

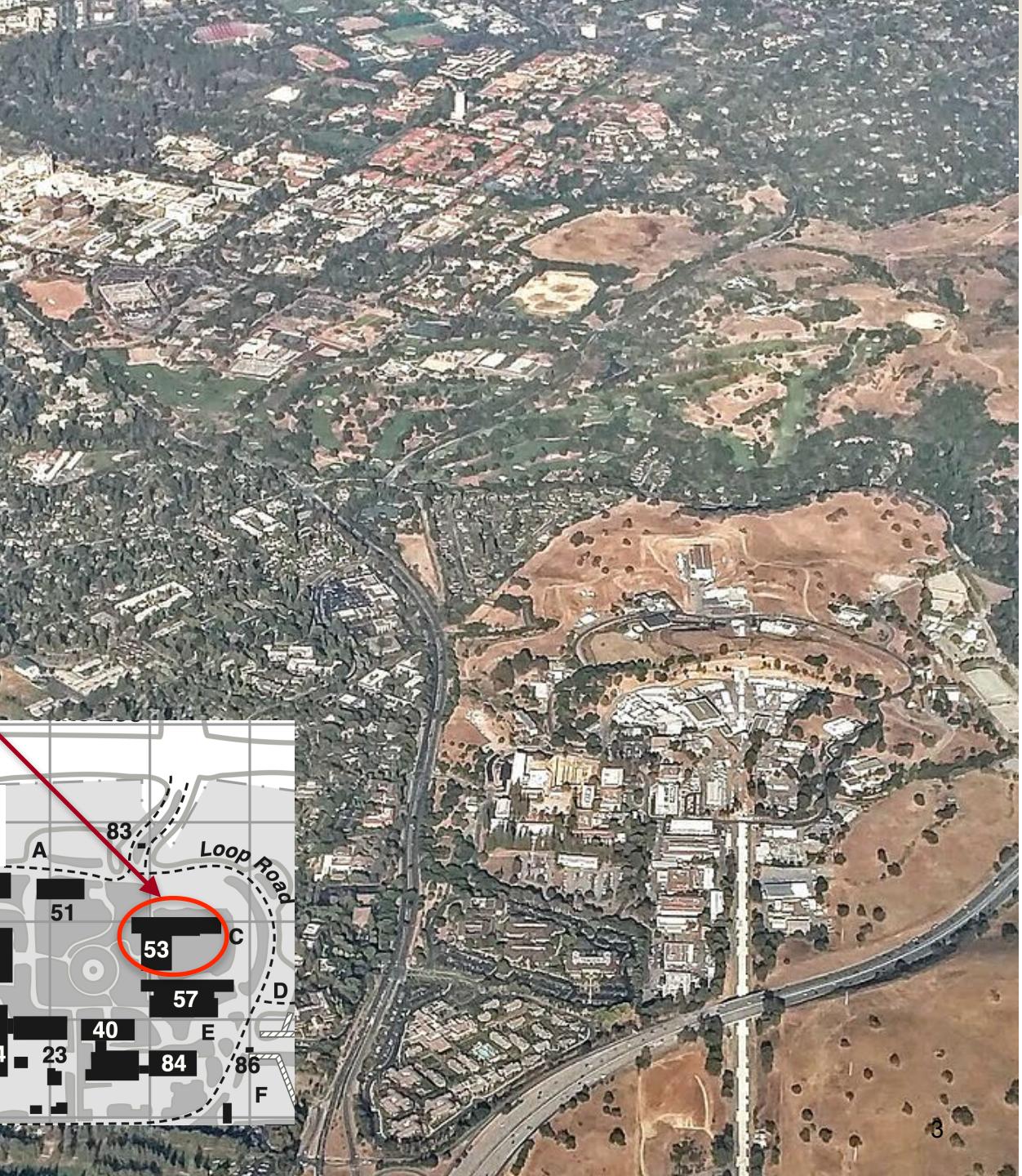
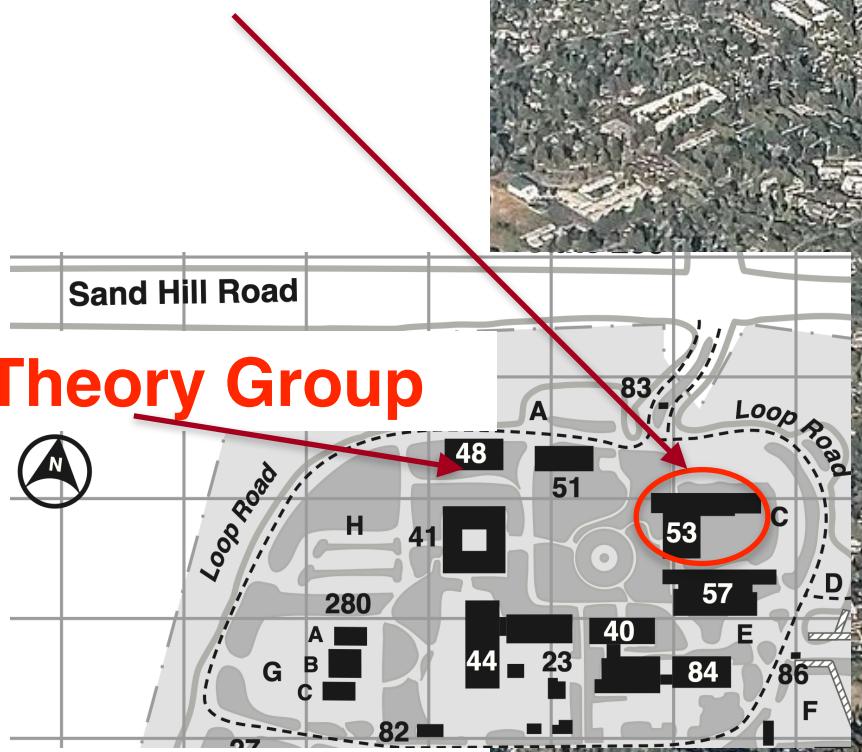
# SLAC Theory Group

