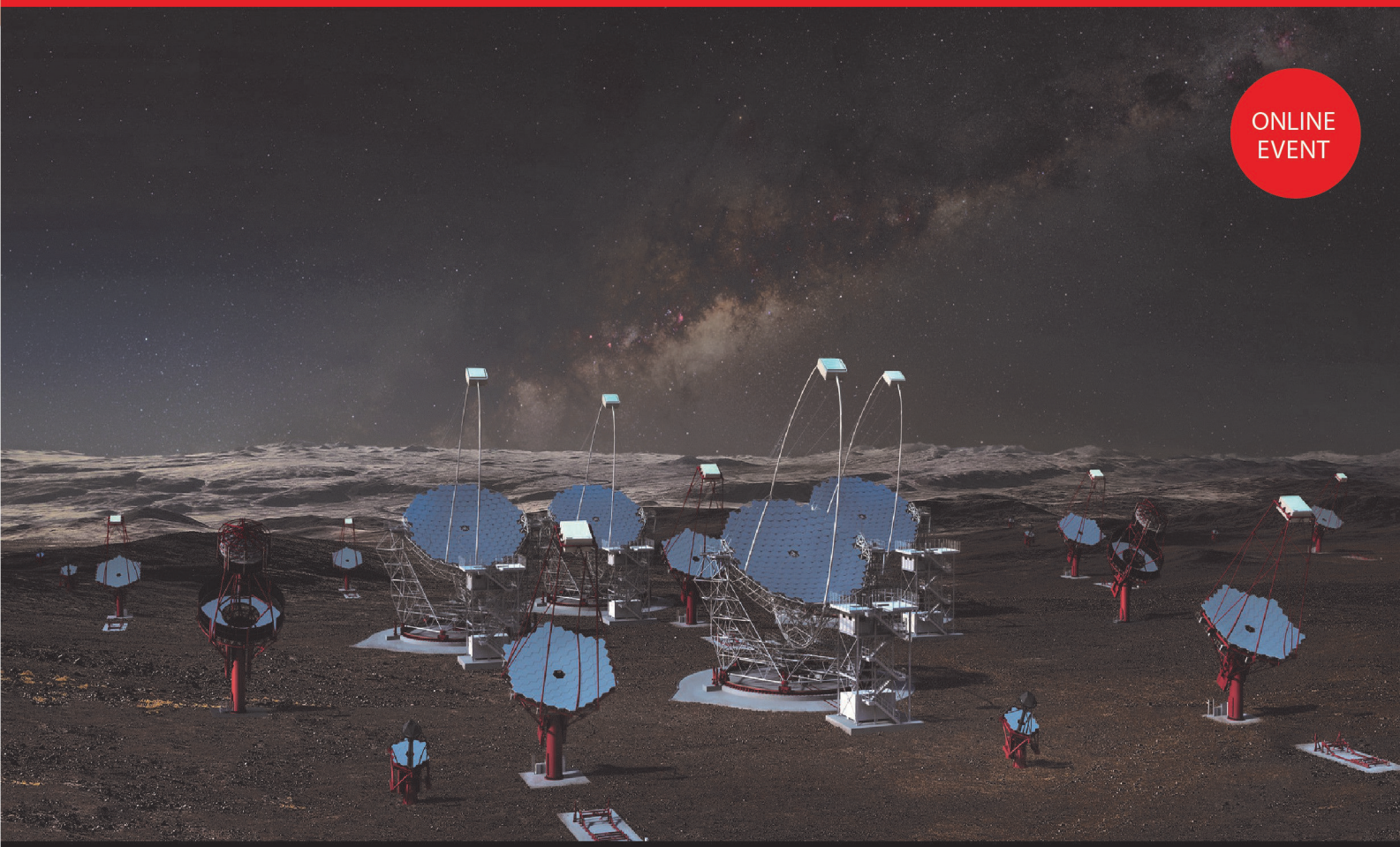
Abstract booklet



Cherenkov Telescope Array UK Science Meeting

24 -25 June 2021

http://cta2021.iopconfs.org/home

IOP Institute of Physics

Thursday 24 June 2021

(Invited) Astronomy at the Highest Photon Energies: the Cherenkov Telescope Array

