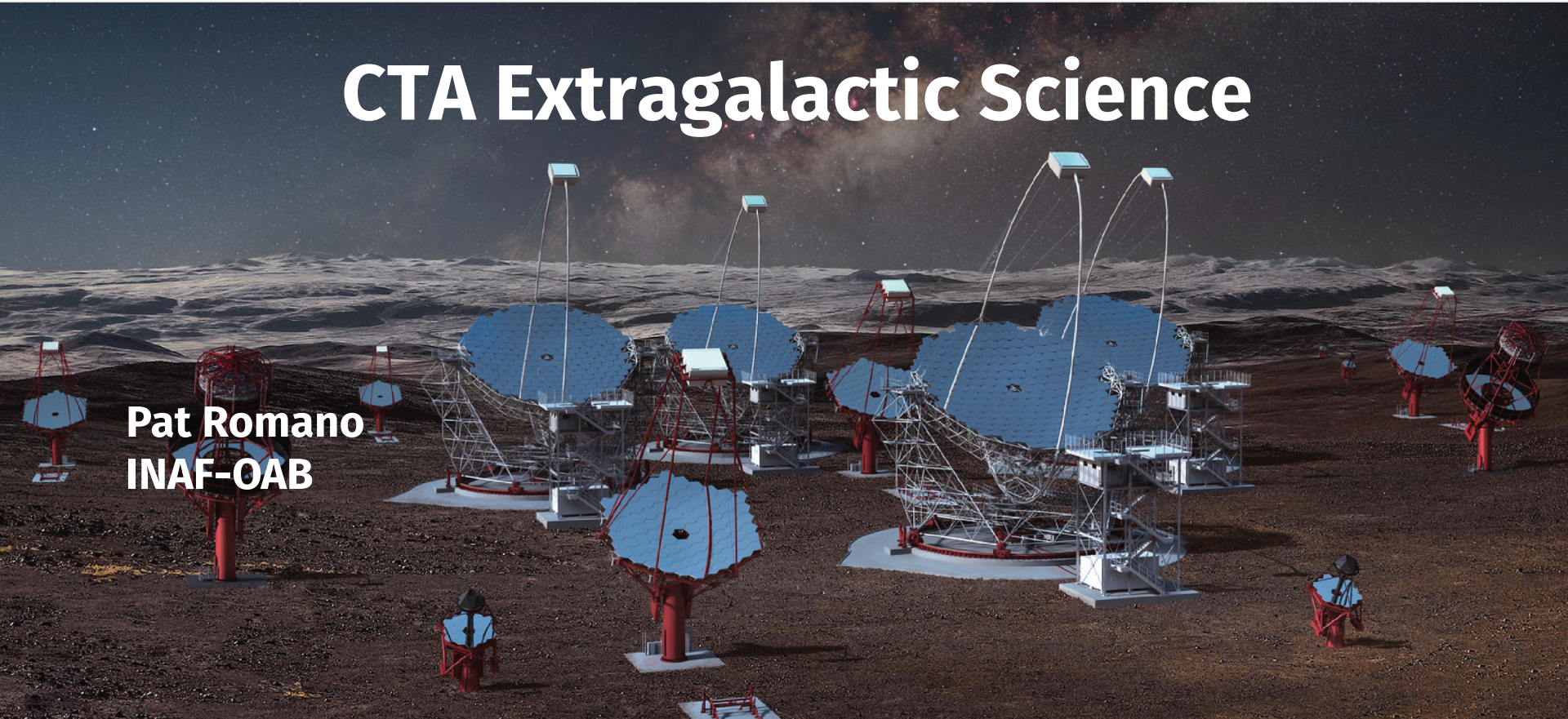
cherenkov telescope array

CTA Extragalactic Science



Pat Romano
INAF-OAB

Outline

- CTA Key Science Projects
- Extragalactic Working Group Task Forces:
  - goals, results, contact points
- OAS involvement & Publishing with CTA