## Open House 2025

- Involved in multiple areas of modern theoretical physics
  - Theoretical quantum field theory
  - Neutrino physics, astrophysics and cosmology
  - Precision calculations for state-of-the-art experiments
  - Particle astrophysics
  - Models of dark matter and novel search strategies
- Major emphasis on connecting theoretical work to existing and planned experiments
- Long history of our students and postdocs becoming intellectual leaders in the field
  - Numerous recipients of prestigious fellowships and faculty positions
  - **Rotation opportunities available!**

# SLAC National Accelerator Laboratory

- Well connected by bus, bike and car.
- We are here



# SLAC HEP Theory Group



Alex Friedland      Bernhard Mistlberger      Rebecca Leane      Michael Peskin      Tom Rizzo

Lance Dixon      **Polylogs**  
                    **NewPhysics**  
                    **QCD**    **N=4SYM**    **SuperNova**  
                    **Amplitudes**    **Dune**  
                    **SCET**    **DM-Radio**  
                    **Substructure**    **Electroweak**  
                    **ILC**    **MachineLearning**  
                    **Faser**    **Searches**    **Jets**  
                    **LDMX**  
                    **Generators**  
                    **Models**    **Genie**    **Precision**  
                    **N3LO**  
                    **Higgs**    **Beyond**  
                    **Dark-Matter**  
                    **Neutrinos**

Federica Devoto      Ian Padilla-Gay      Zhenjie Li      Michael Ruf      Xin Guan      Weishuang Linda Xu

Natalia Toro      Philip Schuster      Giuseppe Lucente

# Graduate students



Federico Pavone



Derek Li



Andrew McEntaggart



Shayarneel Kundu



Aidan Reilly



Alessandro Russo

Polylogs  
NewPhysics  
QCD N=4SYM SuperNova  
Amplitudes Dune  
SCET DM-Radio Electroweak  
Substructure  
MachineLearning  
ILC Searches Jets  
Faser LDMX  
Generators  
Models Genie Precision  
N3LO Higgs Beyond  
Dark-Matter  
Neutrinos



Ian Holst



Joshua Tong



Gowri Sundaresan



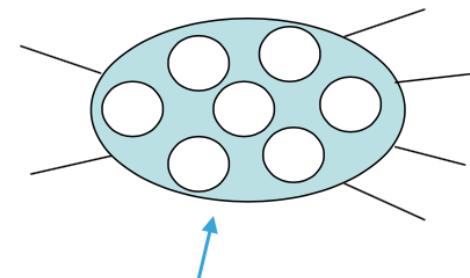
Lillian Santos-Olmsted



Lance Dixon

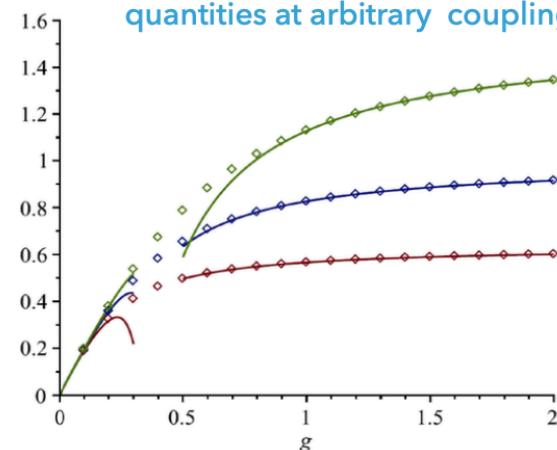
## N=4 SUPER-YANG-MILLS: THE HYDROGEN ATOM OF THE 21ST CENTURY

