Cosmic-Ray Transport Workshop, May 18-19, The Ohio State University, Location: Room 1080 at Physics Research Building

Day 1: Monday (May 18)

08:00–08:45 **Coffee & Pastries**

08:45–08:55 **Welcome Remarks (CCAPP Director)**

08:55–09:25 **Mateusz Ruszkowski**
Connecting Cosmic Ray Transport to Multiphase Structure in Galactic Winds and the CGM: I will present an overview of recent advances in simulations of cosmic ray–driven galactic winds and the CGM, with particular emphasis on the emergence of multiphase structure. I will highlight how different models of cosmic ray transport shape (i) star formation and wind mass loading, (ii) phase-dependent coupling between cosmic rays and the ISM and CGM, and (iii) key observational signatures, and discuss how these pieces fit into a broader physical picture of galaxy–CGM baryon cycling regulated by cosmic rays.

09:25–09:55 **Peng Oh**
Beyond the Diffusion Coefficient: I discuss a generalization of the diffusion coefficient which suitable for anomalous transport, and the impact of anomalous transport on cosmic ray observables.

09:55–10:10 **Naixin Liang**
Multiphase Structure and Memory in CR Transport: Cosmic ray transport in the multiphase medium is often approximated by an energy-dependent diffusion coefficient. However, this description fails when particle motion is governed by intermittent traps (e.g., magnetic mirrors) or strong temporal fluctuations. We present an event-driven framework based on the Montroll-Weiss formalism, where transport is coarse-grained into discrete events. We outline the construction and measurement of the propagator from trajectories obtained in Monte Carlo simulations. This provides a powerful tool for diagnosing transport beyond the diffusion limit. We leverage this machinery to make observational predictions regarding spectral breaks, the arrival time distribution from transient sources, and the large-scale dipole anisotropy.

10:10–10:30 **Benedikt Schroer**
The impact of the eROSITA bubbles on Galactic cosmic-ray transport: We propose that the observed spectral hardening in Galactic cosmic ray fluxes is governed by macroscopic Galactic outflows, such as the eROSITA bubbles, rather than microphysical variations in their scattering properties. Employing a phenomenological transport model, we show that an advective outflow boundary naturally reproduces the 300 GV hardening in secondary-to-primary ratios. Global fits to precision AMS-02 data yield an effective local inner halo boundary of $\sim 5\,\mathrm{kpc}$ and an outflow speed of $\sim 360\,\mathrm{km/s}$, in striking agreement with independent multi-wavelength kinematic constraints of the eROSITA outflows. This interpretation provides a physically grounded, testable alternative to introducing ad-hoc breaks in the diffusion coefficient without increasing the number of free parameters.

10:30–11:00 **Coffee Break**

11:00–11:30 **Fan Guo**
Ion Flux Dropouts during Solar Energetic Particle Events in the Inner Heliosphere: We present fine-scale abrupt ion flux changes (dropouts) during solar energetic particle (SEP) events observed by Parker Solar Probe (PSP) and Solar Orbiter, and new numerical simulations designed to study the dropouts observed in

the inner heliosphere. PSP is shown to detect dropouts near the Sun, and is capable of measuring SEPs from both Sunward and anti-Sunward directions. In the 2021 Aug 23 event, PSP measured several dropouts and an odd onset feature. We present theoretical estimates and numerical simulations on how dropout duration and frequency changes as a function of the distance from the source region. In our simulations, dropouts are modeled as energetic particles from a compact source region propagating in a turbulent magnetic field. In addition, we have included SEP intensities in directions toward and opposite to the source region, similar to the Sunward and anti-sunward detections by PSP. We find that dropouts may explain the anomalous onset and sharp variation of particle intensity of SEPs observed by Parker Solar Probe. We have also done simulations with a dropout feature simultaneously across more than one release of SEPs, similar to what has been observed by Solar Orbiter. The implications of these events to interplanetary magnetic fields will be discussed.

