Center for Cosmological Physics (NSF Physics Frontier Center)

HEP Related Fields

- CMB(1)
- Dark Matter detection
- Tests of QM
- Tests of Gravity
- Gravity wave detection(2)
- edms
- Proton decay
- N, n-bar oscillations

"Don't listen to what they say. Go see"

- 1 year sabbatical at Princeton, 1999-2000
- Got hooked!
- Wanted to create an interdisciplinary environment

How Did the Center Begin?

- Competition for funding by the National Science Foundation (new Program: PFC)
  - About 50 pre-proposals
  - 14 allowed to submit full proposals
  - 8 made presentations over 2 days at NSF
  - 4 were finally funded (August 2001)
  - Process took 1 full year

Center for Cosmological Physics

- 13 Chicago Faculty
- 10 Postdoctoral Fellows
- Graduate and Undergraduate Students
- Visitors, Symposia; Outreach
- 5 year initial term (began 8/01)
- HEP Sabbatical program

"Study, and in general the pursuit of truth and beauty is a sphere of activity in which we are permitted to remain children all our lives." A. Einstein

Charter Personnel

- Ed Blucher
- John Carlstrom
- Sean Carroll
- Juan Collar
- James Cronin
- Joshua Frieman
- Wayne Hu
- Andrey Kravstov
- Randall Landsberg
- Stephen Meyer
- Angela Olinto
- Clem Pryke
- Simon Swordy
- Michael Turner
- Bruce Winstein

Experiment/Theory
Astronomy/Physics
Assistant Professors
Location: LASR, Chicago

SCIENCE THRUST

Fundamental Physics of the Universe

What is:

- Dark Matter?
- Dark Energy?
- Cause of Inflation?
- Nature of ultra high energy cosmic rays?

"Established" phenomena
Outside the Standard Model

Cro

"If anyone in my laboratory," Rutherford thundered, "begins to speak of the Universe, I tell him it is time to leave!"

CorsC

The Universe as a Laboratory for New Physics

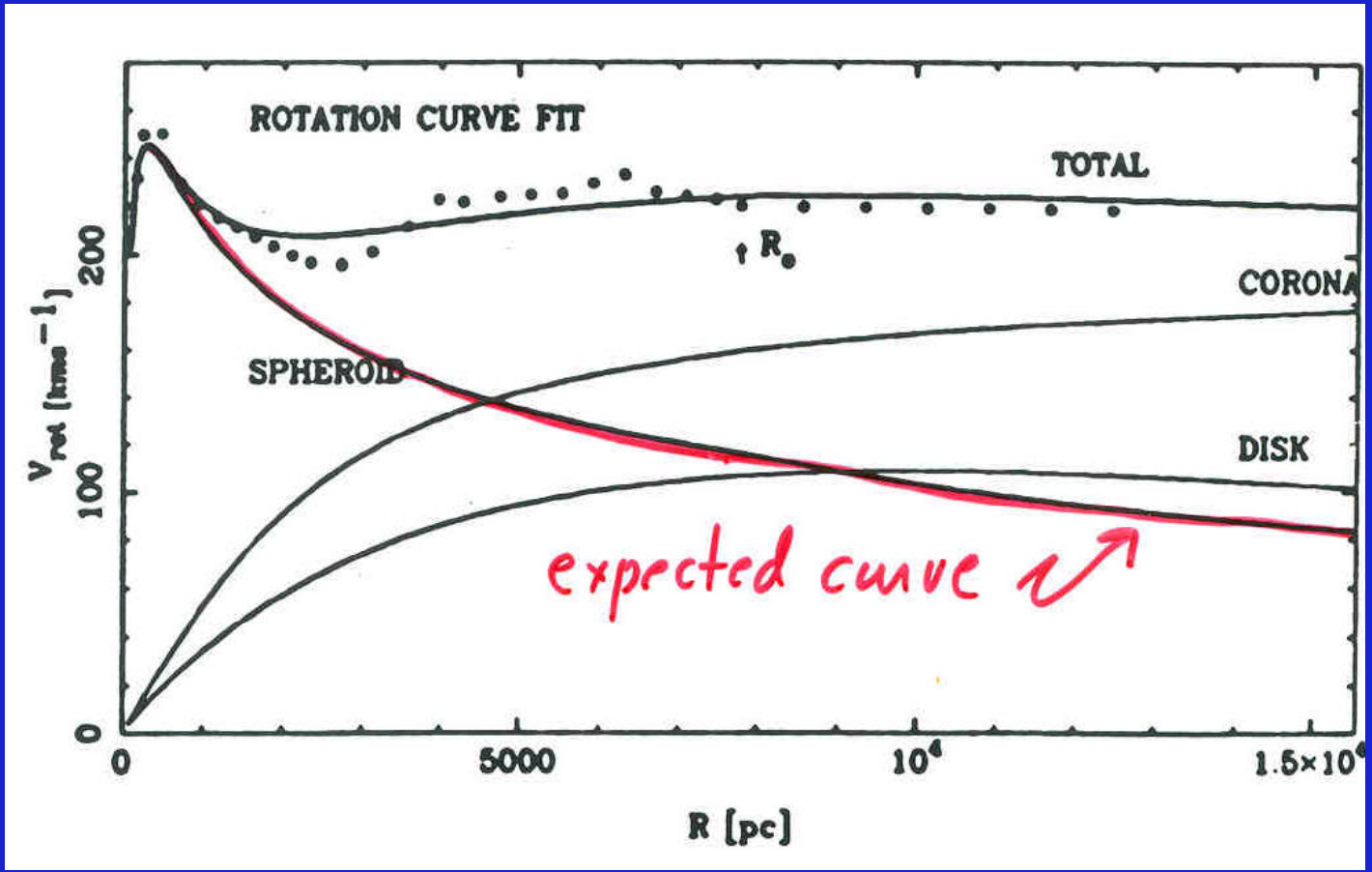
- Dark Matter
- Dark Energy
- Inflation
- Cosmic Rays
- Structure