- ❖ **Solvable** quantum field theory, like QCD, which describes quarks and gluons, but has all sorts of extra handles: supersymmetry, conformal invariance, integrability
- ❖ **“Bootstrap” technique:** use general principles to calculate amplitudes at very high loop order.
  - \* 6 gluons at 8 loops
  - \* 7 gluons at 4 loops
  - \* Higgs boson and 3 gluons at 8 loops
- ❖ **Machine Learning and Perturbative QFT**
- ❖ **New Dualities in Scattering Amplitudes**



~ 1 billion Feynman diagrams in here

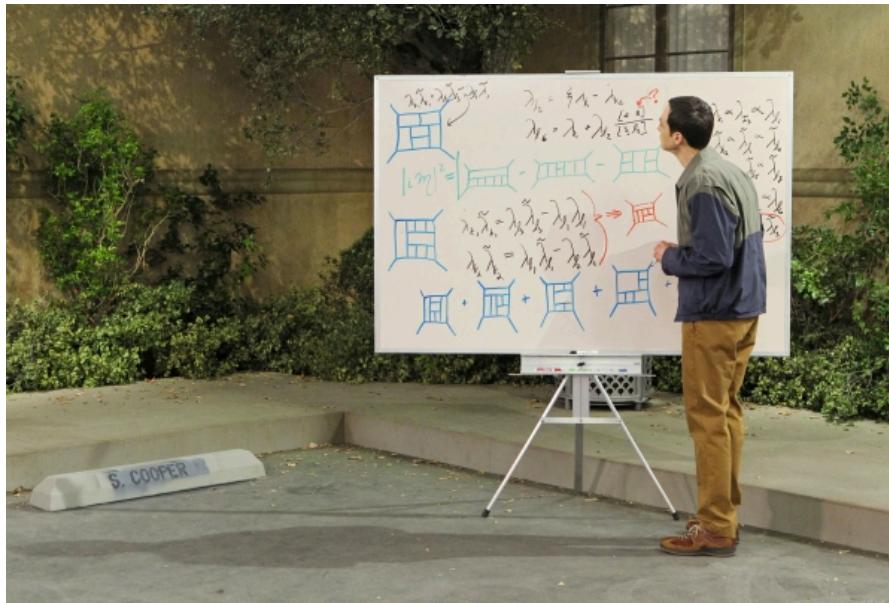
Can calculate specific quantities at arbitrary coupling



# Ever wondered about those diagrams Sheldon was staring at?

SLAC

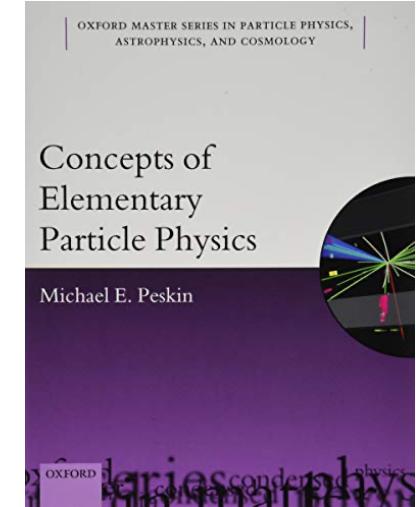
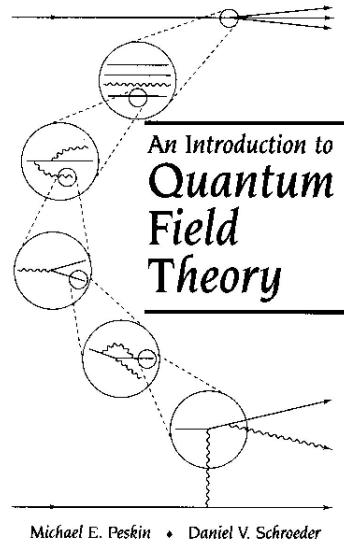
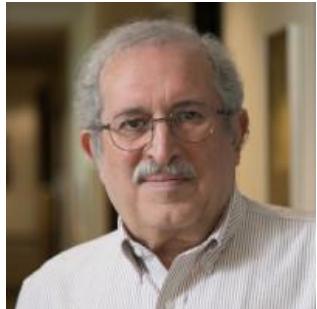
Talk to Lance!



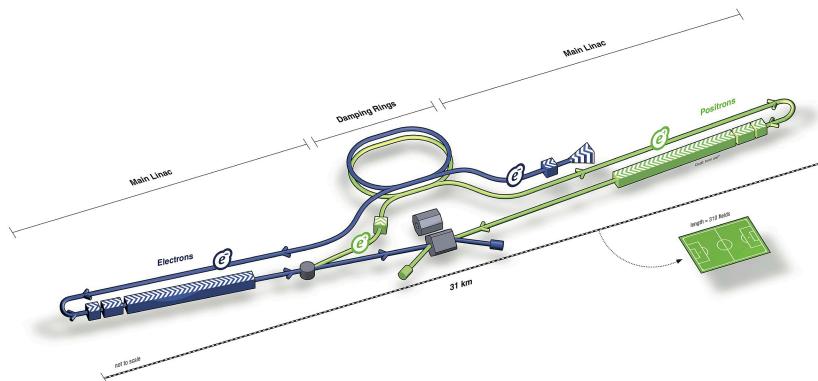
# I have questions about my favorite quantum field theory book.

