AGN astrophysics from X-rays to TeV

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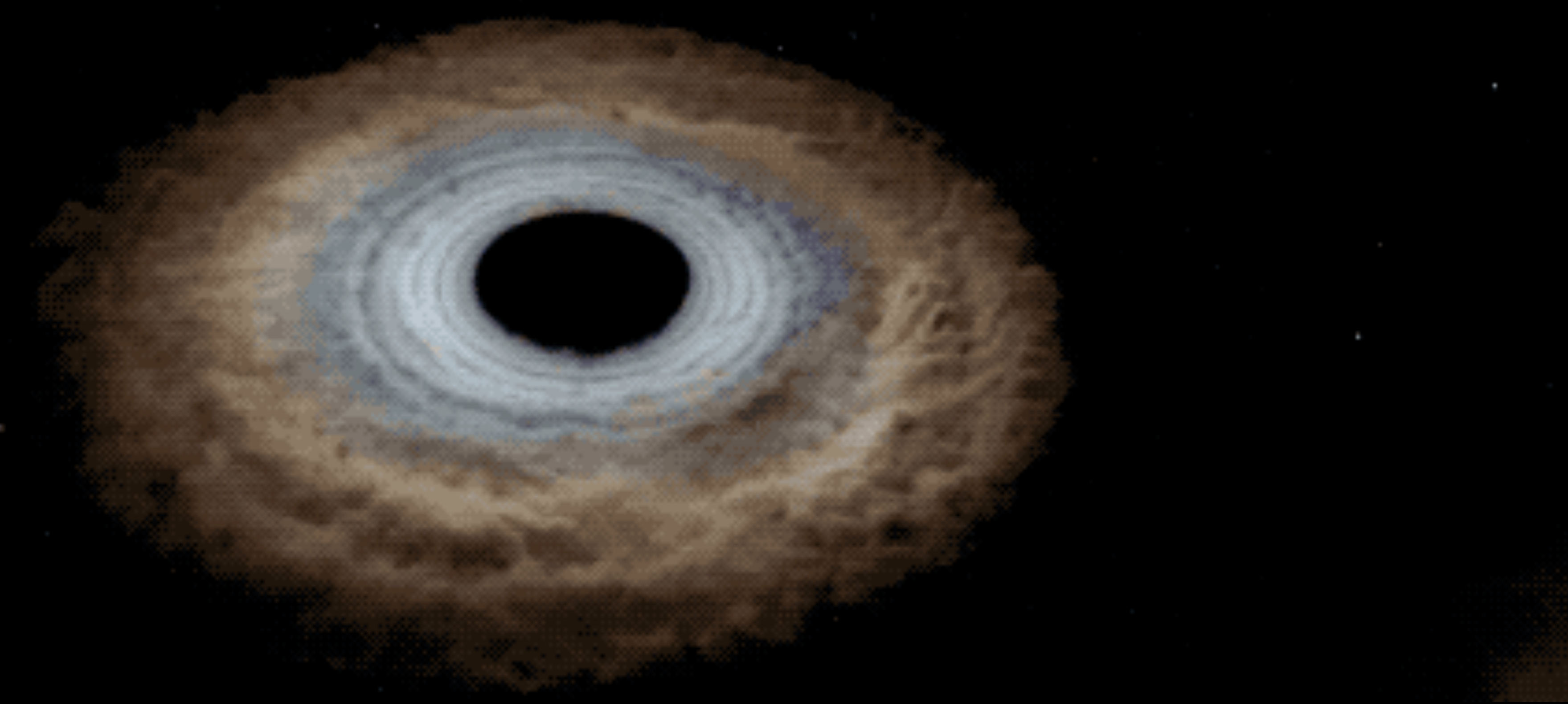

Students:

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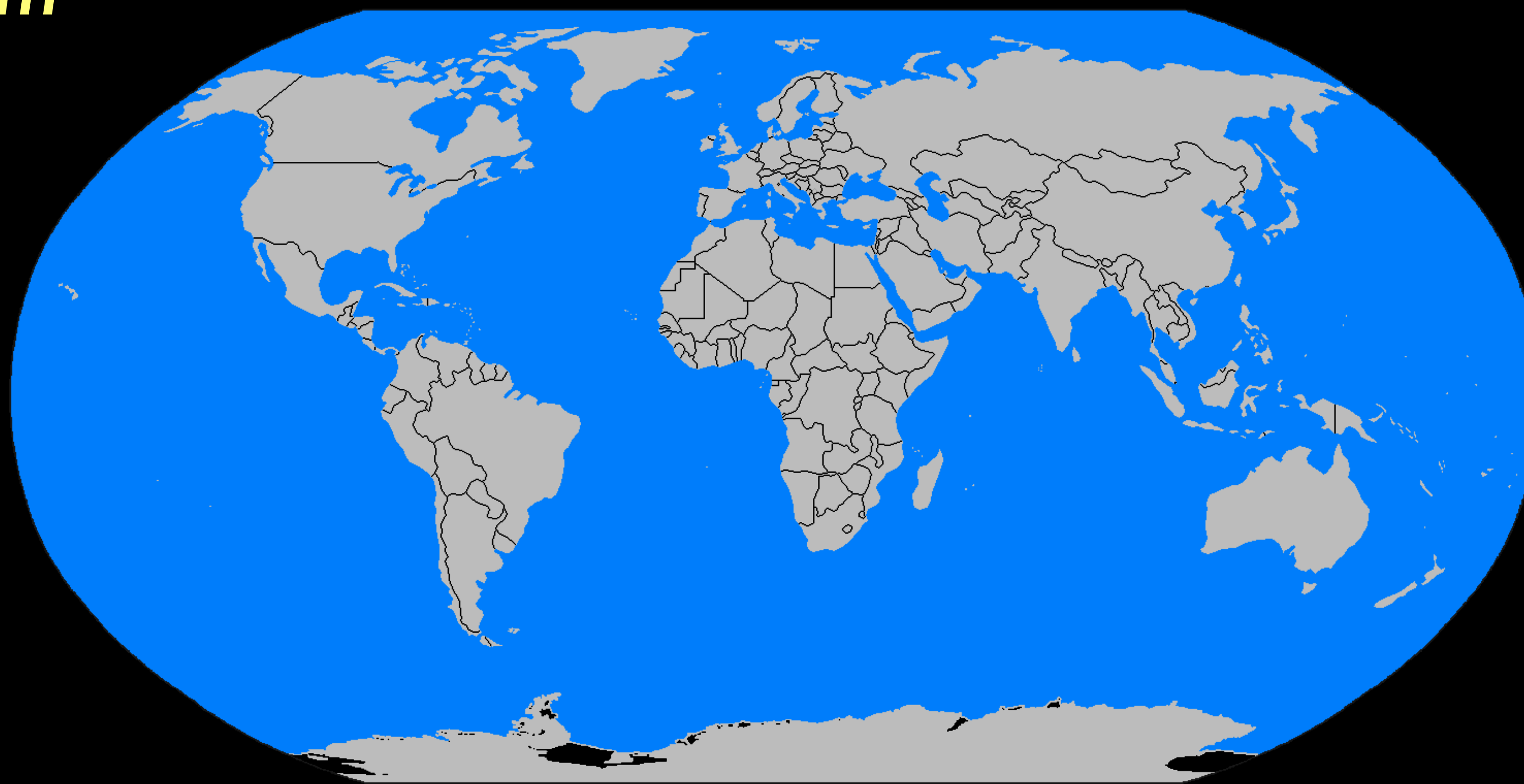
ATHENA
FERMI-LAT Collaboration
CTA Consortium

IASF Milano, Osservatorio di Brera
Osservatorio di Torino
IAPS Roma
...



Max Planck Institute for Radio Astronomy, Bonn
Copernicus Astronomical Center, Warsaw
ESA Noordwijk
University of South Carolina
SRON Utrecht
University of Puebla
STscI, Baltimora
...

ASI/SSDC Roma
Università di Roma Tre
Università di Southampton
Università & INFN Perugia
Università Roma Tor Vergata
...

Awarded funds

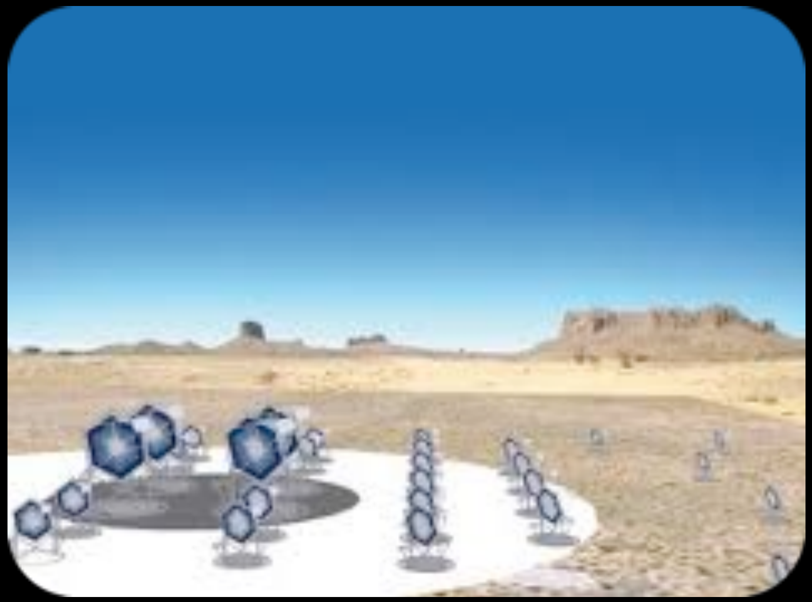
FERMI (personnel)

PRIN SKA-CTA (personnel + travels)

ASI 2 accepted proposal on AGN (personnel + travels)

AHEAD Horizon2020 (travels+hardware/software)

NuSTAR (NARO)



Teaching

- ***High-energy Astrophysics Laboratory*** @OAS in collaboration with DIFA (C. Vignali)

- ***High-energy Astrophysics Laboratory*** @FUDAN University Shanghai

- ***Master Degree students:*** on average 1-3/yr

- ***Ph.D. Students***: on average 1/yr

...since I'm not (we are not) so imaginative...

AGN

Radio Quiet

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Debora Costanzo
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Claudio Sandona'
Cristian Vignali

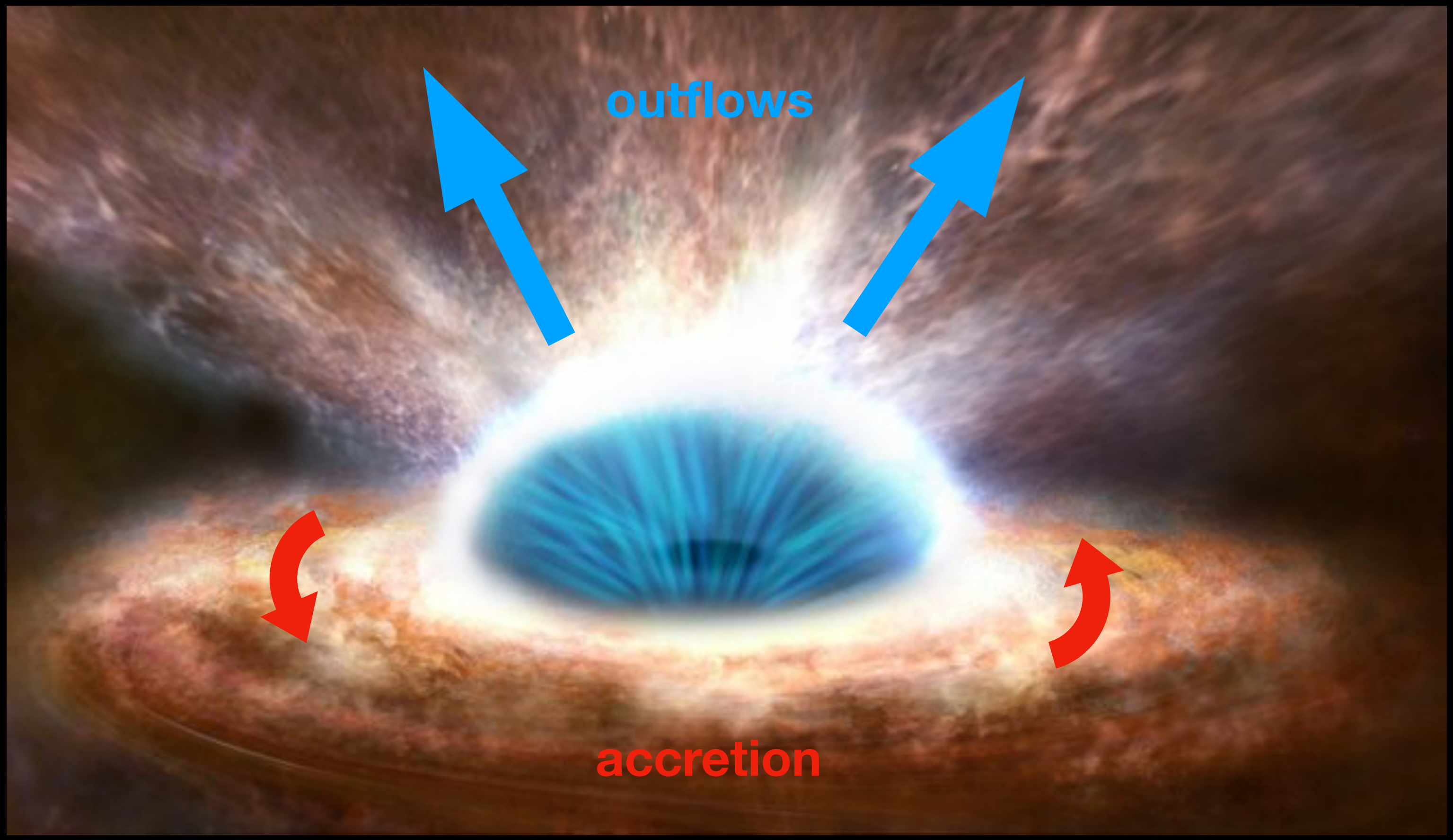
strong contamination

Radio Loud

Andrea Bulgarelli
Paola Grandi
Eleonora Torresi
Bia Boccardi
Duccio Macconi
Cristian Vignali

In red, MA4 permanent staff working on AGN: critical issue, no new "permanent" in AGN MA4 at OAS in the last 10 years

Radio Quiet AGN astrophysics (subparsec scale)



X-rays: production mechanism

Accretion: geometry and physical properties of the matter into the accretion flow

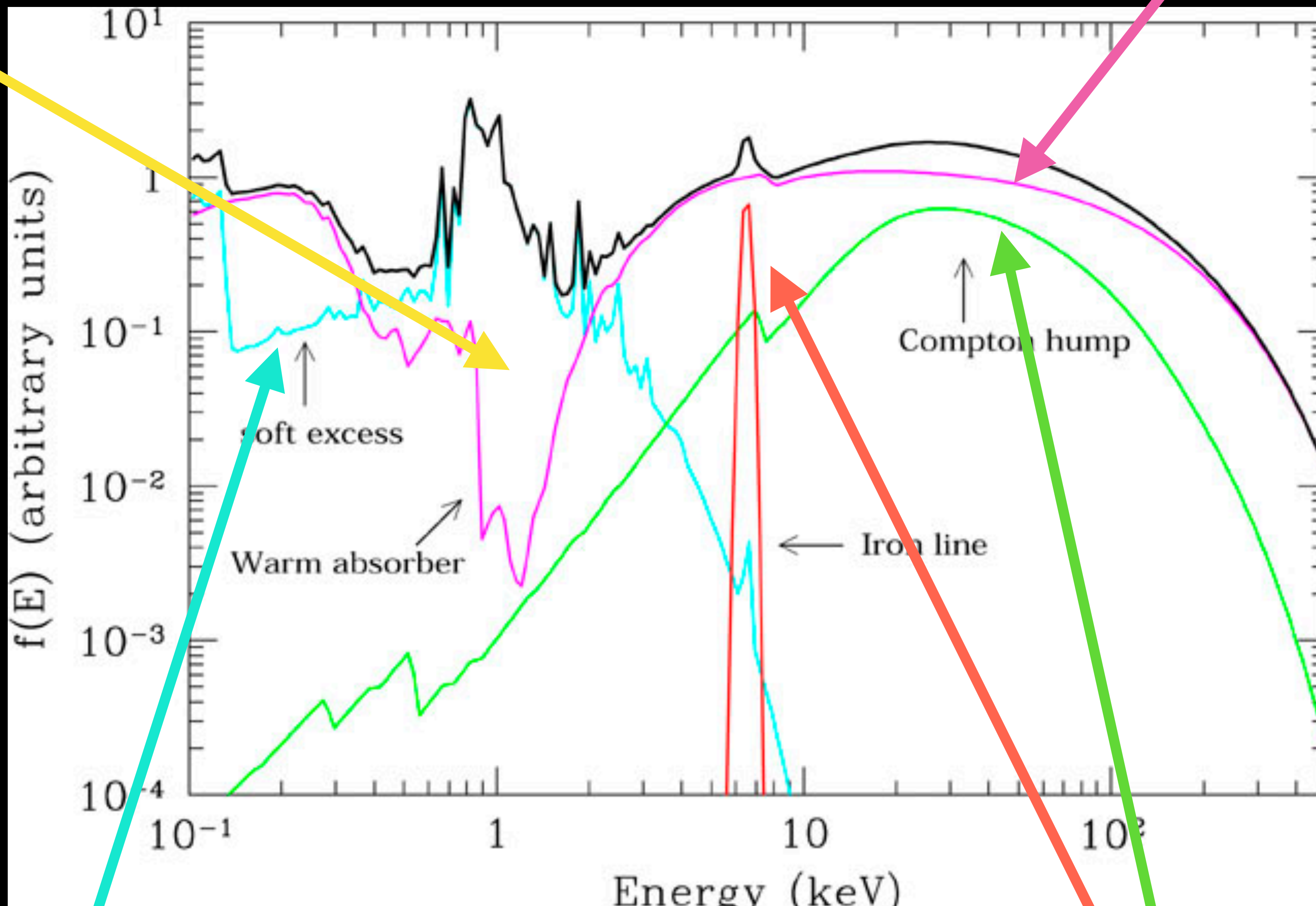
Outflows: geometry and physical properties of the outflows; launching mechanism

Radio Quiet AGN astrophysics (subparsec scale)

The richness of X-ray spectra

Continuum: Emission Mechanism

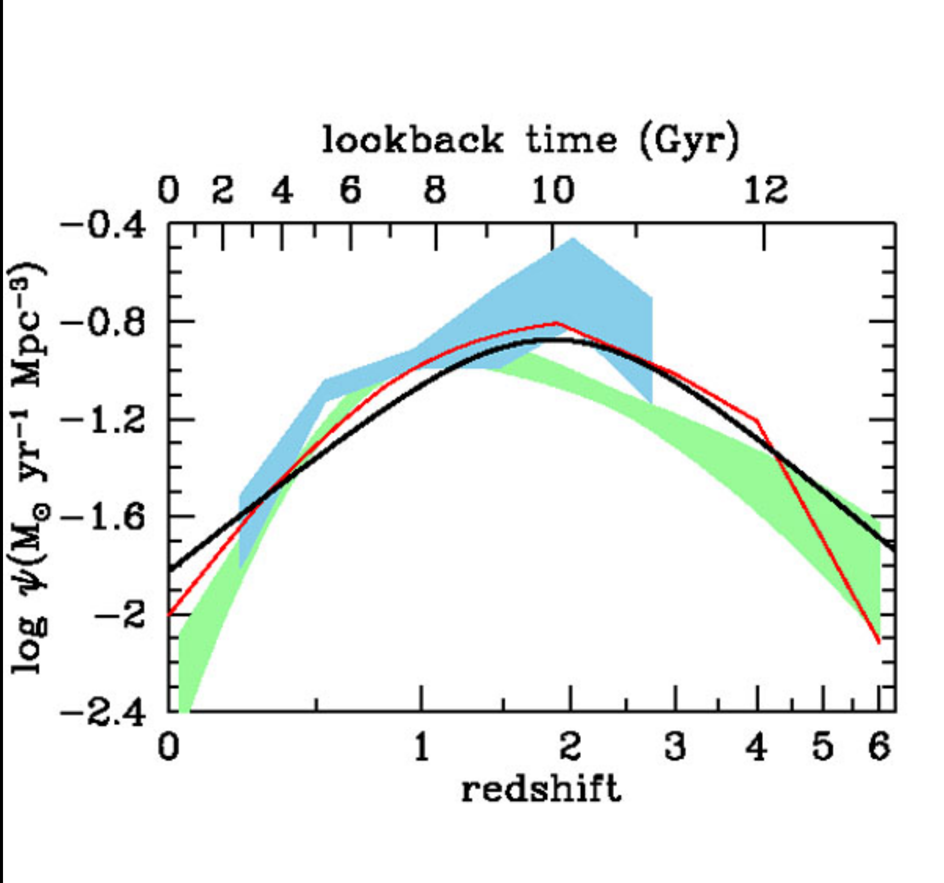
Warm absorber Winds?



Soft excess: Accretion flow? Winds?

