Extragalactic gamma-ray backgrounds with CTA

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Collaborators
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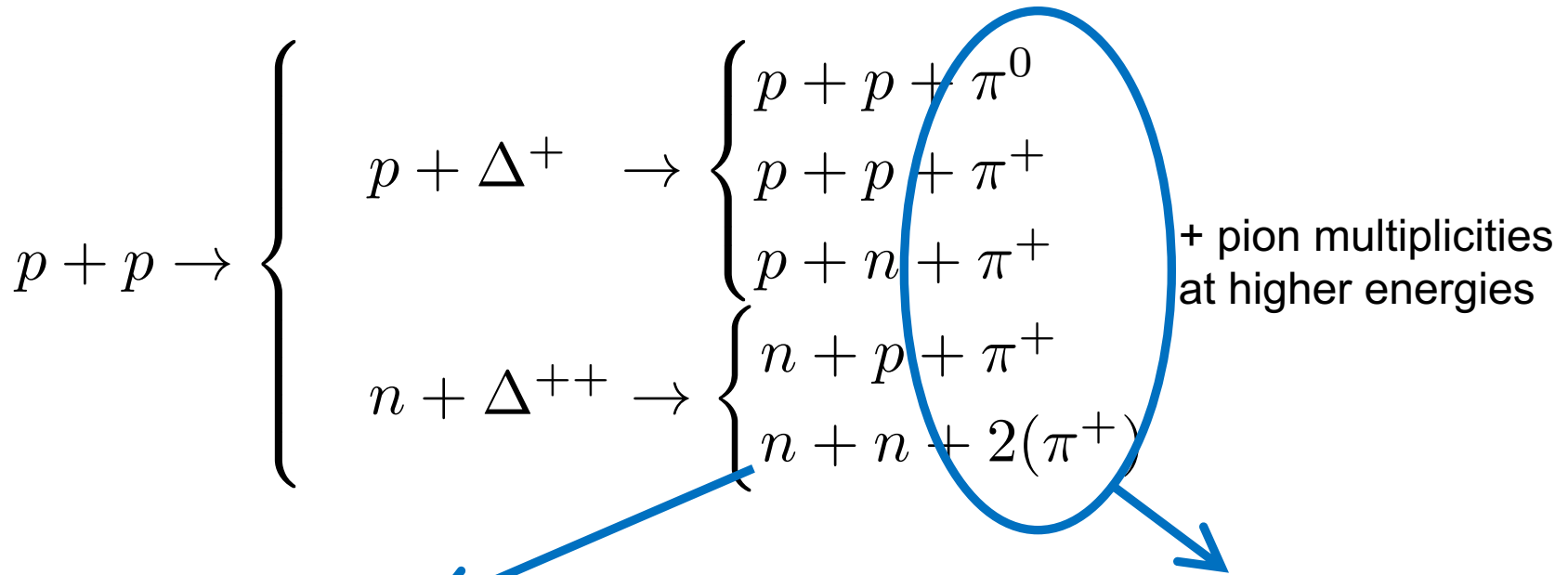Albert Kong (NTHU/ICRR/Oxford)
Khee-Gan Lee (IPMU)
Kinwah Wu (UCL)

Cosmic Rays WG telecon – Feb. 2020

Scope

- Resolving the relative contribution of AGN and star-forming galaxies to the extra-galactic gamma-ray background (EGB) over cosmic time

- Possible alternative probe of galaxy formation/evolution over z (if signatures are sufficiently clear)

- Investigate variation/evolution of internal physics (using EGB spatial/energy spectra together)

Physics: starburst galaxies

Cosmic ray interactions

$$p + p \rightarrow \begin{cases} p + \Delta^+ \rightarrow \begin{cases} p + p + \pi^0 \\ p + p + \pi^+ \\ p + n + \pi^+ \end{cases} \\ n + \Delta^{++} \rightarrow \begin{cases} n + p + \pi^+ \\ n + n + 2(\pi^+) \end{cases} \end{cases}$$

+ pion multiplicities at higher energies

Neutron and photon interactions produce pions
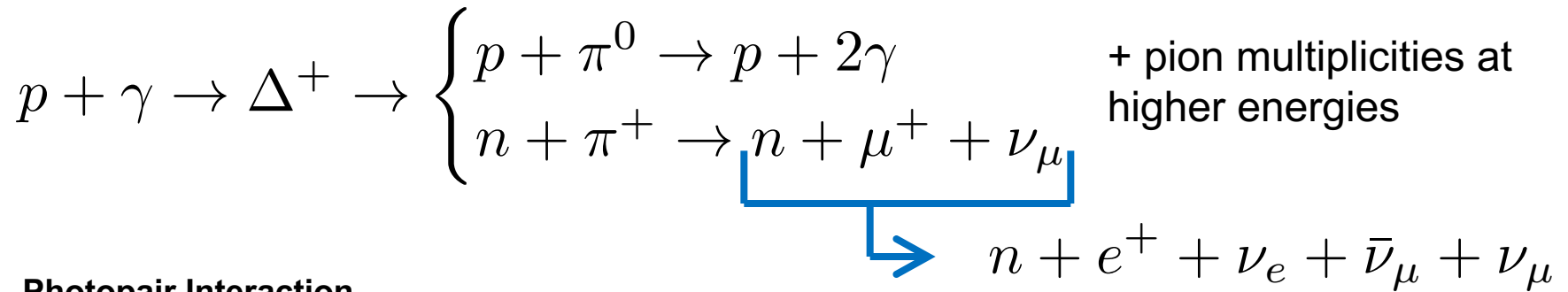
$$n + \gamma \rightarrow \pi\text{'s}$$

