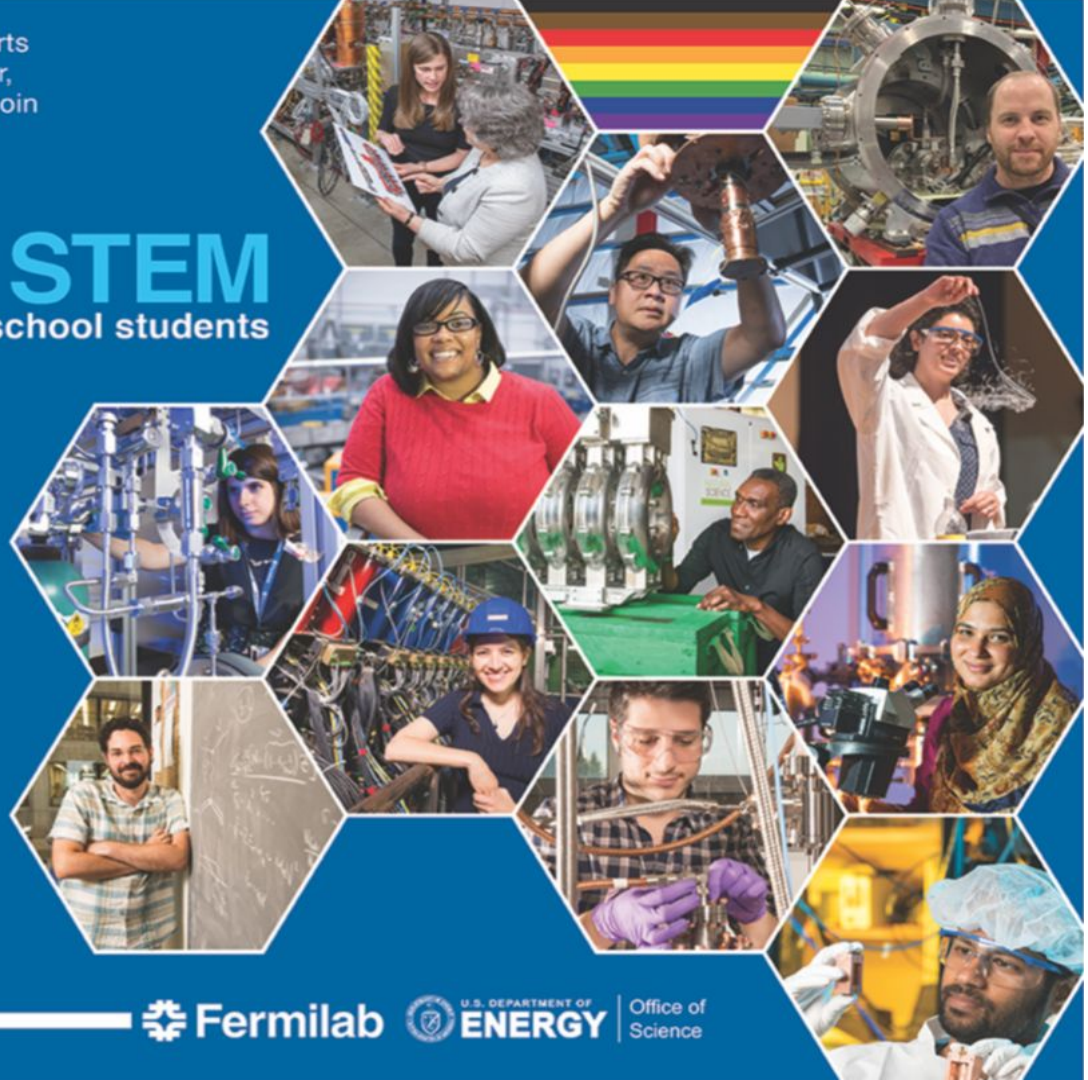
At Fermilab, we bring the world's experts together to solve the mysteries of matter, energy, space and time. Now you can join them online.

Superheroes in STEM

Online conference for high school students

Astrophysics and Computing

Aleksandra Ćiprijanović
Postdoctoral Research Associate
Scientific Computing Division



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A little about me

- I did my undergraduate and PhD studies in Serbia
  - theoretical high-energy and particle astrophysics
- Then worked as a scientist at:
  - The Department of Astronomy, University of Belgrade
  - Serbian Academy of Sciences and Arts

Dr Brian D. Fields

Dr Tijana Prodanovic

Me

ILLINOIS

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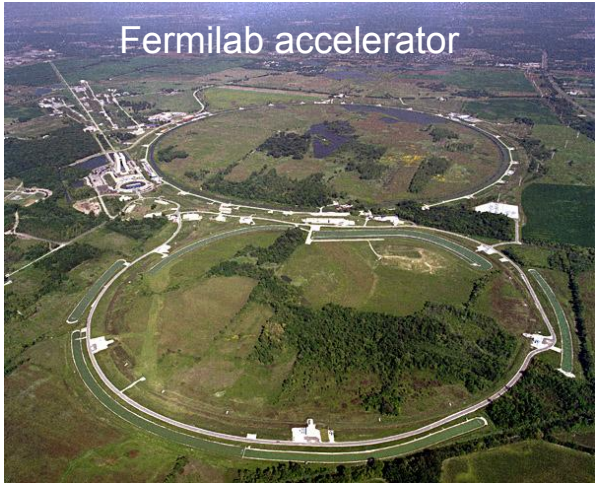
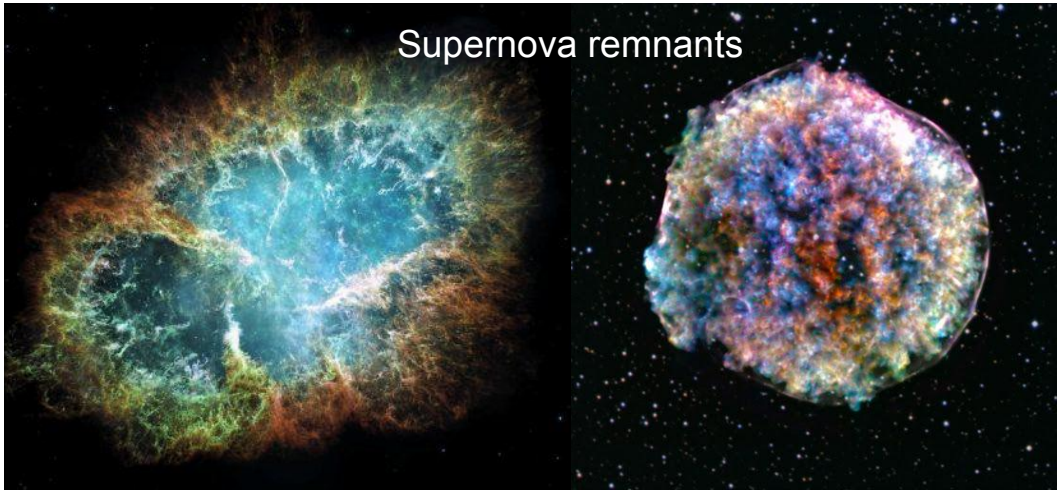
A little about me



