Fermi Summer School 2014

Week 1

	Tues, May 27	Wed, May 28	Thurs, May 29	Fri, May 30	Sat, May 31
8:00	**Breakfast**	**Breakfast**	**Breakfast**	**Breakfast**	**Breakfast**
9:00	The Fermi Mission - Julie McEnery	Fermi AGN Science - Chuck Dermer (pdf)(ppt)	Gamma-ray Binaries I - Guillaume Dubus (pdf)	Gamma-ray Binaries II - Guillaume Dubus (pdf)	Surveying the Sky with CTA - Guillaume Dubus (pdf)
10:00	Space-Based Gamma-ray Astronomy - Liz Hays	The Galactic Center at GeV - Jack Hewitt	SNRs - Daniel Castro (pdf)	Particle Acceleration in SNR - Daniel Castro (pdf)	Dark Matter - Matt Wood (pdf)
11:00	**Break**	**Break**	**Break**	**Break**	**Break**
11:30	Fermi Science: A Theoretical Perspective - Chuck Dermer (pdf)(ppt)	LAT Overview - Matt Wood (pdf)	Lat Performance - Matt Wood (pdf)	Ground-based Gamma-ray Astronomy - Karl Kosack	Student Talks 1 Slide Summaries
12:30	**Lunch**	**Lunch**	**Lunch**	**Lunch**	**Lunch**
1:30	The Likelihood Method - Liz Hays (courtesy Steve Fegan's 2013 presentation) Steve's sample code: - errors_poisson.py - lima.py - conf_lima_1d.py - ul_lima_1d.py - ul_bayes_lima_1d.py Science Tools Intro and Data Exploration - Elizabeth Ferrara	Likelihood in the LAT - Jeremy Perkins Likelihood Tutorial - Jeremy Perkins	LAT XML Models/LAT Catalogs - Elizabeth Ferrara Advanced Likelihood - Jeremy Perkins Code to Install: - LATAnalysisScripts - gtapps_mp Data: - Advanced_Likelihood.tgz	Student Talks LAT Systematics - Jack Hewitt (includes calculation of the pivot energy on slide 9)	1 Slide Summaries (cont) Advanced Tutorials ▪ Pulsar Analysis prep ▪▪ Files ▪ Spatially Extended Sources (A work in progress. email me with bugs or suggestions – Jack) Student Projects
				Crab Feast	

Week 2

	Mon, June 2	Tues, June 3	Wed, June 4	Thurs, June 5	Fri, June 6
8:00	**Breakfast**	**Breakfast**	**Breakfast**	**Breakfast**	**Breakfast**
9:00	The Galactic Center at TeV Energies - Karl Kosack	Fermi GBM and GBM Burst Catalog - Adam Goldstein	Pulsar Observations - Elizabeth Ferrara	HAWC - Miguel Mostafa (pdf)	Final Wrap-up
10:00	Pulsars from a Theoretical Perspective - Alice Harding	GRBs in the Fermi LAT - Judy Racusin	Cosmic Rays from an Observational Perspective - Scott Wakely (pdf)	CTA and the Future - Karl Kosack	Project Results and Feedback
11:00	**Break**	**Break**	**Break**	**Break**	**Break**
11:30	Student Talks 1 Slide Summaries	GRBs from a Theoretical Perspective - Chuck Dermer (pdf) (ppt)	Student Talks	Cosmic-rays and Balloon-based Instrumentation - Scott Wakely (pdf)	Workshop Close Out
12:30	**Lunch**	**Lunch**	**Lunch**	**Lunch**	**Lunch**

1:30	Multiwavelength Analysis Tutorial - Judy Racusin Files
	
	Hardware Topics - Jamie Holder
	
	Advanced Topics
	
	▪ Lightcurves
	▪ (Source Localization)
	▪ (Data Exploration: beyond the science tools)
		Free	1 Slide Summaries
			
			Advanced Topics
			
			▪ Composite and Summed Likelihood
			  ▪ Data Files
			▪ Pulsar Analysis
			  ▪ tempo2 supplement
				TevCat Tutorial - Scott Wakely
				
				Advanced Topics	

			BBQ		

Student Talks and 1 Slide Schedule

Fri. May 30

- Frederic Jaron --- A new gamma-ray feature in LS I +61°303. Abstract **>>** Slides

> LS I +61°303 is a stellar binary system consisting of a rapidly rotating Be star and a compact object in an eccentric orbit. It presents periodic emission from radio to gamma-rays and is one of a handful of known gamma-ray binaries. The presence of two periodicities in the radio emission sets this source apart from the other gamma-ray binaries. One is the orbital period P1 = 26.4960 +/- 0.0028 days, and the other is a superorbital modulation of the radio outbursts with period Plong = 1667 +/- 8 days. Recently, the long-term modulation has also been found in the Fermi-LAT gamma-ray light curve. We present our latest results.