Pions decay to photons, muons, neutrinos, electrons, positrons, antineutrinos
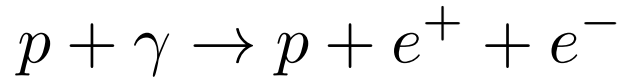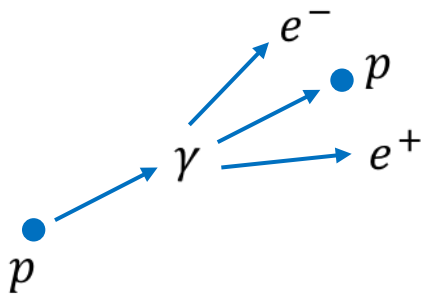
$$\pi \rightarrow \gamma, \mu, e, \nu \dots$$

Physics: AGN

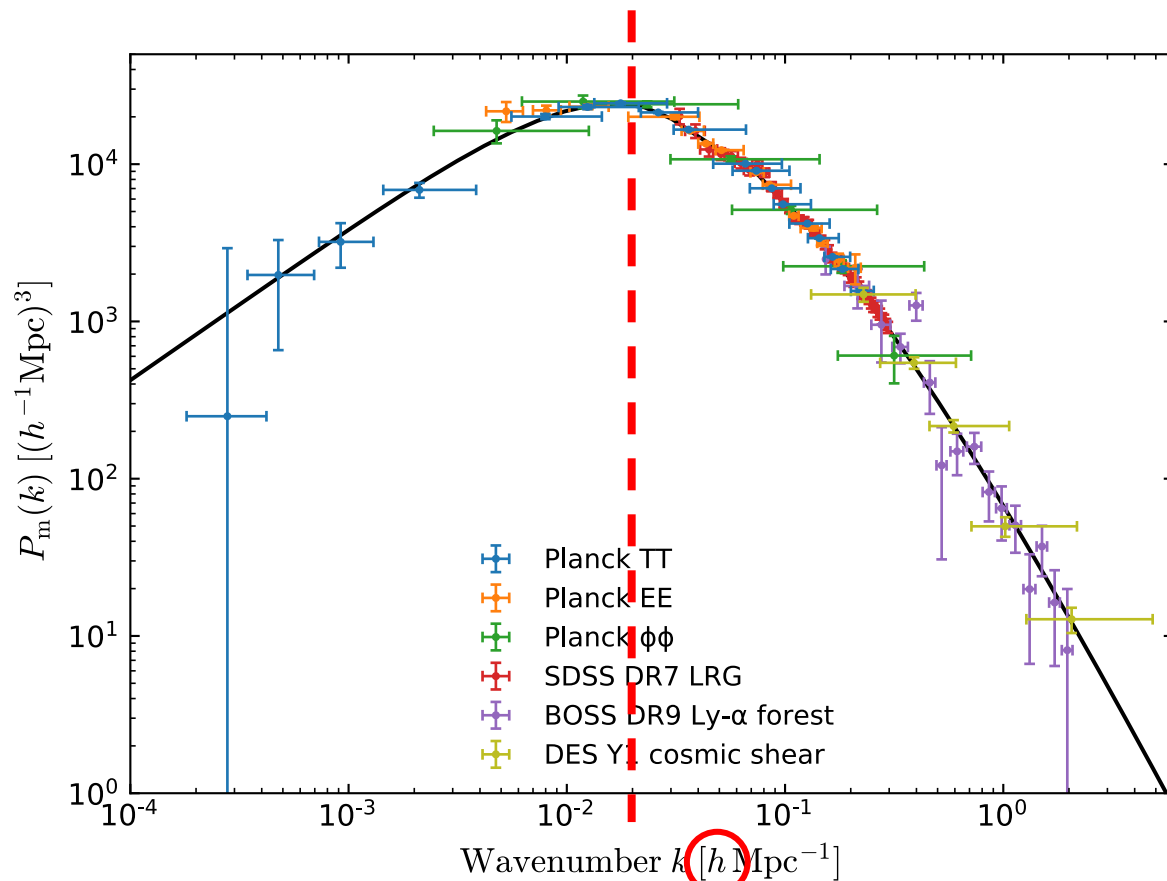## Cosmic ray interactions

Photopion Interaction

$$p + \gamma \rightarrow \Delta^+ \rightarrow \begin{cases} p + \pi^0 \rightarrow p + 2\gamma \\ n + \pi^+ \rightarrow n + \mu^+ + \nu_\mu \end{cases}$$