Extra Dimensions?
CP/Baryogenesis?

Using:

- Radio Telescopes
- Surface Arrays
- Optical Telescopes
- Gravitational Lensing
- Simulations
- Direct Detection

Rotation Curve, Milky Way



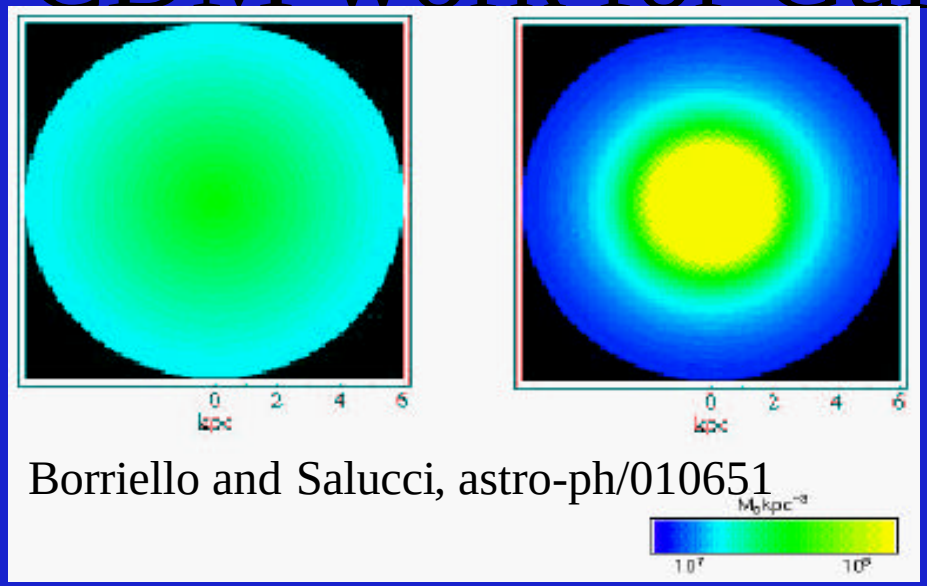
Unavoidable evidence for "Dark Matter"

Accelerations Probed

- $v^2/r \sim (200km/s)^2/100kpc \sim 10^{-11}\ m/s^2$
- Law of Gravity never tested at such low accelerations
  - 1 week to fall 1 meter
- This has led to serious proposals for the modification of Gravity

CENTER FOR COSMOLOGICAL PHYSICS

Does CDM work for Galaxies?

