EP 2: Astrophysics II

Time: Monday 16:15–18:00 Location: KH 01.019

EP 2.1 Mon 16:15 KH 01.019

Modeling the low-ionization broad-line region in a sample of OI/CaII emitters detected by VLT/MUSE and DESI — •Tianyu Zhao — Institut für Astrophysik Georg-August-Universität Göttingen Friedrich-Hund-Platz 1 D-37077 Göttingen Germany

Broad emission-line (BEL) profiles in active galactic nuclei (AGN) contain information about the structure and kinematics of the broad-line region (BLR), where these lines are emitted, as the BEL shape is governed by the BEL-emitting gas moving in the potential of the supermassive black hole (SMBH). The study of BEL profiles is thus a powerful tool to study accretion processes onto SMBHs. However, for the largest part of the AGN population, it is impossible to directly *read-of* information from the line profiles as additional effects such as turbulence or optical-depths effects distort the clear kinematic signature of the moving BLR gas. Only recently, the profiles of O I 8446 and the near-infrared Ca II triplet have been recognized as a powerful diagnostic tool for BLR kinematics, because these line presumably arise in the dense atmosphere/corona of the accretion disk. Novel studies suggest, that these line are not significantly influenced by internal turbulence, thus clearly revealing the kinematic signature*namely double-peaked profiles*of a line-emitting BLR disk. In this master*s thesis, I aim to extend the sample of known OI and Ca II emitters with complex, i.e., not single-peaked, profiles, and constrain the kinematics of the OI/CaII-emitting regions.

EP 2.2 Mon 16:30 KH 01.019

A Three-Dimensional Tomographic Map of Galactic Cosmic-Ray Proton Density — •Hanieh Zandinejad and Torsten Ensslin — Max Planck Institute for Astrophysics, Karl-Schwarzschild-Str. 1, 85741 Garching

Cosmic rays (CRs) are a ubiquitous non-thermal component of the interstellar medium in the Galaxy. While their number density can be inferred from local measurements on Earth, their three-dimensional distribution has largely been explored through simulations. A data-driven three-dimensional map of CRs is therefore essential to better understand their spatial distribution and the locations of their sources.

We infer the spatial distribution of cosmic-ray protons (CRp) by exploiting diffuse gamma-ray emission produced in inelastic hadronic collisions of CRs with interstellar gas. Using gamma-ray data from the Fermi Large Area Telescope together with a three-dimensional gas map, we reconstruct the CRp density in a morphological matching approach based on numerical methods from information field theory. The resulting three-dimensional CRp density is obtained as an ensemble of posterior samples, whose variance quantifies statistical uncertainties and whose mean is consistent with local cosmic-ray proton measurements.

In this talk, I will outline the construction of the prior model, present the morphological matching approach, and discuss the resulting three-dimensional CRp density map, highlighting current challenges in cosmic-ray tomography and the status of the project.

EP 2.3 Mon 16:45 KH 01.019

Accretion Regimes of Neutrino-Cooled Flows onto Black Holes — •Javiera Hernández Morales[1] and Daniel Siegel[1,2] — [1]University of Greifswald — [2]University of Guelph

Neutrino-cooled accretion disks can form in the aftermath of neutron-star mergers as well as during the collapse of rapidly rotating massive stars and the accretion-induced collapse of rapidly rotating white dwarfs. At sufficiently high accretion rates, electrons present in the disk become degenerate, which leads to the neutronization of the accreting plasma and makes these astrophysical systems promising sources of rapid neutron-capture nucleosynthesis (the r-process). We present a one-dimensional, general-relativistic, viscous-hydrodynamic model of neutrino-cooled accretion disks around black holes. We chart the composition of the accretion flow and systematically explore a vast parameter space of accretion rates of $\dot{M} \sim 10^{-6} - 10^{6} M_\odot\,\mathrm{s}^{-1}$, black hole masses of $M_\bullet \sim 1 - 10^4 M_\odot$, dimensionless spins of $\chi_\bullet \in [0, 1)$, and α-viscosity values of $\alpha \sim 10^{-3} - 1$. We find that outflows from such disks are promising sites for r-process nucleosynthesis up to $M_\bullet \lesssim 3000 M_\odot$. These give rise to lanthanide-bearing ‘red’ super-kilonovae transients mostly for $M_\bullet \lesssim 200 - 500 M_\odot$ and lanthanide-suppressed ‘blue’ super-kilonovae for larger $M_\bullet$. Proton-rich outflows can develop specifically for large black hole masses ($M_\bullet \gtrsim 100 M_\odot$) in certain accretion regimes, which may give rise to proton-rich isotopes via neutrino-induced proton-capture nucleosynthesis (the νp-process). We test some of these scenarios by following the trajectories of potential disk winds with the nuclear reaction network WinNet.

