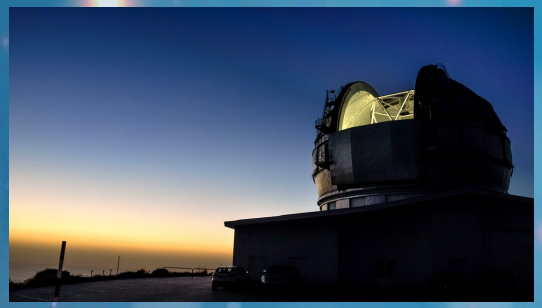
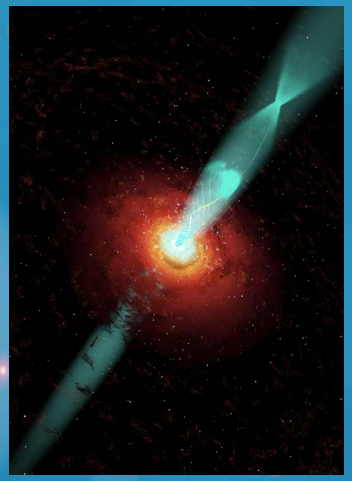
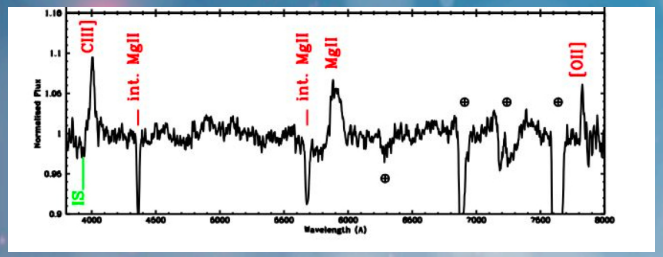
INAF - Osservatorio Astronomico di Padova

Spectroscopy of extragalactic gamma-ray emitters: New identification, classification and Redshift







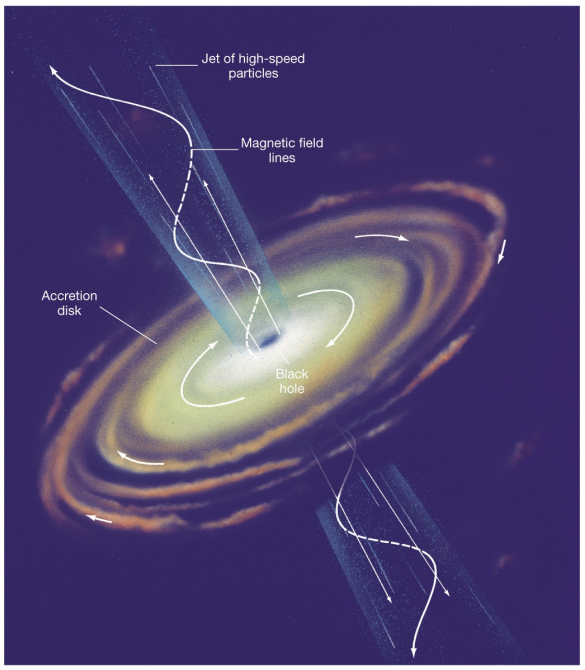
Speaker:
Simona Paiano – INAF OAPD

Collaborators:
R. Falomo – INAF OAPD
A. Treves – Univ. Insubria
M. Landoni – INAF OABrera
R. Scarpa – IAC/GTC
A. Franceschini - UNIPD

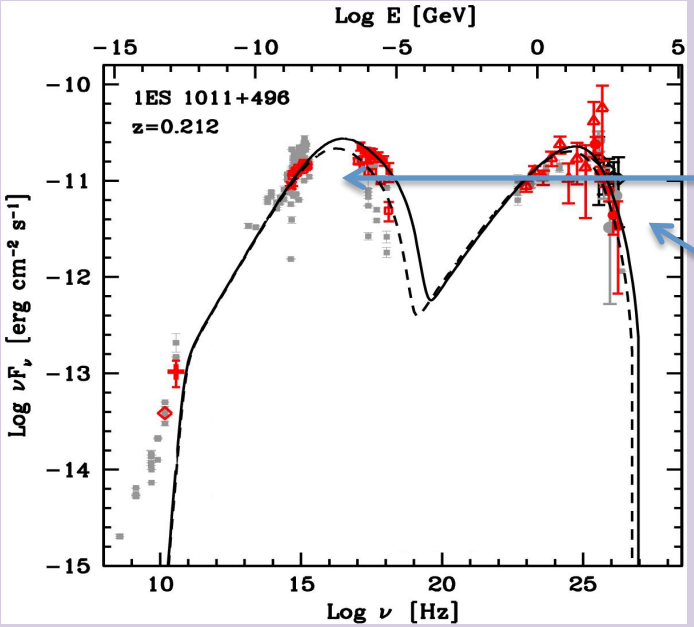
BLAZARs

Class of jetted AGNs with jet pointing towards the observer

- -> The most powerful emitters from radio up to TeV;
- -> Highly polarized;
- -> Strong variability at all wavelength.



Typical MWL double-bump SED shape



Synchrotron emission (Radio-> X-ray)

Inverse Compton emission (X-ray -> TeV)

Adapted from Aleksic+2016

REDSHIFT

BLAZARs

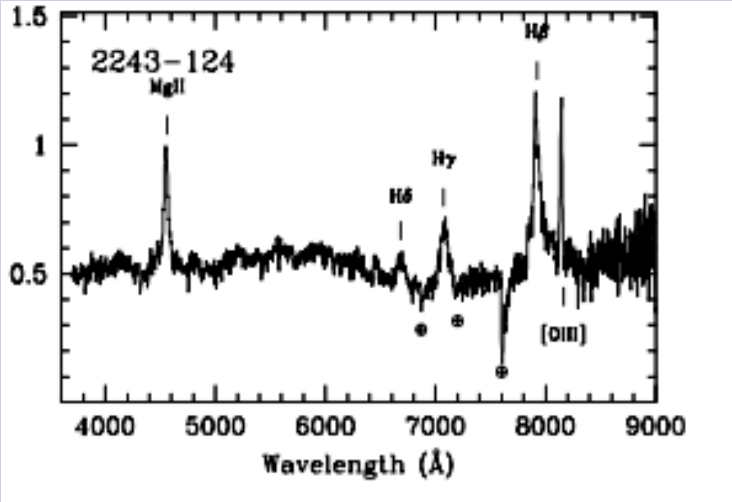
≈ 3500 blazars in the 5th edition of BZCAT (Massaro+2015)

-> sources detected at the radio frequencies
-> 70% detected in the X-ray band

A significant difference is based on the optical spectrum

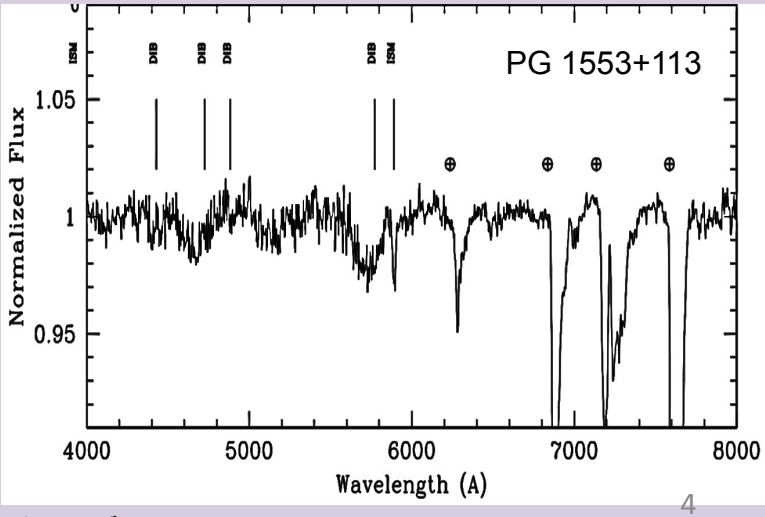
Two broad classes:

FSRQs
broad emission lines
and thermal blue bump



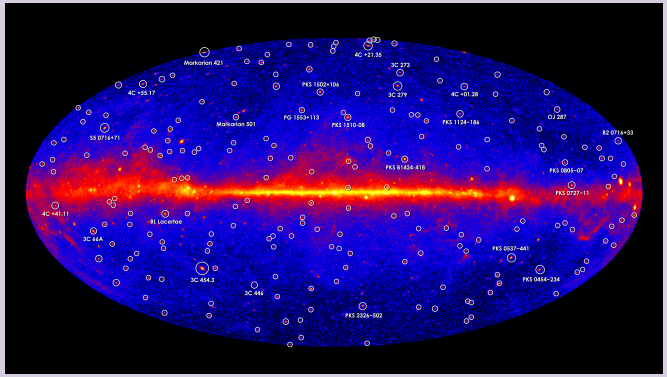
Scarpa+1998

BLLac objects
weak emission lines
or absent



Sbarufatti+2006

THE FERMI SATELLITE & CATALOGS



Blazars represent the most abundant Extragalactic population at GeV-TeV energies

See Gasparrini's talk of this morning!

Several catalogs given by Fermi:

FL8Y > 3FHL > 3FGL > 2FHL > 1FHL >2FGL > 1FGL > 0FGL

4LAC, 3LAC, 2LAC, 1LAC, 2PC, 1PC, GRBCat....

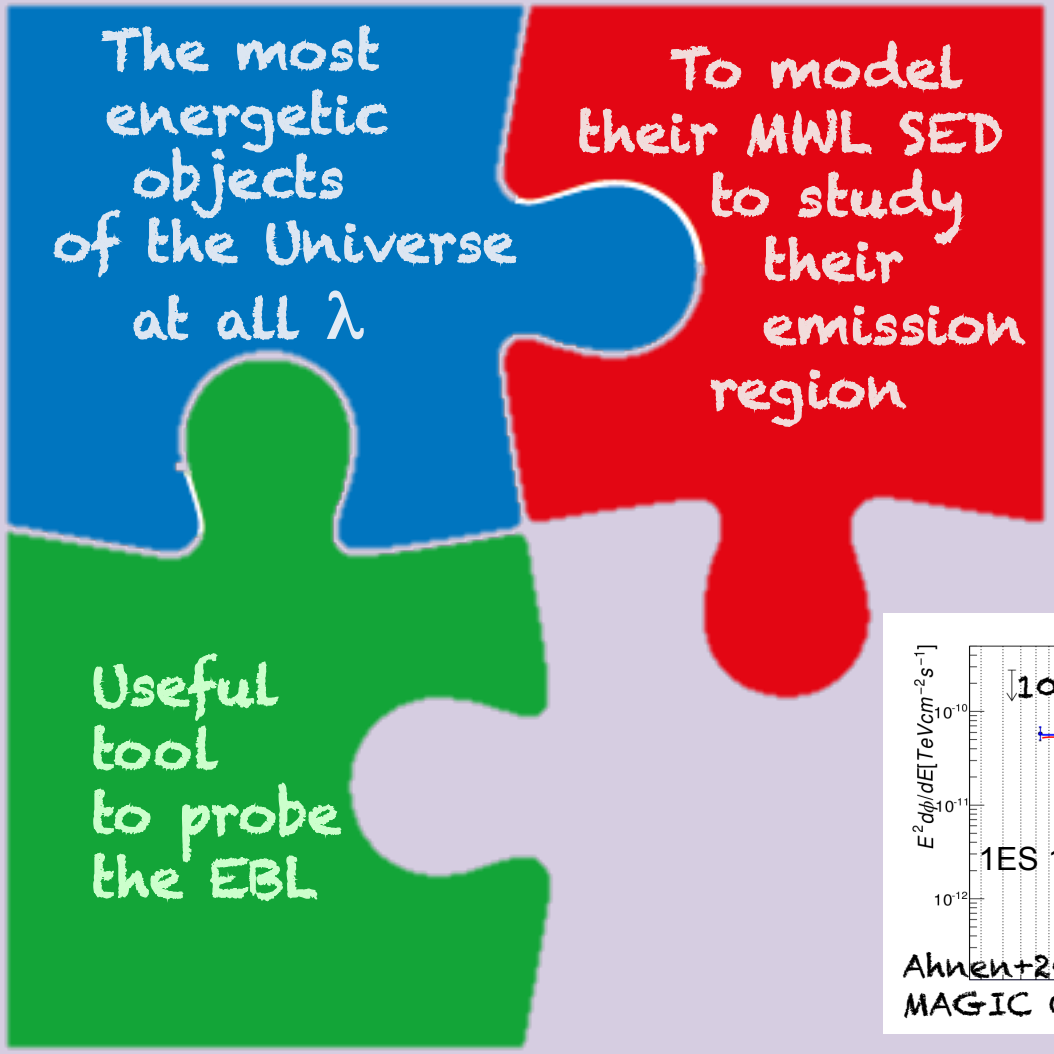
3FGL (FL8Y) catalog reports 3033 (5524) γ-ray emitters:

