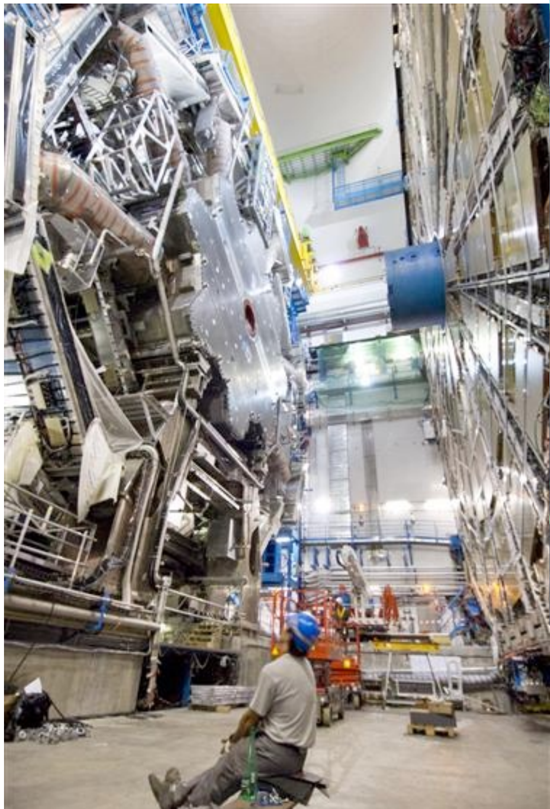
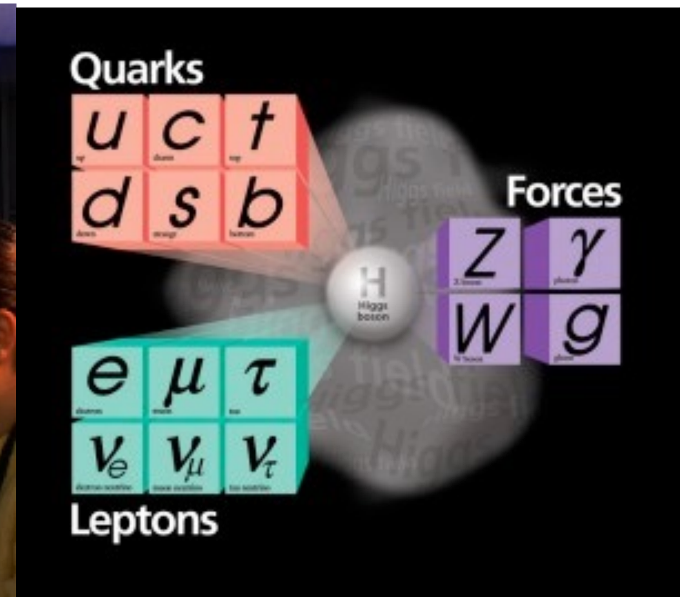
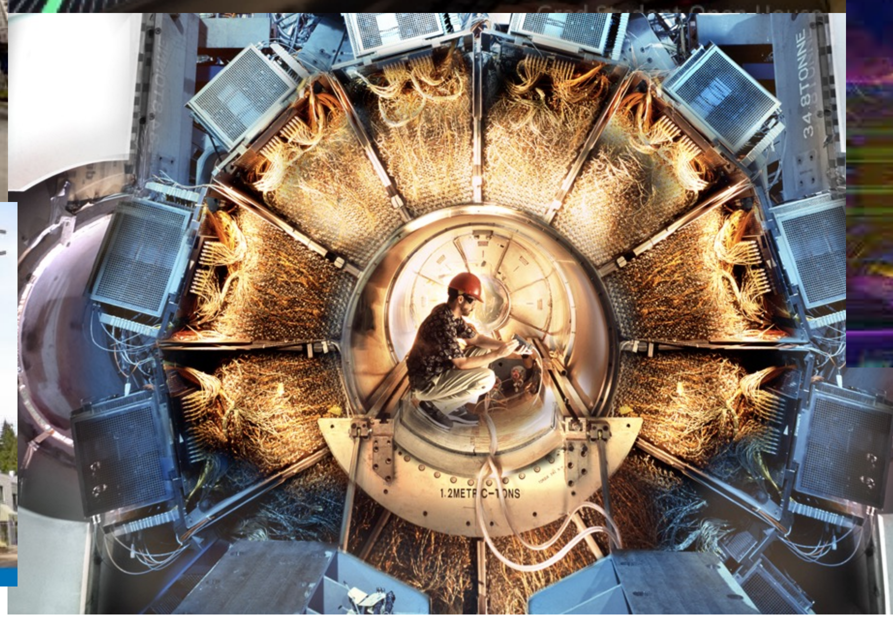
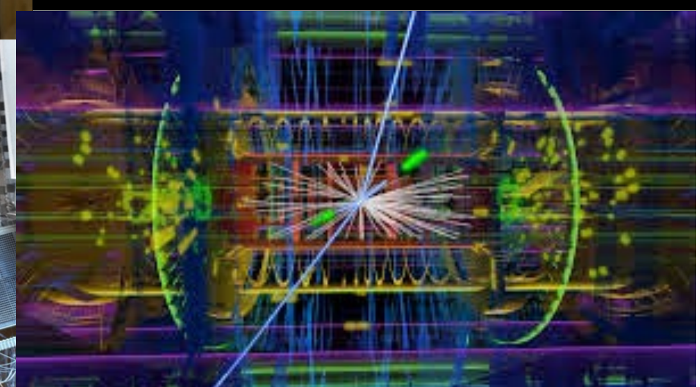
Welcome back!

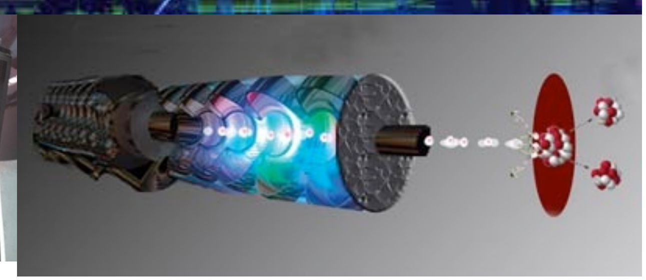
UBC High Energy Physics Research







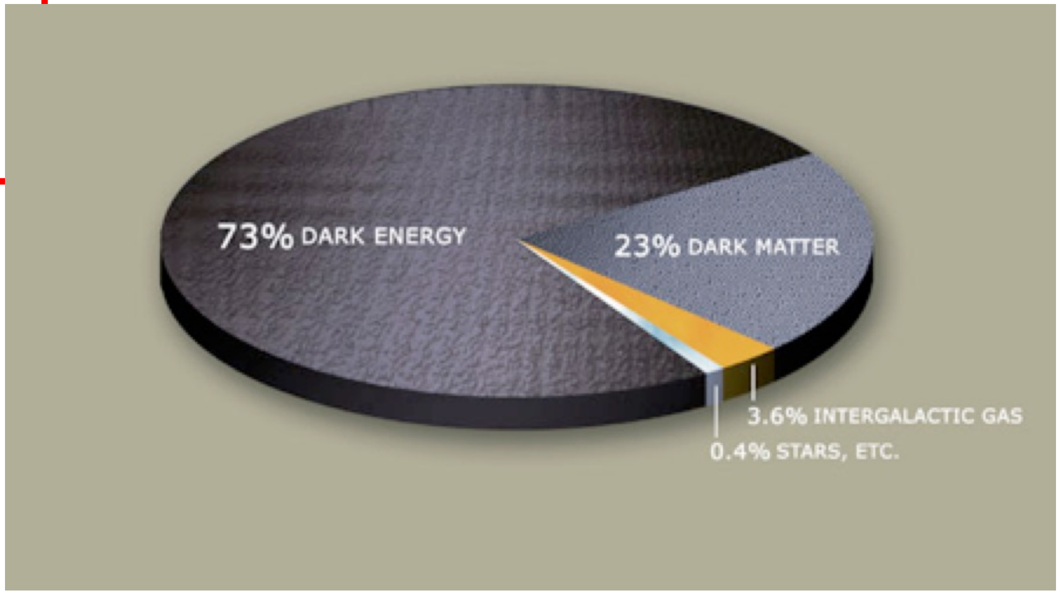


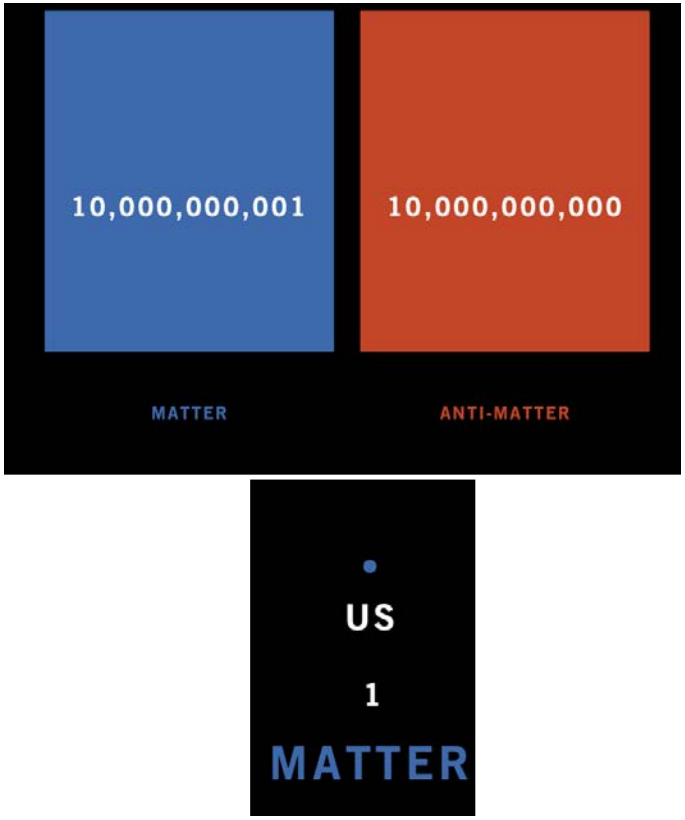


Why study particle/subatomic physics?

- Fundamental questions about the basic laws of physics:
  - what particles exist?
  - what are the interactions between them?
  - what is the role of nuclei and particles in the origin and evolution of the Universe?
- Major discoveries; successful description of reality.
  - Nobel prizes for Higgs at the LHC, neutrino oscillations (SNO), CP violation (BaBar/Belle)
- On the other hand, we know that our model is at best incomplete:
  - Dark matter, matter/anti-matter symmetry, dark energy…

Big questions





- Why is there matter left to make us?
- What is Dark Matter? Dark Energy?
- How many dimensions are there?
- Can we write a Grand Unified Theory?
- Are quarks and leptons indivisible?
- Are there new particles/forces we don't know about?
- Why no CP Violation in the strong force?
- Are neutrinos their own antiparticle?

Some ways to answer these

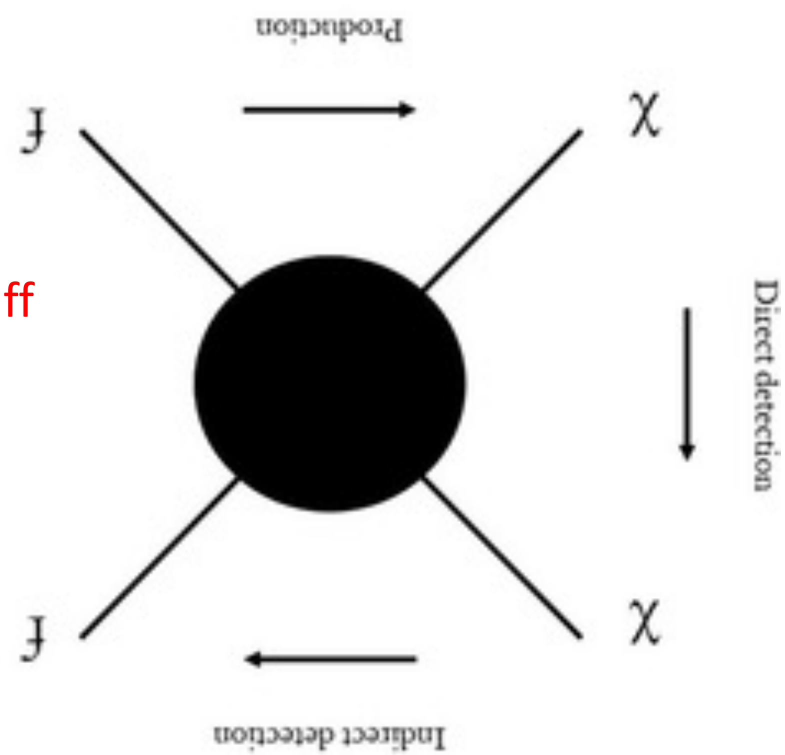
1) Create conditions like just after the big bang in your lab and make, eg, dark matter/Higgs in your lab (Big Particle Accelerators)
2) Use the universe to create dark matter and let it hit you (Underground Labs)
3) Make a huge number of particles and use extremely rare quantum loop effects to probe physics that may be unreachable by more direct means (Ultra high statistics/Rare decay experiments)

Looking in different ways

Dark matter searches

Particle accelerator: smash protons on left, make DM on right

Normal stuff

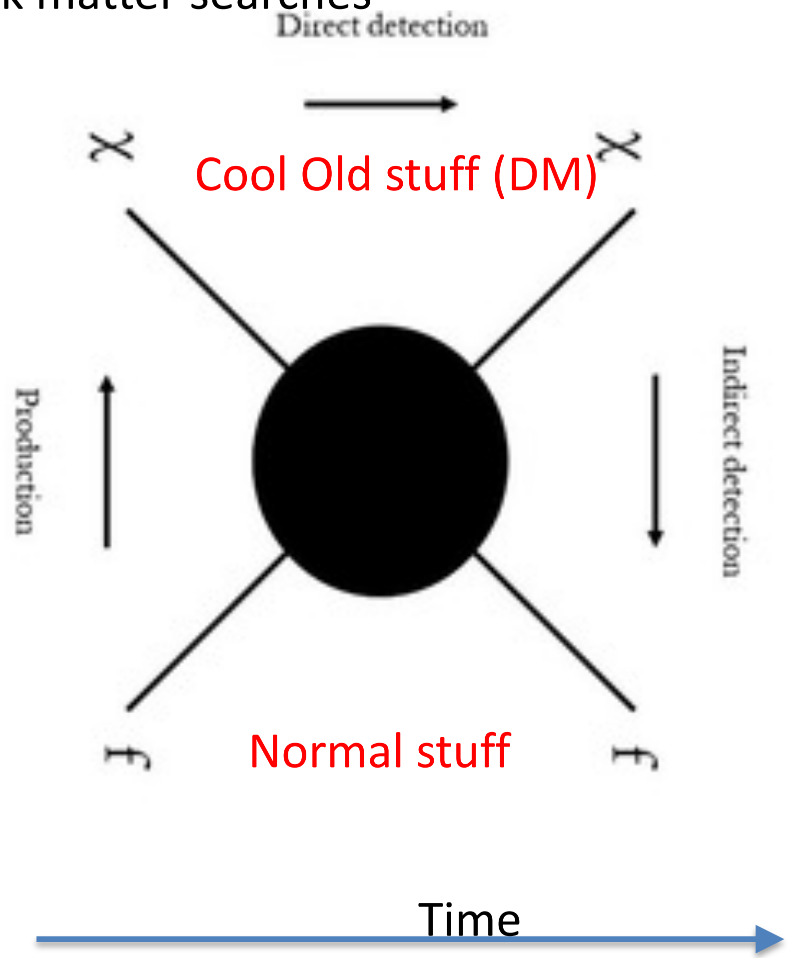


Cool New stuff (DM)

Time

Looking in different ways

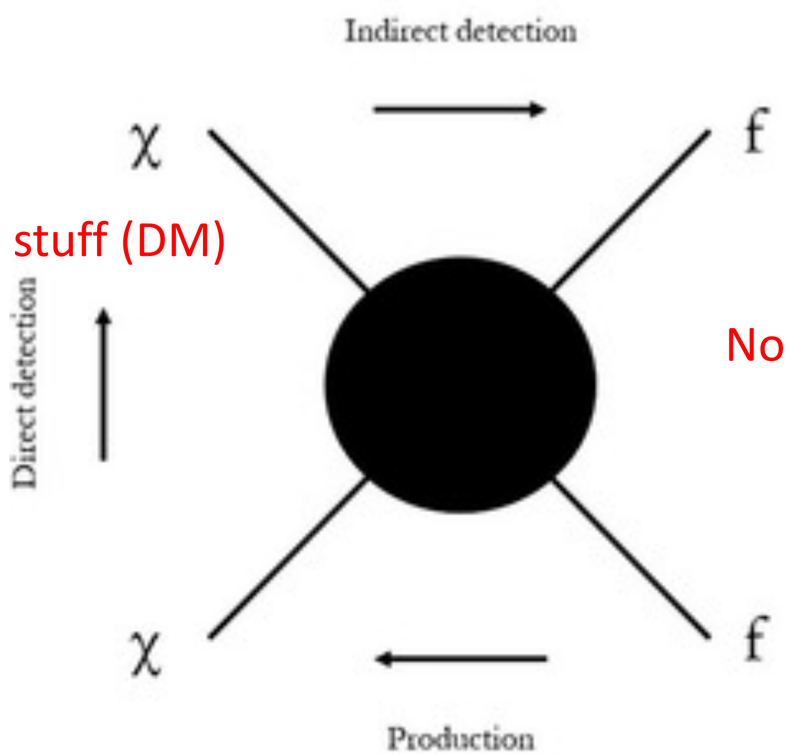
Dark matter searches



Underground detectors: let DM interact with your normal detector particles

Looking in different ways

Dark matter searches



Cool Old stuff (DM)

Normal stuff

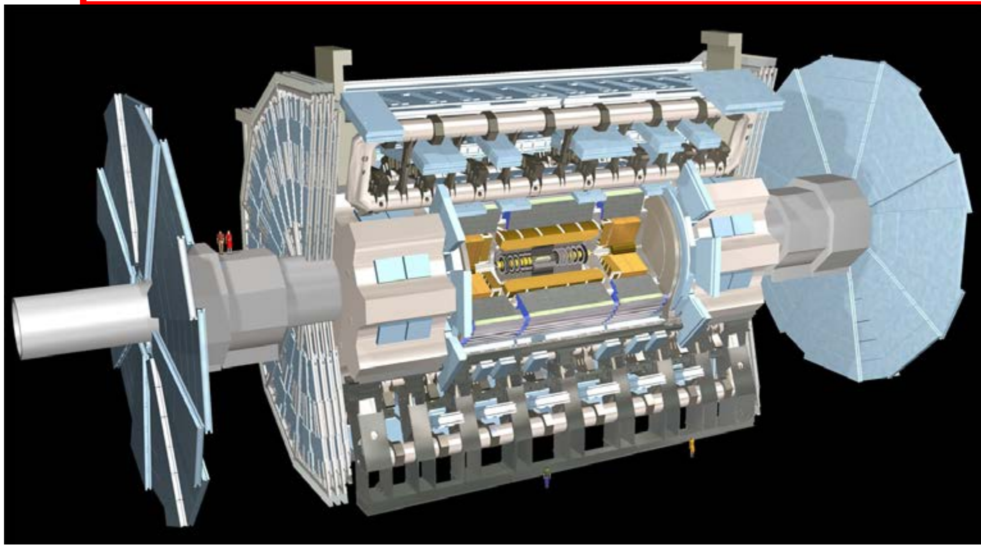
Time

Astro: look for DM annihilation, eg in galactic centres, see normal stuff come out

Why study particle/subatomic physics?

- Sophisticated tools and techniques
  - enormous, advanced detectors and accelerators
  - Deep underground pits (who says no to being 2km underground with only 1 way out?)
  - data analysis; data science; machine learning
  - cutting edge computing and software techniques
  - large, international collaborations
  - time spent at international laboratories

ATLAS @ LHC



Science at the extremes

LHC

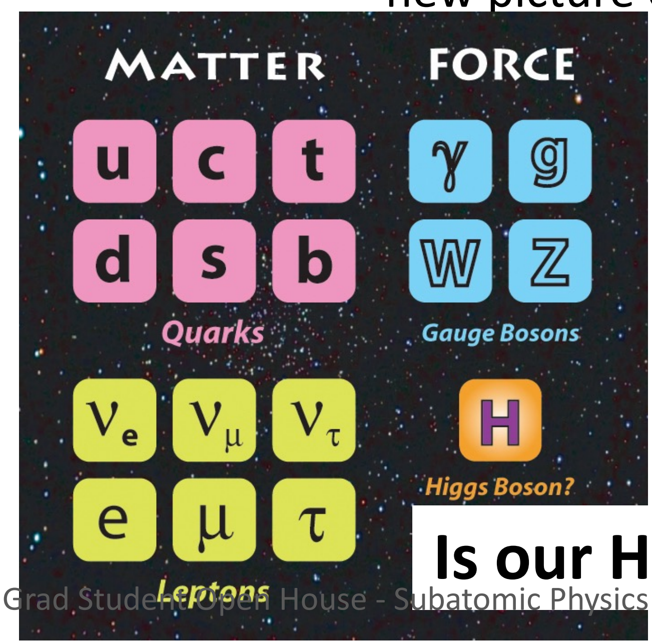
- 27 km circumference accelerator
- Highest energy collider, 13 TeV

ATLAS

- 25m high x 46m long, 7000 tons
- Smallest detector element (pixel): 50x400μm, 80.8M of them
- We are building our upgraded detector here with 5B readout channels, taking a new picture every 25ns

Truly global scientific effort

- 3000 scientists
    - ~1000 graduate students
- 174 institutions
- 38 countries



Is our Higgs really the Higgs?