+ pion multiplicities at higher energies

$$\rightarrow n + e^+ + \nu_e + \bar{\nu}_\mu + \nu_\mu$$

Photopair Interaction

$$p + \gamma \rightarrow p + e^+ + e^-$$

+ Inverse Compton, SSC + …. (variation between sub-classes)

Signatures: spatial anisotropies

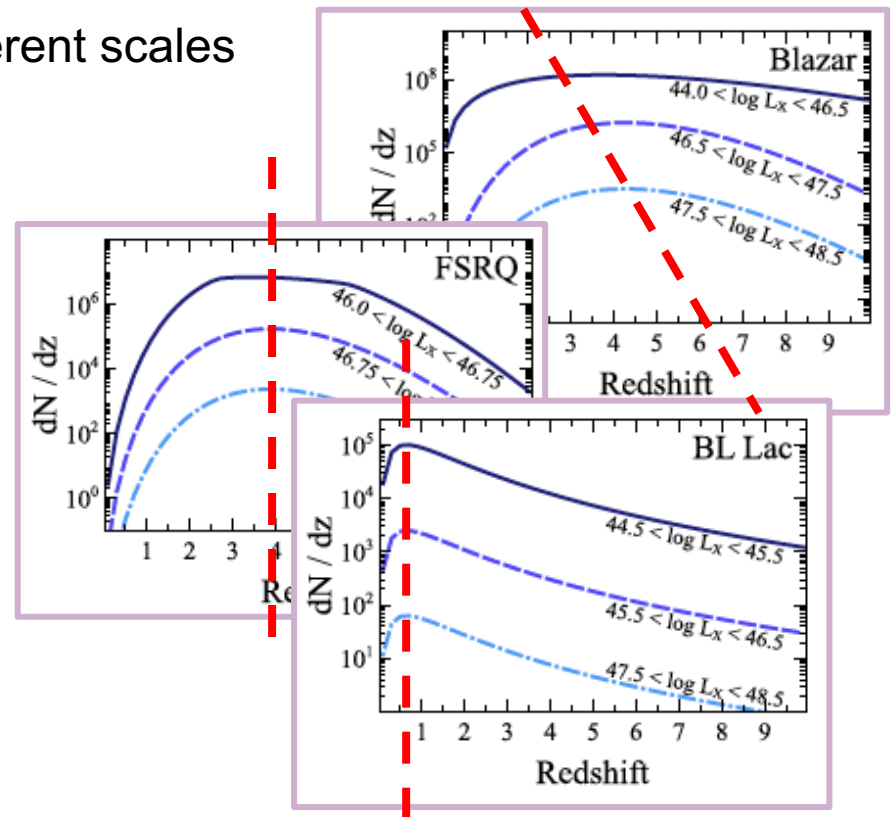Imprints signature at preferred (peak) scale
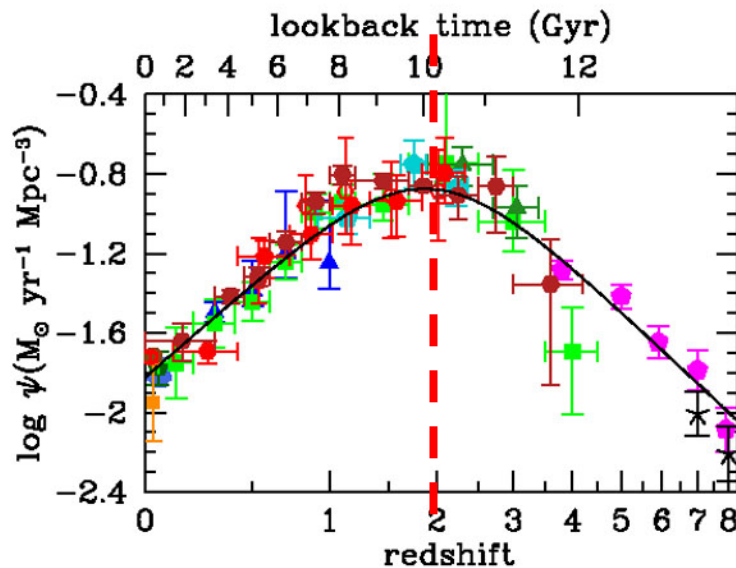

Planck 2018

Redshift (cosmology) dependent

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Signatures: spatial anisotropies

Different populations peak at different redshifts

→ Leaves signatures on different scales

Madau & Dickinson 2014

Silverman 2008; Jacobsen 2015

Summary and outlook

- Modelling intrinsic emission from populations
  - SB intrinsic emission is relatively well understood and easily parametrized
  - Modelling emission from AGN population(s) more complicated; different sub-classes

- Analysis methods
  - Adapted from e.g. CMB studies, using methods native on the sphere
  - (wavelets/curvelets BUT need some understanding of the signal *first*, hence modelling)

- Probable limitations from EBL attenuation/reprocessing
  - How far in z will populations be detectable with CTA?
    - Wide angle approach improves signal (e.g. in case of strong attenuation) so may reveal more than x-correlation with galaxy/AGN surveys
  - IGM B fields could 'smear-out' signal

- Data: Fermi-LAT; CTA KSP 8 ~25% of the EG sky over 3 years