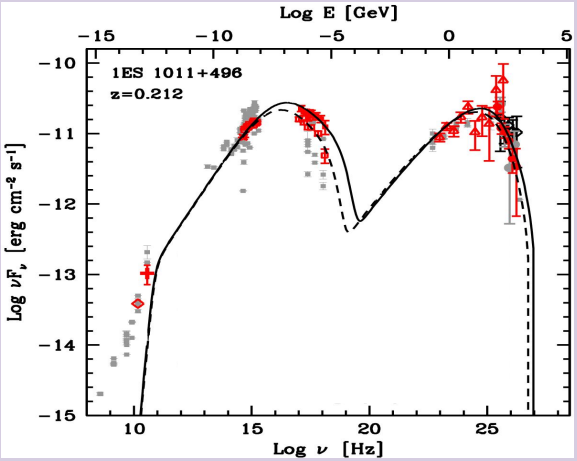
- -> 40% (50%) are blazars (the most numerous class)
- -> ~ 500 (~ 660) FSRQs
- -> ~ 650 (~ 1050) BLLs
- -> ~ 600 (~ 1235) blazars of uncertain type (BCU)
- -> 30% (40%) Unassociated Fermi Objects (most of them probably blazars)

THE TeV BAND & TeV BLAZARS

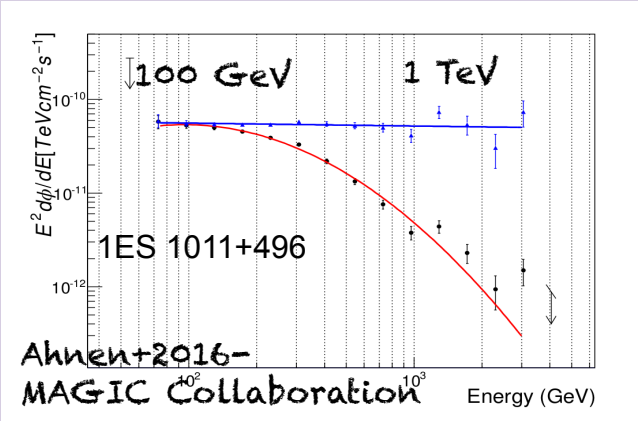
A sub-sample of the GeV blazars
(mainly BL Lacs)
are also emitters at the TeV (1TeV : 25GeV)

TeVcat: -> 59 +2(?) BLLs
-> 7 FSRQs
-> 4 blazars





Aleksic+2016



Ahnen+2016-
MAGIC Collaboration

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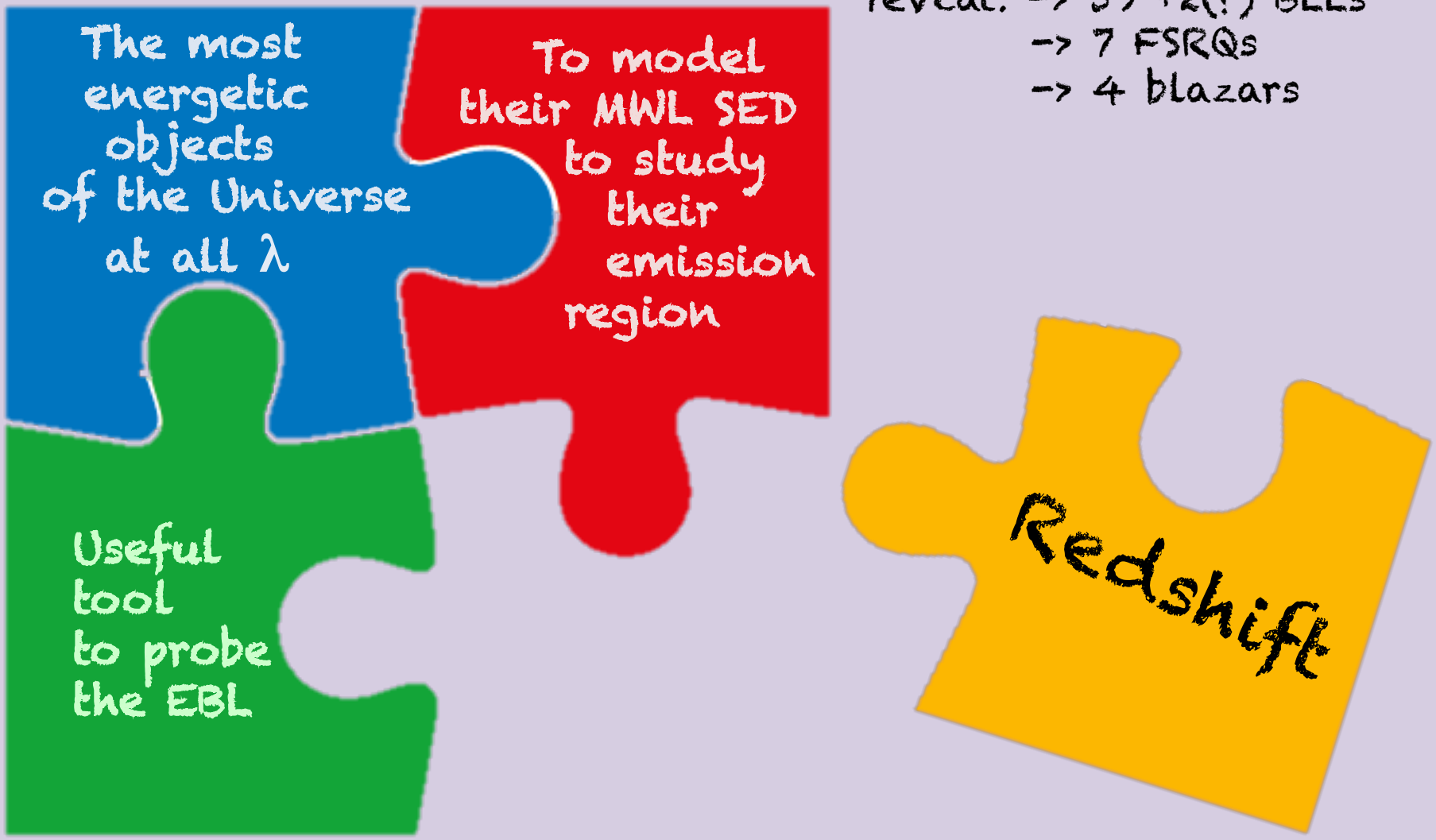