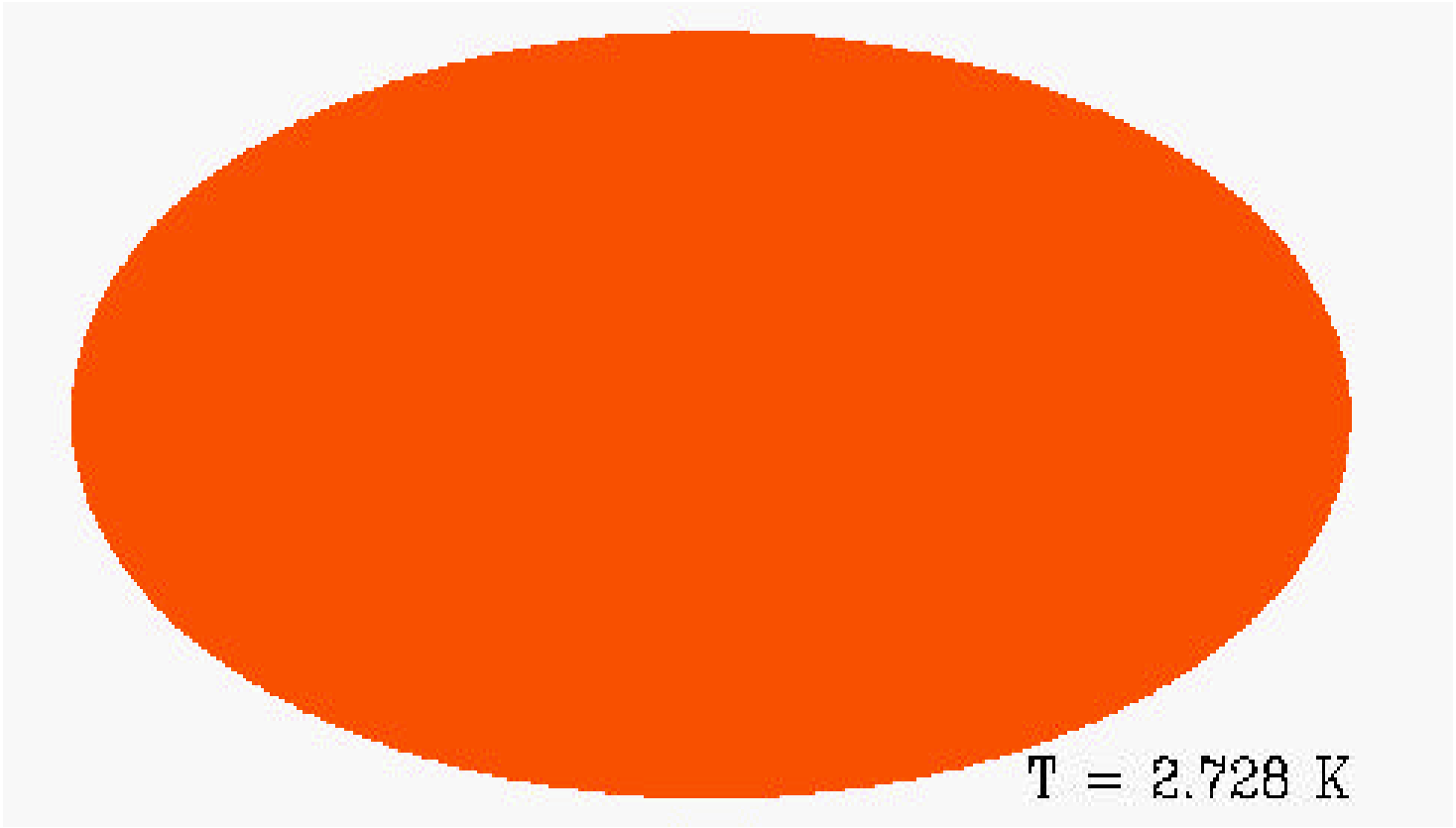


Borriello and Salucci, astro-ph/010651

"From the analysis of high quality optical rotation curves of 9 low luminosity disk galaxies, we find that the properties of the dark halos around these objects are **inconsistent** with the halo density profile of the halos emerging in high resolution Cold Dark Matter N-body simulations. Dark halos around galaxies are almost constant density spheres, very different from the characteristic CDM ?(r) ~ $r^{-1.5}$. This obviously **challenges the theory where the relevant particles are non-interacting**."