Werner Hofmann

Max Planck Institute for Nuclear Physics, Germany

The Cherenkov Telescope Array (CTA) is a next-generation observatory for very high energy (VHE) gamma-ray astronomy – a field that has seen remarkable evolution during the last decades. With one array of imaging atmospheric Cherenkov telescopes each in the northern and southern hemispheres, CTA will provide full-sky coverage, enhances flux sensitivity by one order of magnitude compared to current instruments, covers gamma-ray energies from 20 GeV to 300 TeV, and provides a 6 degree wide field of view with angular resolution of a few arc-minutes. With its superior performance, the prospects for CTA combine guaranteed science -- the in-depth understanding of known objects and mechanisms -- with anticipated detection of new classes of gamma-ray emitters and new phenomena, and a very significant potential for fundamentally new discoveries.

(Invited) The science program for the Cherenkov Telescope Array

Roberta Zanin

Cherenkov Telescope Array Observatory, Germany

Very-high-energy (VHE) gamma-ray astroparticle physics is a relatively young field, and observations over the past decade have surprisingly revealed almost two hundred VHE emitters which appear to act as cosmic particle accelerators. These sources are an important component of the Universe, influencing the evolution of stars and galaxies. At the same time, they also act as a probe of physics in the most extreme environments known - such as in supernova explosions, and around or after the merging of black holes and neutron stars. However, the existing experiments have provided exciting glimpses, but often falling short of supplying the full answer. A deeper understanding of the TeV sky requires a significant improvement in sensitivity at TeV energies, a wider energy coverage from tens of GeV to hundreds of TeV and a much better angular and energy resolution with respect to the currently running facilities. The next generation gamma-ray observatory, the Cherenkov Telescope Array (CTA), is the answer to this need. In this talk I will present the scientific capabilities of this future facility that will allow to address in detail many of the still open questions of the gamma-ray astrophysics. In addition, CTA will allow the entire astronomical community to explore a new discovery space that will likely lead to paradigm-changing breakthroughs. In particular, CTA has an unprecedented sensitivity to short (sub-minute) timescale phenomena, placing it as a key instrument in the future of multi-messenger and multi-wavelength time domain astronomy. In the talk I will cover the main science themes at the basis of the CTA science programme and focus on the Key Science Projects, which will be the priority for CTA's first observations and provide legacy datasets for the community.

(Invited) CDM Predictions for Gamma-Ray Annihilation Radiation

Carlos Frenk

Durham University, UK

The expected properties of gamma-ray annihilation radiation in a LCDM universe depend on the abundance and internal structure of dark matter halos. I will present results from cosmological simulations that reveal the mass function and radial density profiles of CDM halos for all masses, down to the cutoff in the CDM power spectrum at the Earth's mass, and discuss the implications for annihilation radiation.

(Invited) Fundamental Physics with CTA

Malcolm Fairbairn

King's College London, UK

I will review the potential of CTA to constrain Axion physics, Dark Matter physics and Lorentz Invariance Violation.

(Invited) Prospects for VHE Observations of Gamma-ray Bursts with CTA

Paul O'Brien

University of Leicester, UK

GRBs are the most powerful electromagnetic transient phenomena known, and have long been identified as a prime target for CTA within the framework of the wider transient science key project. The large collecting area, access to both hemispheres and rapid response speed of CTA will make it a key facility for the future. At the time the CTA transient key science proposal was written no GRBs had been detected with atmospheric Cherenkov telescope arrays. Since then, a small number of GRBs have been detected, revealing the presence of bright, very high energy (VHE) emission during both the GRB prompt and afterglow phases. I will discuss the science of GRBs and illustrate some of the recent VHE observations, particularly using the H.E.S.S. facility located in Namibia. I will also give a brief overview of forthcoming high-energy space facilities which will find additional transient targets for CTA.

