Astrophysics and Cosmology

- **Prof. Ian Dell’Antonio**
  - Observational Cosmology
  - Gravitational Lensing

- **Prof. Rick Gaitskell**
  - Astro-particle Physics
  - Dark Matter searches

- **Prof. Greg Tucker**
  - Observational Cosmology
  - From Cosmic Microwave Background to Star Formation

- **Prof. Savvas Koushiappas**
  - Theoretical Cosmology/Astrophysics
Observational Cosmology and Gravitational Lensing Group

Currently: Dell’Antonio, 4 graduate students, 4 undergraduate students

Close collaboration with groups at Yale, Harvard and UC Davis

Former members:
Gillian Wilson (associate Professor, UCRiverside)
Jeff Kubo (postdoc, Fermilab)
Hossein Khiabanian (postdoc, Columbia)
Wessyl Kelly (postdoc/technician, Pitt)
Goal: We want to understand the evolution of matter and energy in the Universe.

How we achieve this goal: Using optical, X-ray and Infrared observations of galaxies and clusters of galaxies. We aim to measure the growth of clustering and the evolution of galaxies within that clustering.
New technology—the One Degree Imager at the WIYN telescope in 2012.

Example Graduate Student Project:
The evolution of the cluster mass function using orthogonal transfer arrays

The camera/telescope combination will have the best image quality of any ground-based optical imager. We are leading a program that will use 150 nights of time in 2013-2015 to map out dark matter clustering.

The increase in sensitivity will allow more clusters to be detected: best constraint on Dark Energy

A parallel effort will use DECam (installed early 2012) to measure a larger area but in less detail.
Gravitational lensing as a tool for the study of DARK ENERGY

Beyond ODI and DECam. The 2010 decadal survey highlighted that understanding Dark Energy and its equation of state is one of the critical problems in physics, let alone cosmology. Gravitational lensing is a tool to measure dark energy, and our group is positioned to contribute strongly to this effort.

We are participating in the design and planning for the next generation of missions to be launched in the coming decade, such as WFIRST. We are leading the effort on gravitational lensing by clusters of galaxies for LSST.
Direct Detection Dark Matter (Gaitskell)

- Direct Detection of WIMPs orbit the center of the galaxy
- 50 billion through a person each second
- Occasionally collides with an atom in normal matter
  1/kg/month -> 1/tonne/decade
LUX Experiment/LZ/Sanford Lab

2009-2011 LUX
350 kg LXe
(Gaitskell is DOE Spokesperson)

2011-2013 LZS
3 tonne LXe

2013-2020 LZD
20 tonne LXe

Dark Matter,
Double Beta Decay
and Solar Neutrinos
The LUX Experiment

- 350 kg LXe detector
- 8m x 6m water shield
- 1 mile underground
- 122 PMTs (2” round)
- Low-background Ti cryostat
- PTFE reflector cage
- Thermosyphon used for cooling (>1 kW)
Observational Cosmology

Prof. Greg Tucker

Dr. Andrei Korotkov

Kyle Helson

Ata Karakci

Former students:  Matt Truch (postdoc, UPenn)
                 Jaiseung Kim (postdoc, Niels Bohr Institute, Denmark)
                 Jerry Vinokurov (postdoc, Carnegie Mellon University)
A Brief History of the Universe

Power Spectrum of the CMB

Cosmic Microwave Background (CMB)

Far Infrared Background (from the first dust enshrouded galaxies)

Inflation
Measuring Polarization of the Cosmic Microwave Background (CMB)

CMB polarization probes the universe $10^{-35}$ s after the Big Bang (the epoch of inflation).

The Millimeter-wave Bolometric Interferometer (MBI)

MBI is a prototype to demonstrate the BI technique.

QUBIC – QU Bolometric Interferometer for Cosmology will be installed at Dome C (~2013)

Projects involve designing and building QUBIC, simulating performance and analyzing data
Another way to search for CMB polarization

The E and B Experiment (EBEX)

Next flight will be long duration from the Antarctic in 2011

New Mexico
June 2009

Projects include data pipeline development and analysis
The Balloon-borne Large Aperture Submillimeter Telescope (BLAST)

Antarctica 2006
What BLAST has done:
Resolved the far infrared background (re-radiated starlight) into individual galaxies

Every bump in this map is a galaxy
How do stars form? The collapse time from a gas cloud is longer than one would naively expect → braking mechanism. Is braking due to magnetic fields or turbulence? BLAST will answer this by measuring the polarization of dust.

A star forming region in Vela

This ~10 K cloud is the future birthplace of stars

http://blastexperiment.info
Theoretical Astrophysics/Cosmology

Prof. Savvas Koushiappas
Dr. Jacqueline Chen
Alex Geringer-Sameth

Andrew Favaloro

http://www.physics.brown.edu/BTAC/Home.html
Theoretical Astrophysics/Cosmology

**What we do:** Develop methods that help us understand the distribution of dark matter in the Universe - structure formation

[http://www.physics.brown.edu/BTAC/Home.html](http://www.physics.brown.edu/BTAC/Home.html)
Theoretical Astrophysics/Cosmology

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**Why we do it:** Dark matter detection (direct, indirect) is ultimately linked to the understanding of hierarchical structure formation - the growth of primordial perturbations

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Theoretical Astrophysics/Cosmology

**What we do:** Develop methods that help us understand the distribution of dark matter in the Universe - structure formation

**Why we do it:** Dark matter detection (direct, indirect) is ultimately linked to the understanding of hierarchical structure formation - the growth of primordial perturbations

**How we do it:** We use analytical, numerical and semi-analytical techniques

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Example: Develop new statistical tools for the extraction of a time-dependent spatial signal in an otherwise diffuse unresolved background

Alex Geringer-Sameth & Koushiappas arXiv:1012.1873

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Theoretical Astrophysics/Cosmology

**Future Directions:** Develop a framework where cosmological predictions can be used to interpret data from dark matter experiments

**Physics approach to the problem:**
1) Data from different experimental techniques
2) Sophisticated theory and modelling
3) High-performance computing simulations
4) New and existing statistical and analysis tools

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