Reflection: Accretion flow

Radio Quiet AGN astrophysics (in broad perspective)

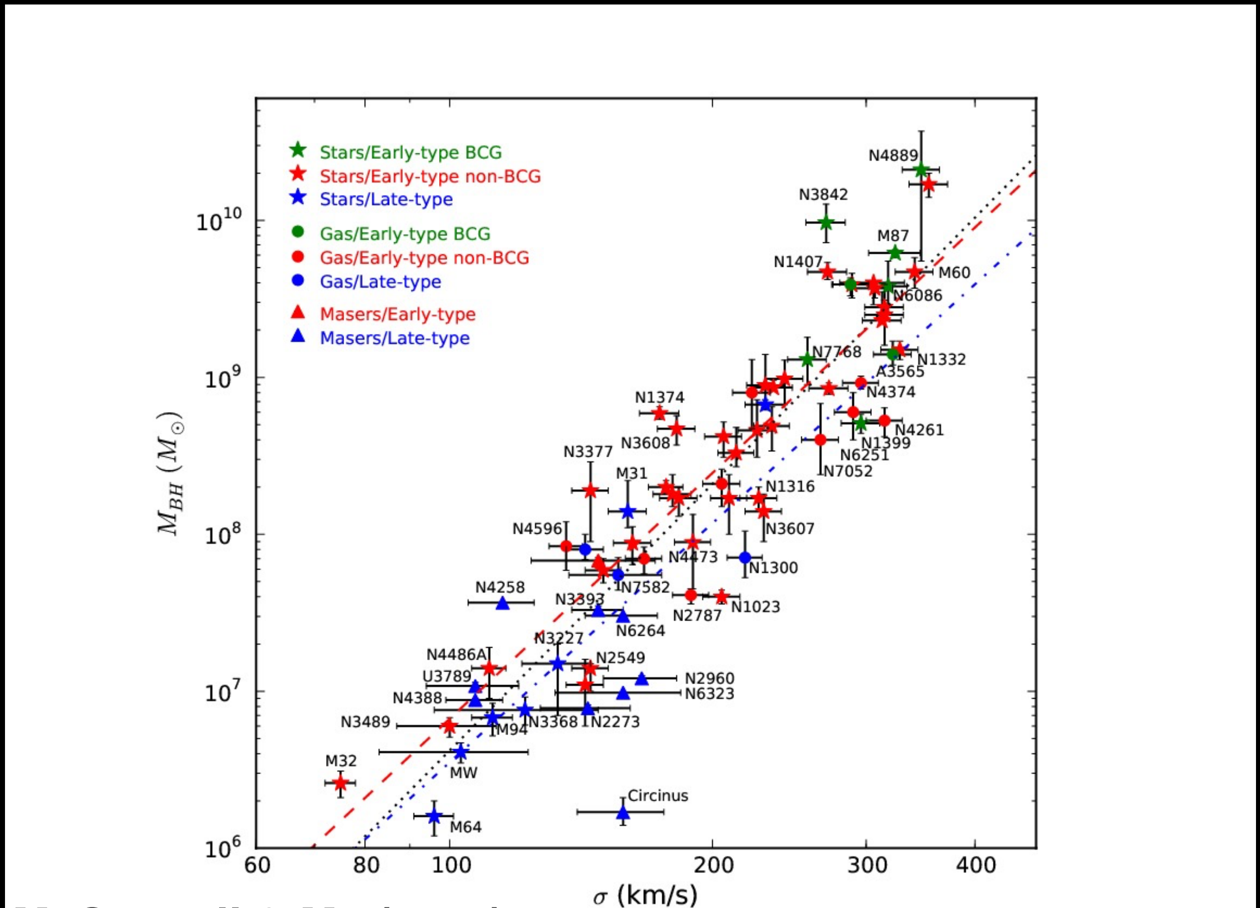


Star formation history (Madau & Dickinson 2014)

BH accretion history from X-rays (Shankar+ 2009)

BH accretion history from X-rays (Aird+ 2010)

BH accretion history from IR (Dalvecchio+ 2014)



McConnell & Ma (2013)

SMBH and host galaxy know each other… feedback? AGN drive winds?

X-ray photons are relatively "few" (but see gamma)… so two phases strategy:

1) acquire a good knowledge of the properties of the flows around SMBH taking advantage of good quality X-ray data

Low-z -> bright Seyfert galaxies

a) Deep spectral analysis
b) Timing analysis
c) Time resolved spectral analysis
d) Broad band and multi-lambda monitoring

Data:

- Accepted campaigns (XMM-Newton LPs) on Mrk509, NGC5548, NGC7469, NGC 4593 (XMM-Newton, Swift, HST, Integral, NuSTAR…)

- Accepted programs (XMM-Newton, NuSTAR)

- Archive (XMM-Newton, NuSTAR)

2) test if and how what seen in nearby Universe holds, at high-z (where feedback mechanism had to act to explain the SMBH<->Bulges relations seen today)

High-z QSOs ->lensed QSO, bright QSO

a) Spectral analysis
b) Time resolved spectral analysis

Data:

- Accepted XMM-Newton LPs (PI Cappi) on bright QSOs

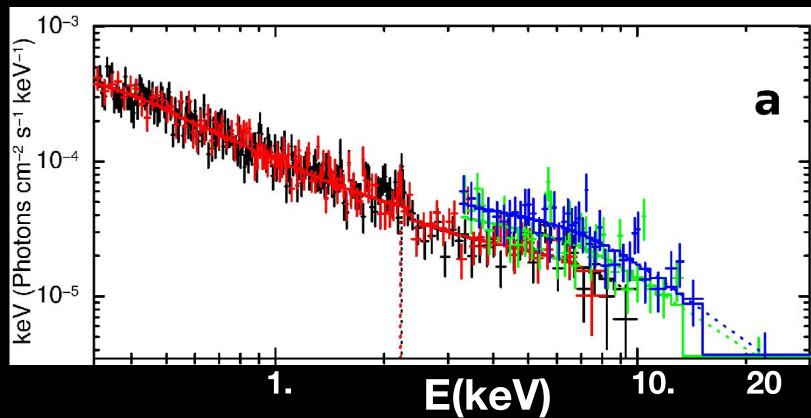
- Accepted XMM-Newton (PI Dadina) and NuSTAR+XMM-Newton (PI Lanzuisi) on lensed QSO

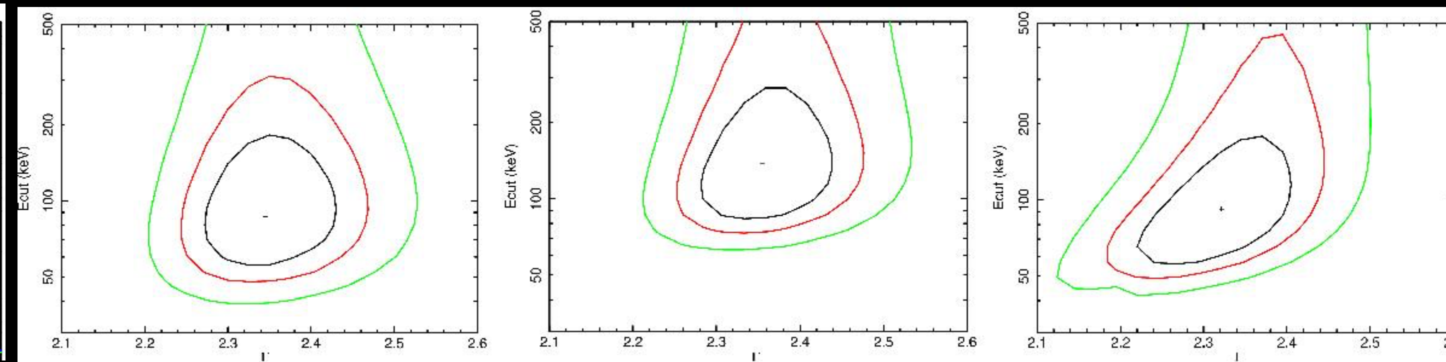
- XMM_newton heritage program (PI Brusa)

- Archives

Investigating the emission mechanisms and accretion flow (in high-z QSO)

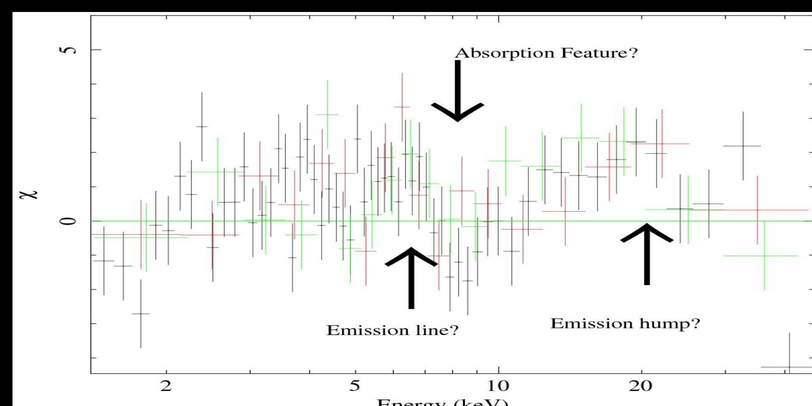
z=2.05 QSO PG1247+267

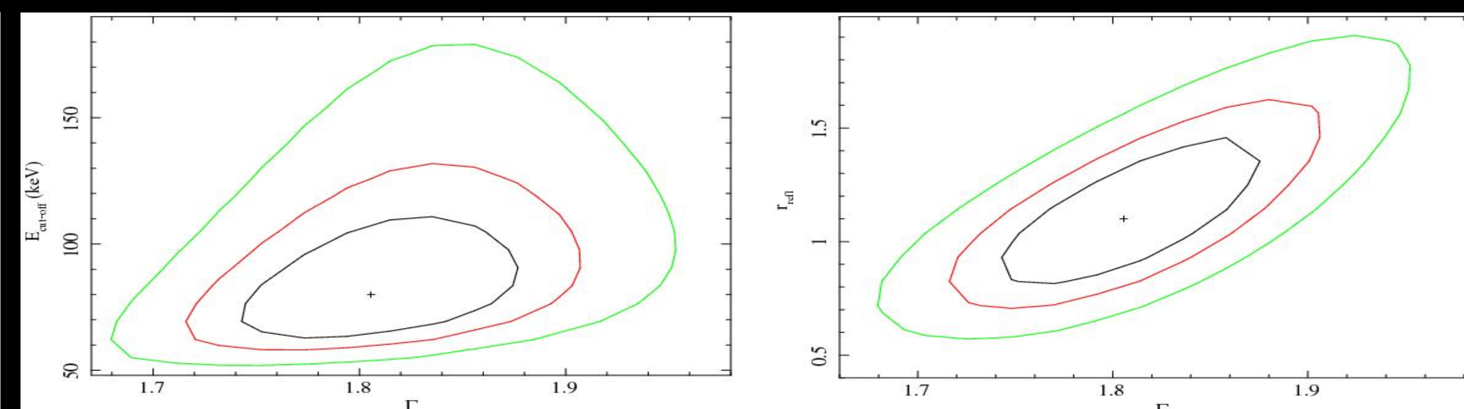




NuSTAR+XMM-Newton data (Lanzuisi+2016)

z=3.62 lensed QSO B1422+321

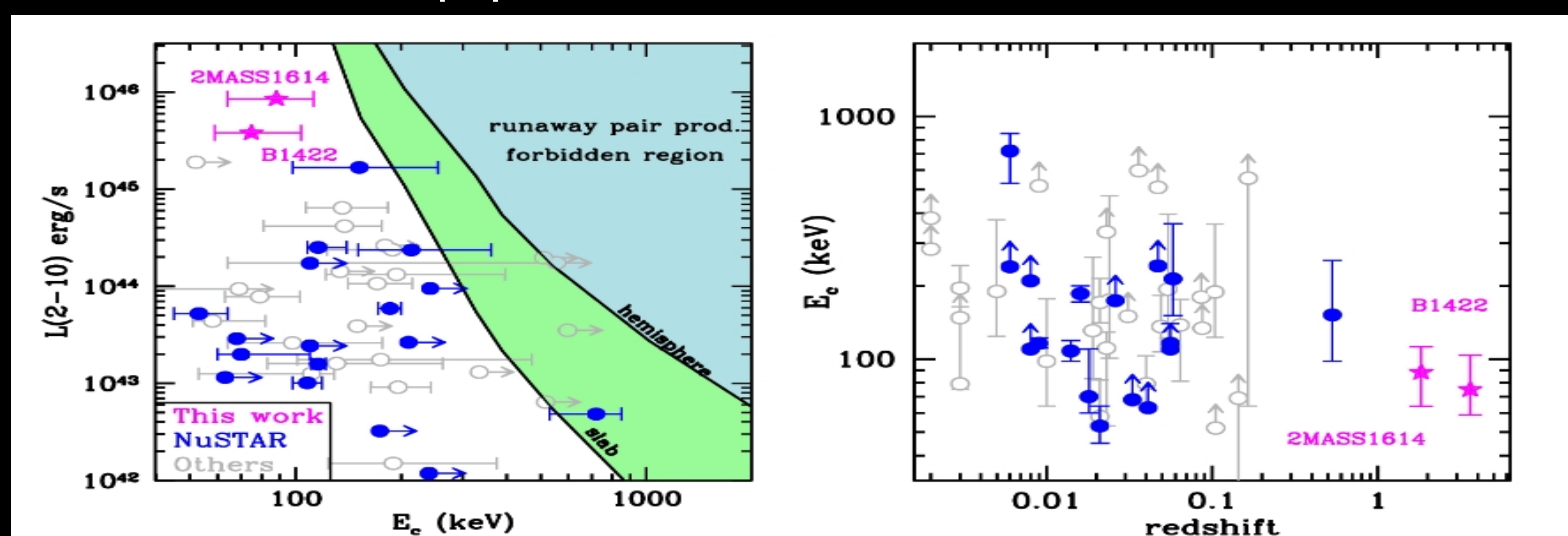




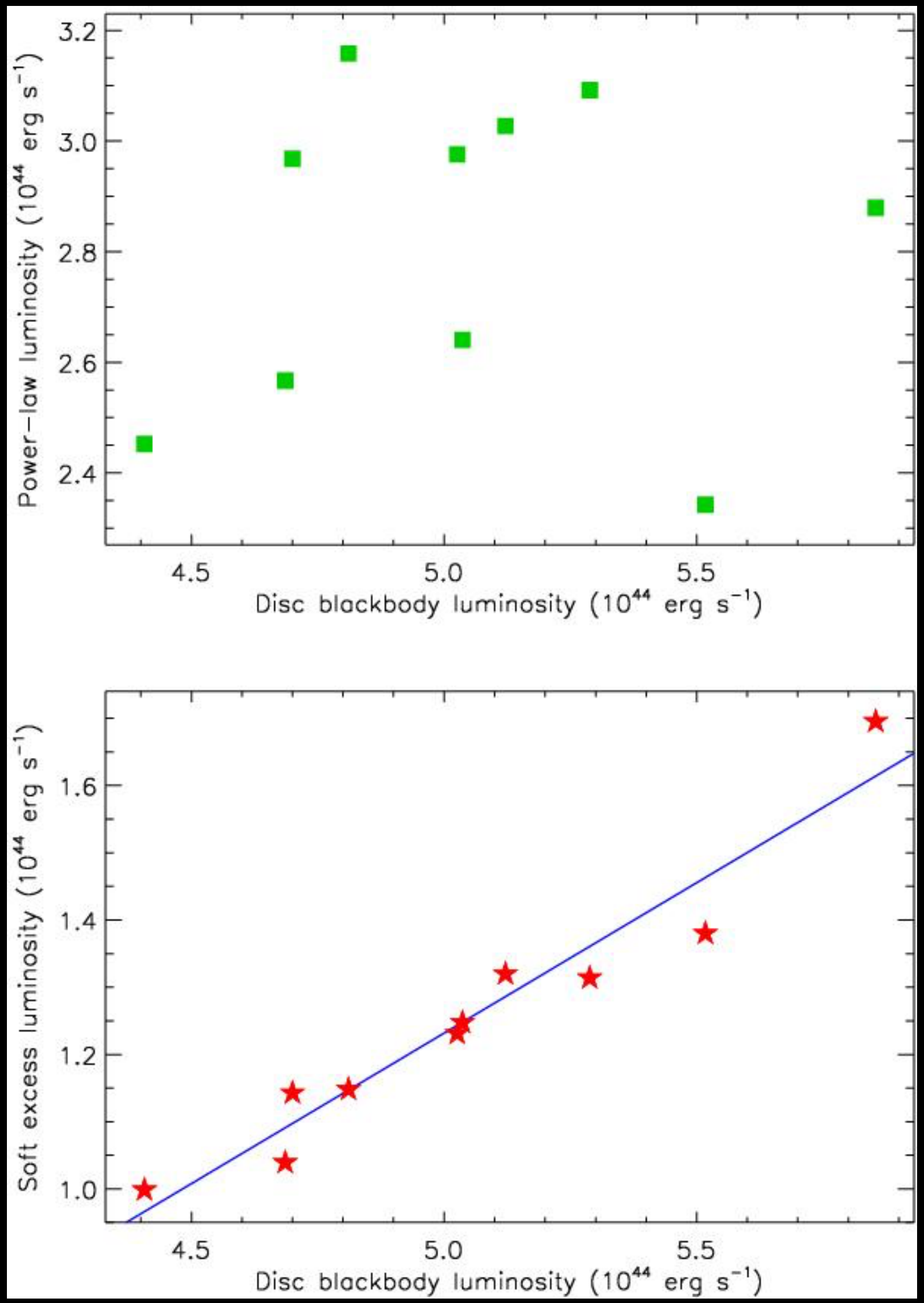
XMM-Newton data (Dadina+2016)
XMM-Newton+NuSTAR data Lanzuisi+ in preparation

Test of the two phase scenario

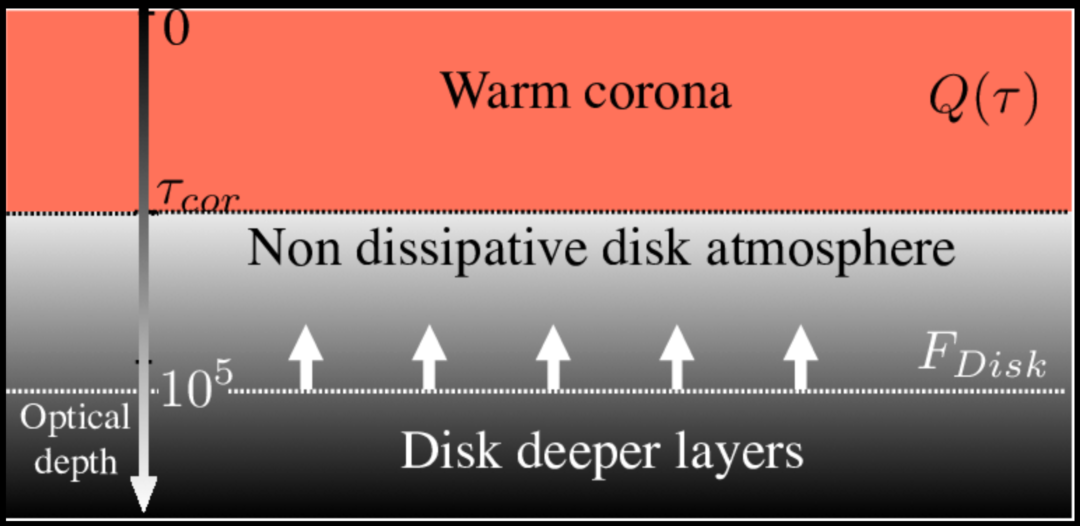
Lanzuisi et al. in prep.



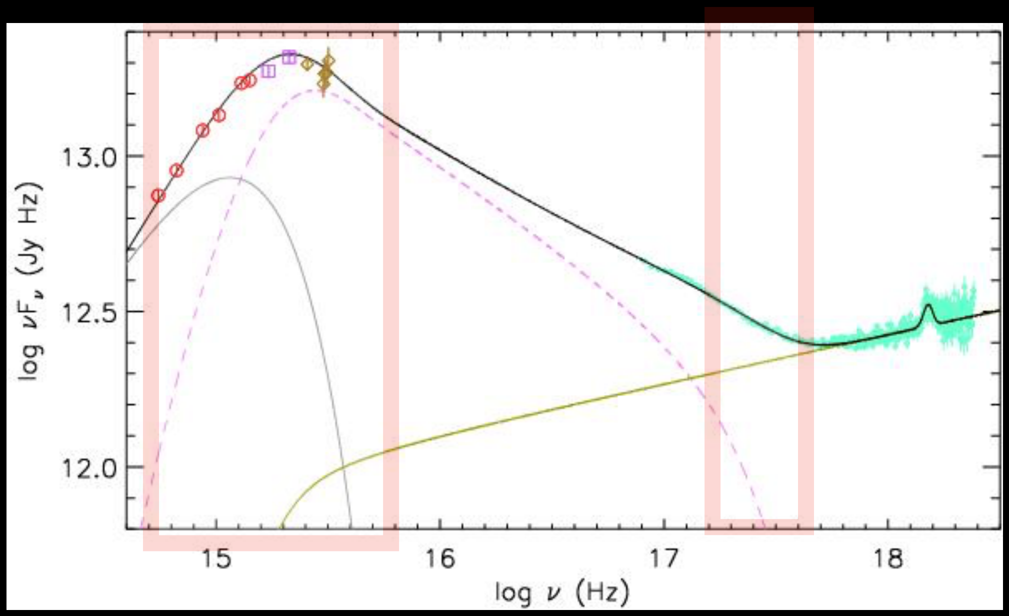
Investigating the origin of the "soft excess"



Warm Comptonization?



