Future prospects for measuring the extragalactic background light and probing for axion signatures

Jonathan Harris

Durham University

Summary

- Extragalactic Background Light
- How this makes the universe opaque to gamma-rays from distant galaxies
- Axions and their motivation
- Prospects for next gen. IACT

Extragalactic Background Light

- Photons that are present throughout the universe
- We're interested in Infrared-UV wavelengths
- These are primarily by stars and star formation
- Because the amount of stars/star formation evolves along with the universe, the EBL intensity at a given wavelength is a function of redshift (distance)

EBL absorbs high energy photons...

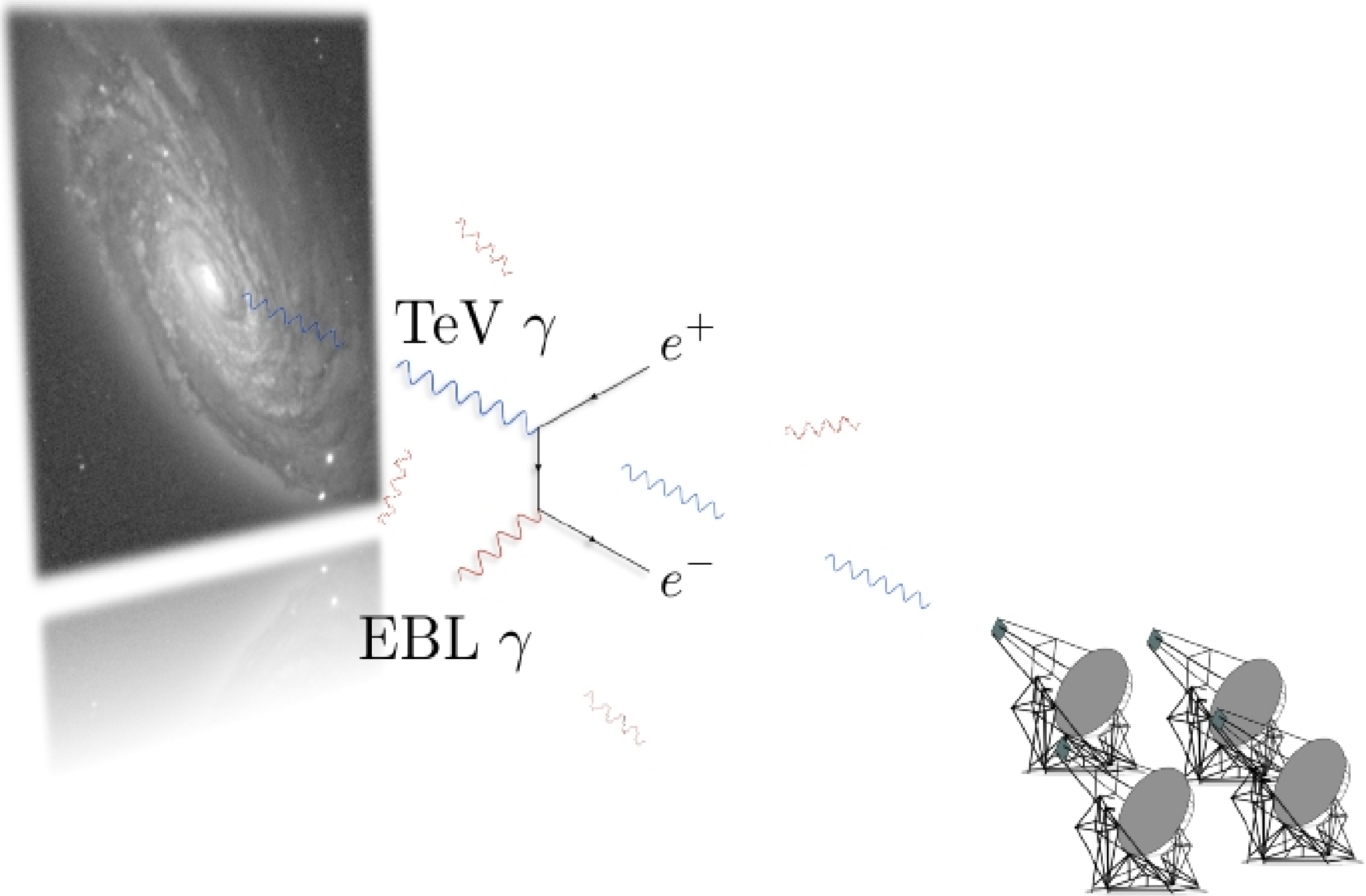


Image credit: Pierre Brun

...but not as much as expected

provide an upper limit on the background light at optical/near-infrared wavelengths that appears to be very close to the lower limit given by the integrated light of resolved galaxies[8]. The background flux at these wavelengths accordingly seems to be strongly dominated by the direct starlight from galaxies, thus excluding a large contribution from other sources – in particular from the first stars formed[9]. This result also indicates that intergalactic space is more transparent to γ-rays than previously thought.

