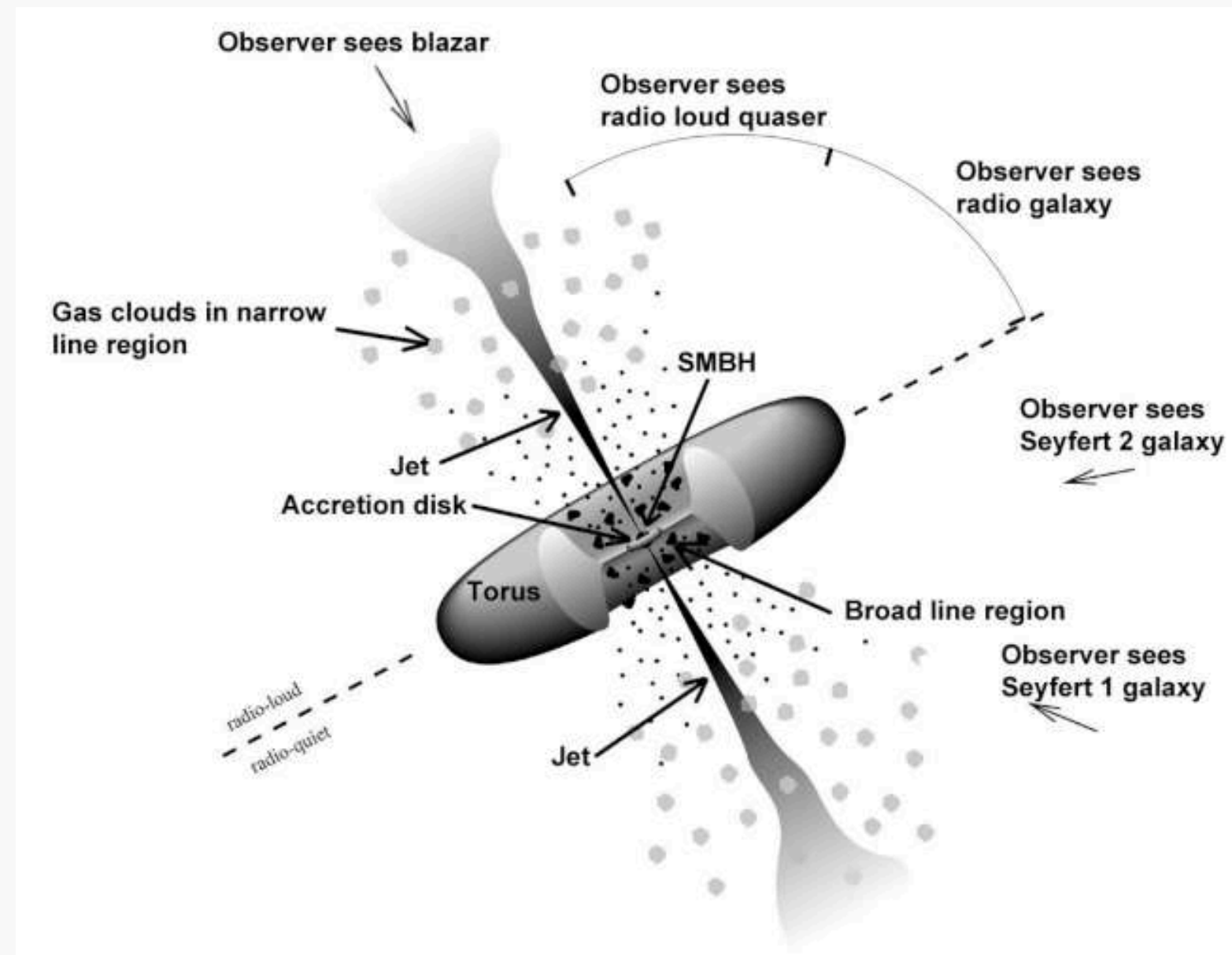


Blazar are part of the AGN, structures at the centre of several so-called active galaxies, powered by a supermassive black hole. The black hole accelerates the matter around it and shoots it out, and the accelerated particles in these jets can emit radiation up to the most energetic gamma rays.