CTA Key Science Projects

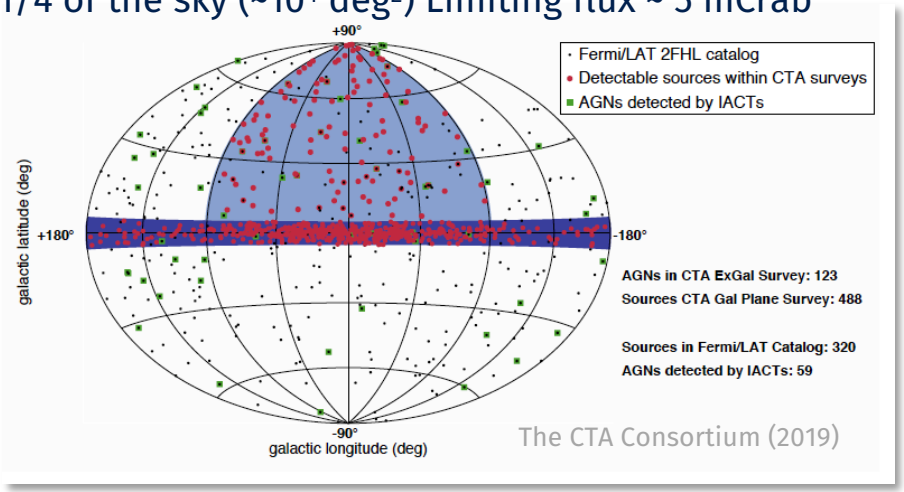
- Focused on **major legacy projects:** surveys & population studies (providing legacy data-sets), large classes of sources, and a few iconic objects

- Large **potential for guest observer proposals –** building on results from the KSP surveys

The CTA Consortium, 2019, World Scientific
https://doi.org/10.1142/10986

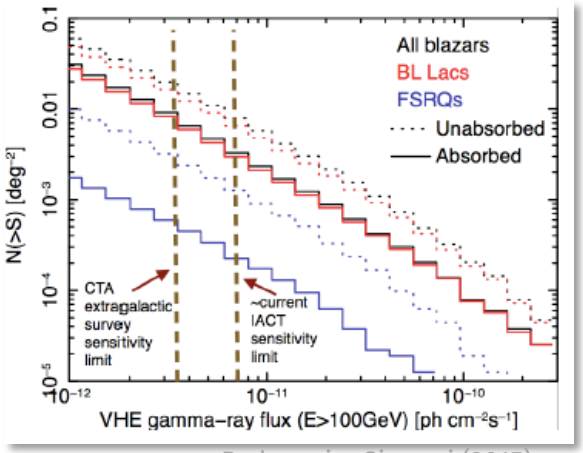
EGAL Survey

1/4 of the sky (~10^4 deg^2) Limiting flux ~ 5 mCrab



The CTA Consortium (2019)

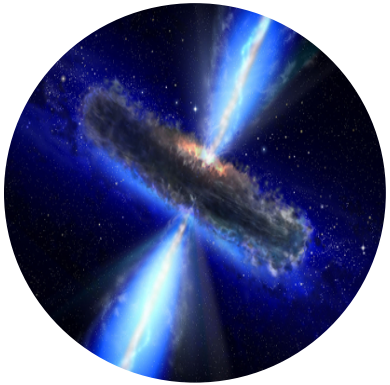
About O(100) sources in 10,000 deg^2



Padovani e Giommi (2015)

Several highly interesting regions such as the **Virgo & Coma clusters**, the **Fermi Bubbles** (North) and **Cen A** (South) will be covered by the proposed survey.

