
MWL FOLLOW UP COORDINATION

Matteo Cerruti
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MWL FOLLOW UP COORDINATION (HOW DO WE DO FOR A SPECIFIC USE CASE)

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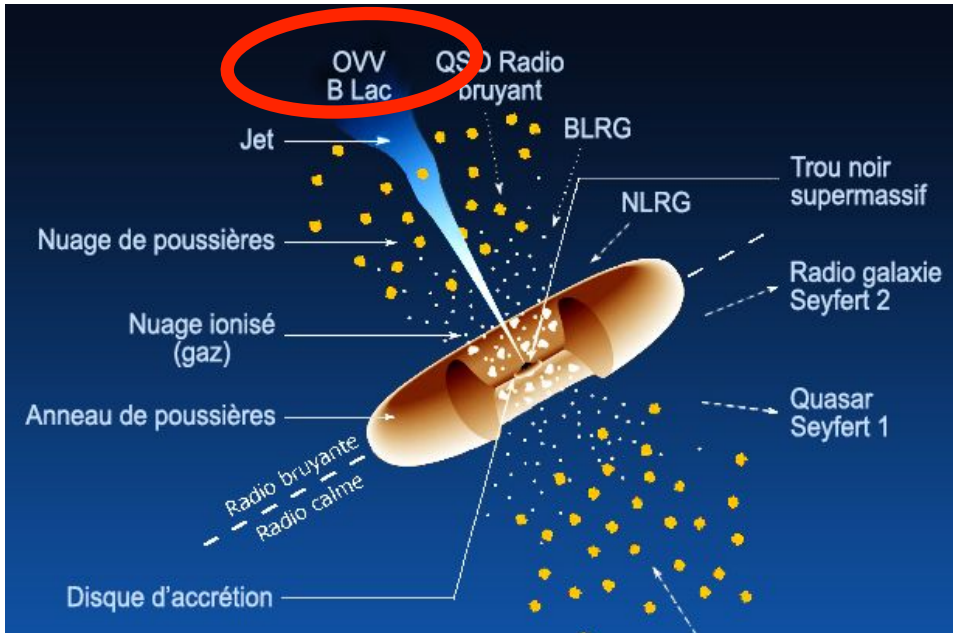


MWL FOLLOW UP

USE CASE: BLAZARS @ TeV

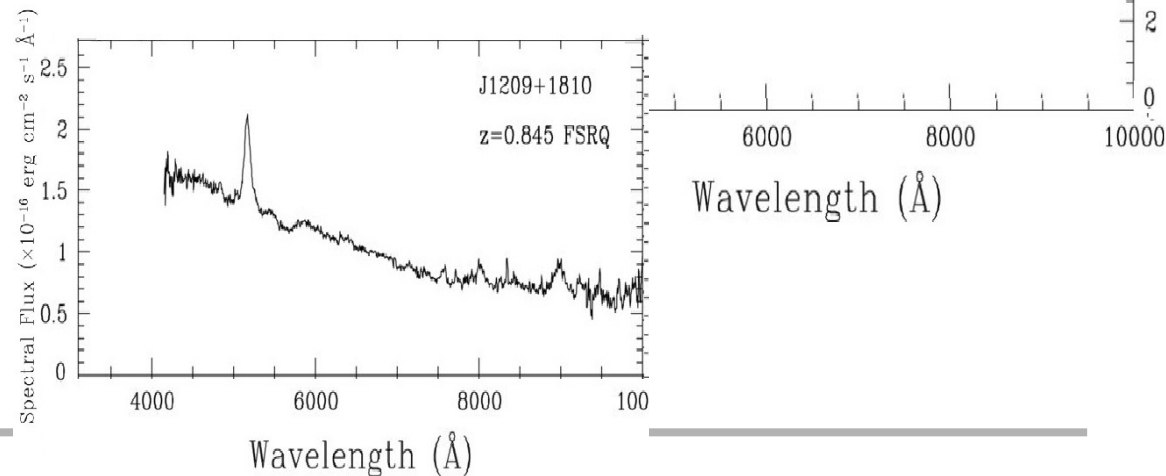
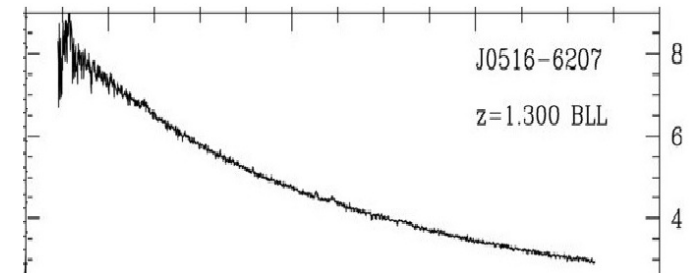
- SOME KEY FACTS ON BLAZARS (AND MISCONCEPTIONS)
- WHAT ARE THE NEEDS, HOW DO WE DO IT
- HOW TO IMPROVE / RISK ASSESSMENTS / FUTURE

BLAZARS



Blazars : **radio-loud** active galactic nuclei whose relativistic jet points towards the observer

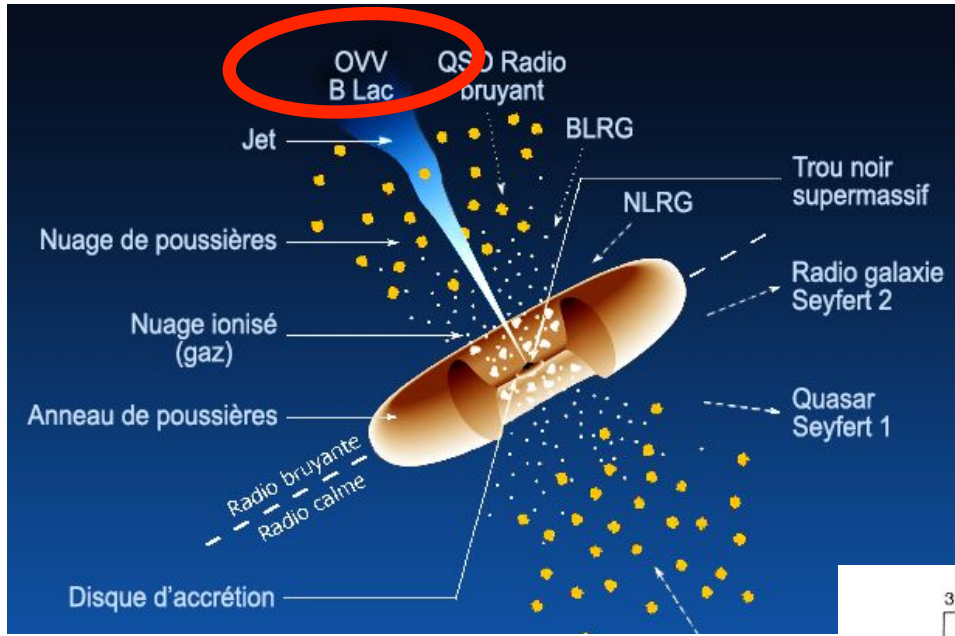
→ jet emission dominates over other AGN components (non-thermal from radio to gamma)



BL Lac objects : no lines in optical/UV
FSRQs : emission lines (BLR) seen

Two kind of jets / two accretion regimes
 (same dichotomy as in radio galaxies)

BLAZARS

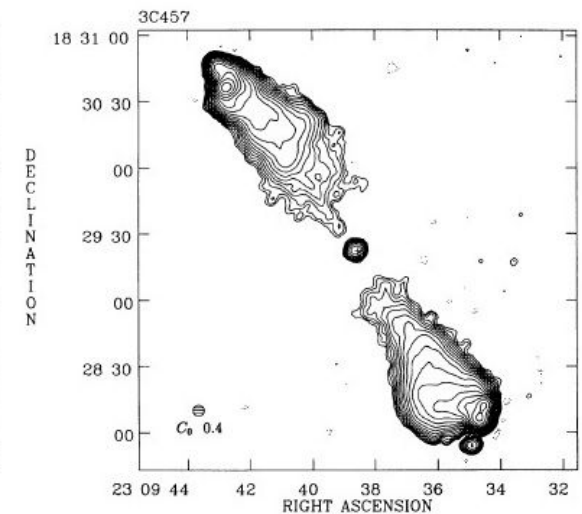
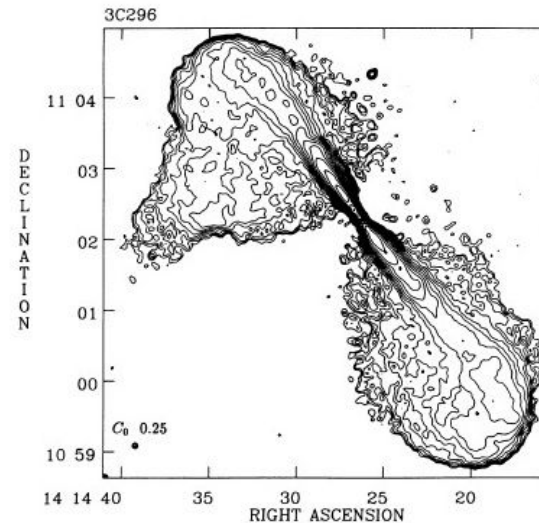