11:30–12:00 **Joe Giacalone**

Particle Acceleration at Shocks in the Heliosphere: Attempting to do Theory in a Data-Rich Field: The heliosphere provides an excellent laboratory for studying particle acceleration. The coincidence of high-energy particles and heliospheric shocks is striking, providing considerable support to the basic theory of diffusive shock acceleration (DSA) theory developed nearly 50 years ago, and has wide use in both heliophysics and astrophysics. However, there are numerous spacecraft observations and they do not always, or even often agree with the standard version of DSA theory. In this talk, I will give some examples, including the physics of anomalous cosmic rays and their acceleration at the solar wind termination shock, and time-dependent acceleration of particles at CME-driven shocks near the Sun as observed by Parker Solar Probe. I will also mention others, such as the wide variety of time-intensity profiles of energetic particles at interplanetary shocks, a general lack of self-excited energetic-particle-induced magnetic waves seen in heliospheric shocks thought to be important in astrophysical shocks, and non-diffusive effects leading to observations of highly anisotropic pitch-angle distributions.

12:00–12:30 **Lulu Zhao**

Toward Self-Consistent SEP Acceleration and Transport Modeling: The Role of Turbulence in the SOFIE Framework: Solar energetic particle (SEP) acceleration and transport are fundamentally controlled by the evolving turbulence environment, particularly in the vicinity of coronal mass ejections (CMEs) and CME-driven shocks. In this work, we investigate turbulence generated self-consistently within the AWSoM-R magnetohydrodynamic (MHD) simulations embedded in the SOFIE framework. SOFIE combines the AWSoM-R global MHD model, automated CME initiation, and energetic particle acceleration and transport modules to simulate SEP events from the low corona into the heliosphere. We focus on how turbulence quantities derived directly from the MHD simulations influence shock acceleration efficiency and the subsequent transport of energetic particles. Using time-accurate CME simulations of the 2012 July 12 event as a case study, we examine how different turbulence treatments affect SEP intensity profiles and spectral evolution throughout the inner heliosphere. Particular attention is given to the coupling between shock properties and the ambient solar wind turbulence structure, highlighting the importance of moving beyond empirical diffusion prescriptions toward more physics-based descriptions of SEP acceleration and transport.

12:30–14:00 **Group Lunch**

14:00–14:30 **Evan Scannapieco**

Turbulence, Magnetic Fields, and Cosmic-Ray Transport in the Driving Regions of Starburst Galaxies: Understanding outflows from starburst galaxies requires connecting the global evolution of the wind to conditions within the driving region. Supernovae, turbulence, magnetic fields, and nonthermal particles interact in complex ways in this region, and I will discuss recent advances in characterizing its structure and dynamics. X-ray Imaging and Spectroscopy Mission (XRISM) observations of M82 provide a new window into this region and reveal supersonic turbulence with properties that cannot be explained by hydrodynamic interactions alone. Numerical simulations show that the structure of supersonic, magnetized turbulence depends on the character of the driving mechanism, which shapes the environment through which cosmic rays propagate. Better constraints on launch-region physics will be important for a more complete understanding of starburst-driven outflows.

14:30–14:45 **Yue Samuel Lu**

Properties and observables of CR-dominated galaxies & their constraints on CR models: Cosmic rays (CRs) are a pivotal non-thermal component of galaxy formation and evolution. However, the intricacies of CR physics, particularly how they propagate in the circumgalactic medium (CGM), remain largely unconstrained. In this work, we study CGM properties in FIRE-2 (Feedback In Realistic Environments) simulations of the same Milky Way (MW)–mass halo at z = 0 with different CR transport models that produce similar diffuse GeV γ-ray emission, as an attempt to further constrain CR transport models. We study the gas morphology and thermal properties, and generate synthetic observations of rest-frame UV ion absorption columns and X-ray emission. CRs lower galaxy masses and star formation rates (SFRs) while supporting more cool CGM gas, which boosts the H I and O VI column densities in the CGM, bringing simulations more in line with observations, but there can be large differences between CR transport models and resolution levels. X-ray emission within and close to galaxies is consistent with thermal (free–free and metal-line) emission plus X-ray binaries, while more extended ($\sim$100 kpc) CGM emission is potentially dominated by inverse Compton scattering (ICS), motivating future work on the spatially resolved X-ray profiles. Although comparisons with observations are sensitive to sample selection and mimicking the details of observations, and our analysis did not result in strong constraints on CR models, the differences between simulations are significant and could be used as a framework for future studies.