ATLAS @ UBC

atlas_faculty@phas.ubc.ca

- Close collaboration between UBC faculty & TRIUMF scientists
- Group: 2 UBC faculty, 2 TRIUMF, 4 postdocs, 8 grad students
- Multiple areas of data analysis involvement
  - Searching for
    - Dark Matter
    - New forces (Z')
    - Using top quarks (Z', Little Higgs,…)
    - Long-lived particles (Dark Sector)
  - Precision measurements
    - Top quark
    - Higgs boson
- Multiple areas of hardware involvement
  - Machine learning to reconstruct high momentum particles
  - New Inner Detector (ITk) construction and readout electronics – for 2026
  - New muon chamber (small wheel) – for 2022
  - Transition Radiation Tracker readout electronics
- Many responsibilities within the collaboration
  - Leading physics groups (top, SUSY, exotics, upgrade)
  - Hardware components (TRT)

Colin Gay
Full Prof /Dept Head

Alison Lister
Associate Prof

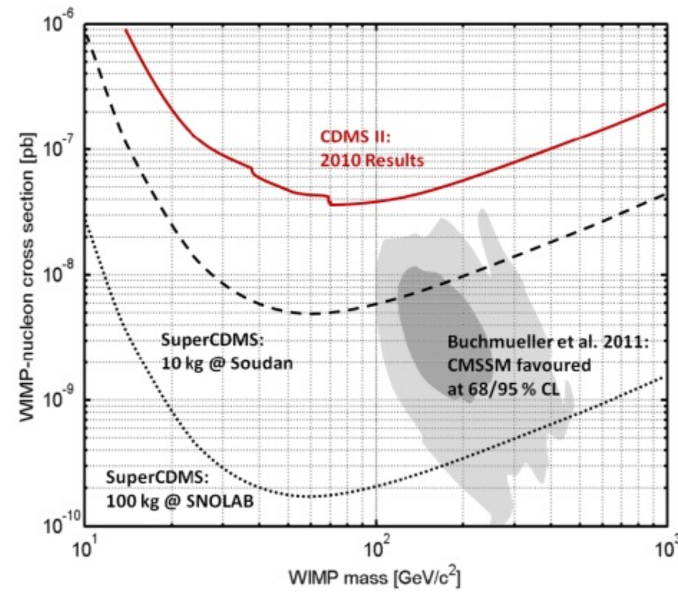
Oliver Stelzer-Chilton
TRIUMF / Adj. Prof

SuperCDMS Dark Matter Experiment

Direct search for dark matter candidates using cryogenic germanium detectors deep underground.

UBC Faculty: Scott Oser

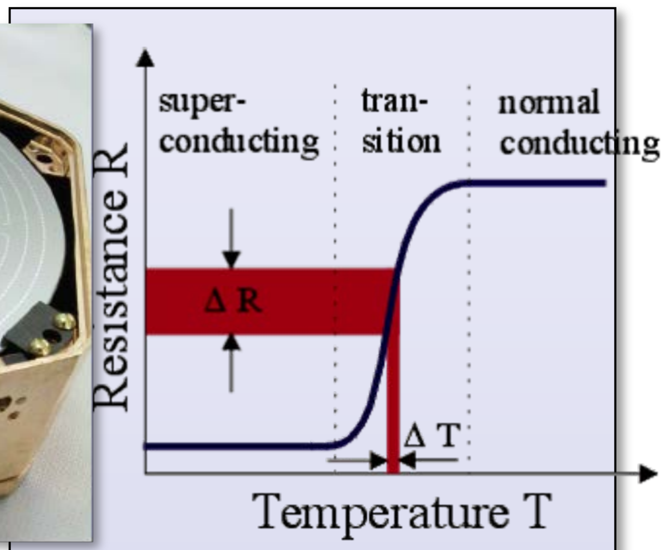
Superconducting sensors operated at transition point used to measure tiny increase in crystal temperature caused by dark matter interactions, along with ionization of crystal.



New experiment at SNOLAB now under construction, with data-taking beginning in 2022.

UBC group working with TRIUMF to develop new DAQ.

Contact: oser@phas.ubc.ca

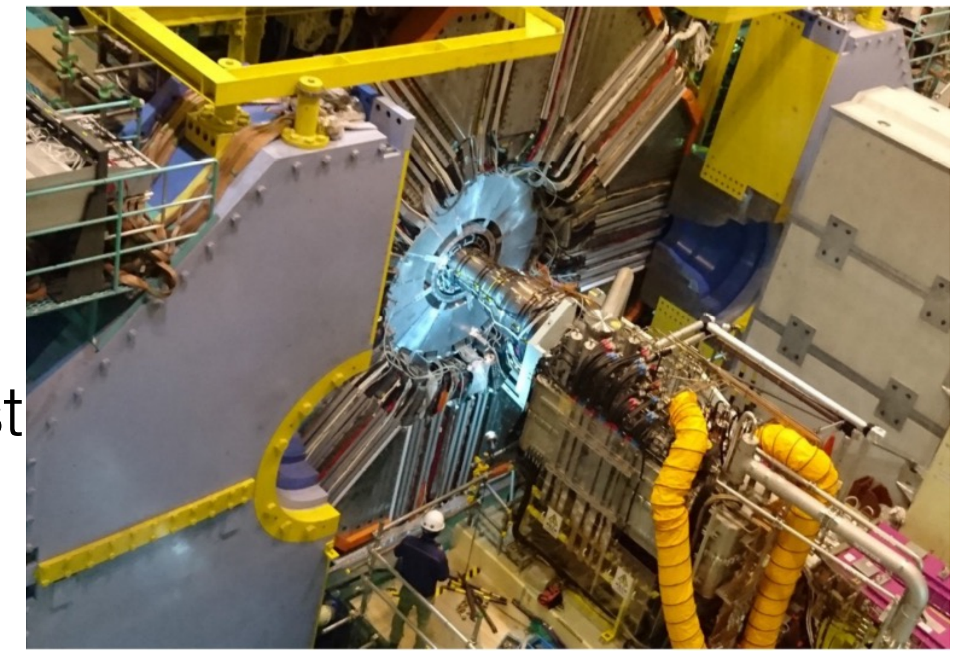


Belle II at the SuperKEKB e^+e^- collider, Japan

Christopher Hearty, hearty@physics.ubc.ca, Henn 268
Janis McKenna, janis@physics.ubc.ca, Henn 262

- Search for new physics through using rare decays, CP violation, forbidden processes, & new particles, using 30x more data than BaBar+Belle

- We are looking for new graduate students — a great opportunity to conduct your research at the world's highest luminosity accelerator.



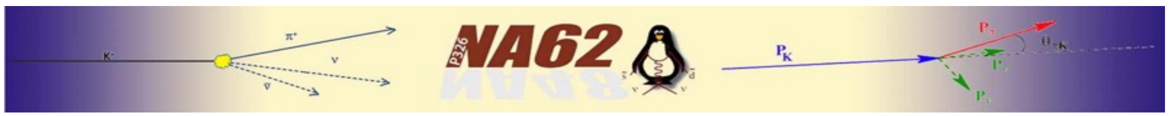
SuperKEKB produced first data with full detector spring 2019.

Particle Physics: Rare Decay Group

Doug Bryman (J. B. Warren Chair)

Seeking new physics at high mass scales: searching for deviations from precise SM predictions.

* CERN NA62: Precise measurment of $K^+ \to \pi^+ \nu \bar{\nu}$, ultra-rare decays.



SM: $B(K^+ \to \pi^+ \nu \bar{\nu}) = (8.4 \pm 1.0)\ x10^{-11}$
NA62 Precision goal: 10%

Projects: Data analysis; Liquid Kr Calorimeter; Pixel tracker

* **TRIUMF** PI E NU

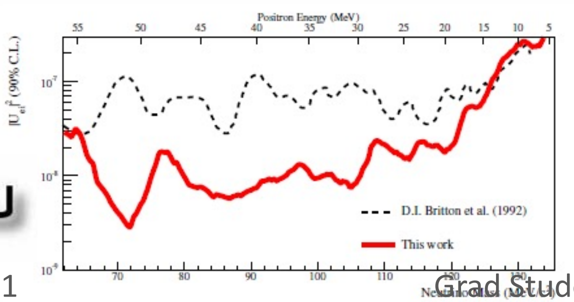
Precise test of e-μ Universality: $B(\pi^+ \to e^+ \nu) = \dfrac{\Gamma(\pi \to e\nu(\gamma))}{\Gamma(\pi \to \mu\nu(\gamma))}$

SM: $B(\pi^+ \to e^+ \nu) = (1.2352 \pm 0.0002)x10^{-4}$
PIENU Precision goal: 0.1%

Recent Searches for Heavy Sterile Neutrinos: Improvements x 10-100

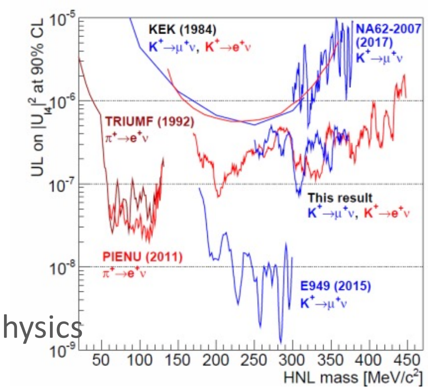
$|U_{li}|^2$ *vs. Mass*

PI E NU



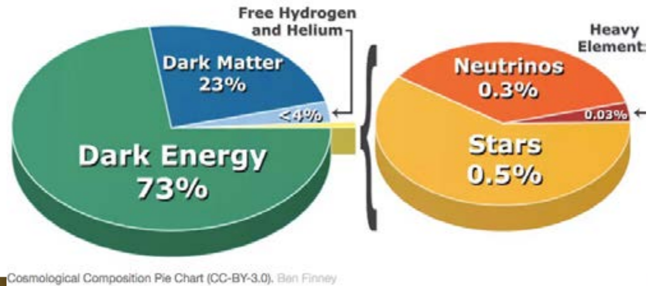
$\pi / K \to l\nu_H$

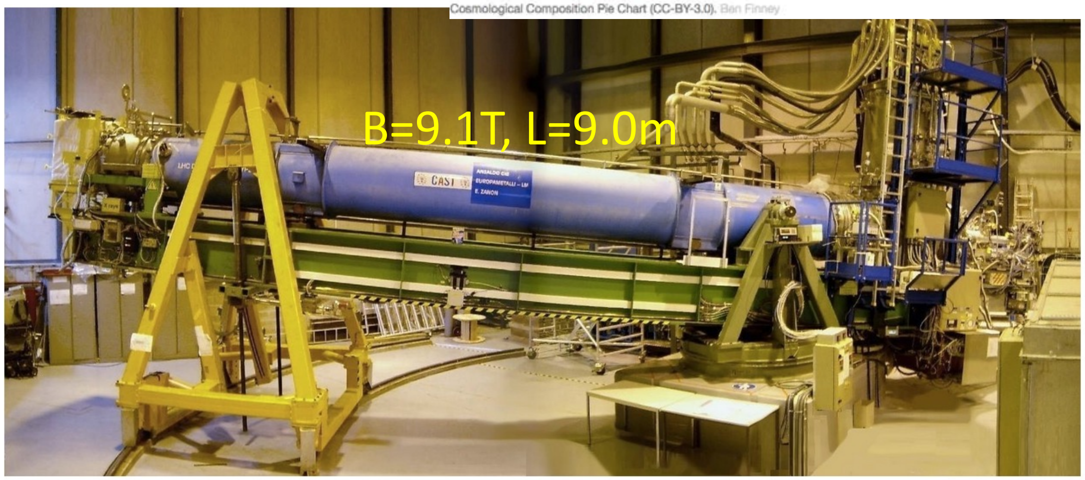
NA62

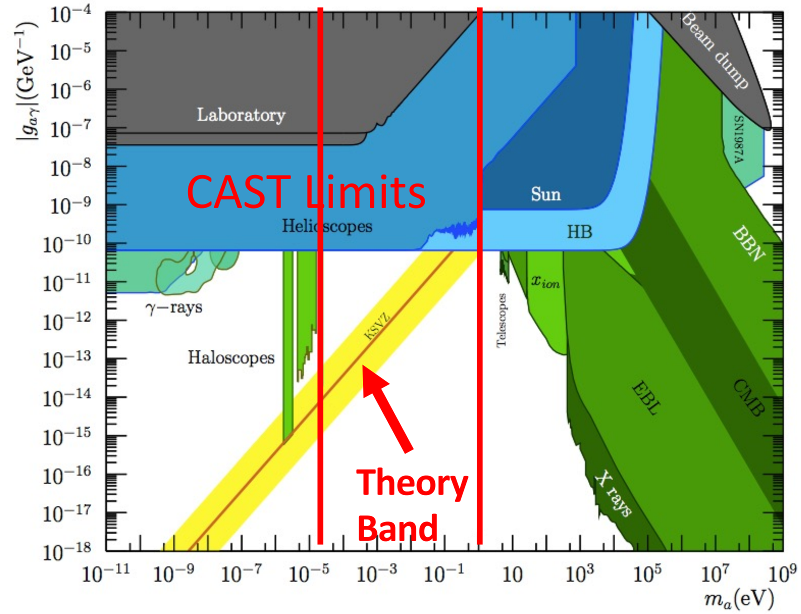


CERN Axion Solar Telescope

Matter/Energy budget of the Universe







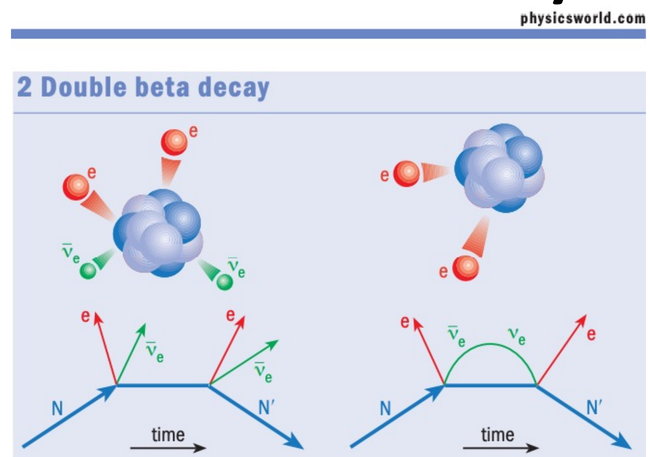
The axion is a pseudoscalar field particle postulated in 1977 to explain the absence of CPV in the strong interaction. It is one of the leading candidates for DM.

Over the past 15 years **CAST** has established the world's best limits on the axion coupling from $m_a = 10^{-5}$ to 1.5 eV using low bkgd x-ray detectors. We are now building Haloscopes (Microwave Cavities) to search in the lower mass region $m_a = 10^{-6}$ -10^{-3} eV.

UBC Theorist Ariel Zhitnitsky has recently postulated that Axion Quark Nuggets could explain the approximate equality of the ratio $\Omega_{dark} \sim \Omega_{visible}$ and that they could be the source of Solar Flares in the corona of the Sun.

We are looking for a new MSc student to join us in this exciting axion search. – M. Hasinoff/A. Zhitnitsky

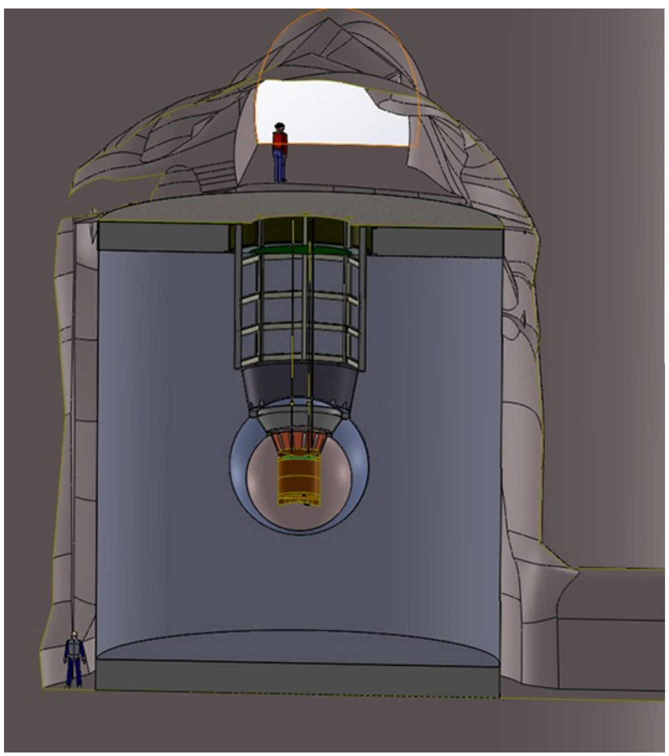
nEXO neutrinoless double-beta-decay

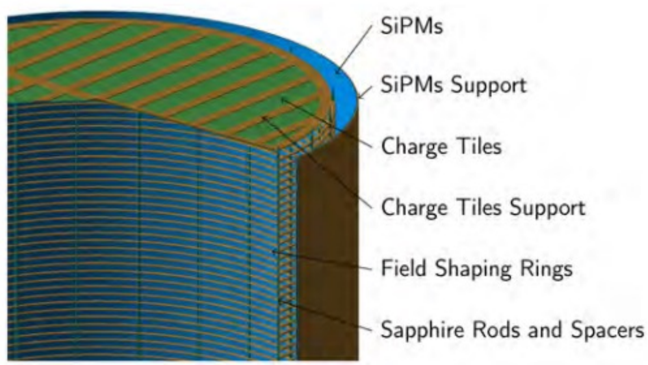


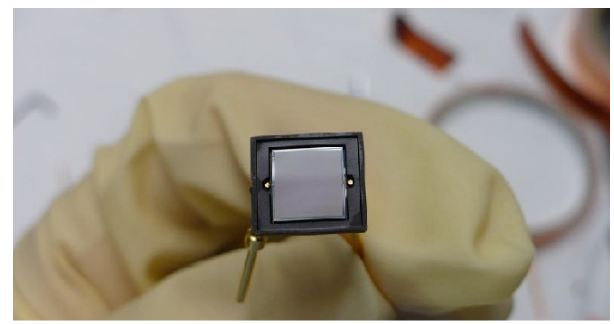
Search for predicted rare beta-decay mode, only possible if neutrino is its own antiparticle

UBC Faculty: Reiner Kruecken

nEXO is a next generation ton-scale ^{136}Xe experiment to be placed into SNOLAB.





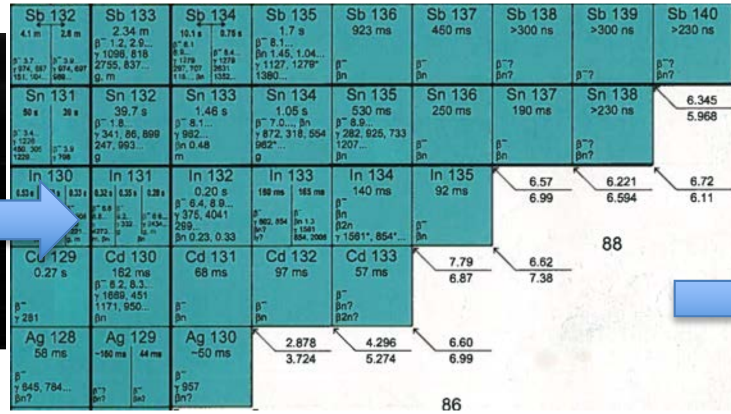


UBC/TRIUMF group working on Silicon Photomultiplier (SiPM) photo detector development for 5 m^2 nEXO photodetector and next generation light-to-digital converter

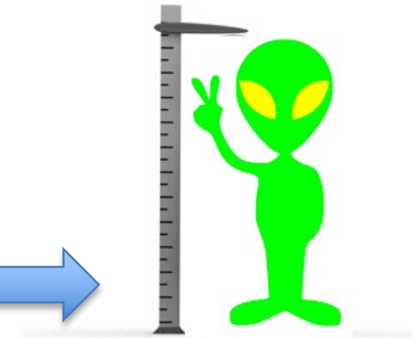
Contact: kruecken@phas.ubc.ca

TRIUMF: From the cosmos to the lab (and back)

Neutron-Star mergers emit gravitational waves and...

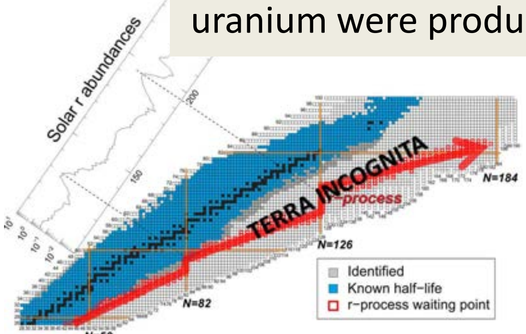


...produce very short-lived, neutron-rich isotopes...



...and we measure their physical properties like half-lives, nuclear structure, decay modes etc.

Why? We want to help understanding how and where the heavy elements from iron to uranium were produced



How? With modern nuclear detection methods and isotopes produced by the worlds' largest cyclotron accelerator


Photo: Margo Dornan

Who and where? TRIUMF

Reiner Kruecken (kruecken@phas.ubc.ca)
Iris Dillmann (dillmann@triumf.ca)

Ion-trap for precision mass measurements, fed by TRIUMF's ISAC accelerator to produce rare short-lived isotopes

Dr. Jens Dilling (TRIUMF, UBC adjunct)

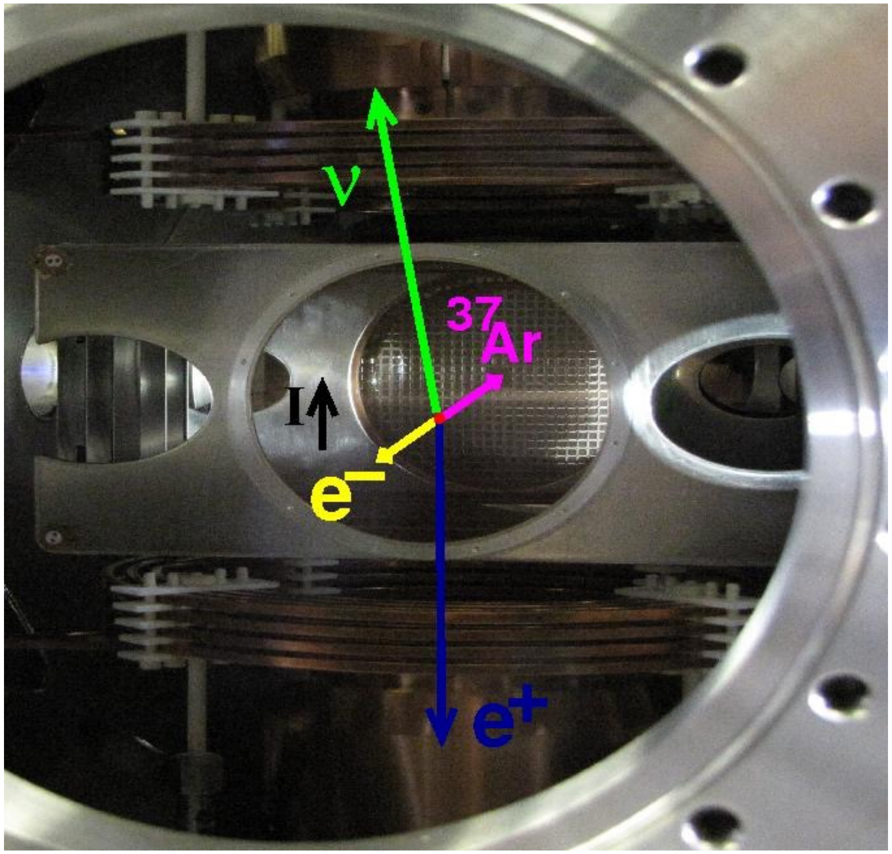
See TITAN and Jens on TRIUMF tour Saturday.