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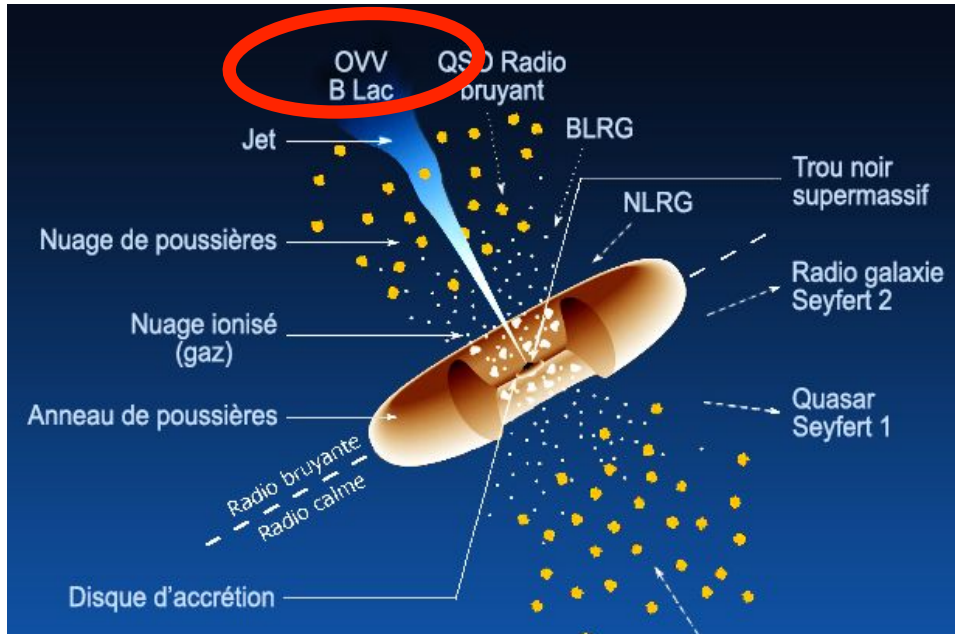
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BLAZARS



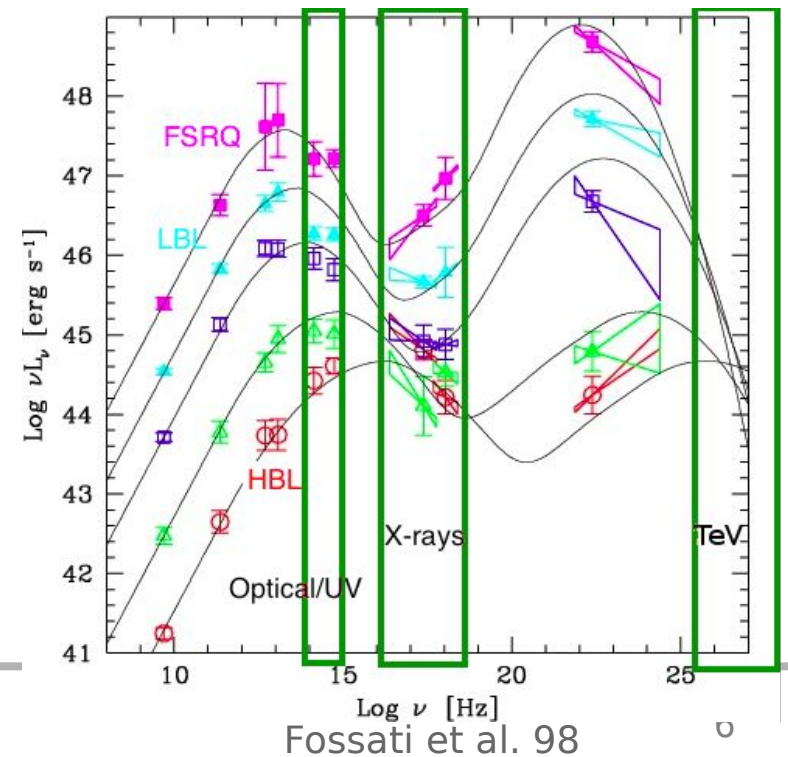
Blazars : **radio-loud** active galactic nuclei whose relativistic jet points towards the observer

→ jet emission dominates over other AGN components (non-thermal from radio to gamma)

SED : two broad components

Blazars classified according to peak energies

- Flat-Spectrum Radio-Quasars (**FSRQs**)
- Low-frequency peaked Blazars (**LBLs**)
- High-frequency peaked Blazars (**HBLs**)
- Ultra-high-frequency peaked Blazars (UHBLs)



BLAZARS

Some common misconceptions

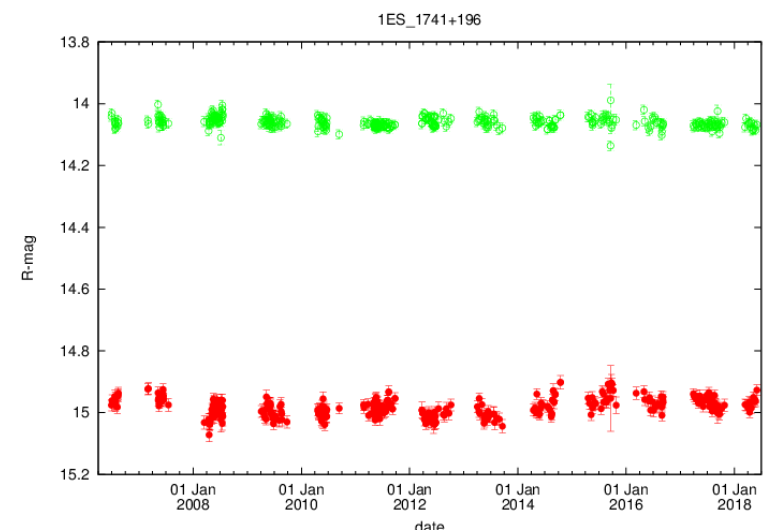
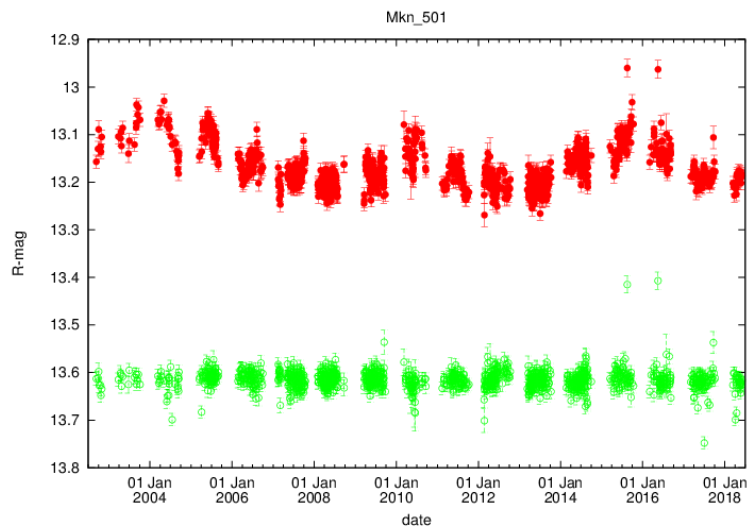
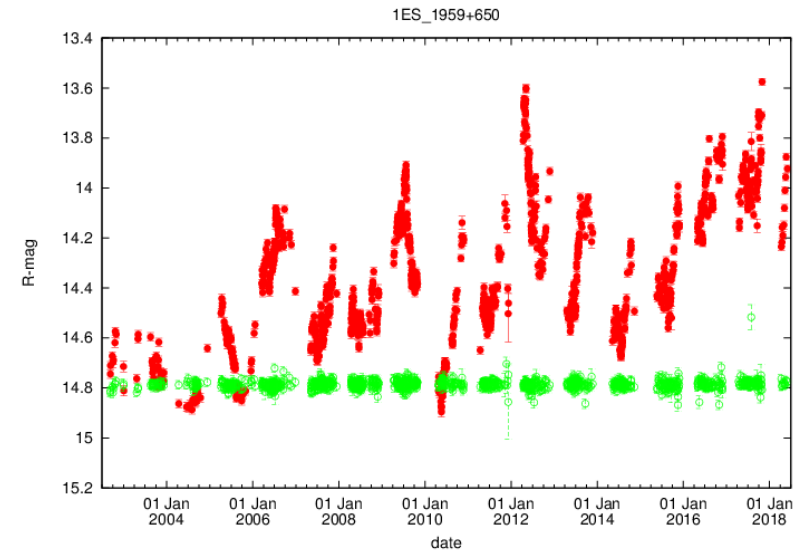
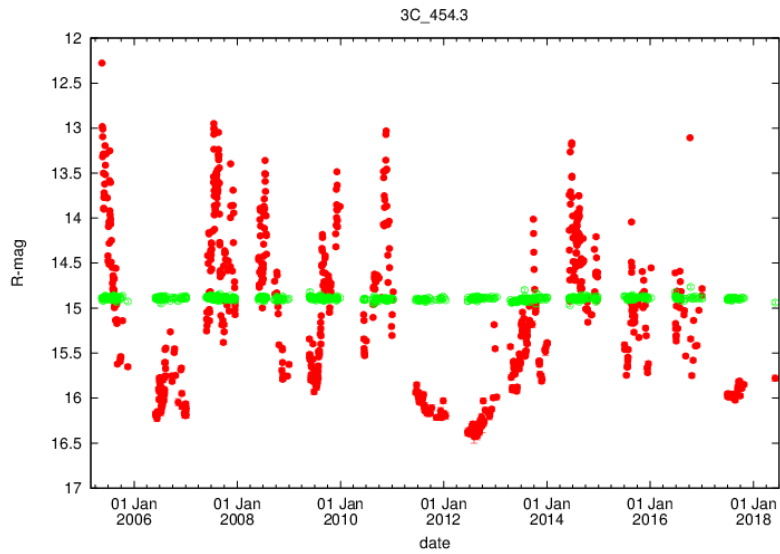
1) **BLAZARS ARE VARIABLE**