(Invited) Relativistic Jets from Stellar Mass Black Holes

Rob Fender

University of Oxford, Department of Physics, UK

I will review the current state of our knowledge of jets from stellar mass black holes in two regimes: 1. black hole X-ray binary systems, in which large numbers of jet formation episodes can be seen coming from the same source, and 2. VHE GRBs, for which we have some of the best existing radio coverage. I will compare their different physical regimes to see if there are overlaps where the VHE GRB mechanism may exist in the X-ray binaries.

(Invited) Pulsars and CTA

Benjamin Stappers

University of Manchester, UK

There have been significant developments in our understanding of the radio pulsar population in the last decade and there is huge potential from future surveys with SKA pathfinders and the SKA itself. I'll discuss some of the exciting results from follow-up of objects seen withFermi, and those discovered by Fermi itself. I'll also discuss attempts to increase the known pulsar population in globular clusters and also talk about related developments in the rotational and emission properties of pulsars and how they might relate to CTA. I'll also discuss options of synergy between SKA and CTA with regard to pulsar searching.

(Invited) Cherenkov Astronomy: Open to the Public?

Hugh Dickinson

The Open University, UK

The public profile of VHE gamma-ray astronomy has undoubtedly grown in recent decades thanks to spectacular discoveries by instruments like H.E.S.S., MAGIC and VERITAS. In this talk I will discuss how citizen science projects like Muon Hunter and its sequels can be used to perform useful scientific analyses while directly engaging society and promoting the science topics behind the headline results. I will discuss how this paradigm can be extended using principles of Open and FAIR data access to allow citizens to explore and analyse curated CTA datasets, showcasing examples using the prototype ESCAPE Science Analysis Platform.

Poster Session 1

P1.1 Deep Learning Research for Imaging Atmospheric Cherenkov Telescopes

Samuel Spencer, Adi Jacobson, Raul Prado, Gernot Maier, Garret Cotter

University of Oxford, UK

New deep learning analyses are a promising new method of background rejection and event reconstruction for Imaging Atmospheric Cherenkov Telescopes (IACTs), particularly in the context of the next generation Cherenkov Telescope Array (CTA). This is as they allow for sensitive analysis of complete camera images at high speed. Unlike other fields of astrophysics where deep learning is being used to characterise astronomical sources, deep learning use in IACT astronomy is comparatively unique in that the analysis targets are Extended Air Showers in Earth's atmosphere. As such, we have access to large datasets of highly complex Monte Carlo simulations of both the air shower particle physics and our detectors. However, this in turn leads to a highly non-trivial domain gap problem when attempting to apply deep learning methods trained on simulations to real data. We will present state of the art results displaying the combined effects of custom simulations, optimisation and graph-based network architectures to attack this problem.

P1.2 A Dome Show for the CTA: Exploring the High Energy Universe

Kerem Osman Cubuk, Michael Burton and Heather Alexander

Armagh Observatory and Planetarium and Queen's University Belfast, UK

Planetaria software systems have been improved significantly in the last decade thanks to technological developments. Today planetaria that use high-end dome software can produce entertaining, exciting, and informative 3D STEAM shows with very small budgets. This is the beginning of a new era for planetarium outreach.

We have produced our first in-house full-dome show, Exploring the High Energy Universe, in the Armagh Observatory and Planetarium. The show starts with the brief introduction to multi-wavelength astronomy and how Milky Way looks in different wavelengths. Then we travel in the universe to have a closer look at cosmic sources of gamma-rays. Finally, we show how CTA will look and why it is so important for future research.