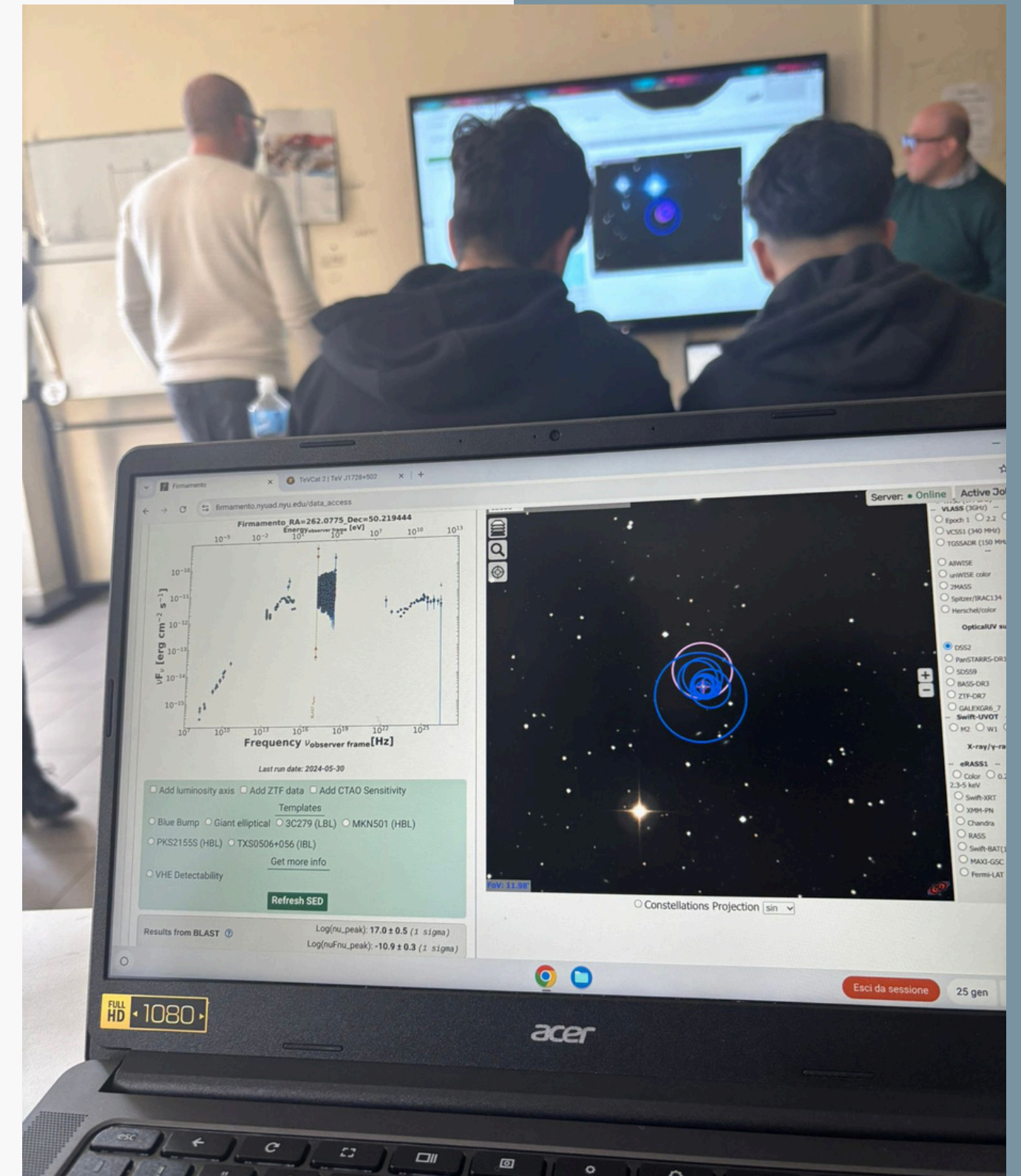
In particular, the jet of particles from the blazars are directed towards the observer (earth).

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# *How is an analysis carried out?*

- collect data from portals accessible to all (Firmamento, Tevcat,...);
- analyze and represent data (in this case we used Python).