14:45–15:00 **Emily Simon**

Hybrid simulations of the Bell instability and Emax in SNRs: The maximum energy (Emax) attainable at supernova remnant (SNR) shocks is intrinsically tied to the non-linear growth of plasma instabilities, which control both particle confinement and the subsequent escape into the interstellar medium. Using hybrid simulations (kinetic ions/fluid electrons) with integrated particle tracking, we investigate the co-evolution of CR acceleration and the Bell instability as a function of shock Mach number. We discuss ongoing results in the context of current SNR observations and their implications for whether SNRs can realistically reach PeV energies before entering the Sedov-Taylor phase.

15:00–15:30 **Coffee Break**

15:30–16:00 **Troy Porter**

Latest results from the first interstellar probe: Voyager 1 signatures of local gas and cosmic-ray source distributions: Voyager 1 measurements in the very local interstellar medium (ISM) provide the first direct view of low-energy cosmic rays (CRs) outside the heliosphere. We use GALPROP to quantify how realistic structure in the nearby ISM, especially local gas inhomogeneities and non-uniform CR source distributions, imprints on the spectra and elemental ratios observed by Voyager 1. Comparing model predictions to the Voyager 1 data, we find the observations favour scenarios with no significant CR sources within $\sim$150—200 pc of the Solar system, implying that the dominant contributors to the local low-energy flux originate beyond this distance. The modelling also supports the inference that a non-negligible primary boron component is required at low energies. These results demonstrate that detailed, local 3D modelling of gas and recent source history is essential for unbiased interpretation of Voyager 1 CR spectra.

16:00–17:00 **Discussion Session**

17:00–17:30 **Igor Moskalenko**

Synthetic Observations of Radio, Infrared, and Gamma-ray Emission in Milky Way Models: I will talk about our recent results on the radio-infrared-γ-ray correlation observed in star-forming galaxies. We test whether it is driven mainly by viewing geometry rather than local cosmic-ray calorimetry. Using synthetic observations of Milky Way-like models, we show that a tight, near-linear relation can arise from line-of-sight integration through a structured disk, but can weaken for edge-on views. Our conclusion is that the correlation is largely geometric in origin, and that its scatter may diagnose galaxy structure and viewing angle.

17:30–19:00 **Pre-Dinner Break**

19:00–21:00 **Group Dinner**

Day 2: Tuesday (May 19)

08:00–08:30 **Coffee & Pastries**

08:30–09:00 **Roland Crocker**

Where do cosmic rays go to die?: Most ∼1-10 GeV hadronic cosmic rays accelerated in star-forming galaxies will eventually escape the relatively dense ISM gas and leak into the circumgalactic medium (CGM). What happens to them thereafter and do they do anything important in this low density environment? I will show that these CRs are, in fact, important: using a new semi-analytic model we have developed over the last few years I will show that CRs, accumulated over the last few Gyr of star formation, contribute non-negligibly to the pressure (gradient) in the CGM of L* galaxies like the Milky Way. I will further demonstrate that the same CR population is important in maintaining the temperature of the CGM via streaming heating. Finally, I will show that the isotropic gamma-ray flux measured by Fermi receives a non-negligible contribution from hadronic emission of CRs in the CGM of all galaxies on our lightcone. IGRB measurements therefore constrain the parameters governing transport of ∼1-10 GeV CRs in the CGM.

09:00–09:30 **Dusan Keres**

Cosmic rays and galaxy evolution in FIRE: Implementation of cosmic ray (CR) transport in FIRE cosmological zoom-in simulations has yielded interesting results. We have calibrated effective CR scattering/diffusion using observed gamma ray emission from nearby galaxies and concluded that a relatively fast escape of GeV CRs from the galactic ISM is needed to match the observations. For the Milky Way-mass galaxies, escaped CRs can form crucial pressure support for the gas in the circum-galactic medium (CGM) and can regulate the nature of gaseous infall and galactic winds. CRs also effectively lower the temperature and density contrast of the gas in MW-mass halos. The effect of CRs on dwarf galaxies and on the high-redshift galaxy population is more limited owing to the small star formation efficieny and CR production in dwarf halos, and high gas densities in high-z CGM. The support for this emerging picture comes from a variety of observations, including the absorption lines from various ions and X-ray emission (caused by the inverse Compton scattering of CMB photons with the GeV CRs) from the CGM of low-redshift L* galaxies, which are better matched with simulations that include CRs compared to simulations without them.