WRONG! They can vary, but not all of them!

Example, extreme-HBLs don't vary much

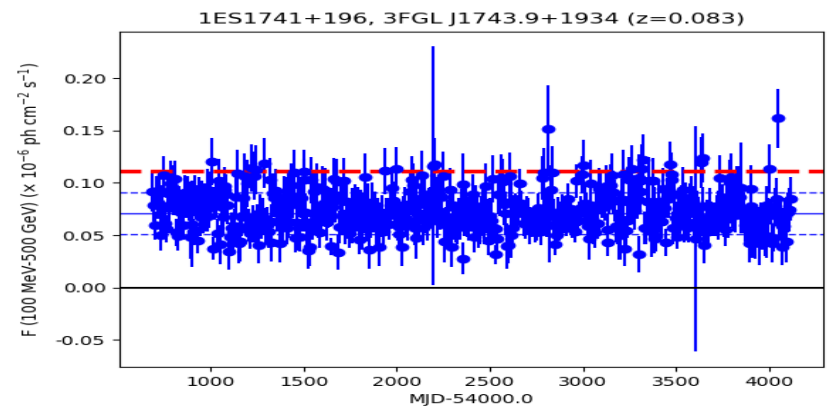
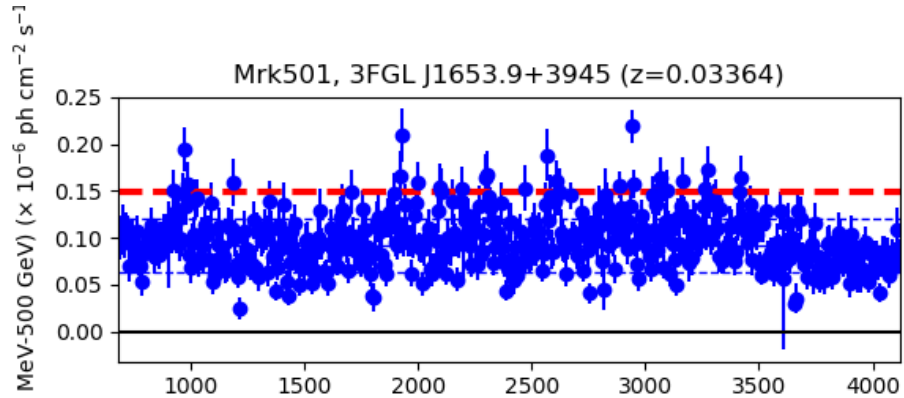
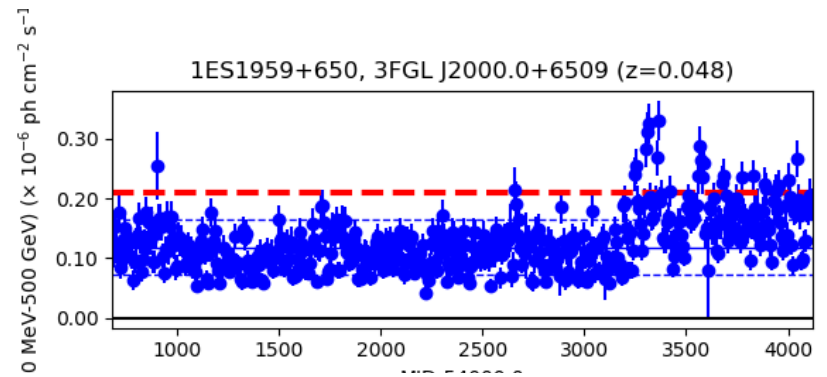
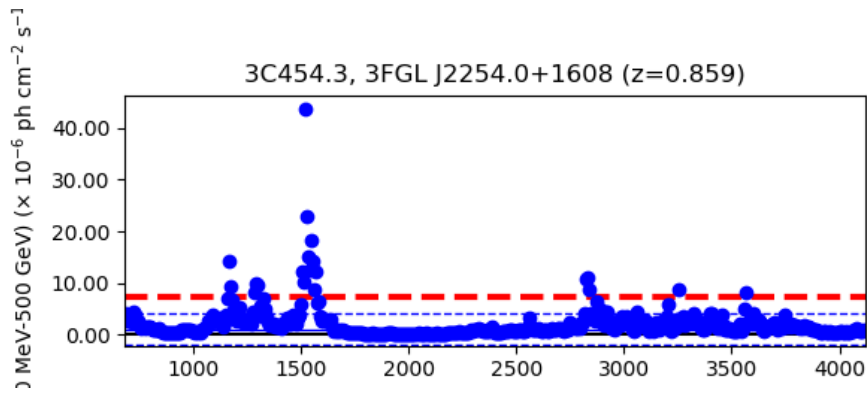
BLAZARS

Optical light-curves from Tuorla optical monitoring
(green reference star)



BLAZARS

Fermi-LAT light-curves (using Lenain et al. 2018)