Różańska+2015

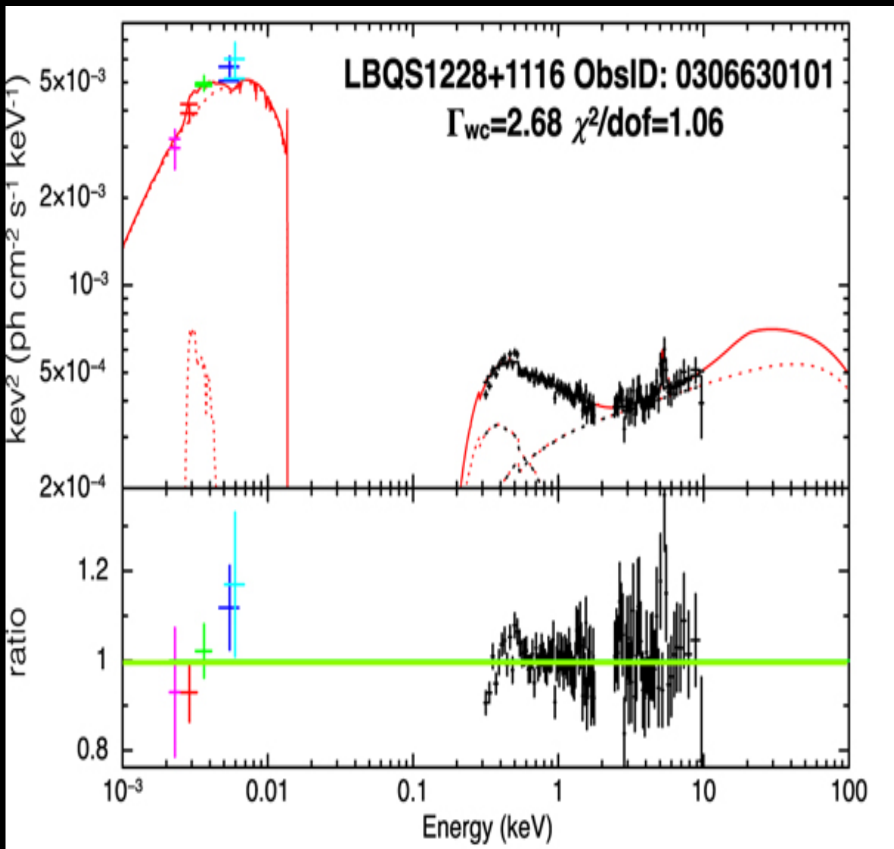


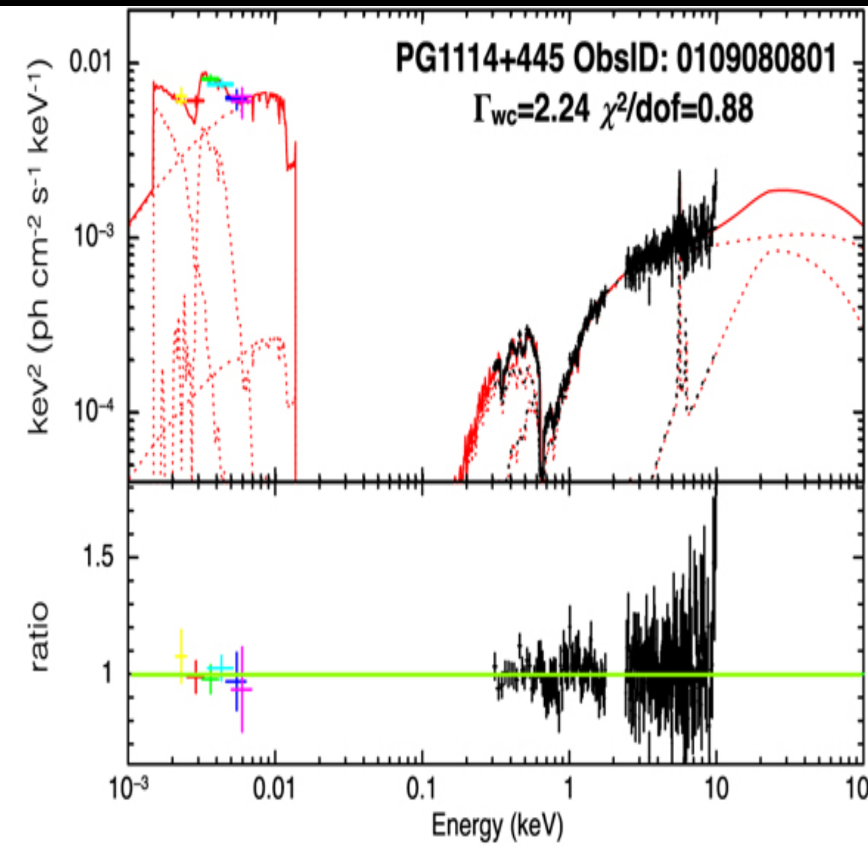
optical emission

Soft Excess

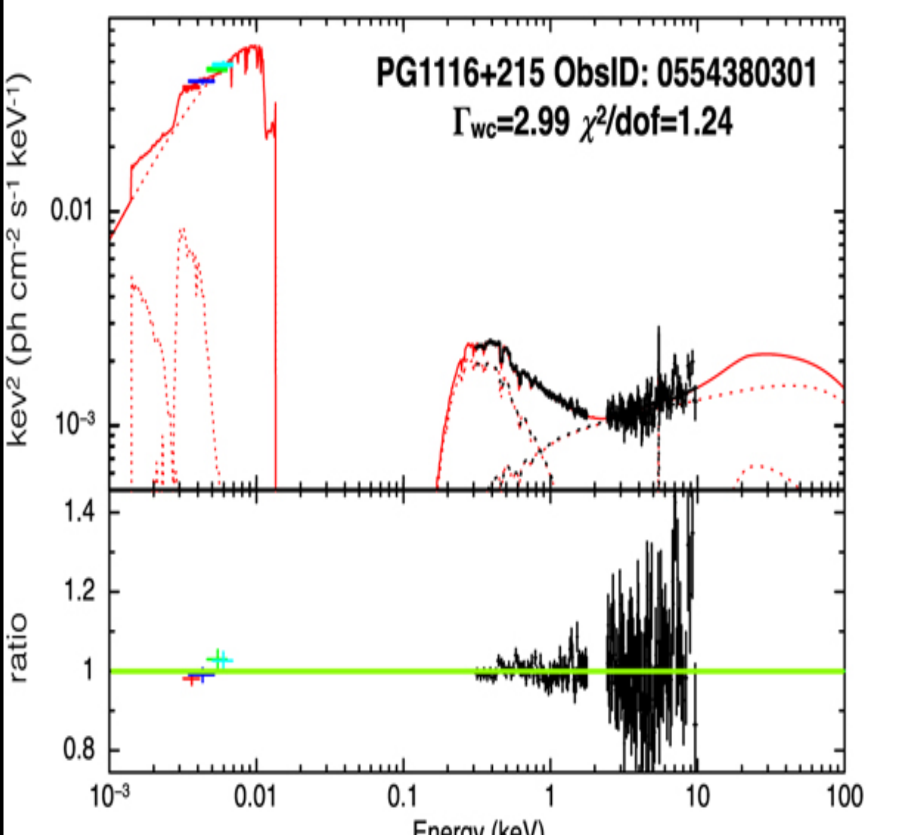
Monitoring of Mrk 509 (Mehdipour+2011)

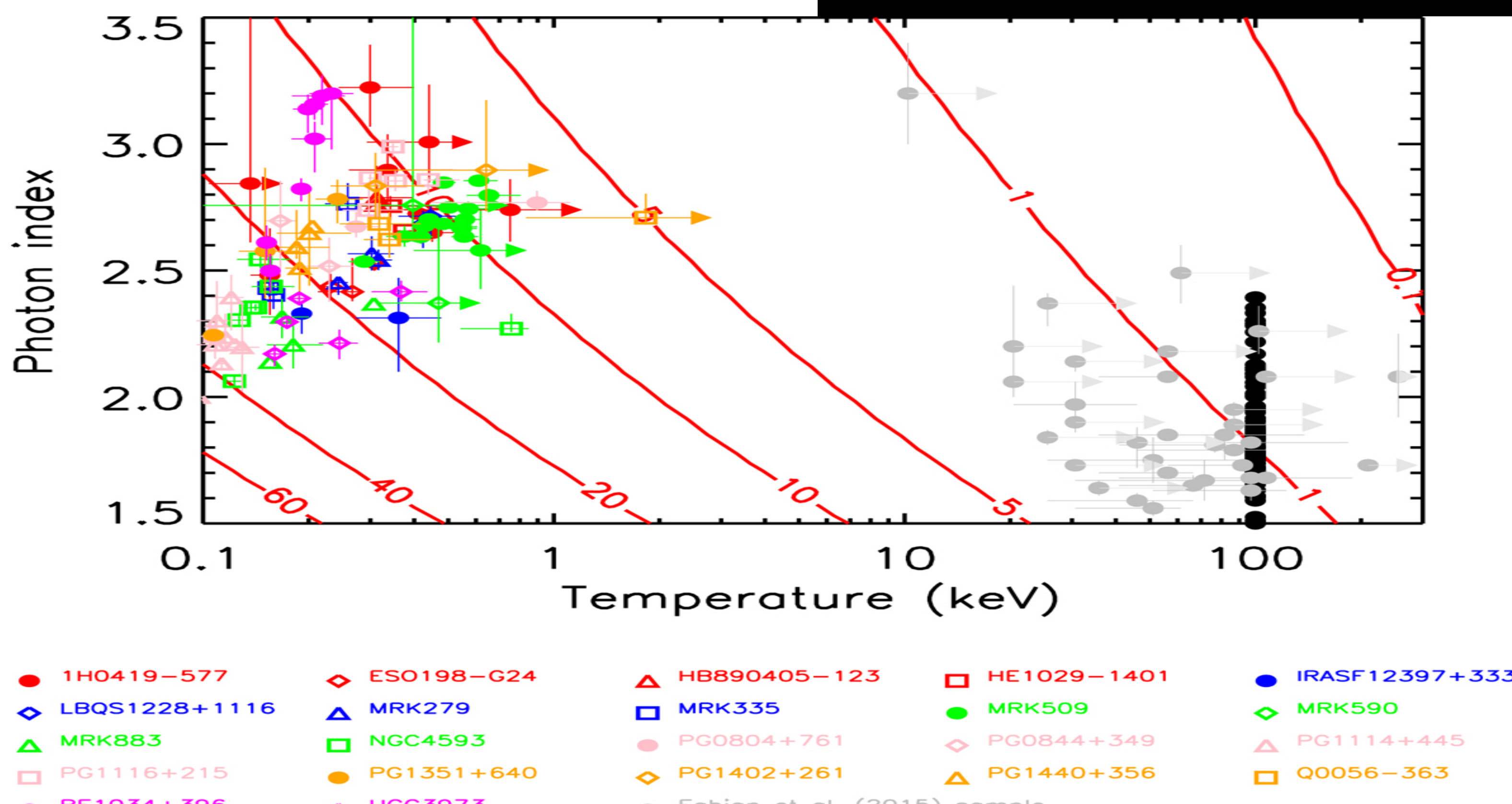
Testing this scenario using 22 nearby Seyfert without absorption and with available optical data





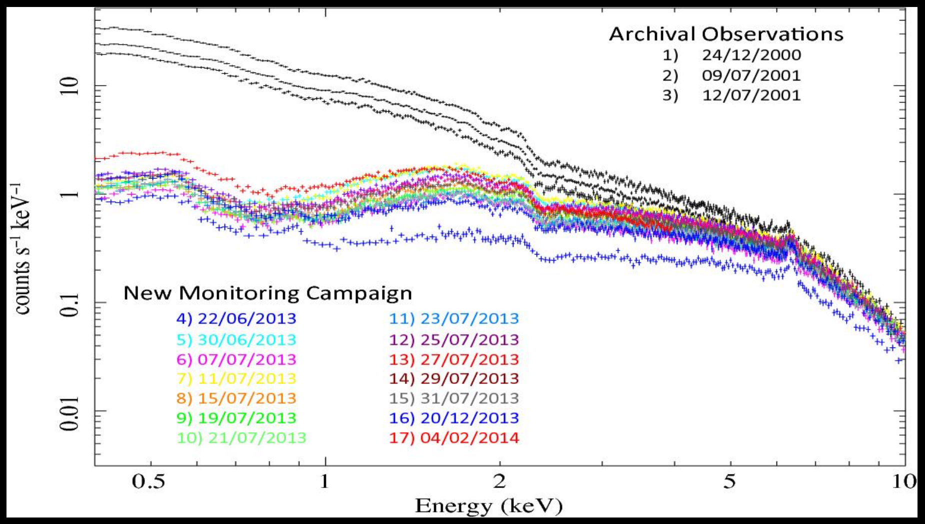
Data consistent with the presence of warm corona



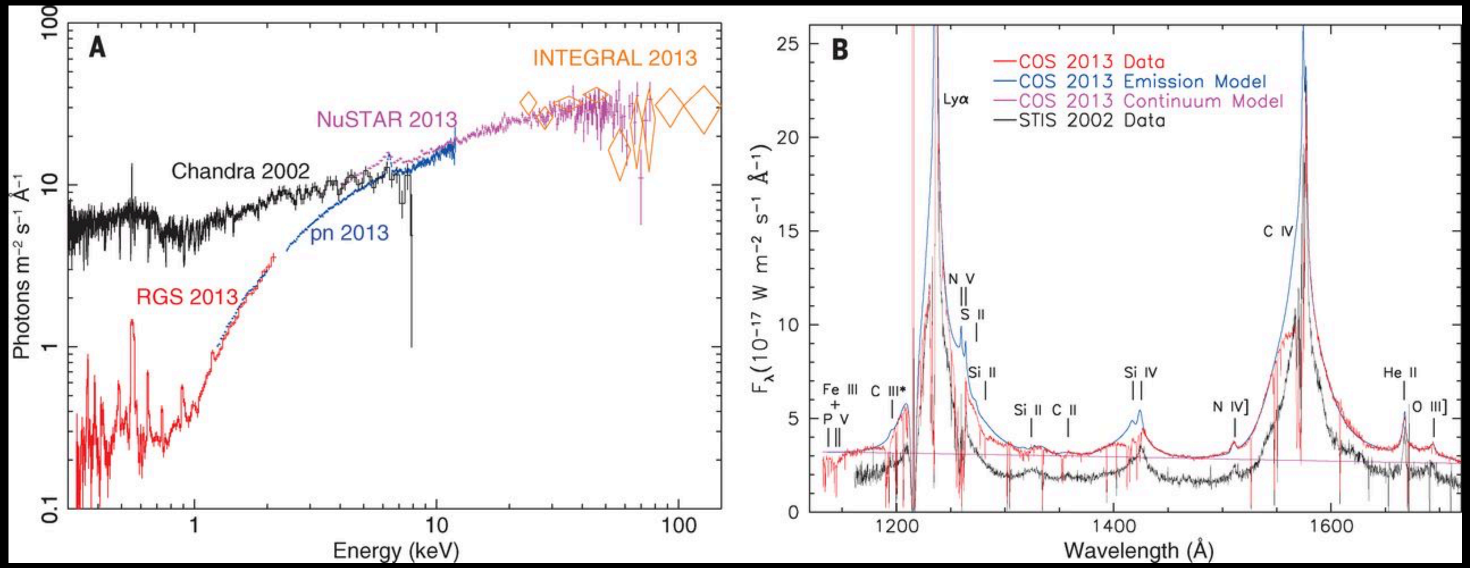


Petrucci+2018

Testing winds and outflows in nearby AGNs: the case on NGC 5548



Cappi+2016
Ursini+2015

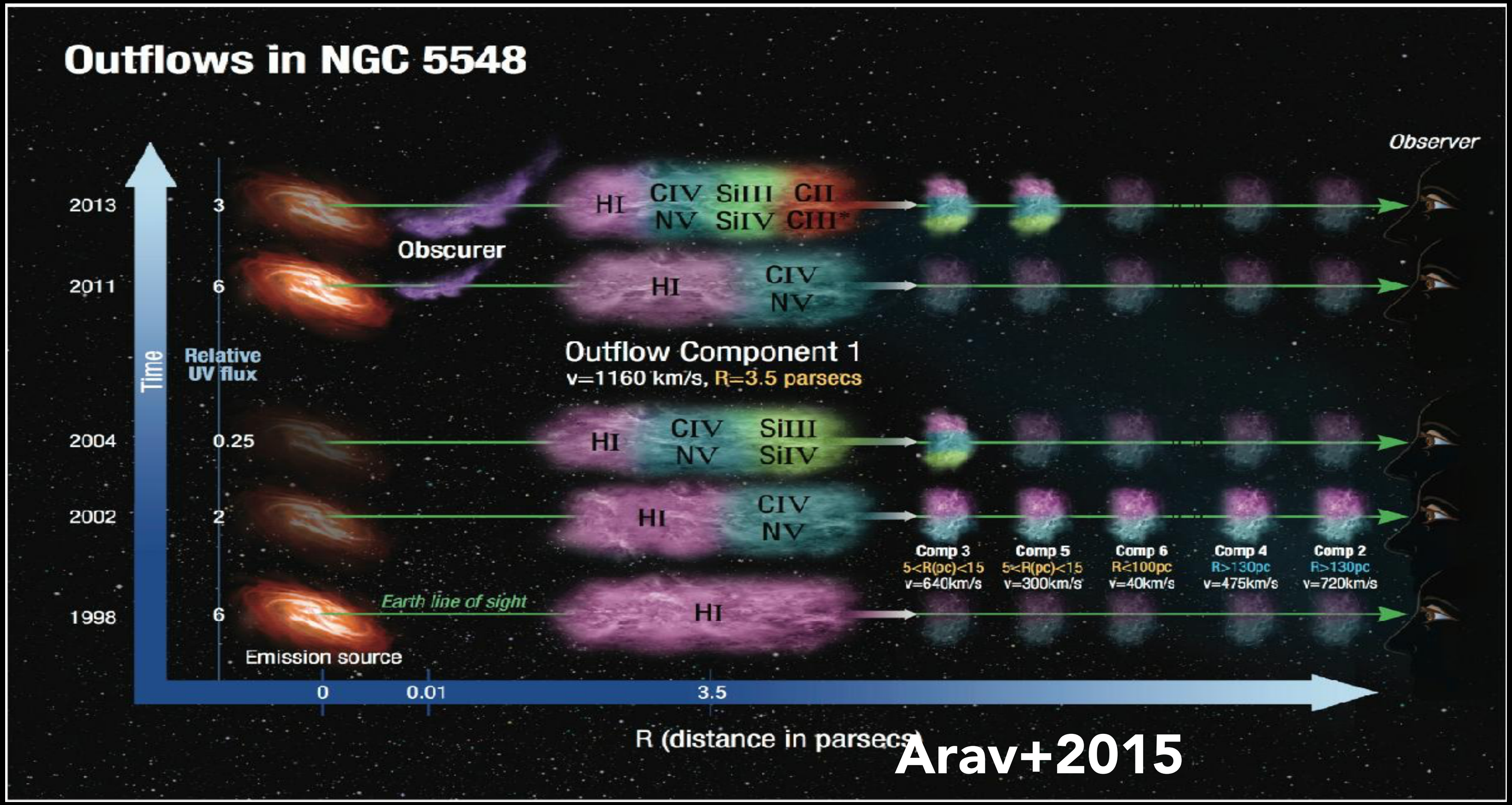


Kaastra+ 2014

Seyefert galaxy have been observed to switch from type I to type II in X-rays

Variable absdorber observed also in optcal-UV

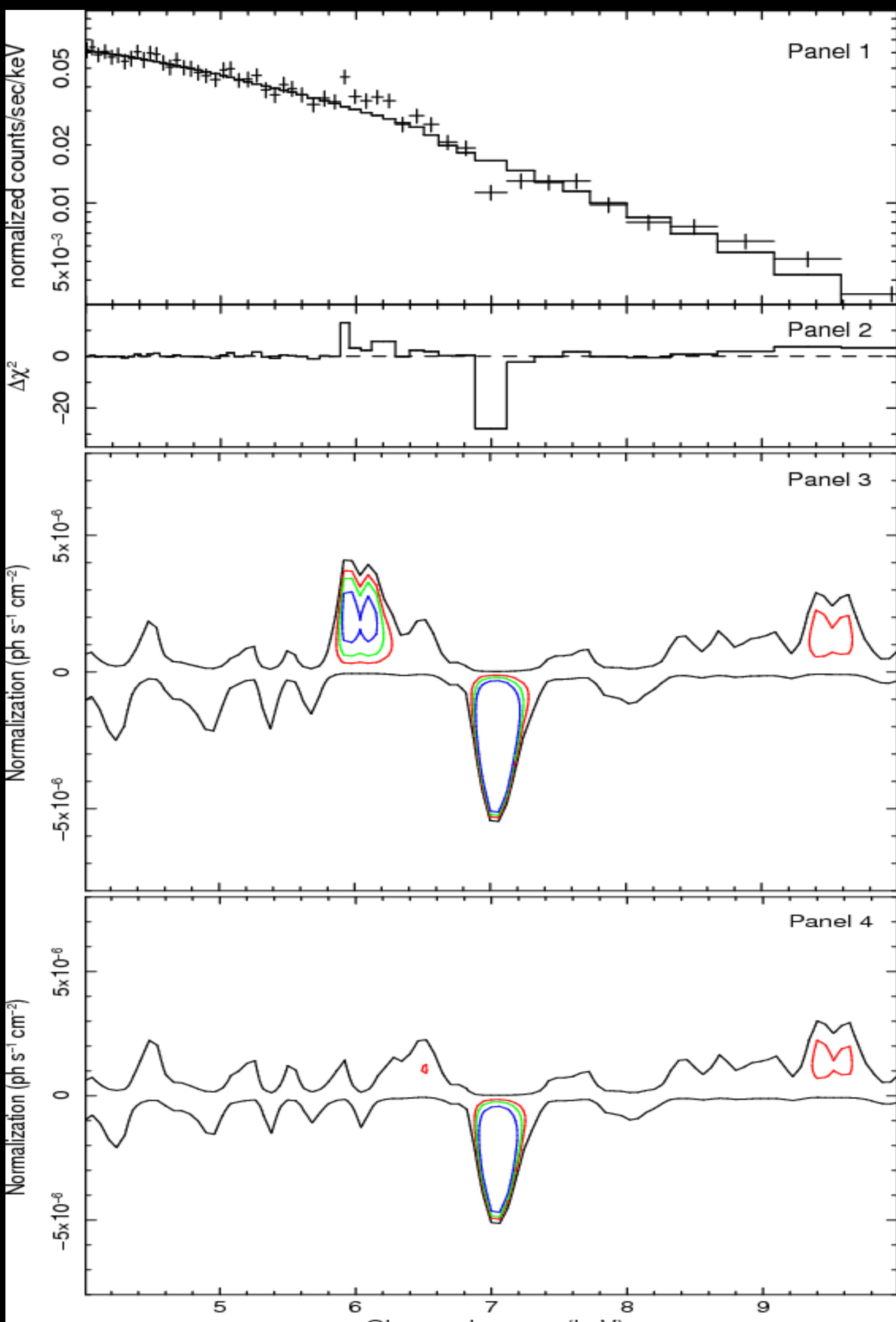
Structurated wind!



Arav+2015

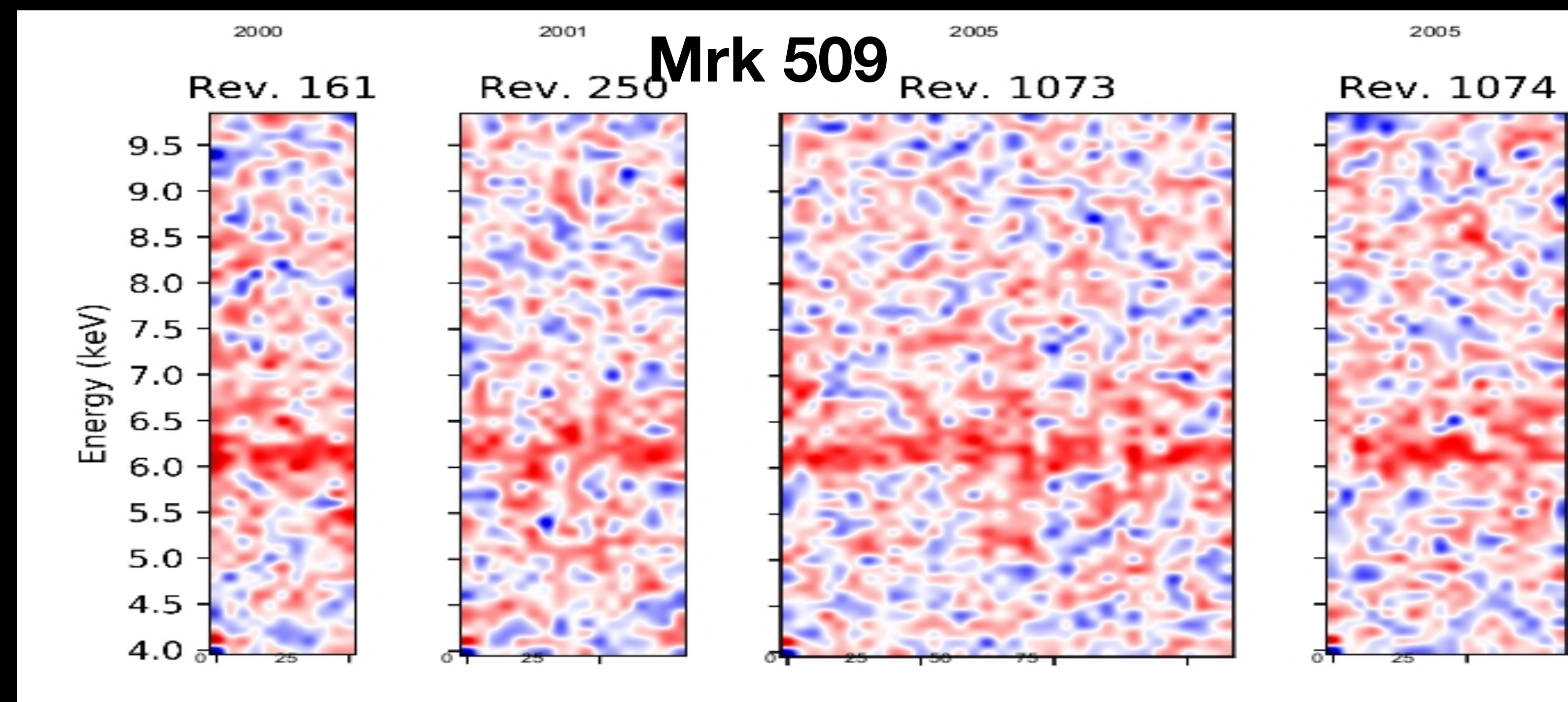
Where do these winds originate? Serching for UFOs in nearby AGN…

~40% of nearby Seyferts display signatures of Highly ionised ultra-fast (0.1-0.4c) outflows (Tombesi+2010,2011,2013)



Time-resolved spectral analysis

Costanzo+ in prep.