P1.3 Relevance of photon-photon dispersion within the jet for blazar axionlike particle searches

Jamie Davies, Manuel Meyer and Garret Cotter

University of Oxford, UK

Axionlike particles (ALPs) mixing with photons in astrophysical magnetic fields could affect the gamma-ray spectra of blazars. Searching for this effect in gamma-ray observations has provided some of the strongest constraints on ALP parameter space so far. Previously, photon-photon dispersion of gamma-rays off of the CMB has been shown to be important for these calculations and is universally included in ALP-photon mixing models. Here, we assess the effects of dispersion off of other photon fields within the source -- produced by the disk, the broad line region, the dust torus, and the synchrotron field -- by modelling the jet and fields of the FSRQ 3C454.3 and propagating ALPs through the model both with and without the full dispersion calculation. We find that dispersion off the AGN fields can strongly affect the mixing, particularly at energies above 100 GeV -- often reducing the ALP-photon conversion probability. This could have implications for future searches planned with, e.g., the Cherenkov Telescope Array, particularly those looking for a reduced opacity of the universe at the highest energies.

P1.4 A systematic search for variable sources in the simulated CTA GPS Data

Stephen Duffy, Masha Chernyakova, Denys Malyshev, Luigi Tibaldo and Jürgen Knödlseder

Dublin City University, Ireland

The Cherenkov Telescope Array (CTA) is the next generation ground-based observatory for gamma-ray astronomy at very-high energies. A deep survey of the Galactic Plane is one of the key targets of the observatory. The aim of this survey is to find new gamma-ray sources and to study variable and transient phenomena. In order to test the CTA sensitivity and to define the best observational strategy, the CTA Galactic Science Working Group (GSWG) has simulated 10 years of Galactic Plane observations using as an input both known sources and a synthetic population built on physical models. An automatic pipeline, based on the ctools analysis software, was used by the members

of the CTA GSWG for the first blind-search analysis of these data, which resulted in a catalogue of all the detected sources. In order to find variable sources in a systematic way, we built light curves of all detected point sources and examine them for variability on the observation (~30 min) time scale. In addition to that, we expand our study to include sources that are classified by the automatic pipeline as extended ones but have point source associations. In this poster, we present our findings and discuss their implications for the search for new gamma-ray binaries.

P1.5 QCD uncertainties in gamma-ray dark matter searches: How large are they?

Adil Jueid, Simone Amoroso, Roberto Ruiz de Austri, Sascha Caron and Peter Skands

Konkuk University, South Korea

Motivated by the various excesses observed by the Fermi-LAT and AMS experiments as well as by the future expected experiments such as CTA, we study thoroughly the physics modeling of particle spectra from dark-matter annihilation or decay into Standard Model (SM) particles. Particles produced in these processes will, in general, undergo QED/QCD bremsstrahlung, hadronization, and hadron decays leading to stable final-state objects such as neutrinos positrons, photons, and protons. The modeling of the spectra of these final-state particles contains some uncertainties which are usually neglected in the physics analyses. I will talk about the different contributions to the QCD uncertainties, their estimates and briefly assess their impacts in the context of phenomenological MSSM stressing out how large they can be for heavy and super-heavy dark matter. These uncertainties are provided in the form of data tables and can be found in Zenodo for masses 10-100000 GeV (https://zenodo.org/record/3764809#.YF8XYC0RrRa) for future use.

P1.6 UAV-based Calibration of Atmospheric Cherenkov Telescopes

Hugh Spackman[1], A Brown[2] and G Cotter[1]

[1]University of Oxford, UK and [2]Durham University, UK

Unmanned Aerial Vehicles (UAVs) have been proposed as a new method for the calibration of imaging atmospheric Cherenkov telescopes (IACTs). With a light source mounted underneath, a UAV can be flown over an array of IACTs and used as a calibration source for multiple telescopes, spread over a large area, simultaneously. For a UAV to be suitable as a calibration source, it must maintain as stable a position as possible in the field of view of the telescopes it is calibrating. This analysis examines telemetry from a rotatory UAVs flights to quantify the uncertainty in the UAVs position when the UAV is instructed to maintain a fixed location. This positional uncertainty will be used, along with sim_telarray, to simulate the UAV-telescope systems and the systematic uncertainties in detections of the UAV calibration source by each size of telescope in the Cherenkov Telescope Array (CTA). With the simulations and uncertainties, it will be possible to optimise UAV flight plans and minimise the time needed to calibrate a full IACT array.