BLAZARS

Some common misconceptions

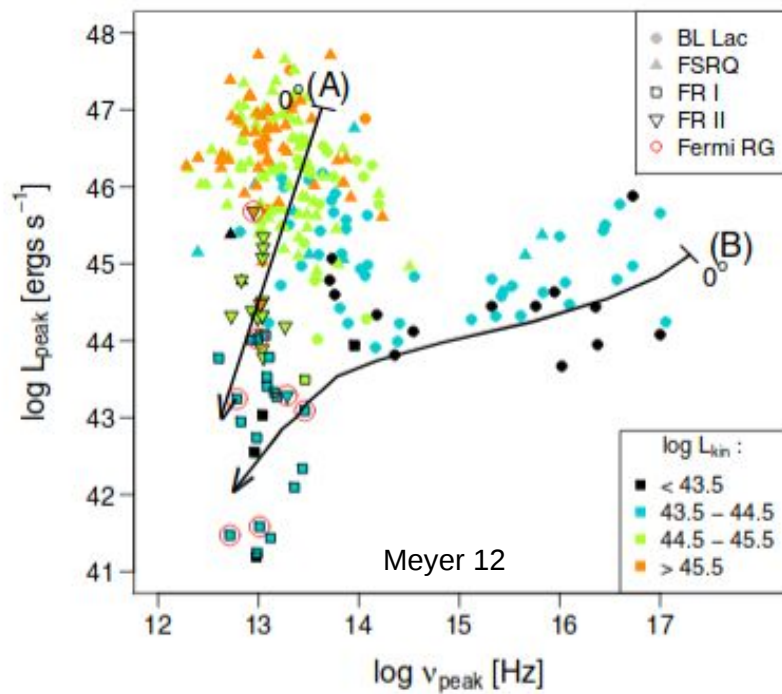
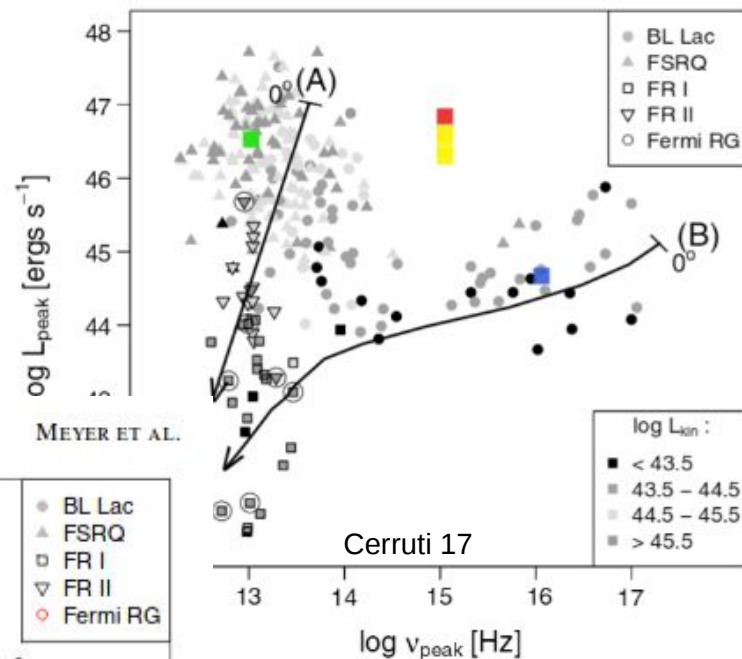
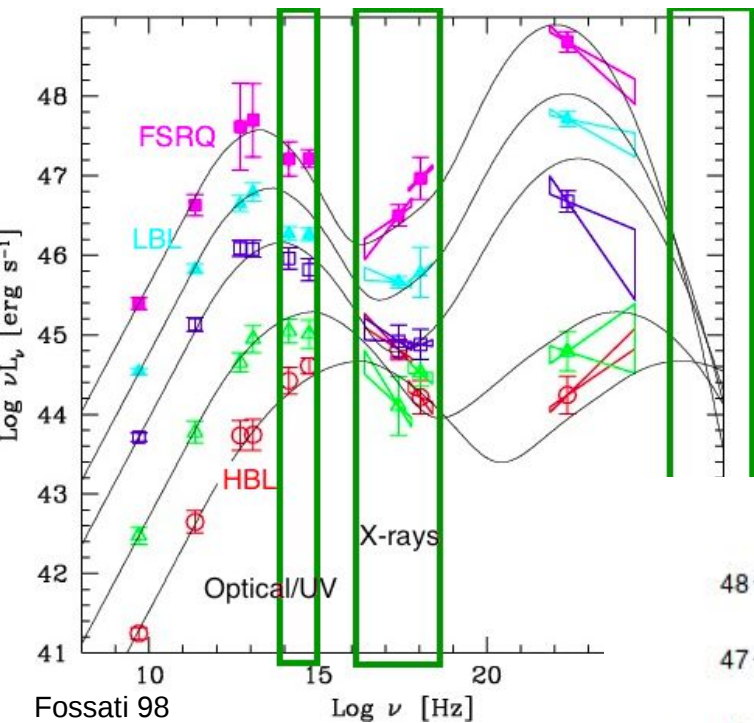
2) BLAZAR SEQUENCE IS SOLID

Not so much! The Fossati+98 has recently been updated by Ghisellini+17

Meyer+12 extended it into a blazar envelope

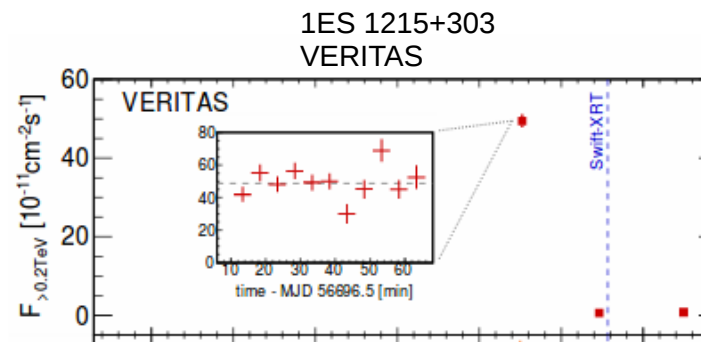
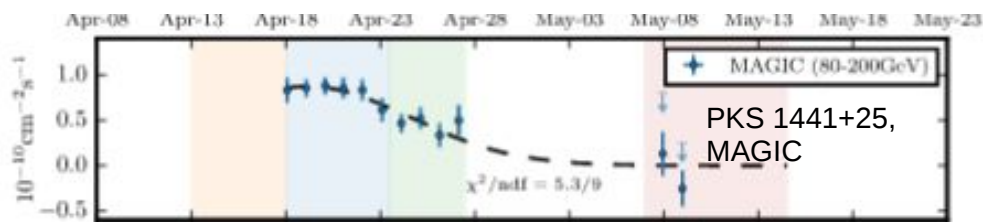
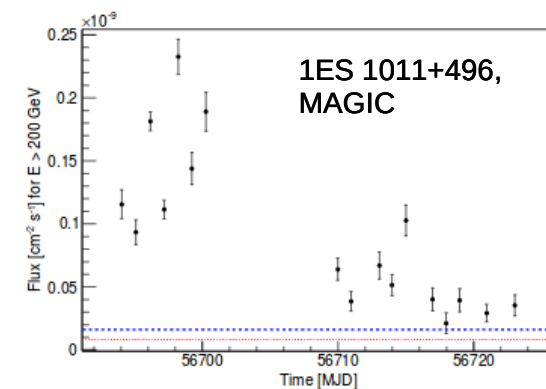
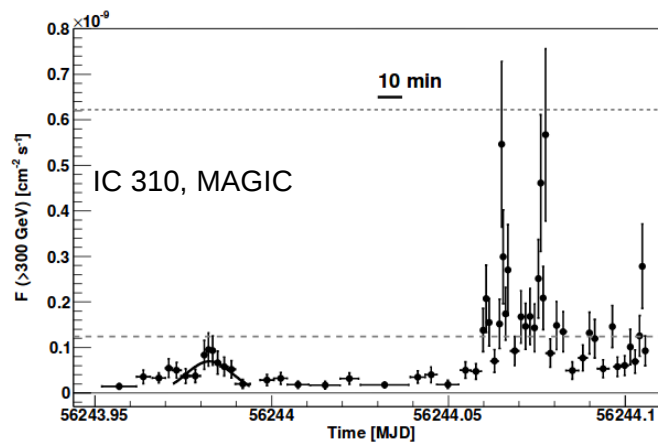
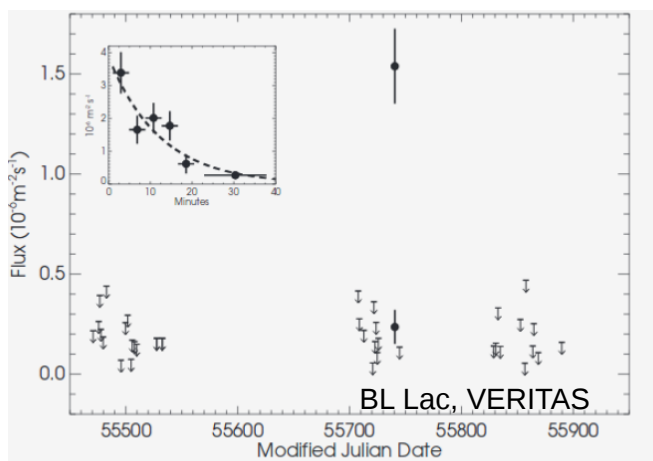
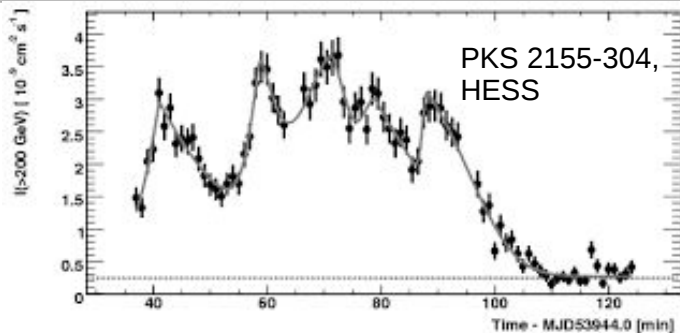
There are outliers to the sequence!