09:30–10:00 **Christoph Pfrommer**

Probing Cosmic Ray Feedback in Galaxies Through Radio Emission: Understanding the processes underlying galaxy formation is one of the most important challenges in astrophysics. Unresolved questions include the disconnect between the short time scale of gas collapse on small scales and the long time scale for galaxy evolution, as well as the mechanism responsible for ejecting mass, momentum, and energy out of galaxies (or preventing their infall) in a way that matches the observed scaling relations. Recent progress strongly suggests that cosmic rays may play a crucial role in controlling these processes in and around galaxies. However, the strength of cosmic ray feedback depends very sensitively on the dynamical coupling of cosmic rays to the plasma. I will present our recent efforts to model cosmic rays and magnetic fields in galaxy formation. After identifying the different stages of a gravitationally driven magnetic dynamo that grows the field to the observed strengths, I will explain how cosmic rays interact with and propagate through the magnetized plasma in the interstellar and circumgalactic media. This demonstrates that cosmic rays play a decisive role in the formation and evolution of galaxies by providing feedback that regulates star formation and drives gas out in galactic winds. Comparing observational data to cosmic ray electron spectra that are obtained by solving the Fokker-Planck equation as well as a simplifying steady-state approximation, and studying the correlation of the far-infrared emission with the radio emission from galaxies enables us to test the cosmic-ray feedback and dynamo models for the growth of galactic magnetic fields. This argues that a complete understanding of galaxy formation necessarily includes these non-thermal components.

10:00–10:30 **Mark Krumholz**

Displaced non-thermal emission as a probe of cosmic ray transport: The past five years has seen the discovery of a growing list of sources of non-thermal emission where the peak of the emission is noticeably displaced from the likely accelerator of the particles powering that emission. These sources appear to be much more common at TeV than GeV energies, suggesting that the population is likely to grow substantially as the next generation of more sensitive TeV facilities come online. In this talk I present a model that explains the origin of these "displaced" sources and explains why they are more common at TeV than GeV energies. I show that displaced source represent a natural experiment that can be used to measure cosmic ray pitch angle scattering rates, and discuss prospects for using these natural experiments to gain insight into the physics of cosmic ray transport more broadly.

10:30–11:00 **Coffee Break & Group Photo**

11:00–11:30 **Mahboubeh Asgari-Targhi**

Braiding, Reflection, and Cascade: Alfvén Wave Turbulence in Closed and Open Solar Magnetic Fields: Photospheric convection continually braids solar magnetic fields by driving random transverse motions of flux-tube footpoints. These motions inject Alfvénic disturbances into both closed and open magnetic field lines. As the waves propagate through the strongly stratified solar atmosphere, gradients in the Alfvén speed and density cause partial reflection, generating counter-propagating wave packets. Their nonlinear interaction drives an anisotropic turbulent cascade to small perpendicular scales, where magnetic energy can be dissipated as heat. I will discuss reduced-MHD models that follow this sequence; braiding, reflection, and cascade, in closed and open solar magnetic structures. In closed fields, waves launched from both footpoints interact within confined magnetic fields, producing turbulent coronal heating. In open fields, footpoint-driven waves propagate into the extended corona and solar wind, while reflection supplies the inward-propagating component needed for turbulence. Comparing these cases shows how magnetic topology, expansion, stratification, and boundary driving shape the cascade and heating profile. The resulting Alfvénic fluctuation spectra can inform energetic-particle transport, including recent applications to Galactic cosmic rays and solar disk gamma-ray emission.