Friday 25 June 2021

(Invited) Detailed Broadband Modelling of Blazars and Model Selection

Hendrik van Eerten

University of Bath, UK

Blazar emission is produced by leptonic processes, hadronic processes or a mixture of both and various routes exist to produce the familiar double-humped spectral energy distribution (SED) of blazars. In the absence of a detailed statistical model comparison, it can be difficult to determine which model is preferred by the broadband data from radio to gamma rays.

Our group has recently introduced a kinetic equation solver code, Katu, capable of evolving systems of interacting particles from protons, photons and electrons to derived particles including neutrinos. Optimized for speed, while maintaining the full detail of the kinetic approach, Katu can be linked to Bayesian inference software and used for analysis and model comparison. Katu has been applied to TSX 0505+056 and Mrk 421, modeling the neutrino flux of the former and showing substantial evidence for the leptohadronic model based purely on the SED for the latter. I will discuss this approach to blazar modelling, and highlight the role played by gamma rays in constraining our understanding of blazar physics.

(Invited) Figuring out Blazars with CTA

Helene Sol

CNRS, France

Blazars represent the largest population of cosmic sources detected at TeV energies with present IACT, while still being poorly understood. Existing basic radiative models and numerical tools are quite successful at reproducing currently available spectra and simple light curves. However a general reference scenario for TeV blazars (and AGN) is not yet at hand, which seriously limits the physical interpretation of the multi-wavelength and multi-messenger data. Answering fundamental questions on the location of the TeV emitting zone, the nature of radiating particles and dominant acceleration processes, the origin of variabilities, and the identification of the key parameter(s) controlling VHE gamma-loudness will be a real challenge for CTA.

(Invited) TeV gamma rays from High-energy Leptons in Radio Galaxies

Martin Hardcastle

University of Hertfordshire, UK

Observations of X-ray synchrotron emission from jets and hotspots of radio galaxies imply that leptons can be accelerated efficiently in those locations to TeV energies, and are thus capable of generating extended gamma-ray structures at distances up to Mpc from the active nucleus. Observations of these structures with the CTA can constrain the (currently poorly known) large-scale

magnetic field strength in the accelerating regions and can also give us clues about the presently poorly understood acceleration mechanisms. I will describe what we currently know about these components at other wavelengths and discuss the present status of, and future prospects for, high-energy gamma-ray observations of extended radio components.

(Invited) Highly variable AGN and the CTA connection

Martin Ward

University of Durham, UK

Variability of AGN can be tracked back optically via photographic plates to the 1890's! High energy X-ray variability of AGN was established in the 1970's, and in gamma-rays this century by data from the Fermi Observatory and current ground-based instruments. Now we are entering the newest window of TeV observations of AGN. I will focus on a couple of examples, and some future prospects.

(Invited) AGN Feedback in Cluster Cores – the CTA to monitor the pulse?

Professor Edge

Durham University, UK

The cores of clusters of galaxies host the most massive galaxies and hence the massive black holes. The cooling of gas in these systems provides the fuel of significant AGN activity that inflates massive jet-filled cavities in the intracluster medium. The CTA offers the capability to detect the flickering of this AGN activity in many local systems and relate that to their longer term activity. NGC1275 is the archetype for this and its Fermi-LAT light curve demonstrates just how erratic its heartbeat is.

(Invited) Multi-wavelength Observations of the ISM with CTA: critical for achieving the science