BLAZARS



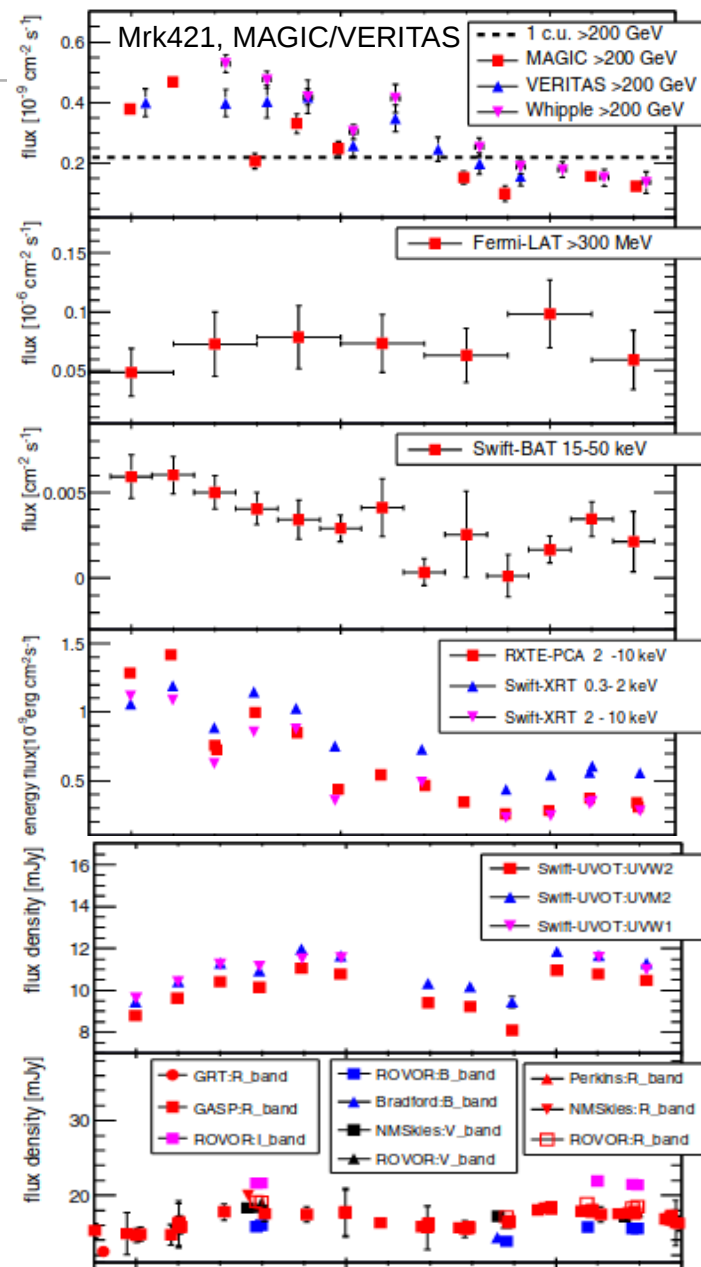
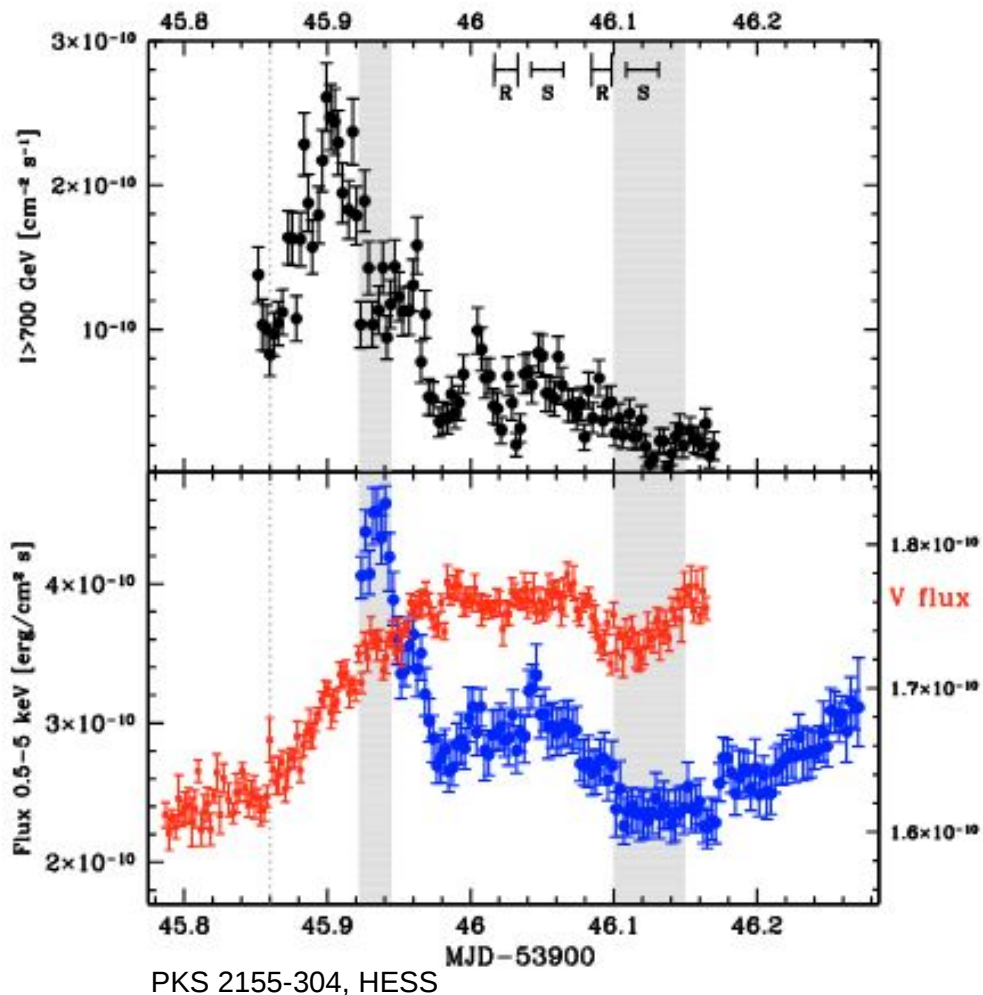
BLAZARS

TeV Blazars are variable on different timescales!

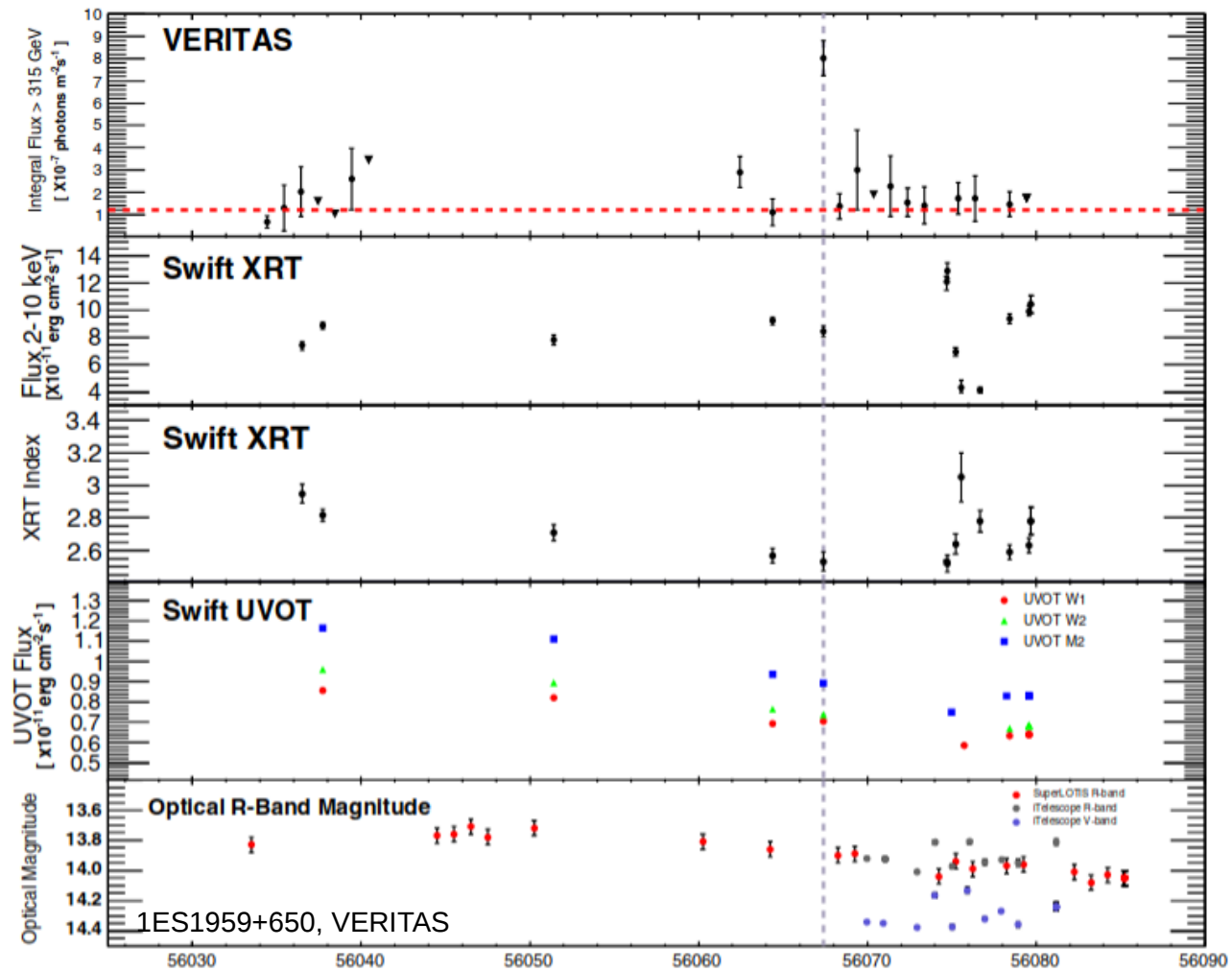


BLAZARS

Variety of MWL correlations



BLAZARS



BLAZARS

A key to access blazar physics is

**STRICTLY SIMULTANEOUS OBSERVATIONS
DURING ACTIVE STATES**

Single band observations are nowadays almost unpublishable, unless it is a peculiar observation (peculiar source, spectrum, light-curve, ...)