# Performance of work

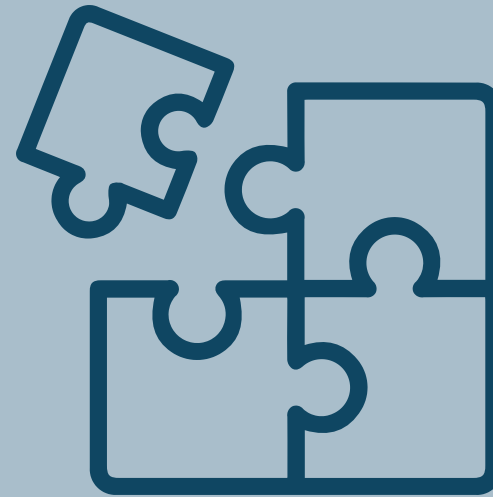
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## Open the SED in python



- First we asked python to open the file with pandas and convert it into dataframe

## Visualize datas

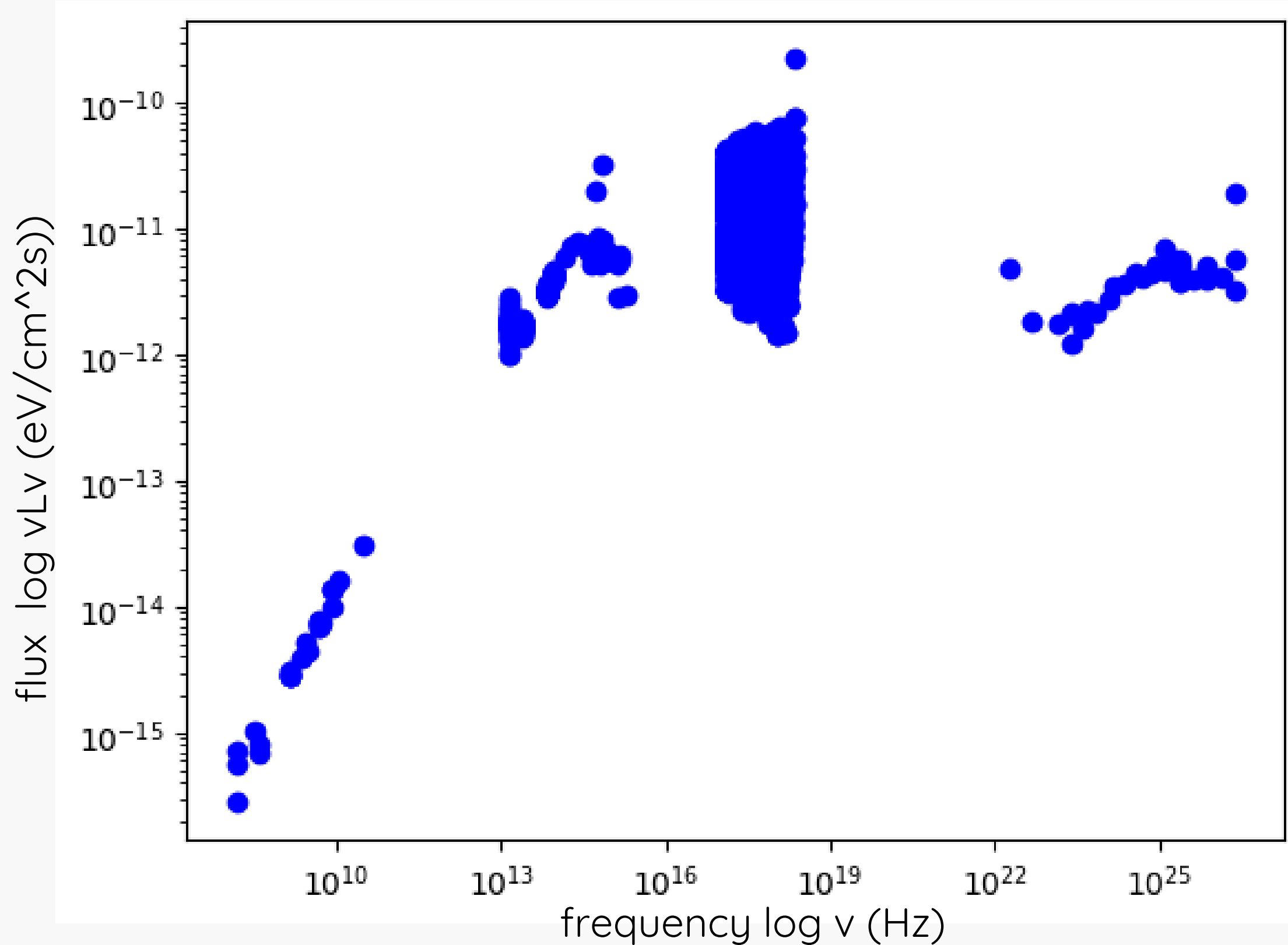


- then we asked python to describe the data
- number of events, flow(min and max), emission,density...

