
KIPAC Theory

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KIPAC Theory Program
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Current Resources & People

- Faculty: (2 FTE equivalent, SLAC funded at 50%)
 - Roger Blandford
 - Tom Abel
 - Risa Wechsler (Head of KIPAC Theory)
 - Leonardo Senatore (Fall 2010)
- Postdocs: (3 FTE equivalent)
 - Oliver Hahn (dark energy / simulations, weak lensing)
 - Matteo Barnabe (dark matter & energy with strong lensing)
 - Brian Gerke (FY10 dark energy) Nadia Zakamska (FY11 high energy astrophysics)
 - SciDAC / Shizuka Akiyama (FY10), Johnathan McKinney (FY11)
 - + theory effort from other KIPAC postdocs / Seghal, Strigari, Busha, Marshall
- Students: (3 FTE equivalent)
 - Hao-Yi Wu (Dark Energy related theory with Wechsler)
 - Ji-Hoon Kim, Peter Behroozi (Numerical simulations with Abel/Wechsler)
 - Paul Simeon (High Energy Astrophysics Theory with Blandford)
- Primary efforts: dark energy, dark matter, inflation, numerical simulations; interpretation of data from Fermi and future projects (e.g. DES, LSST)

Dark Energy

- Precision measurements of the Hubble Constant and DE eq. of state from lensing
 - Suyu et al 2010 with Blandford
- Theoretical systematics in weak lensing
 - Hahn, Teyssier, Carollo 2010: measuring galaxy intrinsic alignments so that they can be distinguished from lensing distortions
- Theoretical systematics in cluster cosmology
 - Determined how well we need to know the dark matter halo mass function in order not to bias current cosmology constraints / Wu, Zentner & Wechsler 2009:
 - Determined requirements on understanding of mass-observable relation / Rozo et al 2010.
- Mock catalog development and implementation
 - Focused on DES but applicable to LSST and other surveys
 - In active use to test and develop methods in cluster cosmology, weak lensing, and large-scale clustering (Wechsler + collaborators)
- Opportunities in cluster cosmology
 - How much impact can X-ray or SZ followup have on limits from an optical survey? Wu, Rozo, & Wechsler 2009 see also public calculator <http://risa.stanford.edu/cluster>
 - Preparation for maximizing power of spectroscopic followup for DES / Gerke, Wechsler & Wu
 - Development of a new cosmological probe based on optically-selected clusters + galaxy clustering Tinker, Wechsler et al in prep

Dark Matter

- Constraints on Particle Dark Matter from Fermi limits on dwarf galaxies
 - Collaboration between KIPAC and Particle Theory postdocs & Fermi team
Essig, Sehgal, Strigari 2009; Essig, Sehgal, Strigari et al 2010
How do you constrain the dark matter cross section astrophysically? Need some environment where you understand how much dark matter there is: dwarf galaxies. Need to know as much as possible about dark matter using their dynamics; look for annihilation. Placed the strongest limit on σ_v in any astrophysical objects.
- The Velocity Distribution Function of Dark Matter Halos
 - Collaboration between Lisanti & Wacker (HEP), Strigari & Wechsler (KIPAC) / Determined the velocity distribution for realistic DM halos; serious consequences for particle dark matter inferences from direct detection compared to more typically used models (which do not agree with cosmological simulations)
- The number of LMC-SMC-like systems around MW-like hosts
 - Liu, Gerke, Wechsler, Busha / Found that only 10% of MW halos have 2 satellites
 - Has relevance to determining how the MW relates to other halos of its mass, which in turn impacts inference from dark matter detection experiments
- Strong Lensing constraints on the dark matter distribution in galaxies
 - Barnabe / Most accurate constraints on the distribution of dark matter in massive galaxies. Informs measurements of DE with lenses, and improves prospects for dark matter model constraints by measuring substructure.

Inflation/Non-Gaussianity

- Inflation theory and pheomenology
 - Developing the theory of how inflation can produce Non-Gaussianity / Senatore, Linde, Silverstein
 - Quantum corrections to Inflation, Eternal inflation / Senatore
- Observational constraints on inflation
 - Limits on f_{NL} form WMAP data / Smith, Senatore, Zaldarriaga 2009; Senatore, Smith
 - Techniques developed by Senatore and collaborators now used by WMAP team
- Halo Mass Function and Scale-Dependent Bias from N-body Sims with Non-Gaussian Initial Conditions
 - Pillepich, Porciani & Hahn 2010 / Characterized the impact of non-Gaussianity on observables predictions will be essential to use clusters + large-scale clustering to constrain inflation models.
- Ongoing work
 - Hahn, Senatore, Wechsler / Joint constraints on non-Gaussianity from CMB and LSS. Inferring the physics of inflation will require combination of inflation phenomenolgy + structure formation simulations + full treatment of systematics from the data.

Numerical Simulations

- Cosmological Simulations
 - Wechsler / Leading mock catalogs for current and future projects.
 - Development of pipeline for large suites of simulations. Currently 200 simulations for SDSS volumes; scaling up to DES volumes, including Blind Cosmology Challenge for DES.
 - Development of simulation analysis tools and constraining galaxy-dm connection.
- New initial conditions generator
 - Hahn / Enables more efficient and accurate resimulations
 - In use with Wechsler & Wu / cluster resimulation project for galaxies in massive clusters
- Adaptive Mesh Fluid Simulations on the GPU
 - Wang, Abel & Kahler 2010 Achieved capability to run on GPU clusters, speedup by a factor of 4 over single processors
- Reionization
 - Alvarez & Abel 2010 / Impact of Absorption systems on reionization
 - Abel & Wechsler / Connecting Reionization to the local Universe
- rpSPH
 - Abel 2010 / development of an SPH algorithm with substantially improved accuracy
- Galaxy Formation Simulations
 - Abel & Kim / galaxy formation with few pc resolution & magnetohydrodynamics

Particle Astrophysics

- Theory contribution to Fermi papers
 - Blandford / 44 Fermi papers in the last year
 - e.g. Theoretical interpretation of gamma-ray emission associated with Nova explosion
 - Modeling of structure of relativistic jets
 - Origin of the gamma ray emission in millisecond pulsars
 - Interpretation of the cosmic-ray electron spectrum
- Simulations of Energy Extraction from Spinning Black Holes
 - McKinney & Blandford 2009 Fermi Observatory has detected nearly a thousand gamma-ray sources, a vast majority of which are likely ultimately powered by high-energy vortices of magnetized plasma around spinning black holes. 3D Simulations reveal that the jets that Fermi observes are actually generated by an enormous release of (otherwise) trapped energy from the black hole via a unique magnetic coupling effect between the spinning black hole and the plasma just outside black hole.

Initiatives and Leadership

- 128 papers published by KIPAC theory group members since Sept 2009
- KIPAC Theory effort @ SLAC is playing a key role in extracting science focused on dark matter and particle astrophysics from Fermi, developing tools to extract dark energy and dark matter from DES, and in planning for future projects (e.g. LSST, WFIRST, CTA, WFXT, direct detection)
- Roger Blandford chaired Astro 2010 Decadal Survey
- Abel & Wechsler preparing proposal for Computational Cosmology Consortium
- Substantially ramped up collaboration between KIPAC and HEP Theory
 - New Hire: Senatore (joint between KIPAC and Theory Group)
 - Collaboration between Wechsler & Wacker ; KIPAC and HEP postdocs
 - New KIPAC postdoc Hertzberg, joint with campus theory (inflation & string theory)
 - Collaboration between KIPAC & HEP Theorists on Dark Matter Frontier Center