The TITAN Experimental Program

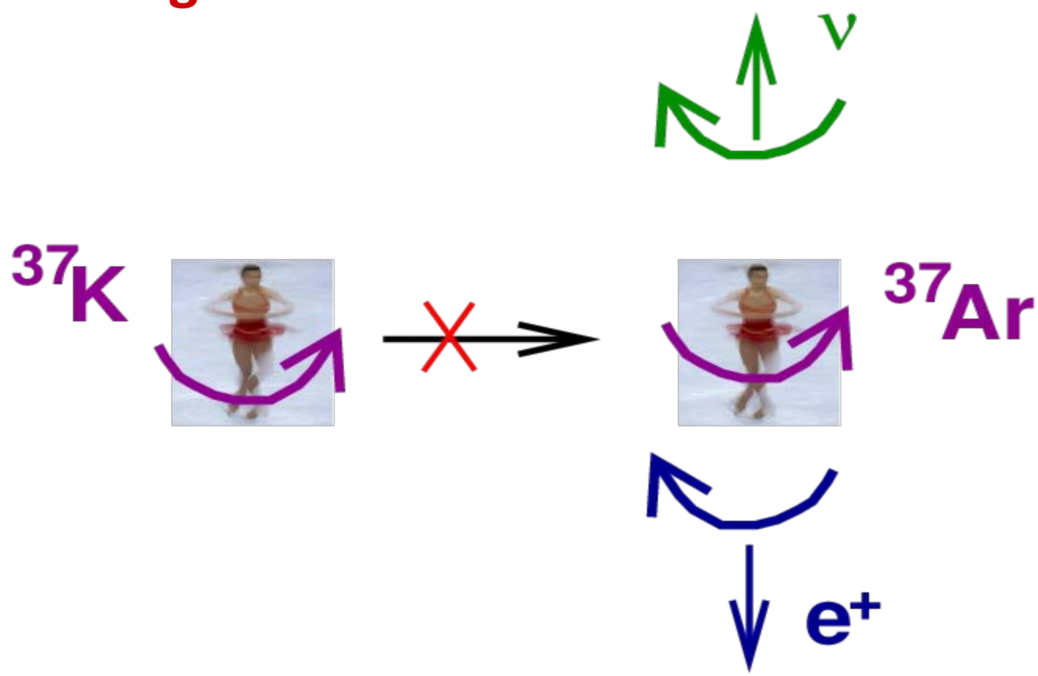
Measuring the mass of short-lived isotopes with high precision

Radioactive isotopes from ISAC are sent to TITAN to undergo cooling, charge-breeding and trapping. The entire process occurs in about 10 milliseconds, allowing radioactive isotopes with short half lives to be studied.

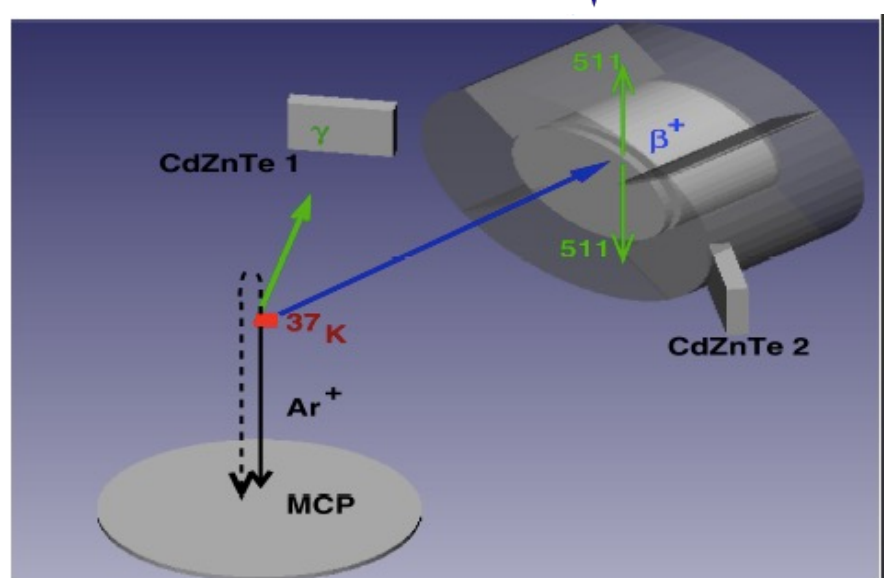
TRIUMF's Neutral Atom Trap for Beta Decay



If this neutrino went up, it was wrong-handed:



If detectors 1, 2 have different rates,
Time-reversal symmetry is violated
(or the detectors are not the same)



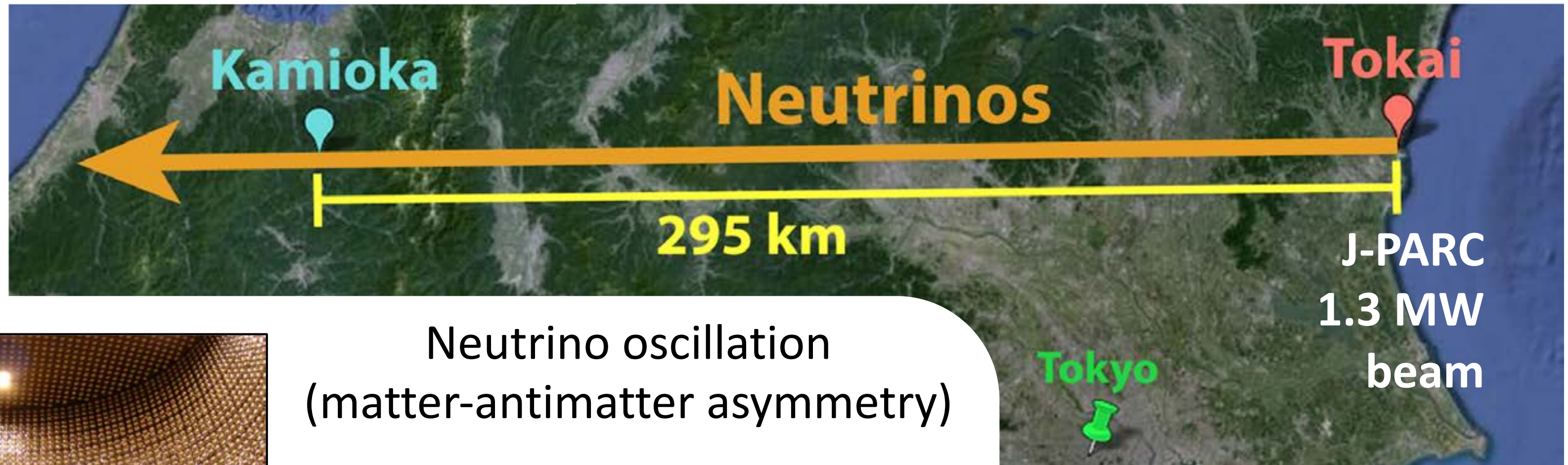
Contact John Behr, TRIUMF
for atomic+nuclear experiments

Backup

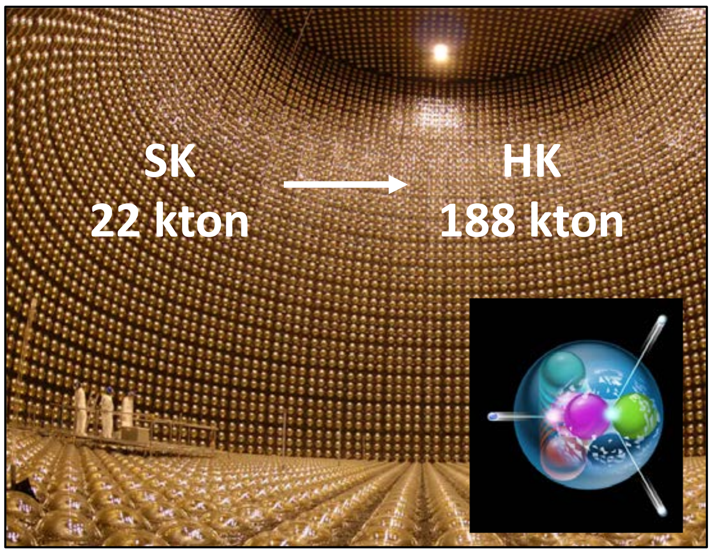
TRIUMF
Patrick de Perio (pdeperio@triumf.ca)
Mark Hartz (mhartz@triumf.ca)
Akira Konaka (konaka@triumf.ca)

Hyper-Kamiokande

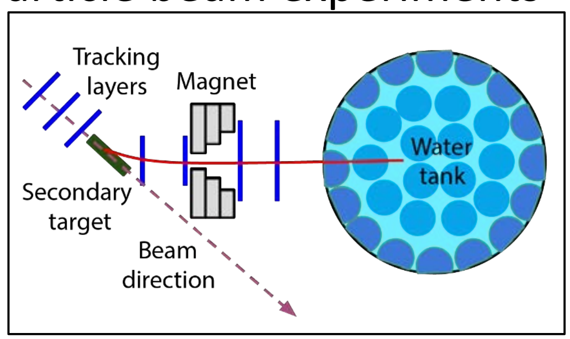
SUPER K



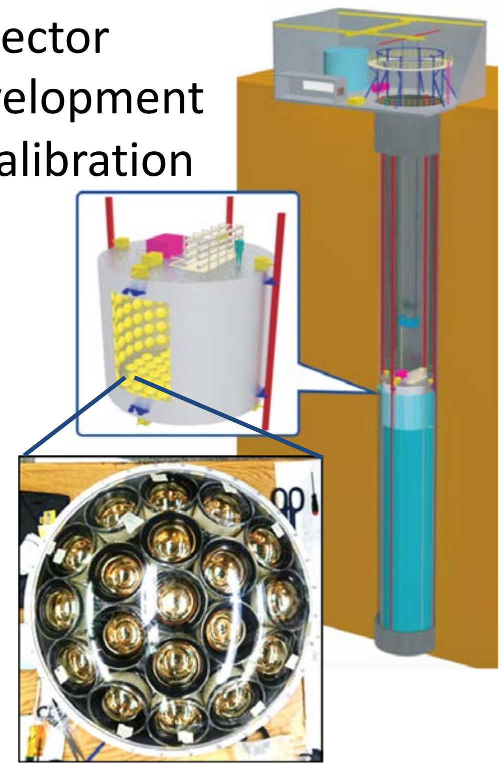
Neutrino oscillation
(matter-antimatter asymmetry)



Particle beam experiments



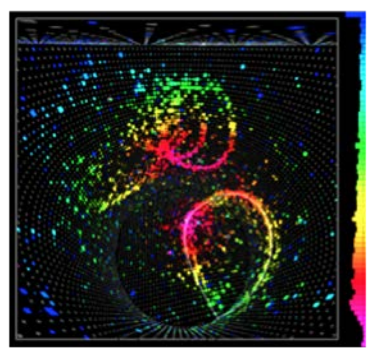
Detector
development
& calibration



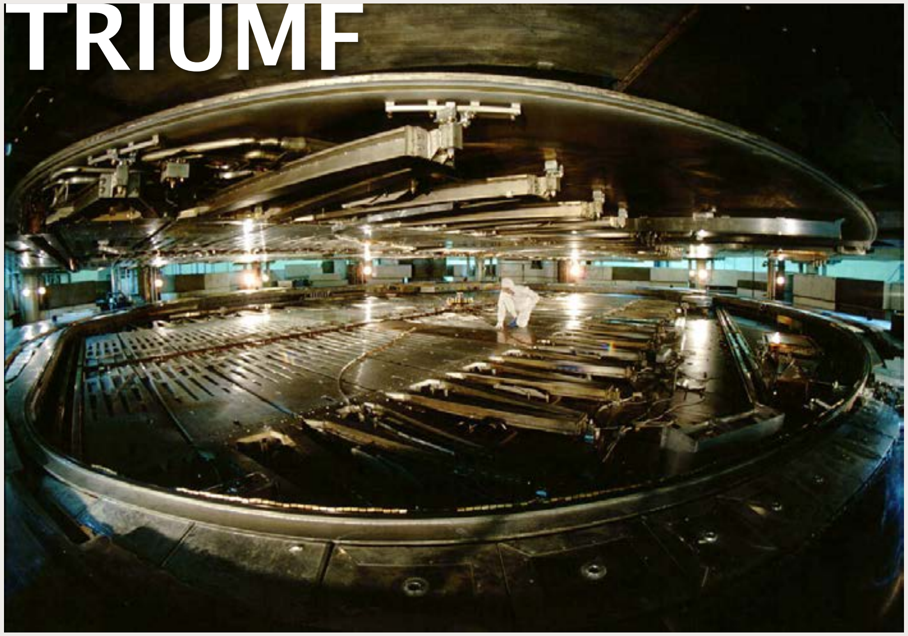
Proton decay

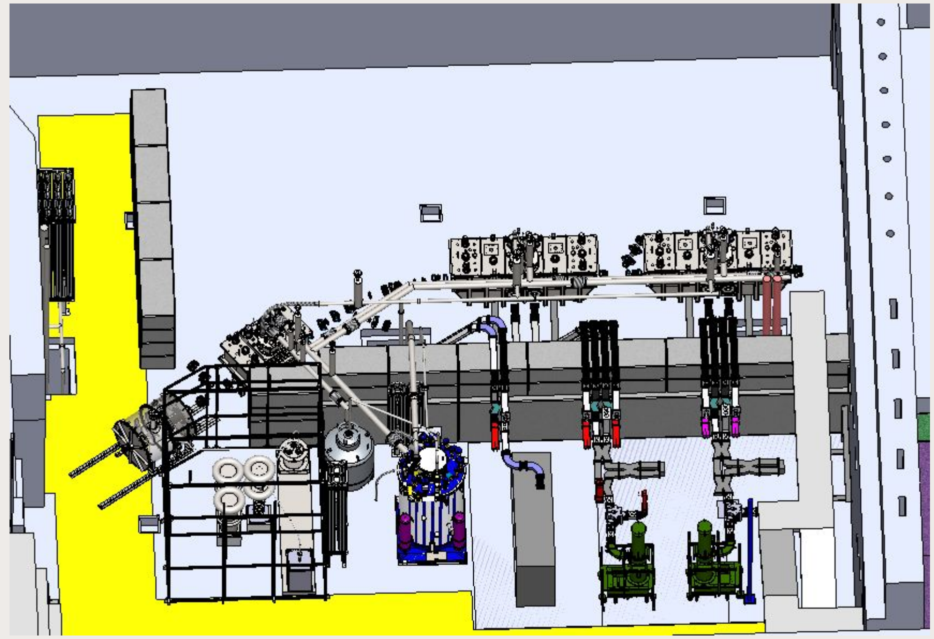
Multi-messenger
astronomy

Machine
Learning



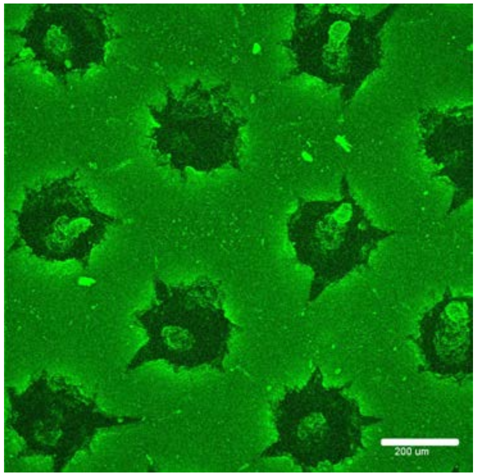
Accelerator Science & Engineering Research at TRIUMF



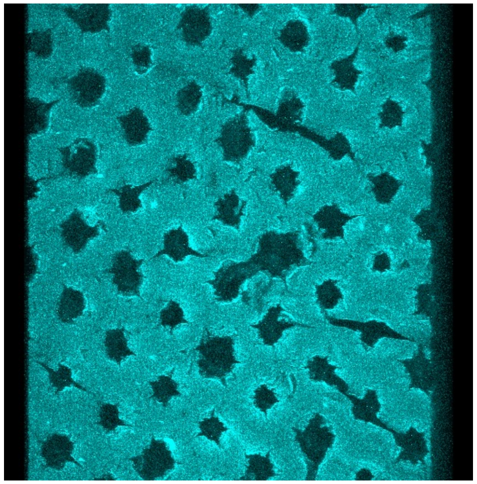


Muon g-2/EDM at J-PARC

- Goal: confirm or refute >3σ disagreement with Standard Model for the anomalous magnetic moment of the muon
  - previous result from BNL E821
  - similar experiment under construction at FNAL (E989)
- Method relies on acceleration of μ^+ after laser ionization of thermal muonium (μ^+e^-)
  - *muonium production from laser-ablated silica aerogel materials developed and demonstrated at TRIUMF*
- Laser ionization development program at RAL (UK) and J-PARC (Japan) pulsed muon beams
  - MPPC detectors, analog and digital (TDC) readout electronics systems to be developed at TRIUMF
  - aerogel target production (ablation) and characterization ongoing at UBC and UVic (Advanced Microscopy Lab – see photos)
  - simulation to understand muonium production in laser-ablated aerogel materials



Confocal microscope images of laser-ablated surfaces of aerogel:
Above: 30 mg cm^{-3}, 500 μm spacing.
Below: 30 mg cm^{-3}, 300 μm spacing.



Contact Glen Marshall at TRIUMF:
glen.marshall@triumf.ca
604-222-7466

a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA

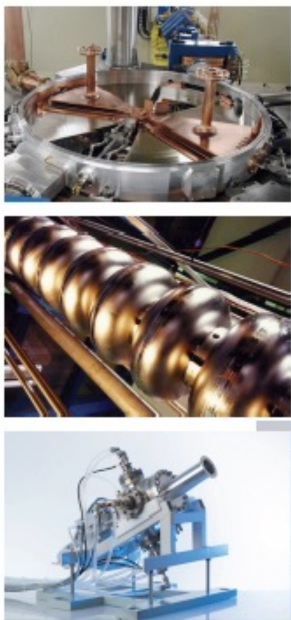
IsoSiM

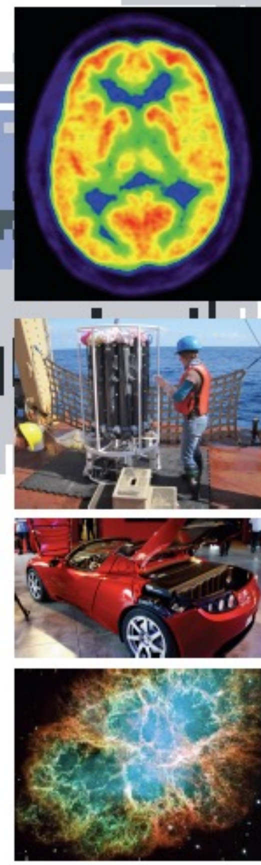
NSERC CRSNG
TRIUMF
Funded by the NSERC CREATE program

CREATE program: Isotopes for Science and Medicine

Production | Processing | Applications

Accelerator Science
Merminga





Medicine
Sossi, Schaffer, Hafeli

Environment
Maldonado

Materials
Kiefl, MacFarlane

Nuclear Physics
Dilling, Kruecken

Benefit:
Graduate Course, Workshops,
Schools, Industry Internships
International Research Experience
Professional Development

www.isosim.ubc.ca

Medical Physics in Vancouver and beyond

Medical Physics operates at the interface of physics and medicine.
The two largest applications are radiation therapy and imaging.

Oh, the places you'll go!

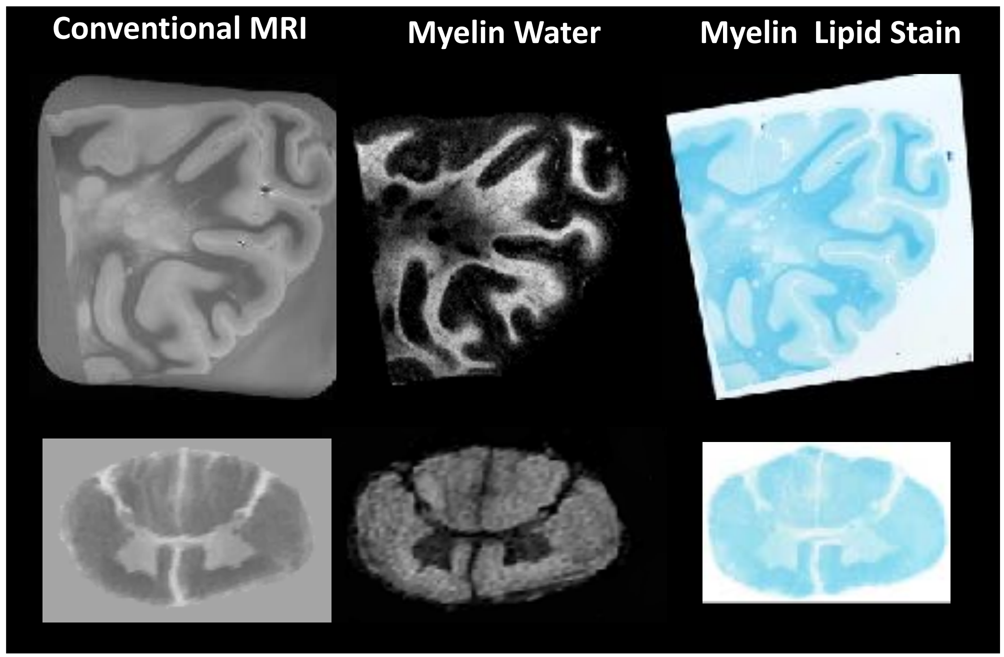
- UBC Physics
- Centre for Brain Health
- Vancouver General Hospital
- BC Cancer:
  - Vancouver, Surrey,
  - Abbotsford, Victoria
- BC Children's and Women's Hospital
- St Paul
- TRIUMF

Magnetic Resonance Imaging in the Central Nervous System:
In vivo and post mortem validation studies

RESEARCH AREAS

- **In vivo** technique development and characterization of human brain and spinal cord (multiple sclerosis, spinal cord injury, controls, etc)
- **Post mortem** validation of advanced MRI with histology

Corree Laule
www.mripathology.ca
corree@physics.ubc.ca
@mripathology

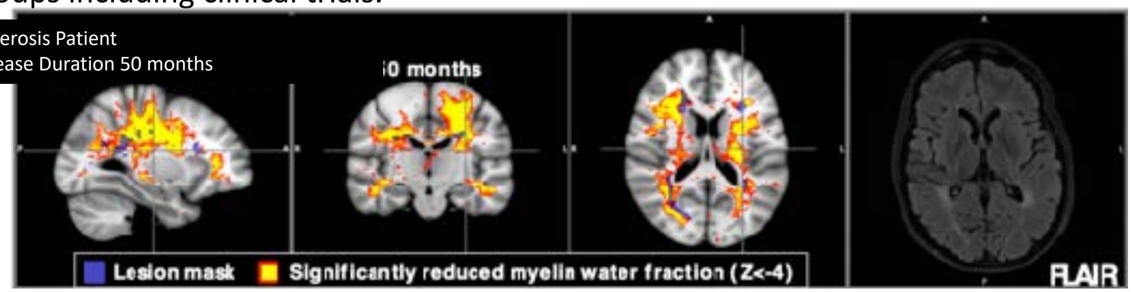


Magnetic Resonance Imaging in Neurological Disease

Shannon Kolind
shannon.kolind@ubc.ca

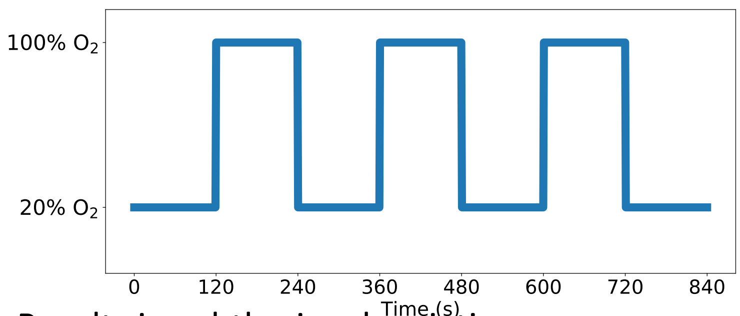
- Our goals are to develop new MRI techniques that can be translated for use in neurological disease, such as multiple sclerosis (MS).
- We work closely with many departments including Neurology, Radiology, and Computer Science to translate technical developments to clinical tools.
- We work on state-of-the-art research MRI scanners (3T and 64mT), with project ranging from designing and pulse programming new techniques, performing simulations, scanning phantoms or healthy volunteers, to applications in patient groups including clinical trials.

