Probing fundamental physics with multiwavelength observations

Instructor: Marco Chianese

11–22 Mar 2024, Theoretical Aspects of Astroparticle Physics, Cosmology and Gravitation
Galileo Galilei Institute, Firenze

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NAP Theory

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GGI lectures on the theory of fundamental interactions 2015

Exercise: supervised brainstorming and discussion

Aim

- Fostering profound discussions on hot topics in current research

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- You will be divided in groups and assigned a *seminal paper* on one of the course topics
- Study the paper in detail, come up with open questions to be answered, and propose potential follow-ups and directions to be explored
- **Do not cheat:** don't search the paper online (arXiv, inspire, google,…) – think and discuss!

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Output

✦ *Very informal presentations* describing the group activity you have done

Timeline

Monday		Wednesday	
14:30 - 15:00	*15:00 - 17:30*	*14:30 - 16:00*	*16:30 - 17:30*
Class	Office hours	Class: presentations + discussions	

- ✦ **Office hours (and not only):** come to us (*room 105*) to ask any kind of questions **at any time!**
- ✦ **Presentations:** arrange an informal group presentation to all of us (*max. 15 minutes*) with the help of the blackboard (no slides)
- ✦ Most importantly, collaborate and discuss among yourself during the school

Informal presentation

Schematically present your brainstorming work, e.g. addressing the following issues:

1. Briefly describe the context and the methodology of the paper, and highlight its main results and take-home messages.
2. How can multiwavelength observations be employed to further investigate the scenario discussed in the paper?
3. What are the possible interesting (new) directions one can explore with current and future data?
4. Does the paper have implications to other astrophysical and cosmological observables?
5. ……

Paper 1

PHYSICAL REVIEW LETTERS **122,** 171801 (2019)

Novel Direct Detection Constraints on Light Dark Matter

Torsten Bringmann[1] and Maxim Pospelov[2,3]

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(Received 5 November 2018; published 1 May 2019)

All attempts to directly detect particle dark matter (DM) scattering on nuclei suffer from the partial or total loss of sensitivity for DM masses in the GeV range or below. We derive novel constraints from the inevitable existence of a subdominant, but highly energetic, component of DM generated through collisions with cosmic rays. Subsequent scattering inside conventional DM detectors, as well as neutrino detectors sensitive to nuclear recoils, limits the DM-nucleon scattering cross section to be below 10^{-31} cm^2 for both spin-independent and spin-dependent scattering of light DM.

DOI: 10.1103/PhysRevLett.122.171801

Paper 2

VOLUME 83, NUMBER 9 PHYSICAL REVIEW LETTERS 30 AUGUST 1999

Dark Matter Annihilation at the Galactic Center

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(Received 24 March 1999; revised manuscript received 24 June 1999)

Cold dark matter near the galactic center is accreted by the central black hole into a dense spike. Particle dark matter annihilation makes the spike a compact source of photons, electrons, positrons, protons, antiprotons, and neutrinos. The spike luminosity depends on the halo density profile: halos with finite cores have unnoticeable spikes; halos with inner cusps may have spikes so bright that the absence of a neutrino signal from the galactic center already places upper limits on the density slope of the inner halo. Future neutrino telescopes observing the galactic center could probe the inner structure of the dark halo or indirectly find the nature of dark matter.

Paper 3

The Astrophysical Journal, 836:47 (9pp), 2017 February 10
doi:10.3847/1538-4357/836/1/47

CrossMark

Evidence against Star-forming Galaxies as the Dominant Source of Icecube Neutrinos

Keith Bechtol[1,2], Markus Ahlers[1,2], Mattia Di Mauro[3,4,5], Marco Ajello[6], and Justin Vandenbroucke[1,2]

Abstract

The cumulative emission resulting from hadronic cosmic-ray interactions in star-forming galaxies (SFGs) has been proposed as the dominant contribution to the astrophysical neutrino flux at TeV to PeV energies reported by IceCube. The same particle interactions also inevitably create γ-ray emission that could be detectable as a component of the extragalactic γ-ray background (EGB), which is now measured with the *Fermi*-LAT in the energy range from 0.1 to 820 GeV. New studies of the blazar flux distribution at γ-ray energies above 50 GeV place an upper bound on the residual non-blazar component of the EGB. We show that these results are in strong tension with models that consider SFGs as the dominant source of the diffuse neutrino backgrounds. A characteristic spectral index for parent cosmic rays in starburst galaxies of $\Gamma_{SB} \simeq 2.3$ for $dN/dE \propto E^{-\Gamma_{SB}}$ is consistent with the observed scaling relation between γ-ray and IR luminosity for SFGs, the bounds from the non-blazar EGB, and the observed γ-ray spectra of individual starbursts, but underpredicts the IceCube data by approximately an order of magnitude.

Paper 4

THE ASTROPHYSICAL JOURNAL, 699:L59–L63, 2009 July 10
doi:10.1088/0004-637X/699/2/L59

SECONDARY RADIATION FROM THE PAMELA/ATIC EXCESS AND RELEVANCE FOR *FERMI*

E. BORRIELLO[1], A. CUOCO[2], AND G. MIELE[1]

ABSTRACT

The excess of electrons/positrons observed by the Pamela and ATIC experiments gives rise to a noticeable amount of synchrotron and inverse Compton scattering (ICS) radiation when the e^+e^- interact with the Galactic magnetic field, and the interstellar radiation field (ISRF). In particular, the ICS signal produced within the weakly interacting, massive particle annihilation interpretation of the Pamela/ATIC excess shows already some tension with the EGRET data. On the other hand, one year of *Fermi* data taking will be enough to rule out or confirm this scenario with a high confidence level. The ICS radiation produces a peculiar and clean "ICS Haze" feature, as well, which can be used to discriminate between the astrophysical and dark matter (DM) scenarios. This ICS signature is very prominent even several degrees away from the galactic center, and it is thus a very robust prediction with respect to the choice of the DM profile and the uncertainties in the ISRF.

Paper 5

The Astrophysical Journal Letters, 771:L34 (6pp), 2013 July 10 doi:10.1088/2041-8205/771/2/L34

MEASUREMENT OF THE EXPANSION RATE OF THE UNIVERSE FROM γ-RAY ATTENUATION

Alberto Domínguez[1] and Francisco Prada[2,3,4]

ABSTRACT

A measurement of the expansion rate of the universe (that is, the Hubble constant, H_0) is derived here using the γ-ray attenuation observed in the spectra of γ-ray sources produced by the interaction of extragalactic γ-ray photons with the photons of the extragalactic background light (EBL). The Hubble constant determined with our technique, for a ΛCDM cosmology, is $H_0 = 71.8^{+4.6}_{-5.6}(\text{stat})^{+7.2}_{-13.8}(\text{syst})$ km s^{-1} Mpc^{-1}. This value is compatible with present-day measurements using well-established methods such as local distance ladders and cosmological probes. The recent detection of the cosmic γ-ray horizon (CGRH) from multiwavelength observations of blazars, together with the advances in the knowledge of the EBL, allow us to measure the expansion rate of the universe. This estimate of the Hubble constant shows that γ-ray astronomy has reached a mature enough state to provide cosmological measurements, which may become more competitive in the future with the construction of the Cherenkov Telescope Array. We find that the maximum dependence of the CGRH on the Hubble constant is approximately between redshifts 0.04 and 0.1, thus this is a smoking gun for planning future observational efforts. Other cosmological parameters, such as the total dark matter density Ω_m and the dark energy equation of state w, are explored as well.