Aharonian et al. Nature 440, 1018 (2006)

TeV observations were consistent only with the very lower limits of EBL intensity derived from galaxy counts.

3C 279, at a distance of more than 5 billion light-years (a redshift of 0.536). No quasar has been observed previously in very-high-energy gamma radiation, and this is also the most distant object detected emitting gamma rays above 50 gigaelectron volts. Since high-energy gamma rays may be stopped by interacting with the diffuse background light in the universe, the observations by MAGIC imply a low amount for such light, consistent with that known from galaxy counts.

Magic Collaboration, Science, 320, 1752 (2008)

Axions

- Another avenue is the EBL is above lower limits but there is less gamma-ray absorption than predicted.
- One of the possibilities is the existence of axions.
- A particle proposed as an extension to the Standard Model to explain lack of CP violating strong interactions.

Axions

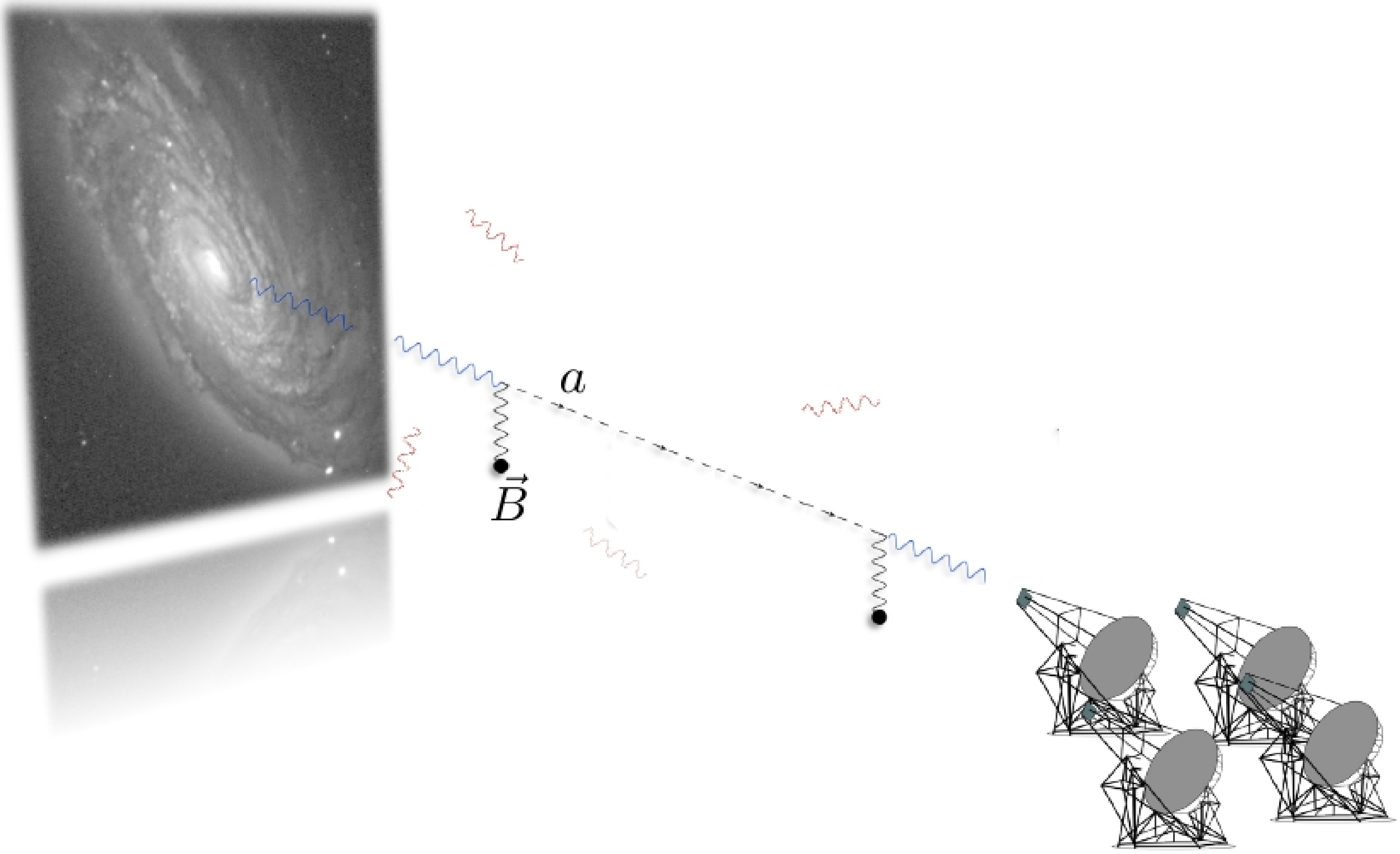


Image credit: Pierre Brun (modified)

Simulations with CTA

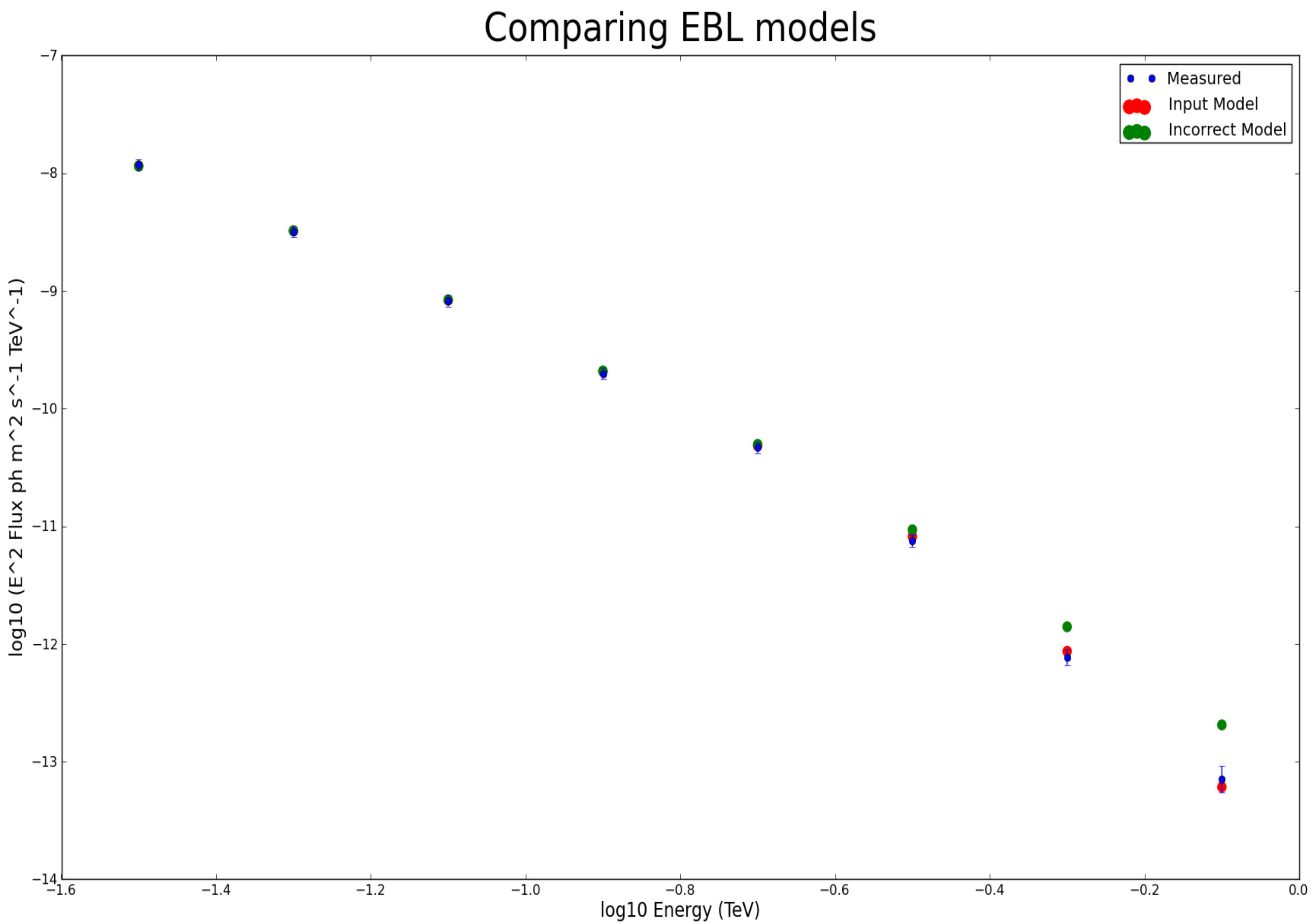
- Cherenkov Telescope Array (CTA) is a next generation ground based telescope array. Currently in design phase.
- Simulate observations of two objects
- Objects in a galaxy cluster which means the B-field around it and therefore the axion conversion rate is reasonably well known (for a given model).
  - 1ES 1101-232 at z=0.186
  - 1ES 0414+009 at z=0.287