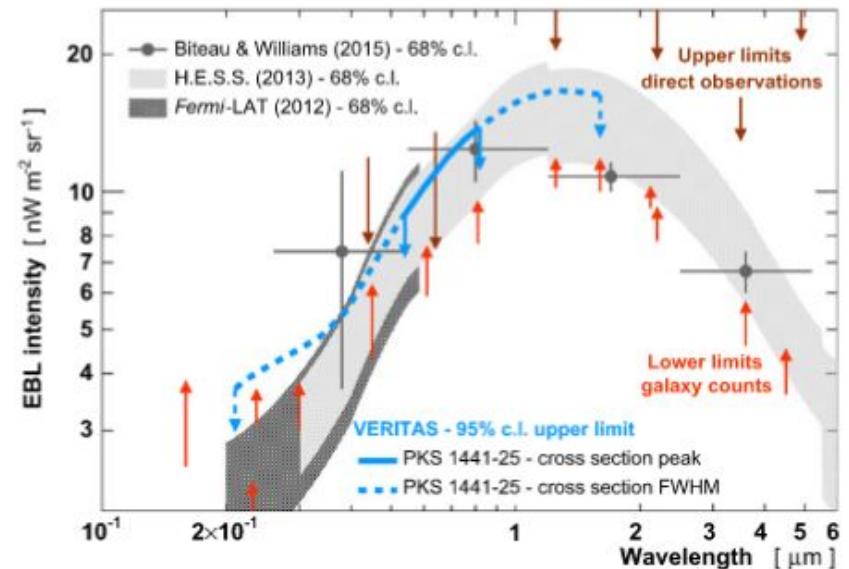
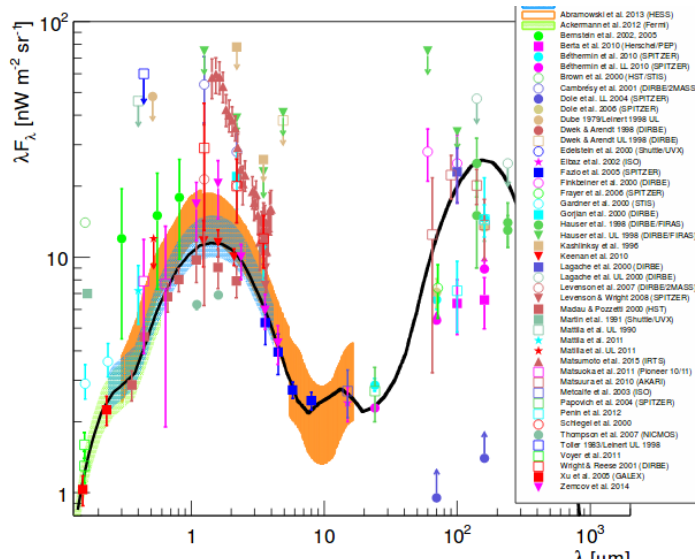
BLAZAR MWL ToOs

Why MWL Campaigns during flaring states?
(Why Target of Opportunity observations?)

1) Higher statistics

A single night of TeV observations on a flaring blazar may be worth years of data taking of non flaring blazars

Example: EBL constraints from single source (single night!)



BLAZAR MWL ToOs

Why MWL Campaigns during flaring states?
(Why Target of Opportunity observations?)

2) Are all blazar sub-classes TeV emitters?

FSRQs have been detected at VHE **only during flaring states**
(are they VHE emitter at all during quiescence? CTA will answer)

2b) Seeing farther away

High-redshift sources have been detected at VHE **only during flaring states**

S3 0218+35 $z=0.944$

PKS 1441+25 $z=0.939$

BLAZAR MWL ToOs

Why MWL Campaigns during flaring states?
(Why Target of Opportunity observations?)

3) **Variability properties** of VHE blazars are not known and one of the questions we would like to answer:

How common are flares like the one from PKS 2155-304 in 2006?
Why some blazars don't flare at all in gamma-rays?

3b) Are flares and quiescent emission produced in the same region / same radiative processes ?

BLAZAR MWL ToOs

Use case: how to have as many instruments as possible observing simultaneously the same source right when it flares?

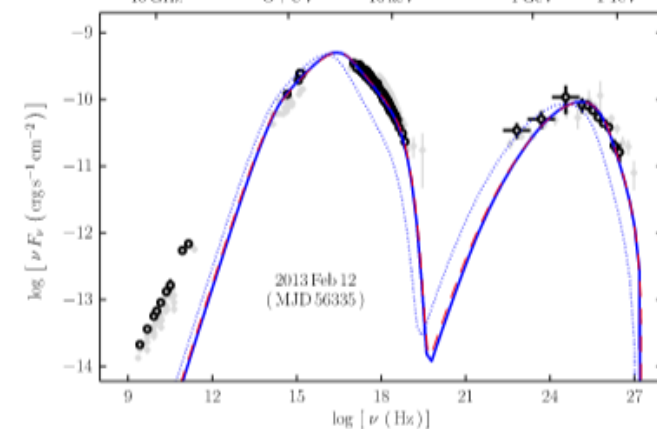
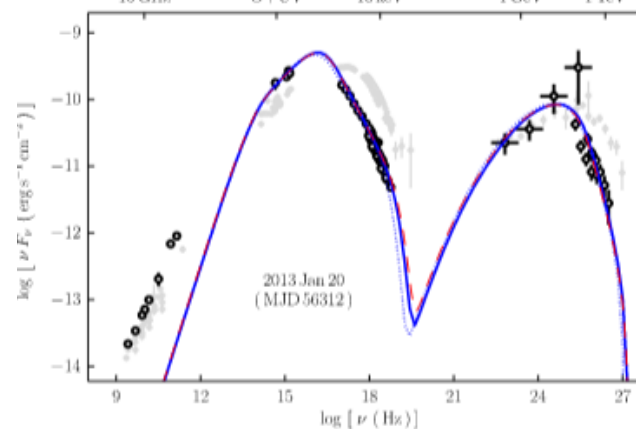
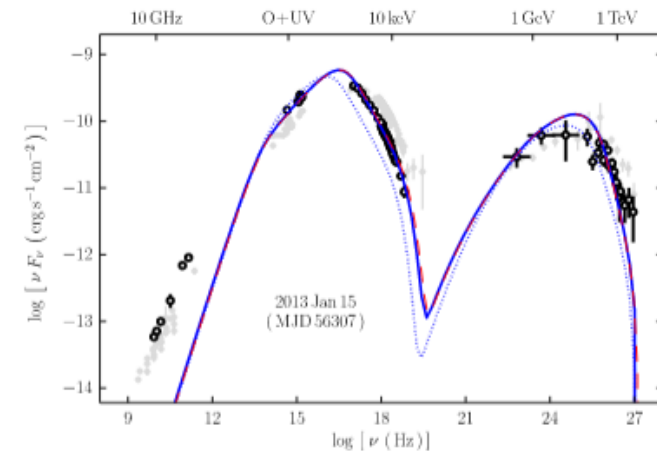
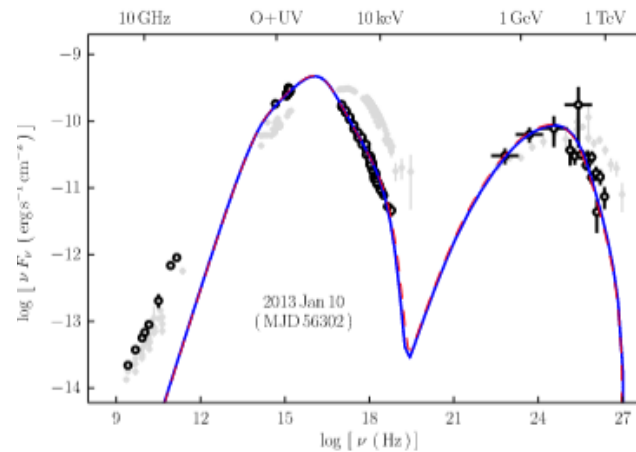
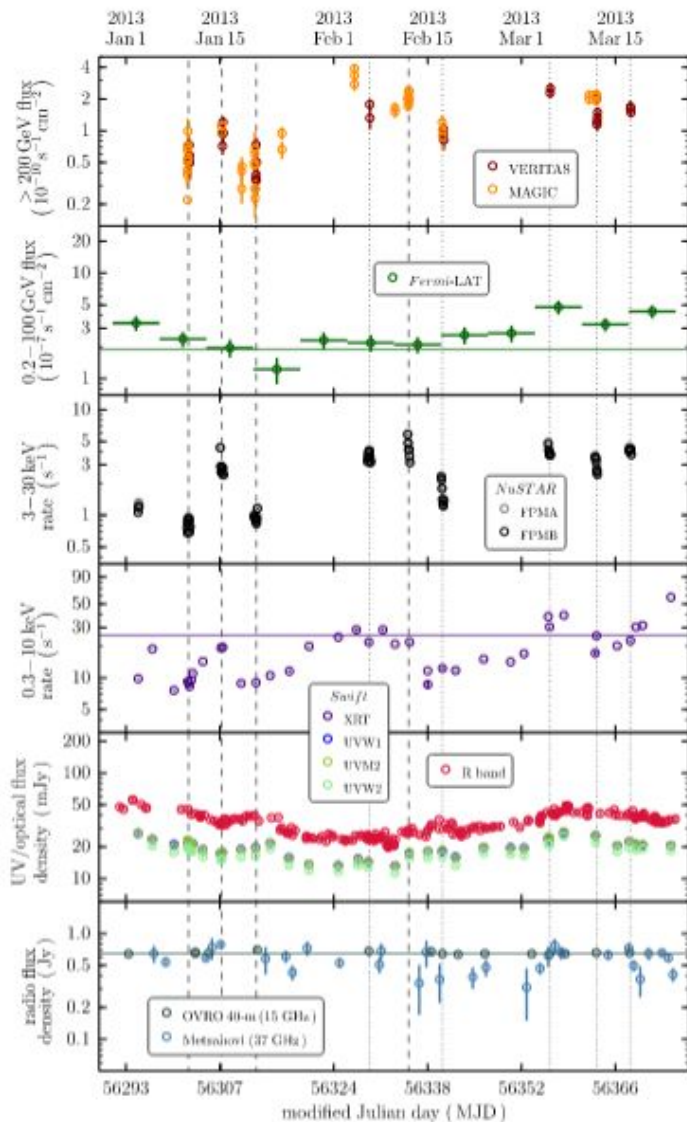
Option 1: you're lucky! (or you want to look at the non flaring state)
You set up a MWL campaign, and you HOPE that the source will be active