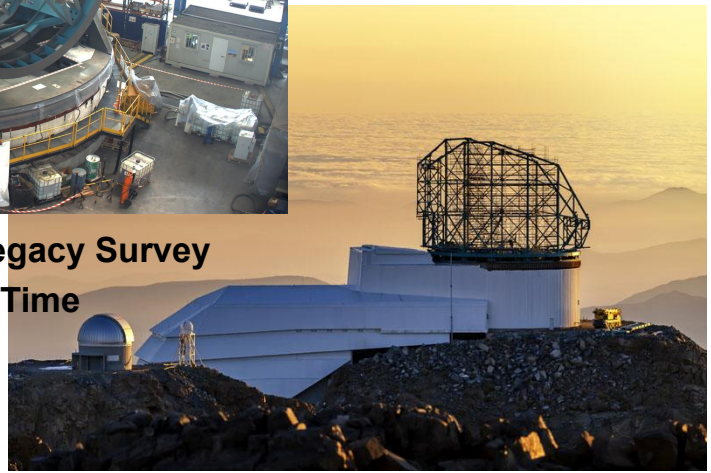


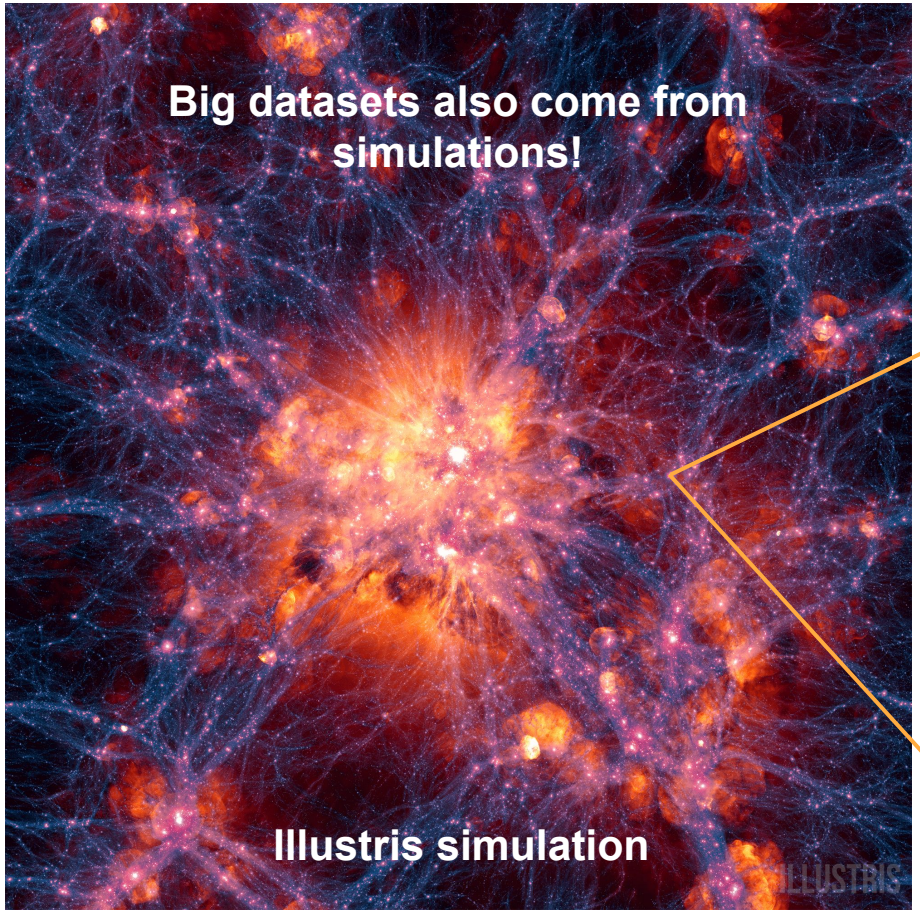
Produce particles of very high energies
(Cosmic Rays)

Big astronomical surveys produce huge datasets

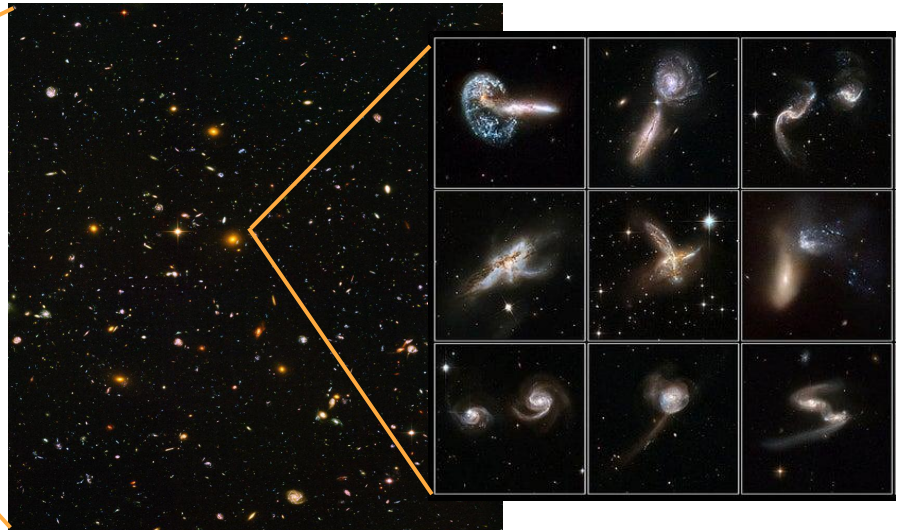

South Pole Telescope

Rubin Observatory Legacy Survey of Space and Time



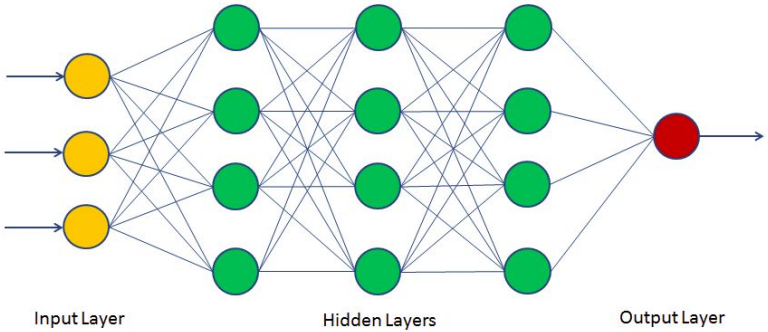


Understanding formation and evolution of structures in the Universe



How can these good boys help?

How can these good boys help?



Machine learning (ML) and neural networks can help us work with big sets of images!