AGNs



Credits: ESA/NASA

AGNs are known to emit **variable radiation** across the entire electromagnetic spectrum up to multi-TeV energies, with fluctuations **on time-scales** from **several years** down to **a few minutes.**

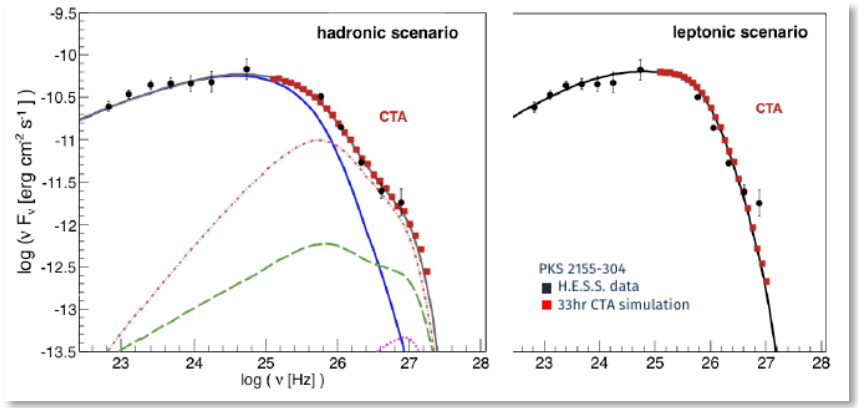
VHE observations of active galaxies harbouring super-massive black holes and ejecting relativistic outflows represent a unique tool to probe the **physics of extreme environments**, to obtain precise measurement of the **extragalactic background light** (EBL) and to constrain the strength of the **intergalactic magnetic field** (IGMF).

AGNs will be useful to investigate fundamental physical phenomena such as the **Lorentz invariance violation** (LIV) and signatures of the existence of **axion-like particles** (ALP).

AGN KSP involves 3 observing programs:
Long term monitoring, high quality spectra (z,type), flare search/follow-up

AGNs – PKS 2155-304

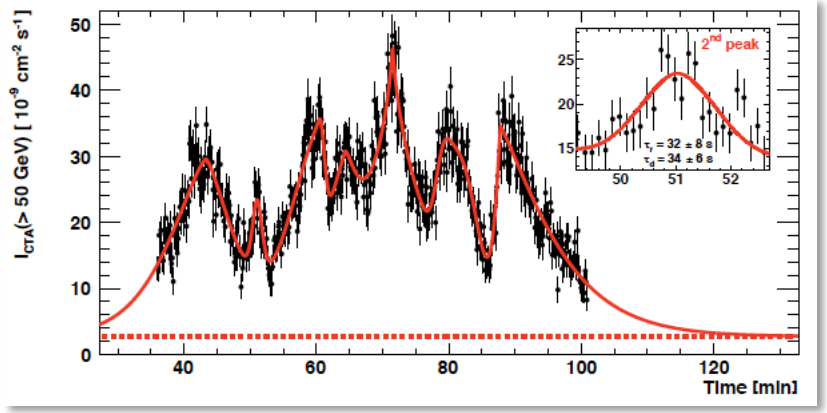
Testing emission scenarios



Zech A., et al., (2017) & The CTA Consortium (2019)

A set of **high-quality spectra** from different blazar types and different redshifts is needed to **unambiguously distinguish intrinsic spectral features**, such as shown here**, from external absorption**.

Testing variability

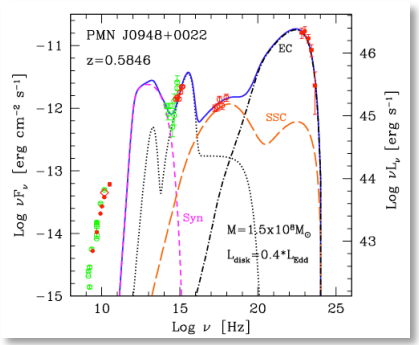


The CTA Consortium (2019)

Sampling blazar fluxes put strong constraints on the bulk Doppler factor, as well as on particle acceleration and cooling processes.