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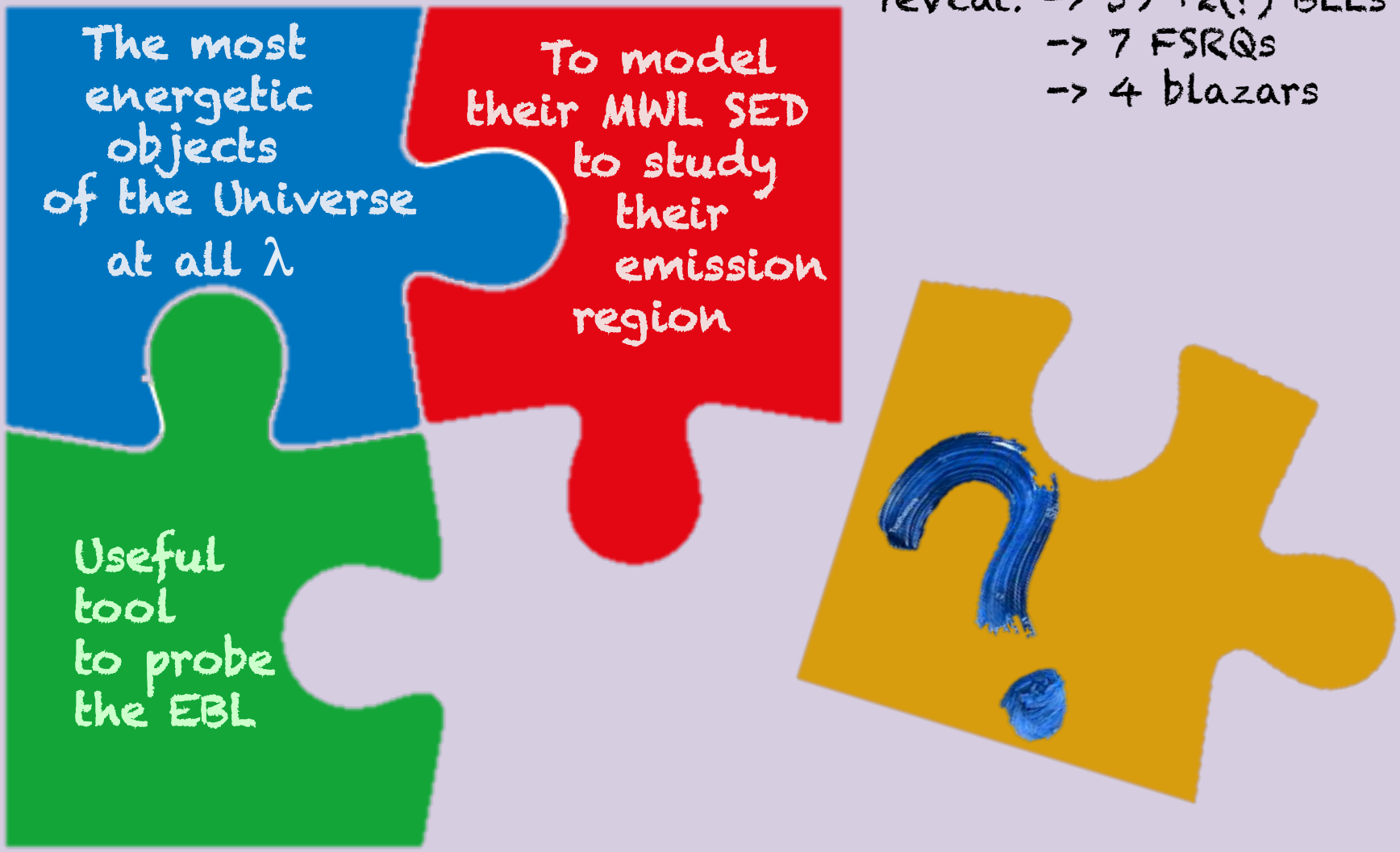
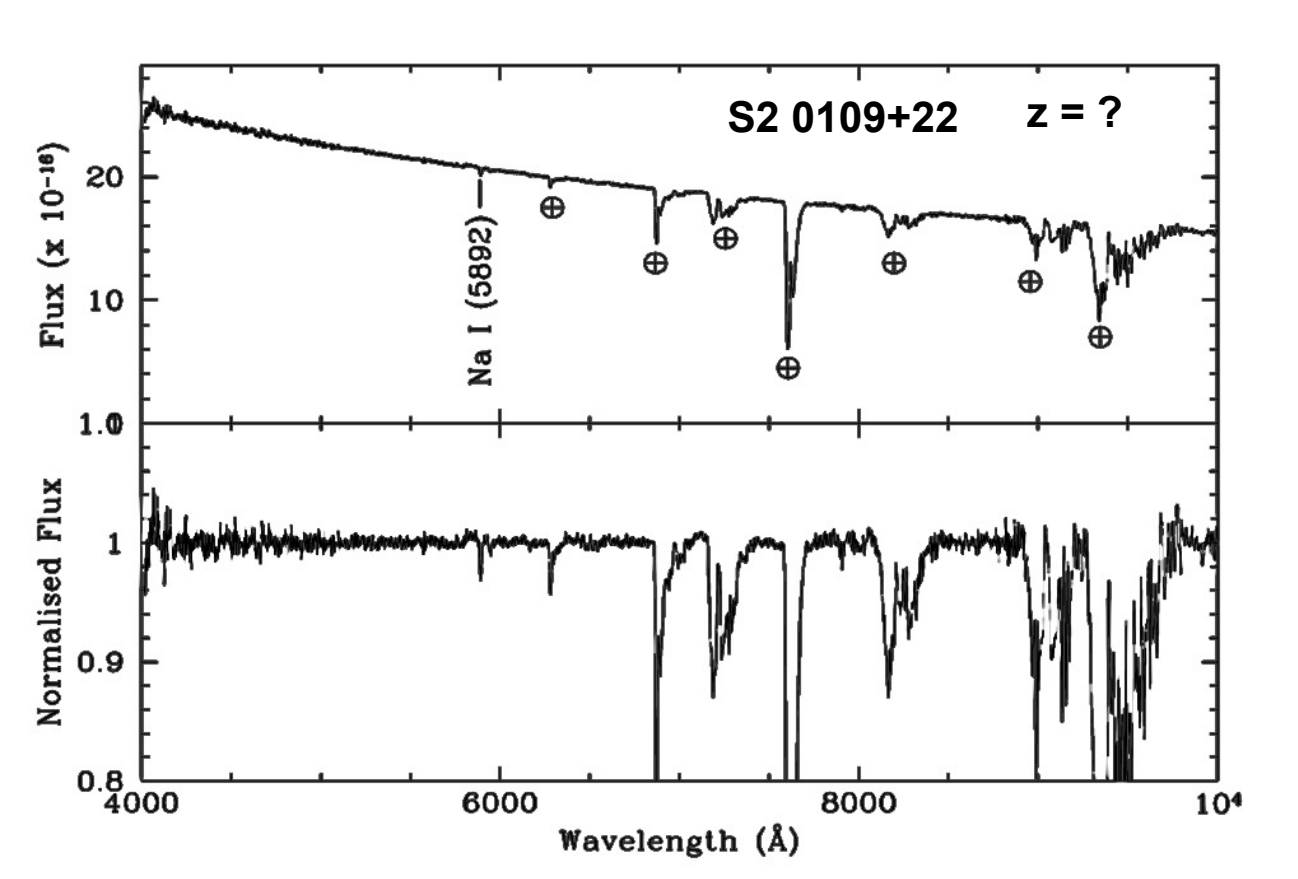


ON THE REDSHIFT OF BL Lacs

The (quasi) featureless optical spectra is the main characteristic of the BL Lac class



Paiano+2016

The determination of their redshift is extremely difficult

≈ 50% of GeV BLLs has unknown or highly uncertain redshift

GTC SPECTROSCOPY CAMPAIGN

It needs to have optical spectra of high S/N and spectral resolution

We are carrying out an extensive spectroscopy campaign using OSIRIS @GTC (10m) of various sub-samples of γ-ray blazars:

-> more than 150 targets observed
-> Spectral Range: 4000-10000 A
-> grisms: R500B, R1000 and R2500
-> Spectral resolution = 600-1200
-> S/N = 50 - 500
(depending on the source mag)

GTC SPECTROSCOPY CAMPAIGN

LIST OF SUB-SAMPLES:

-> 22 TeV and TeV candidate BLLs with unknown/uncertain redshift

-> Paiano et al. (2016), Paiano et al. (2017a)
Landoni et al. (2016), Falomo et al. (2017)

-> 10 high-z GeV BLLs

-> Paiano et al. (2017b)

-> 55 Unassociated Fermi Objects

-> Paiano et al. (2017c),
Paiano et al. (2018b in prep)

-> 16 Optically selected high redshift BLL candidates

-> Landoni et al. (2018)

-> 20 3FHL blazars with unknown redshift -> Paiano et al. (2018d, in prep)

-> 15 high redshift BLL candidates

-> Paiano et al. (2018e, in prep)

-> 10 neutrino BLL candidates

-> Paiano et al. (2018a),
Paiano et al. (2018c, in prep)

GTC SPECTROSCOPY CAMPAIGN

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-> 10 neutrino BLL candidates

-> Paiano et al. (2018a),
Paiano et al. (2018c, in prep)

All published spectra are available at the website

http://www.oapd.inaf.it/zbllac/

See Falomo's poster For ZBLLAC database

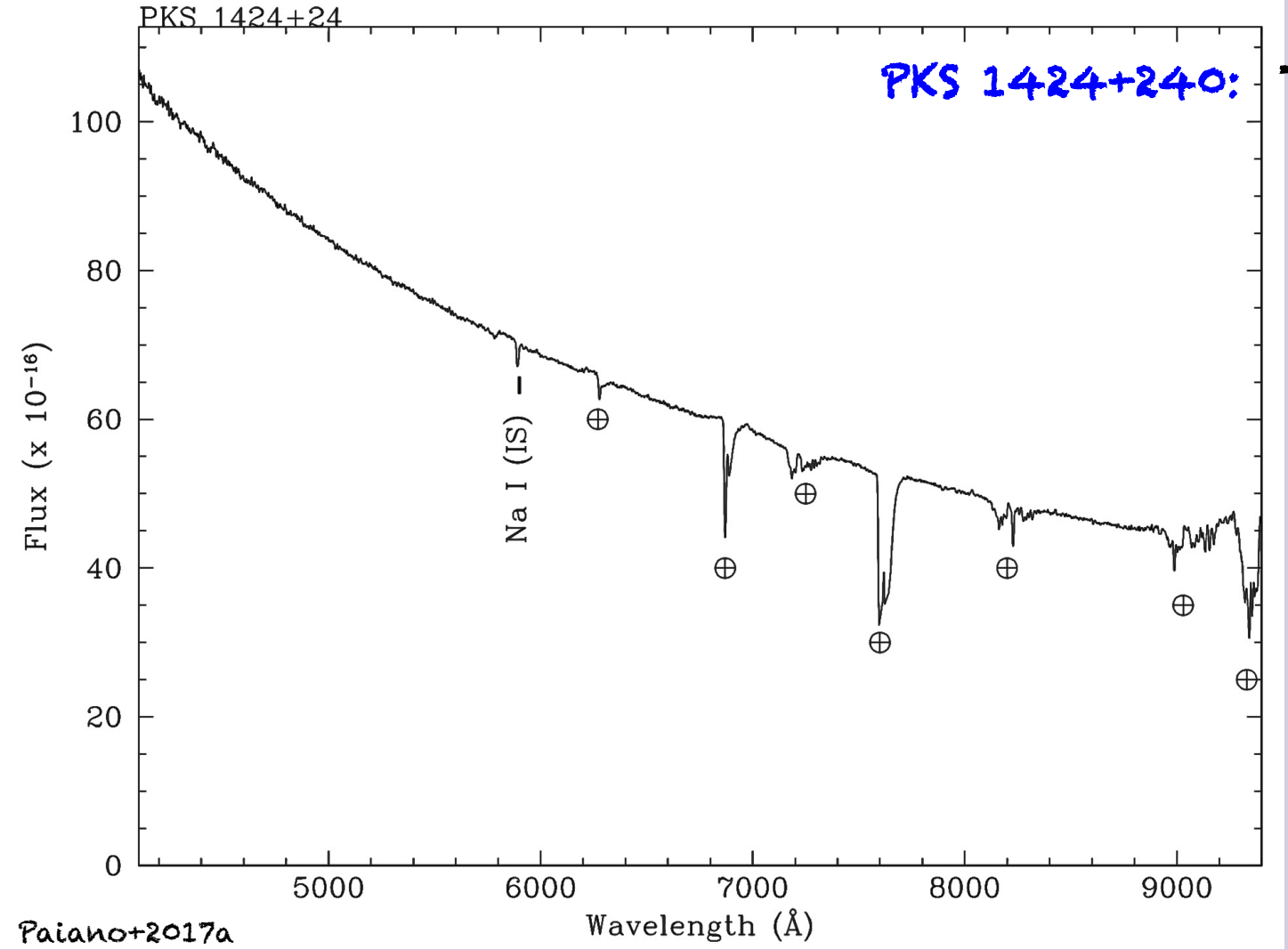
See Paiano's poster about TXS0506+056

Based on the properties of the optical spectra, the objects can be grouped into 4 types

- Emission lines characteristic of low-density gas
- Absorption lines of stars from the host galaxy
- Intervening absorption lines from cold gas
- Featureless spectrum

RESULTS (Some examples...)