SLAC

Talk to Michael!



While you are at it, ask about the physics of the proposed e+e- collider

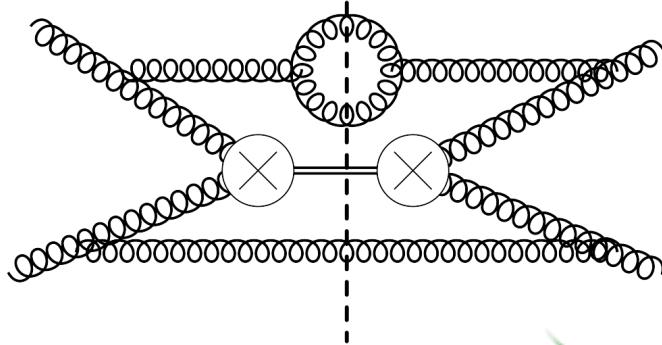




Bernhard Mistlberger



## Probing Fundamental Interactions of Nature with Precision



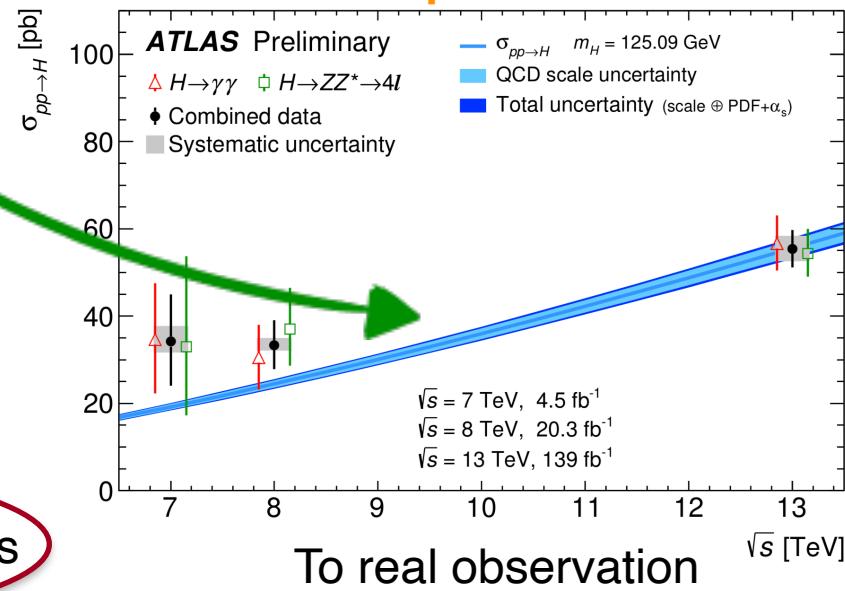
From first principles

**Advance our understanding of QFT and improve our capabilities to predict outcome of scattering processes of fundamental particles.**

The precision frontier of QFT computations

Higgs boson - QCD - Electroweak

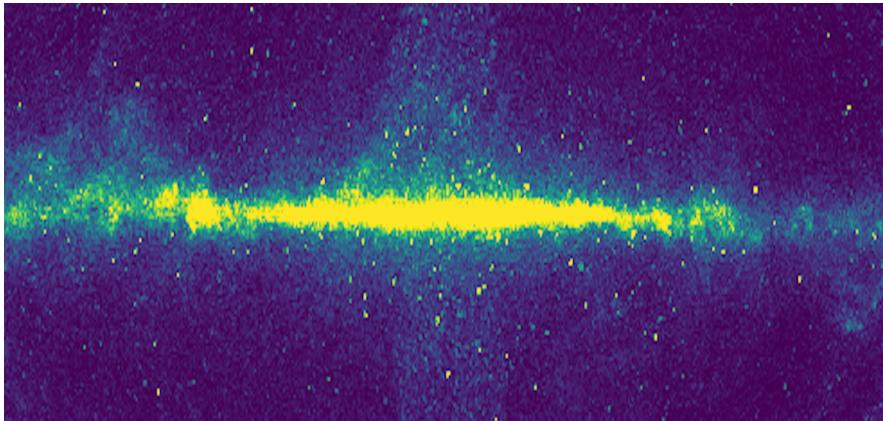
How many Higgs bosons do we expect at the LHC?