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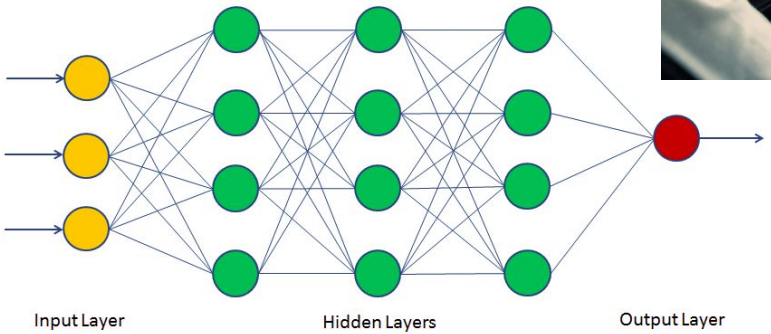
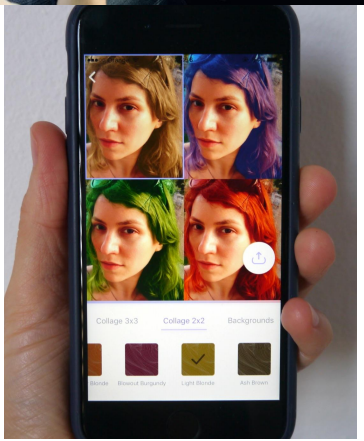
How can these good boys help?

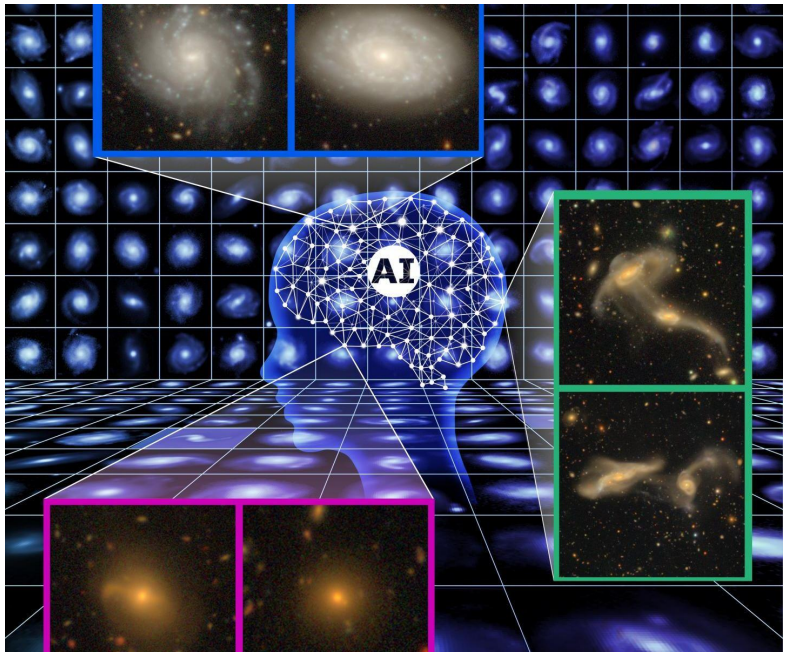




Machine learning (ML) and neural networks can help us work with big sets of images!

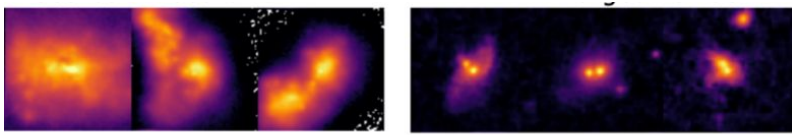
Astronomers use ML for new discoveries!

I use them to study galaxies ...

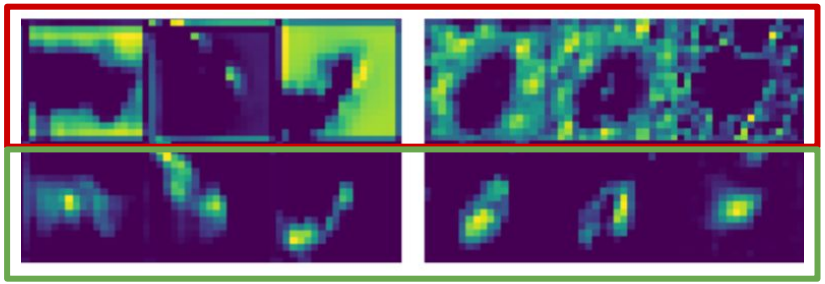


Simulated galaxies

Observed galaxies



Neural network learns where to look for information:



Mergers: galaxy periphery
Non-mergers: central regions

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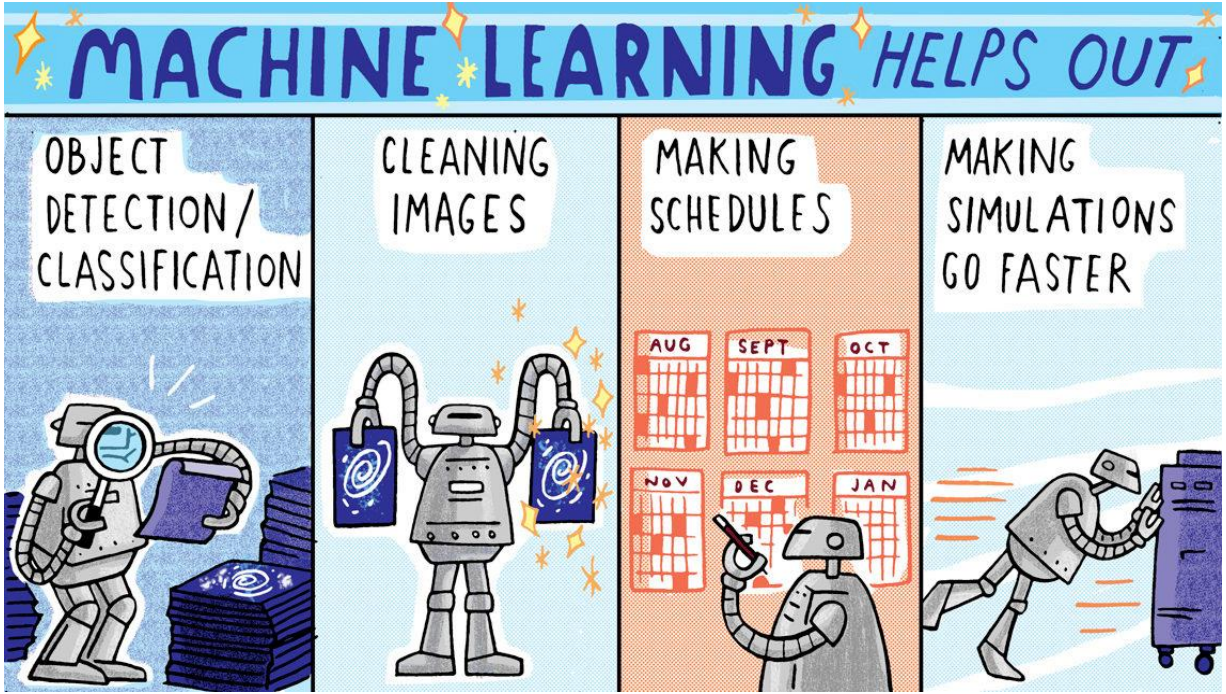
Astronomers use ML for new discoveries!

But there are MANY more applications!