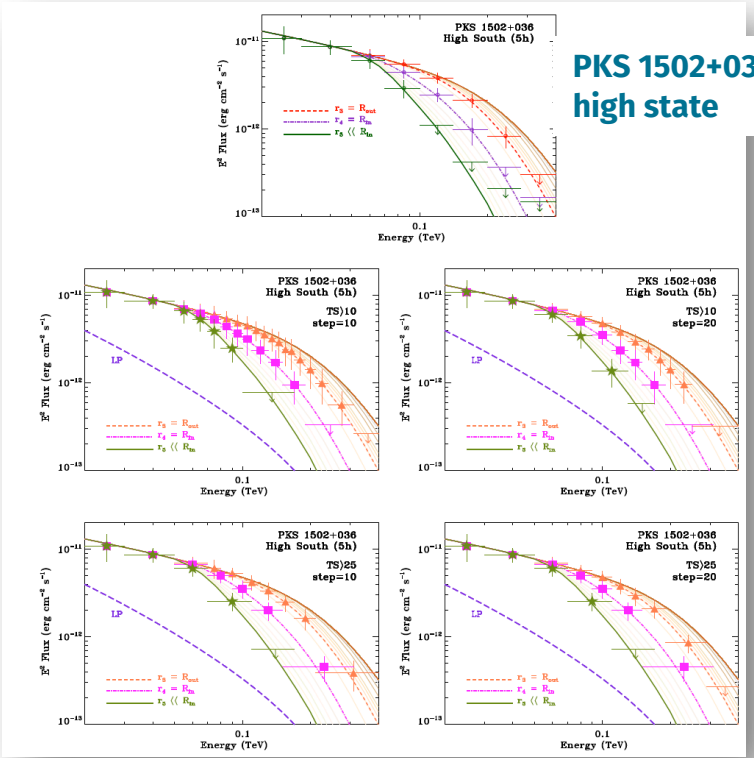
AGNs in the corner: γ–NLS1s

Blazar-like SED with variable γ-ray emission.



Abdo et al., 2009, ApJ, **699**, 976

- Strong γ-ray flares, on time-scale of the order of a few hours/days
- The high-state activity can last for several weeks/months, repeated on a multi-year baseline.



PKS 1502+036 high state

Romano et al., 2020, MNRAS, **494**, 411

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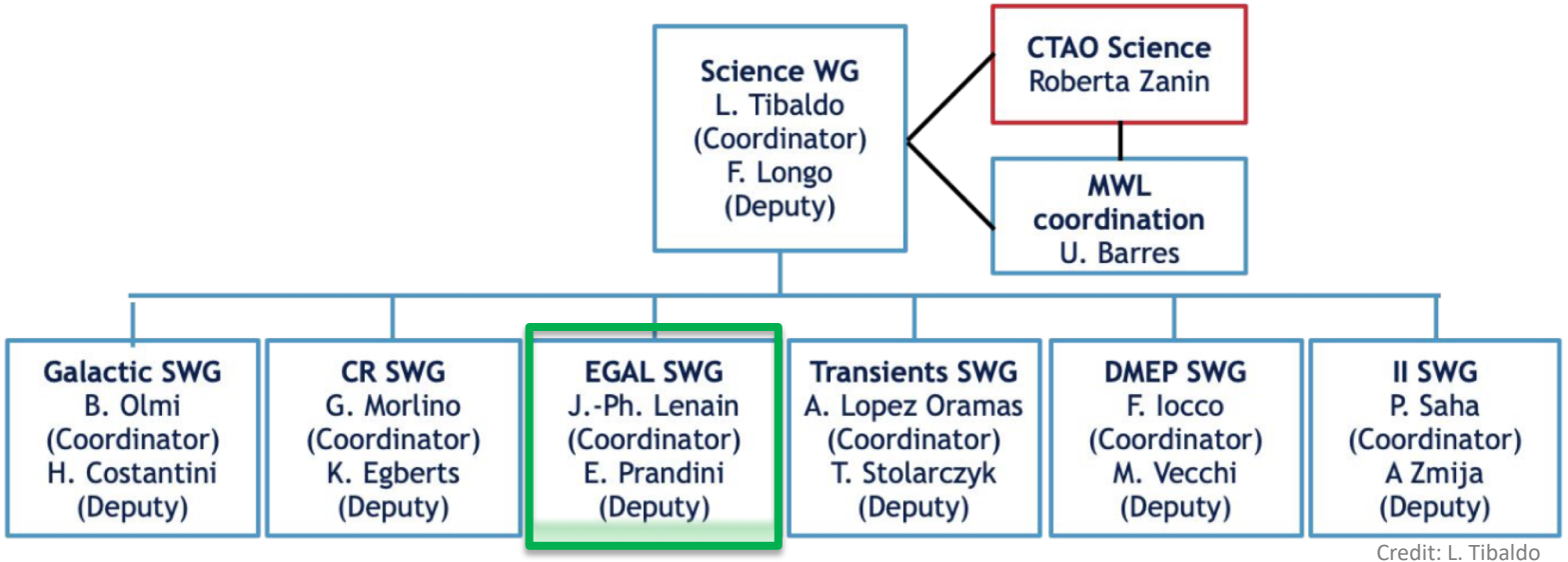
EGAL WG Task Forces