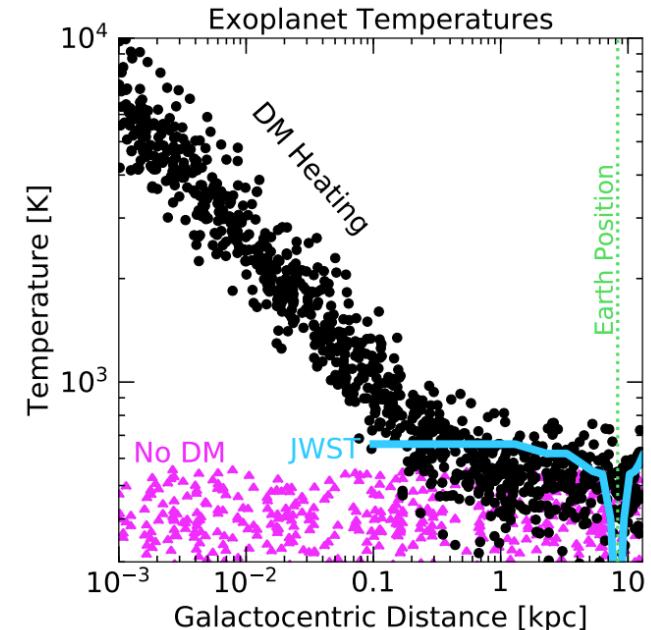
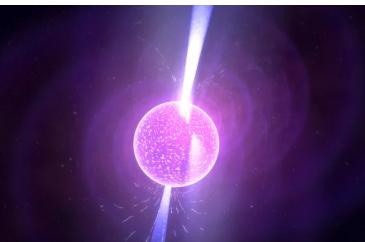
Rebecca Leane

## Particle Theory Meets Astrophysics



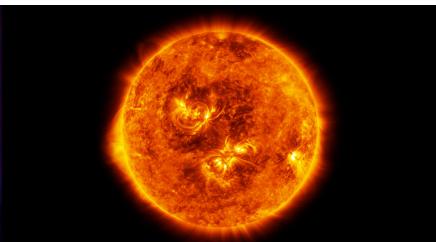
**Techniques to find dark matter  
in astrophysical datasets**

Does dark matter cause the gamma-ray glow  
at the heart of our Galaxy?



**New dark matter searches in  
astrophysical systems**

How does particle dark matter affect  
stars and planets?



# SLAC HEP Theory Group



Philip Schuster



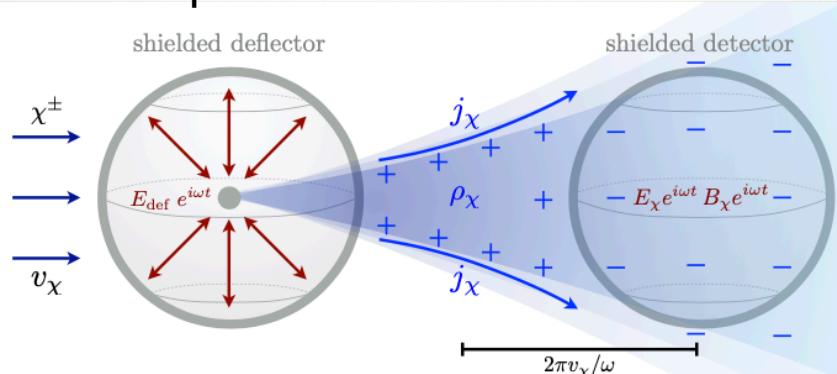
Natalia Toro

SLAC

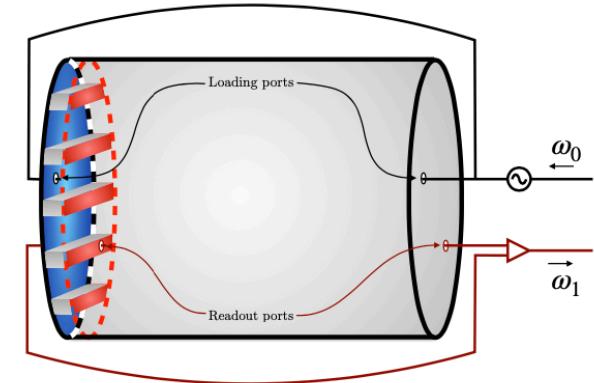
## Imagining what Dark Matter might look like

- Most of the matter in our Universe is “dark matter” - **We don’t know what it’s made of!**
- Each possibility suggests new ways of looking for it.

