Brief overview of some of the department research activities

- **Survey Science**
- **Structure Formation**
- **Extragalactic Optical and Infrared Astronomy**
- **Theory, Cosmology**
- **Gravitational-wave Science**
- **Plasma and High Energy Astrophysics**
- **Exoplanets**
- **Cosmic Microwave Background**

Survey Science

Observational Cosmology and Astrophysics at the University of Chicago

http://surveys.uchicago.edu/

Big Group Meetings: Thursdays @ 2PM CDT (bi-weekly)
https://fnal.zoom.us/j/457644428?pwd=UkVEVytLUzc0VmJDaGdTMkN5U2NYUT09

Small Sub-Group Meetings: Thursdays (bi-weekly)
Please contact Alex DW, Brian, Chihway, Josh for coordinates

Joint Cosmology Meetings: Fridays @ 9AM CDT (bi-weekly)
https://uchicago.zoom.us/j/94057788064?pwd=TWkzQ1dTUGhHeEloNDdnOFZITDIrdz09

The Survey Science Group









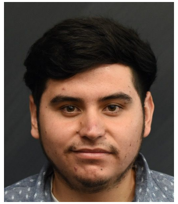




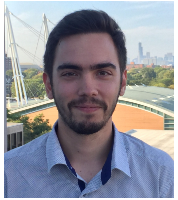
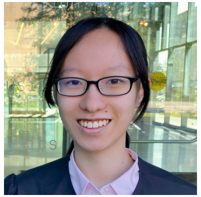










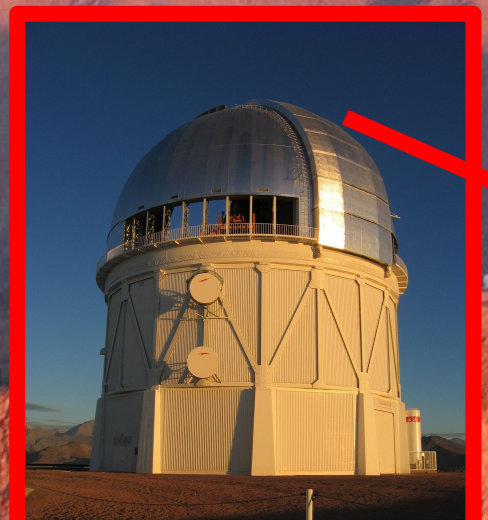
+ ~10 undergraduates

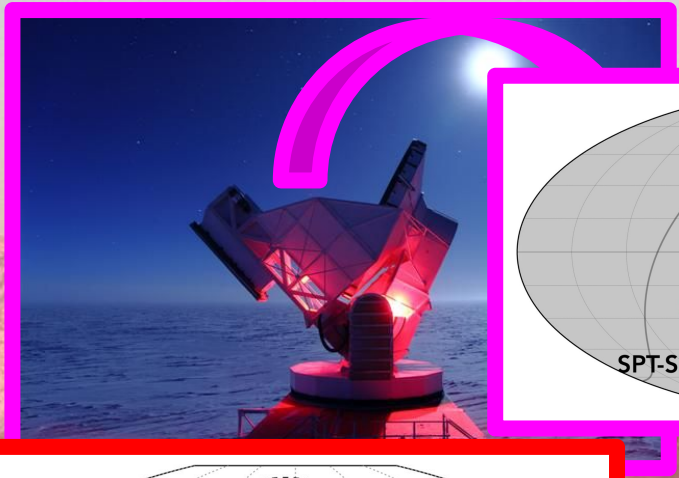
And you!

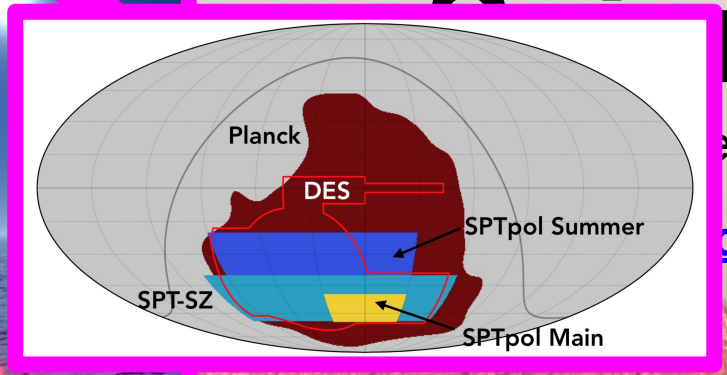
vey Science

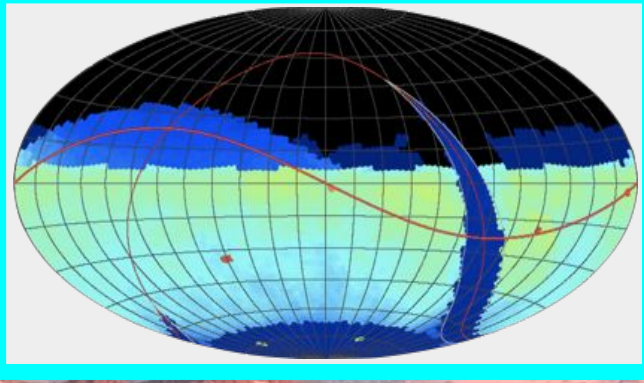
y and Astrophysics at the University of Chicago

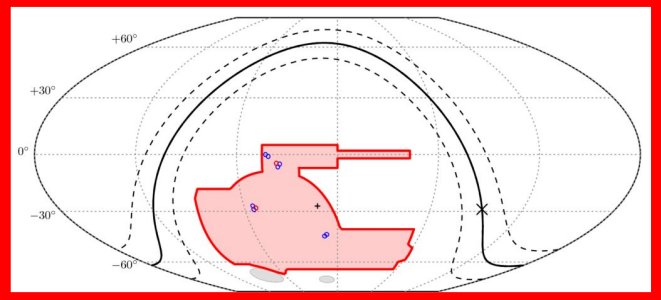
p://surveys.uchicago.edu/

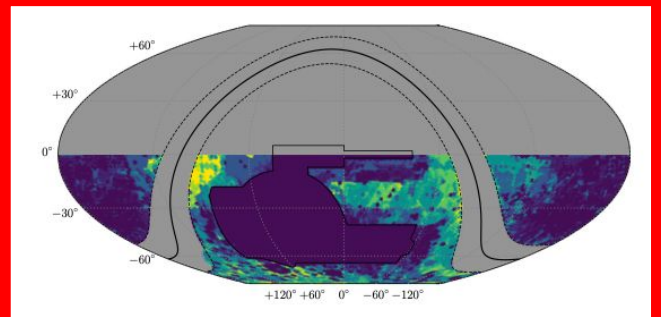





Planck
DES
SPTpol Summer
SPT-SZ
SPTpol Main




+60°
+30°
0°
−30°
−60°

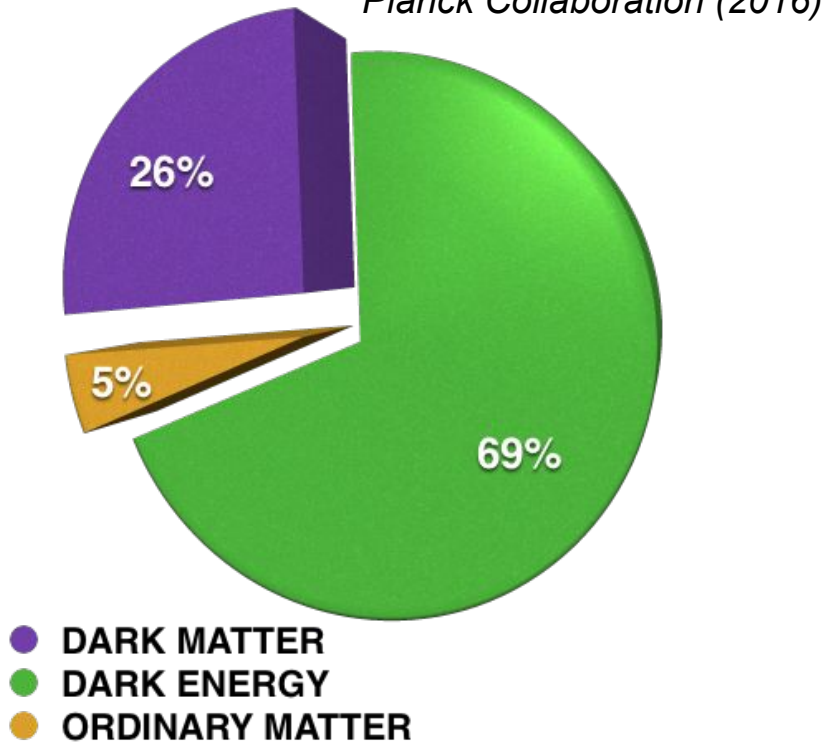

+60°
+30°
0°
−30°
−60°
+120° +60° 0° −60° −120°

Fundamental Science with Cosmic Surveys

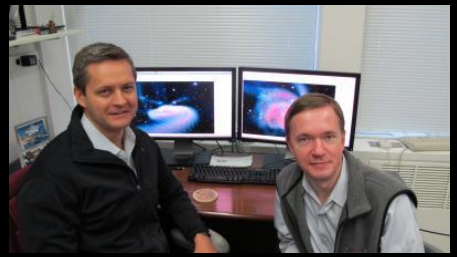
What is the Universe made of?

- **Dark Matter:** Attractive force responsible for the formation of structure in the Universe
- **Dark Energy:** Repulsive force responsible for the accelerating expansion of the Universe
- **Ordinary Matter:** All the stars and galaxies (and exoplanets) and other stuff that we observe

Planck Collaboration (2016)



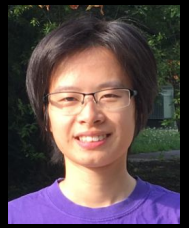
structure and galaxy formation
re-ionization modelling



Andrey Kravtsov
Astro/KICP/EFI

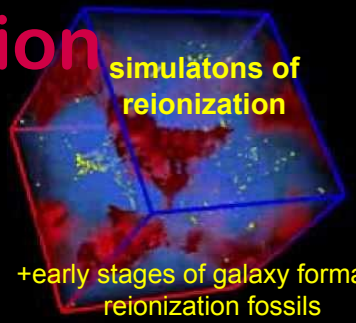
Nick Gnedin
Fermilab/Astro/KICP

Susmita Adhikari
KICP Associate Fellow



Huanqing Chen
Astro grad student

Christine Simpson
McCormick fellow
Astro/EFI/KICP

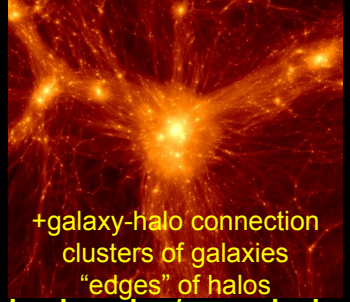


simulatons of reionization

+early stages of galaxy formation
reionization fossils

supercomputer simulations

structure formation modelling



+galaxy-halo connection
clusters of galaxies
"edges" of halos

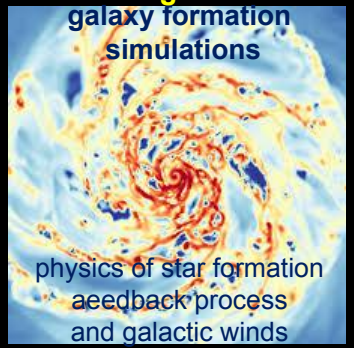
machine learning/numerical methods

Viraj Manwadkar
Astro undergrad student

Arka Banerjee
Schramm Fellow, Fermilab

Clarke Esmerian
Astro grad student

Hanjue Zhu
Astro grad student



friday group meetings 3pm, ERC 419
subscribe to mailing list at
https://box.uchicago.edu/mailman/listinfo/fridayowls

structure and galaxy formation
re-ionization modelling

Camille Avestruz
KICP fellow 15-19
Now Asst Professor
UMichigan

Oscar Agertz
KICP fellow 12-15
Now Asst Professor
Lund University

Surhud More
KICP fellow 09-12
Now Professor
Pune ICUAA and IPMU

Recent graduates:

Denis Erkal
Physics PhD 2013
Asst. Professor,
Surrey Univ, UK

Matt Becker
Physics PhD 2013
Asst. Scientist
Argonne National Lab

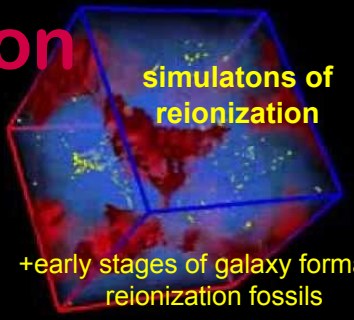
Benedikt Diemer
Astro PhD 2015
Einstein Fellow
Asst Professor
U Maryland

Phil Mansfield
Astro PhD 2020
KIPAC fellow, Stanford

Sasha Kaurov,
Astro PhD 2016
W.D. Loughlin
Fellow, IAS

Cameron Liang
Astro PhD 2018
Postdoc Fellow
UCSB-> Institute for
Defense Analyses

Vadim Semenov
Astro PhD 2019
Hubble Fellow
ITC, Harvard



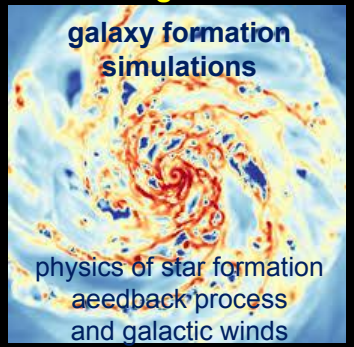
+early stages of galaxy formation
reionization fossils

supercomputer simulations

structure formation modelling

+galaxy-halo connection
clusters of galaxies
"edges" of halos

machine learning/numerical methods



UChicago Research Computing Center

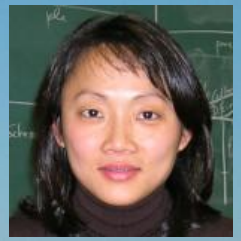
General purpose computing cluster (~16000 cores) used for research and classes by faculty, postdocs, students

Includes fast interconnect (FDR-10), large memory nodes, GPU nodes

https://rcc.uchicago.edu/resources/high-performance-computing

Extragalactic Optical / Infrared Astronomy at the University of Chicago

Hsiao-Wen Chen



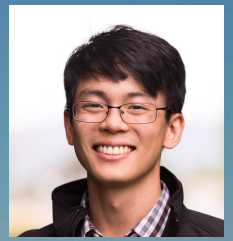
Alex Drlica-Wagner

Wendy Freedman

Josh Frieman

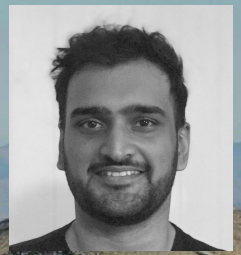
Mike Gladders

Alex Ji



Rich Kron

Ani Chiti



In Sung Jang

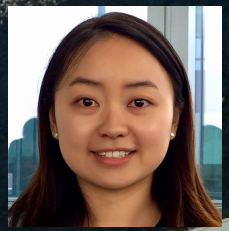
Ilaria Lonoce

Zhijie Qu

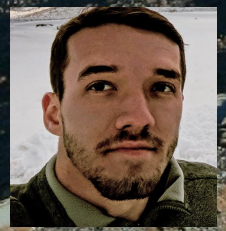
Anowar Shajib

Erik Shirokoff

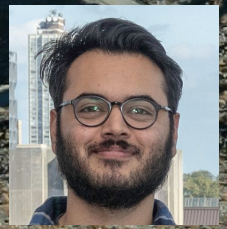
Mandy Chen



Taylor Hoyt



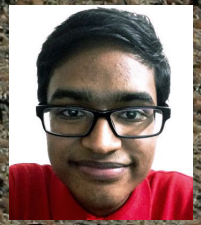
Gourav Khullar



Abigail Lee

Samantha Usman

Naren Kasinath



Rohan Venkat

Probing *the other* dark matter:

observations, semi-analytic models, and instrumentation

Hsiao-Wen Chen

Astronomy & Astrophysics / KICP

The University of Chicago

Current projects:

- An image slicer for Magellan — Revealing the invisible cosmos (U Chicago Women's Board)
- A high-definition view of the complex circumgalactic medium (NSF AAG)
- The CUBS — Cosmic Ultraviolet Baryon Survey (2x169 orbits HST Cycle 25)

Current/former group members

Mandy Chen, 3rd-yr Graduate Student

Zhijie Qu, Postdoc Scholar

Naren Kasinath, 3rd year undergrad

Rohan Venkat, 2nd year undergrad

Erin Boettcher, Postdoc Scholar, GSFC

Jean-Rene Gauthier, PhD '11,
Caltech Millikan fellow,
Senior Principal Product Data Scientist, Oracle

Sean Johnson, PhD '16,
Assistant professor, Michigan, Ann Arbor

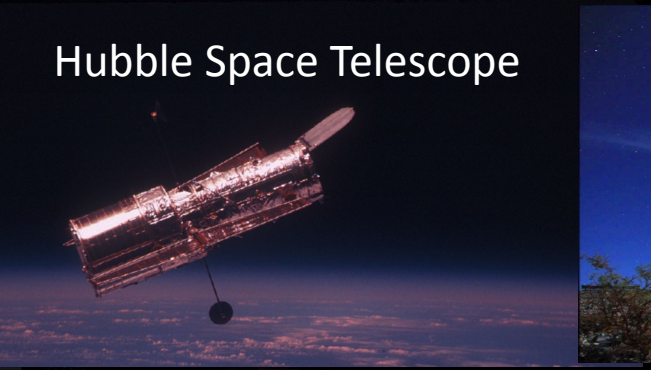
Fakhri Zahedy, PhD '19,
Carnegie Fellow

Yun-Hsin Huang, masters '15,
UArizona graduate program

Taweewat (Champ) Somboonpanyakul, '15, MIT PhD '21

Rebecca Pierce, '17,
UMaryland, aerospace engineering graduate program

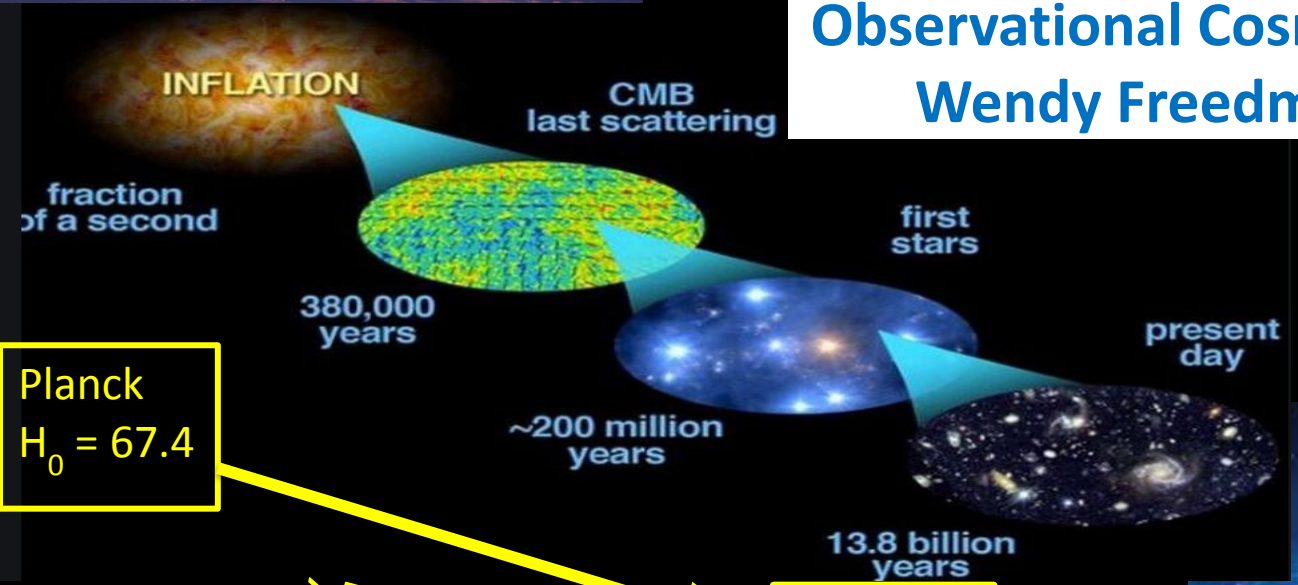
Hubble Space Telescope



Magellan Telescopes, Chile

Giant Magellan Telescope

Observational Cosmology
Wendy Freedman



Planck
H_0 = 67.4

> 5 σ
tension

SHoES
H_0 = 74.0

James Webb Space Telescope

Stellar Populations, IMF

Observational Cosmology
Wendy Freedman

Graduate Students:

Postdocs:

Undergraduate Students:

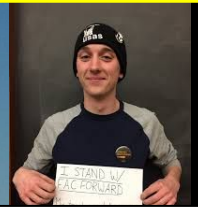

Taylor Hoyt


Abby Lee


In Sung Jang


Ilaria Lonoce


Will Cerny



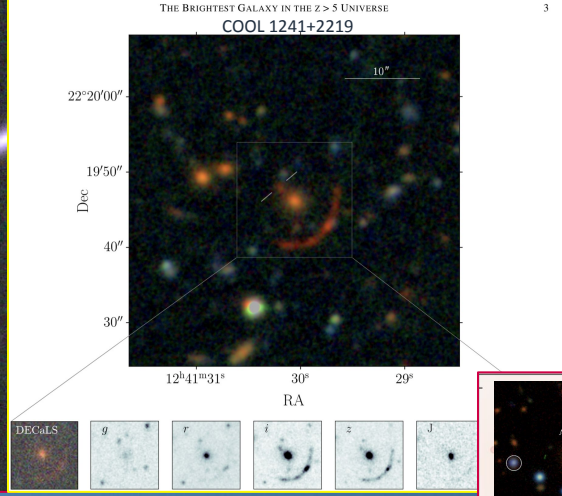
Fin Ashmead


Kayla Owens

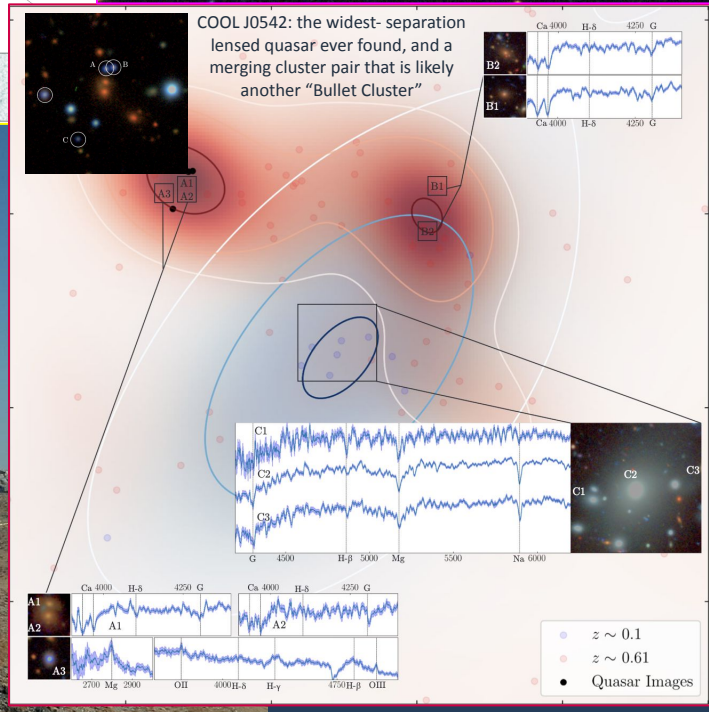

Elias Oakes


Alex Masegian

COOL J2129: the highest redshift confirmed strong-lensing galaxy cluster known, lensing the brightest lensed source known at z>3.2