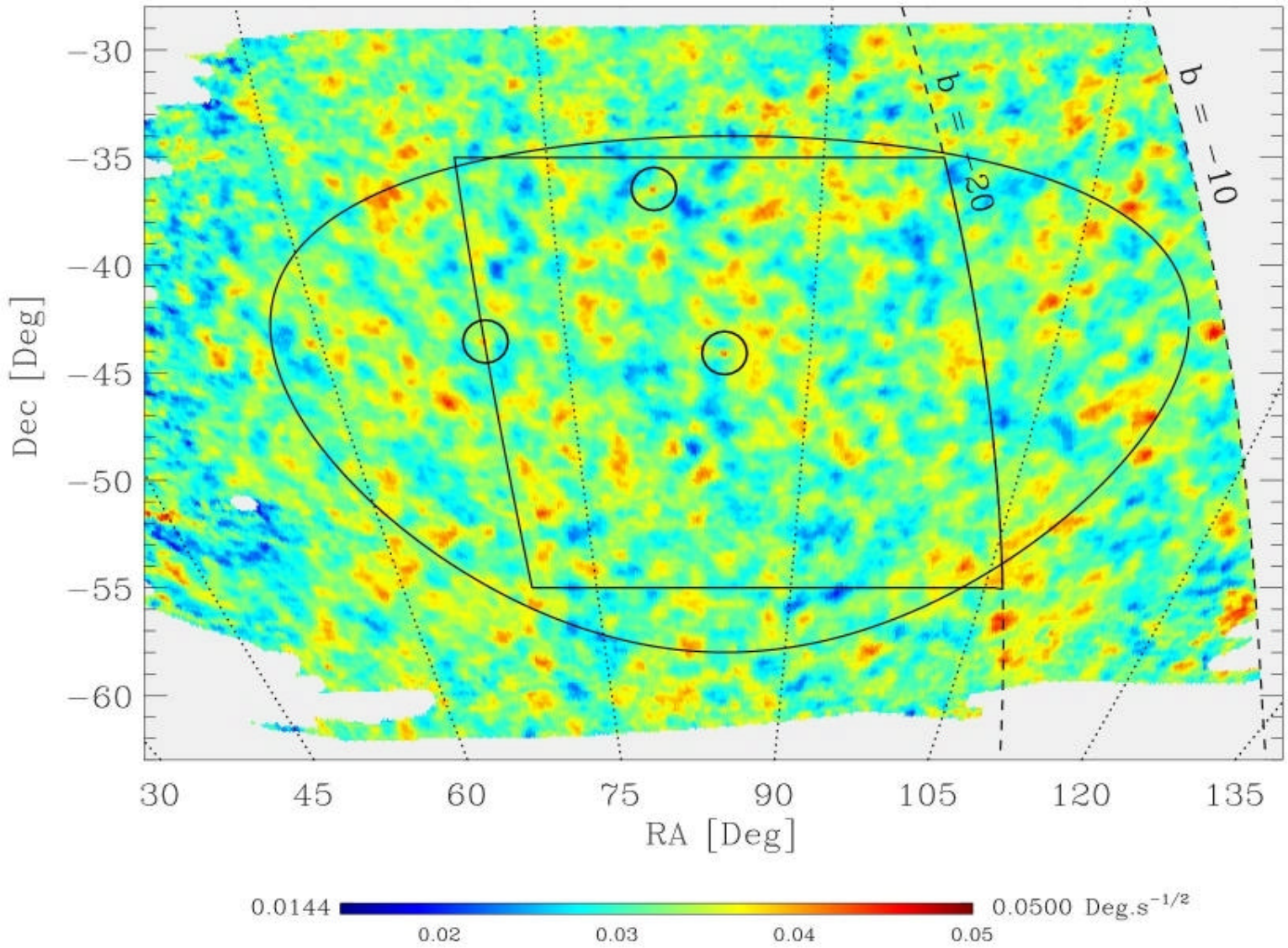
CENTER FOR COSMOLOGICAL PHYSICS

“Sky” Temperature

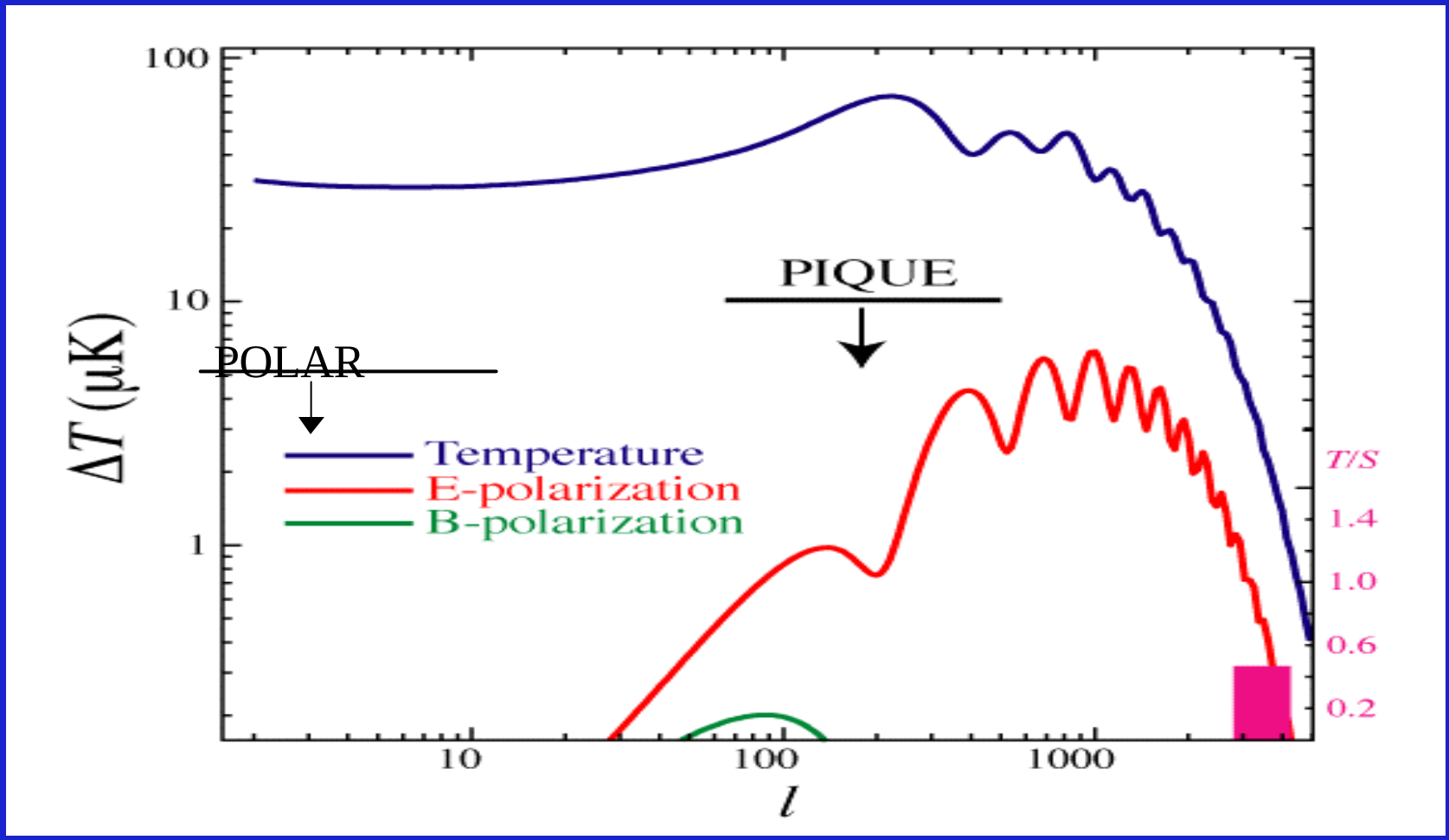


Highly uniform. For a finer look……..

Temperature Variations: 2.727950-2.728050 degrees



CMB Polarization



Energy of Inflation?

- Scale of Inflation < 2 x 10^{16} GeV (COBE)
- New initiatives (most likely a satellite) could have much improved sensitivity (post MAP and PLANCK)
- This could bring the Inflation Scale limit down by $(2500)^{1/4}$ ~ or 3 x 10^{15} GeV