What we really do these days

CTA EGAL Working Group Task Forces



Credit: L. Tibaldo

Jean-Philippe Lenain jlenain@in2p3.fr
Elisa Prandini elisa.prandini@unipd.it

CTA EGAL WG TF: Redshift determination -1

- **Goal**: measure redshifts for a sample of blazars expected to have a higher probability of being detected by CTA (non Consortium publication)
  - > 90 % γ-ray FSRQs have spectroscopic z,
  - Only ~44 % γ-ray BL Lacs have spectroscopic z (nearly featureless, continuum-dominated optical spectra)

- **Impact**:
  - EBL: lack of bright VHE blazars with redshift > 0.2-0.3
  - AGN Population studies

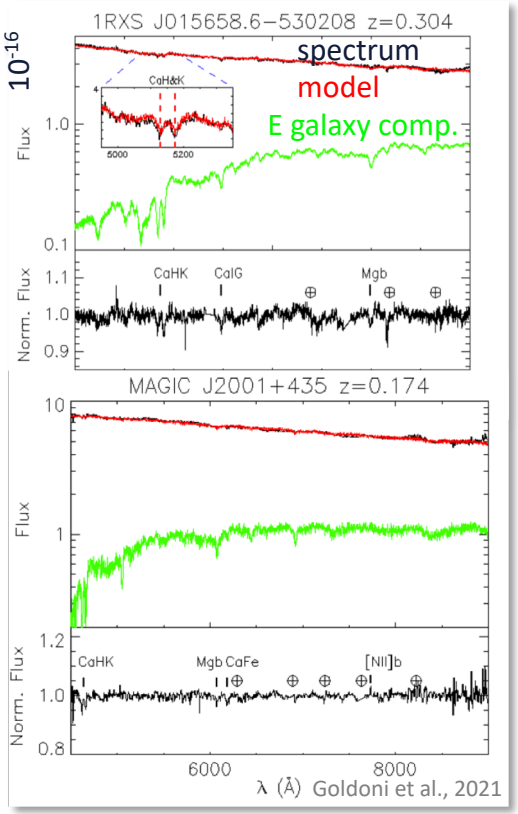
- **Methods**: selection of 3FHL blazars with no z detectable in 30h by CTA (165)
  - Extended host?
    - Yes: Deep opt/NIR spectroscopy (NTT, Keck, SALT; S/N~100, R~1000-2000)
    - No: Deep opt/NIR imaging

CTA EGAL WG TF: Redshift determination -2

Results of Paper I

- 11/19 redshifts+1 tentative
  (0.112 < z < 0.482; zmed=0.23)
- 2(3) spectroscopic lower limits
  (z> 0.868; z> 0.449)
- Optical low state Keck observations of
  MAGIC J2001+435

Paper II (Kasai): SALT spectroscopy (25 src)
Paper III (Fallah Ramazani): imaging (25 src)



CTA EGAL WG TF: Redshift determination -3

Contacts and recent References:

Paolo Goldoni goldoni@apc.univ-paris7.fr

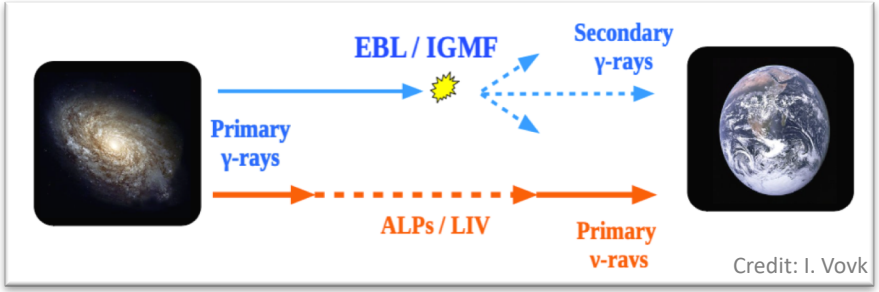
Goldoni et al., 2021, A&A, 650, A106 *Optical spectroscopy of blazars for the Cherenkov Telescope Array*

DOI 10.5281/zenodo.4721386 https://zenodo.org/record/4721386 - .Yp5UmhNBxUR *Review of redshift values of bright AGNs with hard spectra in 4LAC catalog*

Kasai et al., PoS(ICRC2021)881 *Southern African Large Telescope Spectroscopy of BL Lacs for the CTA project*

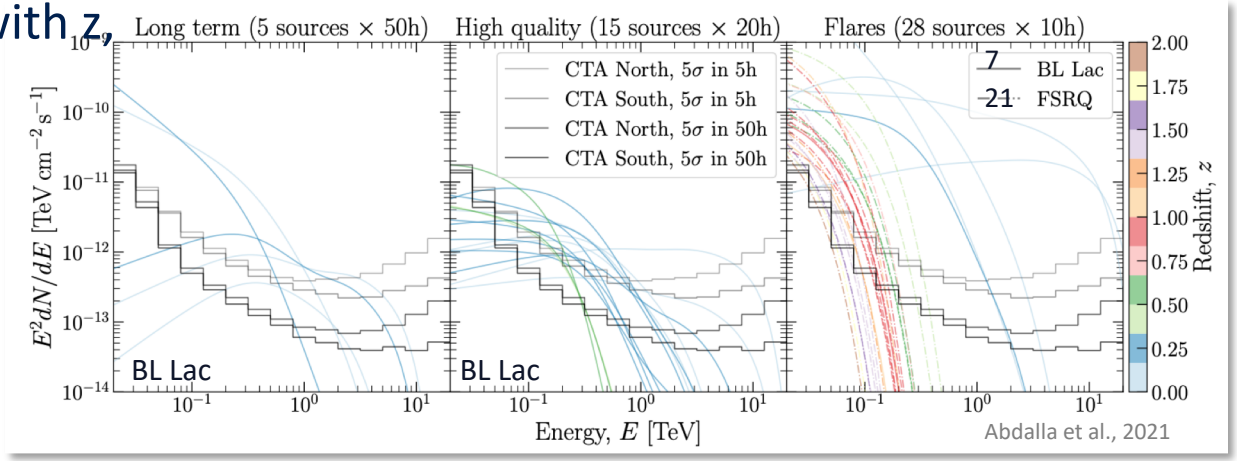
CTA EGAL WG TF: Gamma Propagation - 1

- **Goal**: CTA sensitivity for probing cosmology and fundamental physics with γ rays **(Consortium pub.)**



- **Methods**: 3FHL AGN with z, detected in 1d by Fermi/LAT:

48 sources, z in [0.05,2]