A simulated SPT cluster-scale lens



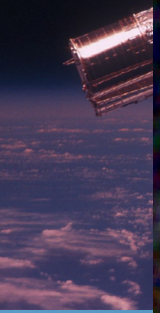
Galaxy and Cluster Evolution, Strong Lensing
Mike Gladders

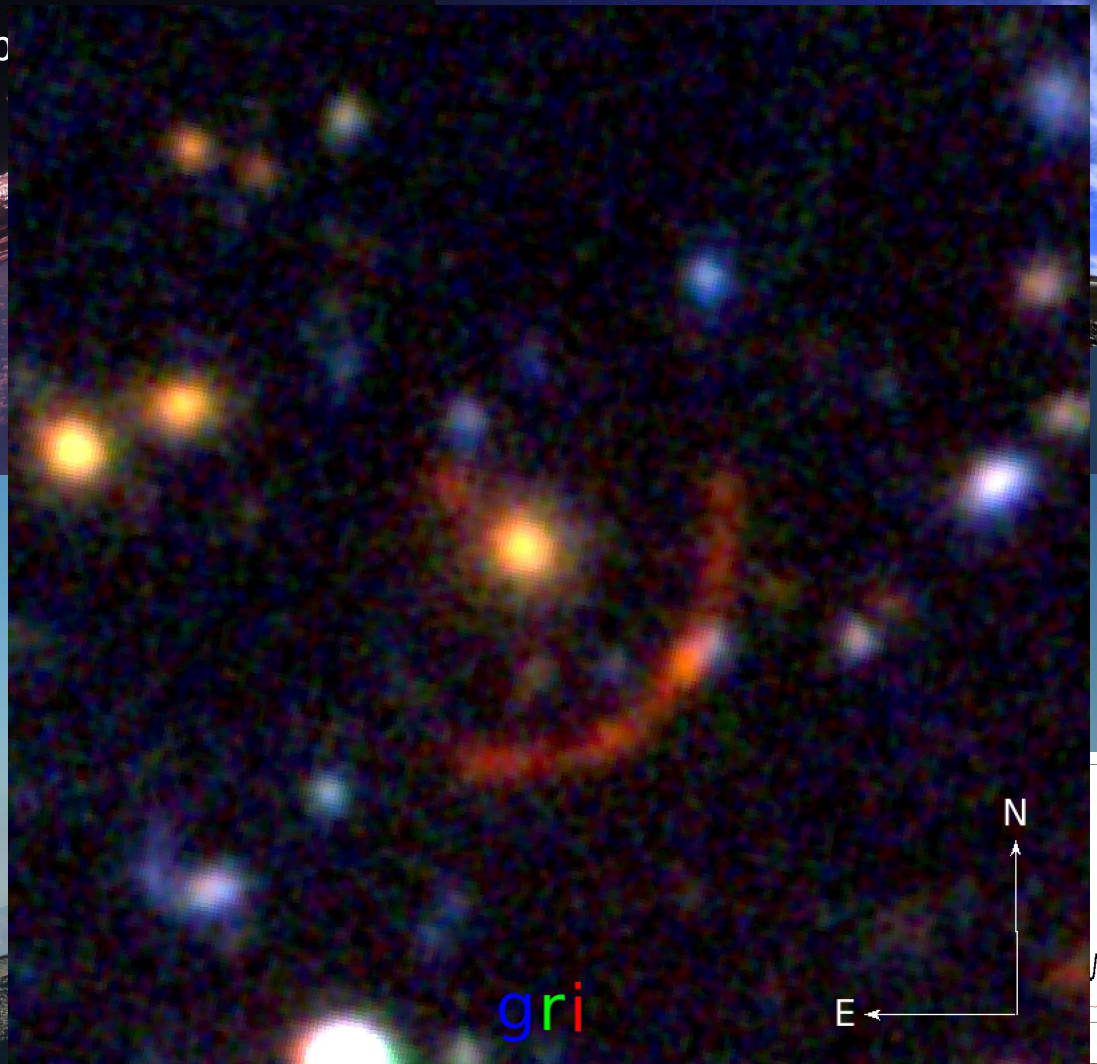
Current PhD Students:
Gourav Khullar

I work extensively with the cluster group of the SPT project understanding massive galaxy clusters, and the simulation group at Argonne simulating strong lensing by these systems, including projects with grad students

2020/2021: The astro “field course” and resulting collaborations with undergraduates students have kept me extremely busy these past two years… with numerous projects in various stages

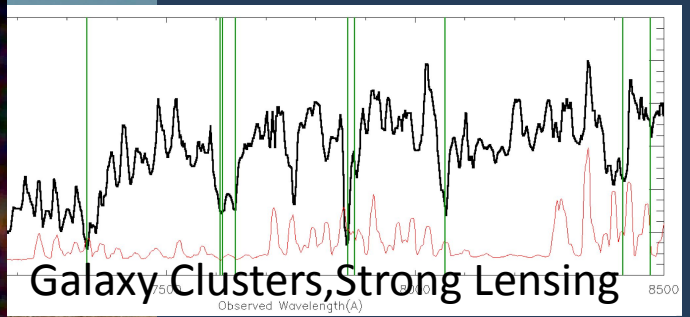
Hubb





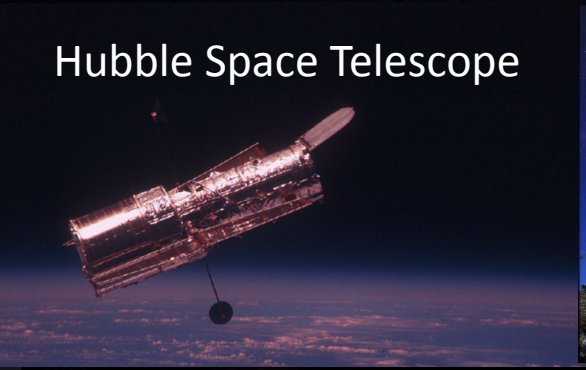
Giant Magellan Telescope

James Webb Space Telescope



Galaxy Clusters,Strong Lensing

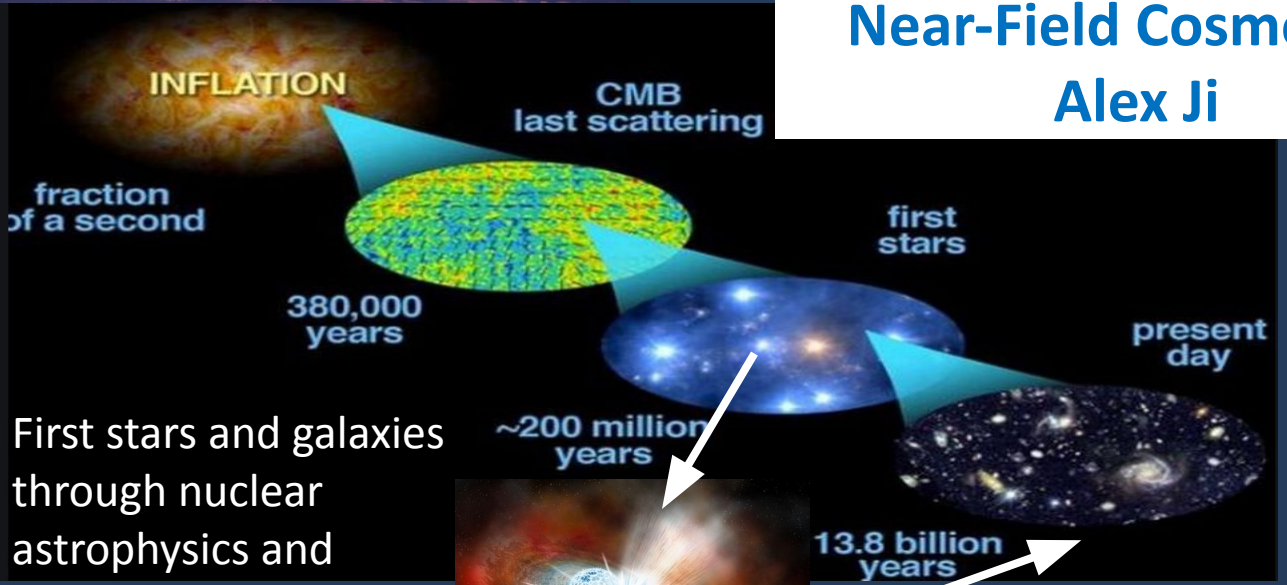
Hubble Space Telescope

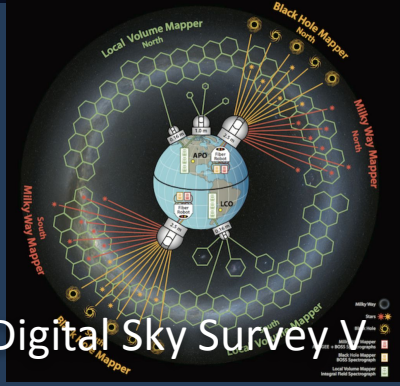


Magellan Telescopes, Chile

Giant Magellan Telescope

Near-Field Cosmology
Alex Ji

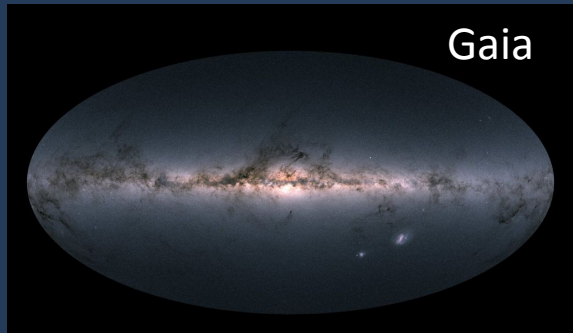




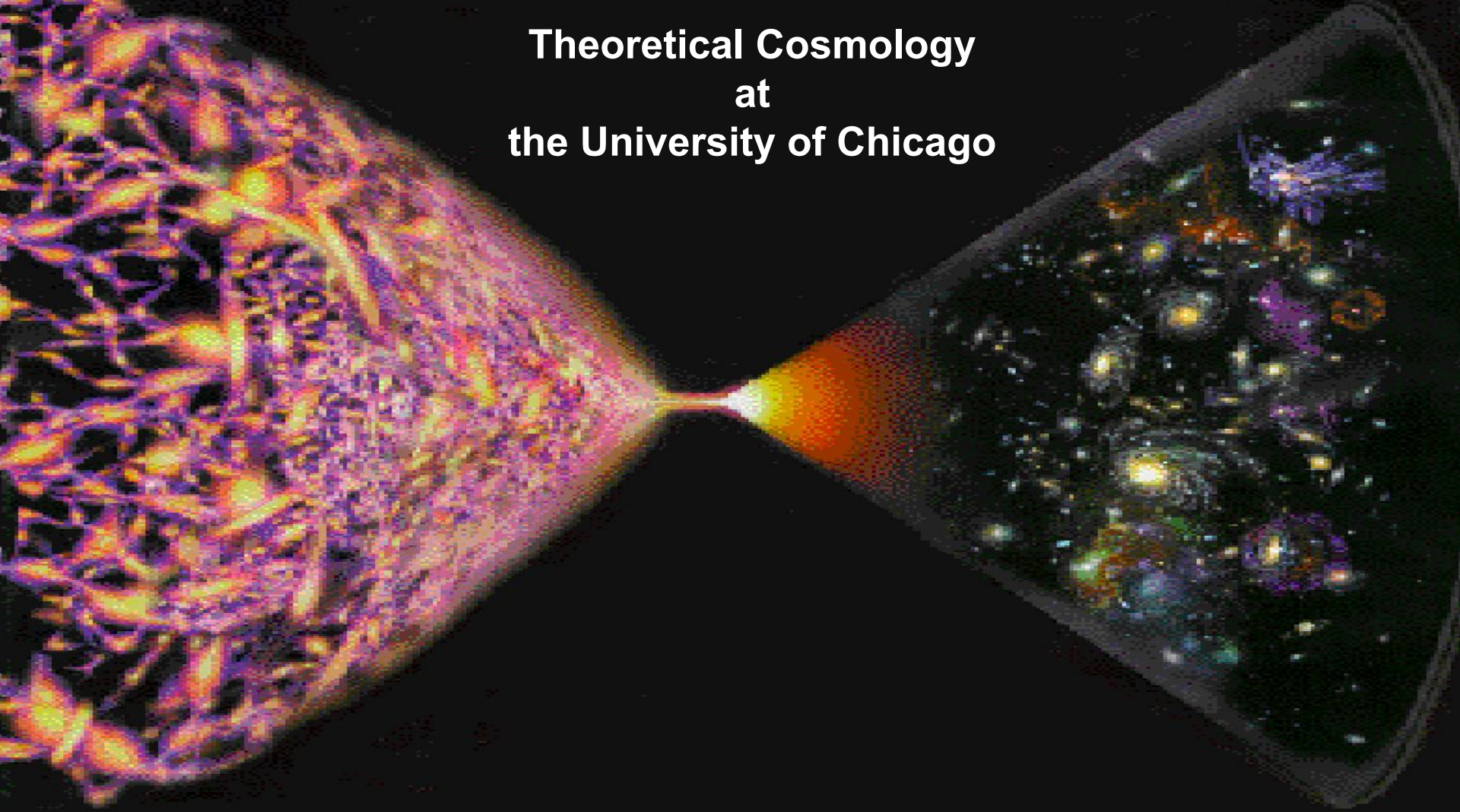
Sloan Digital Sky Survey V

First stars and galaxies through nuclear astrophysics and stellar/galactic archaeology