EP 2.4 Mon 17:00 KH 01.019

R-process nucleosynthesis in collapsar accretion disk outflows and cosmic chemical evolution — •Aman Agarwal[1] and Daniel Siegel[1,2] — [1]Institute of Physics, University of Greifswald, D-17489 Greifswald, Germany — [2]Department of Physics, University of Guelph, Guelph, Ontario, Canada, N1G 2W1

The collapse of rapidly rotating massive stars (“collapsars”; $M_\mathrm{ZAMS} \lesssim 40 M_\odot$ at birth) are leading models for long gamma-ray burst (GRBs) central engines and promising sources of neutron-rich environments for r-process nucleosynthesis. Here, we extend the range of collapsars and explore collapsar accretion disk flows around black holes of mass $M_\bullet = 3 - 3000\ M_\odot$ using long-term, three-dimensional general-relativistic magnetohydrodynamics simulations with weak interactions and find that the accretion flows neutronize above an “ignition” accretion rate $\dot{M}_\mathrm{ign}$. We present remarkable agreement between our simulations and the analytic result $\dot{M}_\mathrm{ign} \propto \alpha^{5/3} M_\bullet^{4/3}$ with α_eff being the effective Shakura-Sunyaev viscosity. We demonstrate by semi-analytical modeling that stellar models of $\sim 250 - 10^5\ M_\odot$ mass can give rise to BHs of $M_\bullet \sim 30 - 1000\ M_\odot$ accreting at $\dot{M} \gtrsim \dot{M}_\mathrm{ign}$, yielding $\sim 10 - 100\ M_\odot$ of r-process elements per event. We highlight their potential as multi-messenger sources of optical/IR transients (“super-kilonovae”) and gravitational waves (GWs) for third-generation (3G) GW detectors. Using a one-zone chemical evolution model and a projection of future 3G GW and abundance observations, we demonstrate a correlation technique to infer the percentage contribution of multiple sources to galactic and cosmic r-process enrichment.

EP 2.5 Mon 17:15 KH 01.019

Differential Rendering of the Night Sky in Imaging Atmospheric Cherenkov Telescopes — •Gerrit Roellinghoff and Stefan Funk — Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen Centre for Astroparticle Physics, Nikolaus-Fiebiger-Str. 2, 91058 Erlangen, Germany

Imaging Atmospheric Cherenkov Telescopes detect Cherenkov light against an irreducible optical background stemming from the night sky, e.g. from stars, airglow, zodiacal light and moonlight. We present a differentiable forward model for predicting this pixel-wise night sky background. The model includes single-scattering atmospheric radiative transfer and ray-traced instrument responses and spectrally models major contributors. Automatic differentiation enables gradient computation with respect to physical parameters such as aerosol optical depth and pointing offsets. This allows for efficient recovery of atmospheric and instrumental parameters from measured data, providing a new approach to instrument calibration for current and future IACT arrays.

EP 2.6 Mon 17:30 KH 01.019

Bayesian imaging of cosmic-ray air showers — •Mrinal Jetti — Max Planck Institute for Astrophysics, Karl-Schwarzschild-Str. 1, 85748 Garching, Germany

High-energy cosmic rays interacting with Earth’s atmosphere generate cascades of secondary particles known as extensive air showers. The electromagnetic component of these showers, consisting primarily of electrons, positrons, and photons, emits coherent, pulsed radio signals. Imaging air showers via their radio emission to infer the shower’s structure and its development and, ultimately, the properties of the primary cosmic-ray particle remains a long-standing problem, with several classical reconstruction methods having been developed.

This project aims to image extensive air showers using their radio emission, measured as time-dependent electric field traces recorded by ground-based antenna arrays. The air shower is modeled as a system of relativistically moving current distributions that give rise to the observed radio signal. Using Bayesian inference within the framework of Information Field Theory, implemented within the Python package NIFTy (Numerical Information Field Theory), the inverse problem of reconstructing the underlying current distributions from the measured electric field traces is addressed.

EP 2.7 Mon 17:45 KH 01.019

Observations of the dark matter halo of the Andromeda Galaxy with INTEGRAL/SPI — •Laura Eisenberger, Thomas Siegert, Saurabh Mittal, Rudi Reinhardt, Dimitris Tsatsis, Niklas C. Bauer, Patrik Ehrmann, and Manja Zimmerer — Julius-Maximilians-Universität Würzburg, Fakultät für Physik und Astronomie, Institut für Theoretische Physik und Astrophysik, Lehrstuhl für Astronomie, Emil-Fischer-Str. 31, 97074 Würzburg

The Andromeda galaxy (M31) is a promising target for the indirect search of dark matter (DM) due to its proximity and expected massive DM halo. It functions as test case for a Milky Way (MW) like galaxy as the isotropic emission from the MW halo itself cannot be measured without large efforts with coded mask telescopes. Since weakly interacting massive particles also produce a significant flux of secondary MeV photons from inverse Compton scattering and positron annihilation, γ-ray observations in the MeV range are a powerful probe of DM with a wide mass range from MeV up to TeV.

We use the spectrum obtained from SPI observations of the M31 region including M33 in order to constrain different DM models. We model the halos of M31 and M33 as extended emission and take the uncertainty of the DM distribution into account by considering different density profiles and substructure boosting. From the 511 keV line from positron annihilation, we estimate the pair production rate in M31 to put a lower mass limit on thermal DM. With forthcoming missions like COSI-SMEX, a coherent multi-galaxy analysis promises to significantly improve upon existing DM constraints.