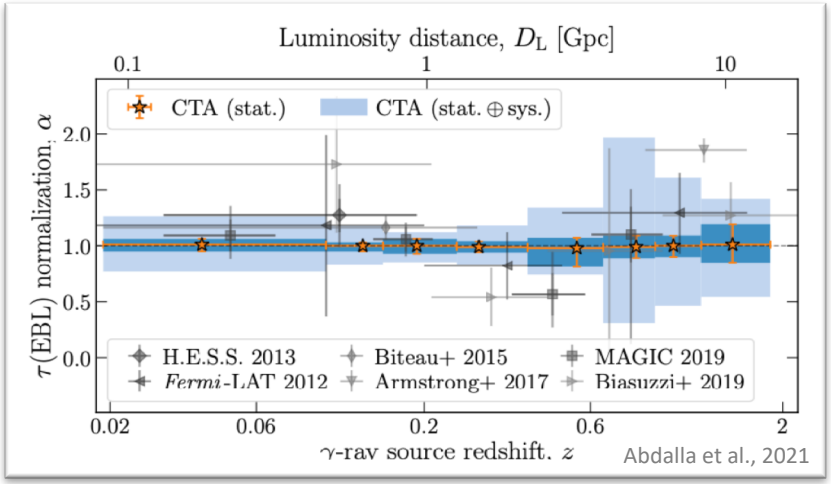
CTA EGAL WG TF: Gamma Propa - 2

Results on EBL

CTA will

- probe EBL over 0.1-100 μm
- may probe star formation up to z ~ 1.5 – 2

- Provides tools to conduct the analyses
- Includes the treatment of systematic uncertainties using bracketing IRFs



Projected CTA constraints on the EBL scale factor

CTA EGAL WG TF: Gamma Propa - 3

Contacts and recent References:

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H. Martinez-Huerta (humberto.martinezhuerta@udem.edu)
M. Meyer (mmanuel.e.meyer@fau.de)
S. Pita (pita@apc.in2p3.fr)
I. Vovk (vovk@icrr.u-tokyo.ac.jp)

CTA Consortium Paper: Abdalla et al, 2021, JCAP, 02,02, 048, *Sensitivity of the Cherenkov Telescope Array for probing cosmology and fundamental physics with gamma-ray propagation*

Vovk et al. PoS(ICRC2021)894 *CTA sensitivity for probing cosmology and fundamental physics with gamma rays*