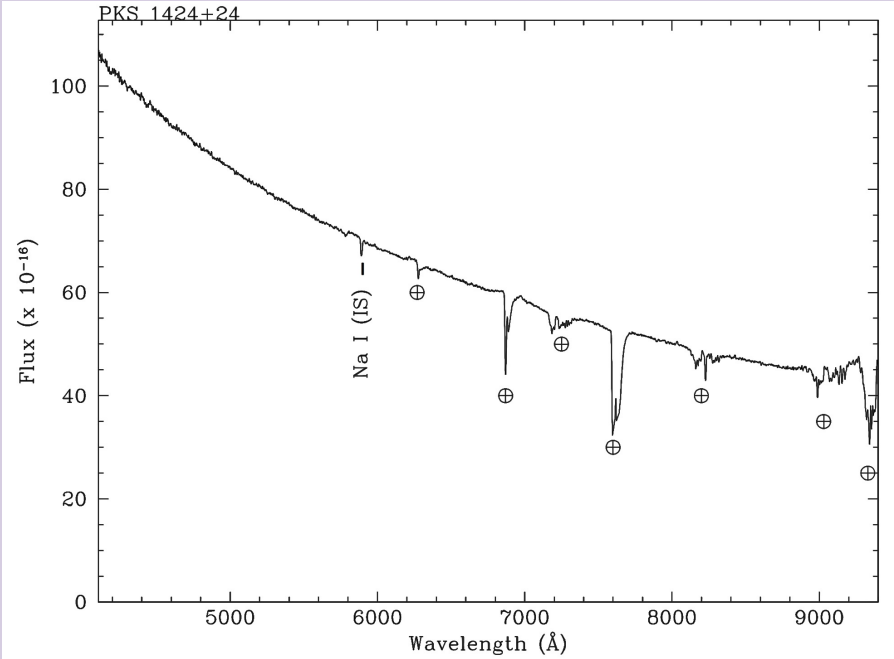
Emission lines characteristic of low-density gas



TeV HBL source

RESULTS

Emission lines characteristic of low-density gas



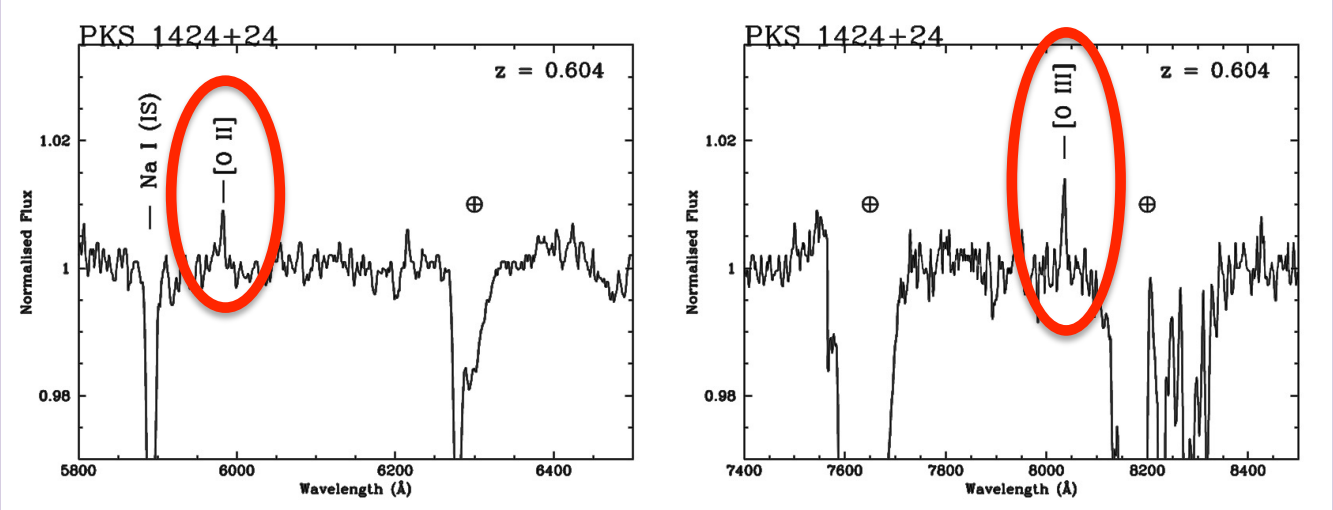
Paiano+2017a

PKS 1424+240: TeV HBL source

[OII](3727) -> EW = 0.05A

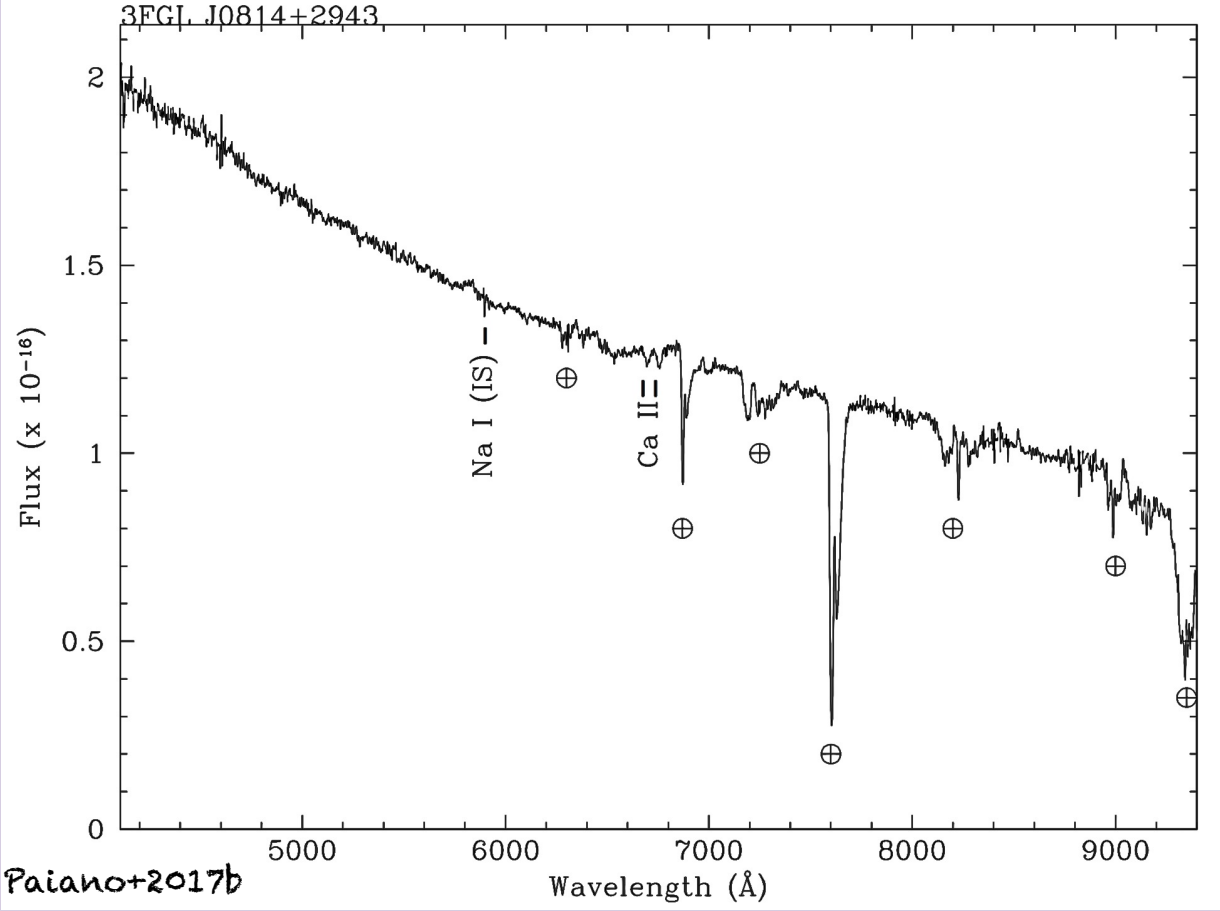
[OIII](5007) -> EW = 0.10A

z = 0.604



RESULTS

Absorption lines of stars from the host galaxy



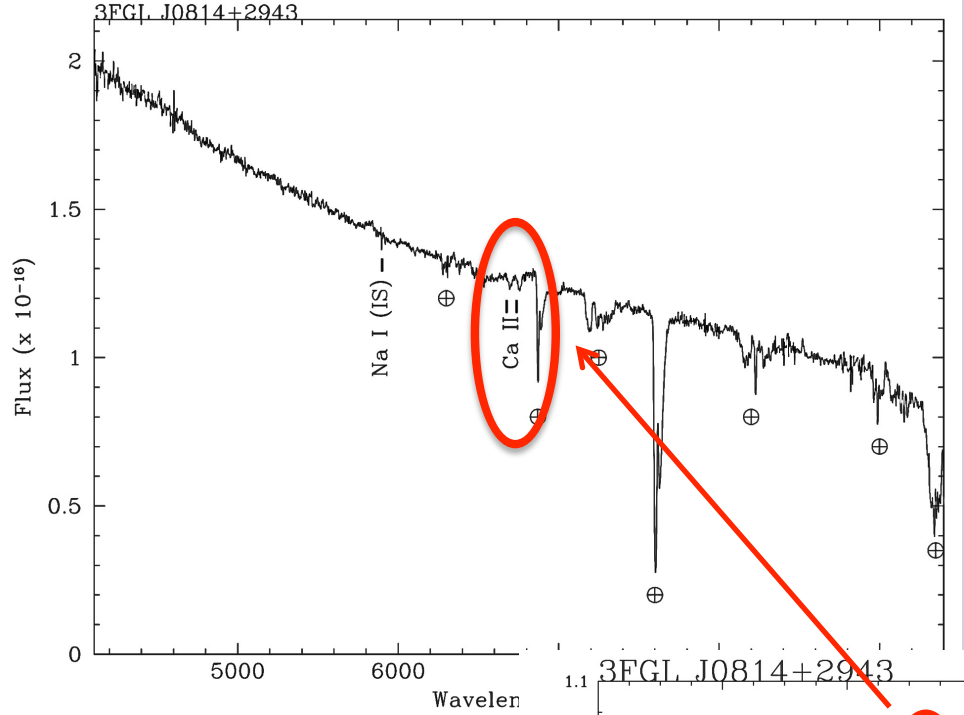
3FGLJ0814+2943

High-z BLL of 3FGL

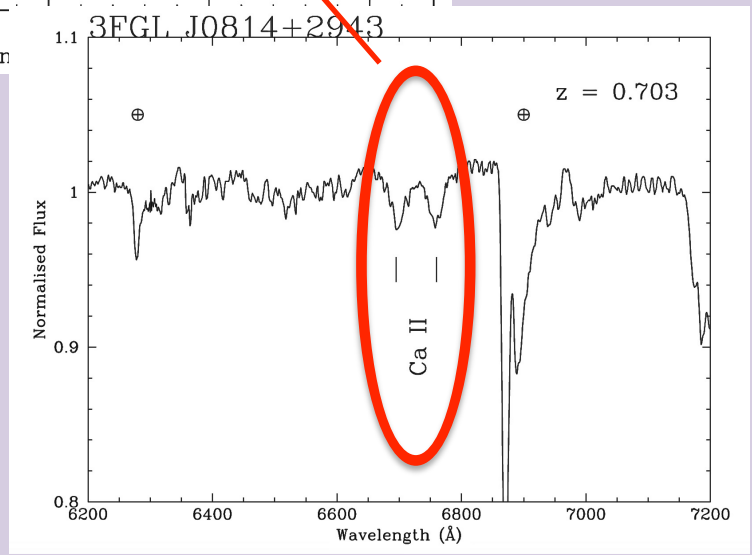
(Literature z = 1.08)

RESULTS

Absorption lines of stars from the host galaxy



Paiano+2017b



3FGLJ0814+2943

High-z BLL of 3FGL

(Literature ~~z = 1.08~~)