11:30–12:00 **Jamie Rankin**

Cosmic-Ray Transport Through a Reconfiguring, Multi-Regime Heliosphere: An Observational Perspective: Understanding cosmic-ray transport in the heliosphere is fundamentally constrained by the challenge of disentangling how particles are shaped not only by their sources, but by the time dependent, structured plasma environment through which they propagate. In this talk, I present an observationally driven perspective on cosmic-ray transport grounded in space based measurements spanning energies from a few MeV to ∼GeV, focused on lower-energy cosmic rays near the peak of the spectrum. I show how in situ observations reveal the heliosphere as a dynamic, multi-scale filter whose influence varies strongly with time, energy, and location, leaving distinct and measurable imprints on cosmic-ray intensities and spectra. At hundreds of MeV, transport signatures are especially sensitive to both transient solar wind structures and long term solar modulation driven by evolving conditions in the supersonic solar wind. Drawing targeted case studies from the near sun to the very local interstellar medium, I highlight how distinct plasma environments correspond to qualitatively different transport regimes. Finally, I discuss how heliospheric observations – with the advantage of locally measured plasma, magnetic fields, and multi-sourced particle populations – can inform broader astrophysical contexts, offering analogs for cosmic-ray transport in other stellar astrospheres and weakly magnetized plasma environments. Throughout the talk, I emphasize where present observations challenge common transport assumptions, identify opportunities where observations and modeling most directly intersect, and outline where key open questions remain.

12:00–12:20 **Zigong Xu**

Anomalous cosmic rays within the inner heliosphere by Solar Orbiter: Radial gradients of cosmic rays are key parameters for understanding the transport of particles in space. Solar Orbiter, launched on 2020 February 10, approaches the Sun approximately every half year, with a closest perihelion distance of 0.29 au after the end of 2022 during the nominal mission phase. The two double-ended high energy telescopes (HET) onboard the Solar Orbiter measure energetic particles in the energy range between a few MeV/nuc and a few hundred MeV/nuc, which are dominated by anomalous cosmic rays (ACRs) and galactic cosmic rays (GCRs) during solar quiet times. By obtaining the radial gradient of the ACR helium in the inner heliosphere, we advance our understanding of how the transport of the cosmic rays is affected by the particle drift effect and the large-scale magnetic field. The helium observations at Solar Orbiter/HET between 11.1 and 49 MeV/nuc are analyzed. Since we focus on quiet time measurements, we remove the periods of solar energetic particle (SEP) events. The intensities are averaged over the Carrington rotation period. The helium observations from the Proton and Helium Instrument (EPHIN) onboard SOHO were utilized as the baseline to correct the long-term variation caused by the solar modulations. We present the first observation of ACR helium at Solar Orbiter/HET between 2020 February and 2022 July in the inner heliosphere before the sun became fully active. We derive the radial gradient of the ACR helium between 0.3 and 1 au. The averaged radial gradient between 11.1 and 49 MeV/nuc is about 22 +-4 % / au and the averaged value between 11.1 and 41.2 MeV/nuc is raised to 32 +- 8 % / au after removing the GCR contribution, which is estimated by a GCR model. In addition, the temporal variation of radial gradients indicates that the gradients are increasing with the enhancement of the solar modulation and the increased tilt angle of the heliospheric current sheet.

12:20–12:35 **Sammy Siegel**

How do GCRs enter and move through a split-tail heliosphere?: The heliosphere is responsible for shielding the solar system from a large percentage of incident galactic cosmic rays (GCRs), but the mechanisms by which GCRs interact with a split-tail heliosphere have yet to be studied. We present work coupling a global, multi-ion, multifluid MHD model of the heliosphere with the SPECTRUM code to study the entry and modulation of GCRs in a split-tail heliosphere. The MHD model includes pickup-ions, Alfven-wave driven incompressible turbulence, latitude-dependent solar wind conditions based on 22-year averaged values, and a Smith-Bieber correction to the Parker solar magnetic field to account for fluctuations in the azimuthal component. We also track the boundaries of the sectored magnetic field regions. The MHD model is used as the background conditions for SPECTRUM, which solves the Parker Transport Equations for the propagation of GCRs. SPECTRUM uses information from the MHD solution to determine drifts and diffusion, providing a physically driven and self-consistent method for determining the influences on GCRs throughout the heliosphere. We highlight the MHD solution and our models for drifts and diffusion in SPECTRUM. We also showcase the resultant GCR spectra produced by SPECTRUM and discuss insights gleaned thus far.