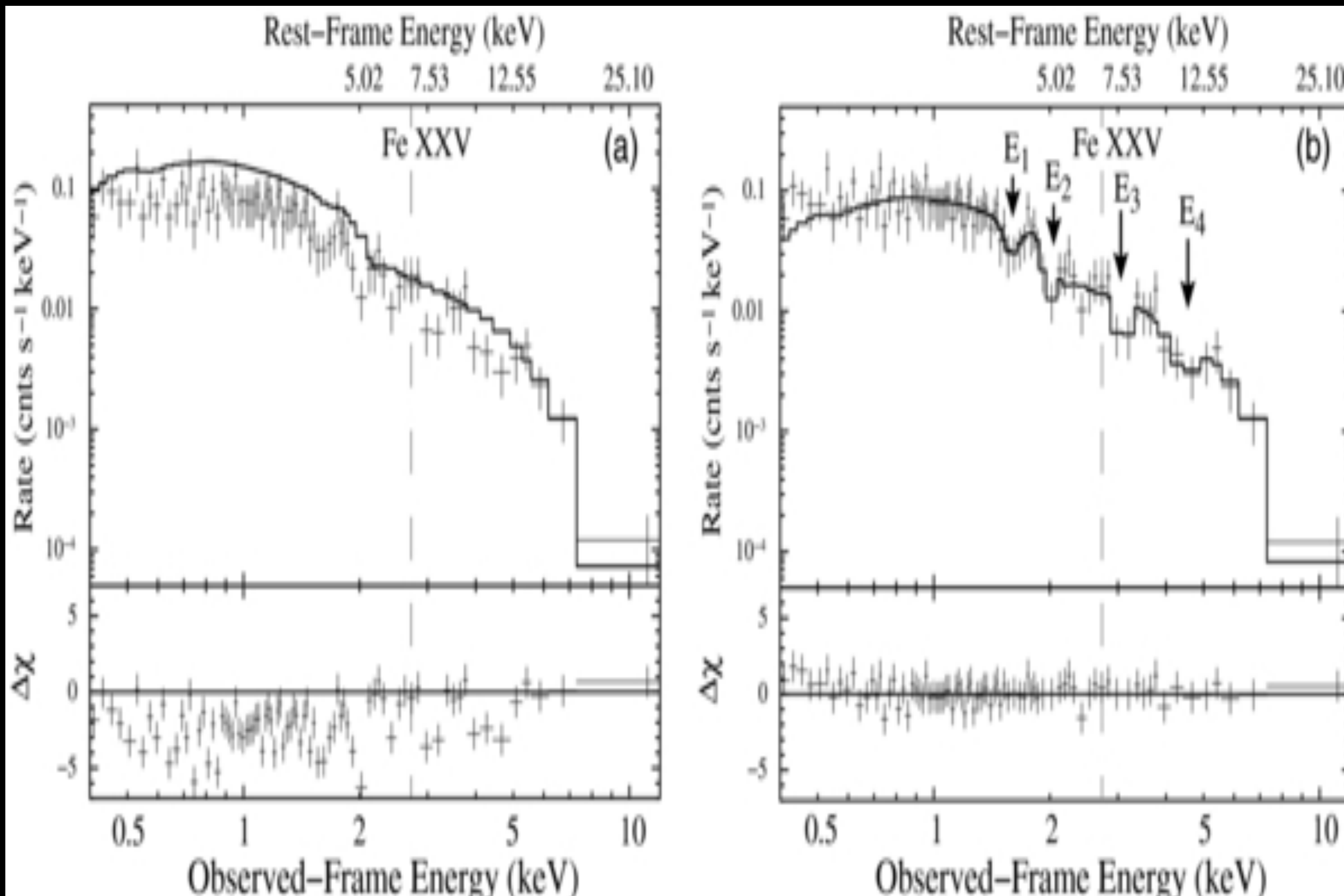
Time

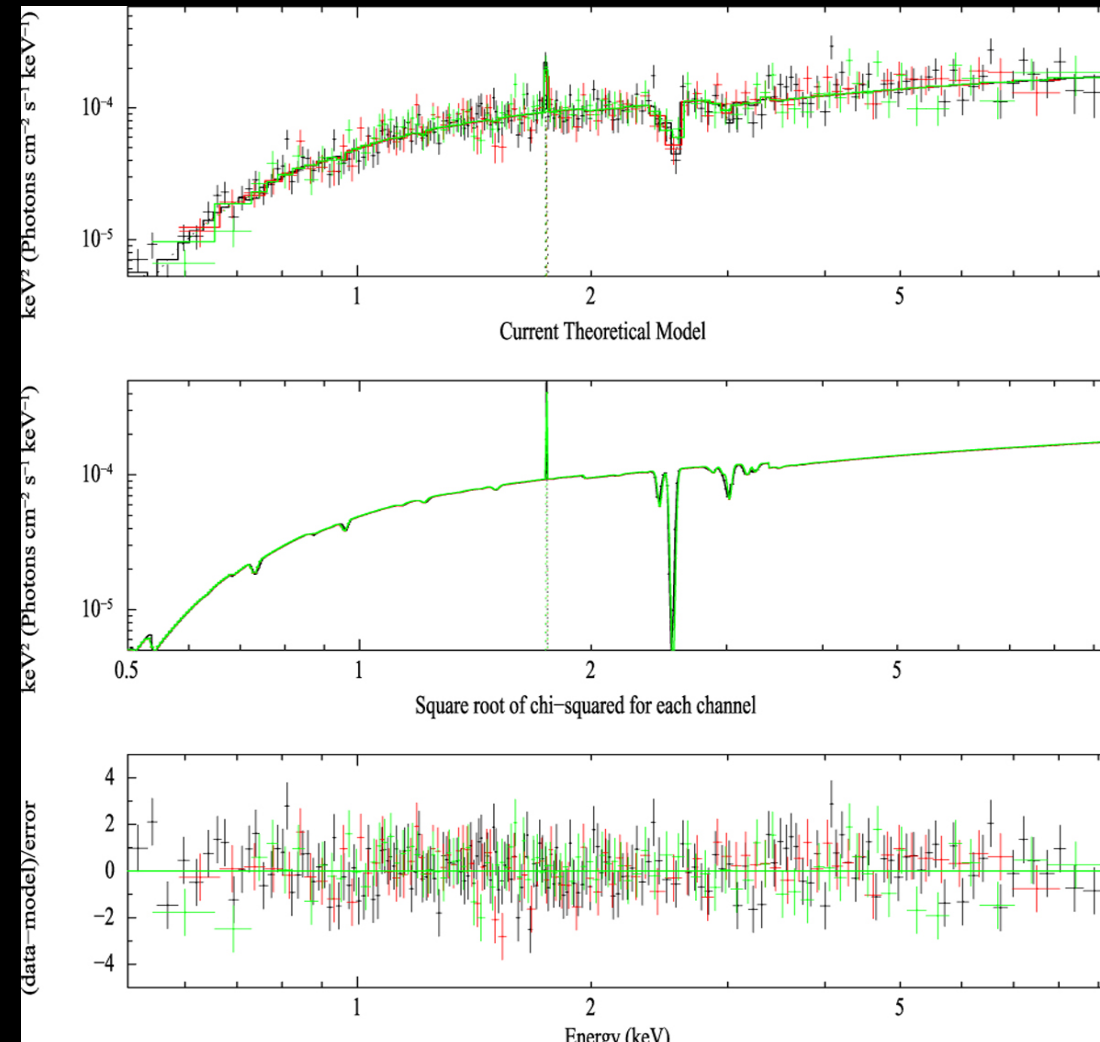
UFOs are detectable as variable absorption features at E~7.0-10 keV due to highly ionised Iron

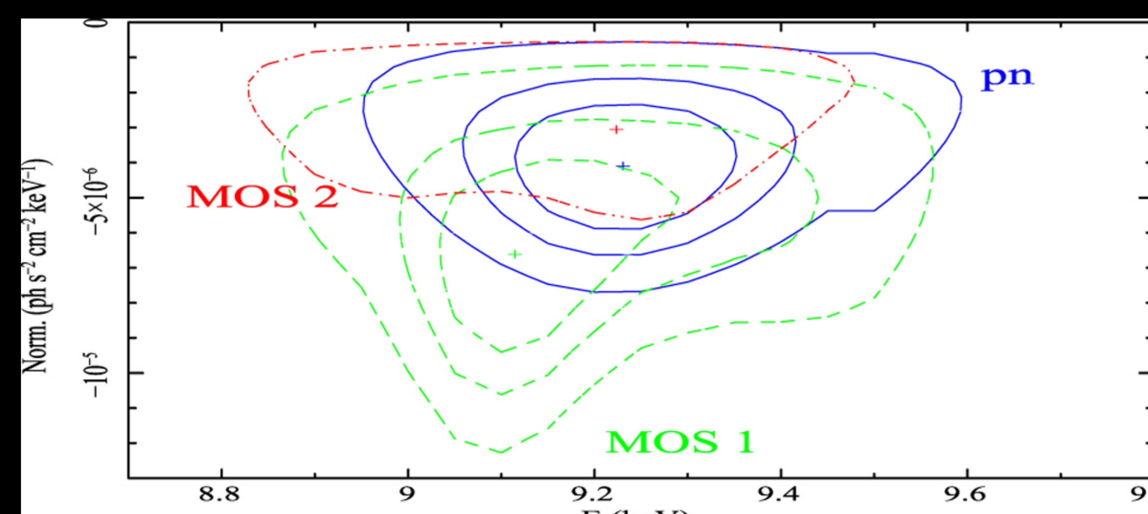
UFOs L_{kin} may be larger than ~$0.05L_{bol}$ thus they can significantly impact on the star formation rate of the host galaxy (King & Pounds 2014)

What about high-z where they had to act to install feedback with their hosts?

Chartas+2014 HS0810+2554 (z=1.51)







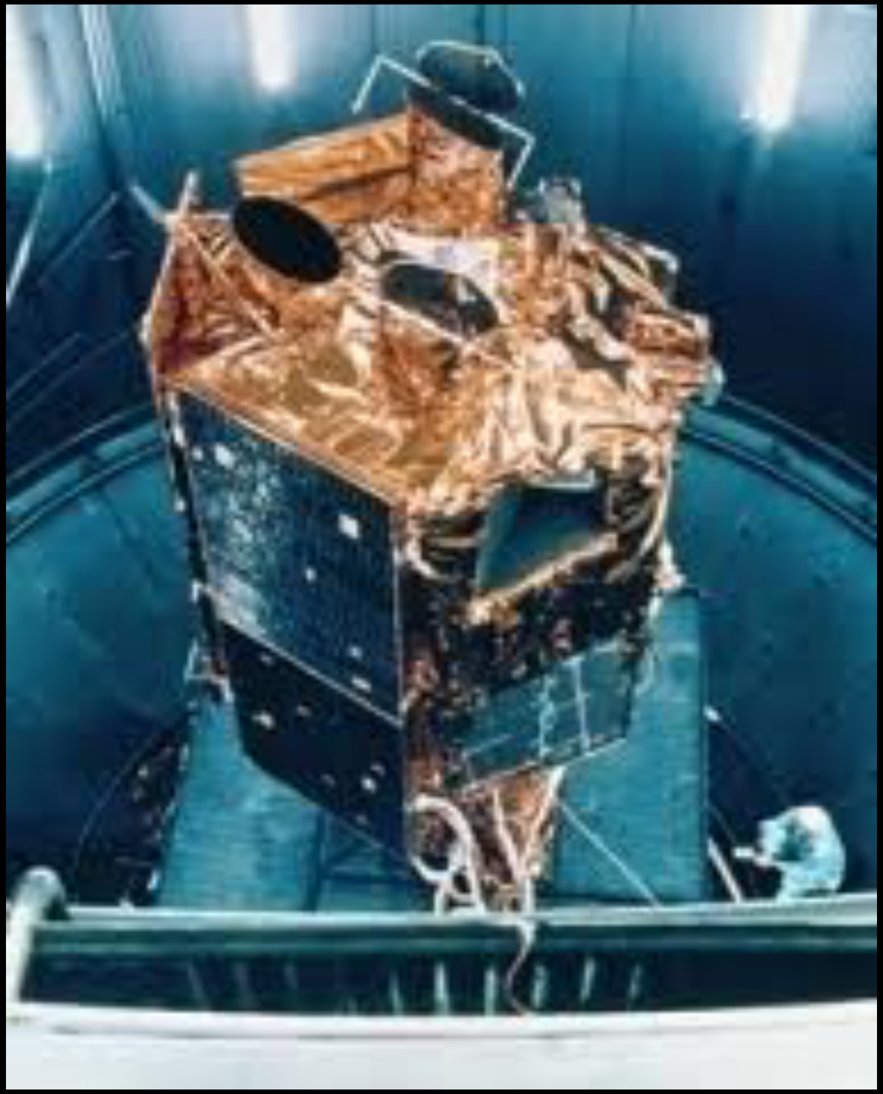
Distant QSO display UFO signatures with observed $L_{kin} > 0.05 L_{bol}$

Near future:

1) XMM-Newton LP on non lensed QSOs (PI Cappi)
2) proprietary XMM-Newton data on other lensed QSOs (PI Chartas, Dadina)
3) XMM-Newton Legacy program on bright QSO (PI Brusa)

Dadina+2018 MG J0414+0534 (z=2.64)

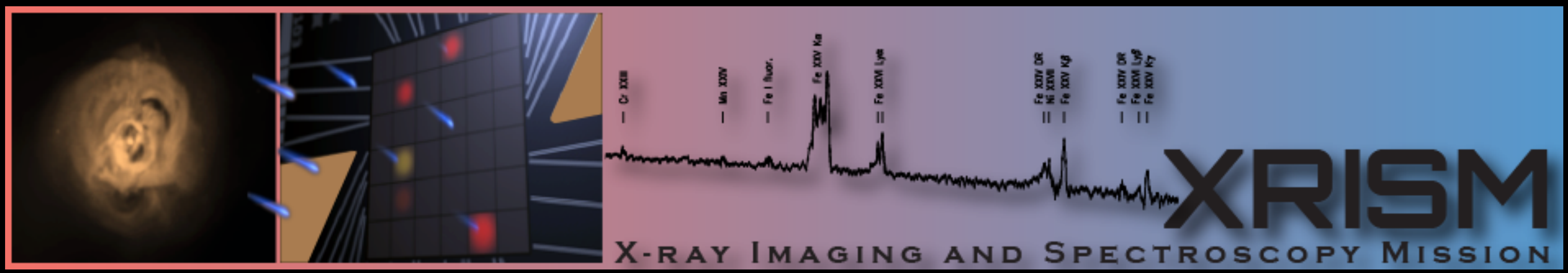
Heritage

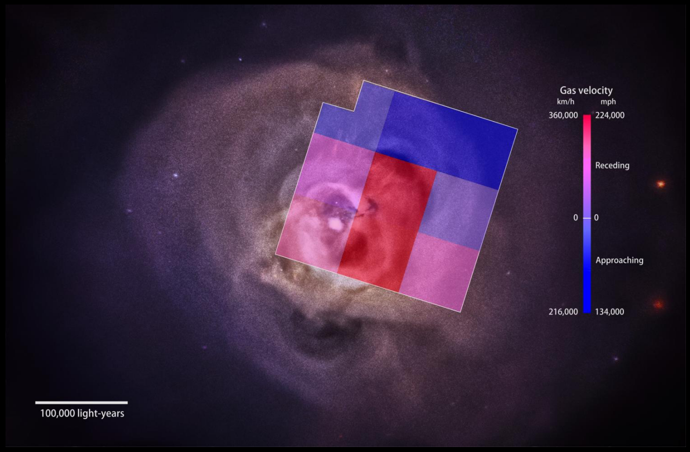


BeppoSAX

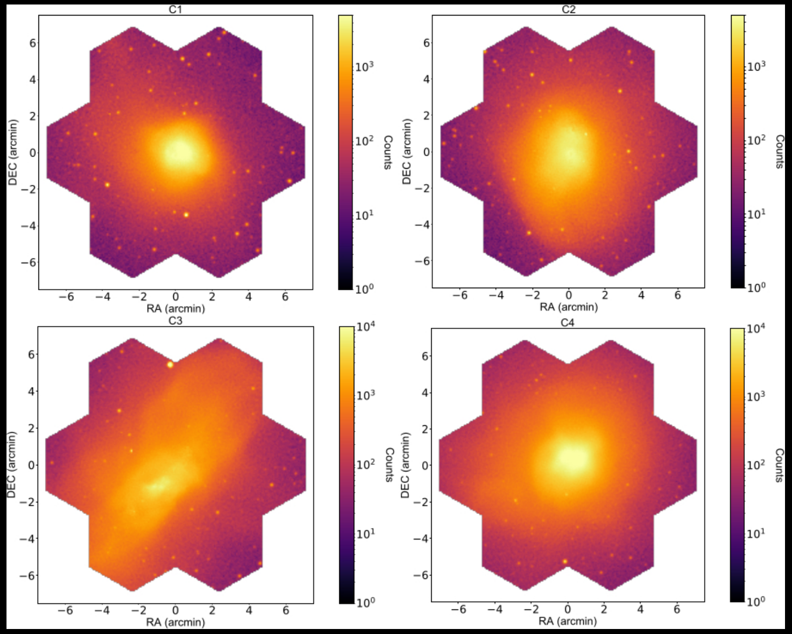
XMM-Newton

Future perspectives





Jaxa led mission; launch in ~2021 - Microcalorimeters for IFU spectrometers in X-rays DeltaE~5-7 eV



Launch 2030
See Cappi's Talk

…and for the high-z Universe, I think that the coupling of the eRosita survey and the XMM-Newton collecting area will give us some interesting results while waiting for Athena….

X-RAY ASTRONOMY *2019*

Current Challenges and New Frontiers in the Next Decade

8-13 September 2019

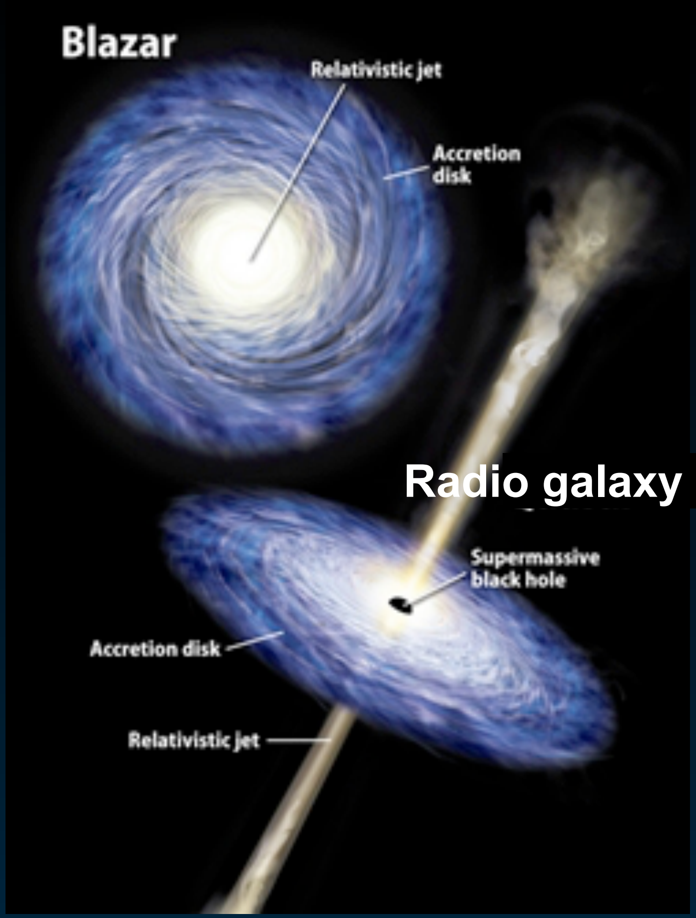
CNR/INAF Research Area, Bologna, Italy

SOC co-chairs:
Roberto Gilli
Cristian Vignali

LOC co-chairs
Marcella Brusa
Mauro Dadina

Radio-Loud AGN
from X-rays to TeV

OAS Days 17.12.2018



Central Engine:

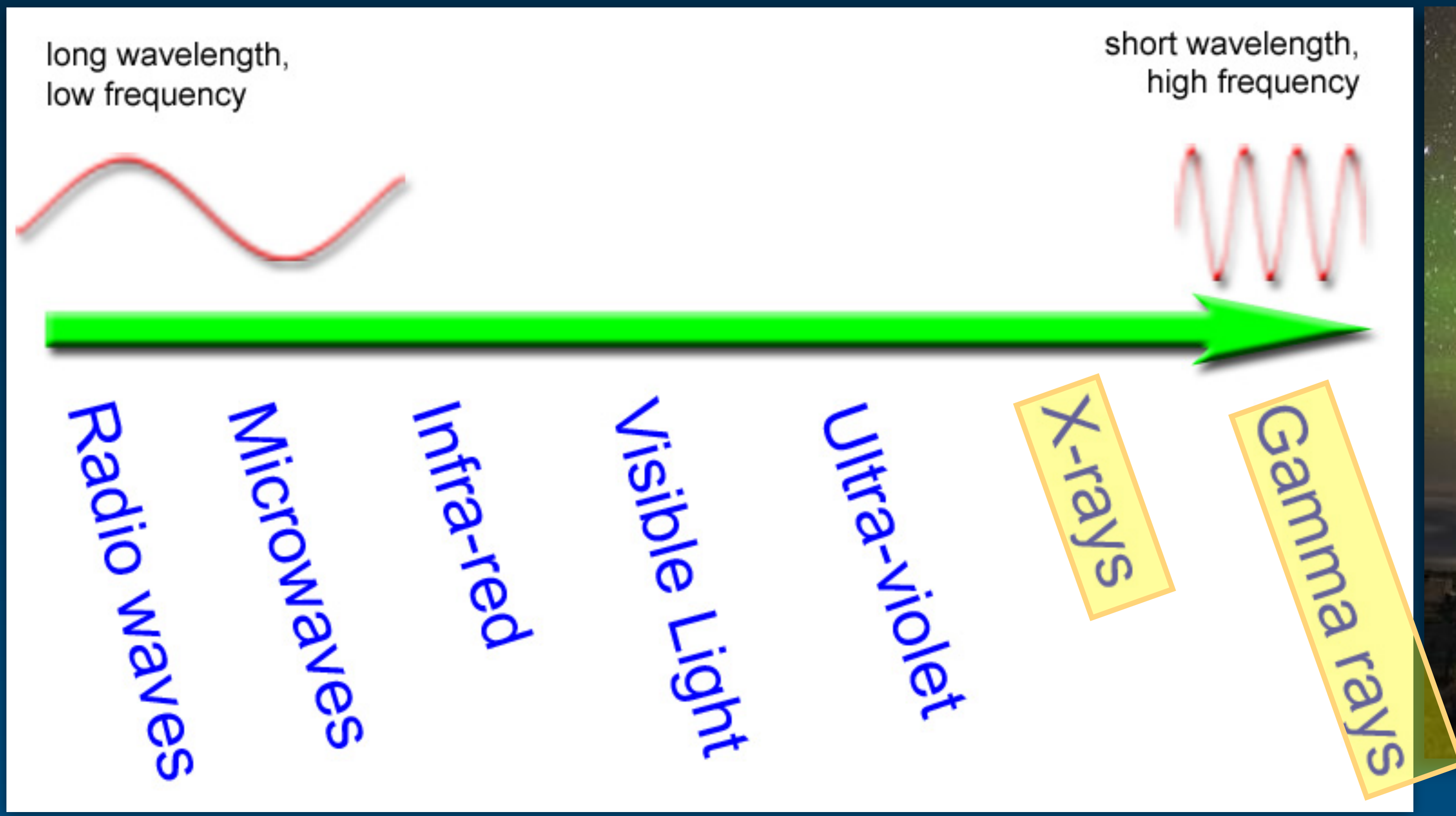
- X-ray study of the nuclear regions (accretion processes);
- X-ray variability (temporal and spectral) study;
- Comparison of the X-ray properties of RL AGN at different inclination angles.