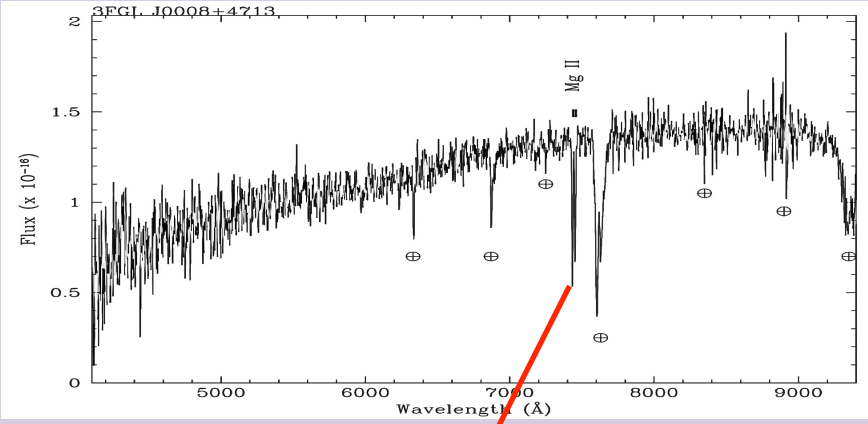
CaII(3934) -> EW = 0.6A

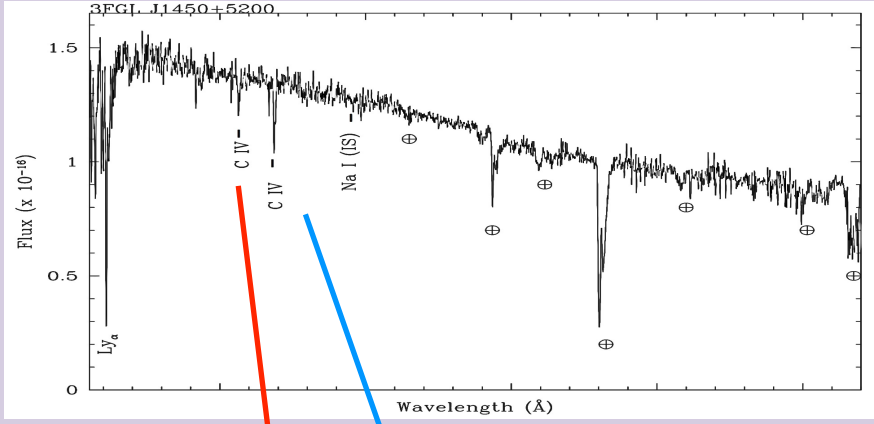
CaII(3968) -> EW = 0.5A

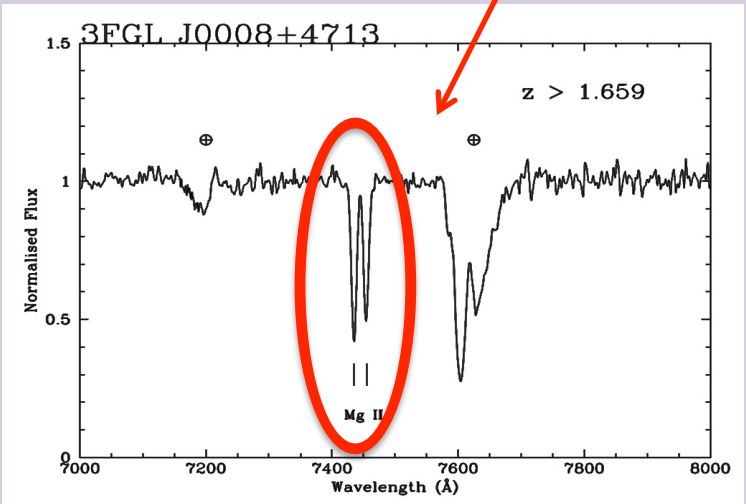
z = 0.703

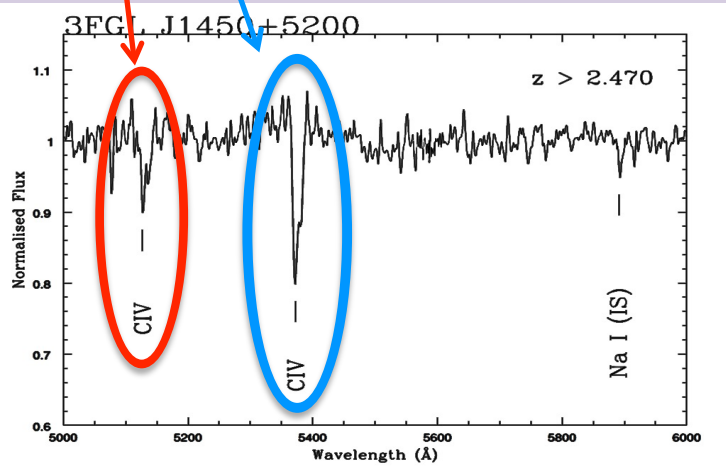
RESULTS

Intervening absorption lines from cold gas -> Redshift Lower Limits









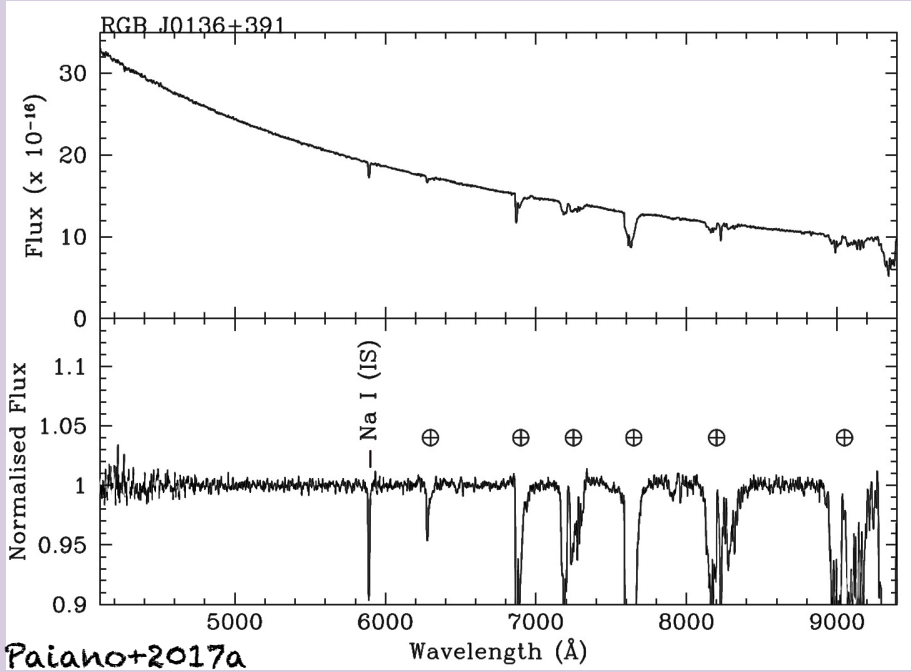
3FGLJ0008+4713
High-z BLL of 3FGL
MgII (2008) -> z > 1.659

3FGLJ1450+5200
High-z BLL of 3FGL
CIV (1548) - Ly-α(1216) z > 2.470 <-
CIV (1548) z > 2.312 <-

Two of the farthest BLLs known!!!

RESULTS

Featureless spectrum



Paiano+2017a

RGB J0136+391

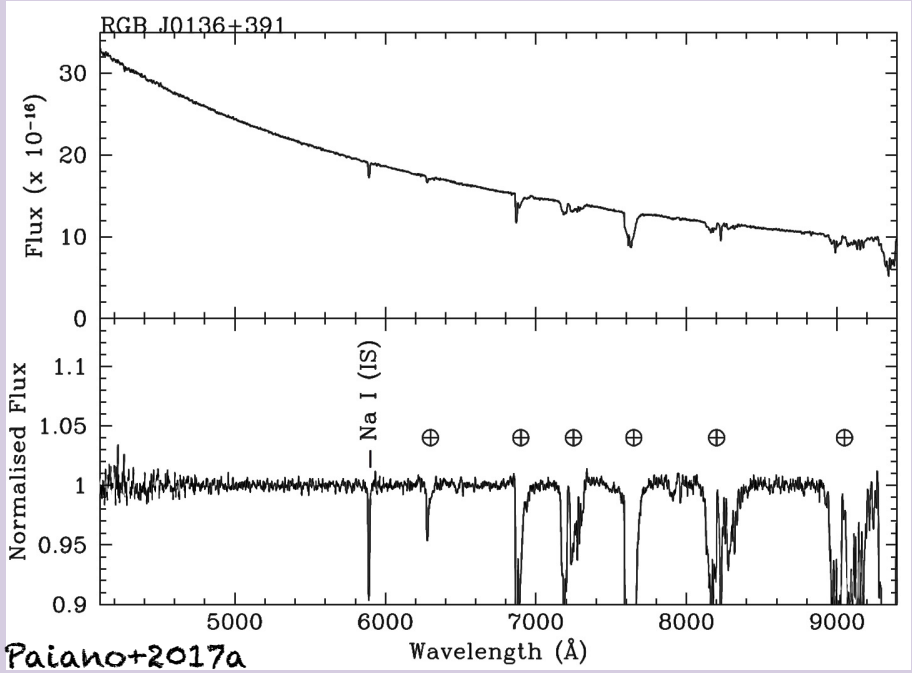
TeV HBL

S/N = 500

r = 15.80

RESULTS

Featureless spectrum

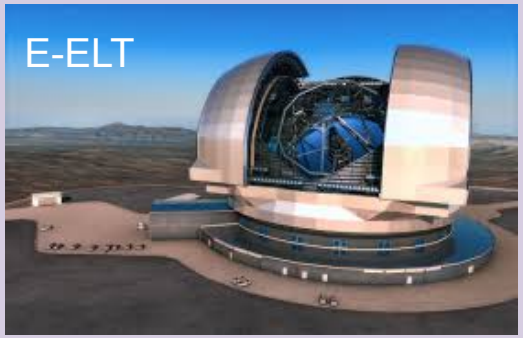


Paiano+2017a

RGB J0136+391
TeV HBL
S/N = 500
r = 15.80

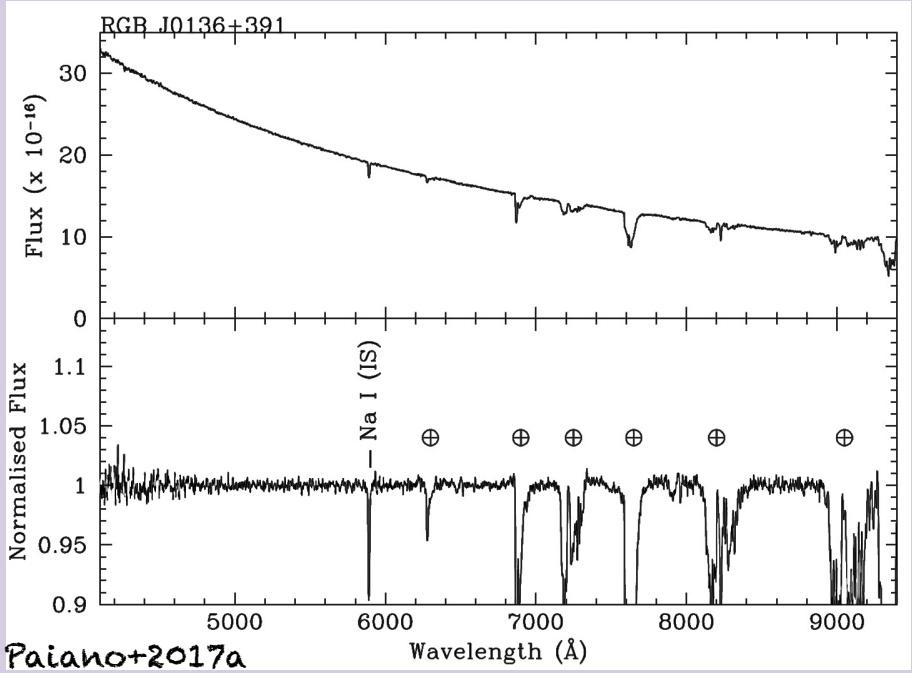
Despite the very high S/N, no absorption/emission lines are detected