- Annika Kreikenbohm --- Multiwavelength observations of the -NLS1 galaxy PKS2004-447. Abstract **>>** Slides

> The five most enigmatic members of the class of narrow-line Seyfert 1 galaxies are objects which exhibit both, bright radio and gamma-ray emission (hereafter -NLS1s). This demonstrates the existence of powerful relativistic jets similar to blazars and radio galaxies. But whether -NLS1s really define a distinct sub-class of active galaxies is still under debate. As the radio-loudest of all -NLS1s, PKS 2004447 plays a key role in settling this debate. I present results from radio and X-ray observations of PKS 2004-447: the TANAMI VLBI program finds a high brightness-temperature core and a one-sided parsec-scale jet while Swift and XMM-Newton observations reveal a moderately variable unobscured X-ray spectrum, which is dominated by a flat power-law component. Furthermore, the -ray properties of PKS2004-447 are briefly reviewed and results are put in context with the other four known -NLS1.

- Xilu Wang --- Gamma Ray Emission From Starburst Galaxies. Abstract **>>** Slides (pptx)

> In star-forming galaxies, gamma rays are mainly produced through the collision of high-energy protons in cosmic rays and protons in the interstellar medium (ISM) (i.e. cosmic ray- induced pi0-radiation). For a "normal" star-forming galaxy like the Milky Way, most cosmic rays escape the Galaxy before such collisions, but in starburst galaxies with dense gas and huge star formation rate, most cosmic rays do suffer these interactions. We construct a "thick-target" model for starburst galaxies, in which cosmic rays are accelerated by supernovae, and escape is neglected. This model gives an upper limit to the gamma-ray emission and tests the calorimetry relation between gamma rays and cosmic rays for starbursts. Only two free parameters are involved in the model: cosmic-ray proton acceleration energy rate from supernova and the proton injection spectral index. We apply the model to five observed starburst galaxies: M82, NGC 253, NGC 1068, NGC 4945 and Circinus, and find the calorimetric relation holds for most of the starbursts, but for Circinus, other gamma-ray sources must be presented to explain for its GeV excess. The pionic gamma-ray emission is calculated from 10 MeV to 10 TeV, which covers the Fermi Gamma-ray Space Telescope (Fermi) energy range.

Sat. May 31

- Nicolas Canac --- Astrophysical and Dark Matter Interpretations of Extended Gamma Ray Emission from the Galactic Center. Abstract **>>**

> We construct empirical models of the diffuse gamma-ray background toward the Galactic Center. Including all known point sources and a template of emission associated with interactions of cosmic rays with molecular gas, we show that the extended emission observed previously in the Fermi Large Area Telescope data toward the Galactic Center is detected at high significance for all permutations of the diffuse model components. However, we find that the fluxes and spectra of the sources in our model change significantly depending on the background model. In particular, the spectrum of the central Sgr A_ source is less steep than in previous works and the recovered spectrum of the extended emission has large systematic uncertainties, especially at lower energies. If the extended emission is interpreted to be due to dark matter annihilation, we find annihilation into pure b-quark and _-lepton channels to be statistically equivalent goodness-of-fits. In the case of the pure b-quark channel, we find a dark matter mass of 39.4(+3.7_2.9 stat.)(±7.9 sys.) GeV, while a pure _+__ channel case has an estimated dark matter mass of 9.43(+0.63_0.52 stat.)(±1.2 sys.) GeV. Alternatively, if the extended emission is interpreted to be astrophysical in origin such as due to unresolved millisecond pulsars, we obtain strong bounds on dark matter annihilation, although systematic uncertainties due to the dependence on the background models are significant.