Gaia



Theoretical Cosmology
at
the University of Chicago



What We Do

String Theory and Cosmology
Inflation
Gravitational Particle Production
Origin of Dark Matter
Dark Energy
Particles and Cosmology
Early Universe Cosmology
Imprint of Inflation on CMB

Primordial Gravitational Waves
Cosmic Origin of Dark Matter
Dark Matter Direct Detection
Dark Matter Indirect Detection
Primordial Black Holes
Modified Gravity
Neutrino Astrophysics/Cosmology
Quantum Cosmology

Who Does It

Astronomy & Astrophysics Faculty


Craig Hogan


Wayne Hu


Dan Hooper


Austin Joyce


Rocky Kolb


Gordon Krnjaic

Other faculty from Physics, EFI, KCTP
Postdocs from Chicago, Fermilab, Argonne
Members of the Kavli Institute for Cosmological Physics (KICP)

KICP: People

30 Senior Members
- Primary Appointments:
  - Astronomy & Astrophysics Dept.
  - Physics Dept.
  - Fermilab
  - Argonne

3 Senior Researchers

20 Senior Associates

12 KICP Fellows

33 Associate Fellows

46 Graduate Students

Numerous Undergraduate Students

144 Total

KICP: Science

Cosmic Microwave Background Experiment

Cosmic Microwave Background Theory

Cosmic Rays

Dark Matter Experiment

Dark Matter Theory

Detector Development

General Relativity and Cosmology

Multi-messenger Astronomy

Neutrinos (accelerators, cosmic, reactors)

Observational Cosmology

Particle Theory and Cosmology

Structure Formation & Evolution

Survey Science

Theoretical Cosmology

Where We Do It Campus

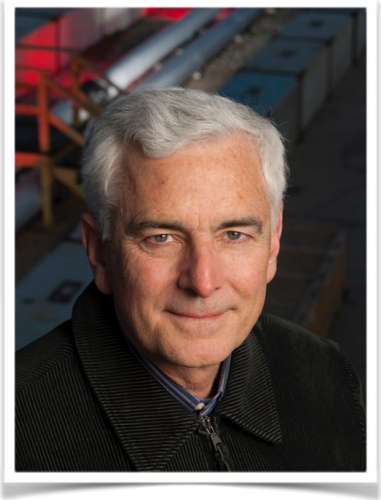
Eckhardt Research Center

Michelson Physics Center

Where We Do It Chicagoland

Fermi National Accelerator Laboratory

Argonne National Laboratory



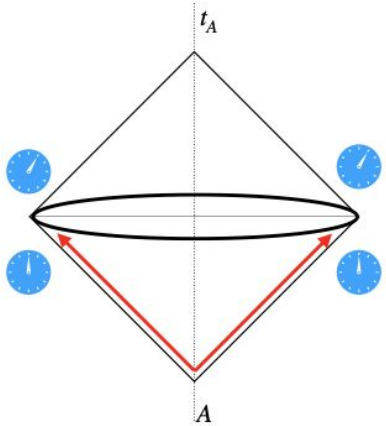
Craig Hogan

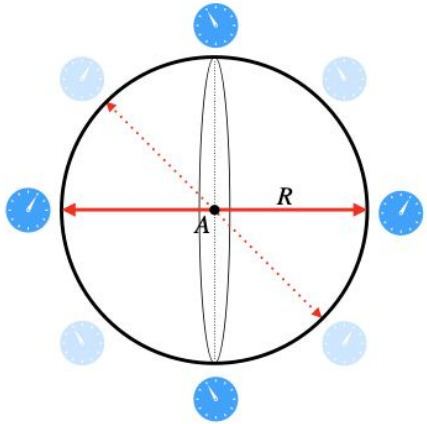
Observable effects of quantum nonlocality and coherence on gravity

"Spooky" causal correlations of primordial perturbations in large-angle CMB anisotropy and large scale structure

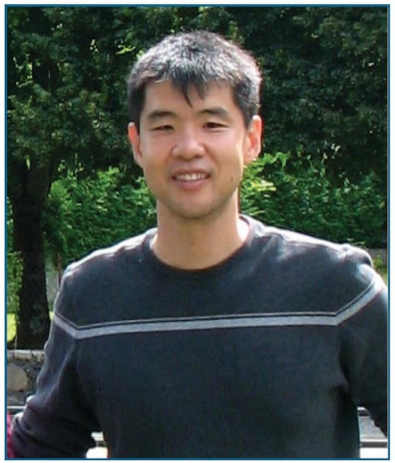
Relation of the cosmological constant to QCD

Experiments (thought and real) with quantum gravity





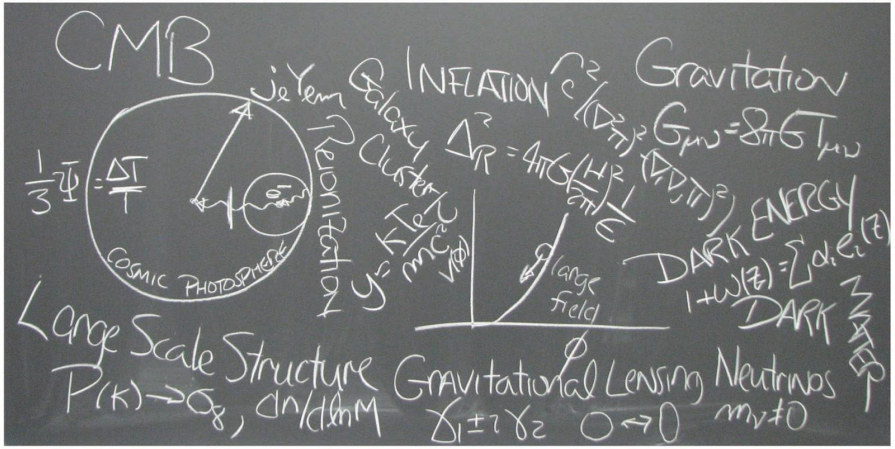
Wayne Hu



Professor, Department of Astronomy and Astrophysics, and the College; Enrico Fermi Institute; Kavli Institute for Cosmological Physics

Research

Hu's research focuses on the theory and phenomenology of inflation, dark energy and gravity as revealed in Cosmic Microwave Background anisotropies, large scale structure and gravitational lensing.



Current Students

Graduate: Meng-Xiang Lin, David Zegeye

Recent Students

Graduate: Sam Passaglia (2020), Pavel Motloch (2018), Chen He (2017), Yin Li (2015), Pierre Gratia (2015), Vinicius Miranda (2015), Cora Dvorkin (2011),...

Department of Astronomy & Astrophysics University of Chicago

Dan Hooper

Research Interests

The Particle Nature of Dark Matter

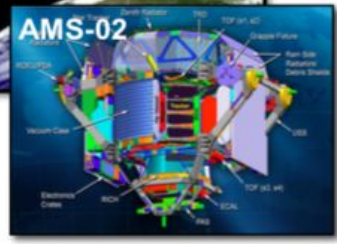
- -Indirect and direct searches
- -The Galactic Center γ-ray excess
- -Dark matter model building

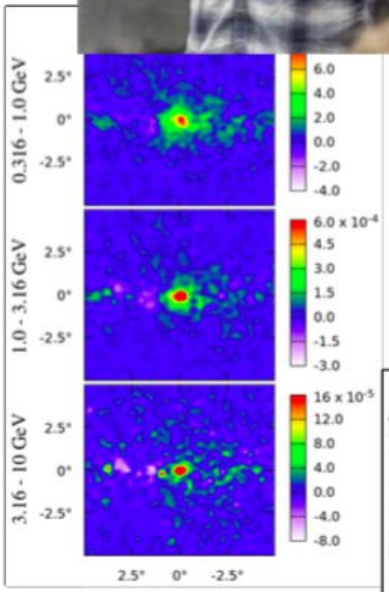
Physics of the early universe

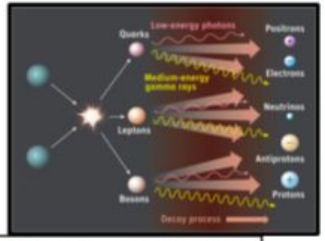
- -Origin of dark matter
- -Exotic relics? Exotic eras?

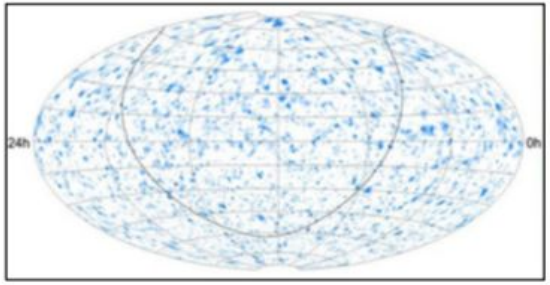
High-energy astrophysics

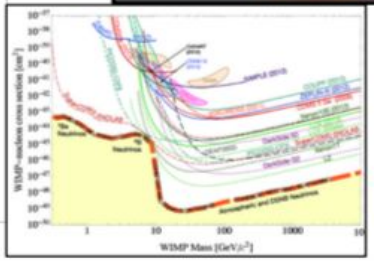
- -Neutrino astronomy
- -Cosmic ray physics
- -Gamma ray astronomy











Austin Joyce

Theoretical Cosmologist: Working at the interface between gravity and high energy physics—particularly through the use of effective field theory/symmetries.