12:35–14:00 **Group Lunch**

14:00–14:20 **Kung-Yi Su**

Modelling cosmic rays at AGN jet-driven shock fronts: We conduct high-resolution, non-cosmological magnetohydrodynamic (MHD) simulations of a massive halo using the FIRE-2 stellar feedback model. We explore AGN jet feedback with CRs by varying the CR energy fraction in jets, the CR coupling sites (in the vicinity of the black hole versus at the shock fronts of large-scale jet cocoons), and jet precession parameters. Our findings indicate that injecting CRs near the black hole efficiently inhibits accretion by lowering the local gas density before the jet propagates to large radii. This produces episodic accretion and leaves the jet with insufficient energy flux to reach large radii and impact cooling flows. By contrast, injecting CRs at the shock front of the jet cocoon sustains a higher jet energy flux for longer and disperses CRs to larger radii. This configuration more effectively suppresses the cooling flow. The period and angle of jet precession influence shock-front positions. We identify an optimal range of precession periods of order tens of Myr that places shocks in the inner circumgalactic medium (CGM), where cooling flows are most severe. We report that this configuration most effectively suppresses cooling flows and quenches star formation.

14:20–14:40 **Sam Ponnada**

Evidence for CR-supported $\sim L*$ Galaxy Halos via X-Ray and tSZ Constraints: Many state-of-the-art galaxy simulations featuring traditional feedback modes have significant challenges producing enough extended soft X-ray ($\sim$ 0.52 keV) emission at $R \sim 0.5R_{vir} - 1R_{vir}$ observed around galaxies with stellar masses $M* < 10^{11}M_{\odot}$, without violating galaxy mass function constraints. Moreover, thermal Sunyaev-Zel'dovich (tSZ) measurements probing the thermal pressure of similar galaxies indicate that it is lower than predictions from simple halo hydrodynamics and many hydrodynamical simulations. In this talk, I will demonstrate that these constraints can be met congruously with a large non-thermal pressure contribution in the form of cosmic rays (CRs) from supernovae and/or active galactic nuclei (AGN), which lowers the tSZ signal, while CR leptons produce plentiful soft X-rays via inverse Compton scattering of the cosmic microwave background. The combination of these two observations is far more constraining on the pressure budget of galactic halos than either alone-if these novel tSZ and X-ray observations are borne out by future studies, then taken together they reveal the strongest evidence for CR support in halos to date. Conversely, it is very difficult to produce the extended X-rays via traditional thermal emission without increasing the overall thermal pressure and thus tSZ signal in tandem, making these tensions even worse. Finally, tSZ and X-rays together unlock a novel observational method to constrain halo CR pressure relative to thermal pressure, with implications for CR transport parameters and AGN feedback energetics across various galaxy mass scales. Taking the currently observed constraints at $M_{halo} \sim 10^{12} M_\odot$ imply that the halo CR pressure must at least be equal to the gas thermal pressure.

14:40–14:55 **Yen-Hsing Lin**

FIR–γ Ray Relation of FIRE-2 Galaxies: Cosmic rays (CR) feedback could be one of the crucial physical processes that shapes the evolution of galaxies, yet the detailed mechanism of CR feedback remains poorly understood. One of the critical observational constrain is using $L_{\rm IR} - L_\gamma$ relation from nearby galaxies. However, this is often done in a simplistic manner in the literature where $L_{\rm IR}$ is converted into SFR by a simple linear relation, which could bias our interpretation. In this work, we analyzed a suite of cosmological zoom-in single-bin cosmic ray magnetohydrodynamics (CR-MHD) simulations with FIRE-2 feedback recipe to understand how would the non-trivial conversion between SFR and $L_{\rm IR}$ could impact our interpretation. We found that at the high luminosity end, heating from the old stellar population could increases $L_{\rm IR}$ by up to a factor of 2 at a given SFR comparing to the Kennicutt relation; while at the low luminosity end, a more leaky star-dust geometry could reduce $L_{\rm IR}$ by a factor of 10. We conclude that the non-linear relation between SFR and $L_{\rm IR}$ should be taken into consideration when trying to constrain κ using γ ray. Finally, the over-production of L_γ in the low luminosity end hints the requirement of higher effective diffusion coefficient or higher magnetic field strength in the dwarf regime.