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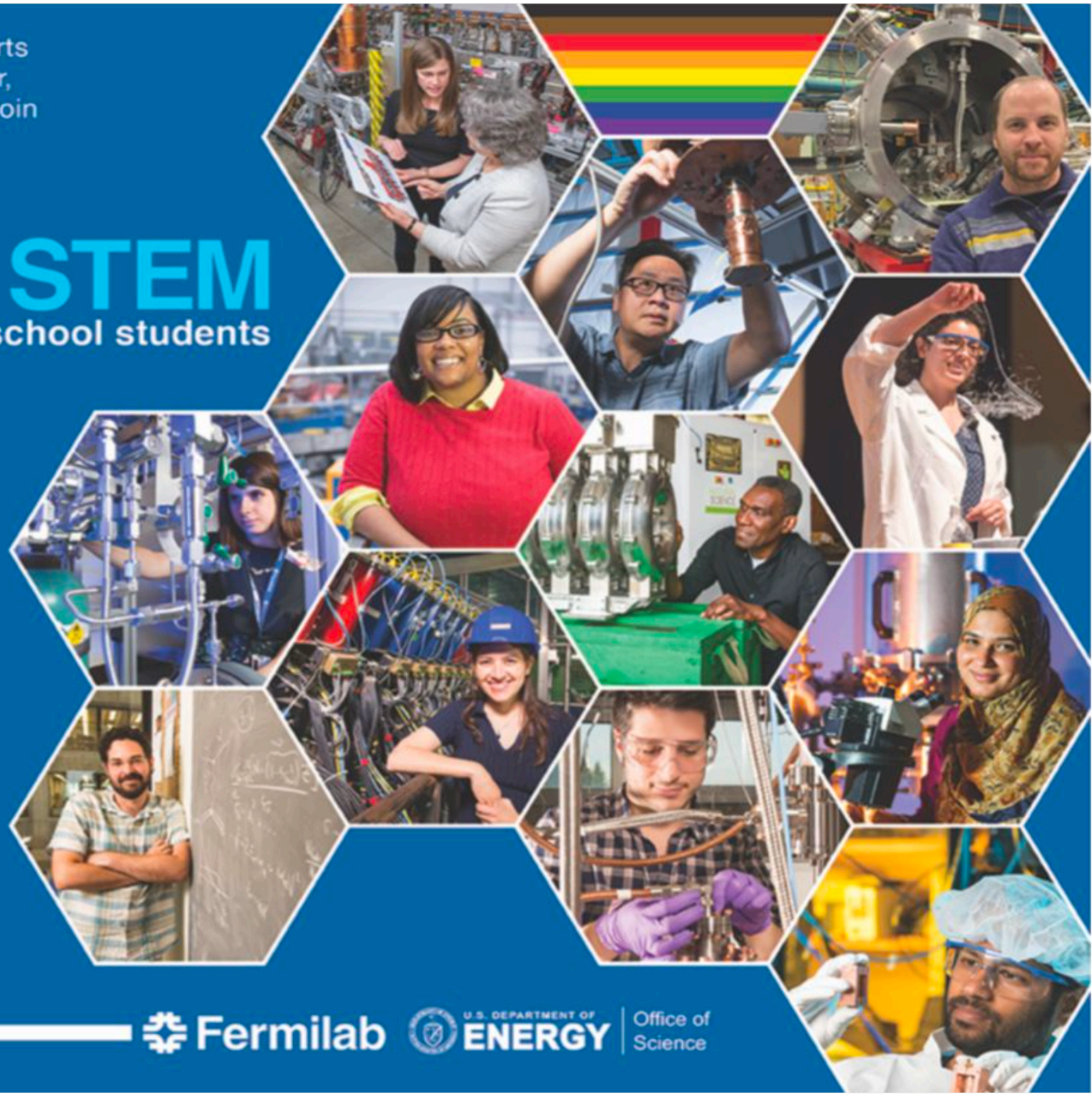
Online conference for high school students

Being an Astronomer

James Annis
Senior Scientist
Scientific Computing Division



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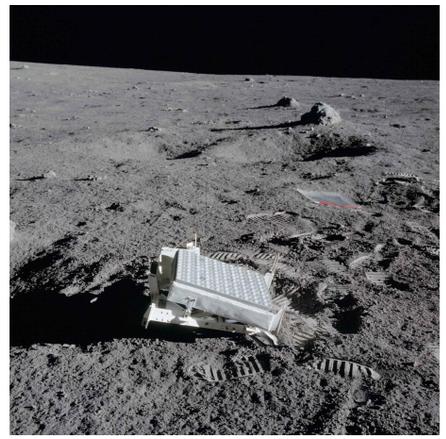
Being an astronomer: How did you start?

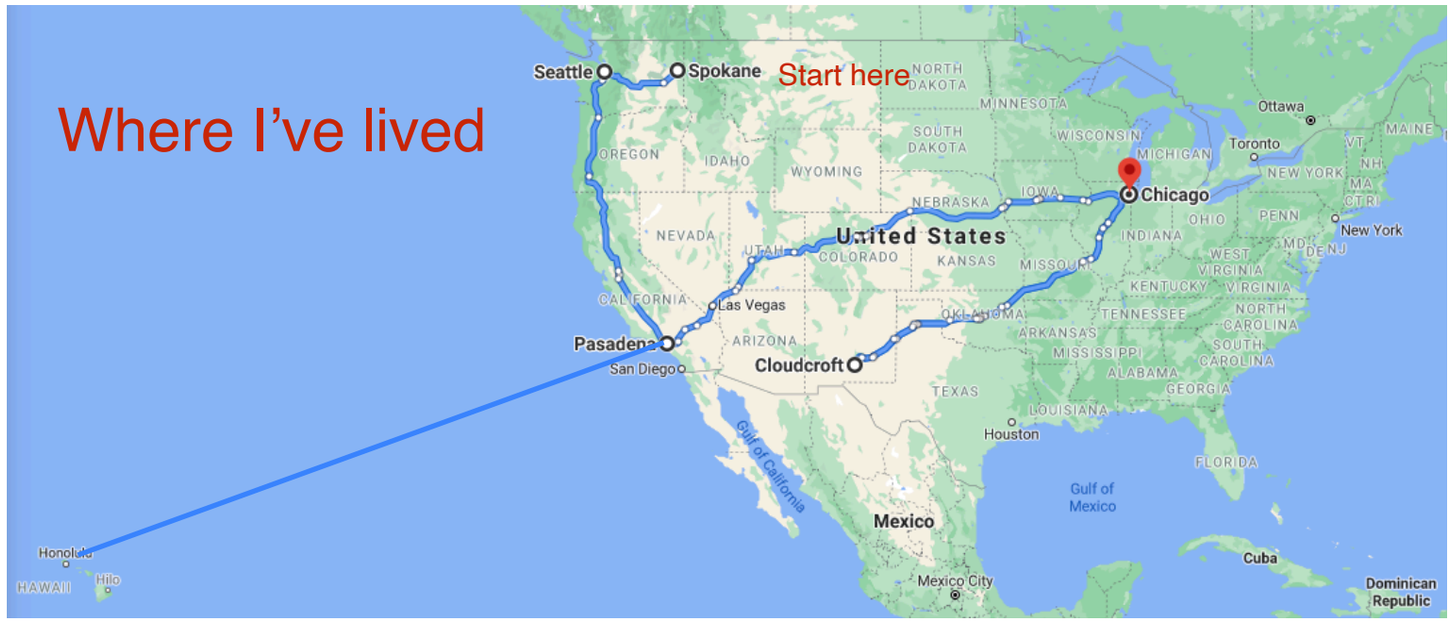
- When I was 7, we landed on the Moon. There was also wars, struggles for racial justice, and a growing recognition of humans' effect on the Earth.
  - Sound familiar? Replace moon with helicopter on Mars, and climate change for effect?