Non-thermal extended structures (jets and lobes):

- Search for gamma-ray counterparts of RL sources;
- Localization of the gamma-ray dissipation zone;
- Spectral Energy Distribution modeling (leptonic models).

Feedback:

- Study of the circum-nuclear environment properties through high-res X-ray spectroscopy;
- Study of the physical properties of the photoionized gas in emission and absorption;
- Warm absorber energetics and comparison with RQ AGN.

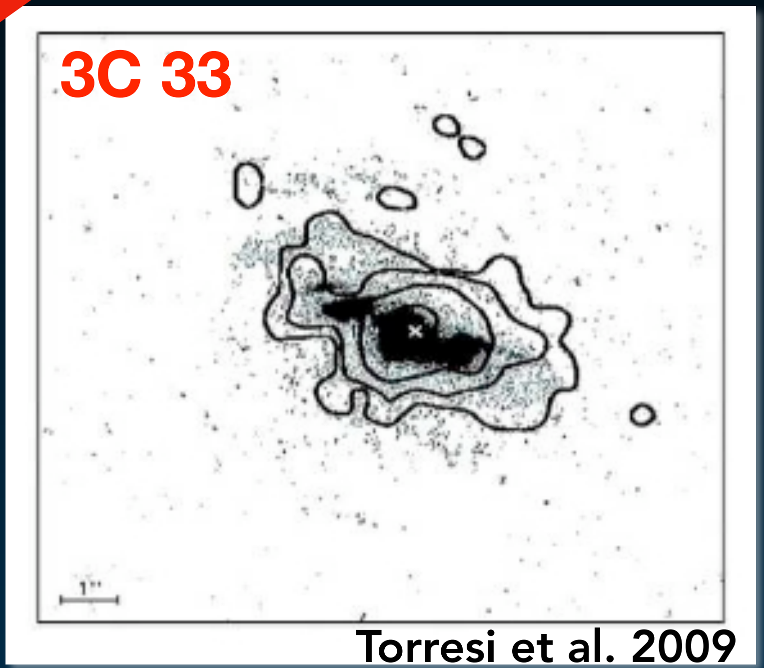


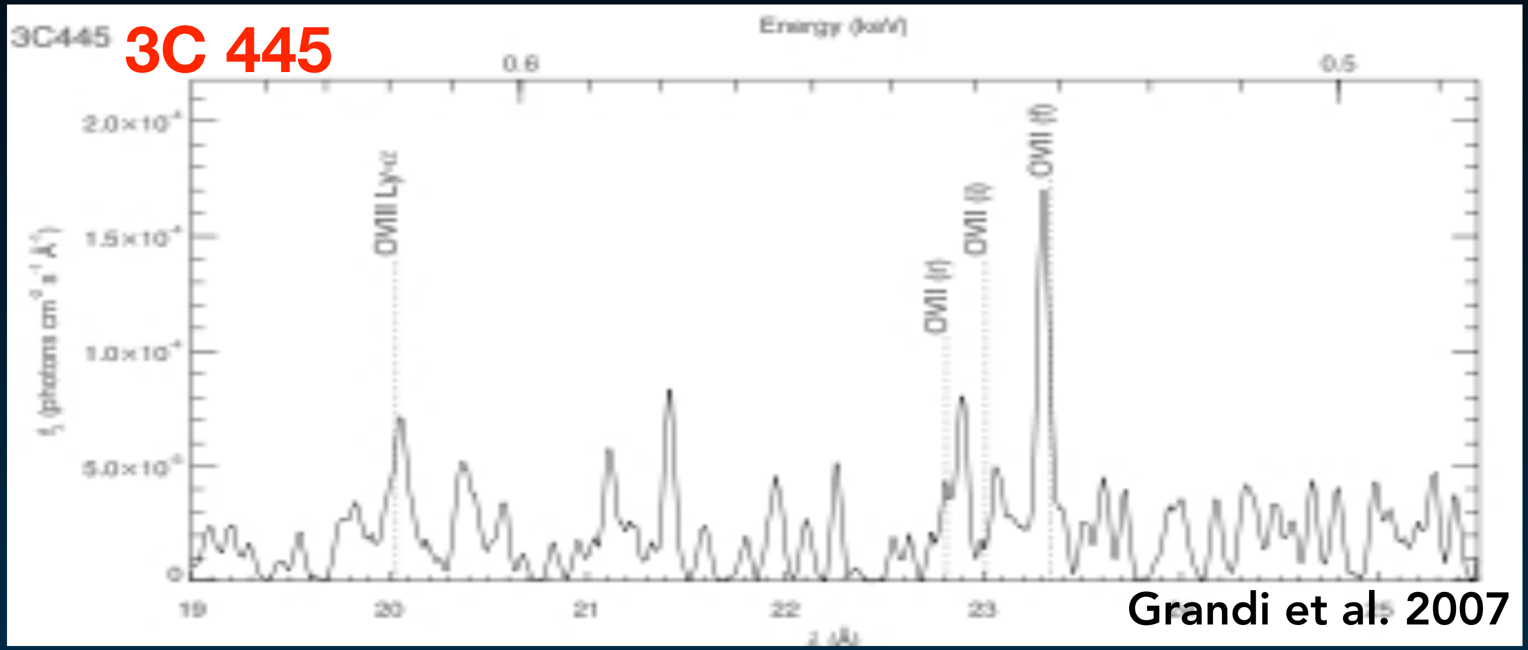
X-rays

Circum-nuclear environment of radio galaxies

Soft excess: NO jet but photoionized gas!

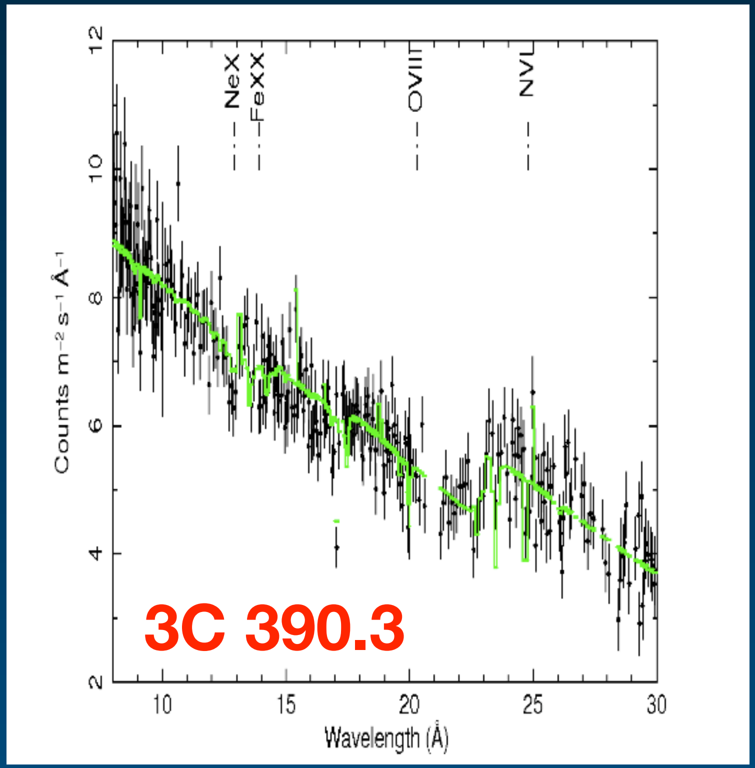
Emission





Absorption

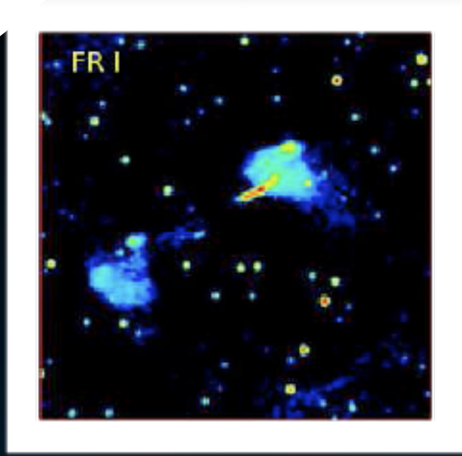
First detection of a warm absorber in radio galaxies with the RGS (Torresi, Grandi et al. 2009, 2010, 2012)



- The kinetic luminosity related to these outflows is <u>always a negligible fraction (<<1%)</u> of both the bolometric luminosity and the jet kinetic power.

X-rays

Exploring the radio morphology-accretion mode link in AGN

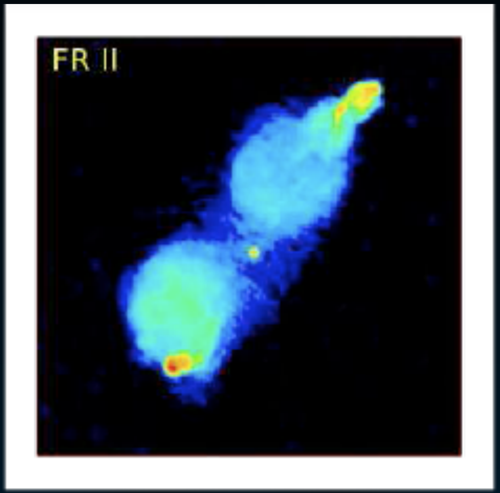


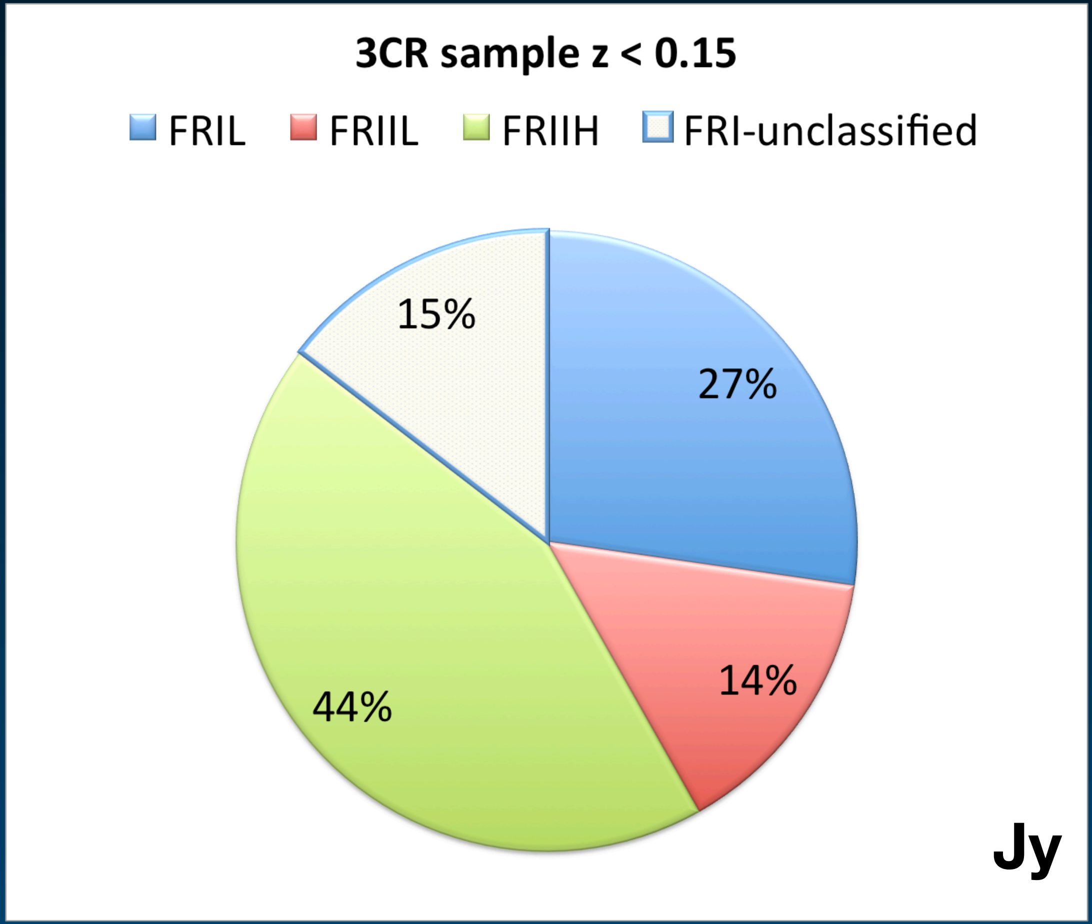
In FR I the jets are thought to decelerate and become sub-relativistic on scales of hundred of pc to kpc.

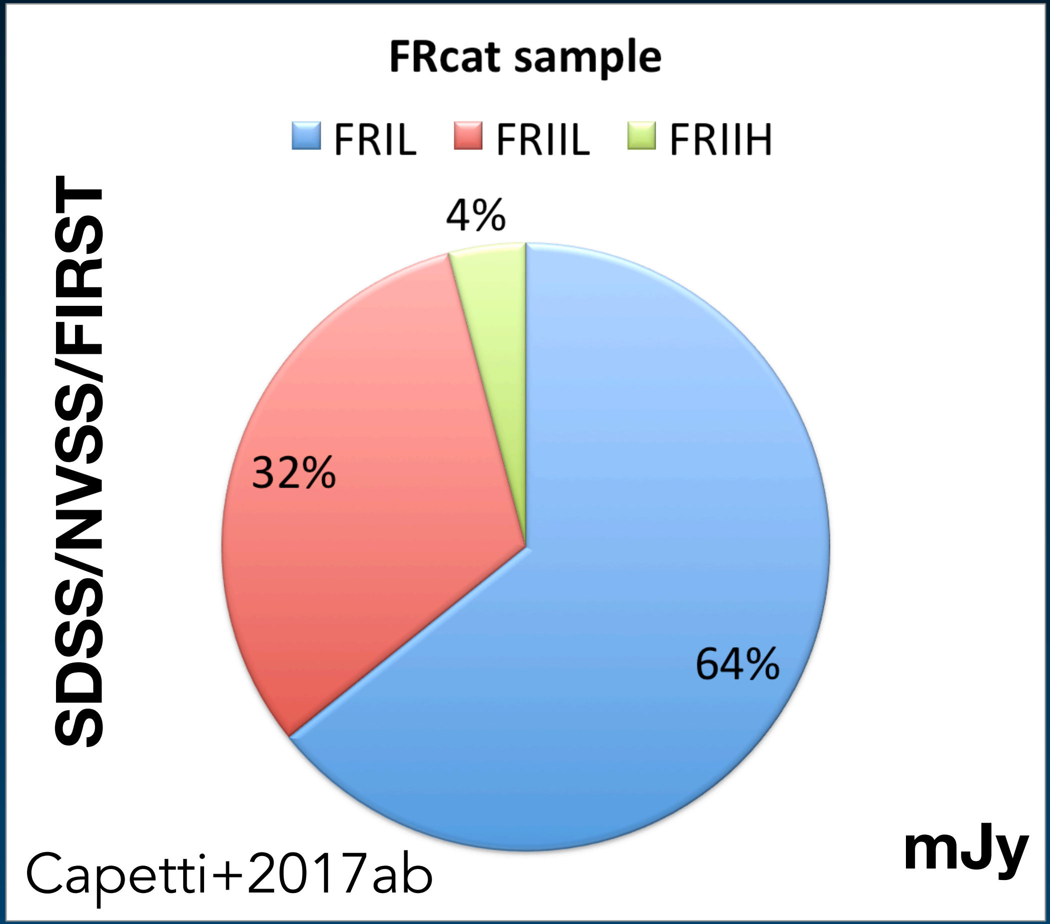
The nuclei of FR I are not generally absorbed and probably powered by inefficient accretion flows **(low-excitation radio galaxies).**

The jets in FR II are at least moderately relativistic and supersonic from the core to the hot spots.

Most FR II are thought to have an efficient engine and a dusty torus **(high-excitation radio galaxies).**







FR I <—> LERG
FR II <—> HERG

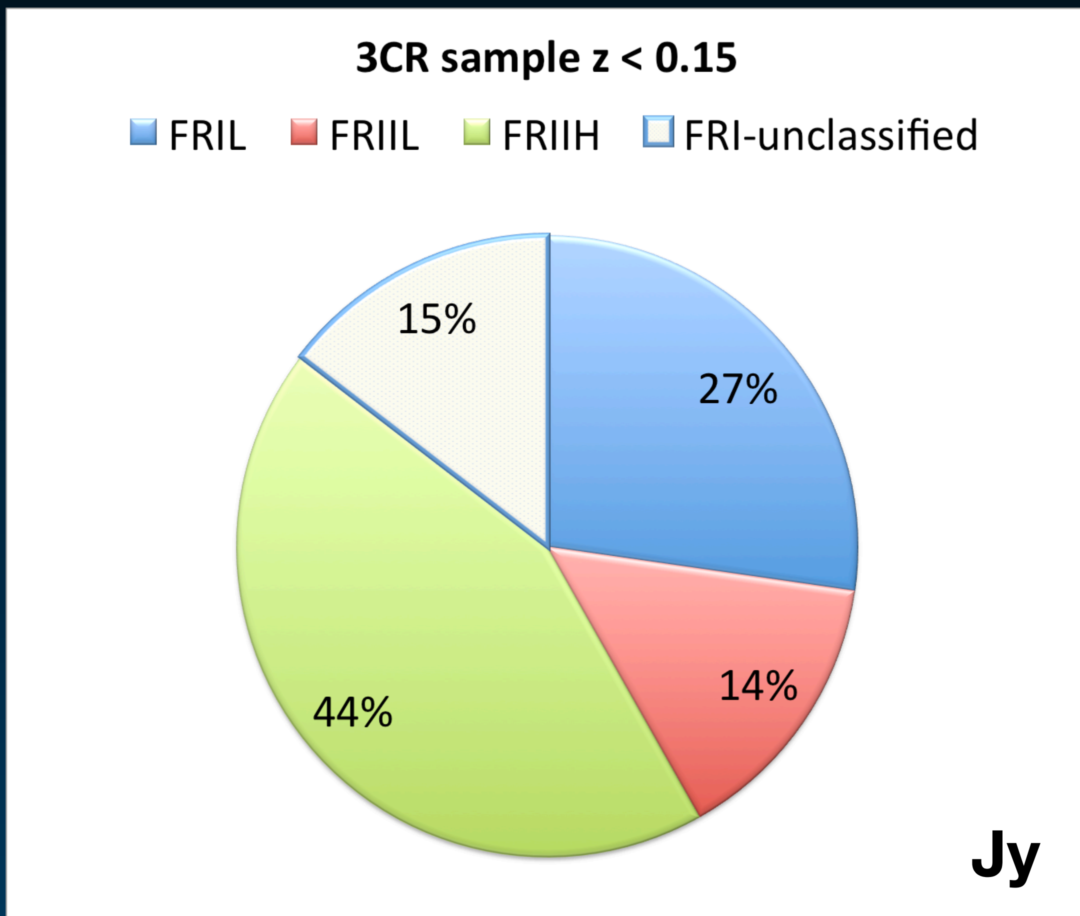
still valid?

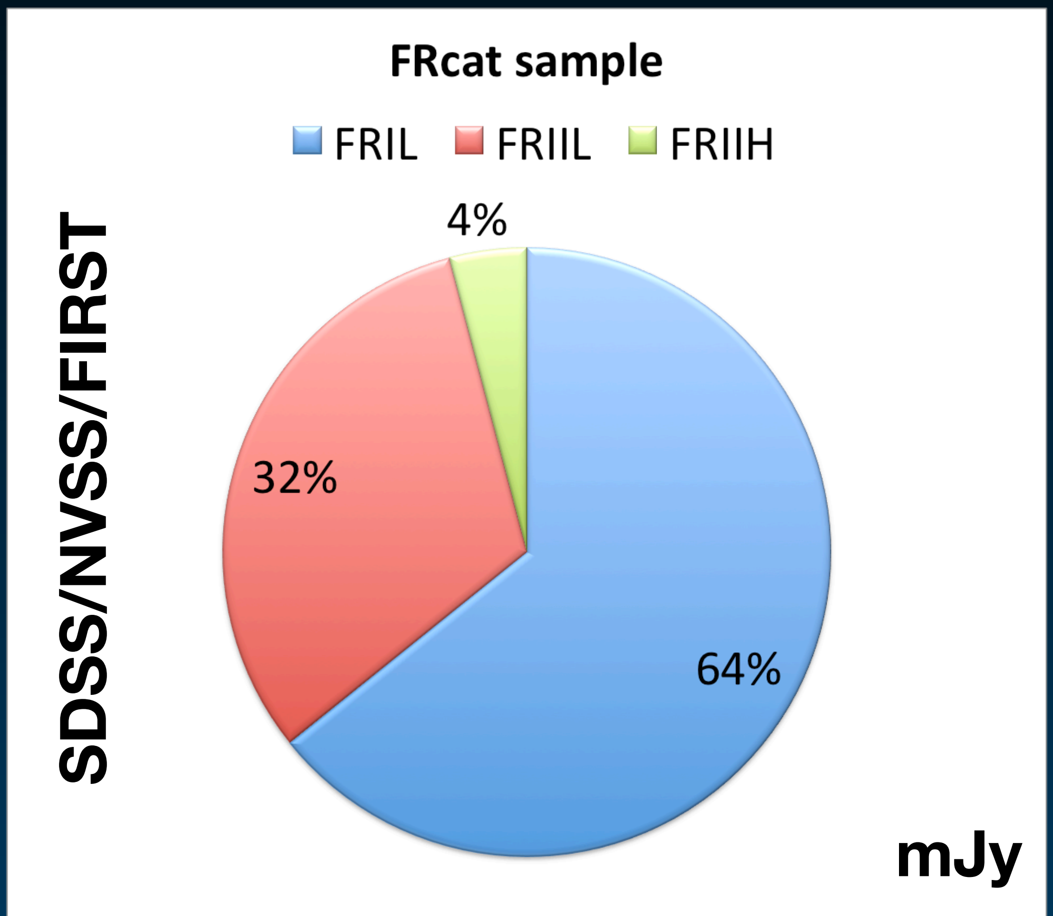
X-rays

Exploring the radio morphology-accretion mode link in AGN

FR I <—> LERG
FR II <—> HERG

still valid?