Simulations with CTA

- Observations of two objects
  - 1ES 1101-232 at z=0.186

  - This source can be used to test different EBL models.
    - Simulated measured flux. Use one EBL model to absorb the intrinsic source spectrum.
    - Fit to the simulated spectrum with several EBL models.
    - See if the correct (input) model can be identified.

- 1ES 1101-232 at z=0.186



$\chi^2 correct = 2.1$ $\chi^2 incorrect = 6.5$

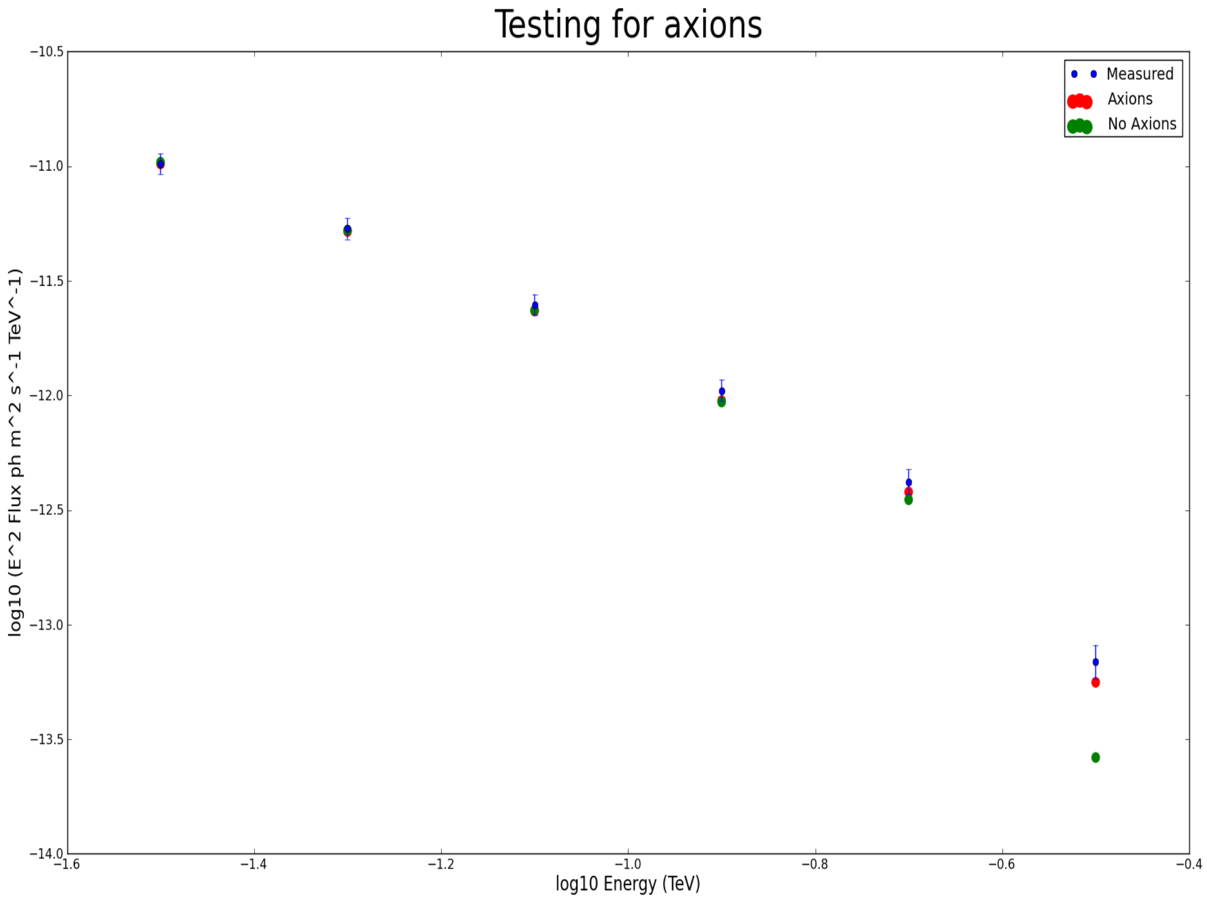
Assuming 10% systematic errors on flux

Simulations with CTA

- Observations of two objects
  - 1ES 0414+009 at z=0.287
    - Simulate measured flux. Use an EBL model and have 30% axion conversion at the source[1]