Multiple Sclerosis Patient
Age 33, Disease Duration 50 months

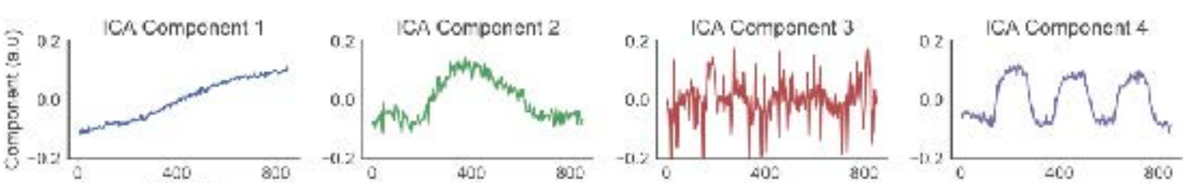


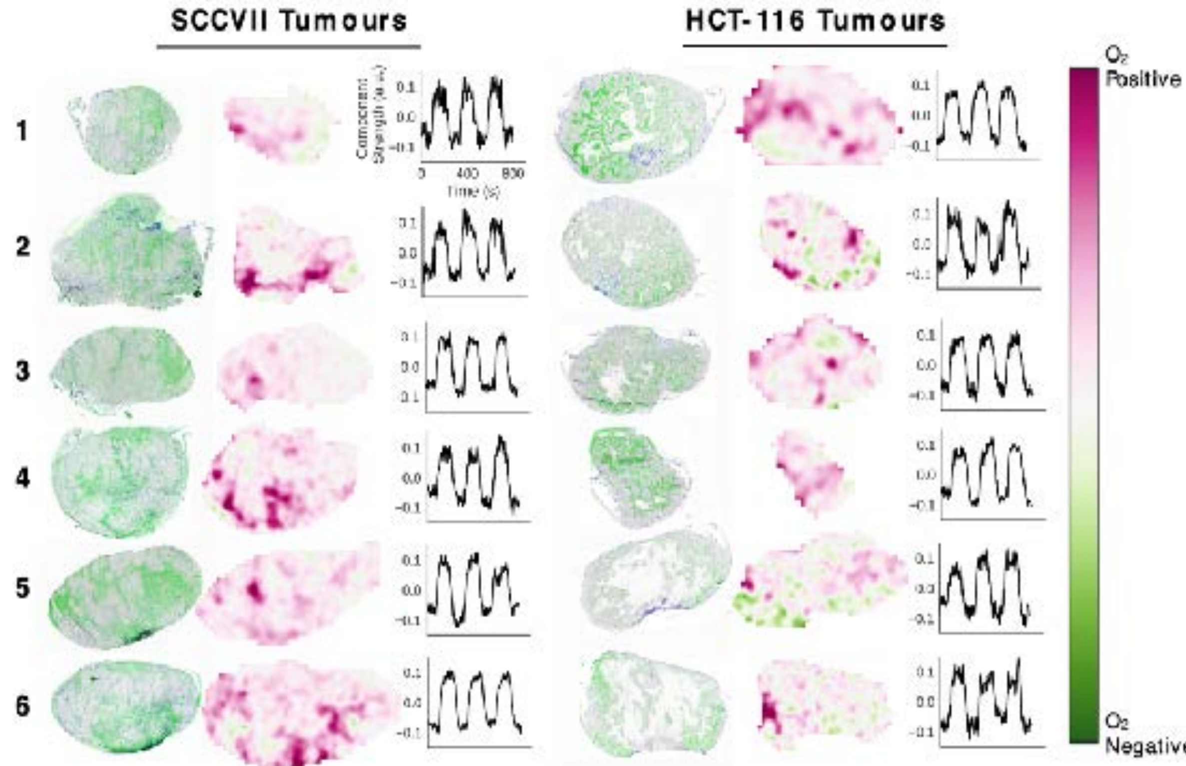
Oxygen-Enhanced MRI (dOE-MRI): Mapping Presence and Absence of Oxygen in Tissue

Oxygen breathing challenge



Results in subtle signal variation



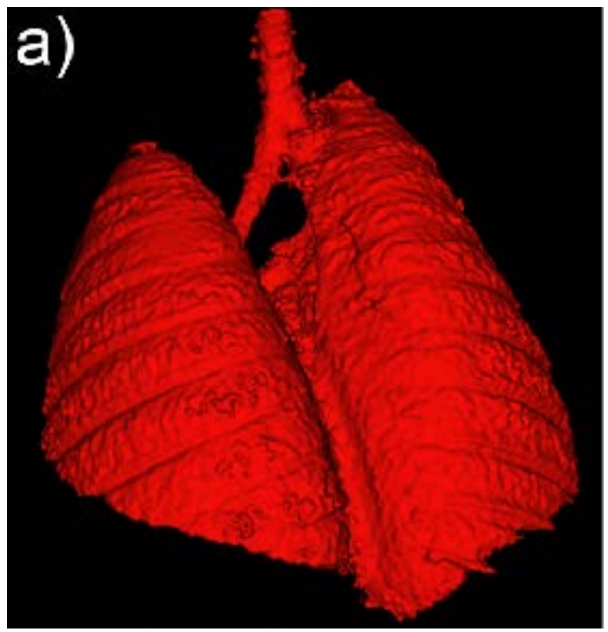


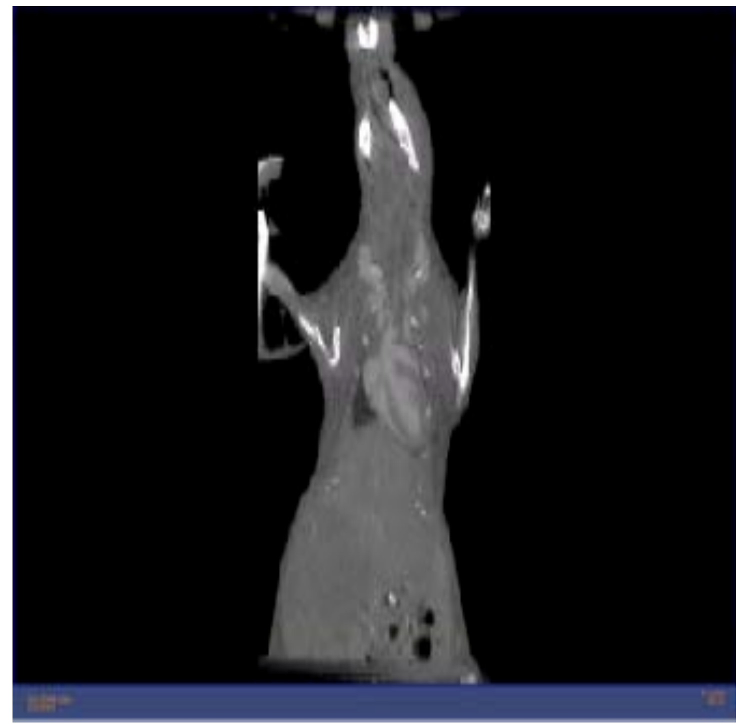
7T @ UBC MRI Research Centre)

Jennifer Baker
Firas Moosvi
Andrew Minchinton
Stefan Reinsberg

Dr. Nancy L. Ford
nlford@dentistry.ubc.ca

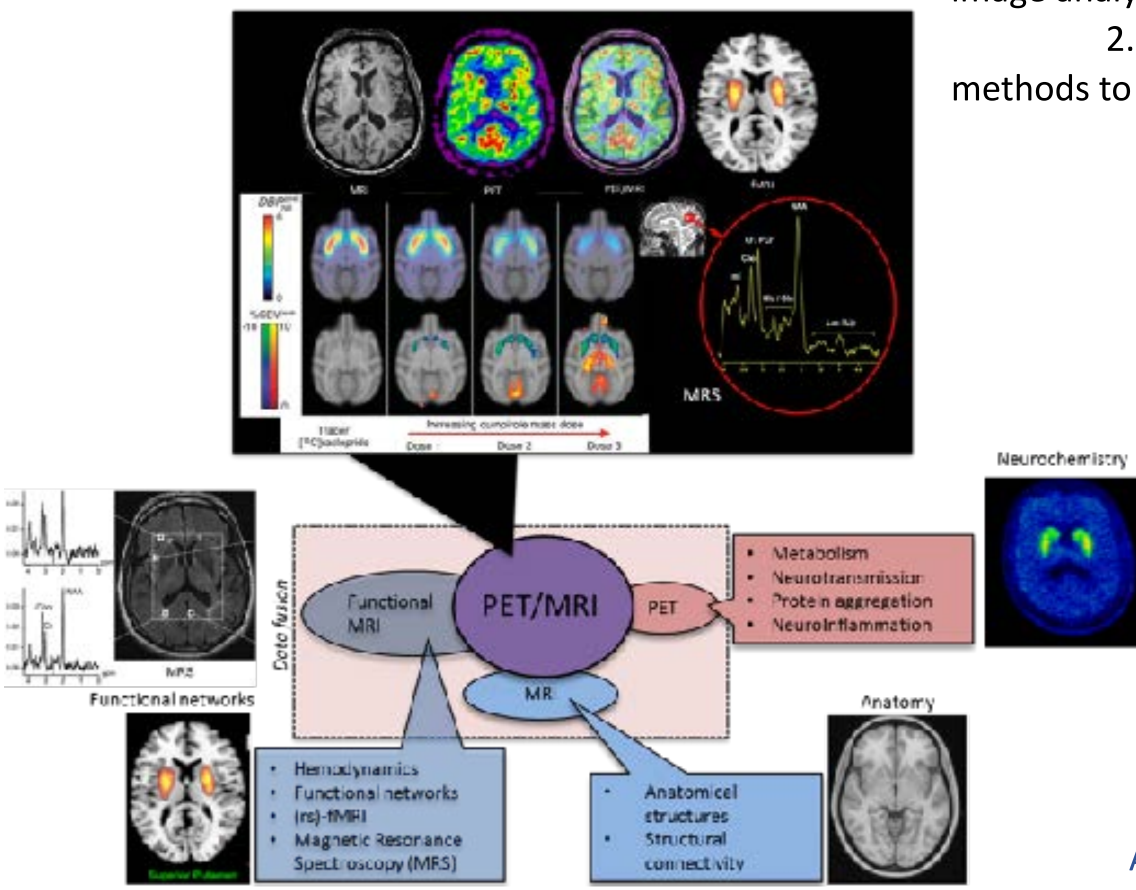
Research Areas:
Cone Beam Computed Tomography (CBCT)
Cardiac imaging
Respiratory imaging
Contrast agents
Image-based analysis





Investigating brain function in health and disease using hybrid PET/MRI in the UBC DM Center for Brain Health

Vesna Sossi



Research areas:

1. instrumentation, image reconstruction and multi-modal image analysis
2. application of advanced multi-modal image analysis methods to human studies

Selected Example of projects:

1. Investigation of **brain energetics** (production and utilization of glucose) in health and disease and susceptibility to exercise (Bevington, PhD)
2. Investigation of the **coupling between task related neurotransmitter release** (PET) and hemodynamic connectivity (MRI) in health and disease (Bevington MSc, Hanania, Reimers, PhD)
3. Investigation of the relationship between **metabolic networks** (PET) and **brain resting state connectivity** (MRI) (Hanania, PhD)
4. Definition of **multi-modal neurochemical and connectivity patterns** as sensitive disease and disease progression biomarkers (J Fu, PhD)

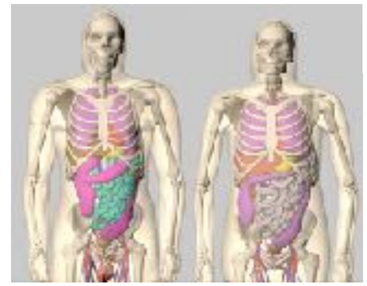
All projects require development of novel PET and MRI data processing and analysis algorithms

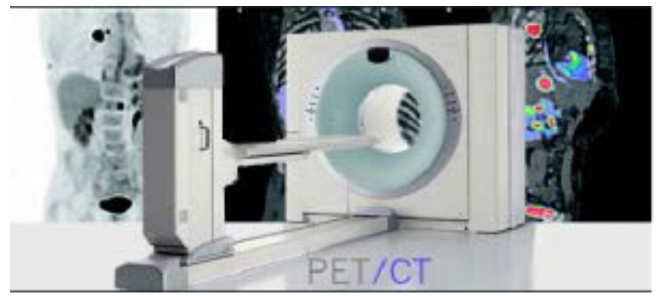
QURIT

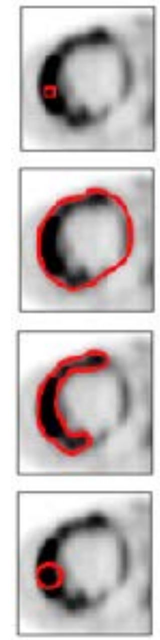
Quantitative Radiomolecular Imaging & Therapy

Quantitative Tomography Lab

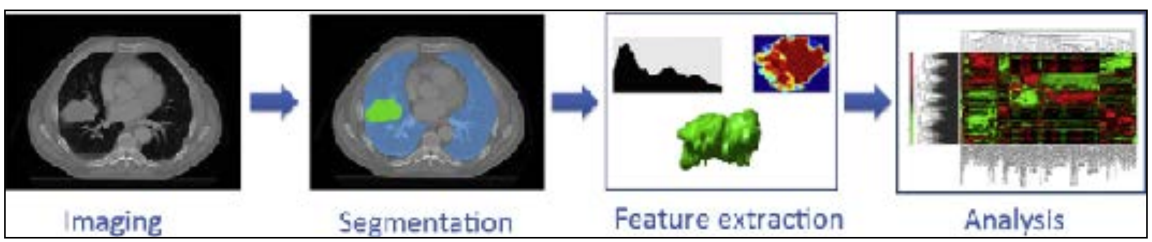
rahmimlab.com

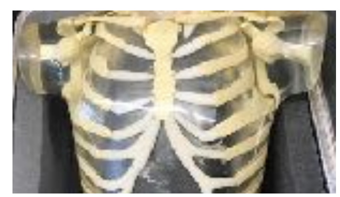






- Molecular Imaging and Therapy of Cancer Patients
- Theranostic (Therapeutic+Diagnostic) Imaging
- Tomographic Imaging (PET/CT, SPECT/CT)
- Quantitative 3D and 4D Image Reconstruction
- Deep learning methods to process images
- AI-based radiomics to predict cancer patient outcomes
- Realistic anthropomorphic phantom studies to optimize clinical imaging





Zeng Lab at BC Cancer Research Centre

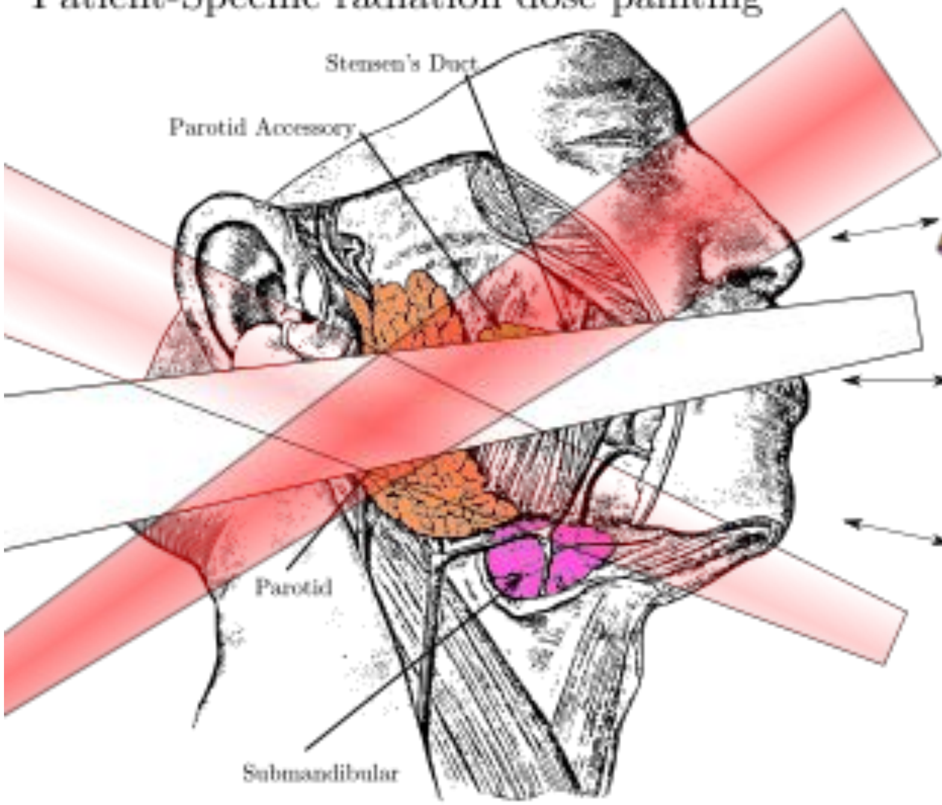
https://www.bccrc.ca/dept/io/labs/zeng-lab
hzeng@bccrc.ca

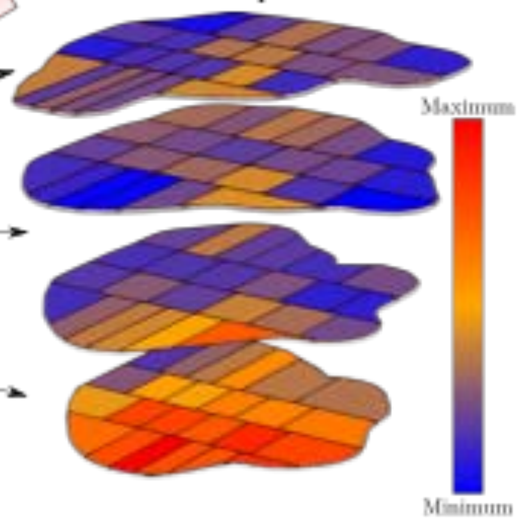
- Research Focus – light-tissue interaction & its applications in medical diagnosis and therapy
- Current Projects
  - Multiphoton Photothermolysis for Precision Microsurgery (for Eye diseases)
  - Skin Cancer Detection - Multiphoton Microscopy and Raman Spectroscopy
  - Lung Cancer Screening - Breath analysis by Raman spectroscopy
  - Colorectal Cancer Detection - Raman Spectroscopy and Endomicroscopy Imaging

Research Interests - Hal Clark PhD, MCCPM, BC Cancer Surrey

haley.clark@bccancer.bc.ca   github.com/hdclark

Patient-Specific radiation dose painting





+ Quantitative medical imaging (radiomics, diffusion, perfusion)
+ Image segmentation, conv. neural networks
+ Automated radiotherapy planning
+ Image registration QA+planning tools
+ Computation, 3D design, additive manufact.

1. Use medical imaging + machine learning to assess patient.
2. Adapt to patient anatomy, function.
3. Deliver radiation that destroys tumours, but spares important tissues.