- Tansu Daylan --- The Characterization of the Gamma-Ray Signal from the Central Milky Way: A Compelling Case for Annihilating Dark Matter. Abstract **>>** Slides

> Past studies have identified a spatially extended excess of ~1-3 GeV gamma rays from the region surrounding the Galactic Center, consistent with the emission expected from annihilating dark matter. We revisit and scrutinize this signal with the intention of further constraining its characteristics and origin. By applying cuts to the Fermi event parameter CTBCORE, we suppress the tails of the point spread function and generate high resolution gamma-ray maps, enabling us to more easily separate the various gamma-ray components. Within these maps, we find the GeV excess to be robust and highly statistically significant, with a spectrum, angular distribution, and overall normalization that is in good agreement with that predicted by simple annihilating dark matter models. For example, the signal is very well fit by a 31-40 GeV dark matter particle annihilating to b quarks with an annihilation cross section of sigma v = (1.4-2.0) x 10^-26 cm^3/s (normalized to a local dark matter density of 0.3 GeV/cm^3). Furthermore, we confirm that the angular distribution of the excess is approximately spherically symmetric and centered around the dynamical center of the Milky Way (within ~0.05 degrees of Sgr A*), showing no sign of elongation along or perpendicular to the Galactic Plane. The signal is observed to extend to at least 10 degrees from the Galactic Center, disfavoring the possibility that this emission originates from millisecond pulsars.

- Lelah Sadeghian --- Dark matter distributions around massive black holes: A fully general relativistic approach. Abstract **>>** Slides

> The cold dark matter at the center of a galaxy will be redistributed by the presence of a massive black hole. The redistribution may be determined by beginning with a model distribution function for the dark matter, and “growing” the black hole adiabatically, holding the adiabatic invariants of the motion constant. Unlike previous approaches, which adopted Newtonian theory together with ad hoc correction factors to mimic general relativistic effects, we carry out the calculation fully relativistically, using the exact Schwarzschild geometry of the black hole. We consider a range of initial distribution functions, including “cuspy” profiles, and find that the density spike very close to the black hole is significantly higher than that found previously by Newtonian analyses. The potential implications for detection of signals from galactic center dark matter will be discussed.

- 1 Slide:
  - Regina Caputo (pdf)
  - Rafal Wojaczynski (pdf)
  - Noel Klingler (pdf)

Mon. June 2

- Siraprapa Sanpa-arsa --- Green Bank Telescope (GBT) Radio Millisecond Pulsars Searches in Fermi unassociated LAT sources. Abstract **>>** Slides

> After Fermi launched in 2008, it has revolutionized gamma-ray pulsar astronomy, by enabling the discovery of many new millisecond pulsars (MSPs). The Fermi Pulsar Search Consortium (PSC) has organized hundreds of radio observations of pulsar-like Large Area Telescope (LAT) unassociated gamma-ray sources. In about 4 years, the PSC has discovered 64 new MSPs. These new discoveries number more than all MSPs in the first 20 years (from 1982 to 2002) of MSP searching combined. Notably, among the 64 new MSPs, there are at least 13 “black widows” and 4 “redbacks” (the rare populations of eclipsing pulsar binaries). As one of the PSC radio telescopes, the Green Bank Telescope (GBT) has, outstandingly, helped uncover 35 new MSPs. By searching more Fermi unassociated sources from the LAT 1-year, 2-year and soon 3-year Point Source Catalog, the GBT will almost certainly discover additional MSPs. The newly discovered MSPs will provide more potential additions to the pulsar timing arrays (like NANOGrav) as well as improve the understanding of MSP formation and evolution.

- Andrew McCann --- VHE Emission from Gamma-ray pulsars. Abstract **>>** Slides

> NASA's Fermi space telescope has provided us with a bountiful new population of gamma-ray sources following its discovery of 140 new gamma-ray pulsars. One common feature exhibited by all of these pulsars is the form of their spectral energy distribution, which can be described by a power law followed by a spectral break occurring between ~1 and ~8 GeV. The unanimity of the break energy across the entire Fermi pulsar sample suggests that the sites of acceleration and processes of gamma-ray emission are common across the different pulsar types. The common wisdom is that the break is followed by an exponential cut-off driven by radiation/reaction-limited curvature emission. The discovery of pulsed gamma rays from the Crab pulsar, the only pulsar so far detected at very high energies (E>100GeV), contradicts this "cut-off" picture. In this talk I will review, from an observational stand point, what we know about the emission of pulsars at VHE energies.

- 1 Slide:
  - Jezebel Rodriguez Garcia (pdf)
  - Ori Weiner (pdf)
  - Juliana Vievering (ppt)
  - Stanislav Stefanik (pdf)

Wed. June 4

- Björn Ahlgren --- Photospheric emission in gamma-ray bursts. Abstract **>>** Slides

> This is a short review of the current status of the research on photospheric prompt emission in gamma-ray bursts (GRBs). While GRB spectra are usually fitted with Band functions, these give little understanding of the underlying emission mechanisms, which has prompted several new approaches to the problem. With the analysis of FERMI data and numerical simulations of GRB prompt emission, the aim is to be able to produce both light curves and spectral curves and to be able to fully explain the phenomenon. In this talk I will focus on models for subphospheric dissipation, in which dissipation of kinetic energy below the photosphere gives rise to spectra which can differ significantly from a simple blackbody. In particular, I will discuss how different parameters such as the Lorentz factor and the optical depth at which the dissipation occurs affect the resulting spectra. My current work involves fitting such models to data for the first time.