Michael Burton

Armagh Observatory and Planetarium, UK

The interstellar medium (ISM) plays a vital role in the production of astrophysical gamma-rays. It is the target for cosmic-ray collisions, and it heavily influences the propagation of cosmic-ray protons and electrons as well as their conversion to radio, X-rays and gamma-rays. Large-scale ISM surveys can provide critical inputs into CTA's science. In the hadronic model for TeV gamma rays their production occurs following the impact of high-energy cosmic rays with nuclei, primarily in the surrounding interstellar medium to the originating cosmic accelerators. The greatest columns of absorbing material are found in molecular clouds distributed along the Galactic Plane. To interpret the TeV images it is essential to have mapped distribution and location of this molecular gas at an angular resolution better than the highest resolution that will be obtained by CTA. We report on the Mopra Southern Galactic Plane survey in CO, mapping the distribution of the three principal isotopologues of this molecule at 0.6 arcmin and 0.1 km/s resolution, along a 120 x 2 degree region of the Galactic Plane. This will allow the optical depth to be determined, essential for measuring column density. In conjunction with Herschel dust emission, which provides the total column along the site line, this will enable column density to be determined as a function of

distance from the Sun. This is a necessary pre-condition for fully exploiting the CTA Galactic Plane survey.

(Invited) Synergies: Radio Astronomy and CTA

Robert Laing

SKAO

I will review recent progress and future opportunities for observations in the radio - sub-mm wavelength range (from 10 m - 0.3 mm). After a brief account of developments at mm wavelengths, including ALMA and the Event Horizon Telescope, I will concentrate on the SKA and its immediate precursors and pathfinders. I will outline the main science drivers for these instruments and the potential synergies between SKA and CTA.

(Invited) Observing gravitational waves with a global network

Ik Siong Heng

University of Glasgow, UK

The Advanced LIGO and Virgo detectors most recently finished a successful third observing run, O3. Detector sensitivity gains realized for O3 have enabled gravitational-wave events to be detected at a significantly higher average rate, including gravitational waves from some compact binary systems involving at least one neutron stars.

This talk will summarise the O3 run and discuss the properties of notable gravitational wave events. The prospects for fourth observing run (O4) and beyond will also be discussed, including the addition of KAGRA and, in later runs, LIGO-India to the global network.

(Invited) Ultra-high energy neutrinos: where do they come from and what can they tell us?

Ryan Nichol

University College London, UK

Multi-messenger astronomy using neutrinos has long been one of the elusive goals of Astroparticle physics. Until the last decade non-terrestrial neutrinos had only been detected from the sun and one burst of neutrinos from supernova 1987A. With IceCube's discovery of astrophysical neutrinos finally the age of neutrino astronomy may be beginning. In this talk I'll review the status of current astrophysical neutrino measurements and discuss the prospects of some future experiments. The synergies between gamma ray measurements and neutrino measurements at these future facilities will be discussed.

Poster Session 2

P2.1 The IceCube high-energy starting event 7.5-yr sample data

Teppei Katori, Kareem Farrag and Rogan Clark

King's College London, UK

The IceCube Neutrino Observatory has established the existence of a high-energy all-sky neutrino flux of astrophysical origin. This discovery was made using events interacting within a fiducial region of the detector surrounded by an active veto and with reconstructed energy above 60TeV, commonly known as the high-energy starting event sample, or HESE. We revisit the analysis of the HESE sample with an additional 4.5 years of data and improved systematics treatment. Here, we describe the analysis, then we report on the latest astrophysical neutrino flux measurements, astrophysical tau neutrino search, flavor and cross-section measurements, and new physics search.

https://arxiv.org/abs/2011.03545
https://arxiv.org/abs/2011.03560
https://arxiv.org/abs/2011.03561

P2.2 Neutrino Target of Opportunity program for the Cherenkov Telescope Array

Alberto Rosales de Leon, Konstancja Satalecka, Anthony M. Brown, Olga Sergijenko, Chun Fai Tung, René Reimann, Theo Glauch and Ignacio Taboada