Major CPU Reccomendation

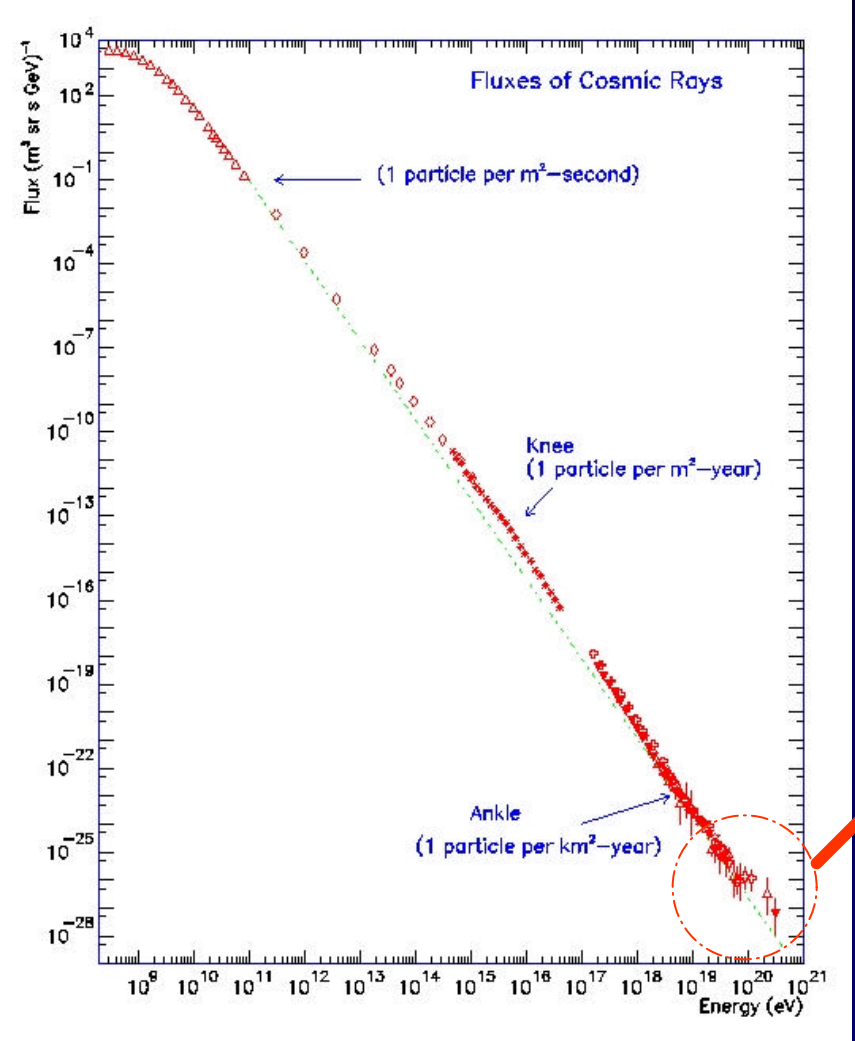
High Energy Particles from Space

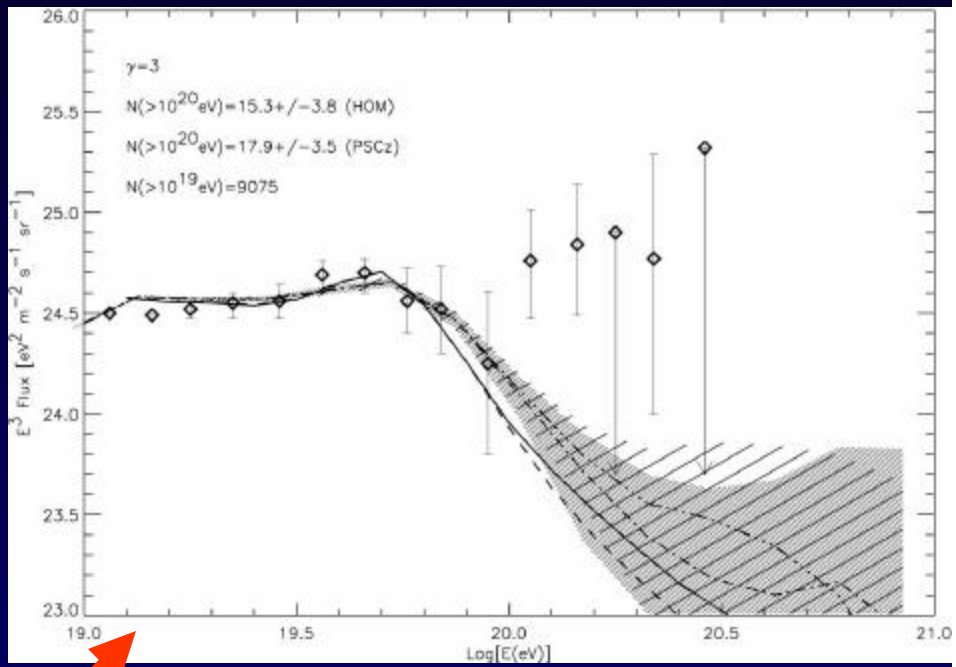
Carroll, Cronin, Olinto, Swordy

- Search for gamma-radiation from dark matter annihilation
- Detection of cosmic high energy neutrinos
- Search for effects of quantum gravity
- Investigation of exotic particle signatures (monopoles)
- CIB investigation