Redshift measurement likely possible only with future facilities as ELT



RESULTS: Lower limit of the redshift

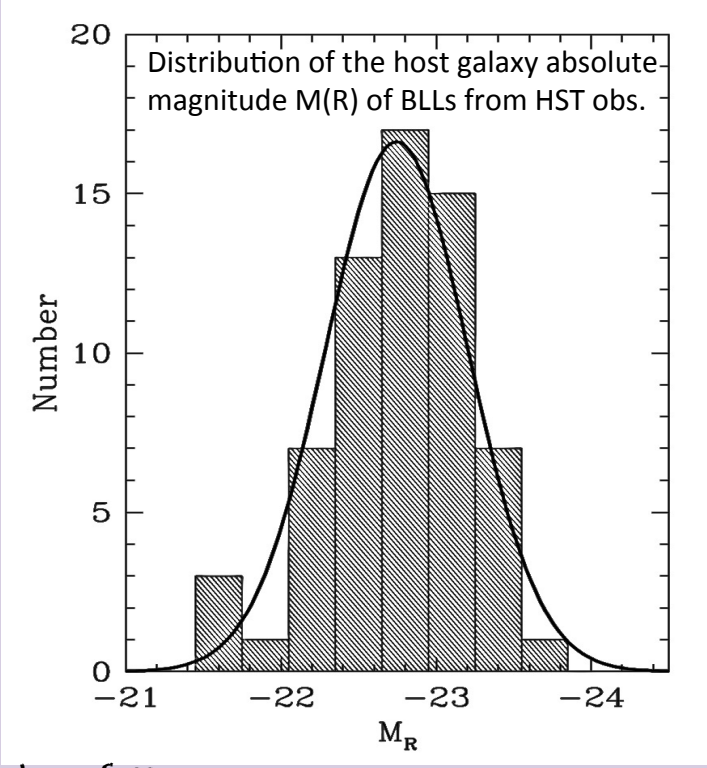
Featureless spectrum



Paiano+2017a

RGB J0136+391
TeV HBL
S/N = 500

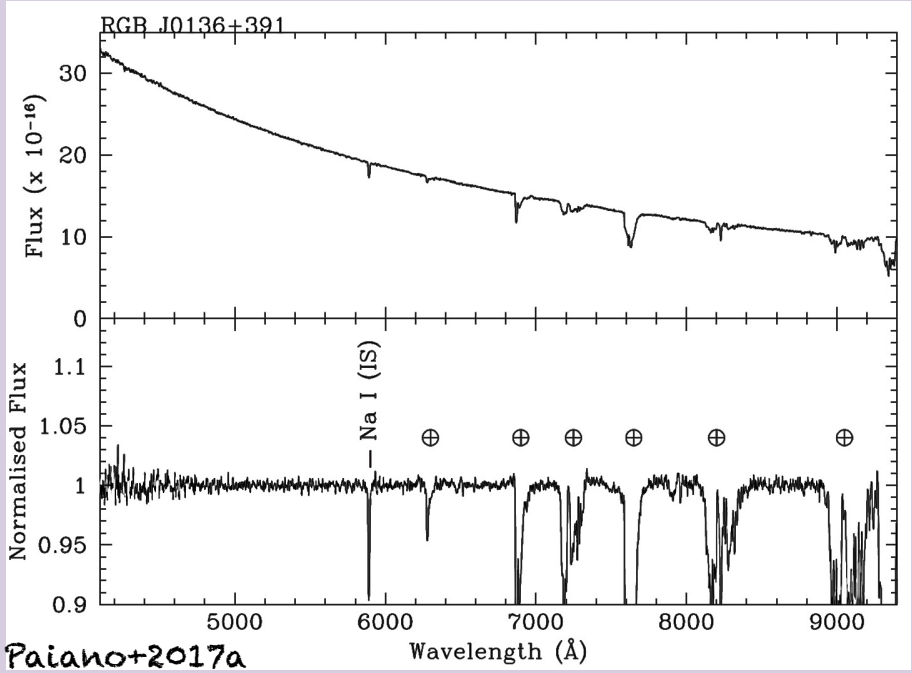
Non-thermal Nucleus
+
Elliptical host galaxy
[M(R) = −22.9]
=
Observed spectrum



Sbarufatti+2005

RESULTS: Lower limit of the redshift

Featureless spectrum



Paiano+2017a

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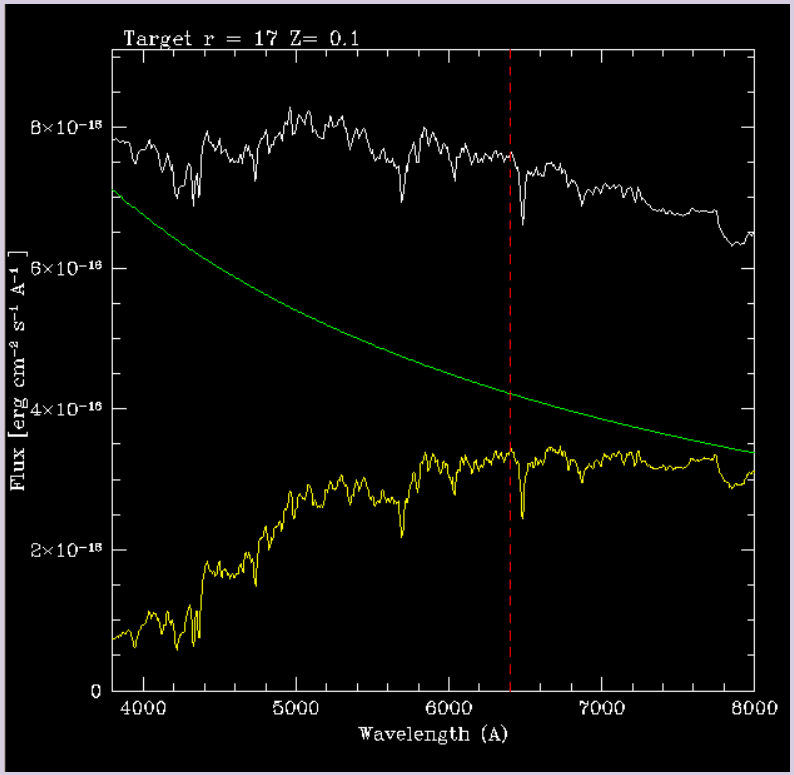
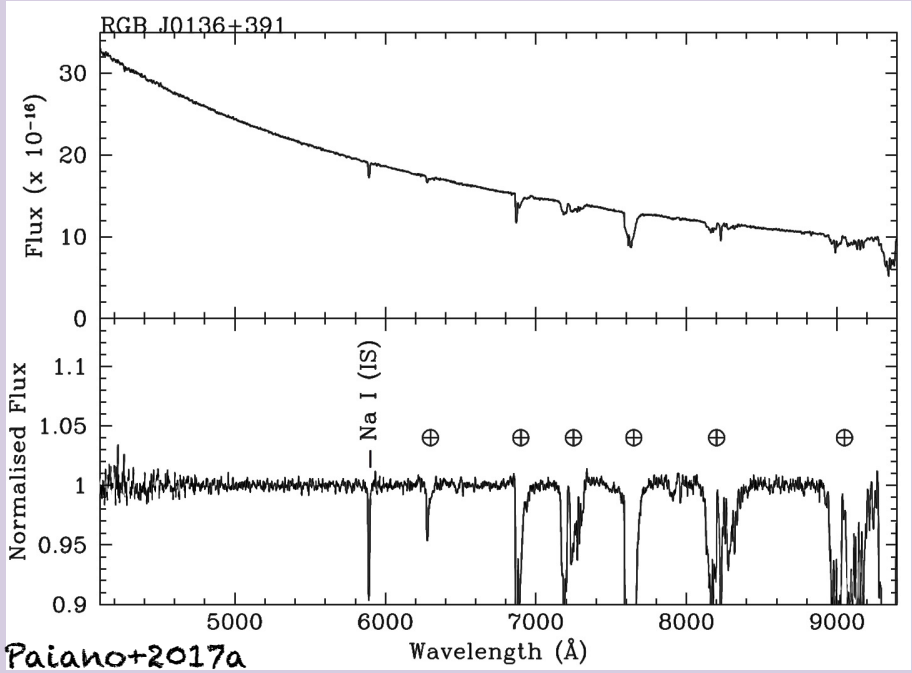