The CARA Project

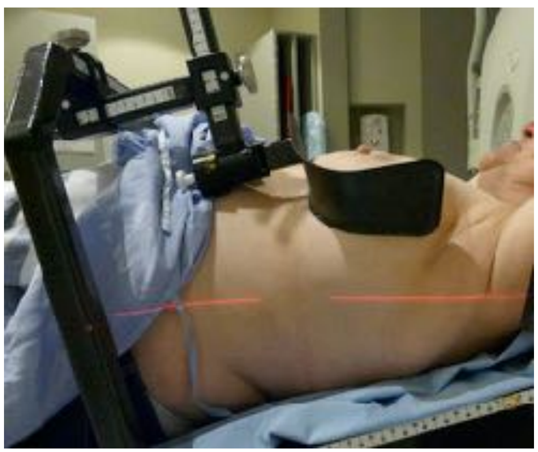
Principle Investigator C Duzenli

2016 Innovation Grant
$39,000

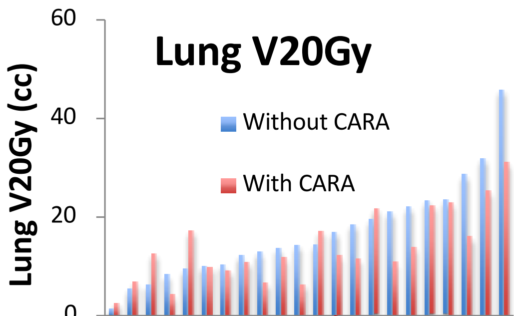
2018 Innovation-to-Impact Grant
$350,000

Patent 2019

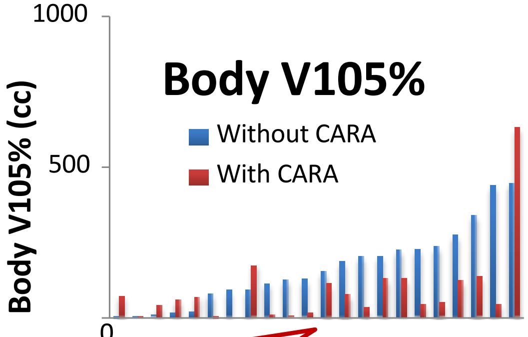
Randomized trial 2019-2021



20 Patient Pilot Study



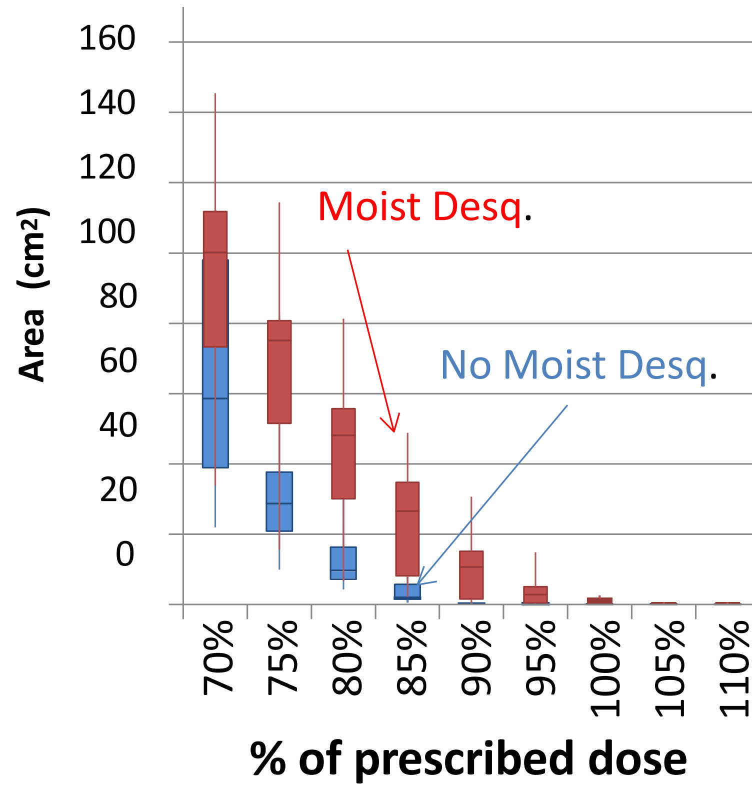
V20 Gy lung reduced in 73% of patients

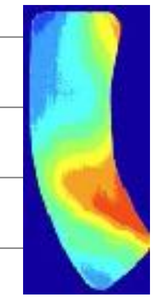


V105% (cc) reduced in 73% of patients

In-Vivo Measured Skin Dose-Area is Predictive of Moist Desquamation

Skin dose measurements





Emilie Carpentier[1,2]*, Cheryl Duzenli[1,2], Bradford Gill[2], Erika Facchin[2], Sheri Grahame[2], Cathy Crumley[2], Theodora Koulis[3], Robert Olson[1,4], Elisa Chan[2]

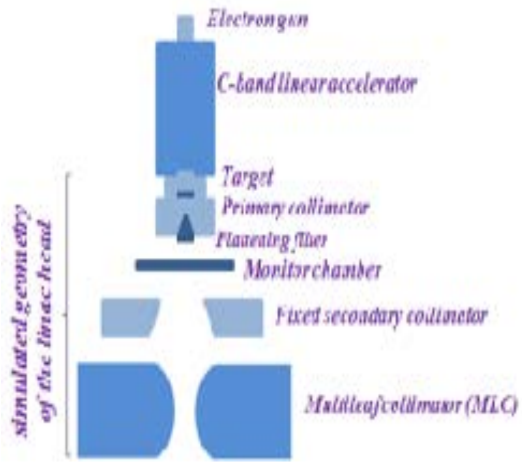
Monte Carlo Modelling of Vero 4DRT platform for 4pi "Dynamic Wave Arc" Deliveries

1st Patient Treated Oct 2019!

Alanah Bergman
Maryam Rostamzadeh
BC Cancer Vancouver, UBC

Yoshitomo Ishihara
Mitsuhiro Nakamura
Kyoto University

Tony Popescu
Ermias Gete
Tony Mestrovic
BC Cancer Vancouver, UBC



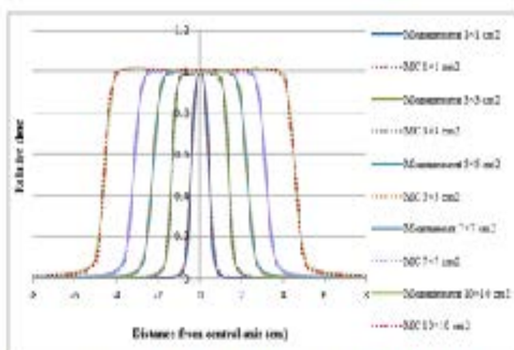
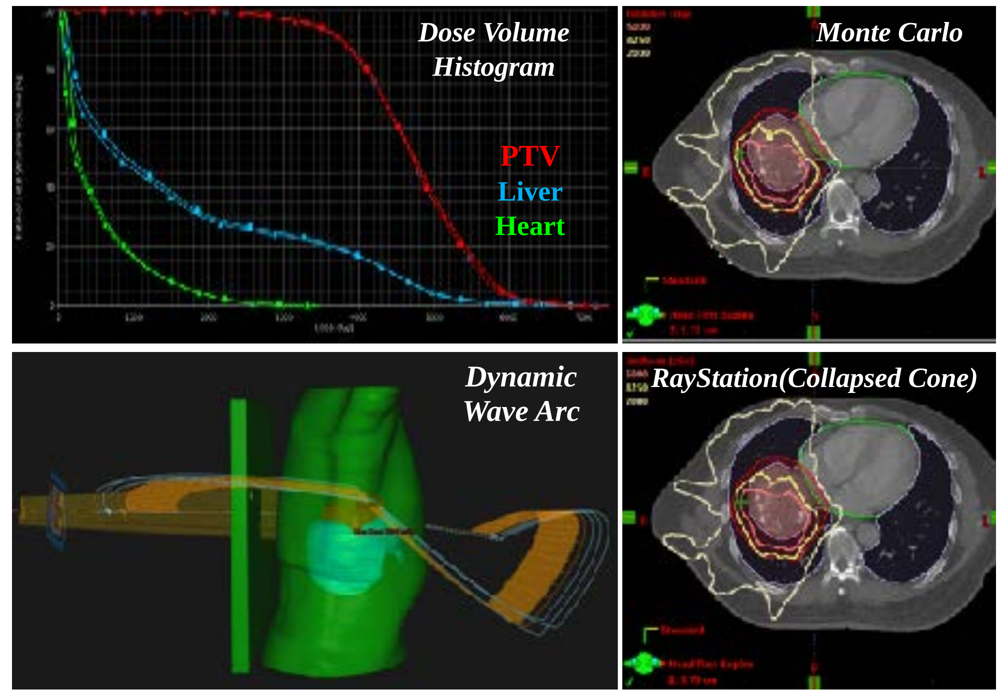


Figure 4.9 In-Plane profiles of the simulated and measured doses for various field sizes at SSD=90 cm at depth=1.5 cm



Monte Carlo for Secondary Dose Calculation Verification on Patient Geometries

BC CANCER

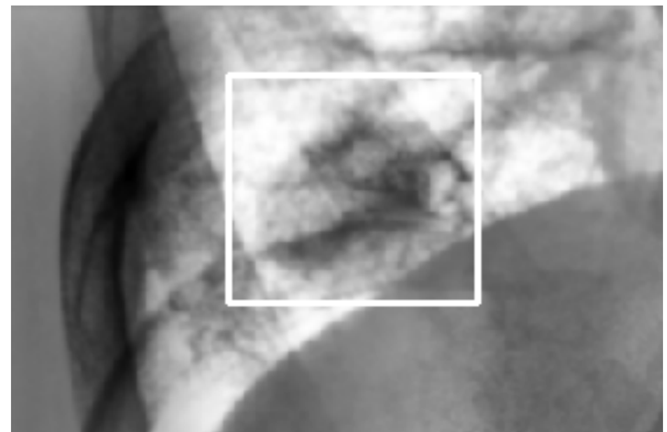
Provincial Health Services Authority

Fiducial-less Dynamic Tumour Tracking for Lung and Liver SABR

a place of mind

UBC

Dynamic Tumour Tracking



Fiducial-less Tracking of Lung Tumour directly
(or other surrogate e.g. diaphragm)

lanah Bergman
arie-Laure Camborde
ania Karan
ony Mestrovic
mily Carpentier
teven Thomas
itchell Liu MD
oy Ma MD
ina Zhang MD
aryam Rostamzadeh

Current Liver SABR Tracking requires implanted Fiducials, an Invasive Procedure

Current Lung SABR relies on ITV method (motion encompassing) as Fiducials not implanted

→ Future: Tracking with NO fiducials

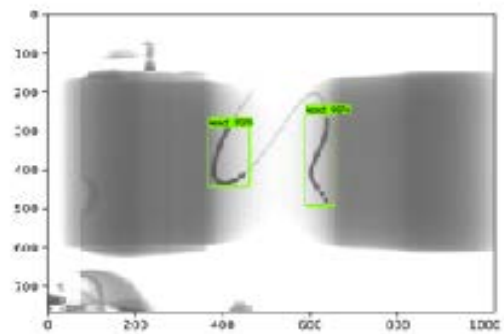
BC CANCER

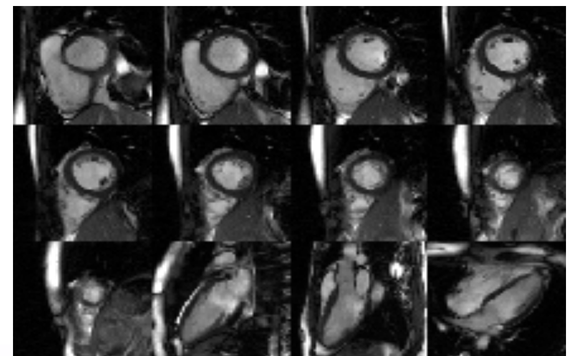
Provincial Health Services Authority

a place of mind

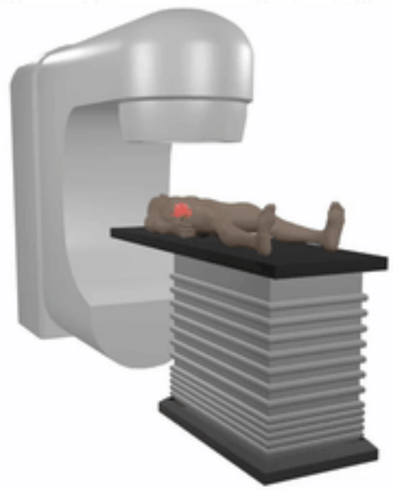
UBC

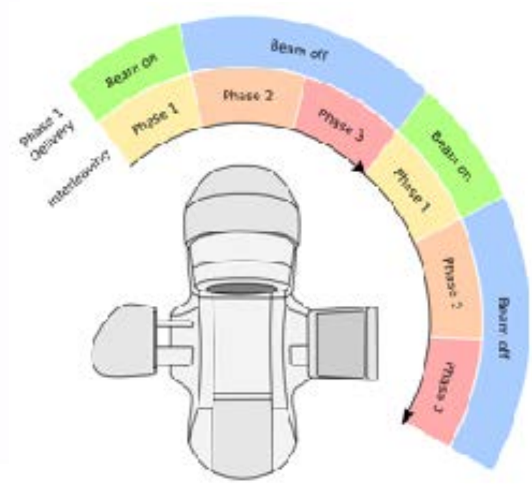
Stereotactic Radiosurgery for the treatment of Ventricular Tachycardia





Courtesy of Richard Thompson

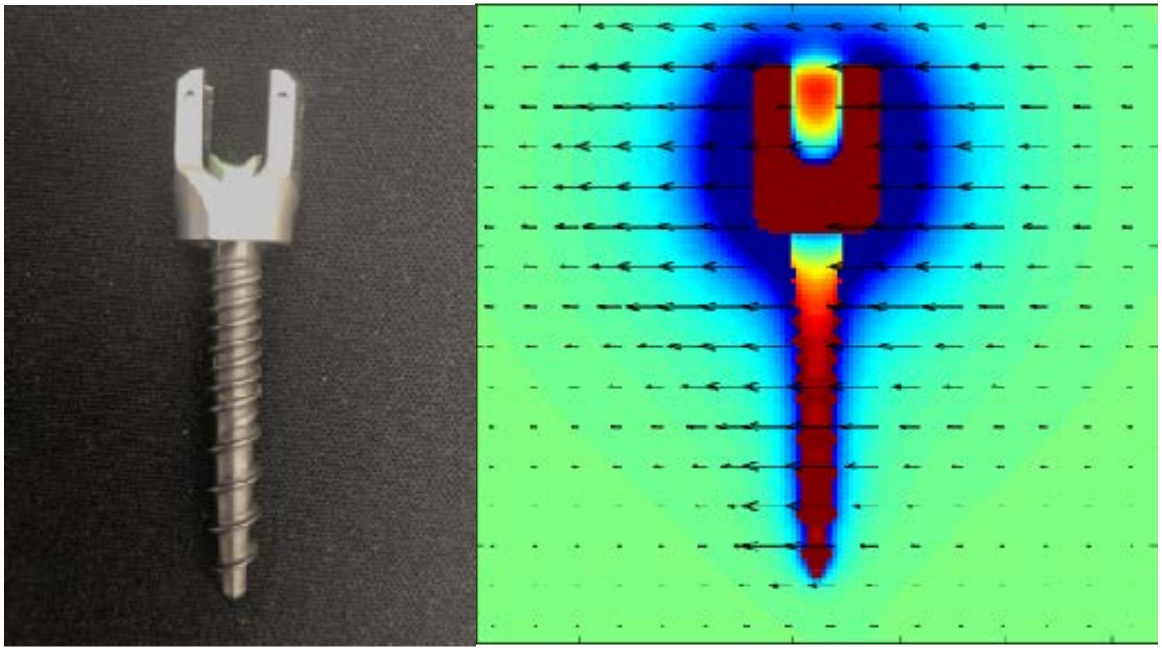




P-I Steven Thomas BC Cancer Vancouver, UBC
Marc Deyell Division of Cardiology, UBC
Devin Schellenberg BC Cancer Surrey, UBC
Kirpal Kohli BC Cancer Surrey, SFU

Co-I Justin Poon UBC Physics
Tania Karan BC Cancer Vancouver
Marie Laure Camborde BC Cancer Vancouver
Richard Thompson, U of A, BME/Cardiology
Tony Teke BC Cancer Kelowna, UBC
Eric Tran BC Cancer Vancouver, UBC
Alanah Bergman BC Cancer Vancouver, UBC
Mitchel Liu BC Cancer Vancouver, UBC
Brad Gill BC Cancer Vancouver

Patient specific susceptibility induced MRI geometric distortion prediction & correction for patients with metallic implants receiving spine SABR



P-I Steven Thomas BC Cancer Vancouver
Keith Wachowicz U of Alberta
Nic Dea VGH Combined Neurosurgical and
›edic Spine Program
Emma Dunne BC Cancer Vancouver

Co-I Teo Stanescu Princess Margret Hospital Hal Clark
BC Cancer Vancouver
Monte Martin BC Cancer Vancouver
Don Ta BC Cancer Vancouver
Hannah Carolan BC Cancer Vancouver
Mitchel Liu BC Cancer Vancouver

Dose perturbation of esophageal stents in VMAT

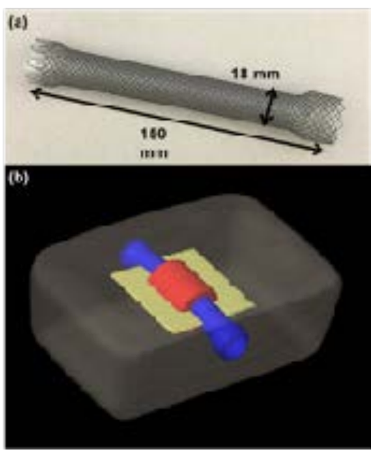
Robert Kosztyla[1], Cheryl Duzenli[1], Basil S. Nasir[2], Shilo Lefresne[1]

(1) BC Cancer - Vancouver, Vancouver, British Columbia, (2) Centre Hospitalier de l'Universite de Montreal, Montreal, Quebec

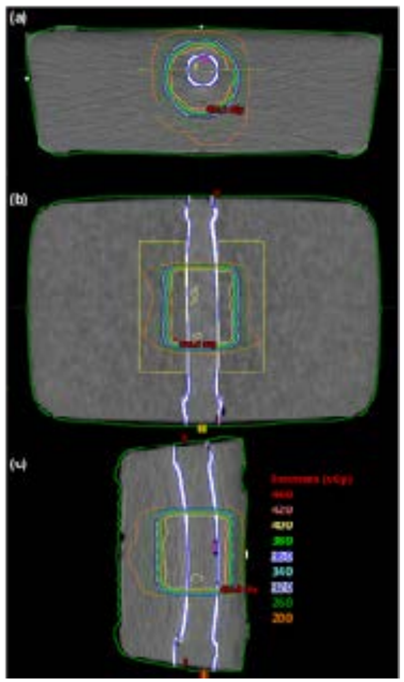
There is concern about the safety of combining stents with radiotherapy due to potential impact of the stent on dosimetric parameters leading to undercoverage of the tumor or increased toxicity.

Prior studies using static photon beam arrangements identified dose perturbations of 5–20%.

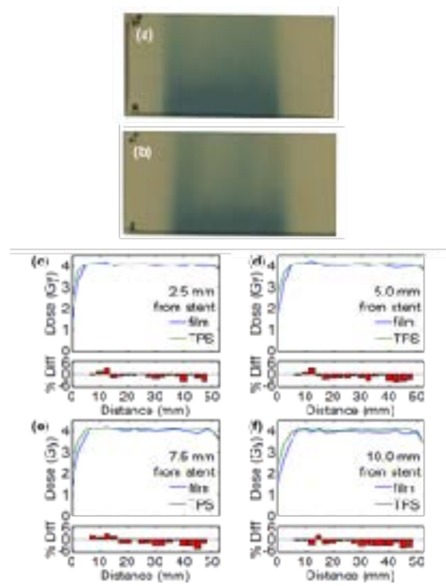
Perturbations arising from volumetric modulated arc therapy (VMAT) have not been reported.



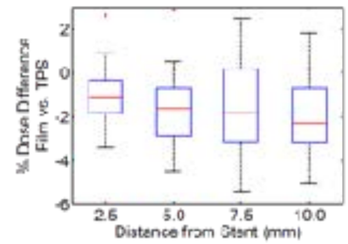
CT images in (a) axial (b) coronal, and (c) sagittal planes of the phantom are shown with the isodose distribution of the VMAT plan calculated by the TPS.



Gafchromic EBT3 films following irradiation. The bottom of each film abutted the stent during irradiation. (c-f) Dose and percentage dose difference in film vs TPS along profiles at different distances from the stent.



Percentage dose difference measured on film versus the dose calculated by the TPS for different distances from the stent.



The measured dose distribution at distances greater than 2.5 mm from the stent agrees with the dose calculated by the treatment planning system.

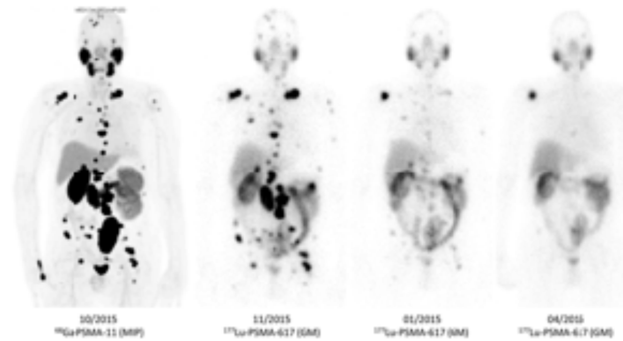
Future investigation should entail Monte Carlo simulations to investigate dose perturbations at distances less than 2.5 mm from the stent, and confirmation of similar findings with stents of varying composition

Staff personal dosimetry from Lutetium-177 nuclear medicine treatments

M. Peter Petric, Sheila MacMahon, Lauren Fougner

Background

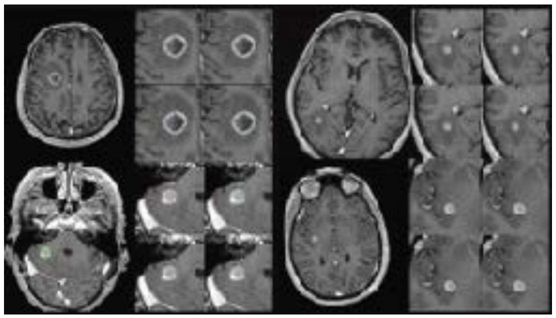
- Therapeutic Lu-177 injections for treatment of metastatic prostate cancer patients (PSMA-bound) or neuro-endocrine cancer patients (DOTATOC-bound)
  - Doses: 7.4 GBq at 6 week intervals
  - Beta emitter [490 keV] with some gamma emission [210 keV]
  - Medium-lived isotope [$t_{1/2}$ = 6.6 days]



Objective

- Assess staff personal dosimetry from Lu-177 treatments including eye doses
- Monitored staff includes:
  - Cyclotron staff (synthesize doses)
  - PET technologists (administer injections & monitor patient vitals)
- Enhanced staff dose monitoring includes:
  - Eye dosimeters
  - Electronic personal dosimeters fitted with beta detection modules
  - Standard OSLD body and TLD ring dosimeters

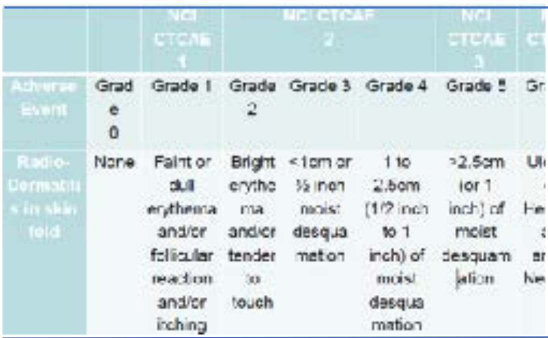
BC Cancer Vancouver



Automatic Deep Learning-based Segmentation of Brain Metastasis on MPRAGE MR Images for Stereotactic Radiotherapy Planning

C.L.Swift

Poster: 3B



Adverse Event	Grade 0	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Gr
Radio-Dermatitis in skin fold	None	Faint or dull erythema and/or follicular reaction and/or itching	Bright erythema and/or tender to touch	<1cm or ½ inch moist desquamation	1 to 2.5cm (1/2 inch to 1 inch) of moist desquamation	>2.5cm (or 1 inch) of moist desquamation	[illegible]

A Breast Skin Assessment Pilot (POSI B-SKIP) Comparing Patient Reposted Outcomes and Therapist Assessment of Moist Desquamation in Breast

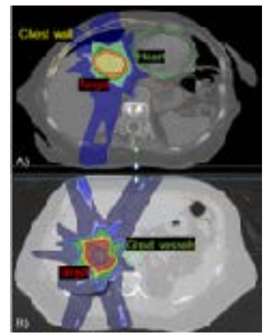
C. Duzenli

Poster: 33A

FLASH Radiotherapy at BC Cancer: Vancouver

T. Karan, C. Duzenli, P. Petric, A. Bergman

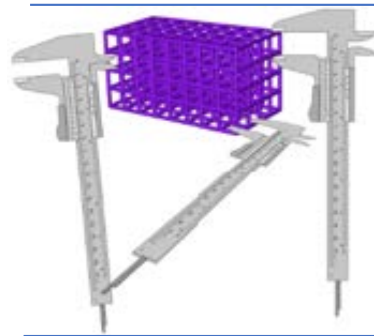
Poster: 13B



Advancing to complex radiotherapy techniques with dynamic tumor tracking (DTT) on the Vero4DRT linear accelerator

A. Mestrovic, A. Bergman, E Gete, ML Camborde, CL Swift, T Karan

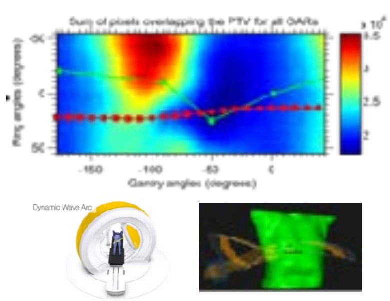
Poster: 8A



Can Low-Cost Magnetic Resonance Distortion Phantoms be 3D Printed?