- Lee Yacobi --- Constraints on the hadronic content of Fermi GRBs. Abstract **>>** Slides (pptx)

> Recently the Fermi-LAT has detected approximately 35 GRBs with gamma ray emission above 100 GeV. Several models have been proposed to explain this high-energy emission, including hadronic models, where photon-hadron process produces charged pions and subsequently the 100 TeV neutrinos. We are using the data from Fermi-GBM to calibrate the photon (representing electrons) energy content of the GRB jet. Given the non-detection of GRB neutrinos, we aim to put upper limits on the proton (turned pion) energy content. The same photon-hadron process that is expected to produce the charged pions and subsequently the 100 TeV neutrinos, would also generate neutral pions that decay to photons of similar energy. These high-energy photons have been hypothesized to cascade through pair production processes down to the GeV regime, where they can escape the jet and be observed by Fermi-LAT. These high-energy photons have been hypothesized to cascade through pair production processes down to the GeV regime, where they can escape the jet and be observed by Fermi-LAT. Within this scenario, we are using the observed GeV photon fluence to put another upper limit on the energy content of the protons in the jet. Within this scenario, we are using the observed GeV photon fluence to put another upper limit on the energy content of the protons in the jet.

- Henrike Fleischhack --- A template method for measuring the iron spectrum in cosmic rays with Cherenkov telescopes. Abstract **>>** Slides

> The energy-dependent abundance of elements in cosmic rays is an important part of the understanding of acceleration and propagation of cosmic rays. Imaging Air Cherenkov Telescopes, used mainly in gamma ray astronomy, can measure the direct Cherenkov light emitted by heavy nuclei as well as the Cheronkov light emitted by their air showers. Thus they are sensitive to the charge of the primary particles. I will introduce a template method that can be used to reconstruct charge and energy of primary particles simultaneously. With this, we can separate heavy nuclei from lighter cosmic rays, and thus measure the abundance and spectrum of these nuclei in the range of tens to hundreds of TeV.

- 1 Slide:
  - Kimberly Zoldak (pptx)
  - Ramesh Koirala (ppt)
  - James Lau (pdf)

Supporting Material

Really useful usage notes page for likelihood tools! [Likelihood Usage Notes]

Liz's favorite page on livetime and exposure: [http://fermi.gsfc.nasa.gov/ssc/data/analysis/documentation/Cicerone/Cicerone_Likelihood/Exposure.html]

Things to do and Eat

These are places we've gone in the past for food:

- These are close by (walking, bike ride)
  - Rose & Crown (http://roseandcrownlewes.com)
  - Striper Bites (http://www.striperbites.com)
  - The Buttery (https://butteryrestaurant.com)
  - Notting Hill Coffee (http://www.nottinghillcoffee.com)
  - Half Full (http://www.halffulllewes.com)
  - Kindle (http://www.kindlerestaurant.com)
  - Jerry's Seafood (http://www.jerrys-seafood.com)
  - Gilligan's (http://gilliganswaterfront.com/home.html)
  - King's Ice Cream (http://www.kings-icecream.com/)
- These need a car to get to
  - Dogfish Head (worth at least one trip if you like beer: http://www.dogfish.com/restaurant/index.htm)
  - JD's Filling Station (http://www.jdsfillingstation.com)
  - There are lots of restaurants along Coastal Highway (Route 1) but need a car.
  - If you're looking for a trip for dinner, head to Rehoboth.

Some useful shops:

- R&L Liquors (207 Second Street)
- Rite Aid Pharmacy (444 Savannah Road, probably need a car)
- Ocean Suds II Laundromat (18675 Coastal Highway)

Things to do. Basically, I know these have been done, ask for details.

- Fishing Trip (on a boat!)
- Take the Ferry to Cape May
- Rent Kayaks (http://www.eastofmaui.com/)
- Cape Henlopen
- Check out Rehoboth
- Dogfish Head Brewery Tour (not the restaurant) (http://www.dogfish.com/community/tours/index.htm)
- Rent Bikes