Durham University, UK

Astrophysical sources capable of hadronic acceleration to relativistic energies have long been believed to be sources of astrophysical neutrinos. Nevertheless, the long exposure neutrino sky map shows no significant indication of point sources so far. This may point to a large population of faint, steady sources or flaring objects as origins of this flux. The most compelling evidence for a high-energy neutrino point source so far has been the 3σ spatial and temporal correlation between the flaring gamma-ray blazar TXS 0506+056 and a high-energy neutrino detected by IceCube in September 2017. These observations were the result of a Neutrino Target of Opportunity (NToO) program in which all currently operating Imaging Atmospheric Cherenkov Telescopes (IACTs) take part. The case for TXS 0506+056 being a neutrino source was made stronger by evidence of a 5-month long neutrino flare in 2014-2015. The Cherenkov Telescope Array (CTA) will be the next-generation ground-based IACTs. In this work, we investigate the detection probability for the very high energy (VHE) gamma-ray counterparts to neutrino sources from the populations simulated by the FIRESONG software to resemble the diffuse astrophysical neutrino flux measured by IceCube. We scan over parameters that can be used to describe the populations, such as luminosity and density (density rate) for steady (flaring) objects. Several CTA array layouts and instrument response functions are tested in order to derive optimal follow-up strategies and estimate the potential science reach of the NToO program for CTA. We find that CTA has a very high per alert probability of detecting a steady source counterpart in certain parameter space regions. For the

blazar flares resembling the neutrino flare of TXS 0506+056 in 2014-2015, CTA will detect more than 40% of the sources in 30 minutes of observation.

P2.3 Modelling the contribution of star-forming galaxies to the diffuse, isotropic gamma-ray background.

Matt Roth, Mark Krumholz, Roland Crockera and Silvia Celli

Australian National University, Australia

The Fermi LAT has discovered a diffuse, isotropic gamma-ray background whose origins are still uncertain. Many source candidates have been proposed, with modelling usually restricted to using luminosity functions, calibrated on a few observed local sources and extrapolated to cosmological abundances, to estimate the contribution from different classes of emitters. In this work, we construct a model to derive the gamma-ray emission originating in individual star-forming galaxies, by considering the propagation, calorimetry and interaction with the ISM of cosmic rays produced in supernova remnants. We apply this procedure to a subset of galaxies in CANDELS, for which we have a sufficient number of structural parameters available as input to the model, all the way out to beyond cosmic noon, and obtain a gamma-ray spectrum for each galaxy. We verify our model by computing the gamma-ray spectra of nearby, resolved SFGs, model a source count distribution, and the FIR-gamma relation. Applying the model to the CANDELS sample to estimate the total contribution from star-forming galaxies to the diffuse, isotropic gamma-ray background, yields a good fit to the spectral shape and intensity of the observed emission, with SFGs dominating the background. Our model thus makes clear predictions for the source count distribution of star-forming galaxies which are below the detection threshold of any current gamma-ray instrument and we hope that CTA will extend the population of gamma-ray observed SFGs significantly.

P2.4 Completion of the Template for the CTA Survey of the Southern Galactic Plane: The Mopra CO Survey

Kerem Osman Cubuk, Michael Burton and Gavin Rowell

Queen's University Belfast, UK

Molecular hydrogen (H2) is the most abundant and most important molecule for the star formation. Despite its abundance it is almost impossible to observe H2 directly in the star forming molecular clouds. The second most abundant molecule, carbon monoxide (CO), is easy to observe thanks to its very low energy requirement for its first rotational transition. We have observed four isotopologues of CO (12CO, 13CO, C17O, C18O) in the Southern Galactic Plane. We will provide column density, total mass, and mass distribution maps of the covered region. The Mopra CO Survey will be a template for the future CTA research. In this poster, we present our decade long project's details and some initial results.

P2.5 Poster The Southern Wide-Field Gamma-Ray Observatory (SWGO)

Paula Chadwick, Anthony Brown, Garret Cotter, Tim Greenshaw and Jon Lapington

Durham University, UK

Cherenkov telescopes such as CTA are highly sensitive instruments, with excellent angular resolution. However, they also have a low duty-cycle, being restricted to cloudless and largely moonless nights, and have a narrow field-of-view. The proposed Southern Wide-field Gamma-ray Observatory (SWGO) is an extensive air-shower array, which is ideal to study the emission from very extended regions and to detect transient sources. It will be highly complementary to CTA and to neutrino telescopes such as KM3Net and IceCube. This poster will outline the scientific motivations for and the design concept of SWGO.

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