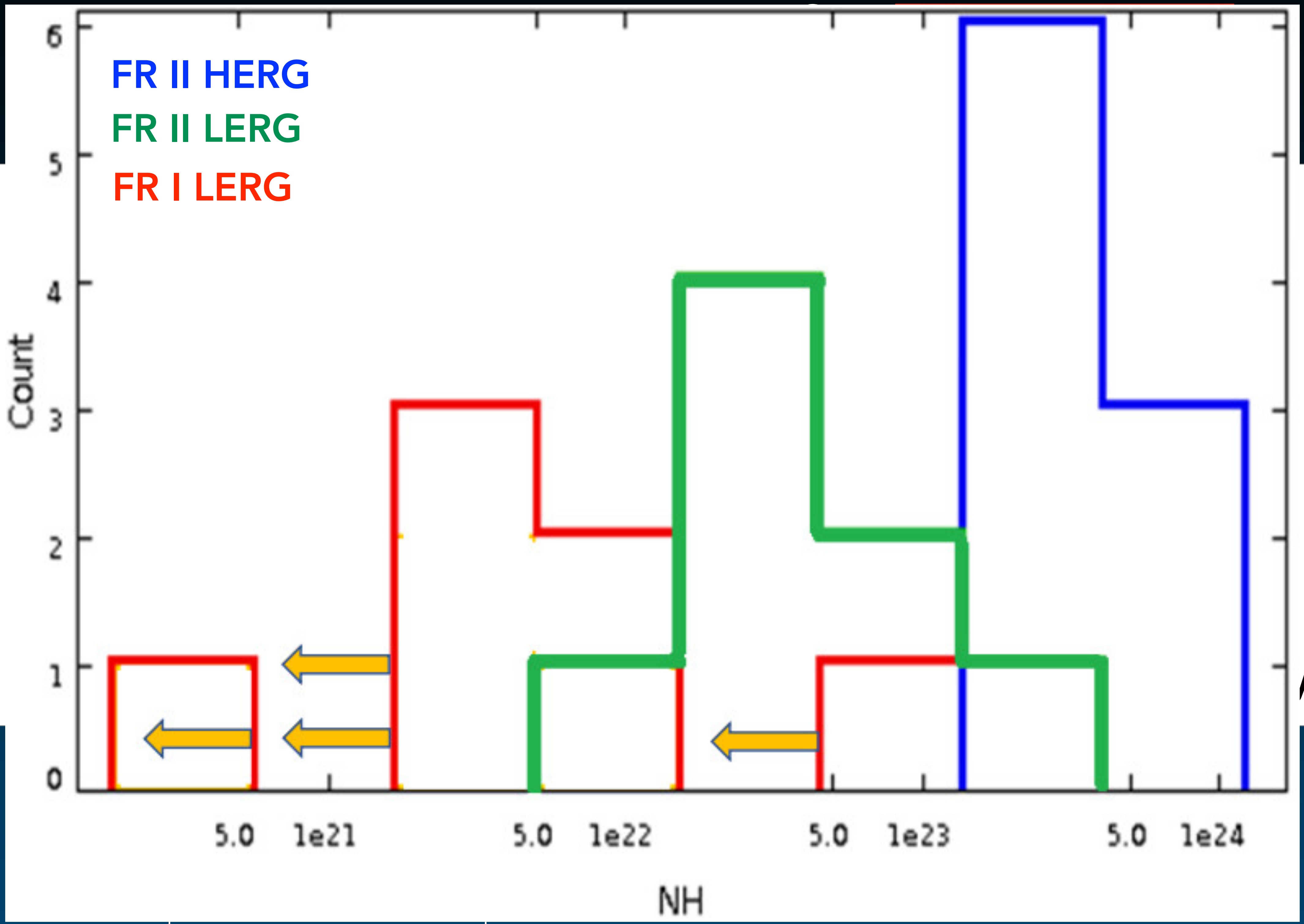




Master Thesis of
Duccio Macconi

X-rays

Exploring the radio morphology-accretion mode link in AGN



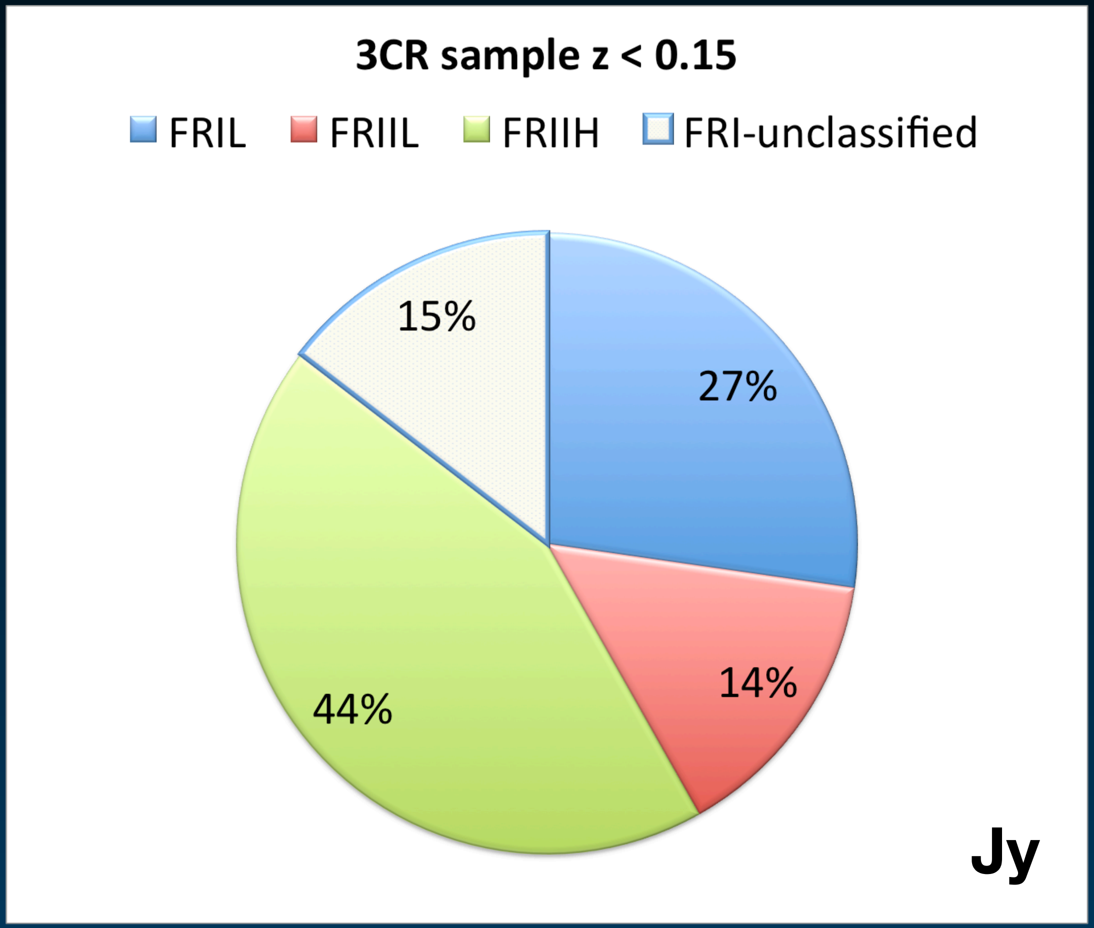
Duccio Macconi

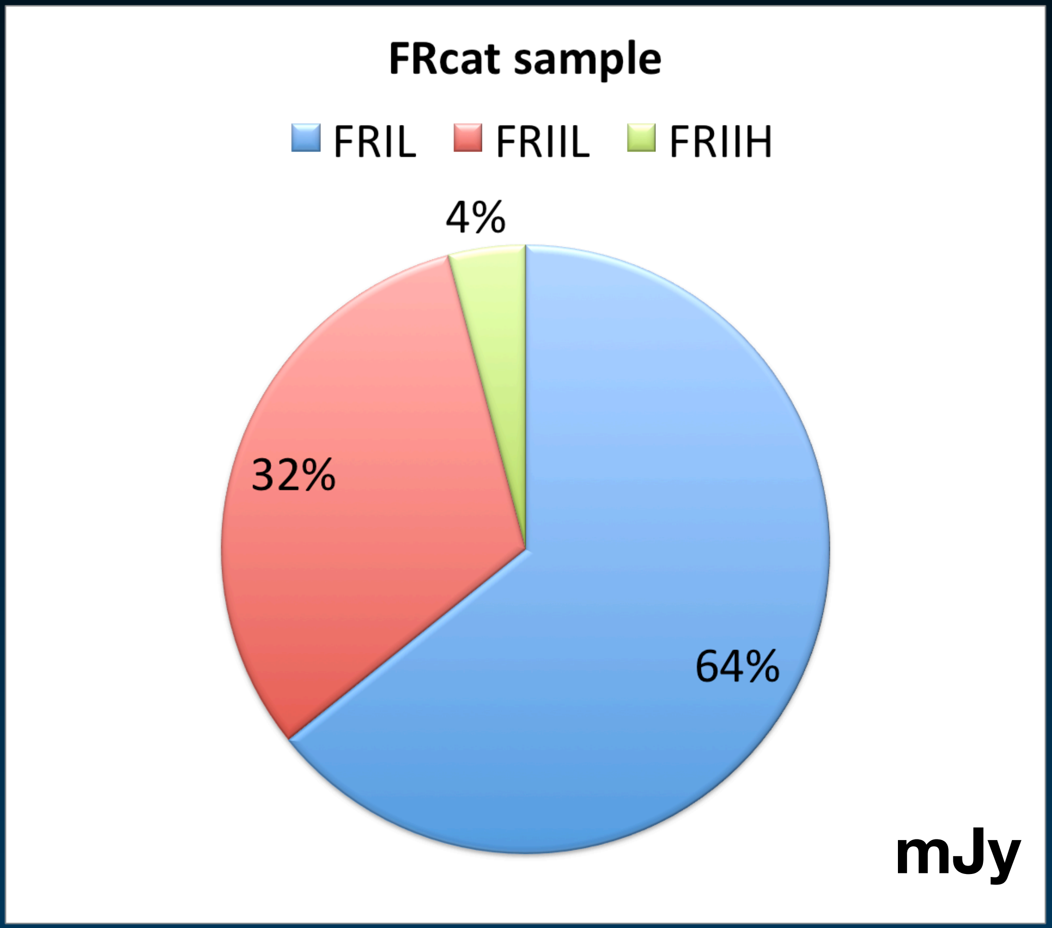
Exploring the radio morphology-accretion mode link in AGN

X-rays

FR I <—> LERG
FR II <—> HERG

still valid?



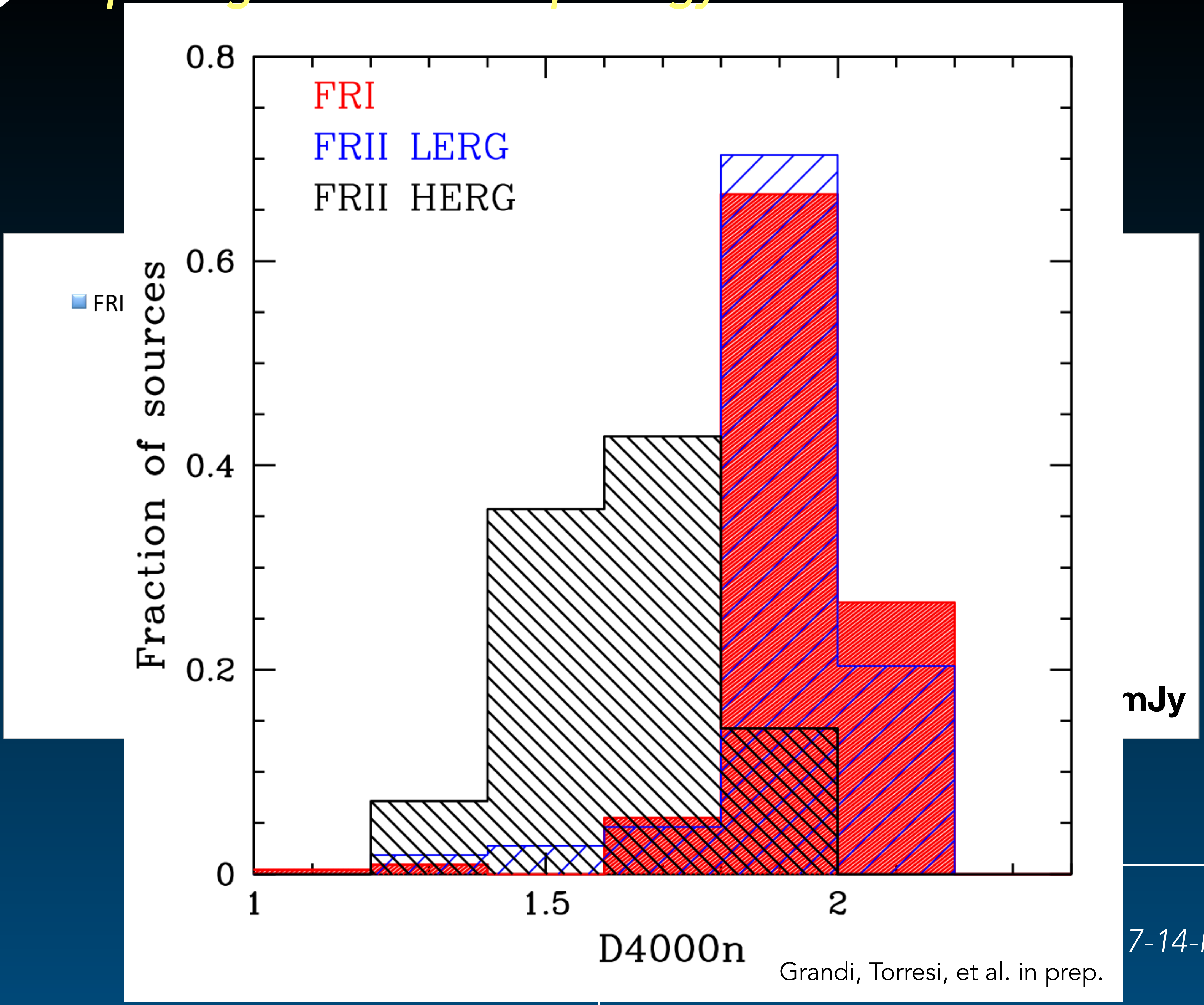


Master Thesis of
Duccio Macconi

Bando ASI
Accordo attuativo ASI-INAF n. 2017-14-H.0
(PI. E. Torresi)

Exploring the radio morphology-accretion mode link in AGN

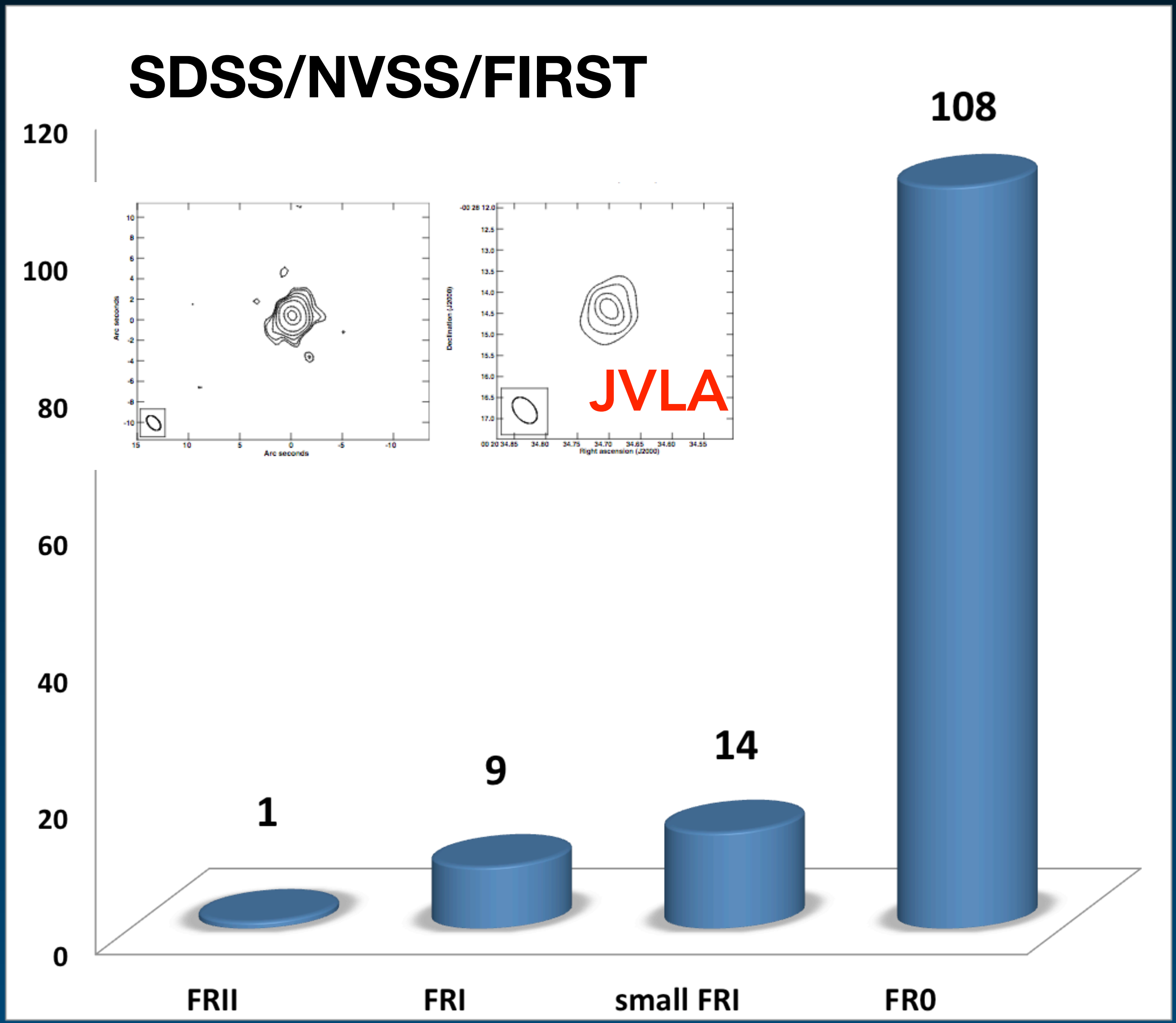
X-rays



Grandi, Torresi, et al. in prep.