Cosmology as a probe of fundamental physics:

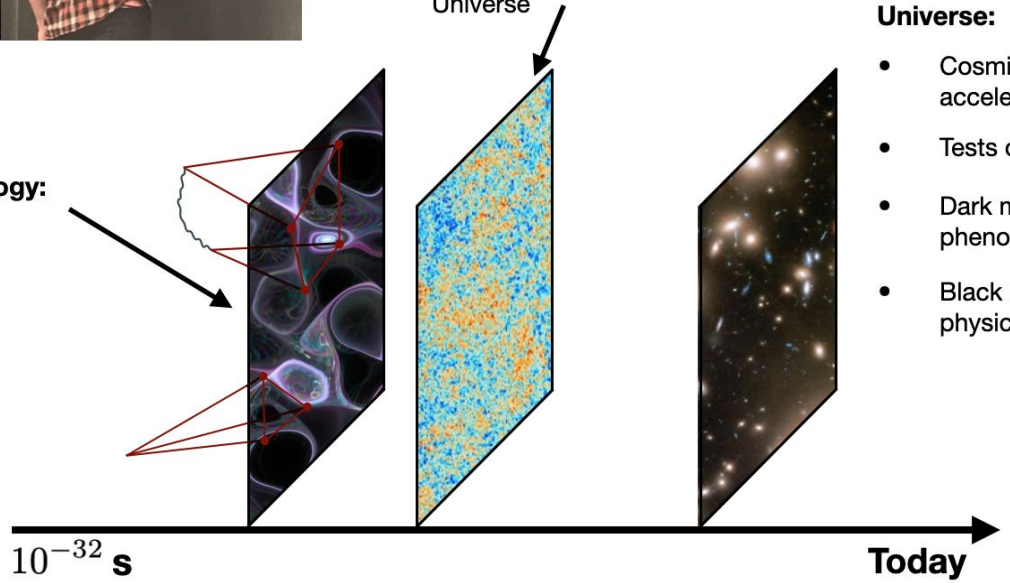
- Signatures of new particles
- The origins of structure in the Universe

Physics of the late Universe:

- Cosmic acceleration
- Tests of gravity
- Dark matter phenomenology
- Black hole physics

Early universe cosmology:

- Inflationary physics
- New calculational approaches ("bootstrap")



Rocky Kolb

Last three papers:

Completely dark photons from gravitational particle production during the inflationary era
With Andrew J. Long (Rice)
Published in: *JHEP* 03 (2021) 283

Catastrophic Production of Slow Gravitinos
With Andrew J. Long (Rice), and Evan McDonough (UChicago)
Physical Review D, in press (2021)

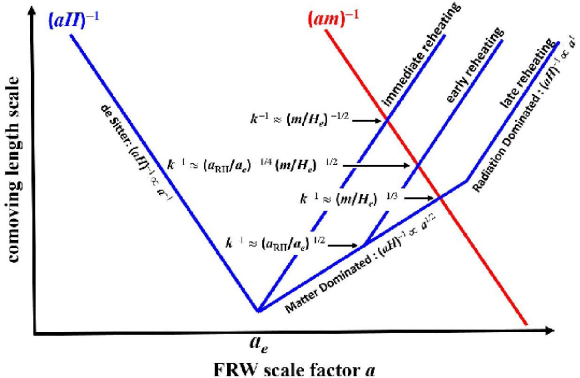
Gravitino Swampland Conjecture
With Andrew J. Long (Rice), and Evan McDonough (Winnipeg)
Physical Review Letters, in press (2021)

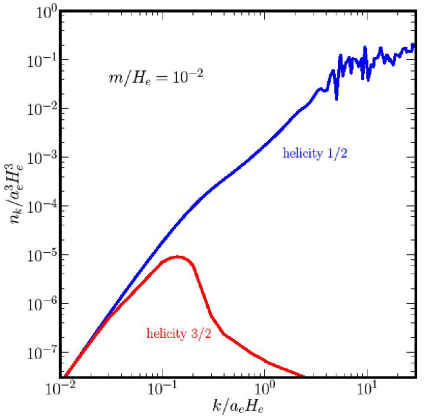
Current projects:

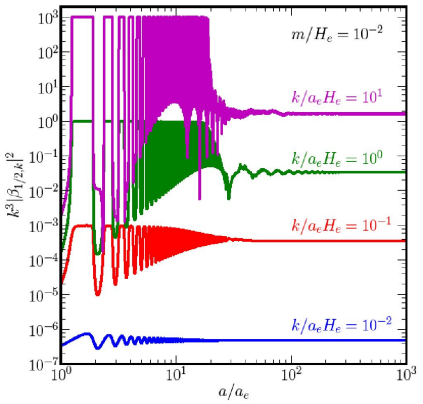
Gravitational production of massive gravitons
With Siyang Yang and Andrew J. Long (Rice) and Rachel Rosen (Columbia)

Rarita-Schwinger fermions as dark matter
With Daniel Chung and Eddie Basso (Wisconsin)

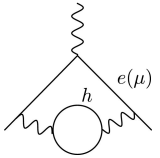
Supergravity in the swampland?
With Andrew J. Long (Rice), and Evan McDonough (Winnipeg)







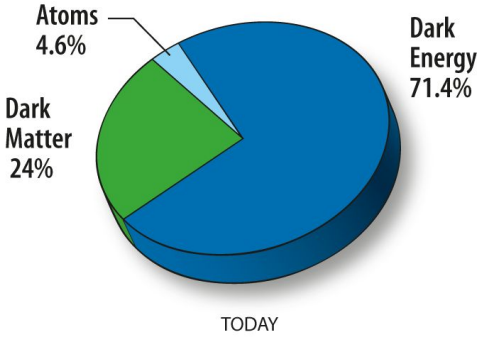
Gordan Krnjaic (“Kern-ya-yitch”)

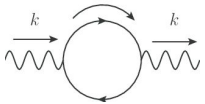


Theoretical cosmologist

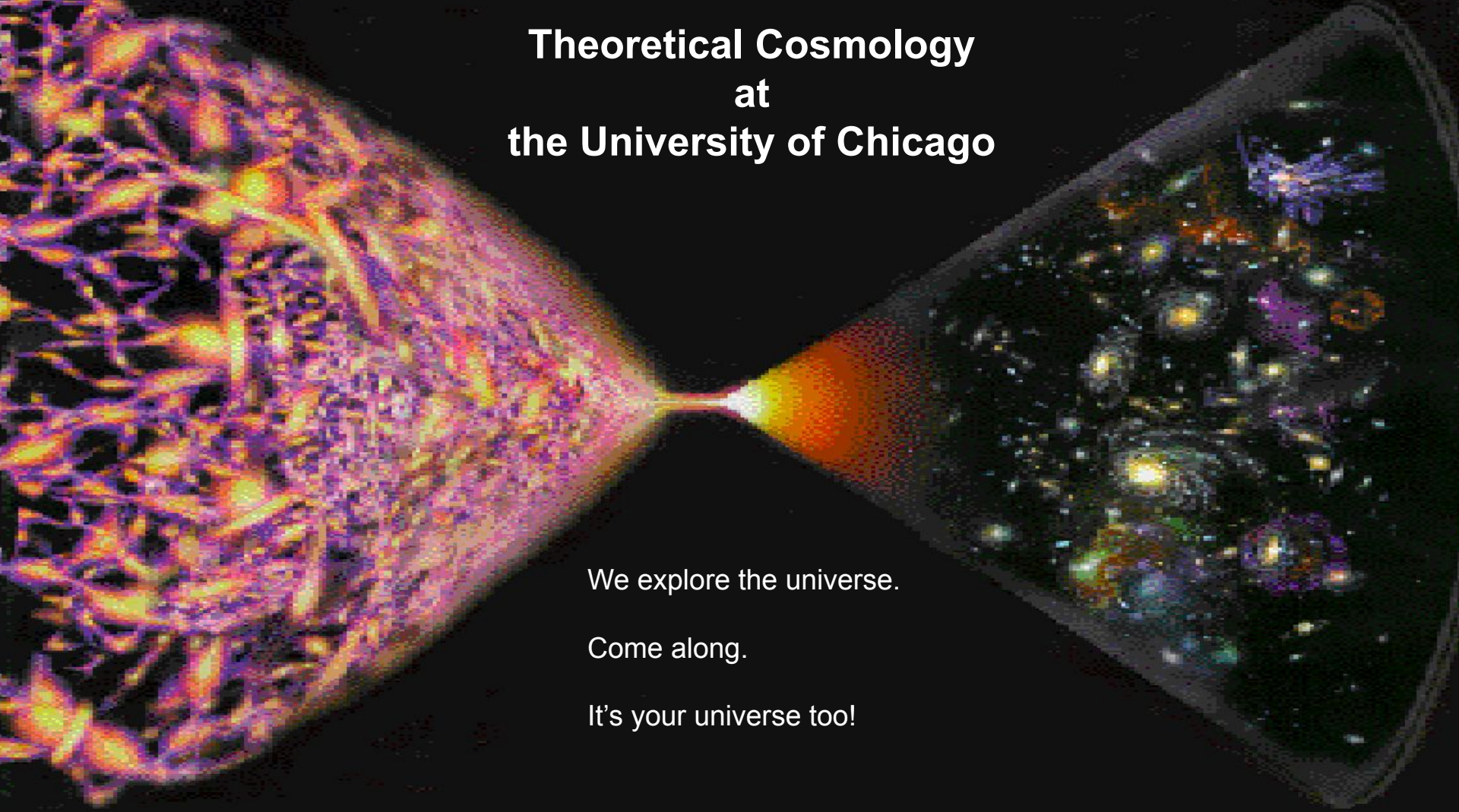
Research Interests

- Dark matter
- Neutrinos
- Baryogenesis
- Primordial black holes
- Early universe theory
- Proposing new experiments





Theoretical Cosmology
at
the University of Chicago

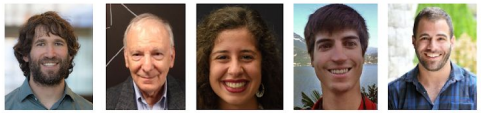


We explore the universe.

Come along.

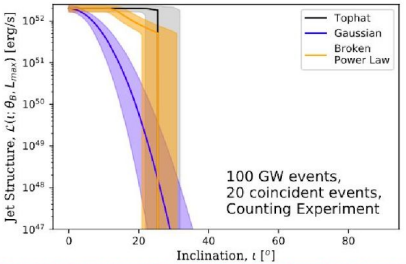
It's your universe too!

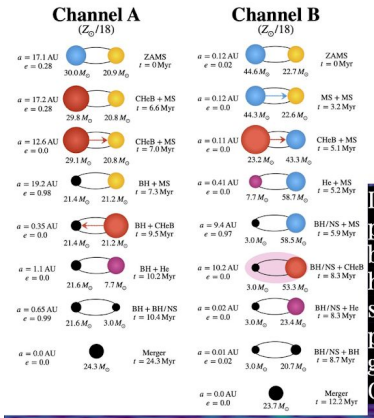
Gravitational-Wave Science at UChicago



Daniel Holz, Robert Wald, Amanda Farah, Jose Maria Ezquiaga, Mike Zevin

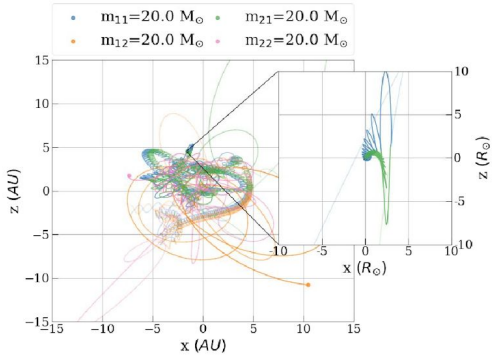
Our group studies the most extreme objects in the universe using gravitational waves. We employ theoretical, computational, and data analysis techniques to probe everything from black holes and neutron stars to the expansion of the universe.



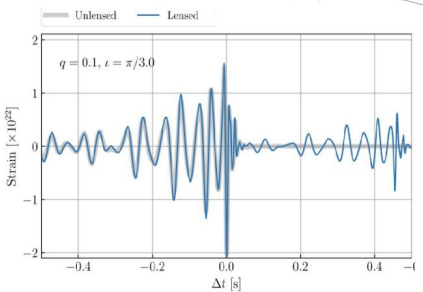


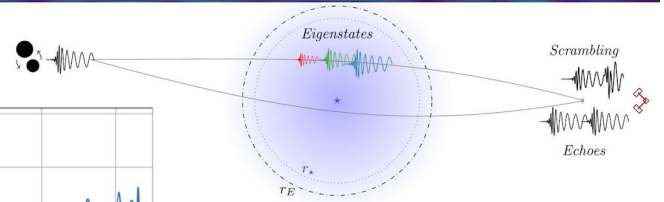
Left: potential formation pathways for compact binary systems with highly asymmetric masses similar to those that produced gravitational-wave signal GW190814

Above: Simulated constraints on the jet structure of gamma-ray bursts. Below: Time-frequency trace of binary neutron star merger GW170817



Left: N-body simulations of chaotic gravitational encounters that result in a rapid, highly-eccentric merger.