Center Extends Auger and Veritas Science

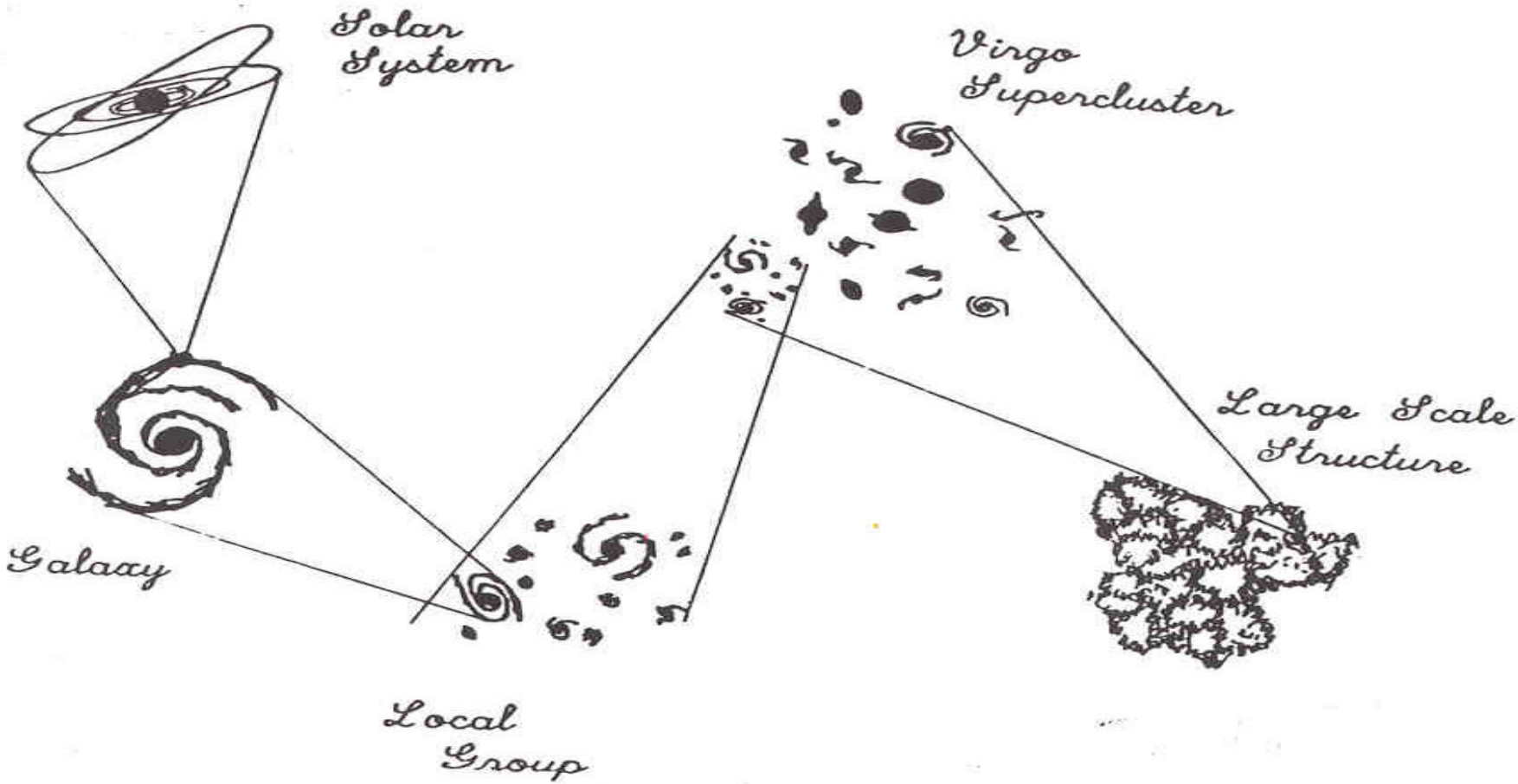
Ultra high energy cosmic ray measurements





Shaded region - sensitivity of Auger search for GZK cutoff.