PROS: easy to organize, can be planned months in advance

CONS: will pass all proposals / observing committees only if the result will be interesting (i.e. publishable) even if non flaring

BLAZAR MWL ToOs

→ Example: with NuSTAR we organized campaigns on the brightest VHE blazars



Mrk 421, MAGIC & VERITAS

BLAZAR MWL ToOs

Use case: how to have as many instruments as possible observing simultaneously the same source right when it flares?

Option 2:

You organize in advance **A LOT of strictly simultaneous observations**

PROS: Relatively easy to organize, increased chance to get high state
Study long-term variability / duty cycles

CONS: Requires a lot of observing time, the majority of which not very interesting.

→ Examples: all Cherenkov telescopes have their own optical telescope for optical monitoring (called ATOM for HESS)

BLAZAR MWL ToOs

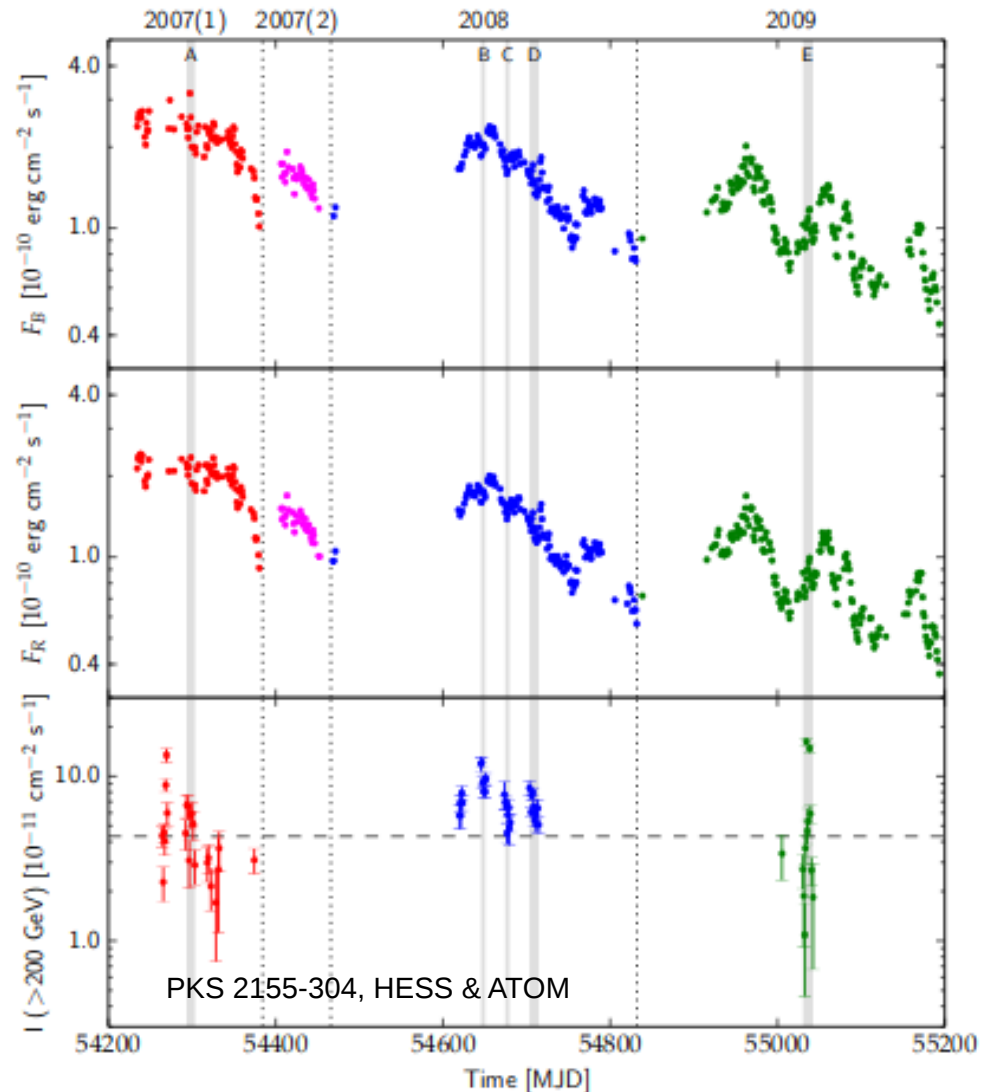
Use case: how to have as r
simultaneously the s

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PROS: Relatively easy to organize,
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CONS: Requires a lot of observing
interesting.

→ Examples: all Cherenkov telescopes
optical monitoring (called ATOM for



BLAZAR MWL ToOs

Can we do systematic simultaneous MWL long-term blazar observations?

YES! **VERITAS Blazar long-term program**

VERITAS + Swift + 48" FLWO telescope (+ Fermi-LAT): they have YEARS of simultaneous optical / UV / X-rays / GeV / TeV monitoring of the TeV blazars in the Northern Hemisphere (to be published yet)

→ Gold mine of years of strictly simultaneous SEDs for dozens of sources

BLAZAR MWL ToOs

Use case: how to have as many instruments as possible observing simultaneously the same source right when it flares?