RGB J0136+391
TeV HBL
S/N = 500

Mag=17, z=0.10, Diluited EW=1.6A

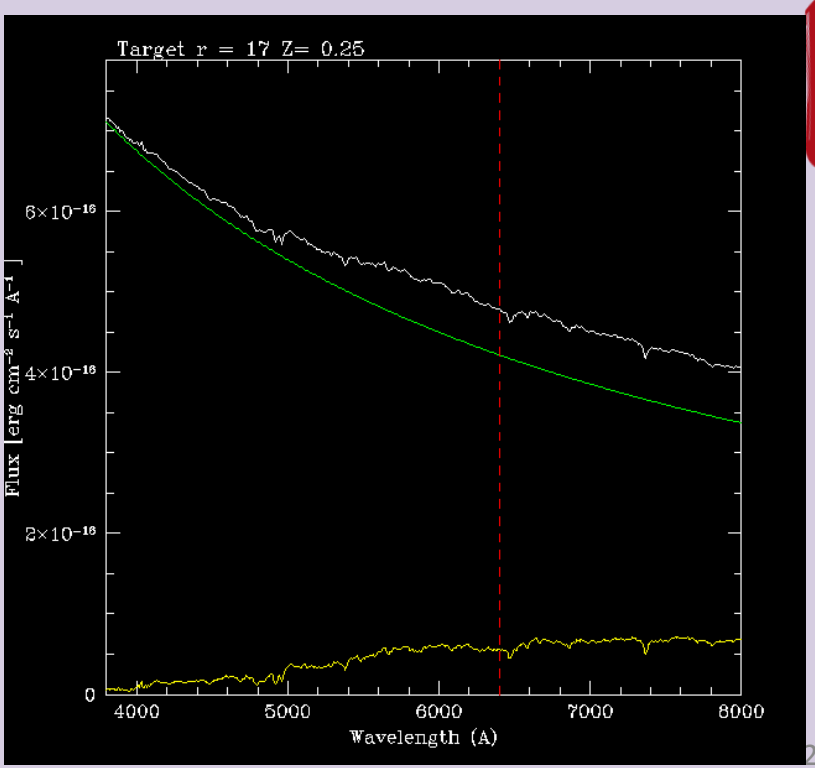
RESULTS: Lower limit of the redshift

Featureless spectrum



Paiano+2017a

Non-thermal Nucleus
+
Elliptical host galaxy
[M(R) = -22.9]
=
Observed spectrum

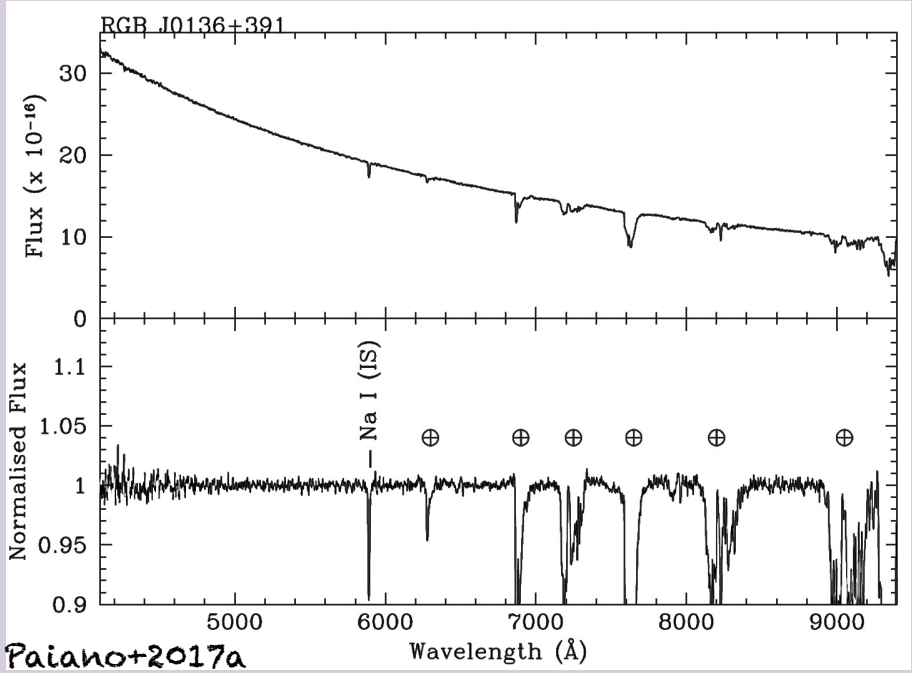


RGB J0136+391
TeV HBL
S/N = 500

Mag=17, z=0.25, Diluited EW=0.5A

RESULTS: Lower limit of the redshift

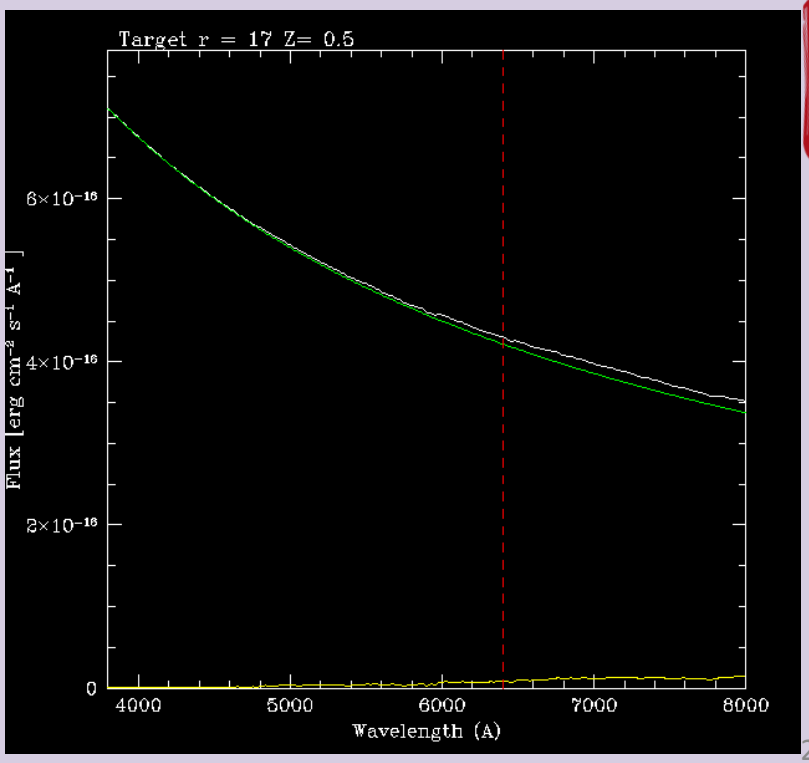
Featureless spectrum



Paiano+2017a

RGB J0136+391
TeV HBL
S/N = 500

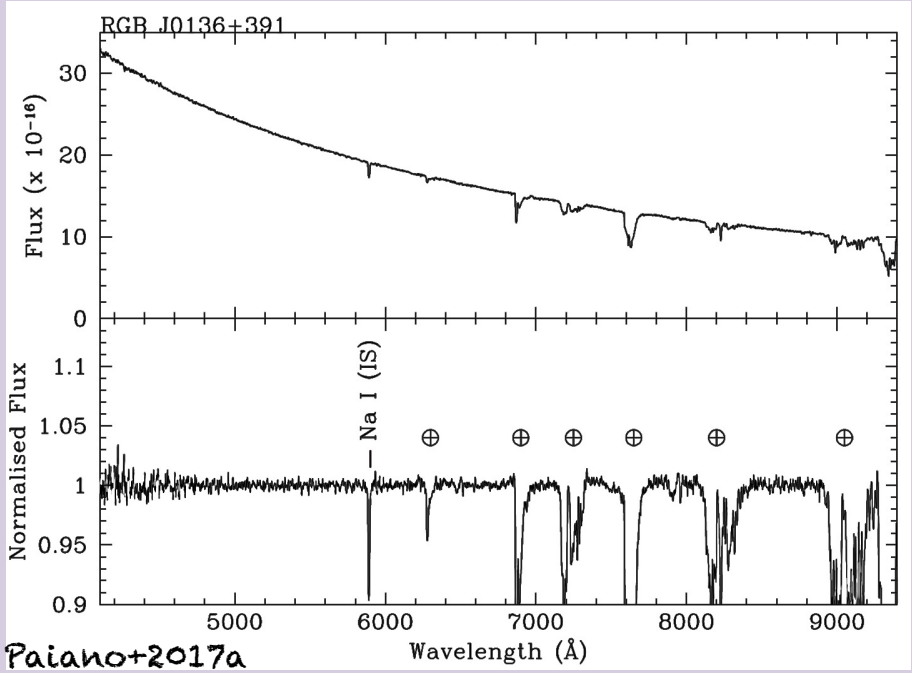
Non-thermal Nucleus
+
Elliptical host galaxy
[M(R) = -22.9]
=
Observed spectrum



Mag=17, z=0.50, Diluited EW=0.15A

RESULTS: Lower limit of the redshift

Featureless spectrum

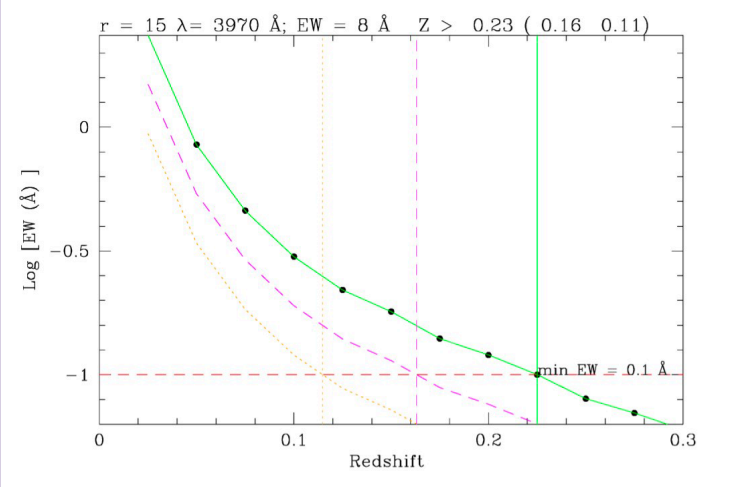


Paiano+2017a

Non-thermal Nucleus
+
Elliptical host galaxy
[M(R) = -22.9]
=
Observed spectrum

We can derive UL EW . . .

$$EW_{obs} = \frac{(1+z)EW_0}{1+\rho A(z)}.$$



RGB J0136+391
TeV HBL
S/N = 500
minEW = 0.08

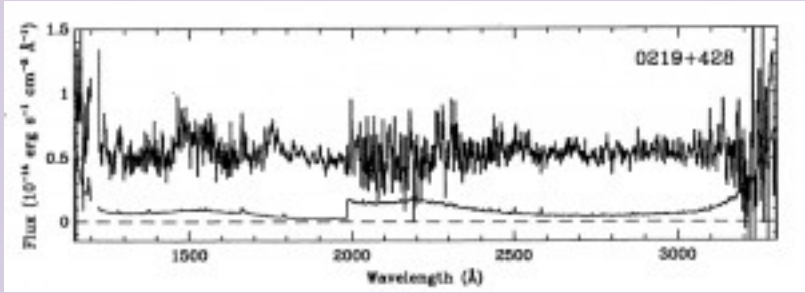
$z_{Lim} > 0.27$

. . . and a lower Limit on the redshift

RESULTS: Lower limit of the redshift

For several cases, we disprove the previous published redshift

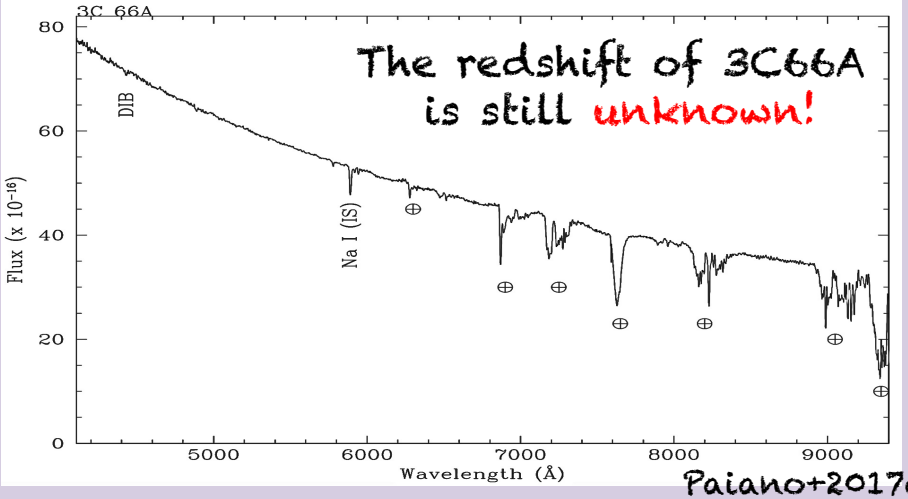
CASE OF 3C66A



One of the first BLLs studied !!

