Cosmic Controversies
"Tools"

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Tool

A guy with a hugely **over-inflated** ego, who in an attempt to get undue attention for himself, will act like a jackass, because, in his deluded state, he will think it's going to make him look cool, or make others want to be like him. The person may even insincerely apologize later on, but only in an attempt to get more attention, or to excuse his blatantly intentional, and unrepentantly tool-ish behavior.

Standard Model

- Magnificent achievement
  - Metaphysical speculation to enduring measurement
  - Technology-driven; 70+70 octaves; mostly standard physics
  - Universe is basically simple (5? numbers + astrophysics)
  - Fundamental puzzles – DM, Inf, CC…
- Tensions
  - This is normal
  - Systematics, measurement, new astrophysics, new constituents
  - Optimistic that will reconcile and learn much
- Beyond Standard Model
  - Nature of fundamental elements
  - Narrative history of our universe, galaxies, stars, planets

Observational Hiatus before
- DESI, ELTs, Euclid, JWST, LSST, SO, 21 cm…

Major discoveries were "unscripted"

- CMB – antenna noise
- Quasars (massive BH) – radio source identifications
- Stellar BHs – X-ray source identifications
- Massive and mutable ν's – checking solar model
- Neutron stars – lunar X-rays
- Pulsars – interplanetary scintillation
- Gamma ray bursts – nuclear weapons monitoring
- Dark matter – galactic and stellar orbits
- Cosmic acceleration – supernova explosions
- 51 Peg b – brown dwarfs
- Gravitational lenses – quasar follow up
- Gravitational radiation – pulsar timing
- Massive black hole binaries – LIGO….

Discoveries, like burglars, break in the through the side window, not walk though the front door
Stovepiping is futile

Central Paradox of Strategic Planning

October 2014 - April 2015 "Discoveries"

- Planck results->standard model ($wnf_{nl}\Omega_k m_\nu$…), dusty B-modes
- 8 "habitable??" exoplanets->life in the universe???
- 9 new dwarf galaxies -> dark matter limits
- ~10^{10} M_{sun} black hole at z=6->cosmic dawn
- Gravitational lenses - SN, ALMA-> pre-SN, substructure
- M82 neutron star with L~100 L_{edd}->accretion physics
- PD456 outflows->environmental impact, galaxy formation
- FRBs 40% circ pol->new transients 10-100mHz
- IceCube neutrinos -> cosmological origin?

When way forward is unclear, diversify portfolio,
invest more in smaller ventures,
favor observatories over experiments

Multi-wavelength/messenger cosmology

- Ultra High Energy Cosmic Rays
  - 100,000,000 TeV
- Very High Energy Neutrinos
  - Cosmogenic sources
- High Energy Gamma Rays
  - HAWC, CTA…
- Neutrinos
  - KATRIN, EXO, JUNO, Hyper-K, DUNE
- Ultra Low Energy Gravitons (zeV-peV)
  - LIGO, VIRGO, LISA? IPTA….

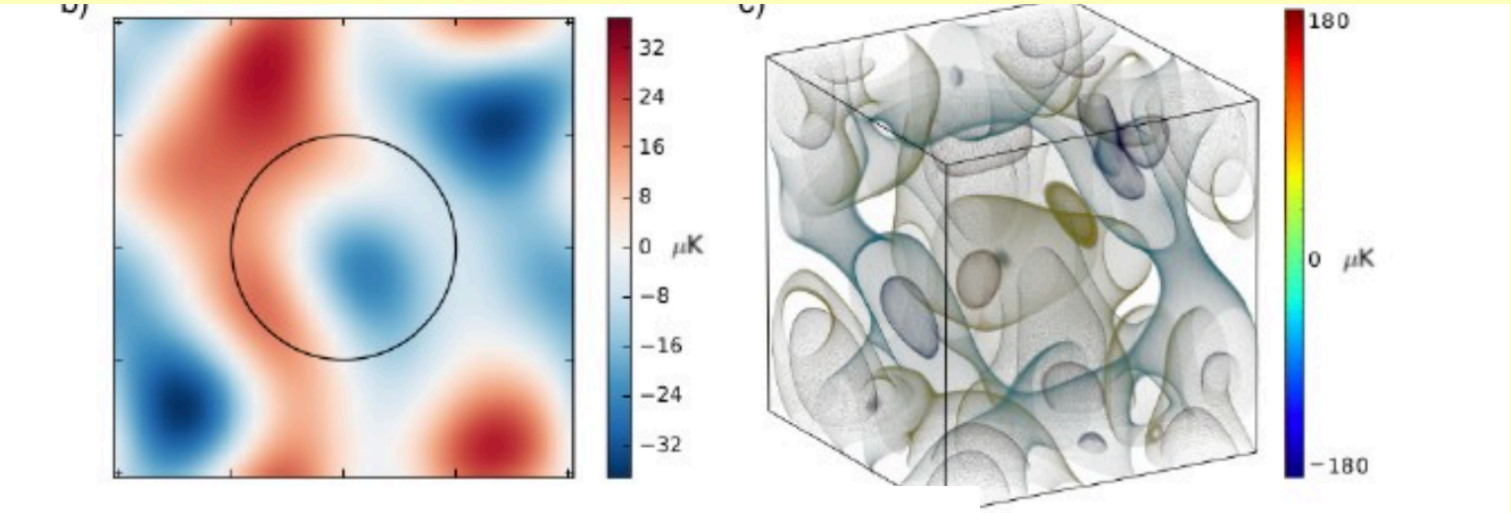
Common transients, like GRB, FRB, ERB, are great tools for cosmological investigations

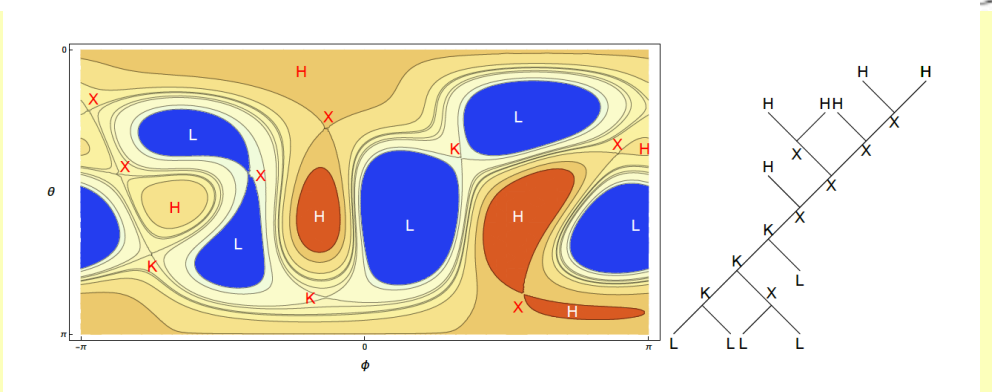
More to Cosmology than Fundamental Physics

- Describe OUR Universe
  - Maps!
  - Good for surveys
- Tell the story of galaxies
  - Fossil record
  - "Near field" cosmology; GAIA
  - Bias for large scale structure
- Spectroscopy essential
  - 2061!

Are galaxies more like protons or people?

Music of the Sphere





+Laurence Perrault-Levasseur….

Maps have broad appeal and are useful!

Simulations, Data, Machine Learning

- Simulations - prominent part of cosmology
  - 3rd neural net revolution
  - Validated speedups of "routine" tasks
- Emulations
  - Internal consistency without data
- "Marginalize over the astrophysics"
  - Subgrid modeling, pressure smoothing
  - plasmas, radiation
  - Rank ordering

Ensure that students learn relevant physics and astrophysics