Options 3:

Organize a **fast MWL campaign** as soon as there's an interesting event

PROS: almost guaranteed high reward, almost always results in high impact publication

CONS: Much more difficult to organize (fast reacting) and some ToO time still needs to be secured in advance

→ This is our **key program in HESS ToOs:**

Monitor MWL info, check threshold, aggressively trigger a MWL campaign (around 10 people turning, 24/7)

BLAZAR MWL ToOs

Example: HESS ToO observations of a Fermi-LAT flare

- Fermi-LAT sends an alert
- HESS observes at VHE
- ATOM observes in optical
- We trigger Swift, asking for observations in our observing window (100% success rate for our requests so far)

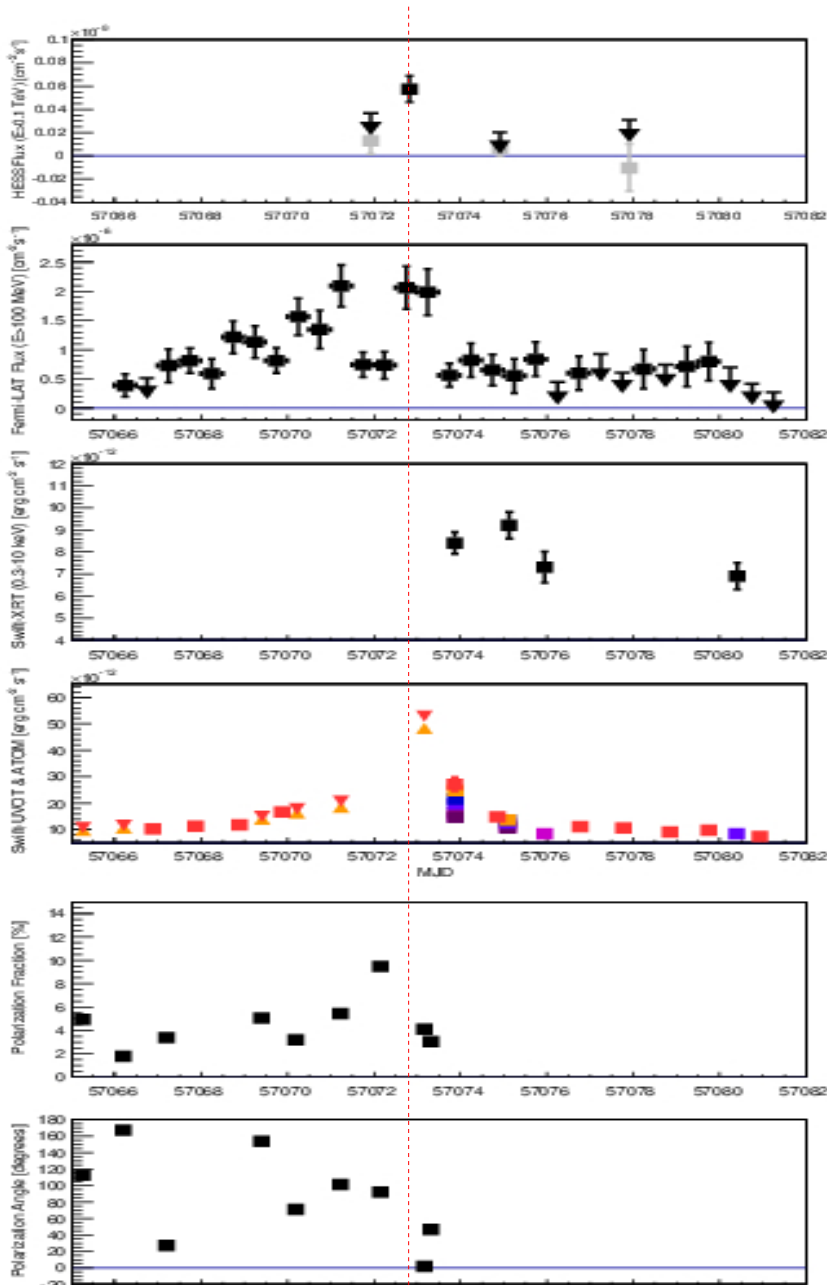
Can we go further? Yes!

Secure ToO time via AO programs

i.e. we currently have a secured NuSTAR shot we can use

Share info and coordinate via MoU between HESS and MWL partners, i.e. we share info with other IACTs, HAWC, Fermi, ... (see Fabian's talk from yesterday)

BLAZAR MWL ToOs



Example: PKS 0736+017 flare

- triggered HESS ToO following Fermi

- triggered Swift for the night after, but the gamma-ray flare was faster than 24 hours!
We don't have X-ray observations of the flare!

→ Lesson learned: now we trigger Swift as soon as we trigger HESS

RISK ASSESSMENT

- **Heavily rely on MWL partners** and their availability, and don't control them. If Fermi-LAT breaks (as he recently did for a while) we loose our best survey instrument
- **Heavily rely on the success rate of our ToO proposals** in X-rays. Swift is very blazar friendly, and Swift data are in every blazar paper. What after Swift?
- Part of the cooperation is under **MoUs**, or under **pre-approved ToO proposals**. Need constant work to keep collaborations working and pre-approved ToO are yearly re-evaluated.
- **Manpower!** This is not automatic, nor will. We need people to run smoothly / form PhD to coordinate campaigns / write successfull proposals / get data

WHAT WITH CTA?

Coordinated blazar campaigns will be a key part of
CTA blazar program

Optical / Radio monitoring shouldn't be an issue (but we need to set this up)

X-ray will be done similarly as we do with Swift (and/or other X-ray satellites)

High energy gamma-rays more critical...until when will Fermi last?

What next? E-ASTROGAM?

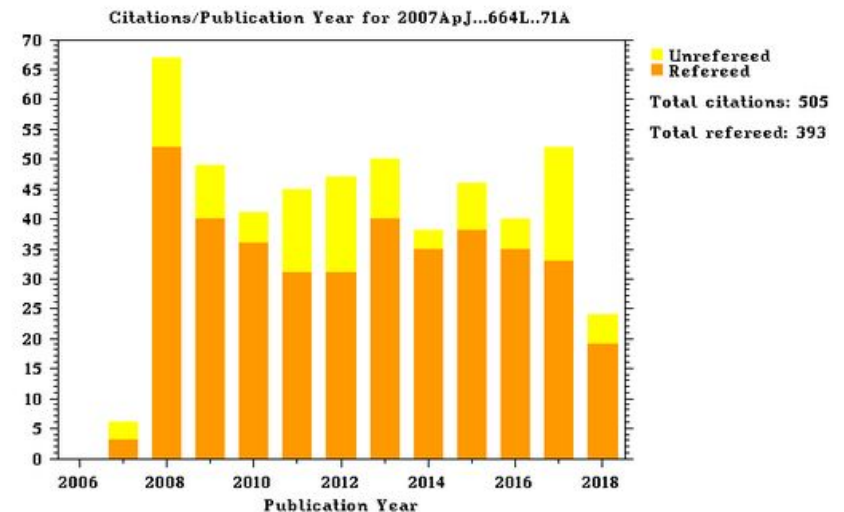
OUR DREAM

One of HESS most cited papers is still the flare from PKS 2155-304 in 2006

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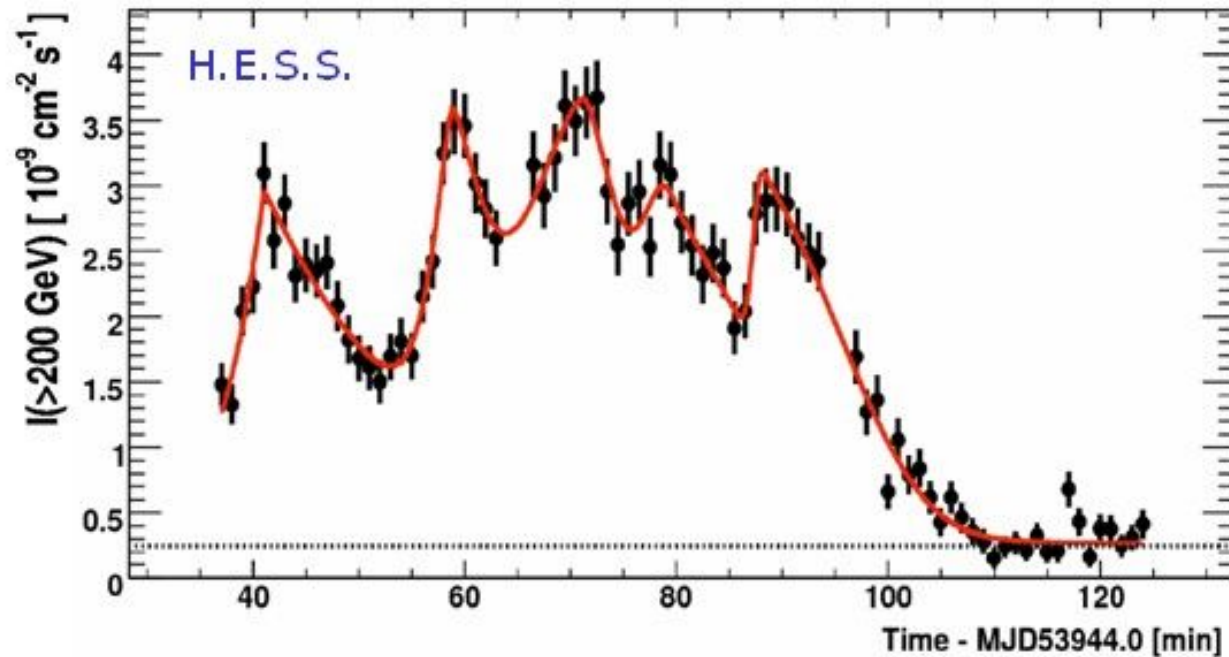


Without simultaneous MWL coverage!

NEVER HAPPENED AGAIN!

What is the duty cycle of these events? Unknown

OUR DREAM



NEXT TIME IT HAPPENS, WE NEED TO BE OBSERVING
WITH AS MANY INSTRUMENTS AS POSSIBLE