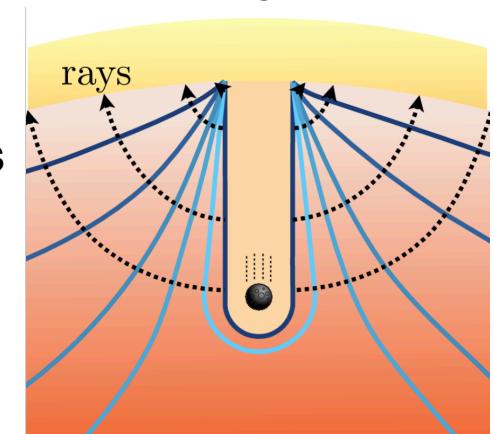
Milli-charged dark matter can be deflected to produce EM fields



Dark asteroids can cause shocks in celestial bodies



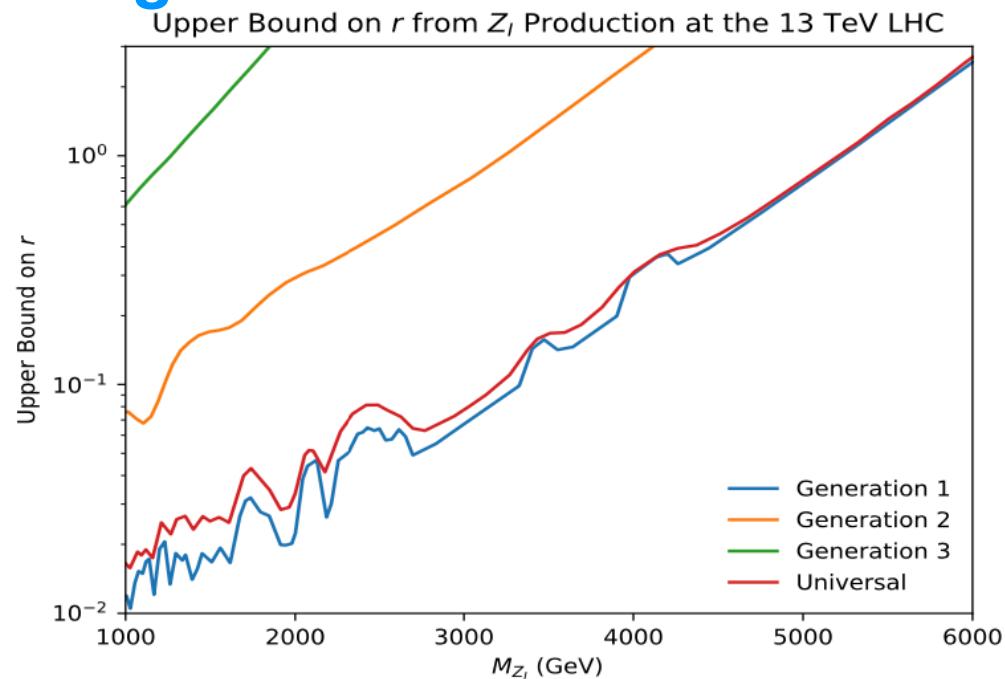
Axion dark matter can excite resonant transitions in superconducting RF cavity



## The next theory of nature: Dark Photons & Kinetic Mixing

- ❖ **Hidden-sector dark matter**  
involves new forces visible mainly at high-intensity, moderate-energy experiments
- ❖ **Grand unification** motivates models with correlated new physics discoverable at the LHC.
- ❖ **Novel signatures:** heavy gauge boson  $Z'$  coupling to a single generation of particles for example

$$b\bar{b} \rightarrow Z' \rightarrow \tau\bar{\tau}$$



# SLAC HEP Theory Group

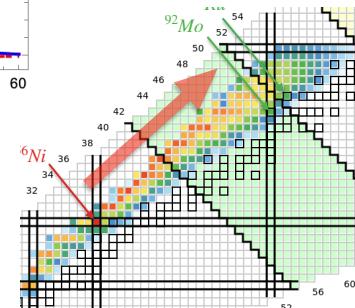
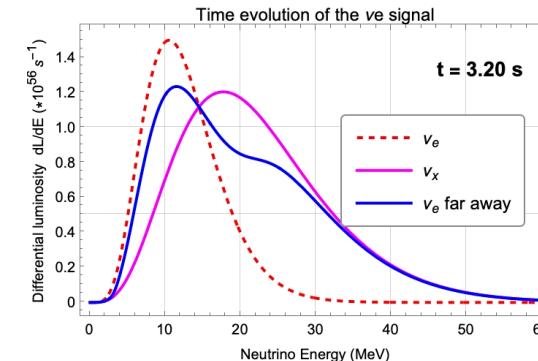
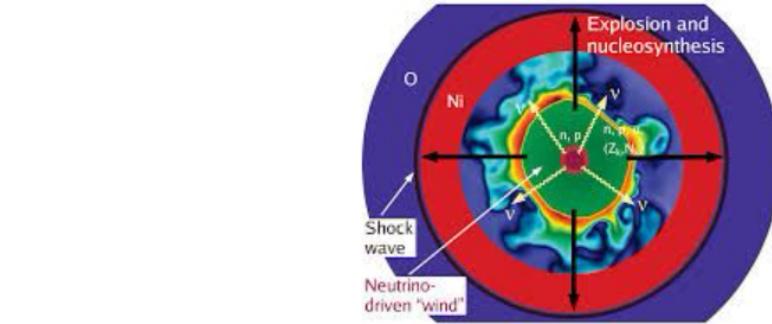