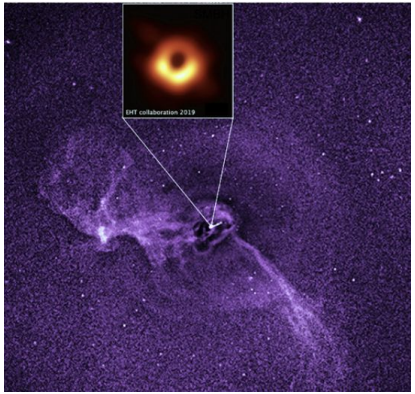


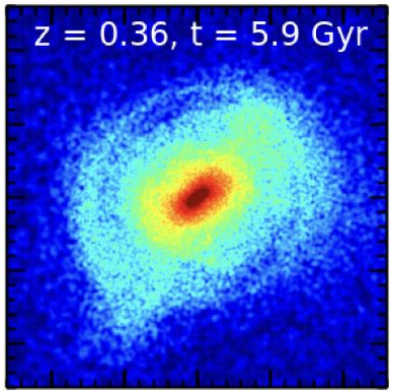


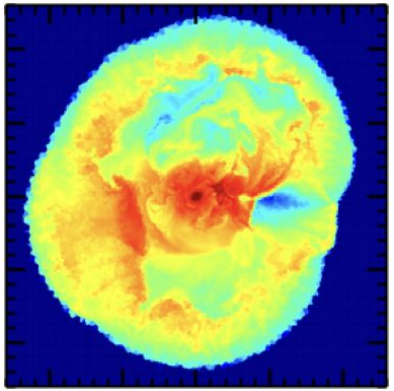
Top: Additions to GR cause lensed GWs to be severely different than GR signals
Left: Strong lensing can make lensed GWs appear as non-GR signals for type II images, even in classical GR.

High-energy X-ray Astrophysics

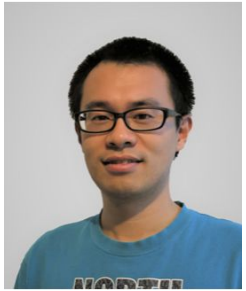
- Physics of galaxy clusters
- AGN feedback
- Observational plasma physics
- X-ray observations
- Numerical simulations
- X-ray missions: XRISM, Athena



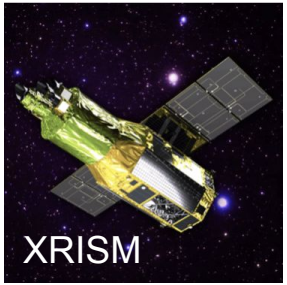


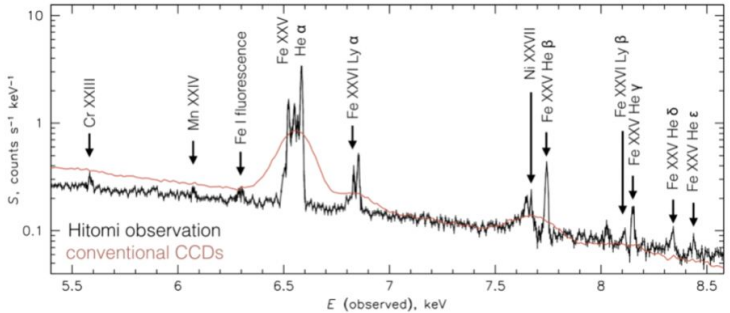


PI: Irina Zhuravleva

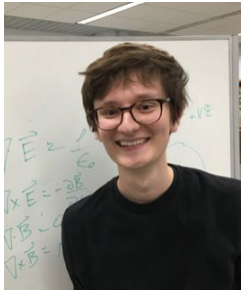


Postdoc: Congyao Zhang





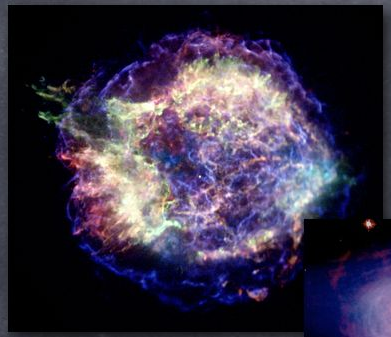
Yunchong Zhang

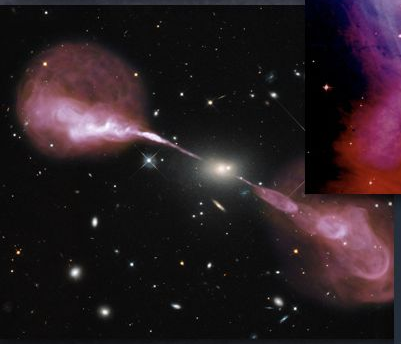


Nicholas Earley

Astroplasmas / High-Energy Astrophysics

- Cosmic rays (all energies)
- Non-thermal emission
- Now on supercomputers!





UChicago Tradition: *Compton, Fermi, Chandrasekhar, Parker*


Damiano Caprioli


Christine Simpson


Siddhartha Gupta


Rebecca Diesing


Rostom Mbarek

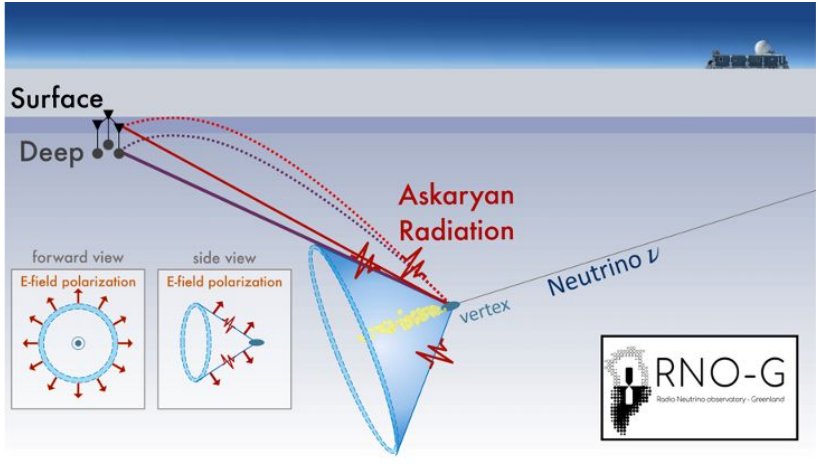

George Zacharekgas

Plus several undergrad/master students

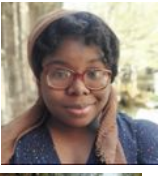
Also: F. Cattaneo, V. Dwarkadas, B. Rosner

Ultra-High Energy Neutrino Astronomy, Vieregg Group

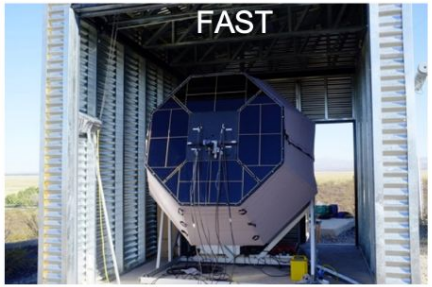
Radio Neutrino Observatory in Greenland: First Deployment was in 2021! Full Array installed by 2024.



Payload for Ultrahigh Energy Observations (PUEO): New UChicago-led Astrophysics Pioneers Mission to Launch in 2024!



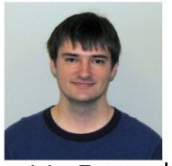
Paolo Privitera



Radomir Smida
Research Ass. Prof.

Danielle Norcini
KICP Fellow.

Dan Baxter
KICP Fellow (now at Fermilab).



John Farmer.

Julian Cuevas-Zepeda

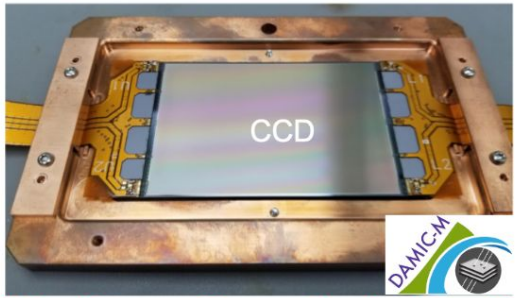
Sravan Munagavalasa

Rachana Yajur

Ryan Thomas

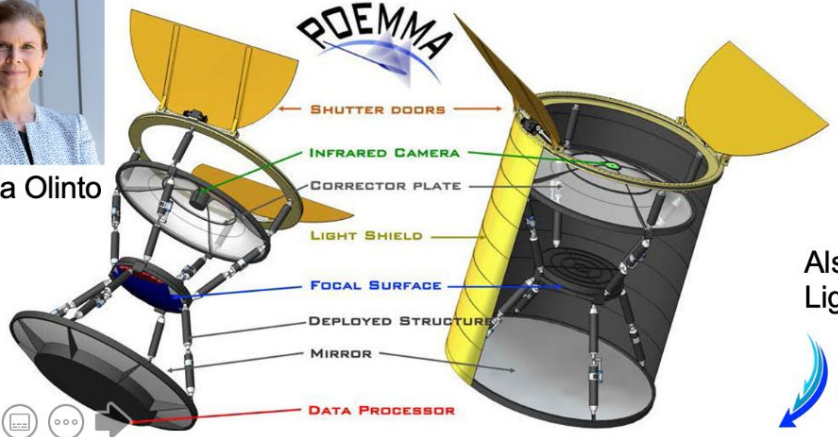
Jonty Paul

UHE Cosmic rays and neutrinos

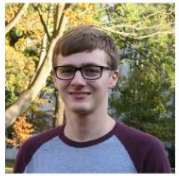


Ariel Matalon

Angela Olinto

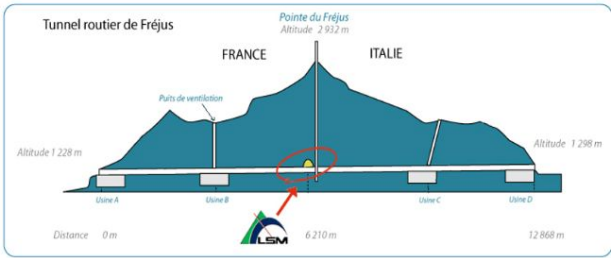


Dark Matter direct detection



Nick Corso

Also: Scott Wakely
Light cosmic rays



Exoplanets

Astronomy & Astrophysics faculty

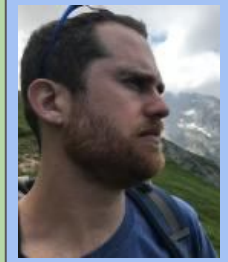
Bean

Fabrycky

Rogers

Powell
(Starting 2023)

Geophysical Sciences faculty



Abbot

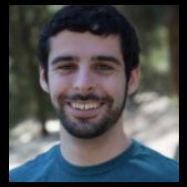
Ciesla

Kite

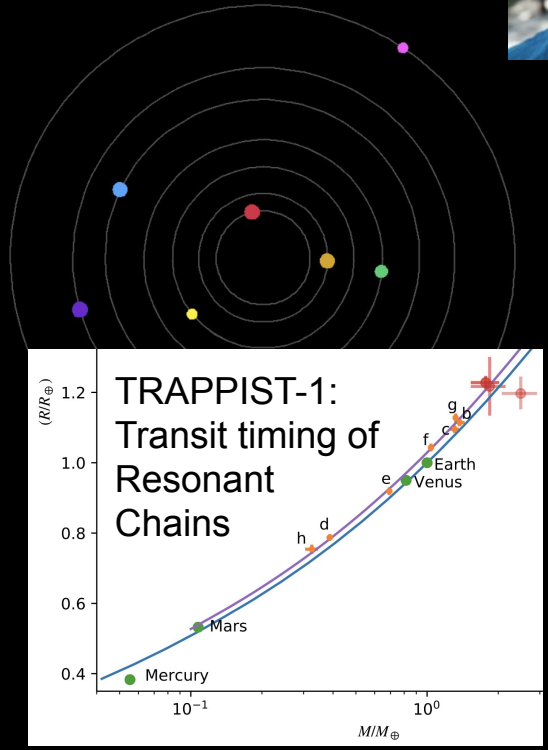
UChicago goes to Reykjavik

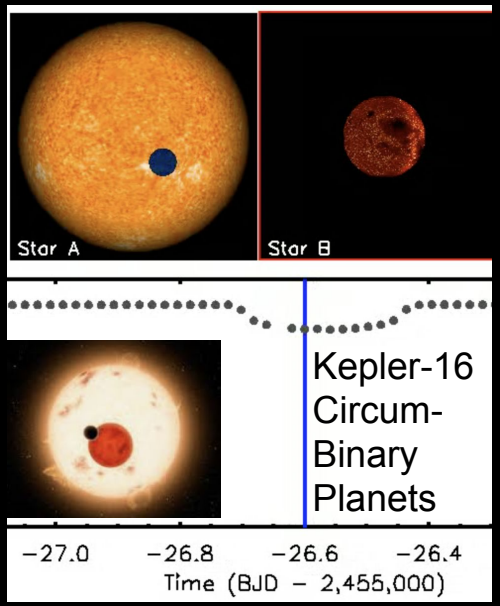
(Extreme Solar Systems IV)