- And science fiction, lots of science fiction.
- I thought science would be the way to change the world.
- I ended up in the most useless of science: astronomy and cosmology, but I'm here for the view and the fascination.
- Why would you want to do astrophysics? Because you can.

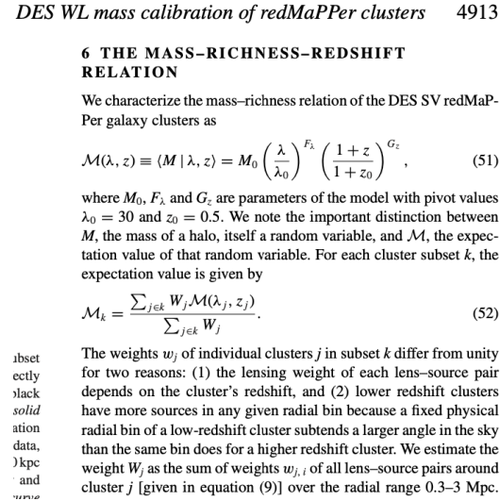
Being an astronomer: Cosmopolitan Citizenship

- You will have to travel for the education and for the training
  - College; U. Washington
  - Intern: Pasadena, CA
  - Graduate school: U. Hawaii
  - Postdoc: Fermilab (and Cloudcroft, NM, where a telescope lived)
  - Staff: Fermilab



- You will have to learn other languages:
  - Physics
  - Computation
  - Already know English? You're ahead of the game

- You will have to learn to read the literature:
  - But that is what grad school is for
  - Tending the literature is what we do, really.



DES WL mass calibration of redMaPPer clusters 4913

6 THE MASS–RICHNESS–REDSHIFT RELATION

We characterize the mass–richness relation of the DES SV redMaPPer galaxy clusters as

$$\mathcal{M}(\lambda, z) \equiv \langle M \mid \lambda, z \rangle = M_0 \left(\frac{\lambda}{\lambda_0}\right)^{F_\lambda} \left(\frac{1+z}{1+z_0}\right)^{G_z}, \quad (51)$$

where M_0, F_λ and G_z are parameters of the model with pivot values $\lambda_0 = 30$ and $z_0 = 0.5$. We note the important distinction between M, the mass of a halo, itself a random variable, and $\mathcal{M}$, the expectation value of that random variable. For each cluster subset k, the expectation value is given by

$$\mathcal{M}_k = \frac{\sum_{j\in k} W_j \mathcal{M}(\lambda_j, z_j)}{\sum_{j\in k} W_j}. \quad (52)$$

The weights w_j of individual clusters j in subset k differ from unity for two reasons: (1) the lensing weight of each lens–source pair depends on the cluster's redshift, and (2) lower redshift clusters have more sources in any given radial bin because a fixed physical radial bin of a low-redshift cluster subtends a larger angle in the sky than the same bin does for a higher redshift cluster. We estimate the weight W_j as the sum of weights $w_{j,i}$ of all lens–source pairs around cluster j [given in equation (9)] over the radial range 0.3–3 Mpc.

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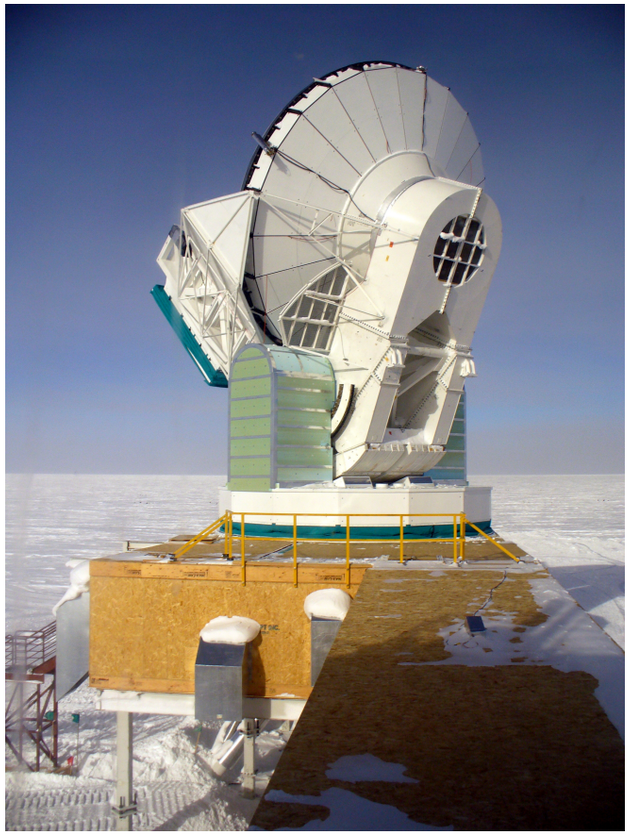
Being an astronomer: Study the Sky, Study the Universe

You get to know your chosen machine intimately.

The beginning of time:

Microwaves



CMB maps

South Pole Telescope,

South Pole

The densest things:

Gravitational waves

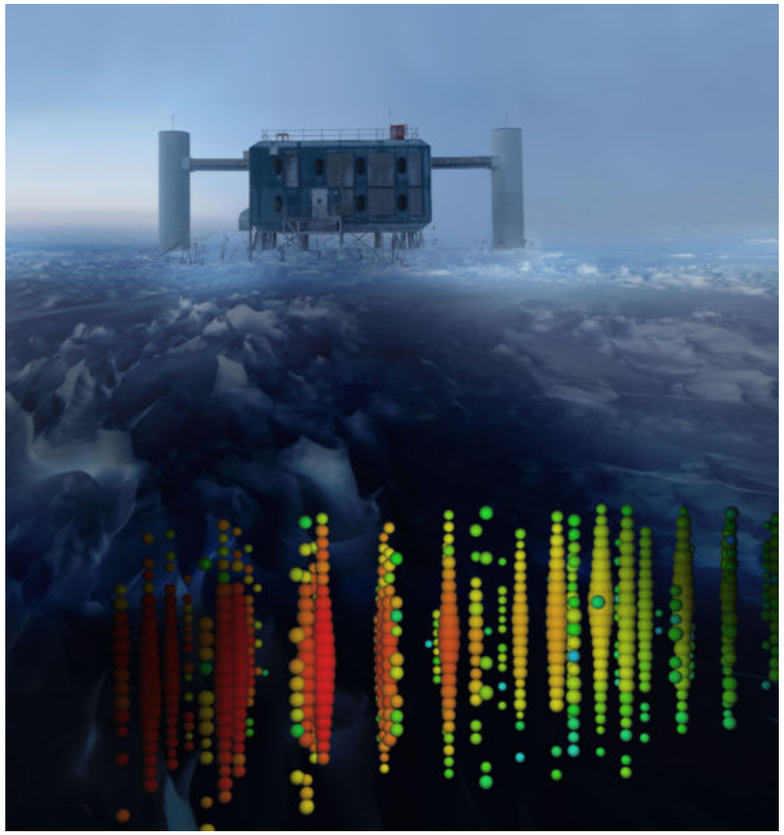
Black hole mergers

LIGO/Virgo,

WA, LA, Italy

EM tornados:

Neutrinos



Highest energy neutrinos

Ice Cube,

South Pole

Being an astronomer: Study the Sky, Study the Universe

You get to know your chosen machine intimately.