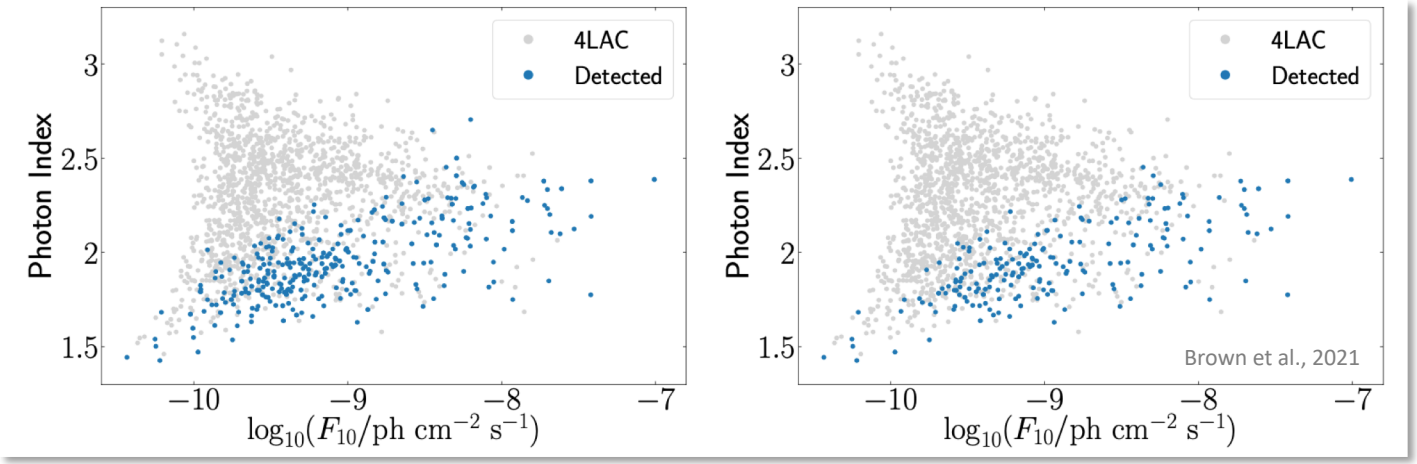
CTA EGAL WG TF: AGN Population - 1

- **Goal**: quantify CTA's ability to conduct source population studies of γ-ray bright AGN
  (**Consortium** publication – initial draft stage**)**
  - How many/what kind/what redshift of source will CTA detect?
  - How long will it take?
  - Luminosity function reconstruction of BL Lacs (Egal Survey)

- **Methods**: selection of 4LAC sources with known z (validated by redshift TF!): 1551 sources
  - SED extrapolation from *Fermi* to VHE (with best of PL or LP)
  - EBL absorption (Dominguez+2011)

CTA EGAL WG TF: AGN Population - 2

Results



Flux vs Photon index in omega and alpha configurations, respectively

-grey: simulated (~10^3)

-blue: detected (~10^2)

CTA EGAL WG TF: AGN Population - 3

Contacts and recent References:

Tarek Hassan tarek.hassan@ciemat.es

- Hassan et al., PoS(ICRC2017)632, *Extragalactic source population studies at very high energies in the Cherenkov Telescope Array era*
- Nievas Rosillo, Hassan, PoS(ICRC2021)722 *A data-driven evaluation of Fermi-LAT extrapolation schemes to the VHE regime*
- Brown et al., *PoS(ICRC2021)887 Active Galactic Nuclei population studies with the Cherenkov Telescope Array*

CTA EGAL WG TF: AGN Variability - 1

- **Goal**: investigate CTA's potential to discriminate between different particle acceleration and emission scenarios (**Consortium** publication – proposal stage**)**

- **Methods**: selected different source types (HSP, ISP, FSRQ) to be used as input for the theoretical simulations
  - Use time dependent theoretical SED to produce light curves in the CTA energy range
  - Optimisation of observational strategies for AGNs

CTA EGAL WG TF: AGN Variability - 2

Contacts

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J. Becerra-Gonzalez jbecerra@iac.es

CTAO Science Data Challenge

- Goals:
  - Reach out external scientific communities
  - Validation of science requirements
- Characteristics:
  - Open, blind, and realistic
- Timescale:
  - ask Roberta!

INAF publishing with/within CTA EGAL WG

Miti da sfatare:

- Si pubblica solo se parte di CTA
- Il processo di referaggio interno e' lunghissimo
- Se ne parlo mi rubano l'idea
- Se faccio il lavoro devo mettere tutti

INAF publishing with/within CTA EGAL WG

- Galanti et al., 2020, MNRAS, 491, 5268, *Fundamental physics with blazar spectra: a critical appraisal*
- Galanti et al., 2020, MNRAS, 495, 3463, *Probing the absorption of γ-rays by IR radiation from the dusty torus in FSRQs with the Cherenkov Telescope Array*
- Romano et al., 2020, MNRAS, 494, 411, *γ-γ absorption in the broad-line region radiation fields of narrow-line Seyfert 1 galaxies with the Cherenkov Telescope Array*
- Tavecchio et al., 2019, MNRAS, 483, 1802, *Putting the hadron beam scenario for extreme blazars to the test with the Cherenkov Telescope Array*
- Lamastra et al., 2019, Astropart. Phys., 112, 16, *Unveiling the origin of the γ-ray emission in NGC 1068 with the Cherenkov Telescope Array*
- Romano et al., 2018, MNRAS, 481, 5046, *Prospects for γ-ray observations of narrow-line Seyfert 1 galaxies with the Cherenkov Telescope Array*
- Angioni et al., 2017, Astropart. Phys., 92, 42, *Radio Galaxies with the Cherenkov Telescope Array*

cherenkov telescope array

Thanks!

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