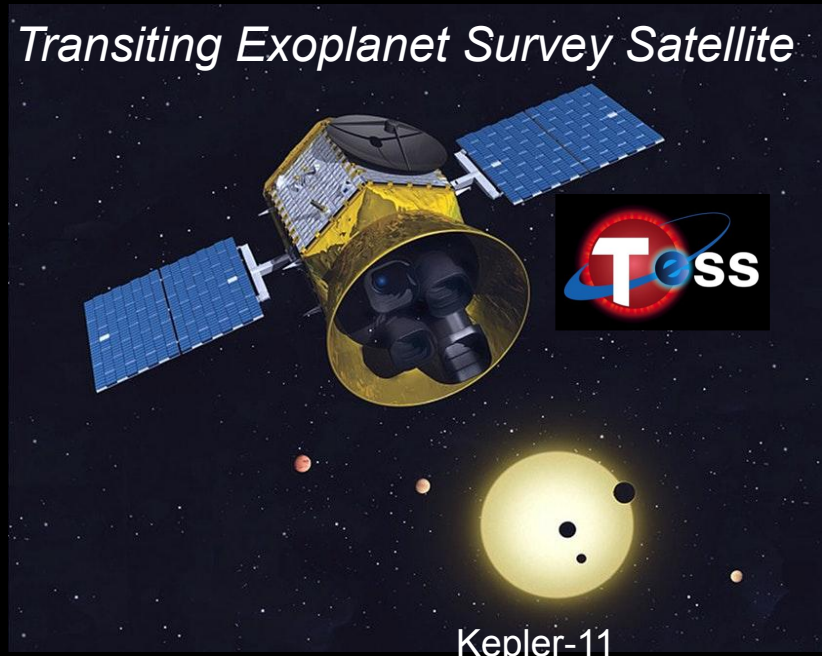
Exoplanet Dynamics Group - Daniel Fabrycky



Evolution: N-body, migration, tidal dynamics, ...
System architectures: i's, e's, spin-orbit, mass/radius,...
Types: Resonant Chains, Binary hosts, Exomoons, ...





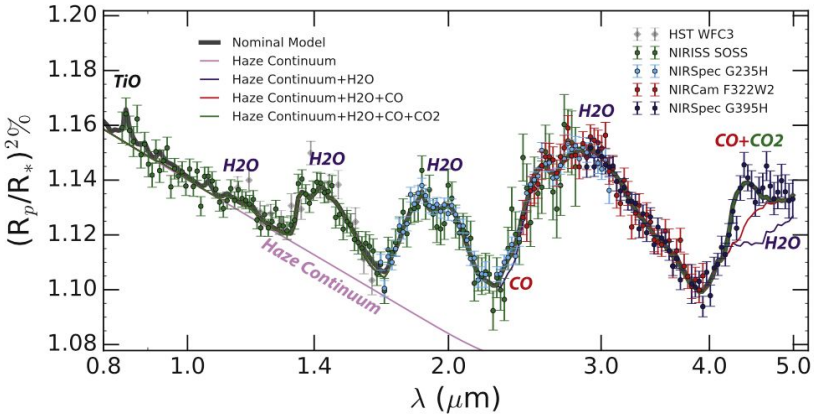


Exoplanets

Bean group will have access to ~300 hours of JWST exoplanet atmosphere observations in Cycle 1, including the lead of the very first observations.

JWST launch robustly expected by the end of the year.

JWST will revolutionize our understanding of planets and the origins of life by revealing the atmospheric compositions, structures, and dynamics of transiting exoplanets in unprecedented detail.

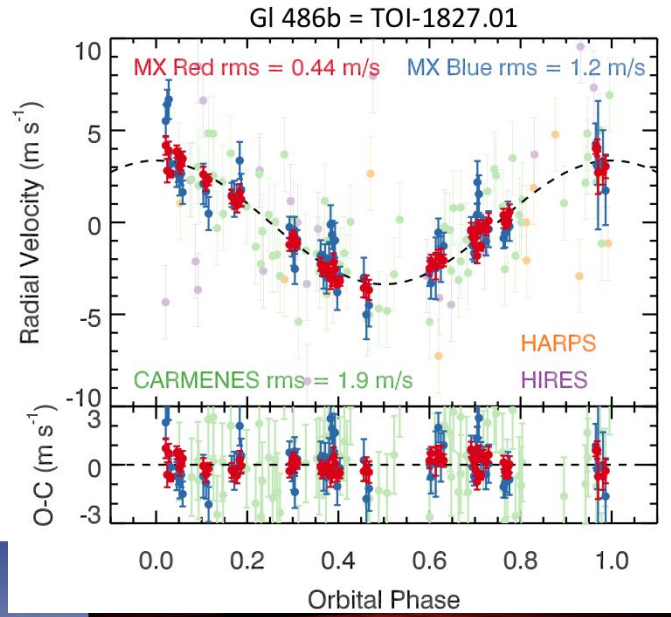


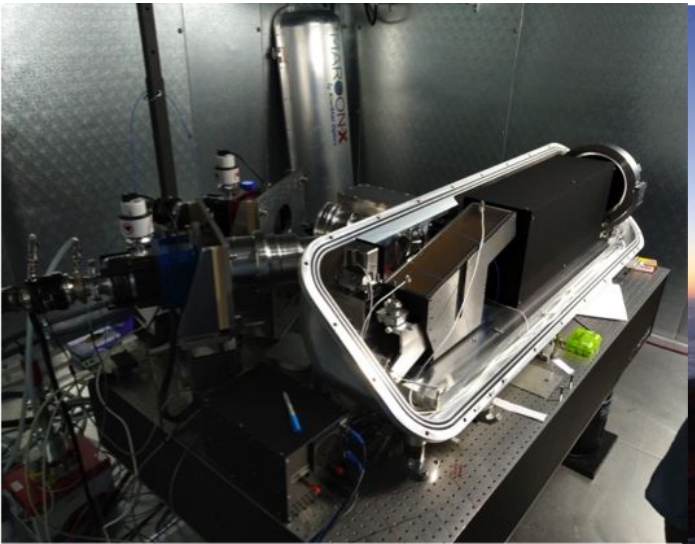
Exoplanets

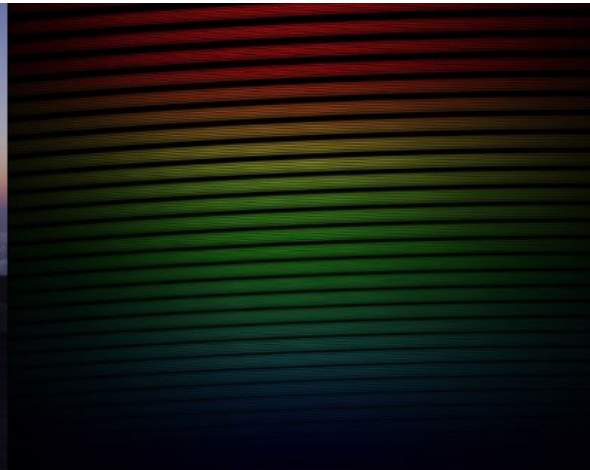
MAROON-X

New radial velocity instrument built at U. Chicago and recently commissioned on the Gemini-N telescope

Aim to detect rocky planets in the habitable zones of nearby M dwarfs



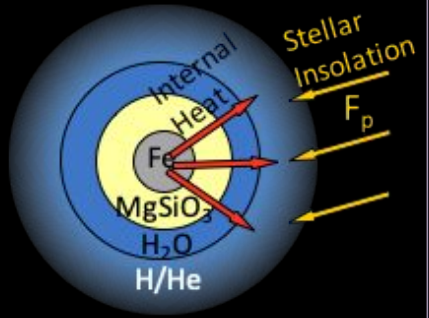




Exoplanets

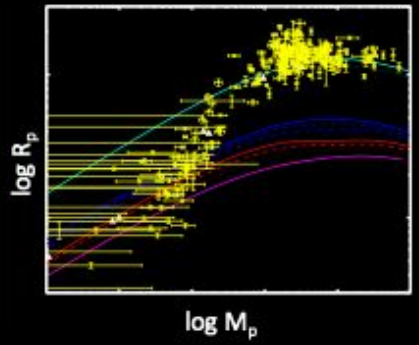
Rogers - Theory and Computation Group
Uncovering the Composition Distribution of Planets

Planet Evolution Model Database



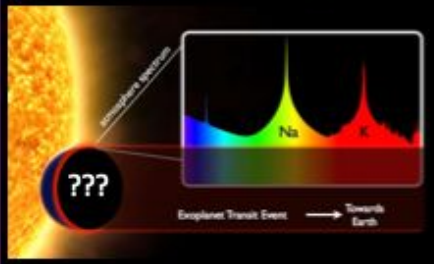
Building an extensive, accessible, and versatile database of planet interior structure and evolution models (from sub-Earths to super-Jupiters) to predict planet size at specified mass, composition, insolation, and age.

Planet Population Statistics



Developing frameworks to derive constraints on the planet mass-composition distribution from large numbers of noisy M_p-R_p measurements.

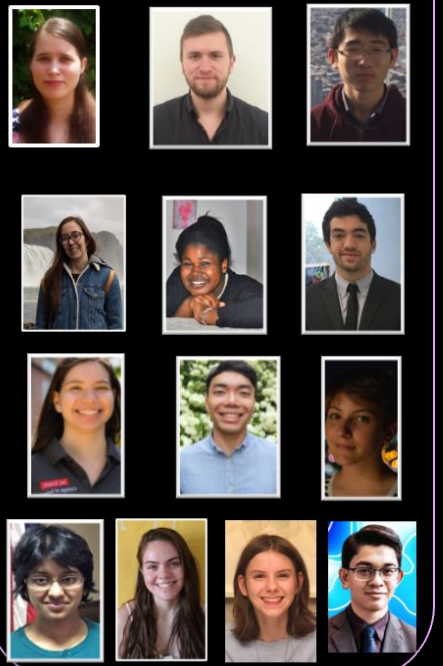
Connecting Planet Interiors and Atmospheres



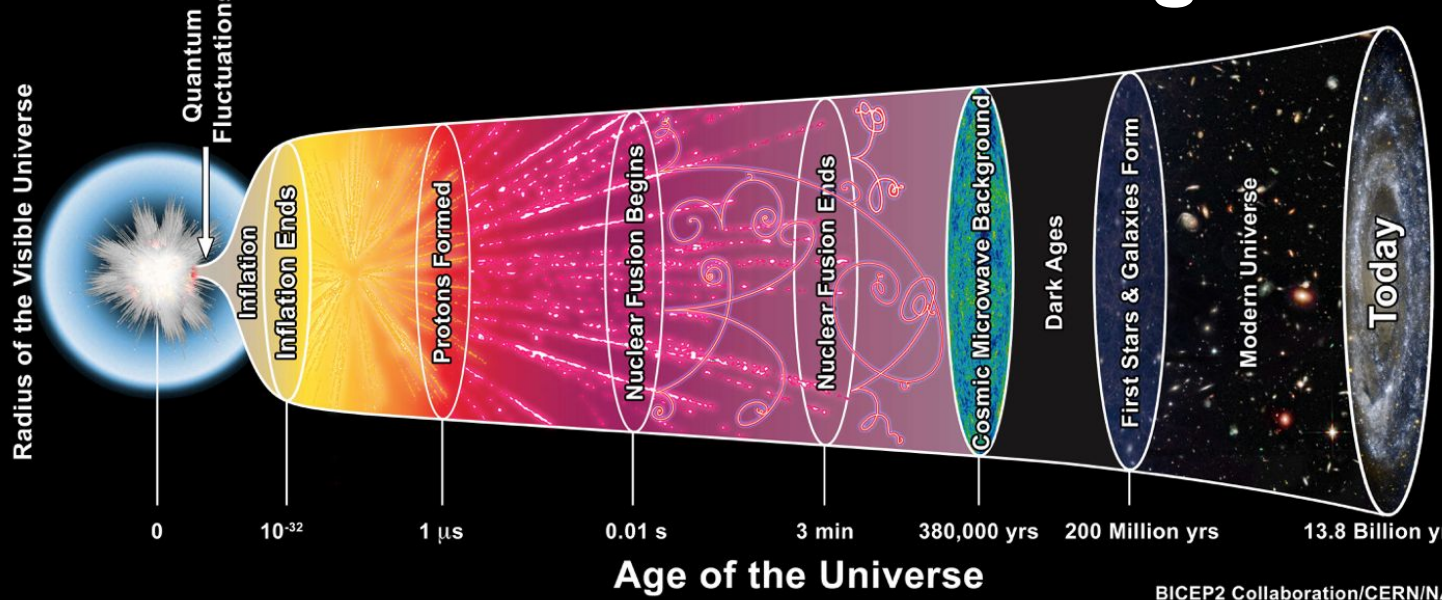
Studying the planet interior-atmosphere connection to identify atmospheric abundance patterns that could be used as robust indicators deep interior structure and processes.