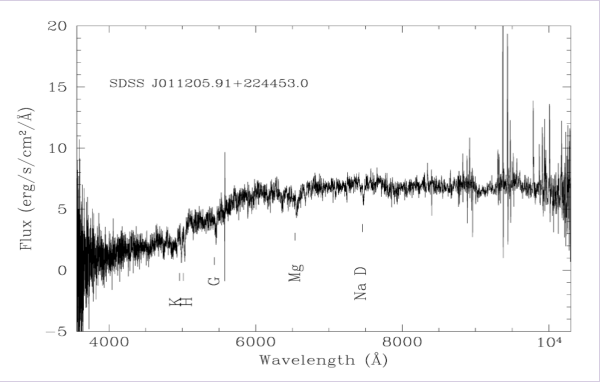
z = 0.444

(Miller+78 , Lanzetta+1993)

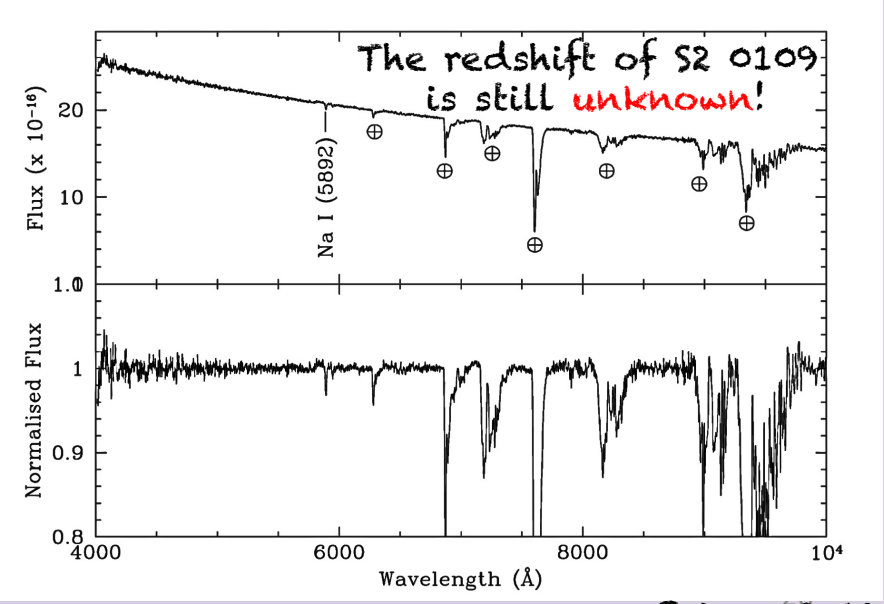


Paiano+2017a

CASE OF S2 0109+22



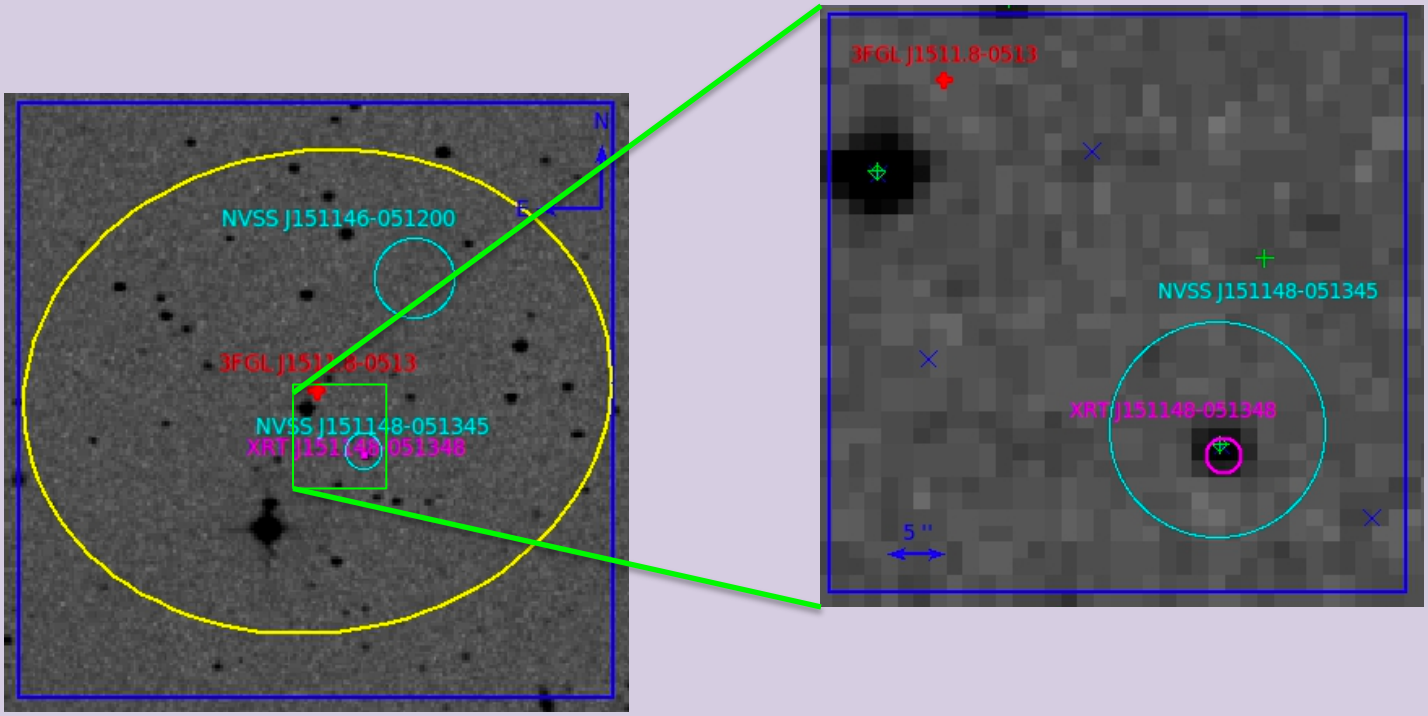
z = 0.26, but this is the redshift of a close galaxy!



Paiano+2016

SPECTROSCOPY OF UNASSOCIATED γ-RAY SOURCES (UGSs).

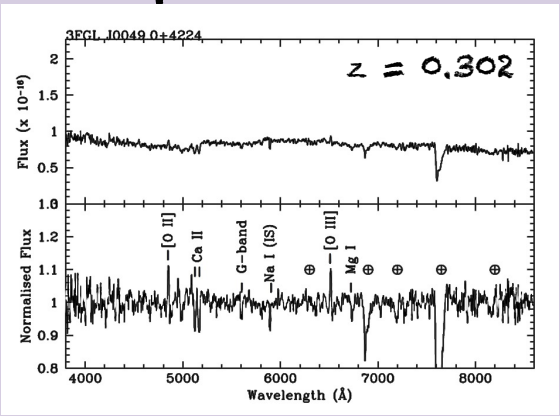
On-going spectroscopic campaign of a sample of
50 optical counterparts of UGSs
selected using Swift X-ray data covering the 3FGL sky position, to find possible MWL counterparts

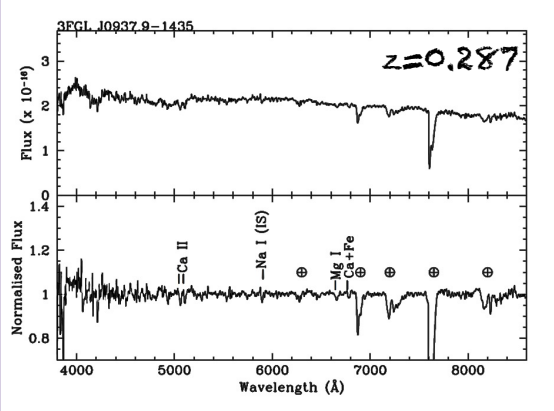


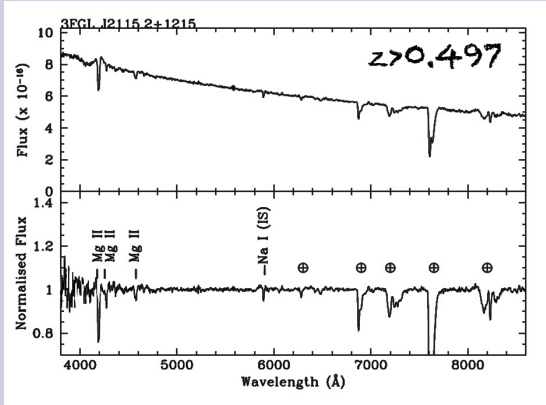
Adapted by
Paiano,Franceschini+2017

SPECTROSCOPY OF UNASSOCIATED γ-RAY SOURCES (UGSs).

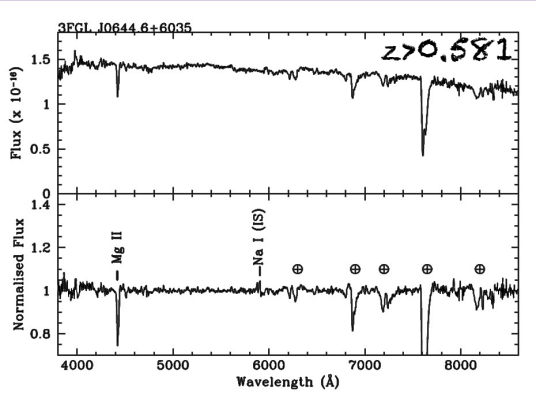
Examples of GTC spectra of optical counterparts of UGSs

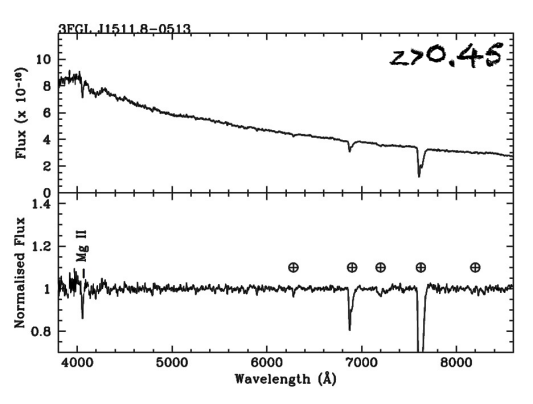


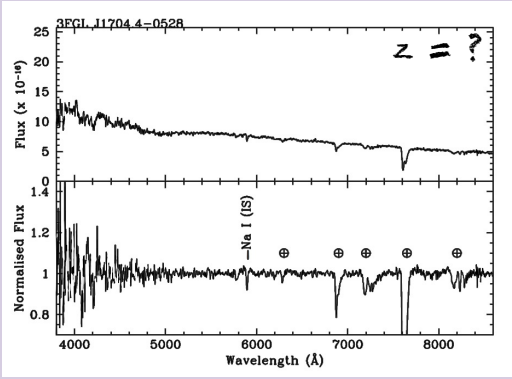




Paiano+2017c







We establish the blazar nature for >90% of our targets and find their redshift for most of them

CONCLUSIONS

The knownledge of the redshift of BL Lacs plays a fundamental role of the puzzle

-> High S/N GTC spectra of γ-BLLs allowed to obtain new redshift or set stringent sound lower limits
All published spectra available at
http://www.oapd.inaf.it/zbllac/

-> 25% of BLLs in the sample are at z >0.5
10% at z > 1

-> We established the blazar nature of many optical counterparts of UGSs, and we found the redshift

* Search for high redshift and neutrino BLL candidates as good targets for future CTA observations

* The measure of the redshift of BLL with still featureless spectra (very high nucleus-to-host ratio) will be likely possible only in the ELT era.


THANK
YOU

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