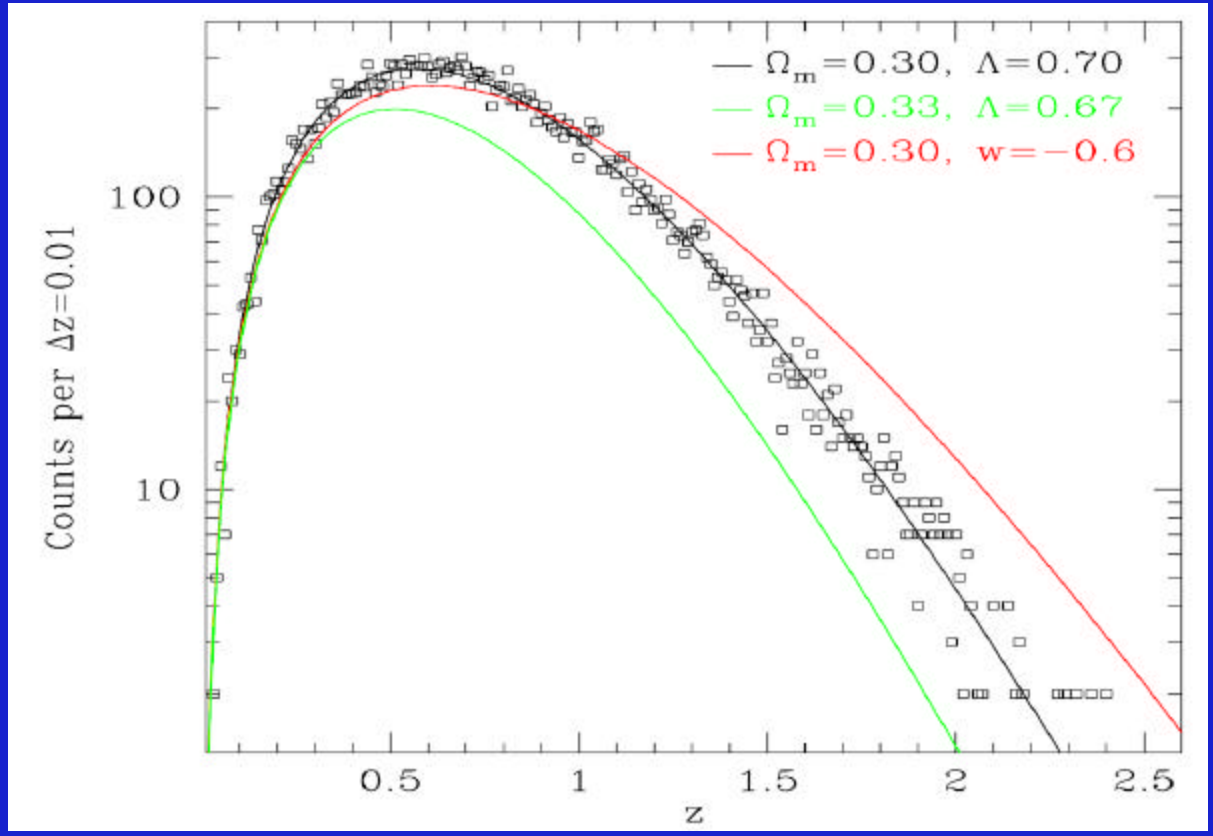
Structure of Matter



Where did all the galaxies come from?

- Amplification of these small non-uniformities in temperature, density
- **Gravity** is the most important agent
  - Dark Matter and Dark Energy
- I will show animations of structure formation over the past 10 billion years
  - Done by Andre Kravstov 100 MLY

Getting at DE from Cluster Surveys using the S-Z effect



Background Cosmology Affects Number of Clusters vs. Redshift

CENTER FOR COSMOLOGICAL PHYSICS

To realize these great opportunities at the Frontiers of Physics, a new integrated approach with astronomers and physicists, experimentalists and theorists working together in a Center environment is crucial.

- We are committed to the center concept
- A model for a new approach to science research

Example: What is the Dark Energy (DE)?

- What do experiments tell us about DE?
  - S-Z surveys, CMB, Large Scale Structure, High Redshift Supernovae
- Theory will provide direction for new experiments.
- What are promising particle-physics models?
  - Vacuum Energy, Light scalar fields, Topological Defects, Candidates from SUSY and String Theory, Modified Gravity on large scales
- Can we directly detect DE?
  - Explore interactions of DE with cosmological particles: polarized photons, high energy cosmic rays

CfCP Hosted Dark Energy Symposium in December

"I remember in 1949, on a bulletin board at the Princeton Institute of Advanced Studies, a photomicrograph of a nuclear emulsion event, showing what is now known as a K-meson decaying to three pions. We all saw it. There could be no doubt that something interesting was going on, very different from what was then known, but it was hardly discussed because no-one knew what to do with it."

-Jack Steinberger

Cosmology/Astro

- Like EPP in the 1950s:
  - Explosion of new results
  - New, strange phenomena
  - Many means of probing
  - Brightest theorists working with the data
  - Driven by young scientists

- Our Responsibility to learn and encourage our students to “participate” in this field

CENTER FOR COSMOLOGICAL PHYSICS

Major Results, Past 5 Years

- Geometry of the Universe
- Fluctuations in the CMB
- Discovery of Dark Energy
- Discovery of Accelerating Universe
- Strong Evidence for Inflation
- Structure Formation
- Neutrinos have Mass
- Extra Galactic gamma ray sources
- $>10^{20}$ ev particles

Comment

- Need to study and understand Galaxies in order get at the fundamental Cosmological Physics
  - Galaxies are messy
- Need to understand jets in order to get at the fundamental Particle Physics
  - Jets are messy

HEP Role?

- Intellectual
- Software, computing, electronics
- Staging of detector systems
- Documentation/communication
- Management
- We seem to be more cautious in claiming new results

  particularly ones that agree with theory!

- Help evaluate new initiatives

CENTER FOR COSMOLOGICAL PHYSICS

Conclusion

- Several phenomena "very different from what was known" in astro/cosmology
- We **do** know what to do with them.
- Interdisciplinary aspects are most exhilarating

CENTER FOR COSMOLOGICAL PHYSICS