    - Fit simulated spectrum using the input EBL model both with and without axions.
    - See if the axions give a significant improvement to the fit.

[1] Horns et al. Physical Review D 86, 075024 (2012)

- Observations of two objects
  - 1ES 0414+009 at z=0.287



$\chi^2 axions = 1.8$ $\chi^2 no\,axions = 4.9$

Assuming 10% systematic errors on flux

Summary

- Very High Energy gamma-ray measurements let us probe the extragalactic background light.
- The effect EBL absorption is lessened if photons oscillate into axions.
- Preliminary results suggest next gen telescopes such as CTA will be able to probe EBL models and identify axion signatures.

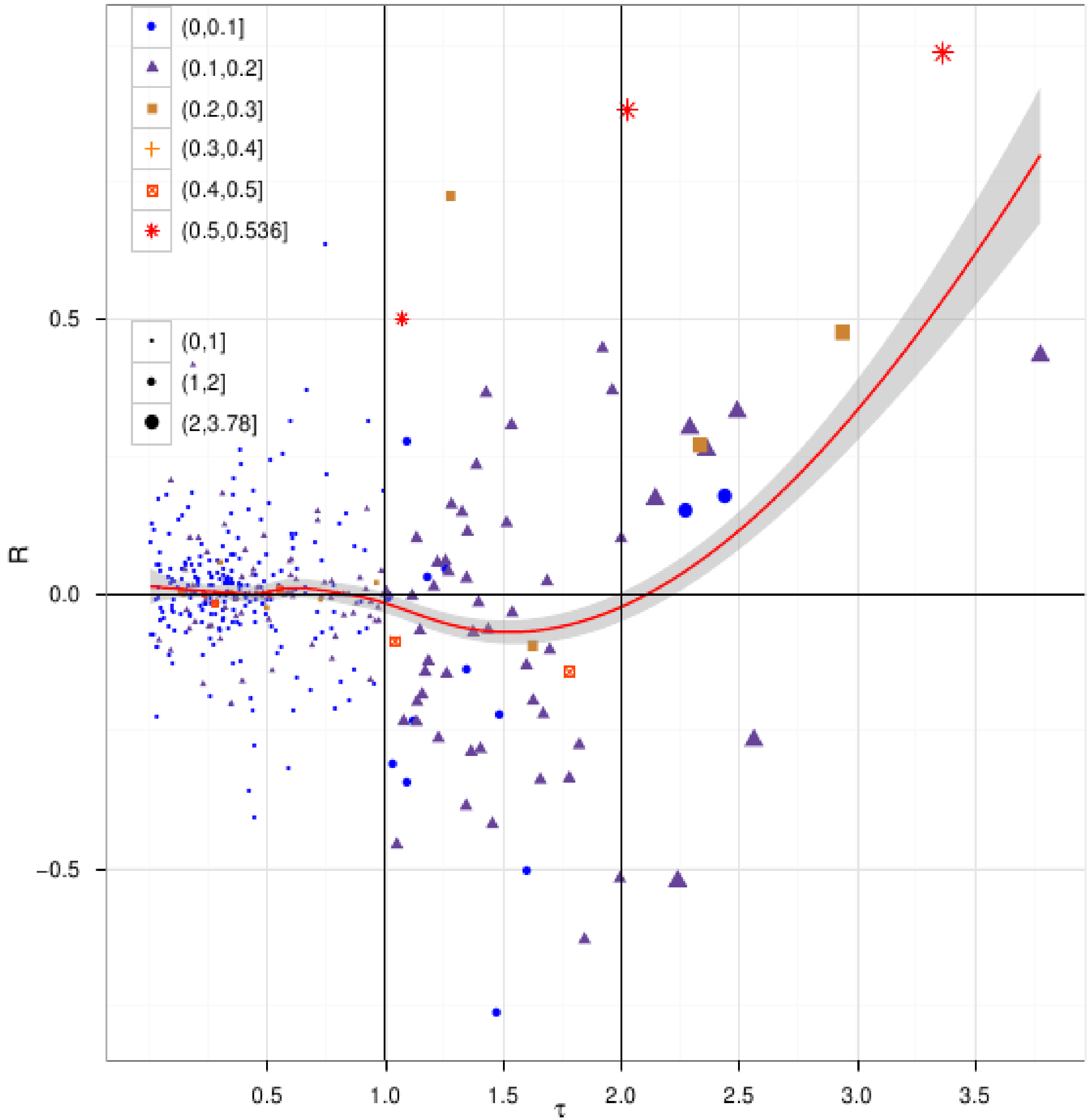
Thank you!