FR 0 radio galaxies

- FR 0 are compact sources and lack extended radio emission
- From the optical point of view they share similar nuclear and host properties with FR I
  - host galaxy;
  - black hole masses ($M_{BH}>10^8 M_\odot$)
  - spectroscopic classification (LEG)
- FR 0 represent the bulk of the Radio-Loud AGN population in the local Universe (the number density of the FR0Cat sources is ~5 times higher than that of FR I Baldi et al. 2017)

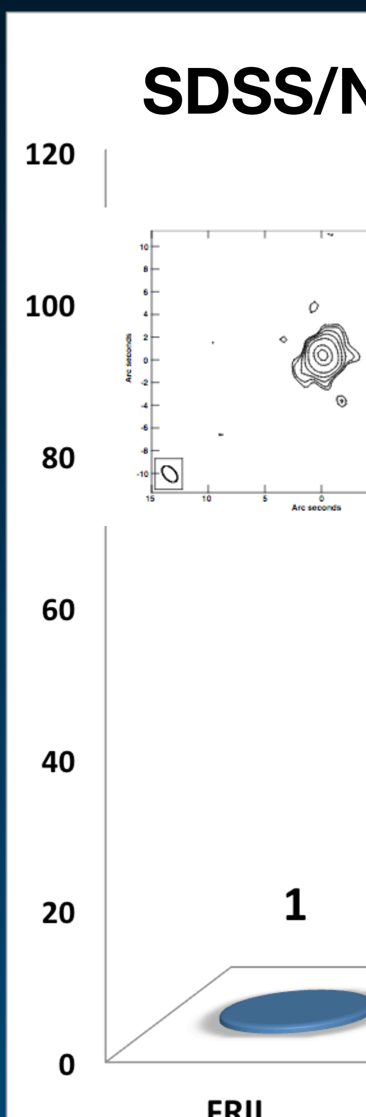


X-rays

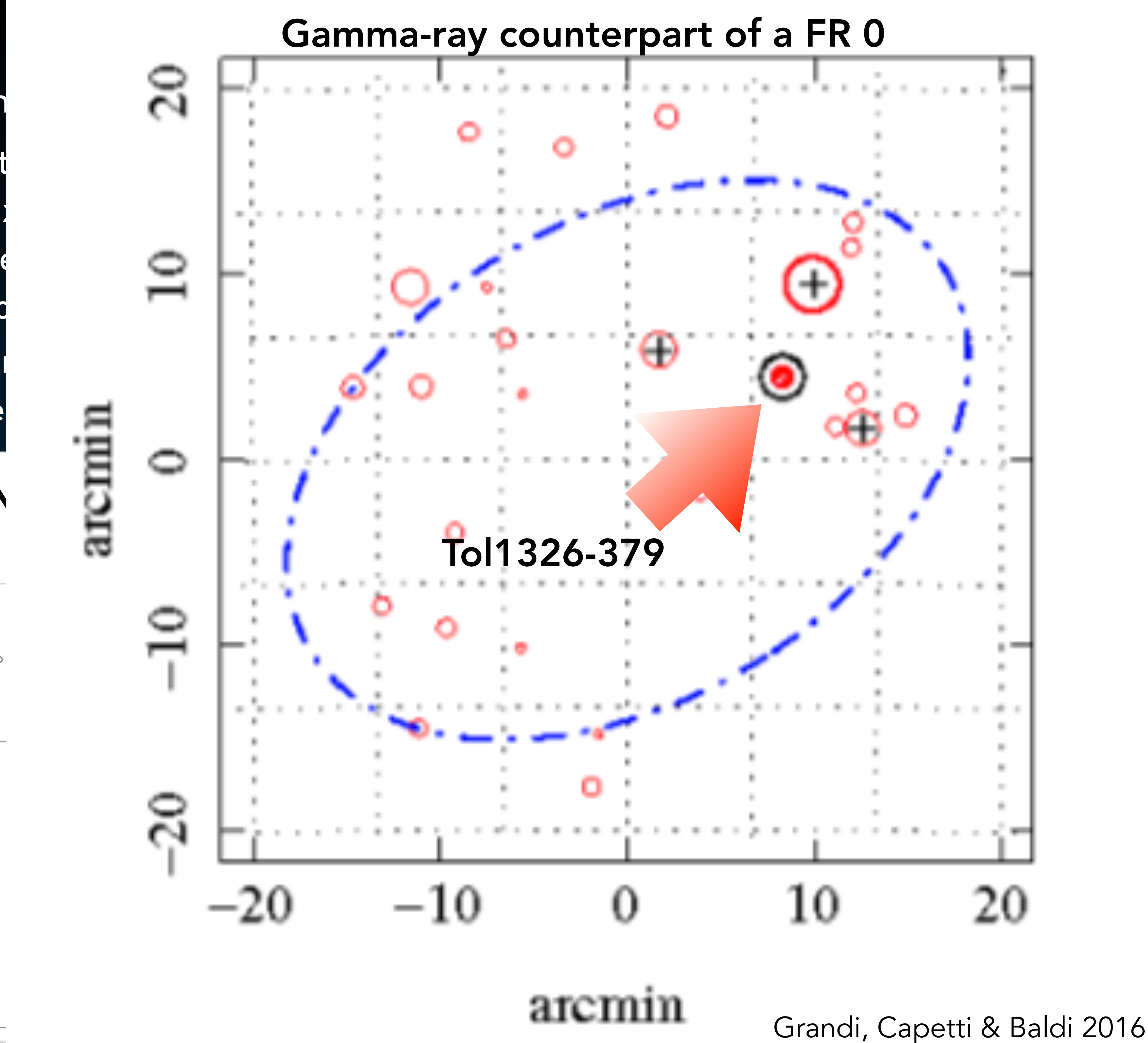
Torresi, Grandi et al. 2018

- FR 0 and FR I are similar also in the X-ray band: $L_{2-10\ keV}=10^{40}-10^{43}$ erg/s
- Inefficient accretion processes (ADAF-like): Ldot=$10^{-3}-10^{-5}$
- Non-thermal origin (jet) for the X-ray radiation, as suggested by the radio-X correlation (as in FR I)
- Study of the environment (in collaboration with M. Gitti) …in progress…

- FR 0 are com
- From the opt
  - host gala
  - black hole
  - spectrosc
- FR 0 represe   number density of the



et al. 2018



Grandi, Capetti & Baldi 2016

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0^{43} erg/s
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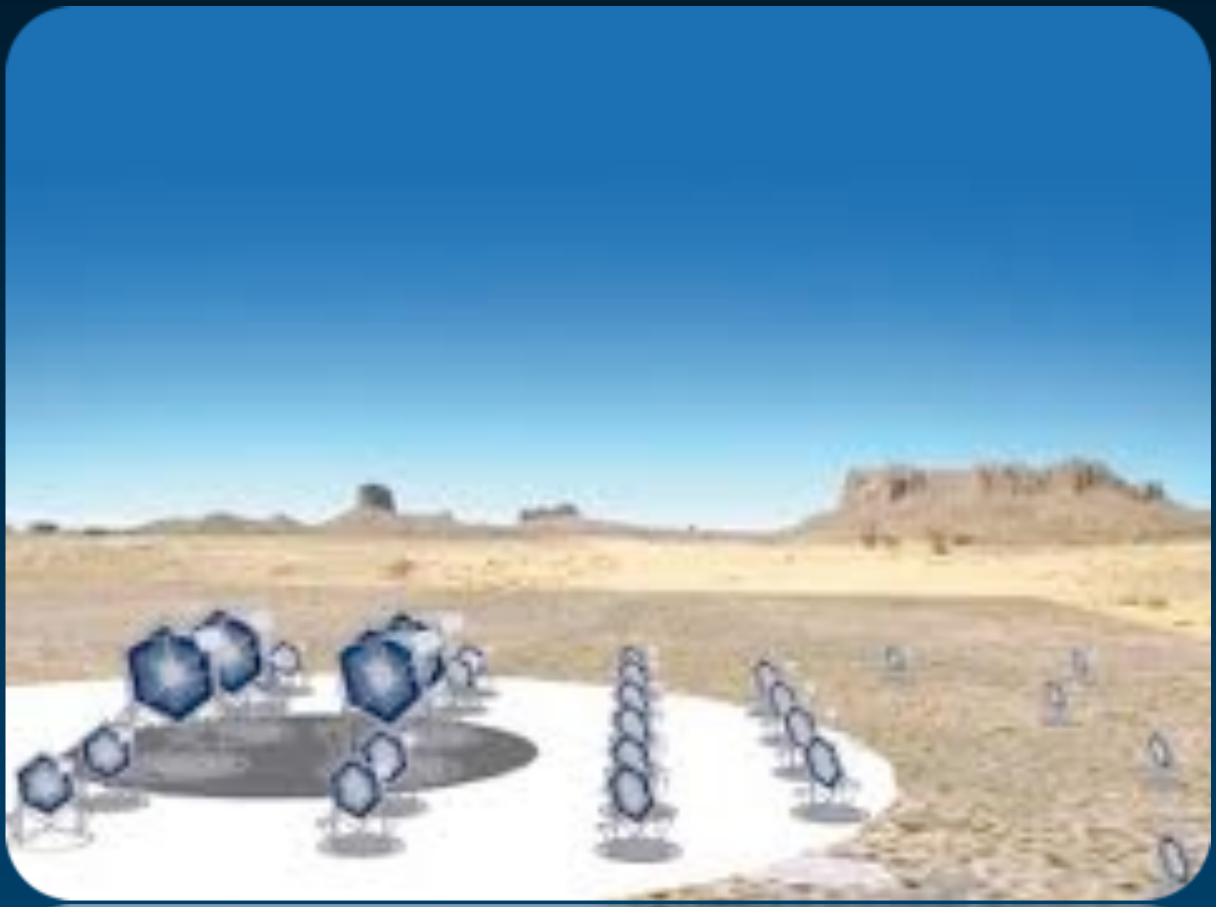
l)
ent (in
collaboration with M. Gitti) …in progress…

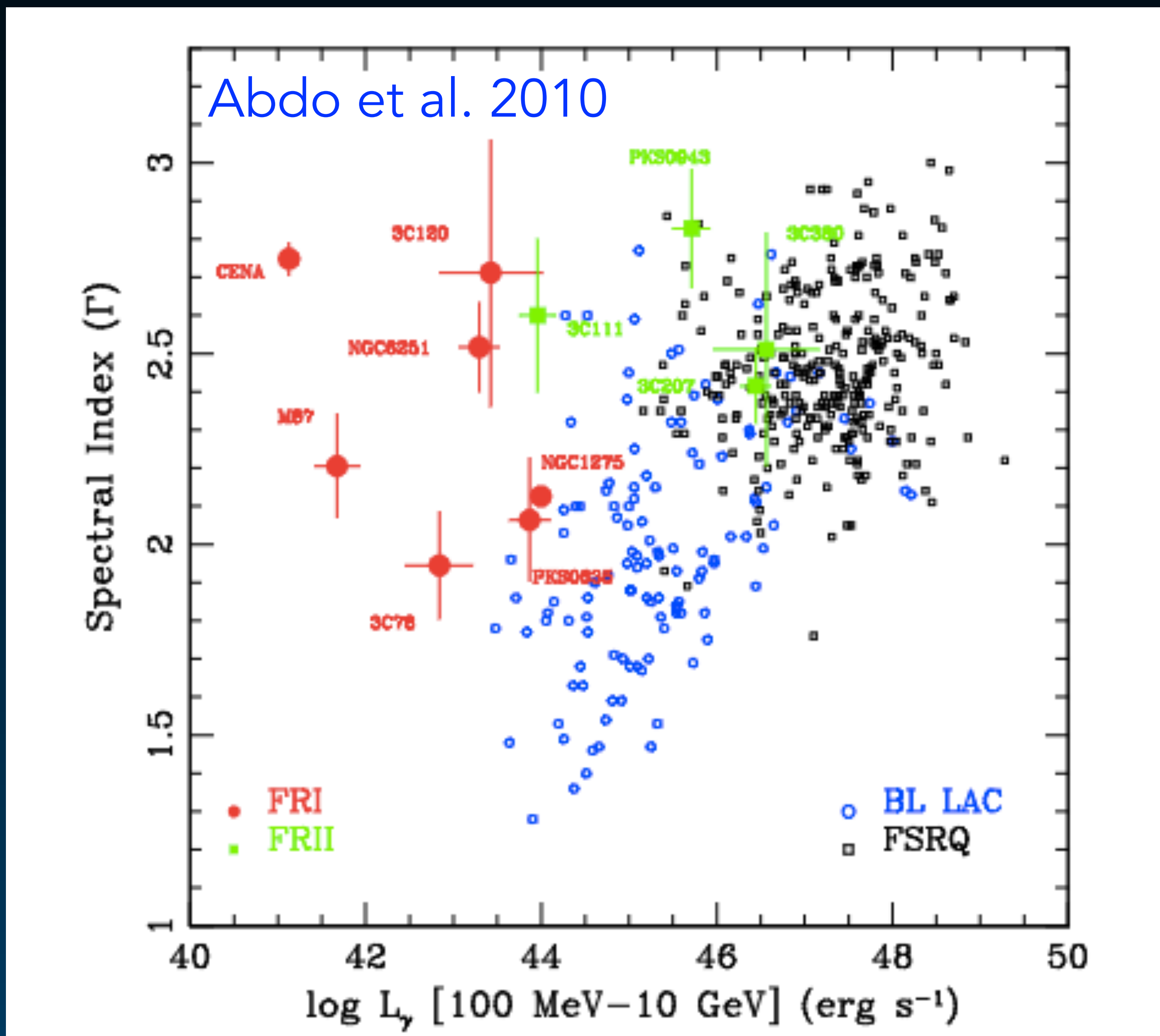
GeV & TeV studies

- Fermi-LAT results and ongoing work
- CTA perspectives



Fermi-LAT

Fermi has given a great contribution to the **discovery of radio galaxies** as GeV emitters (only 3 RG previously detected by EGRET!)



Generally **faint**

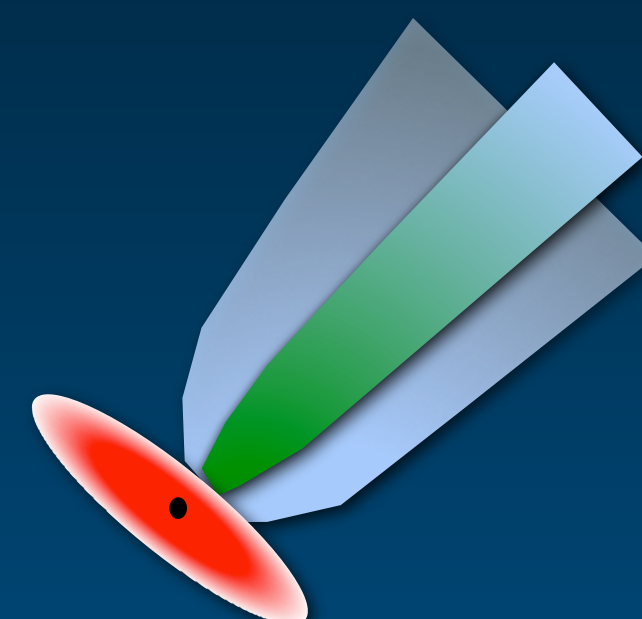
$F_{(>0.1\ GeV)} \sim 10^{-8}$ ph cm^{-2} s^{-1}

and **steep** Gamma>2.4

Radio galaxies are a de-boosted version of blazars

Different detection rate between FR I and FRII

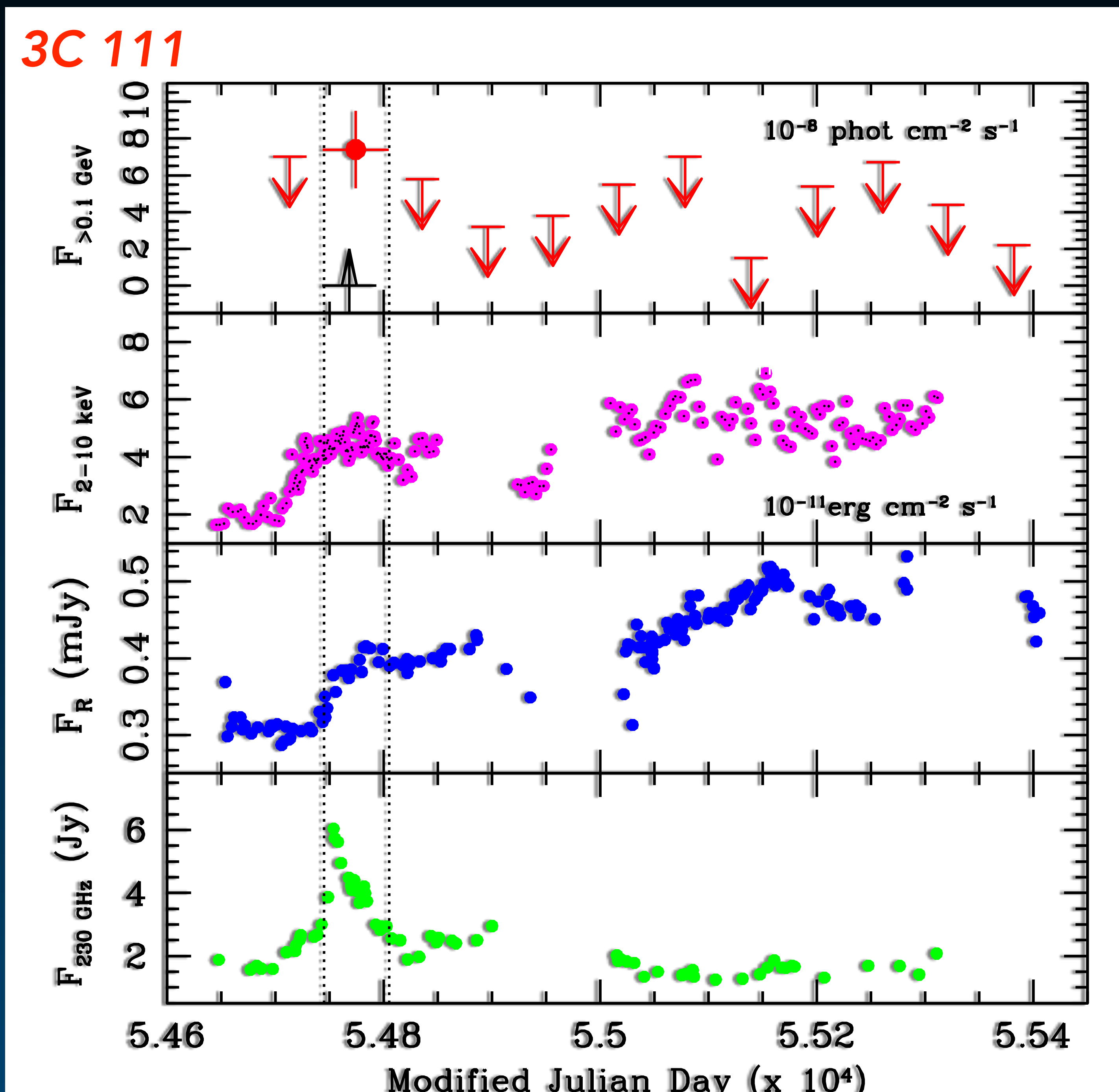
Different jet structure in FR I and FR II (spine-layer scenario)

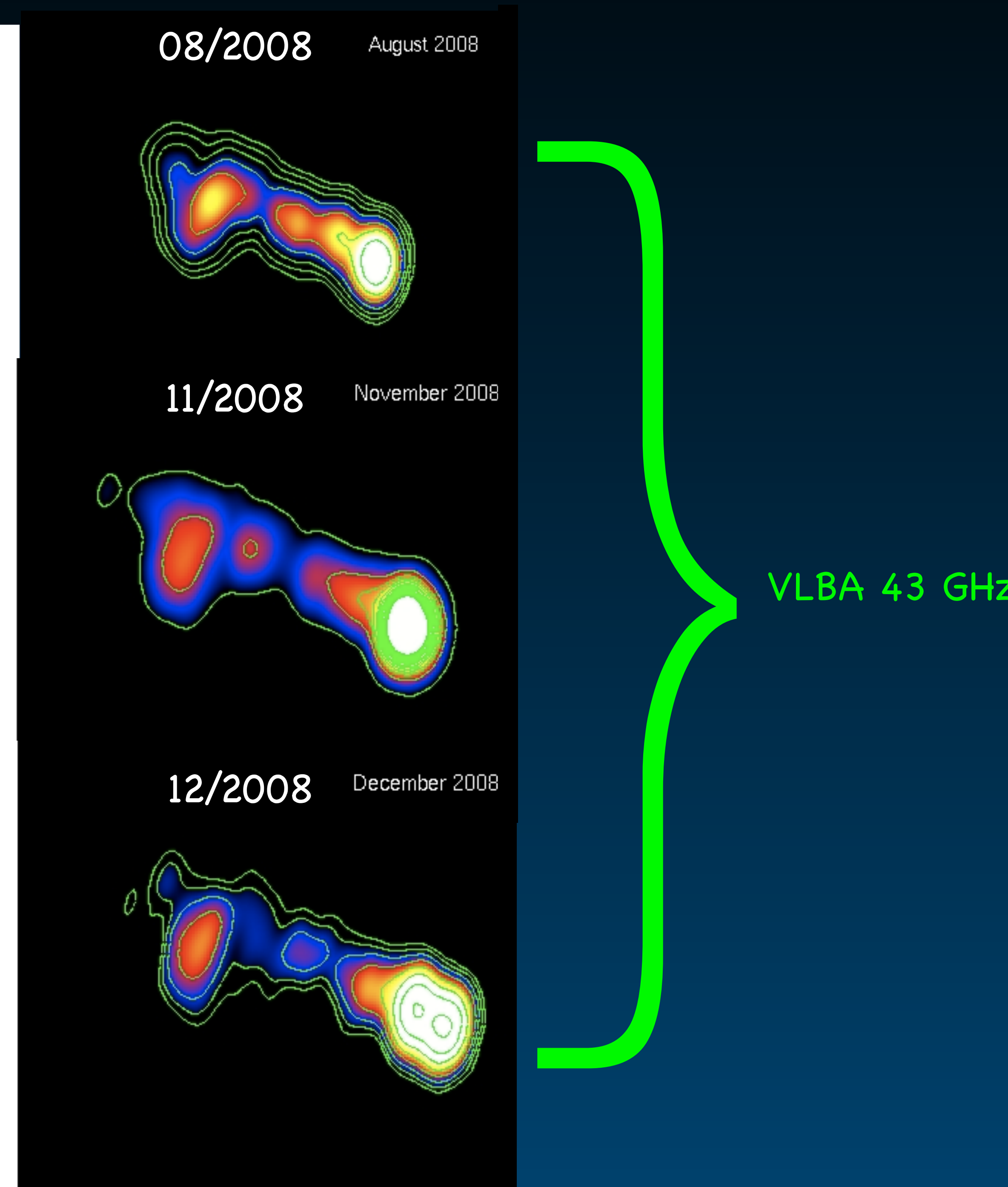


Fermi-LAT

Localisation of the gamma-ray emitting region:

clear link between expulsion of a radio knot from the core and the gamma-ray flare





Grandi, Torresi & Stanghellini 2012

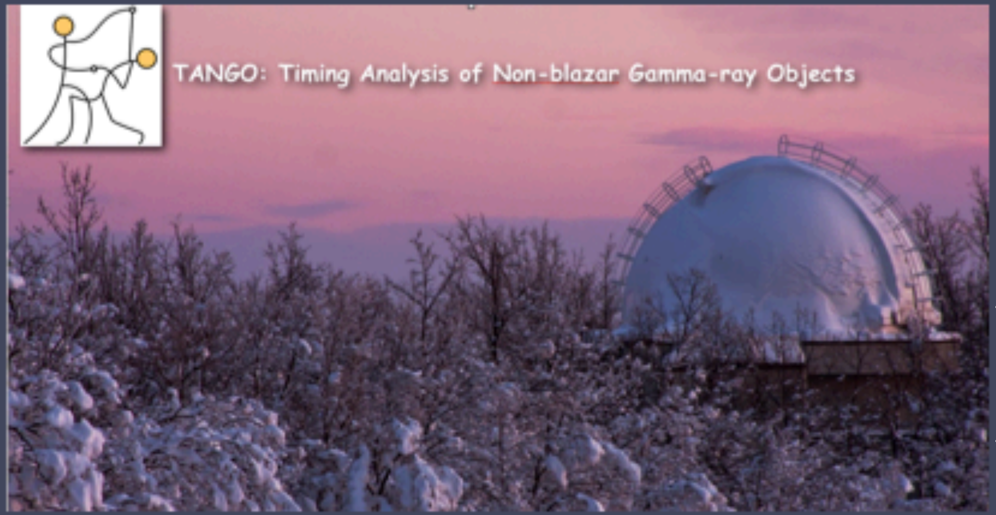
Size of the gamma-ray emitting region **R≲0.1 pc.**
Distance of the emitting zone from the BH ~**0.3 pc**

A MULTIWAVELENGTH PERSPECTIVE OF MISALIGNED AGN: THE TANGO PROJECT

TANGO

Timing Analysis of Non-blazar Gamma-ray Objects

TANGO Home | People | News | The sample | Useful links



Credits: T. Trombetti/I. Bruni

The aim of this project is to study the time variability of radio galaxies and steep spectrum sadio quasars, also known as Misaligned AGN (MAGN). Some of these sources already have a gamma-ray counterpart discovered by the LAT instrument on-board *Fermi*, others are potential gamma-ray candidates. For more information about MAGN observed by Fermi-LAT in 11 months of survey please refer to MAGN.pdf.