Group Meetings Wednesdays @ 2pm.

All are welcome!



The Cosmic Microwave Background



Inflation

- *Energy-scale of Inflation (~10^{16} GeV)*

Neutrinos

- Beyond standard model: *relic particles*
- *Sum of the neutrino masses*

Dark Energy

- *Test gravity and dark energy*

Astrophysics

- *Galaxy clusters*
- *Transients*
- *Our galaxy*
- *Search for planet 9*

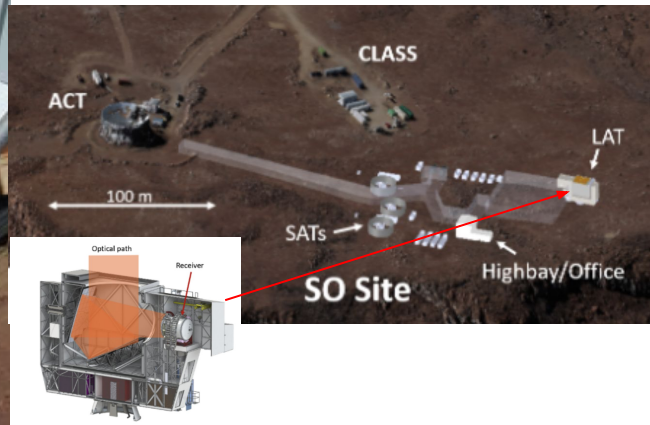
CMB Projects

South Pole Telescope (SPT)

Atacama Cosmology Telescope (ACT)

CMB-S4

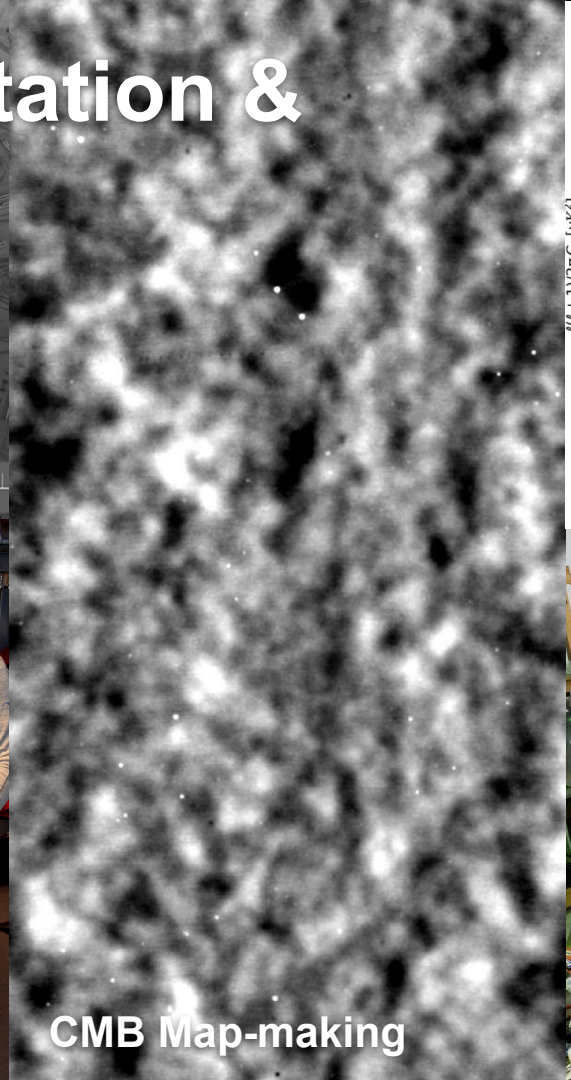
Simons Observatory



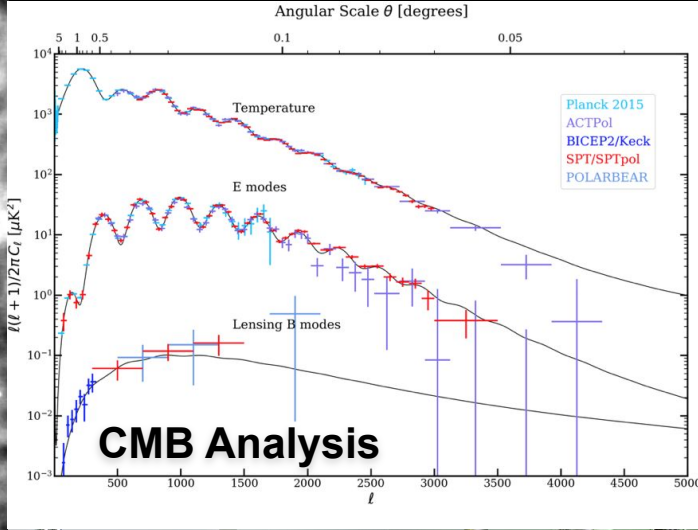
CMB Instrumentation & Analysis

Detector Development

Integration and Deployment



CMB Map-making



Optics and Receivers

Large Millimeter Telescope (SuperSpec)

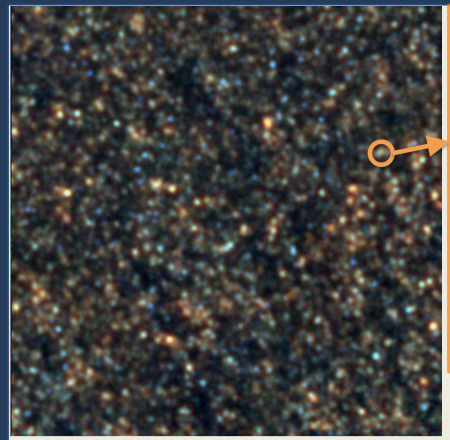
South Pole Telescope (SPT-SLIM)

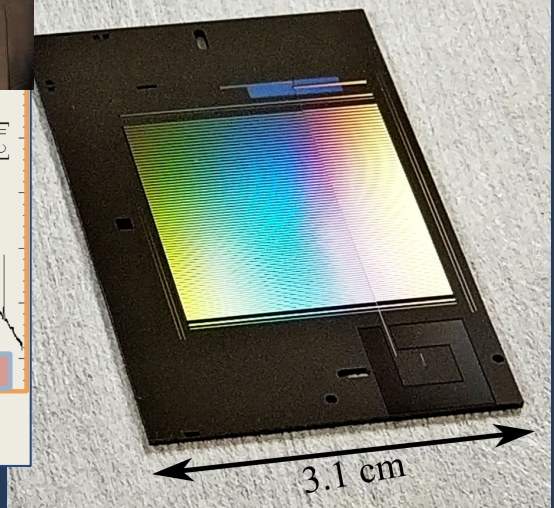
New instruments for submm-wavelength spectroscopy and line intensity mapping.

Erik Shirokoff

Current members:

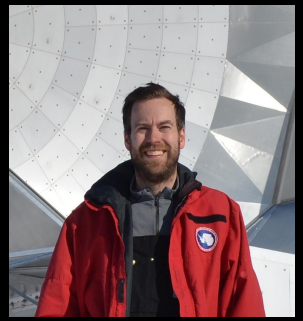
Pete Barry
Kirit Karkare
Ryan McGeehan
Amy Tang (graduated)
Cory Cotter
Aaron Steiger



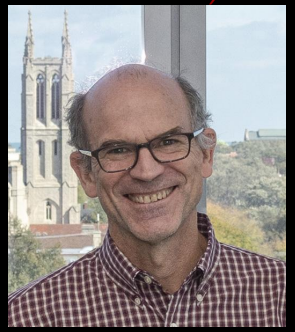


The Cosmic Microwave Background

Faculty (primary appointments listed)



Brad Benson
Fermilab
SPT, CMB-S4



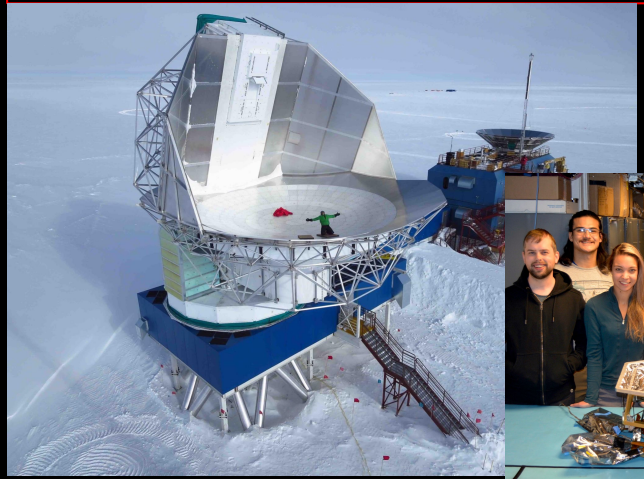
John Carlstrom
U. Chicago A&A
SPT, CMB-S4

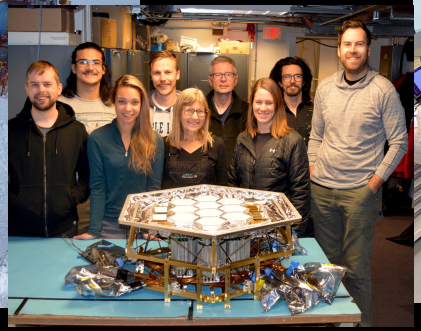
Clarence Chang
Argonne
SPT, CMB-S4

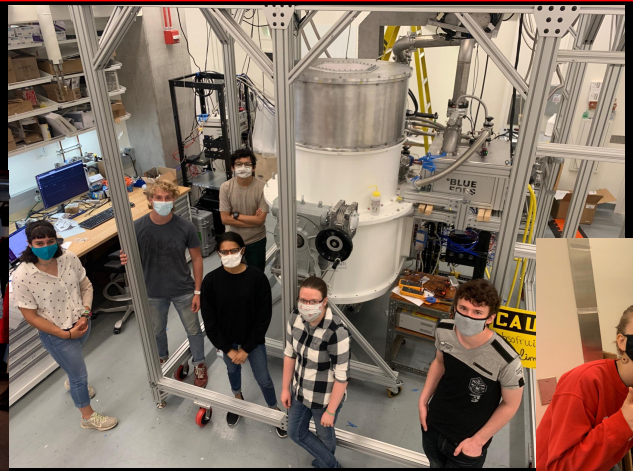
Tom Crawford
U. Chicago, A&A
SPT, CMB-S4

Jeff McMahon
U. Chicago A&A
ACT, SO, CMB-S4

Abby Vieregg
U. Chicago Phys.
Bicep/KECK, S4







Selected action shots of group members. (I blame covid for the absence of an up to date group photo)