Horns & Meyer

- The most systematic study to date is probably Horns & Meyer JCAP02(2012)033

- They study the gamma-ray spectra of 25 sources in the optically thin regime (little EBL absorption)

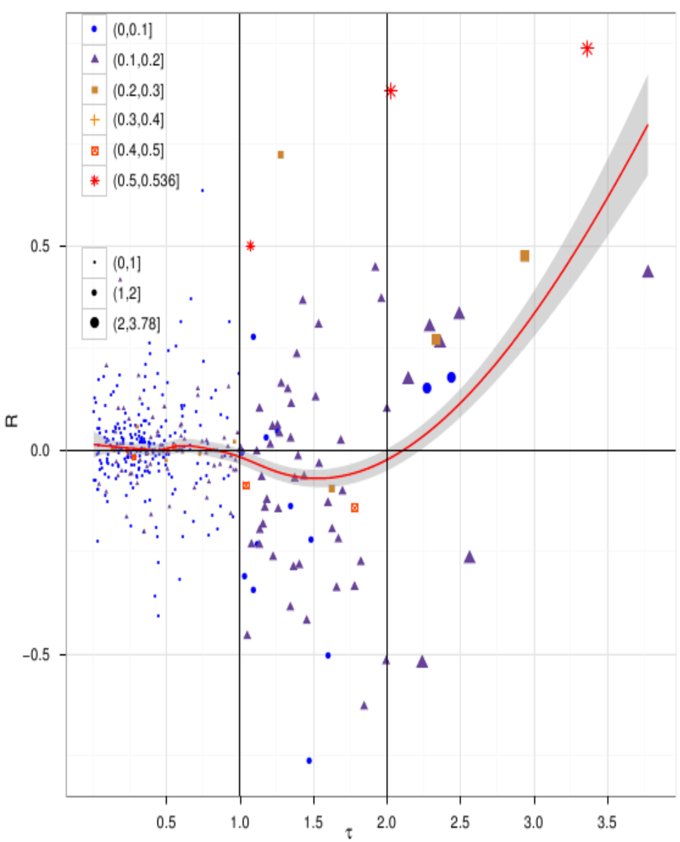
- They then extrapolate these spectra to the optically thick regime **using the lower limit model of the EBL** and compare them to observations at these energies.



Horns & Meyer Figure 4

Sigf = 4.2 s.d.

What can CTA do?



Horns & Meyer Figure 4

- CTA is expected to detect ~20 blazars at z>1 (Inoue, PoS(AGN 2011)025)
- At z=1 and CTA peak sensitivity (0.9 TeV) the object will have an optical depth of 9.
- So we should be able to extend this graph out by a factor for 3 and see if the predicted trend continues.
- This may also be a promising topic for the CTA mini-array (thanks Paula!). The mini-array has a very high energy threshold and there will also be very low noise at this energy. So, we can pick a few objects that will only be detectable with certain EBL model/axion combinations.

TeV observations were consistent only with the very lower limits of EBL intensity derived from galaxy counts.

- This means no wiggle room for emission from other sources: constraints on poorly understood Population III stars

- The HESS limits to EBL were derived with a spectral index of 1.5 on the blazars. Realistically, the spectrum may be softer meaning even less absorption

Kneiske Lower Limit model

- A factor of 2-3 lower than observational data
- “not surprising given the fact that a lower limit EBL is used, which by definition is missing some amount of emission”