14:55–15:10 **Noufel Dante Maalal**

On the True Interstellar Anisotropy of TeV Cosmic Rays and its Implications for the Local Interstellar Medium: We use Tibet $AS\gamma$ anisotropy data for 4 teraelectronvolt (TeV) cosmic rays to investigate the properties of the pitch-angle focusing and diffusion caused by the interstellar magnetic field and turbulence. First, the particle pitch-angle distribution in the local interstellar medium is reconstructed from the Tibet anisotropy map using the Liouville mapping method. Under the diffusion approximation, we found that the expected pitch-angle diffusion coefficient is an asymmetric function of particle pitch-angle. Without organized magnetic or cross helicities of interstellar magnetic field turbulence, such an asymmetry can be interpreted as evidence for focusing by a nonuniform interstellar magnetic field. A model incorporating a symmetric pitch-angle diffusion coefficient and focusing effects reproduces the observed pitch-angle distribution. The model fit indicates that the length of the magnetic field inhomogeneity is a few times the parallel mean free length of TeV cosmic rays, and that the interstellar field gets weaker along the field direction into the northern Galactic halo. The inferred particle pitch-angle diffusion coefficient suggests particle scattering by compressible magnetic field turbulence. Additionally, we estimate that the parallel and perpendicular cosmic ray intensity gradients have lengths of ~ 7.76 pc, $\sim 1.72\kappa_{29}$ kpc, respectively, where κ_{29} is the spatial diffusion coefficient in units of 10^{29} cm^2/s. Moreover, we have shown that the temporal rate of change is no more than $7.08 \times 10^{-7}/\kappa_{29}$ yr^{-1} in relative intensity.

15:10–15:25 **Souradeep Das**

Relaxation of Energy Constraints for Positrons Generating the Galactic Annihilation Signal: Even 50 years after the discovery of a positron annihilation line from the inner Galaxy, no class of astrophysical sources has emerged as a definitive explanation for both the emission morphology and flux. Positrons produced by dark matter annihilation or decay have been proposed, but the mass of any such candidate is constrained by continuum γ-ray emission at energies greater than 511 keV. Earlier analyses have claimed that this emission requires that the positrons have kinetic energies less than a few MeV at injection, disfavoring both much of the dark matter parameter space and many potential compact astrophysical source classes such as pulsars. However, these constraints were not based on a full forward model of the γ-ray line and continuum data, and did not marginalize over uncertainties about the relative angular distributions of the line and continuum. Here we describe an improved analysis that overcomes these limitations, and show that constraints on the injection energy are much weaker than previously claimed; even under conservative assumptions the data are consistent with initial energies up to $\sim$60 MeV.

15:25–15:50 **Coffee Break**

15:50–16:10 **Christopher Hirata**

Impact of cosmic rays on the pair beam instability from TeV blazars: TeV gamma rays from blazars interact with the extragalactic background light and produce ultrarelativistic, strongly forward-directed pairs. The (in)stability of these pair beams is important for intergalactic magnetic field (IGMF) constraints, the distribution of secondary gamma rays, and the thermal evolution of the intergalactic medium (IGM). Pair beams drive a linear instability of plasma oscillations at wave numbers of order the skin depth. We introduce another ingredient in the physics of pair beams: the cosmic ray electrons in the IGM. The MeV gamma ray background can Compton scatter off of thermal electrons in the IGM, thus acting as a "guaranteed" source of cosmic ray electrons even in regions of the IGM that have not yet been shocked. We estimate that these electron cosmic rays contribute of the IGM pressure of $\sim 2\%$ today. We find that these electrons cause linear Landau damping of plasma oscillations, leaving only a narrow region of k-space unstable. Despite this, the fraction of beam energy transferred into plasma waves if the IGM is unmagnetized is increased because the plasma oscillations that dominate the angular broadening of the beam are the most suppressed.

16:10–17:00 **Discussion Session**

End of Workshop