## Graphical representation

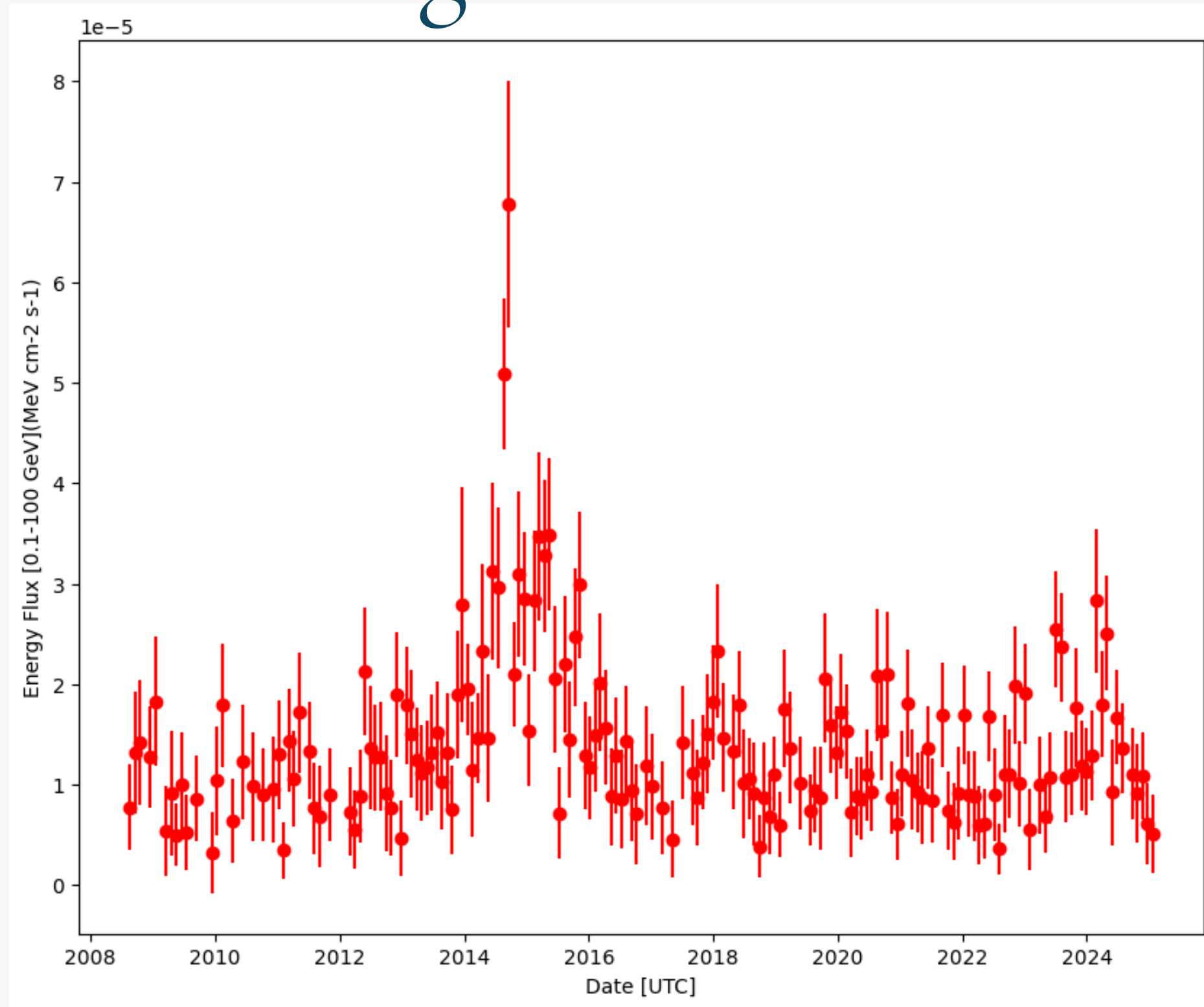
- Using a logarithmic scale we were able to display the multifrequency graph of our data
- spectral emission density (frequency-flux)\_graphic
- light curve graphic (date-energy flux)

# Spectral emission density



This graphic shows the emission spectrum based on frequency (hertz) and flux (erg/cm<sup>2</sup>s), the figure clearly shows two peaks, known as sincroton light and inverse Compton, typical of a blazar.

# Light curve



This figure shows the light curve of the source; it expresses values as a function of energy and time. The highest energy value has been registered in 2014, but it's necessary to consider the variability of uncertainty shown in the graph as vertical lines.



Thank you.