H. Clark

Poster: 7D



Optimization and evaluation of dynamic wave arc trajectory radiotherapy for patients treated on a dedicated Stereotactic Ablative Radiotherapy (SABR) system

A. Pourmoghaddas, A. Bergman

Poster: 10A

Radiomics and machine learning for outcomes prediction

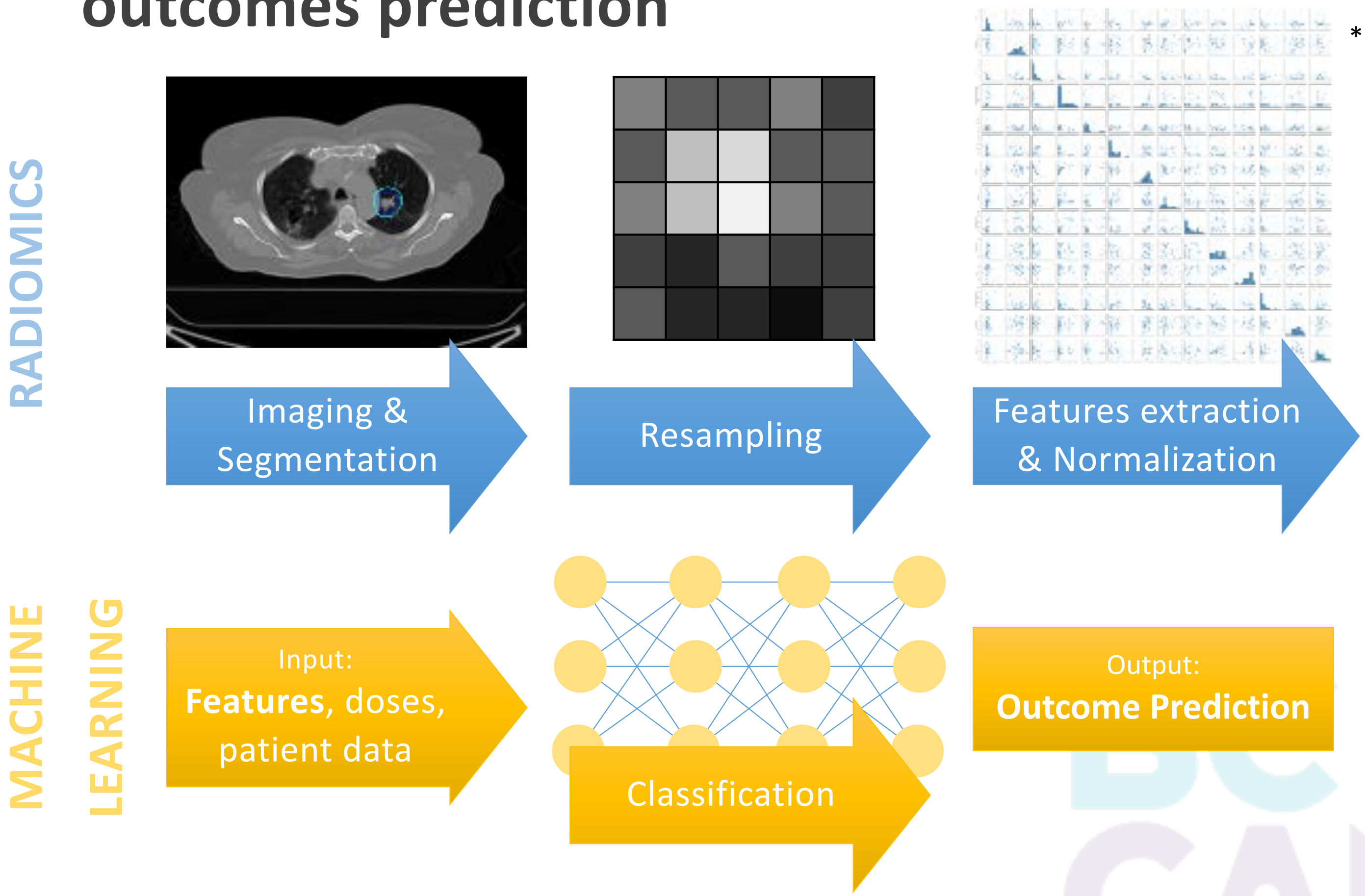


*Figure courtesy of **Lorna Tu**

slloyd@bccancer.bc.ca for more information

Medical Physics in Vancouver and beyond

Medical Physics operates at the interface of physics and medicine.
The two largest applications are radiation therapy and imaging.

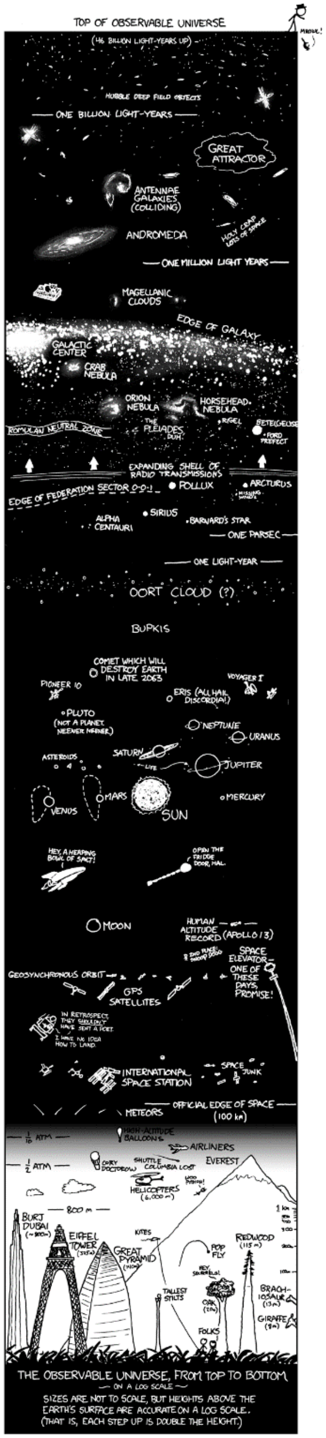
Oh, the places you'll go!

- UBC Physics
- Centre for Brain Health
- Vancouver General Hospital
- BC Cancer:
  - Vancouver, Surrey,
  - Abbotsford, Victoria
- BC Children's and Women's Hospital
- St Paul's Hospital
- TRIUMF

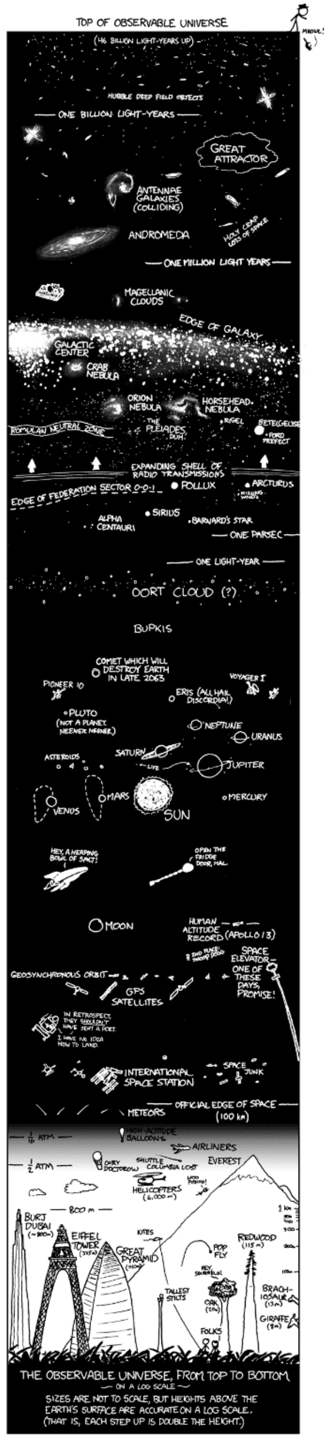
The Universe

distance and size scale of the Universe
on a logarithmic scale

xkcd.com/482/



distance and size scale of the Universe
on a logarithmic scale
xkcd.com/482/

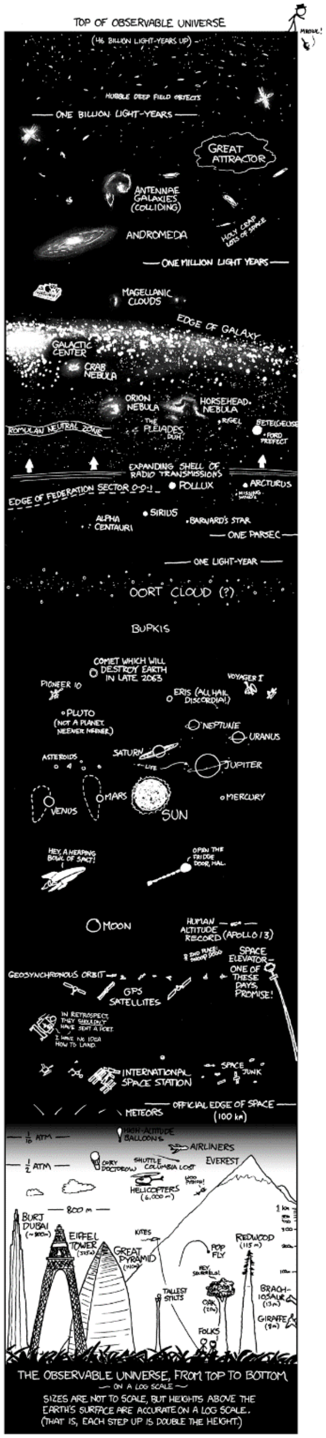


The Universe at UBC

Jaymie Matthews
Astrophysicist
UBC Physics & Astronomy

distance and size scale of the Universe
on a logarithmic scale

xkcd.com/482/



CMB (Cosmic Microwave Background)