Alex Friedland

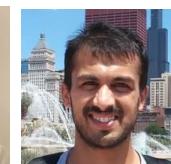


## Using neutrinos to see inside a supernova

- When a massive star explodes, neutrinos carry information directly from its core.
- Our aim is to understand how to extract from the neutrino signal in the DUNE detector what happens deep inside the star!
- Neutrinos oscillate in a complicated, time-varying density profile. Density features are imprinted on the signal
- The neutrino signal can tell us if the conditions are right for synthesis of heavy isotopes



With Amol Patwardhan, SLAC -> Reed College faculty  
 Payel Mukhopadhyay, Stanford PhD -> Neutrino Theory Network Fellow  
 Ian Padilla-Gay, SLAC -> N3AS Network Fellow  
 Giuseppe Lucente (PD), Derek Li, Federico Pavone (grad students)



# SLAC HEP Theory Group



Alex Friedland

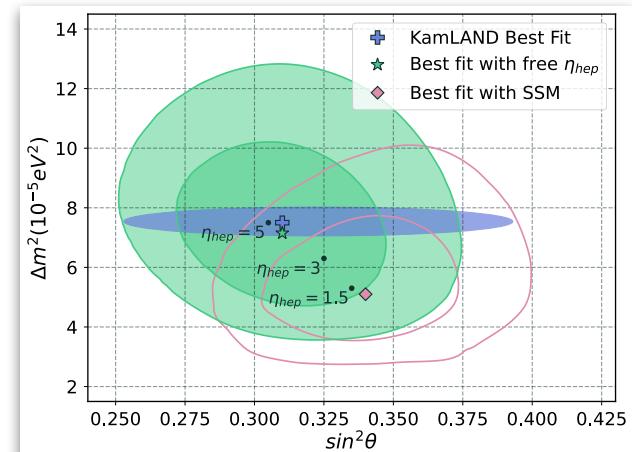
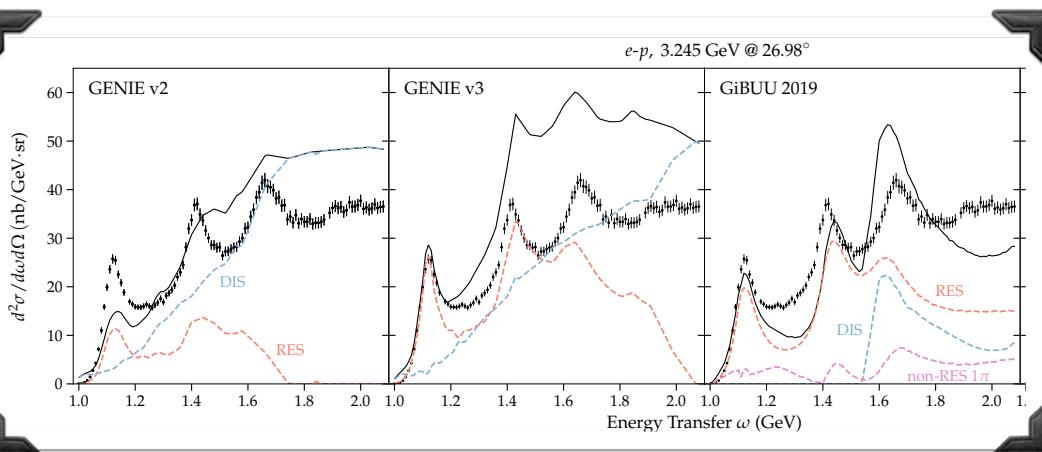


## Other current neutrino-related projects

With Shirley Li, SLAC Postdoc -> UC Irvine faculty  
 Artur Ankowski, SLAC Postdoc -> Wroclaw Senior researcher

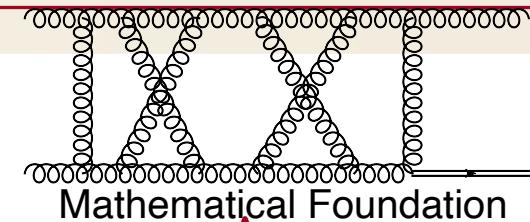


- ❖ Precision solar neutrino physics (Are tensions in the data due to new particle physics? Nuclear reaction rates?)
- ❖ Cosmological neutrino bounds (mass/number of species)
- ❖ Neutrino-nucleus interactions, for precision physics at DUNE and Hyper-Kamiokande (CP violation, new physics interactions, etc)