The sample of MAGN detected by Fermi is populated by bright radio sources with intermediate jet inclination angles. The gamma-ray emission is probably produced in compact regions along the jet. In particular, multiwavelength studies have shown that gamma-ray and optical flares can be connected to the ejection of a radio blob from the core. Therefore, multiwavelength campaigns (from radio to gamma-rays) are formidable tools to localize and constrain the size of the high-energy dissipation region.

https://hangar.iasfbo.inaf.it/tango/index.html

TANGO MW campaign (Timing Analysis of Non blazar Gamma-ray Objects)

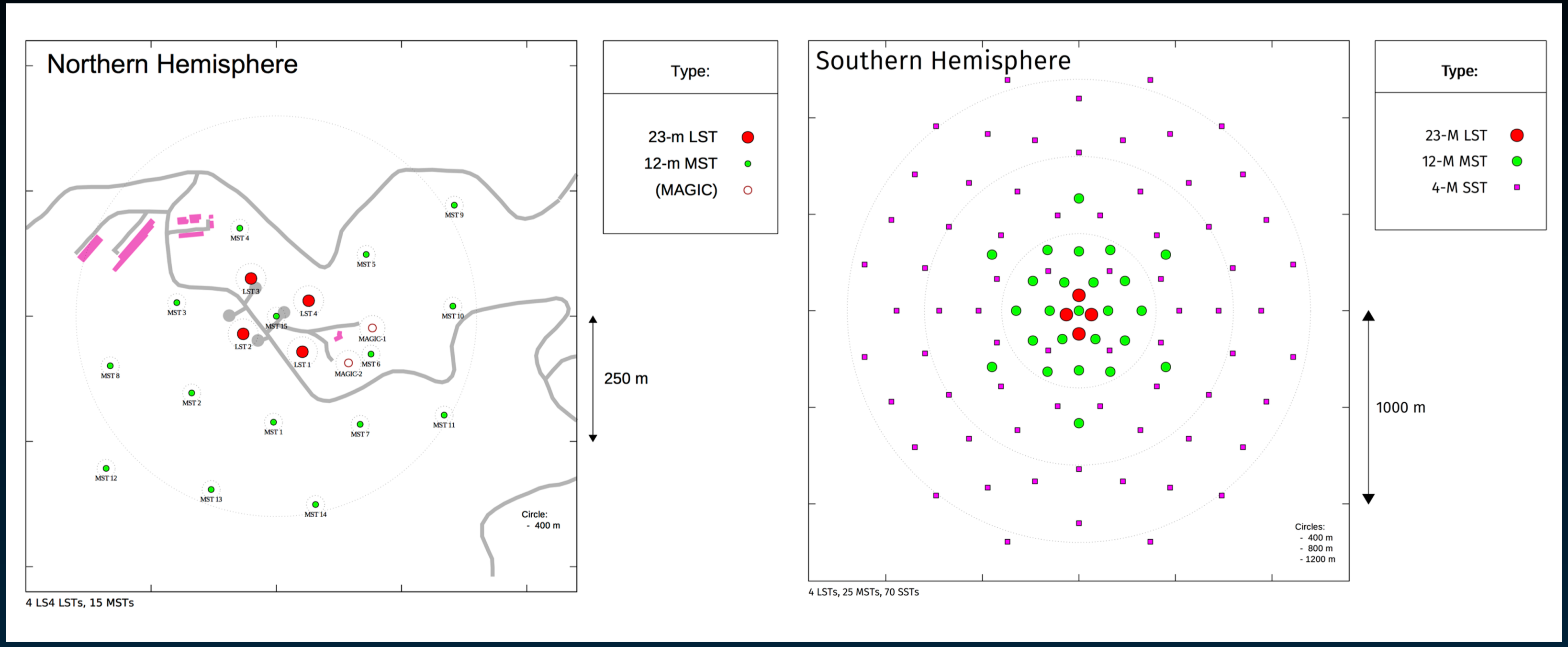
http://hangar.iasfbo.inaf.it/tango/index.html

Towards the CTA

CTA will be the largest ground-based gamma-ray detection observatory in the world, with more than 100 telescopes in the northern and southern hemispheres

CTA is expected to increase our ability in revealing radio galaxies in the TeV sky, thanks to **an order of magnitude improvement in sensitivity w.r.t. current IACTs.**

CTA will operate as an observatory



Large Size Telescope (LST) : 20-200 GeV

Medium Size Telescope (MST) : 0.1-10 TeV

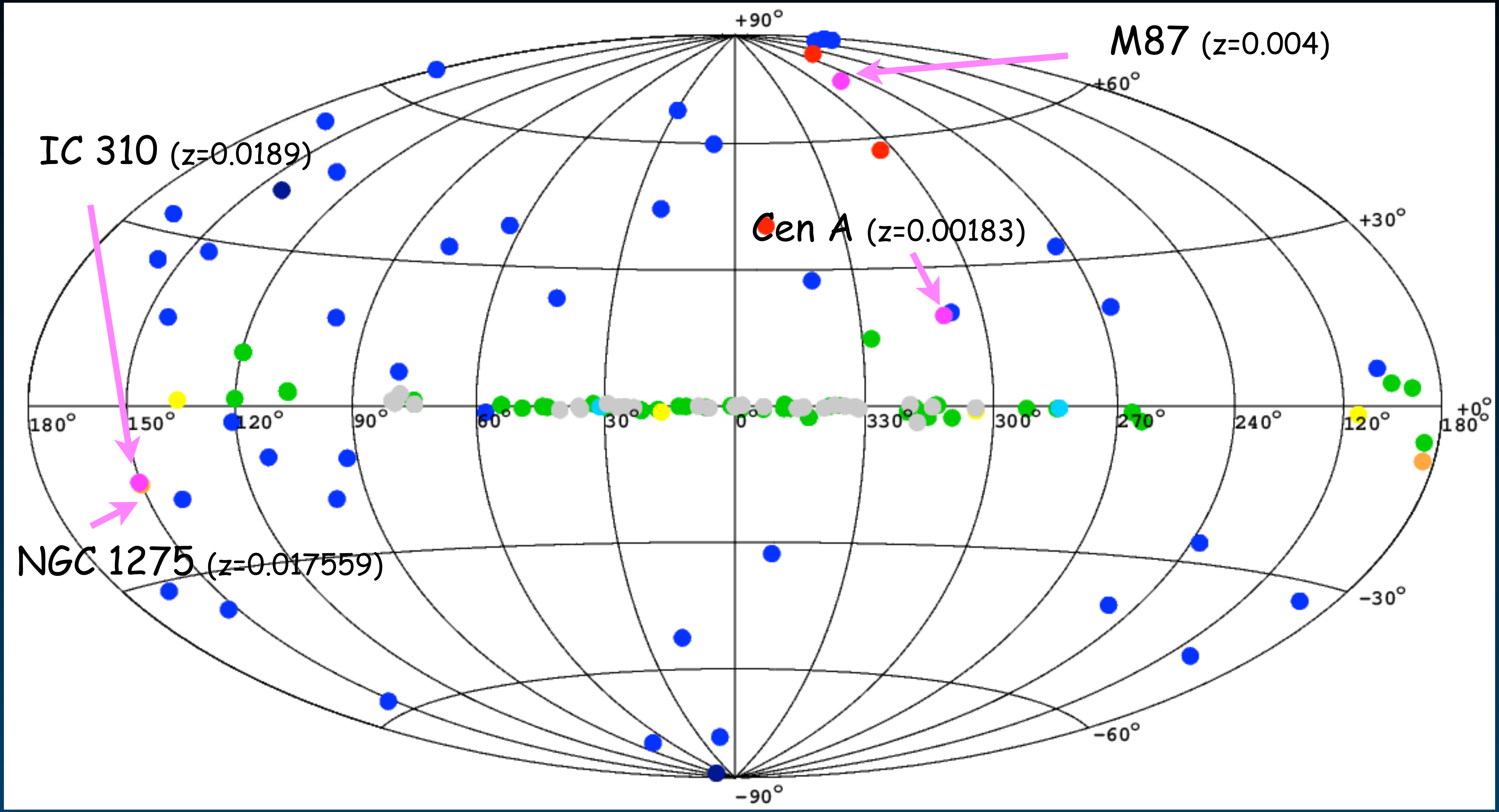
Small Size Telescope (SST) : up to 300 TeV

@OAS

- Optimization of observation strategies for Radio-Loud AGN
- Top Level Use Cases (to define the software architecture)
- Scientific cases for the Real Time Analysis

A. Bulgarelli's talk

Radio galaxies with CTA

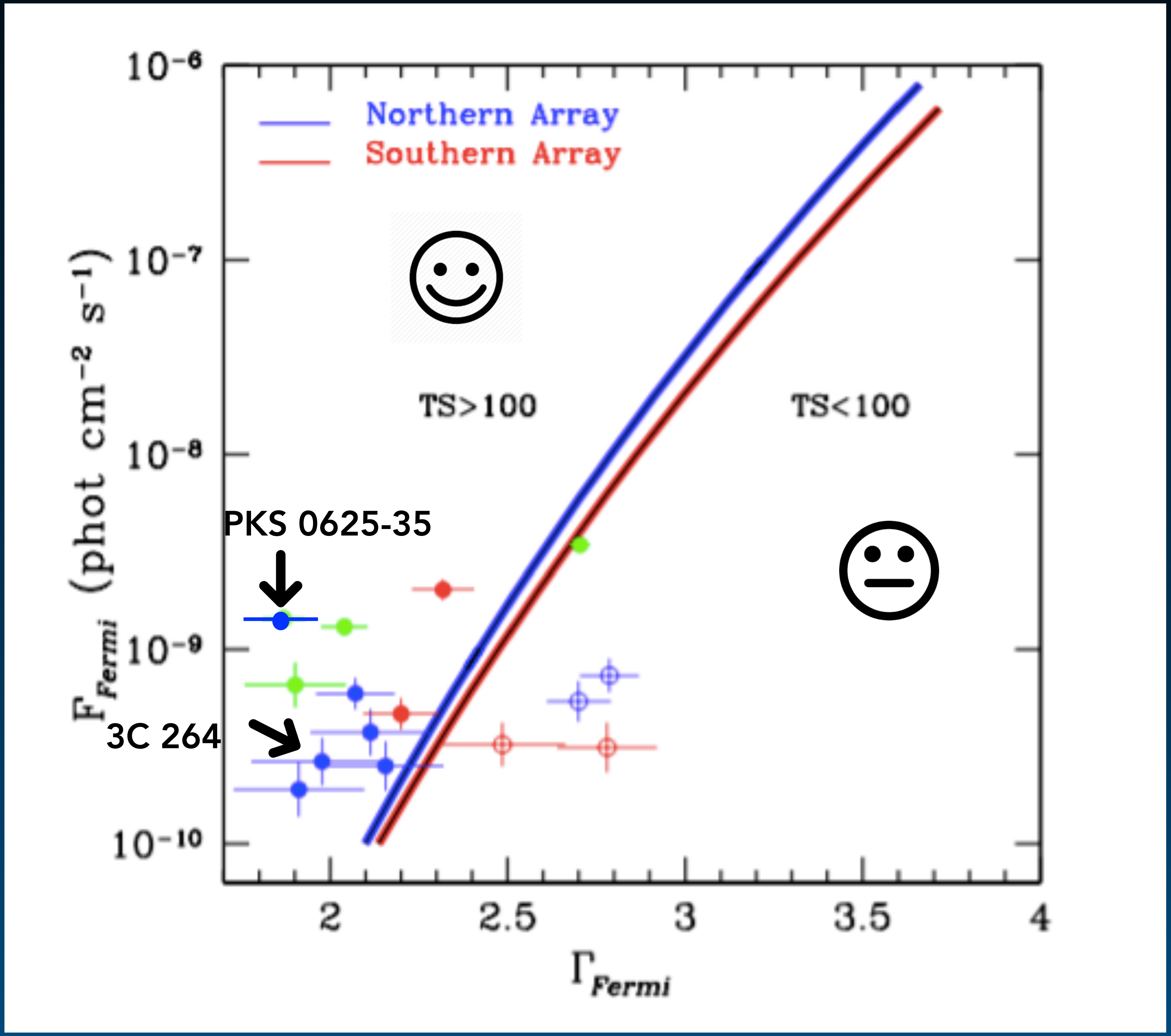


http://www.asdc.asi.it/tgevcat/

http://tevcat.uchicago.edu/

TeV

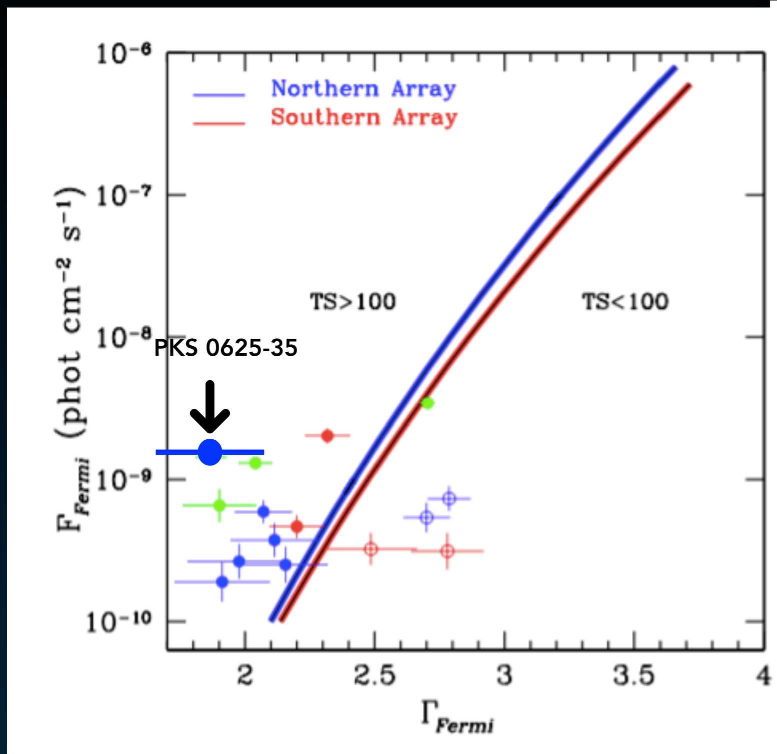
Given a Fermi-LAT flux and spectral slope in the 1-100 GeV energy range it is possible to estimate if the Fermi AGN will be detectable by CTA

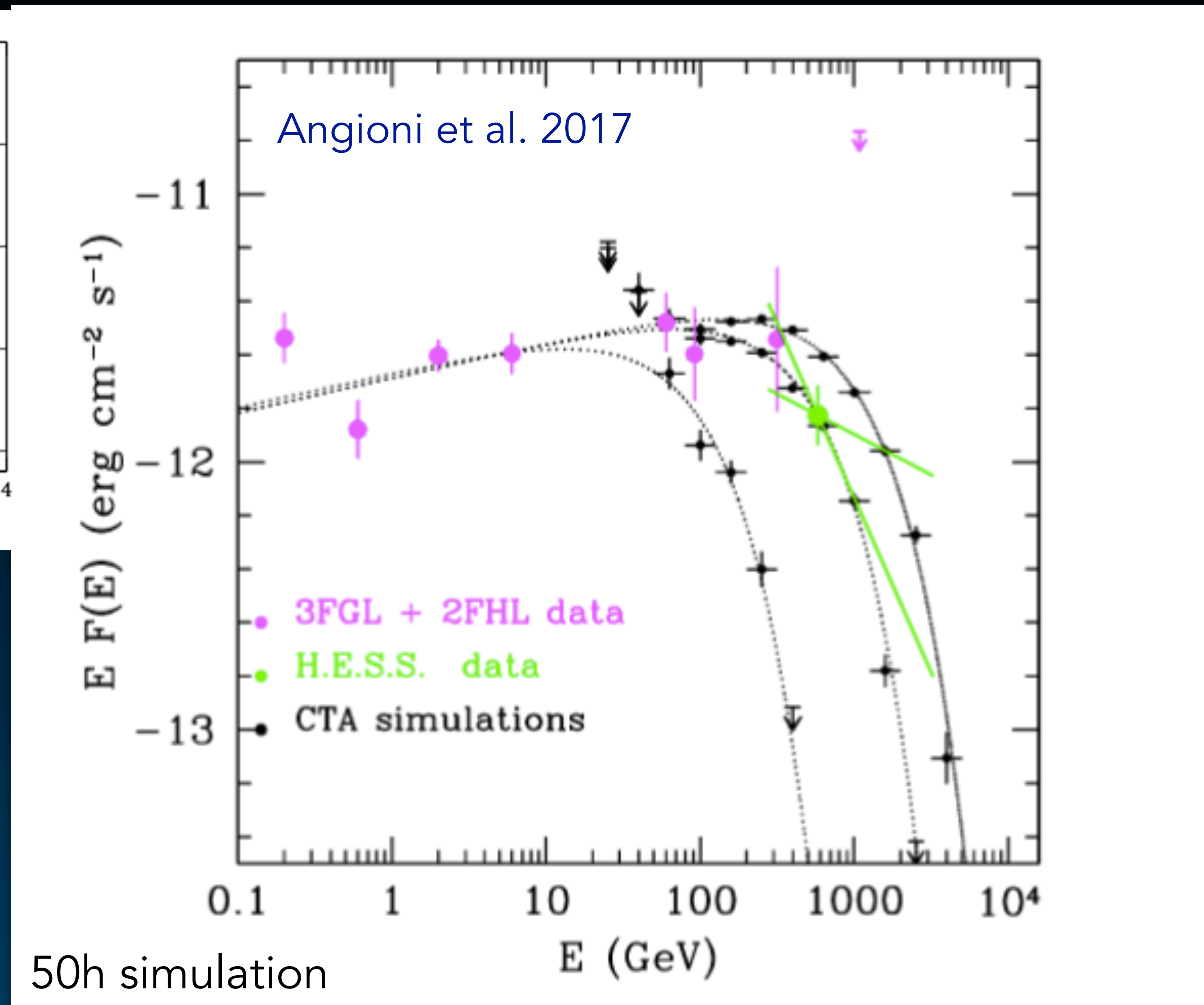


Sources with $\Gamma_{Fermi} \leq 2.1$ can be easily revealed for 1-100 GeV fluxes down to 10^{-10} ph cm^{-2} s^{-1}.

As the slope steepens larger fluxes are required to overcome the sensitivity threshold of the array.

PKS 0625-35





ELSEVIER
Astroparticle Physics
Volume 92, June 2017, Pages 42-48

Radio galaxies with the Cherenkov Telescope Array

R. Angioni [1, a, b, c], P. Grandi [a], E. Torresi [a, b], C. Vignali [b, d], J. Knödlseder [e]

Show more

https://doi.org/10.1016/j.astropartphys.2017.02.010

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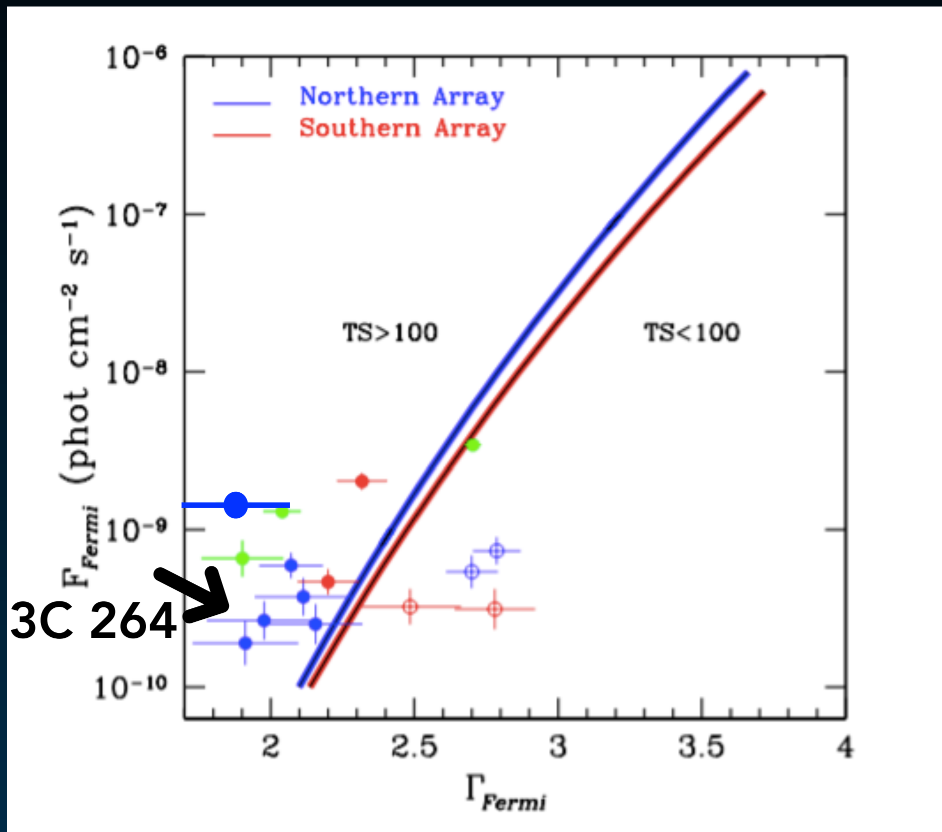
Better quality of the spectrum will be crucial to distinguish between different emission models to explain the VHE radiation.

3C 264 detected in March 2018!



VERITAS discovery of VHE emission from the FRI radio galaxy 3C 264

ATel #11436; *Reshmi Mukherjee (Barnard College) for the VERITAS Collaboration*
on ***17 Mar 2018; 00:25 UT***
Credential Certification: Reshmi Mukherjee (muk@astro.columbia.edu)

Subjects: Gamma Ray, TeV, VHE, Request for Observations, AGN, Blazar

Tweet Recommend 49

We report the VERITAS discovery of very-high-energy emission (VHE; >100 GeV) from the FRI radio galaxy 3C 264, also known as NGC 3862. Nearly 12 hours of quality selected data, collected by VERITAS between 09 February 2018 and 16 March 2018 (UTC), were analyzed. Preliminary results yield an excess of 60 gamma-ray events above background at the position of the source, corresponding to a statistical significance of 5.4 standard deviations. Our preliminary flux estimate (E>300 GeV) is (1.3 ± 0.2)e-12 cm^-2 s^-1, or approximately 1% of the Crab Nebula flux above the same threshold. The Fermi-LAT 3FHL catalog (Ackermann et al. 2017 ApJS 232, 18) lists a photon index of 1.65 ± 0.33 for 3C 264 which, when extrapolated to the VHE band, is consistent with the VERITAS detection. At a redshift of 0.0217, 3C 264 is a more distant analog to M87, with superluminal motion of ~7c (Meyer et al. 2015, Nature 521, 495) detected in its kpc-scale optical jet. With this discovery, 3C 264 is the most distant radio galaxy detected at VHE so far. VERITAS will continue to observe 3C 264; multi-wavelength observations are encouraged. Questions regarding the VERITAS observations should be directed to Reshmi Mukherjee (rm34@columbia.edu). Contemporaneous target-of-opportunity observations with the Swift satellite have also been scheduled. VERITAS (Very Energetic Radiation Imaging Telescope Array System) is located at the Fred Lawrence Whipple Observatory in southern Arizona, USA, and is most sensitive to gamma rays between 85 GeV and 30 TeV (http://veritas.sao.arizona.edu).

Proposal MAGIC ongoing
(PI. R. Angioni)

Boccardi, Migliori, Grandi, Torresi, Vignali, et al. in prep.

Future perspectives