Or use light:

The Dark Energy Survey:

A -big- camera on a 4m telescope

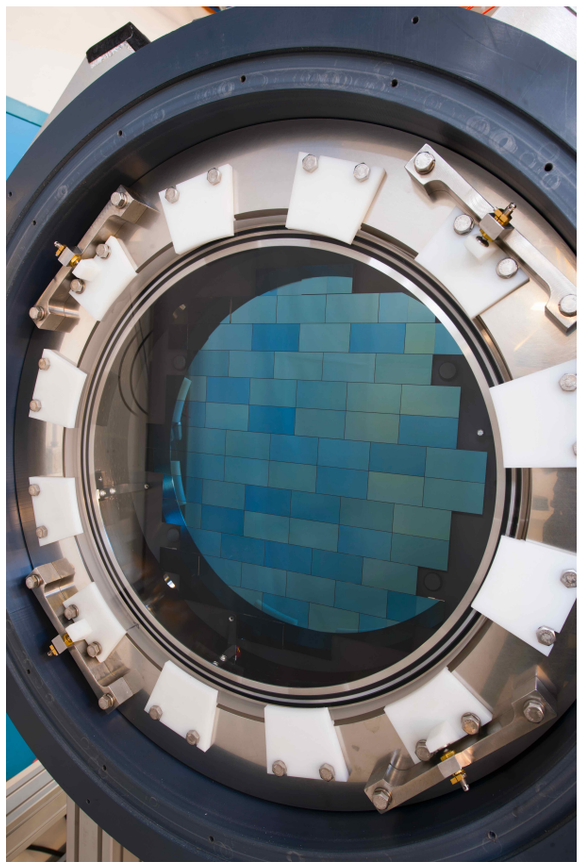
Map the galaxies, map the dark matter

Where you and 500 of your closest friends, all having gone through the cosmopolitan scientist training, spend time analyzing the universe.

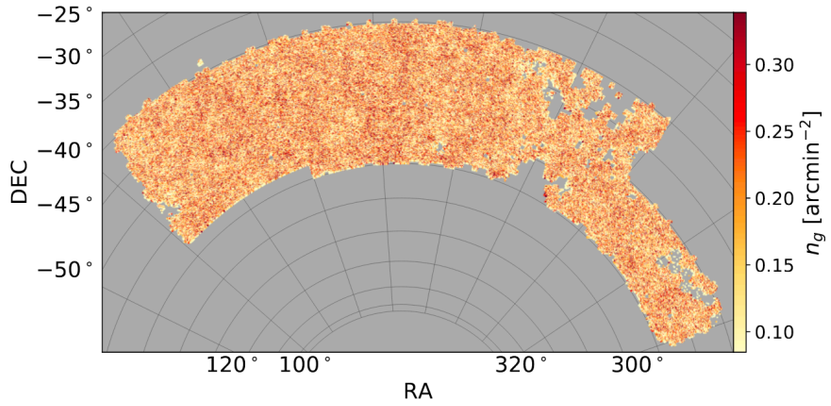
Blanco 4m telescope

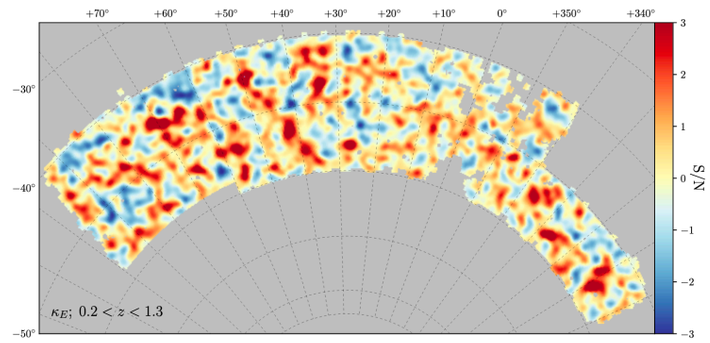
CTIO Observatory

Chile



DECam





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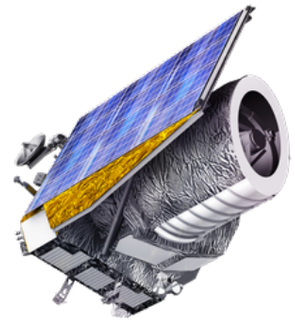
Being an astronomer: Plan for the future



ESA's Euclid Space Telescope

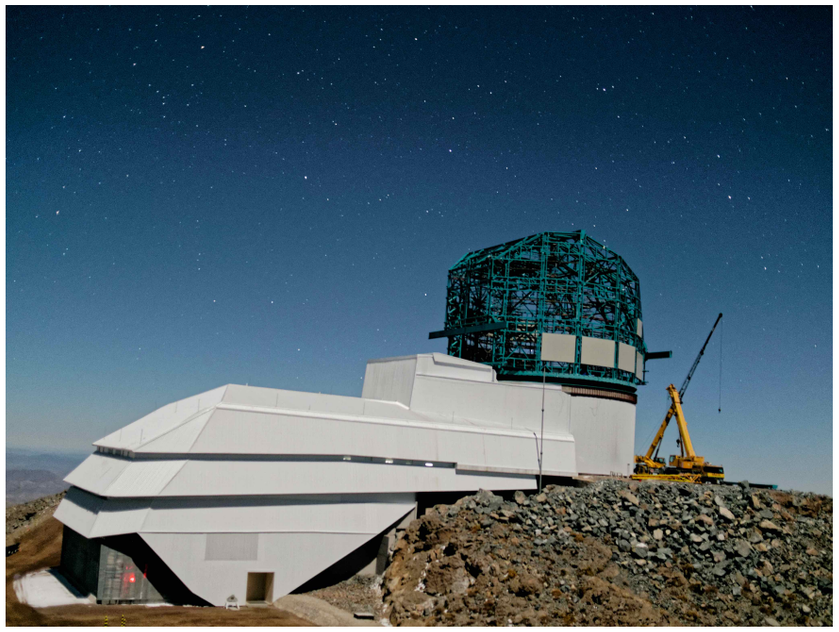
NASA's Roman Space Telescope

Or use light:

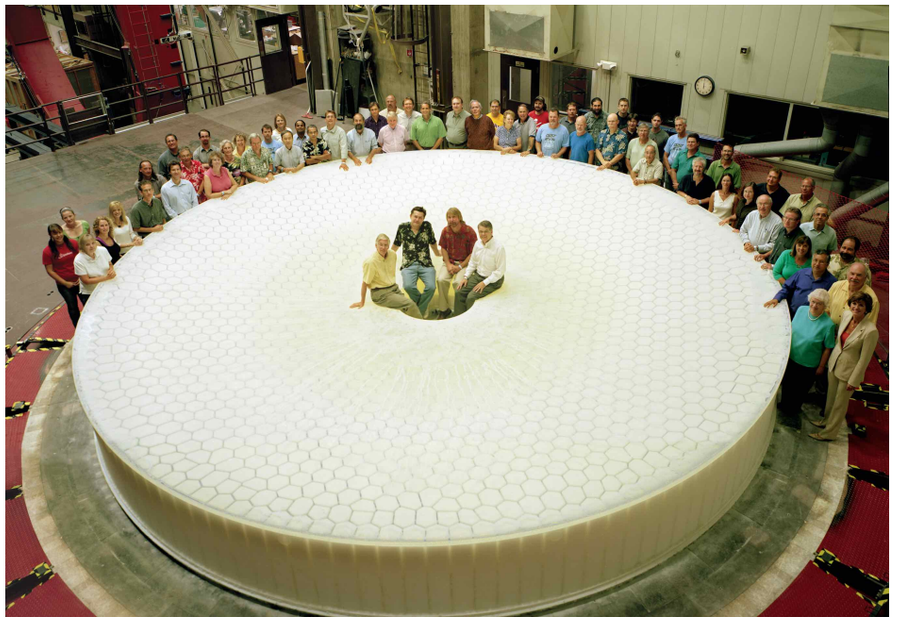
The LSST at the Rubin Observatory

A -huge- camera on a 8m telescope

Map the galaxies, map the dark matter



Rubin Observatory, Chile



Vera Rubin,

Discoverer of dark matter

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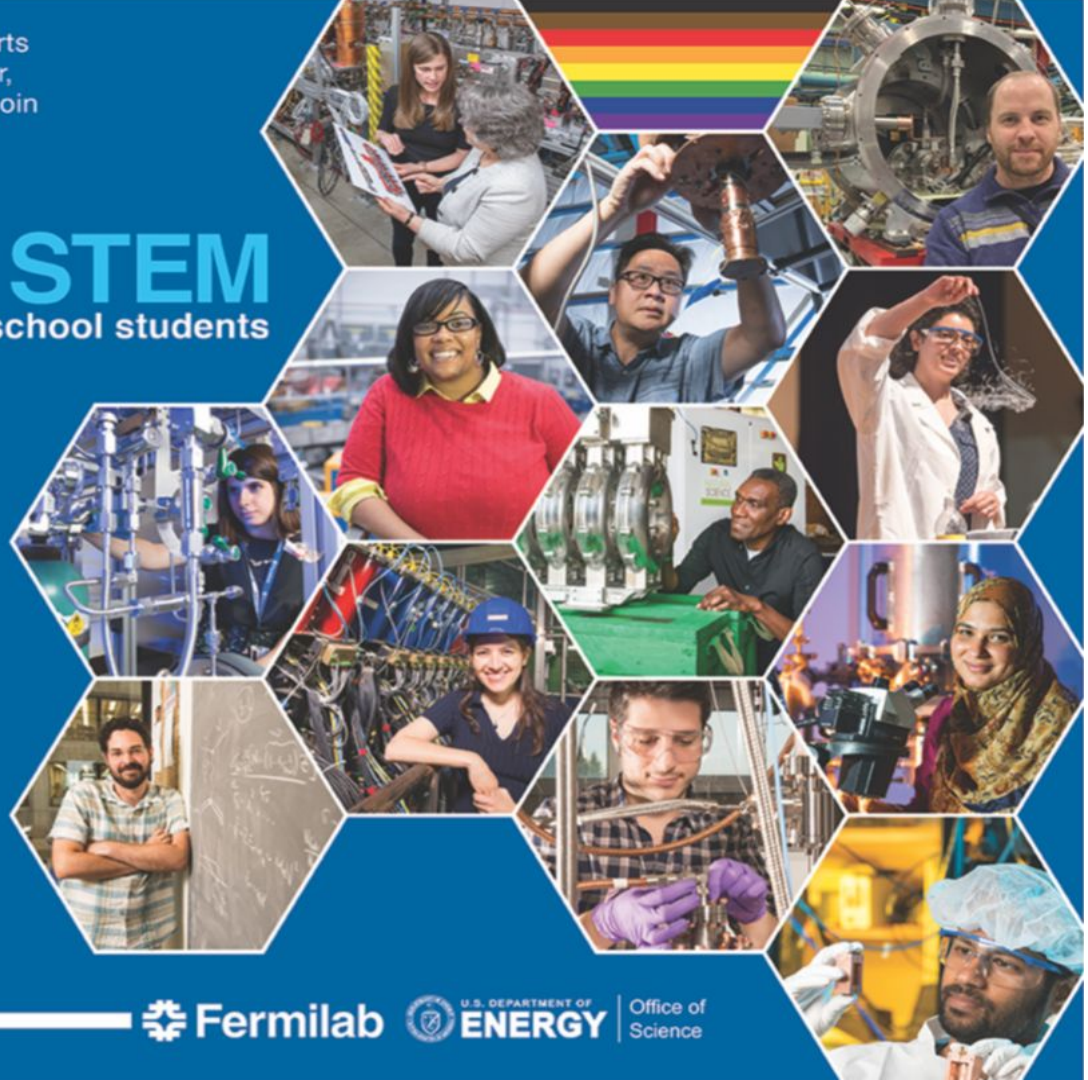
Cosmology

Arka Banerjee
Schramm Fellow in Theoretical Astrophysics, PPD



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How did I get here?

- Grew up in India, in the city of Kolkata.
- Moved to Delhi for my undergraduate degree.
- Then, on to Mumbai for my Master's degree.

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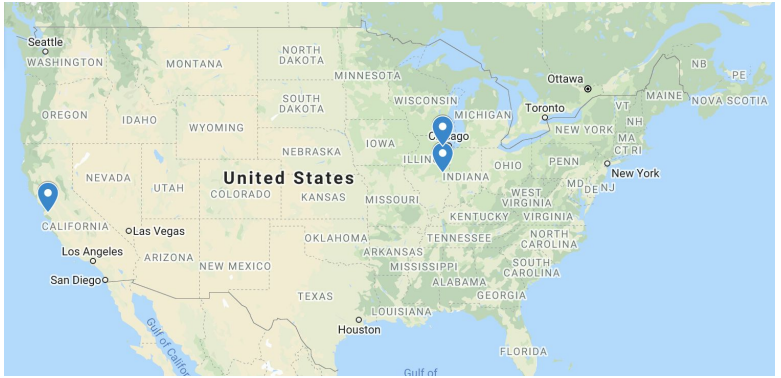
How did I get here?

- Moved to the US for my Phd from the University of Illinois, Urbana-Champaign.
- Spent 3 years as a Postdoctoral Fellow at Stanford University.
- Joined Fermilab last year as a Schramm Fellow.