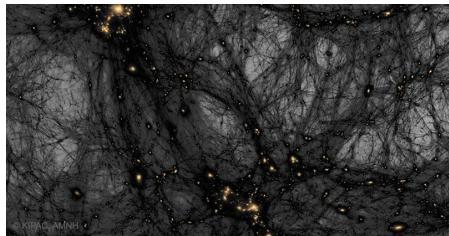


# Advancing Particle Physics: SLAC HEP Theory Group

SLAC



Mathematical Foundation



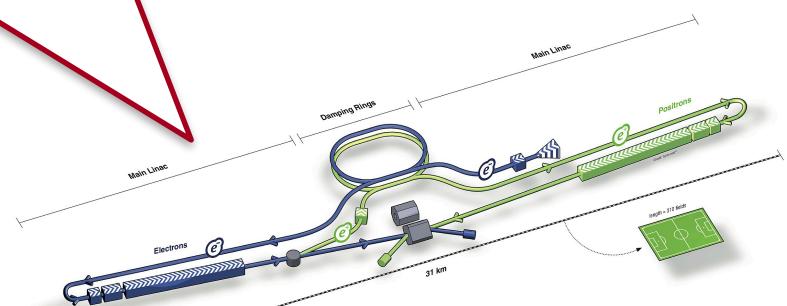
Mysteries of our Universe



Particle Phenomenology

Particle Theory

Largest Experiments of Nature

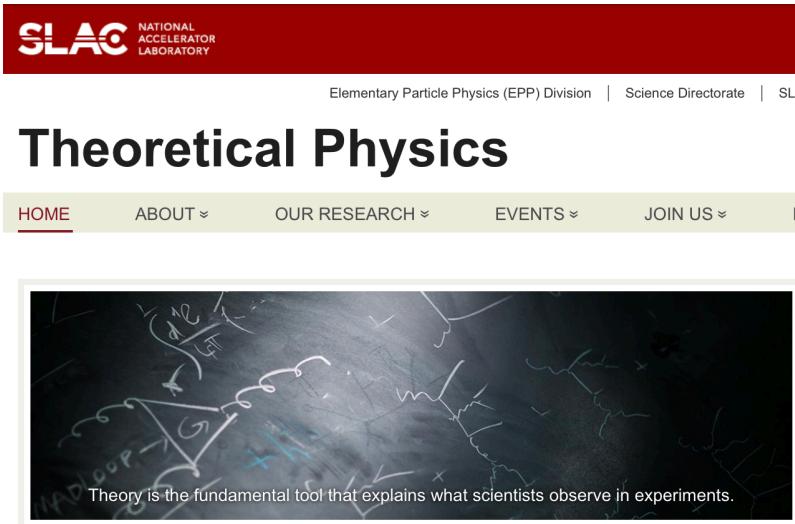


Design Future of Experimental Exploration

# How to get in touch with us

SLAC

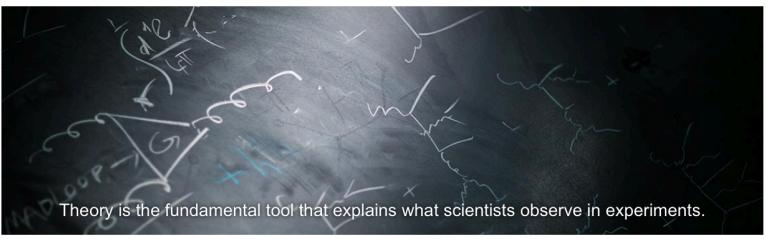
- Find us at <https://theory.slac.stanford.edu>.



Elementary Particle Physics (EPP) Division | Science Directorate | SLAC

## Theoretical Physics

HOME ABOUT ▾ OUR RESEARCH ▾ EVENTS ▾ JOIN US ▾ F



Theory is the fundamental tool that explains what scientists observe in experiments.

- Seminars:  
We & Fr at 12:30 in Madrone (B048, rm 224)
- Amplitudes & QCD Journal Club  
Contact Bernhard Mistlberger
- Dark Matter Journal Club  
Contact Rebecca Leane

- Send us an e-mail, we are happy to chat:

- ❖ Lance Dixon: [lance@slac.stanford.edu](mailto:lance@slac.stanford.edu)
- ❖ Alexander Friedland: [alexfr@slac.stanford.edu](mailto:alexfr@slac.stanford.edu)
- ❖ Rebecca Leane: [rleane@slac.stanford.edu](mailto:rleane@slac.stanford.edu)
- ❖ Bernhard Mistlberger: [bernhard@slac.stanford.edu](mailto:bernhard@slac.stanford.edu)
- ❖ Michael Peskin: [mpeskin@slac.stanford.edu](mailto:mpeskin@slac.stanford.edu)
- ❖ Thomas Rizzo [rizzo@slac.stanford.edu](mailto:rizzo@slac.stanford.edu)
- ❖ Philip Schuster: [schuster@slac.stanford.edu](mailto:schuster@slac.stanford.edu)
- ❖ Natalia Toro: [ntoro@slac.stanford.edu](mailto:ntoro@slac.stanford.edu)

# Meeting SLAC HEP Theory Group

SLAC

- Second floor of Bldg 48, Madrone conference room (224), 2:00-3:30 pm