Other galaxies Large Scale Structure

Local Group of Galaxies

Milky Way

Star clusters and star/planet formation

Stars Exoplanets

Trans-Neptunian Objects

Planets, dwarf planets, moons, asteroids

Sun

Moon

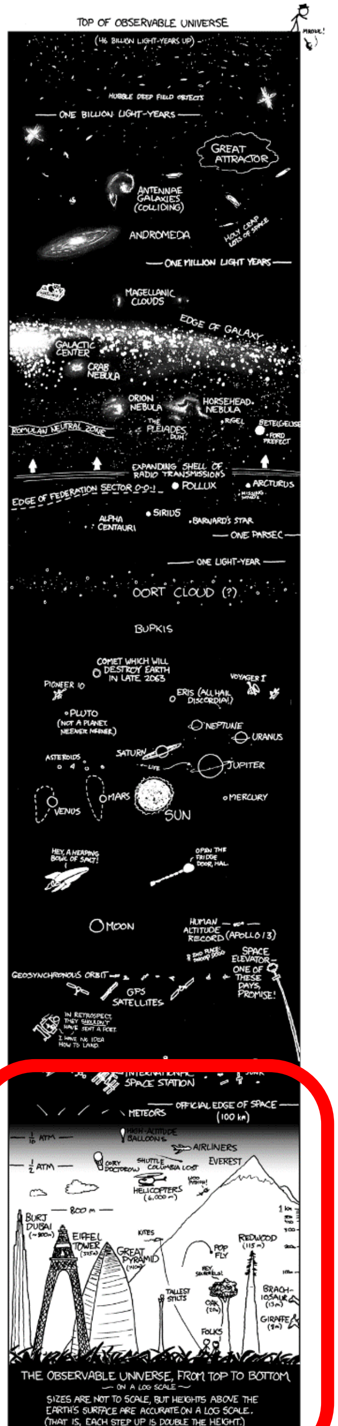
space telescopes

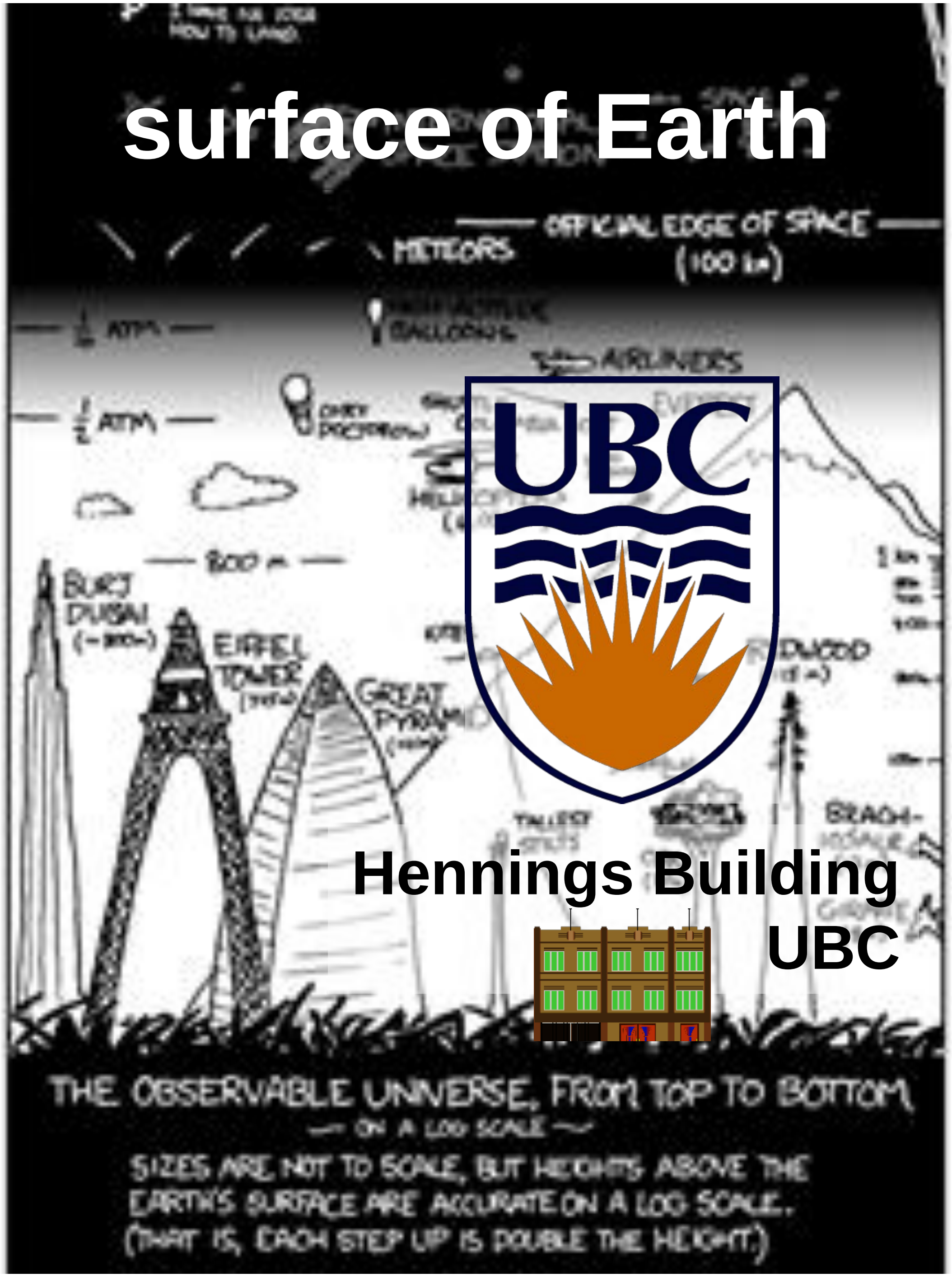
high-altitude balloons

surface of Earth Largest telescopes

distance and size scale of the Universe
on a logarithmic scale

xkcd.com/482/



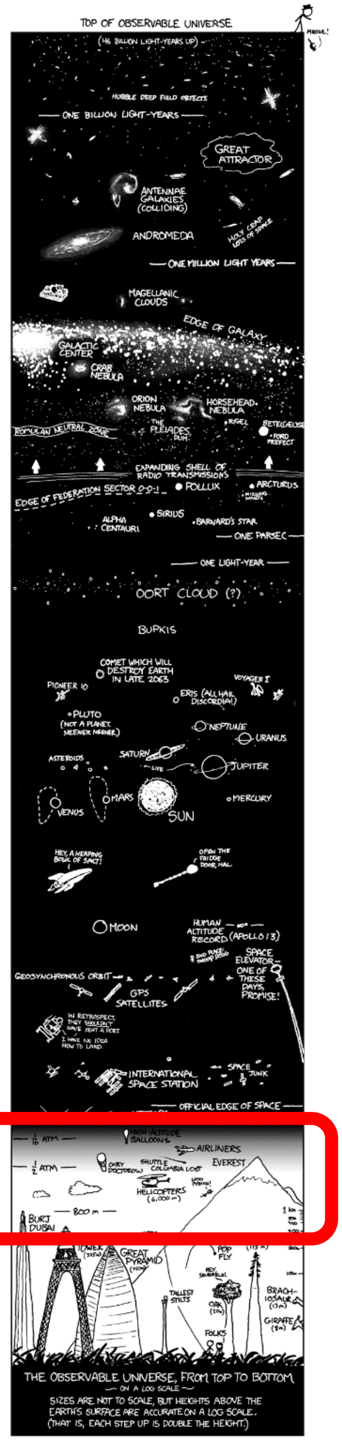


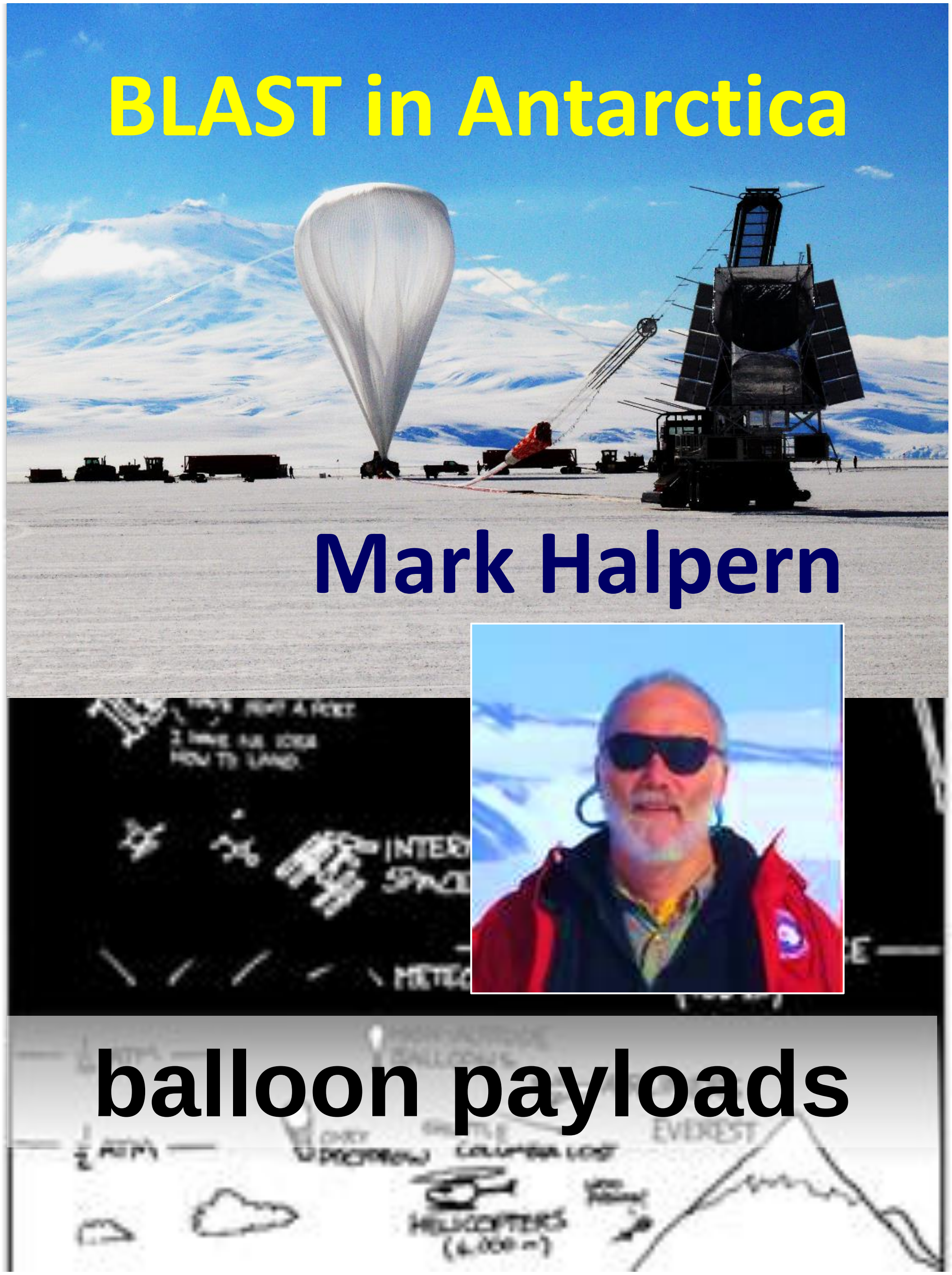
surface of Earth

Hennings Building
UBC

distance and size scale of the Universe
on a logarithmic scale

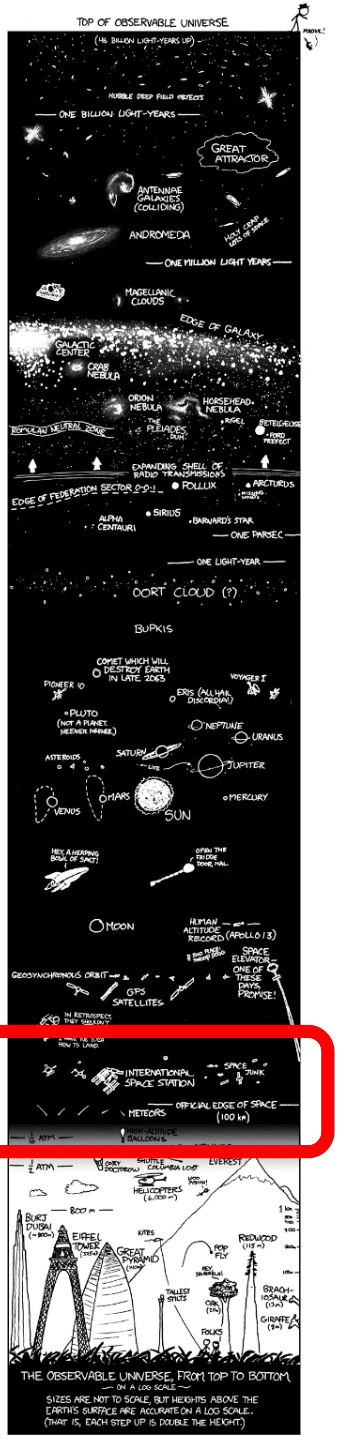
xkcd.com/482/



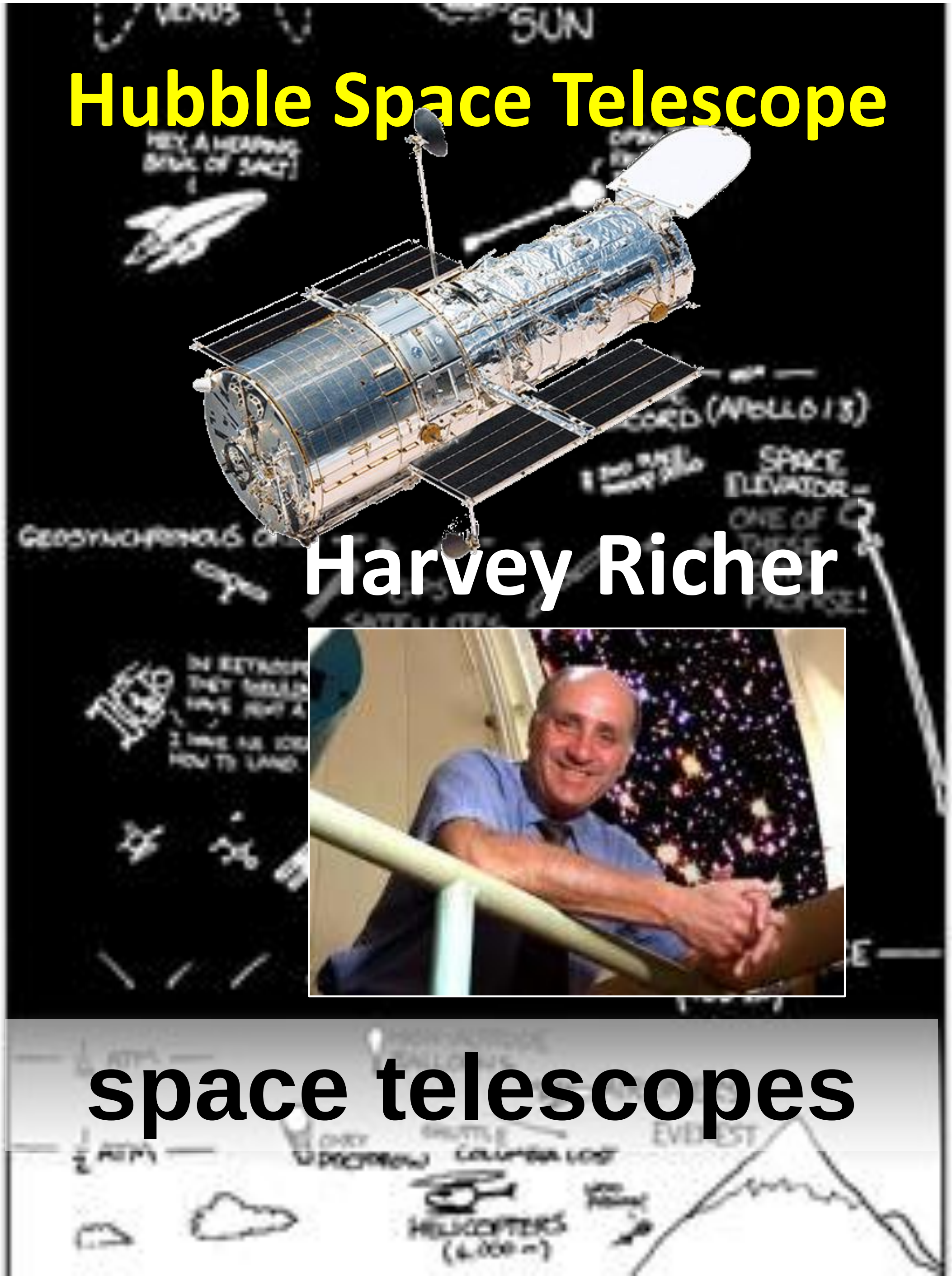


distance and size scale of the Universe
on a logarithmic scale

xkcd.com/482/



Hubble Space Telescope

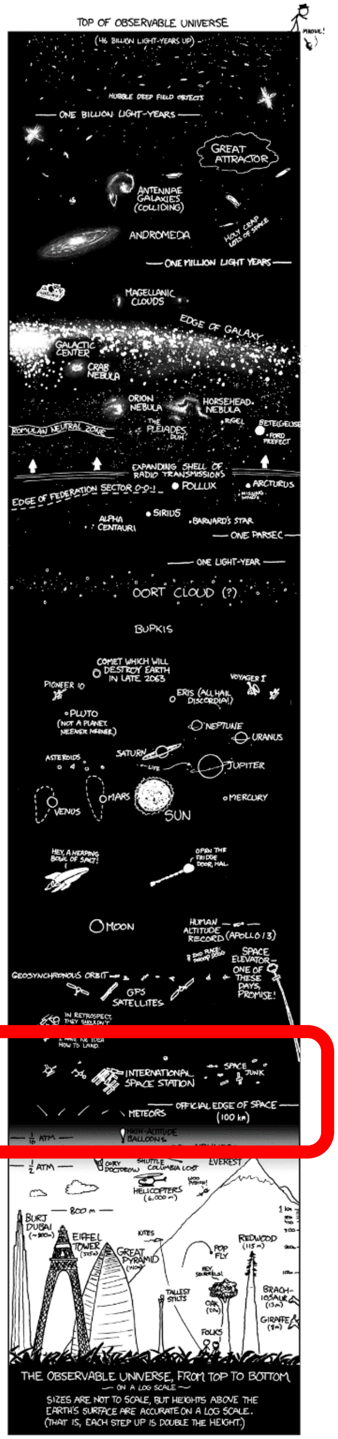


Harvey Richer

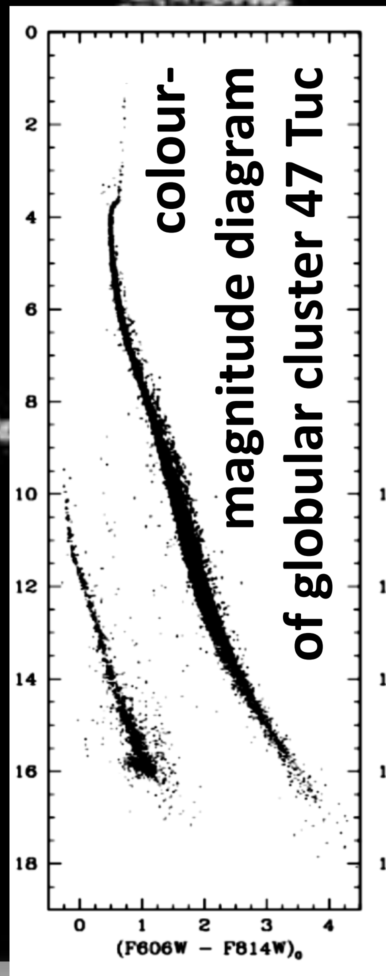
space telescopes

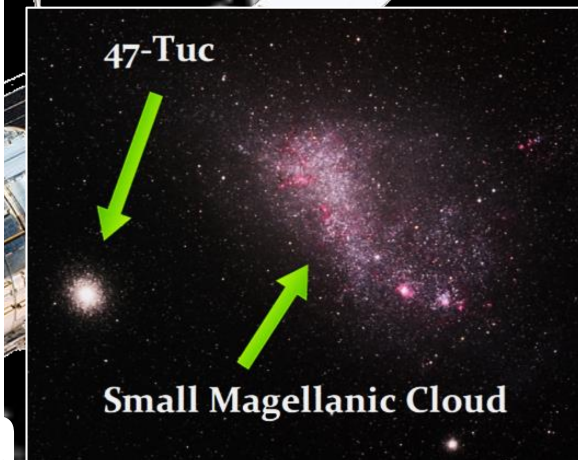
distance and size scale of the Universe
on a logarithmic scale

xkcd.com/482/



Hubble Space Telescope



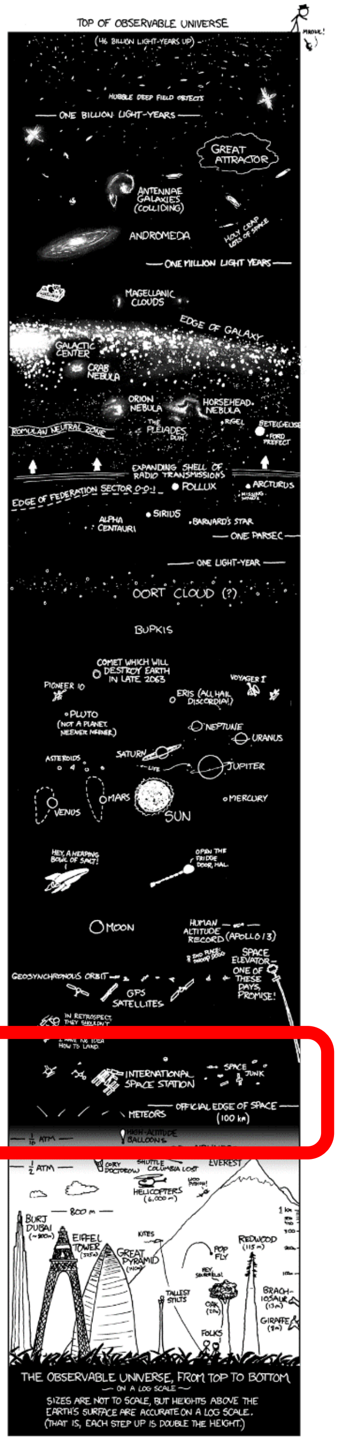


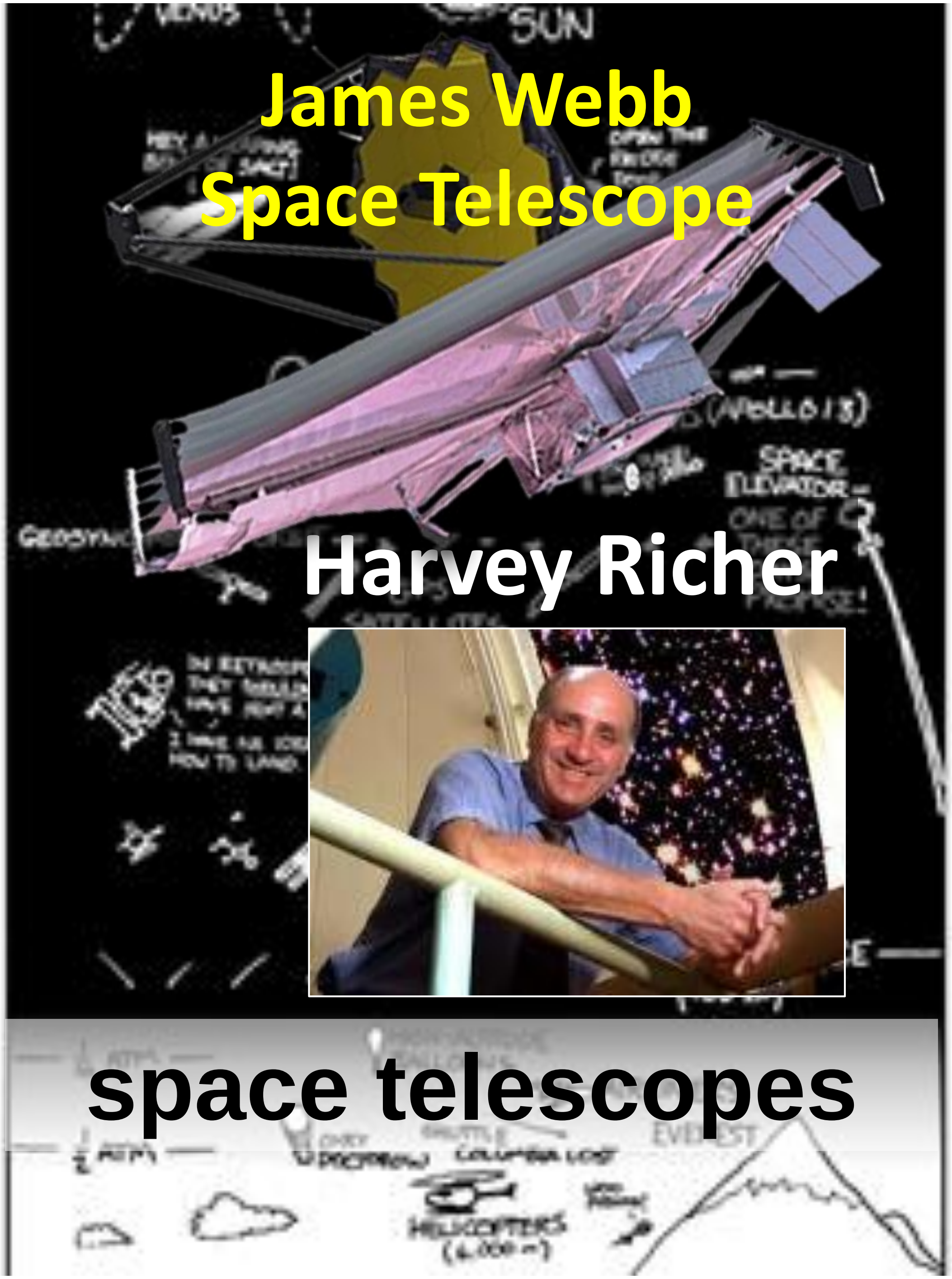
space telescopes

Some of the 'deepest' images ever made with Hubble lead to better estimates of the ages of the oldest star clusters and better knowledge of cluster formation dynamics

distance and size scale of the Universe
on a logarithmic scale

xkcd.com/482/





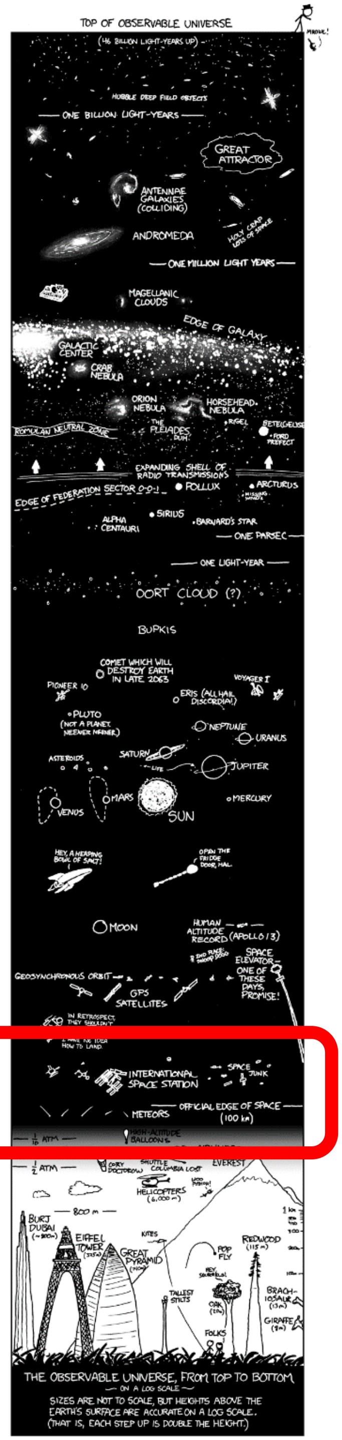
James Webb Space Telescope

Harvey Richer

space telescopes

distance and size scale of the Universe
on a logarithmic scale

xkcd.com/482/



distance and size scale of the Universe
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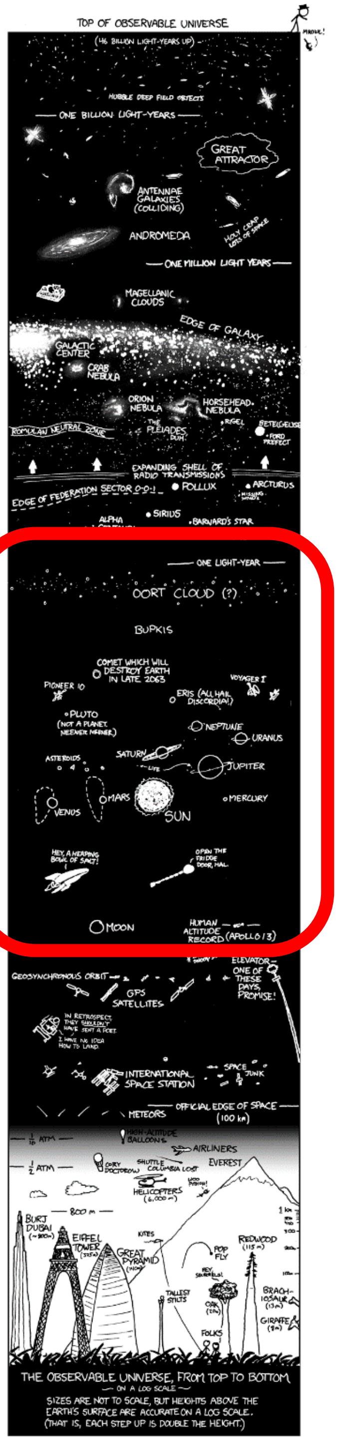
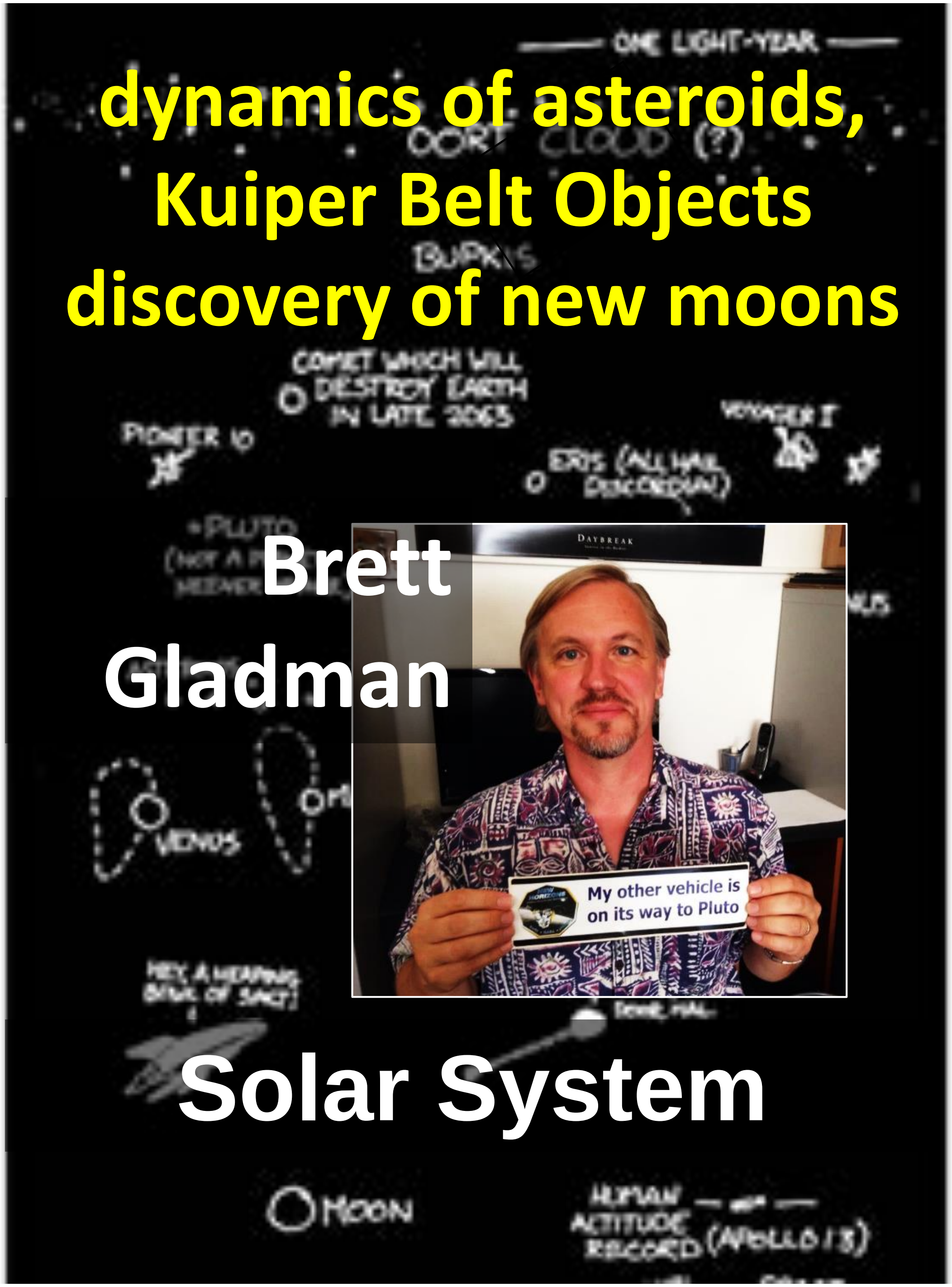




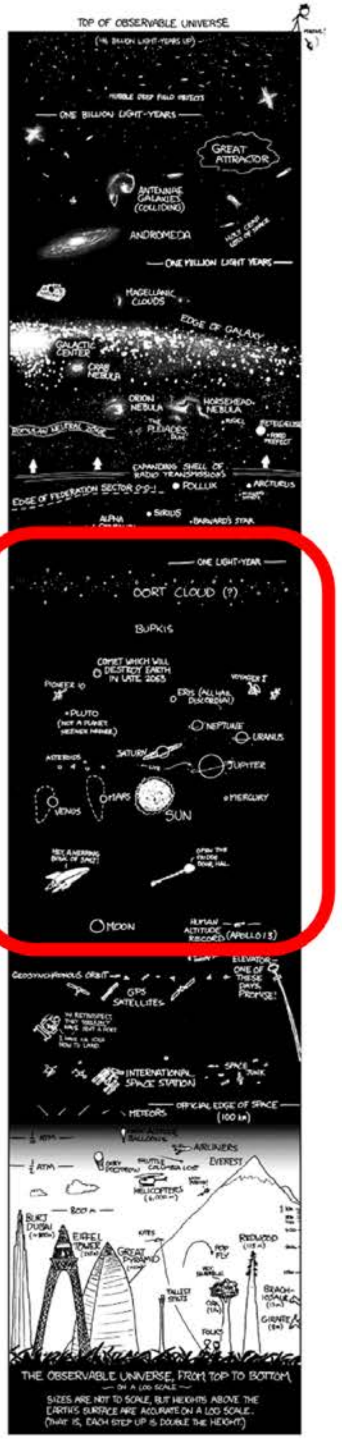
dynamics of asteroids,
Kuiper Belt Objects
discovery of new moons