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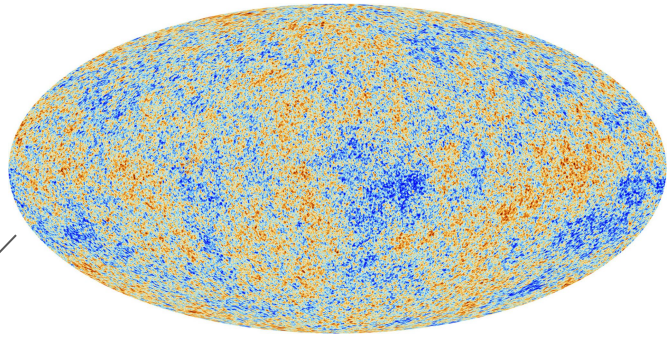
What keeps me busy...

- I am a cosmologist, so I try to understand how the Universe around us came to be the way it is.



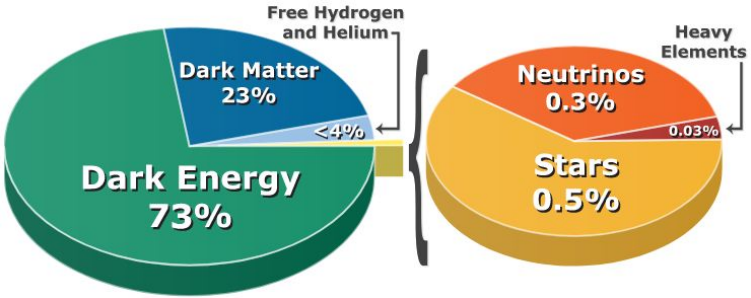
Map of the Universe 300,000 years after the Big Bang.

How did the Universe evolve?

A patch of the Universe today, 14 billion years after the Big Bang.

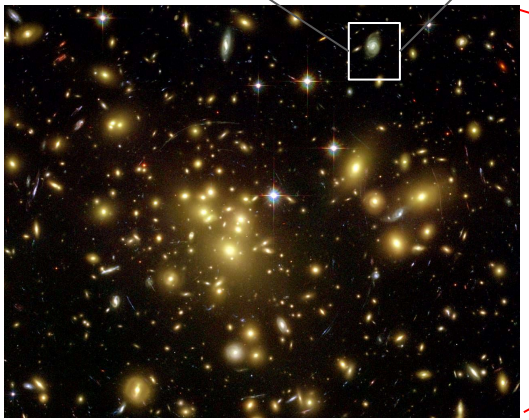
What keeps me busy...

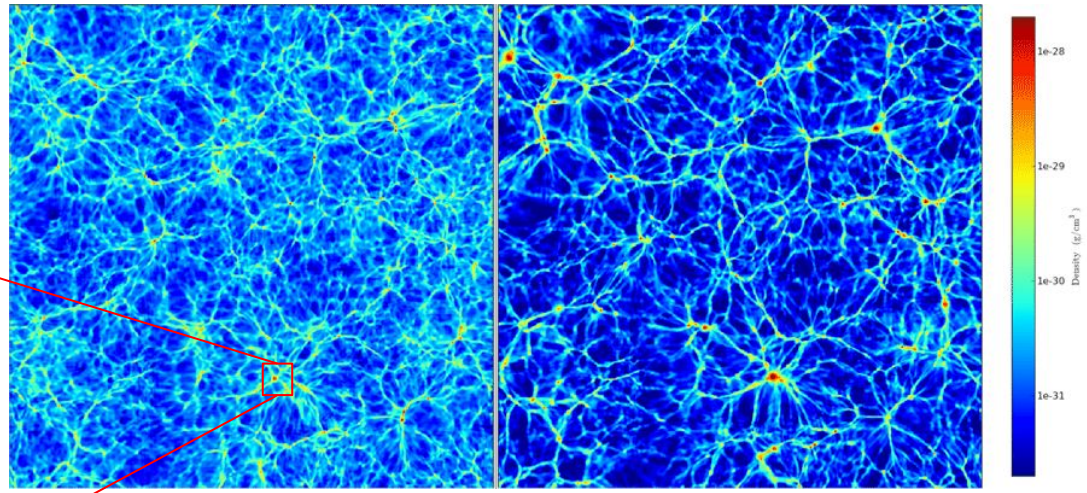
- We try to answer fundamental questions like:
  - What is Dark Energy?
  - What makes up Dark Matter?
  - How much do neutrinos weigh?



Neutrinos are the lightest known fundamental particles ($<10^{-36}$kg), but there are so many of them in the Universe that their masses can be measured through their effects on massive clusters of galaxies in the Universe.

What keeps me busy...





Computer simulations are needed to
model these effects of neutrinos and interpret the data.

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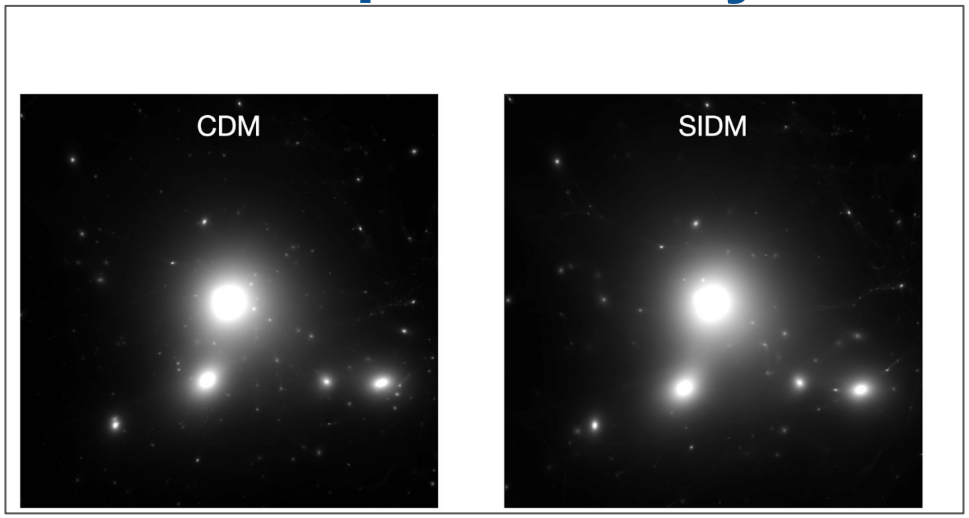
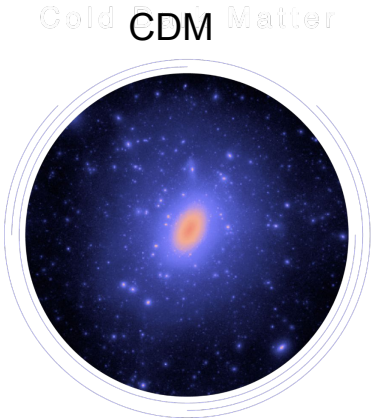
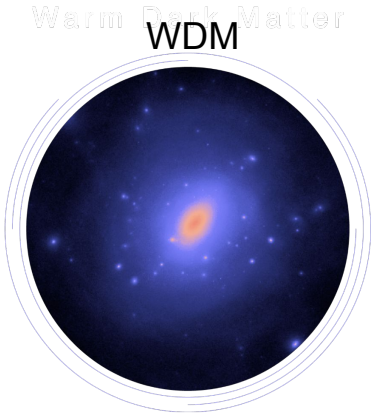
What keeps me busy...



What does the Milky Way look like when we change the nature of Dark Matter in our simulations?





Questions?