Brett
Gladman

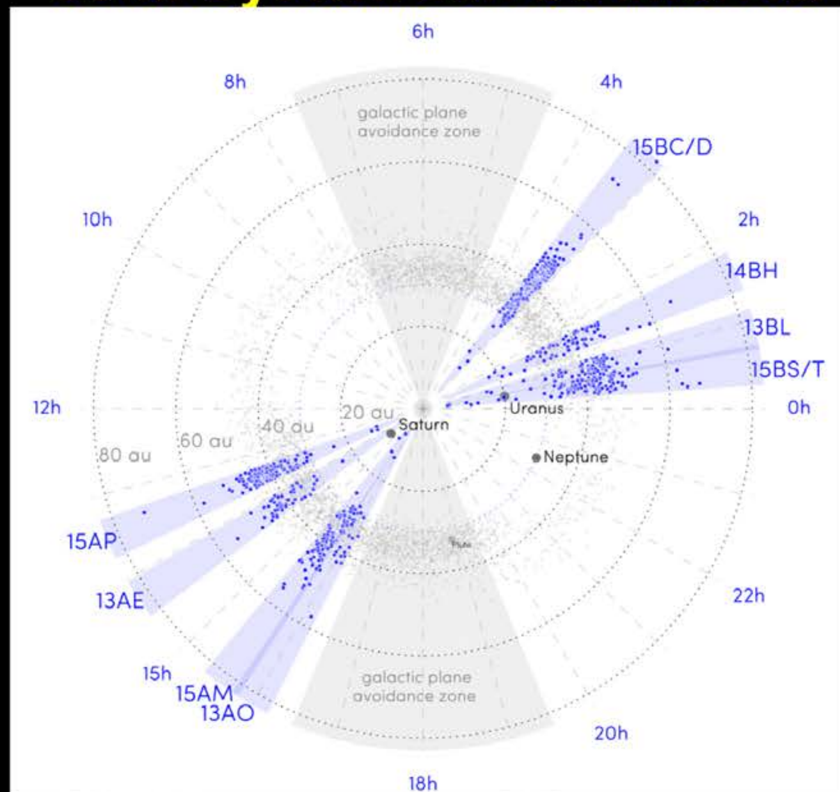
Solar System

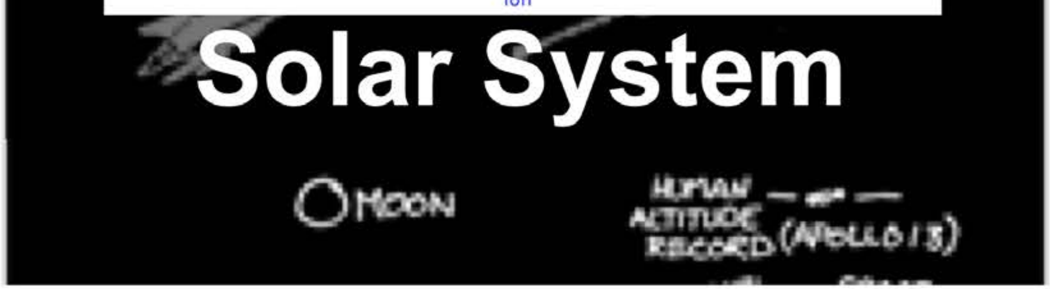
distance and size scale of the Universe on a logarithmic scale

xkcd.com/482/

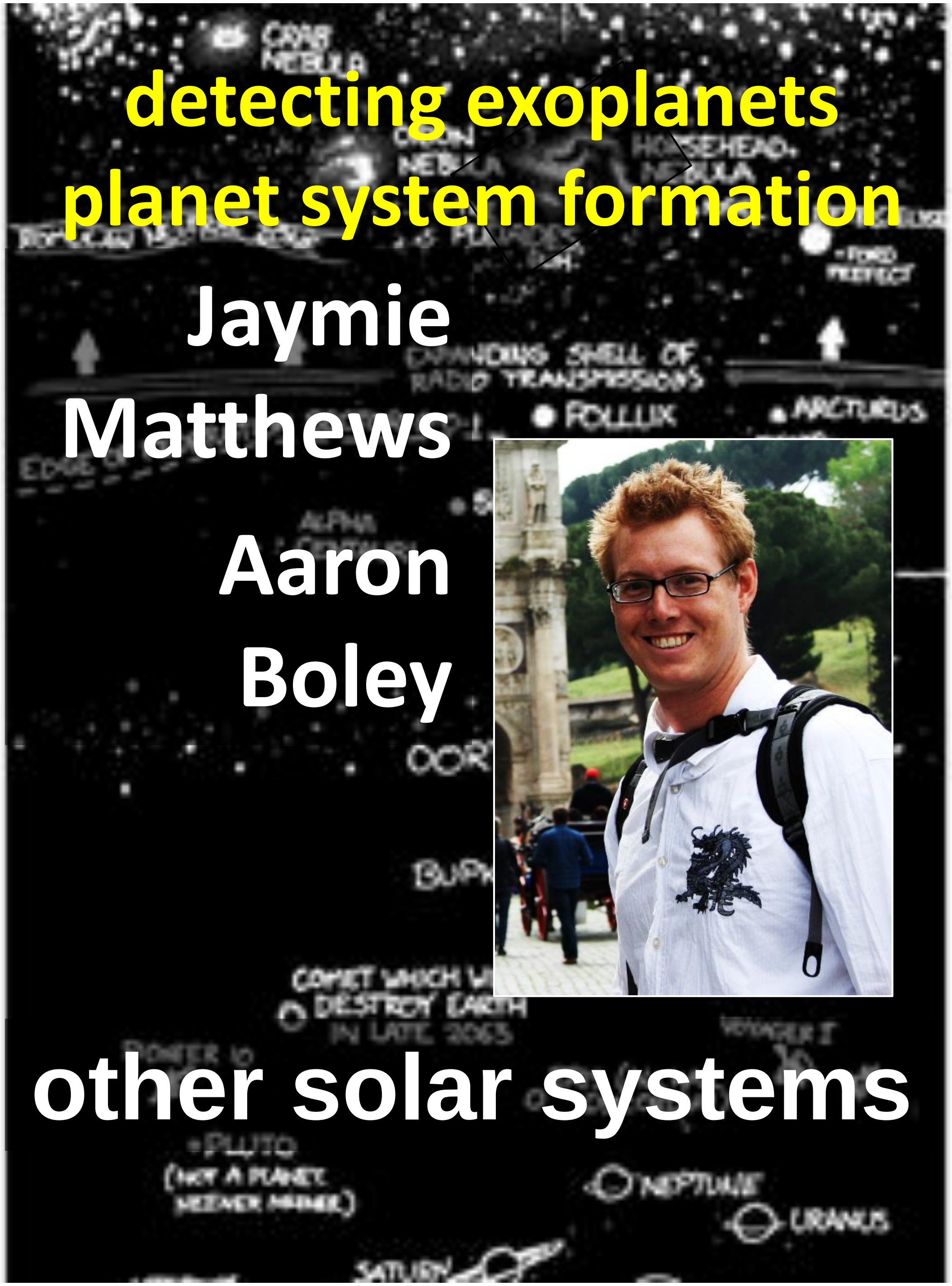


surveys of Kuiper Belt Objects provide data sets from which the dynamical history of our Solar System can be inferred





distance and size scale of the Universe
on a logarithmic scale
xkcd.com/482/



detecting exoplanets
planet system formation

Jaymie Matthews

Aaron Boley

other solar systems

Forbes Magazine's Top 30 Under 30

Michelle Kunimoto

Master's Candidate, University of British Columbia

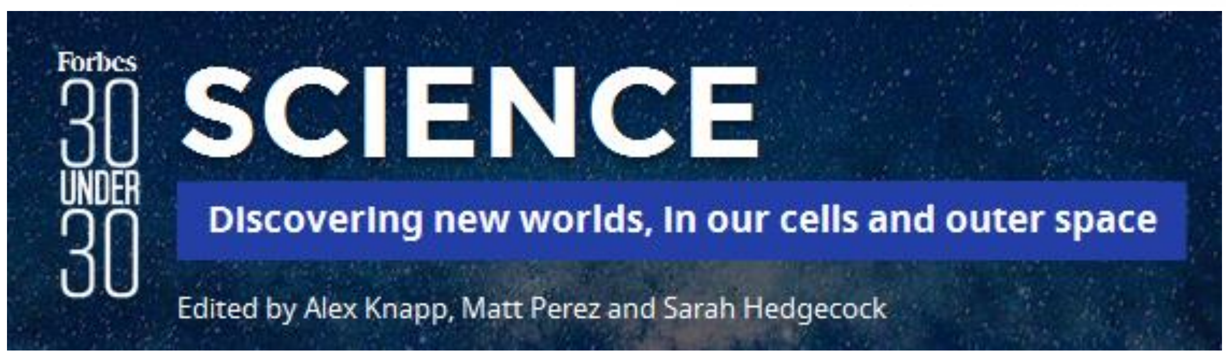
Age	**23**
Residence	**Vancouver, Canada**
Education	**Bachelor of Arts / Science, University of British Columbia**

Currently studying astronomy for her Master of Science following her undergraduate in honors physics and astronomy, Kunimoto discovered four planet candidates using Kepler data. She also tracked the data necessary for astronomers to better understand a dusty hyperluminous quasar.

Michelle Kunimoto on Forbes Lists

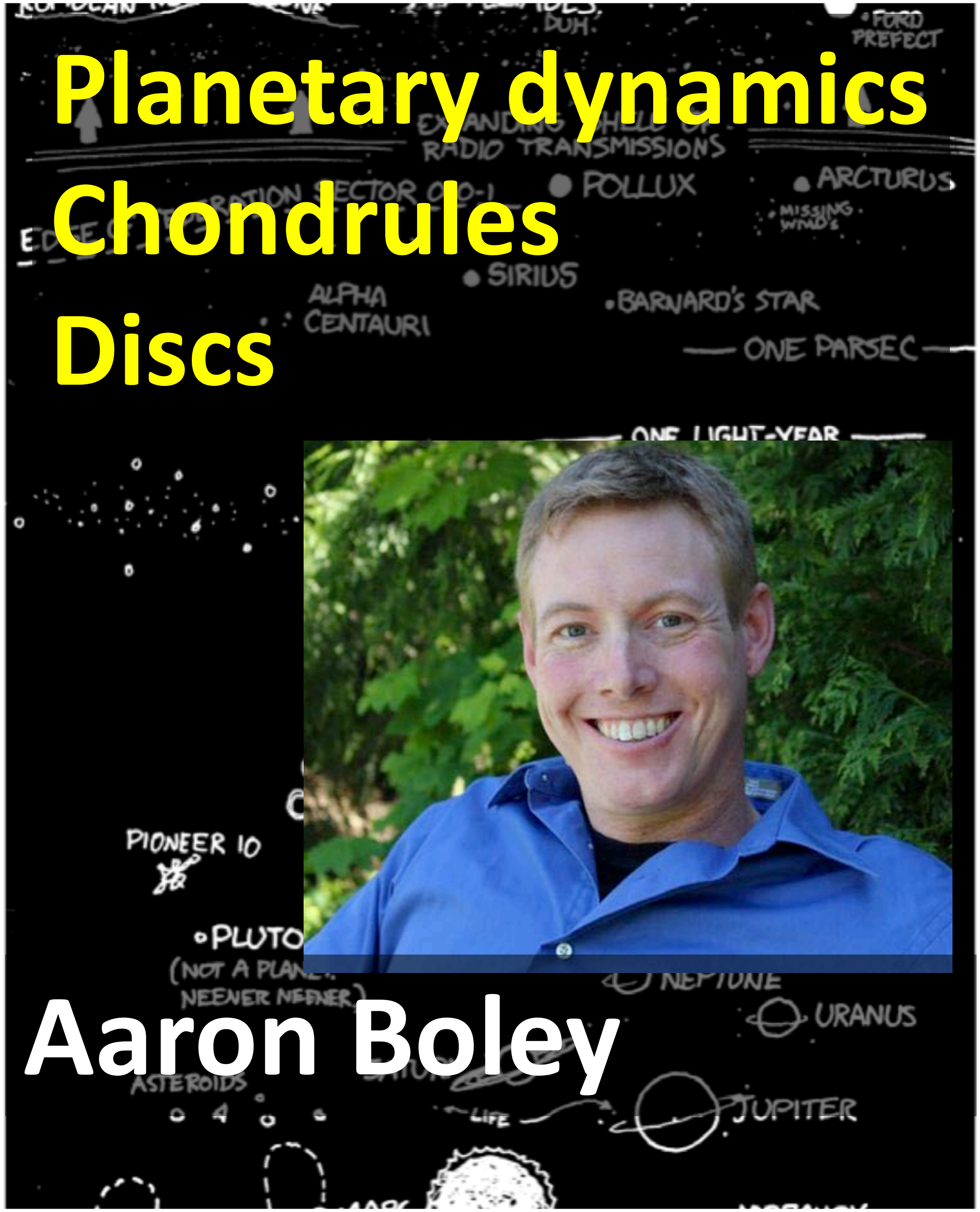
30 Under 30 - Science (2017)

www.forbes.com/30-under-30-2017/science/



distance and size scale of the Universe
on a logarithmic scale
xkcd.com/482/

Planetary dynamics
Chondrules
Discs



Aaron Boley

distance and size scale of the Universe on a logarithmic scale

xkcd.com/482/

Orbital Debris
Outer Space Treaty

Aaron Boley

space policy

distance and size scale of the Universe
on a logarithmic scale
xkcd.com/482/

asteroseismology, cluster evolution, white dwarfs

Jaymie Matthews

Harvey Richer

Jeremy Heyl

stars and clusters

distance and size scale of the Universe
on a logarithmic scale

xkcd.com/482/

radio data
on pulsars

Ingrid
Stairs

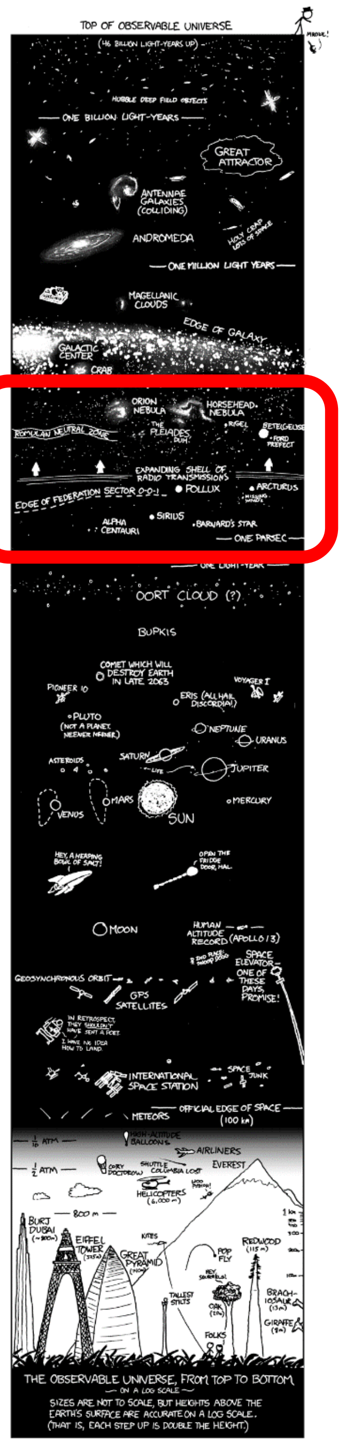
neutron star
theory

Jeremy
Heyl

stellar “corpses”

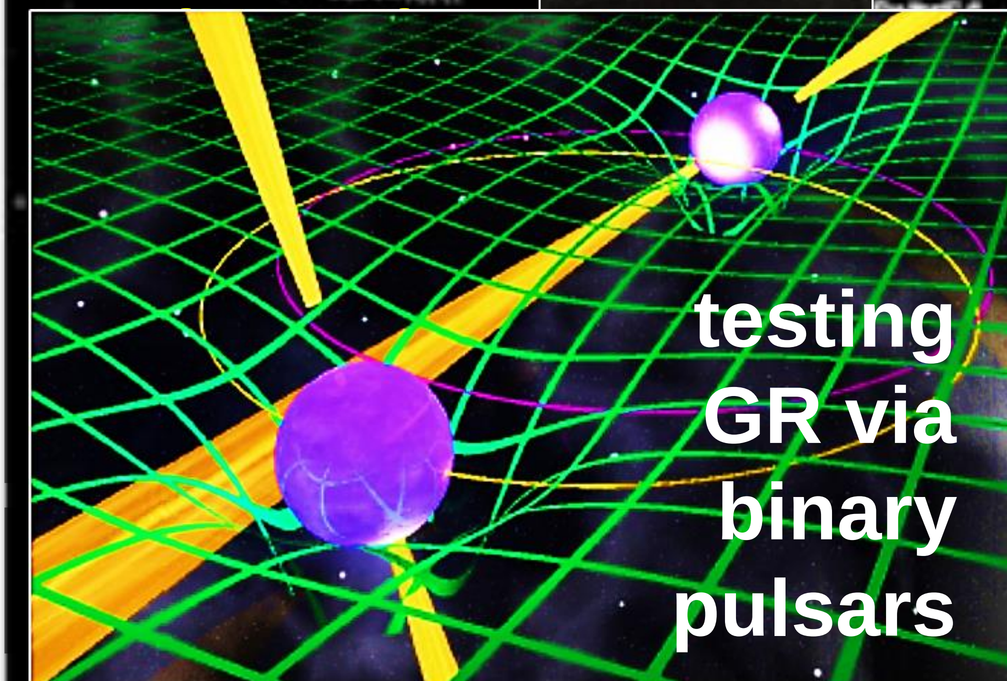
distance and size scale of the Universe
on a logarithmic scale

xkcd.com/482/



radio data on pulsars

Ingrid Stairs



testing GR via binary pulsars

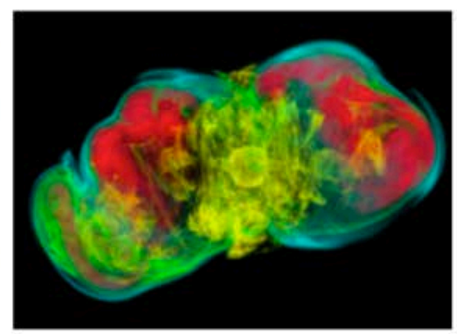
distance and size scale of the Universe
on a logarithmic scale
xkcd.com/482/

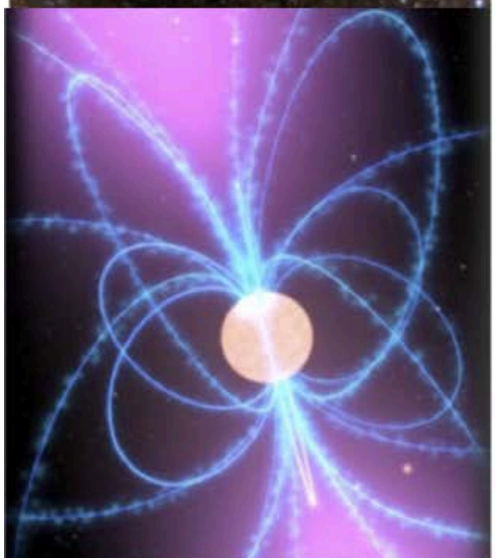
Jess McIver

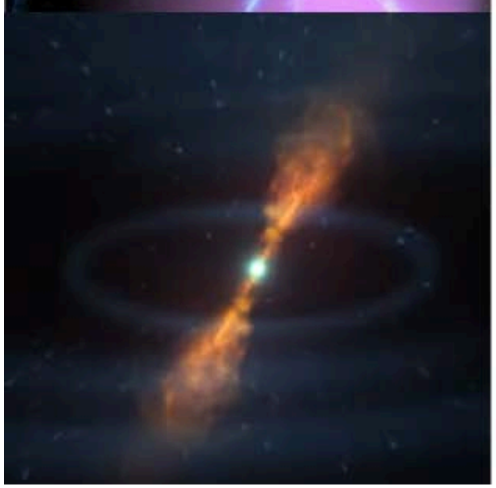
Gravitational wave astrophysics
and multi-messenger astronomy

- What's out there in the **dark stellar graveyard**?
- What can we learn about **how stars live and die** from the cosmic collisions of black holes and neutron stars?
- How fast is the **Universe expanding**?
- Why do **core-collapse supernovae** explode?
- What is the structure of **highly dense matter**?
- What mechanisms drive **energetic jets** and generate **heavy elements** in the Universe?

Learn new skills:
'big data' science,
Bayesian analysis,
machine learning







Jess McIver

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and multi-messenger astronomy

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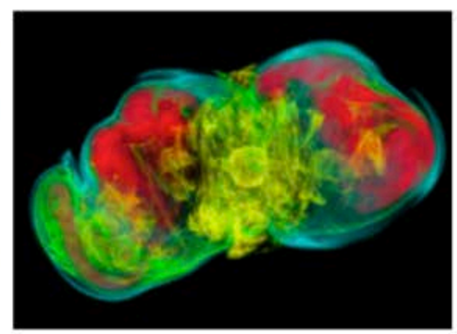
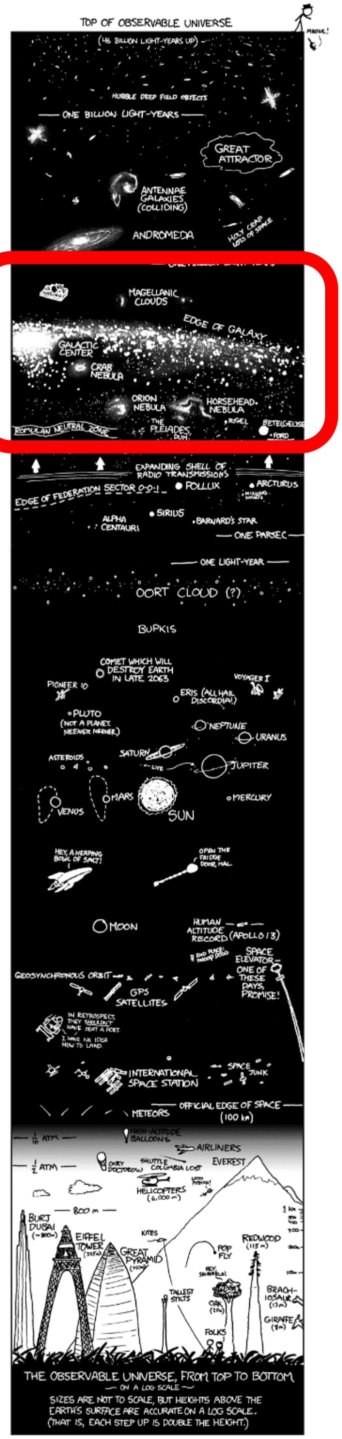


distance and size scale of the Universe
on a logarithmic scale

xkcd.com/482/



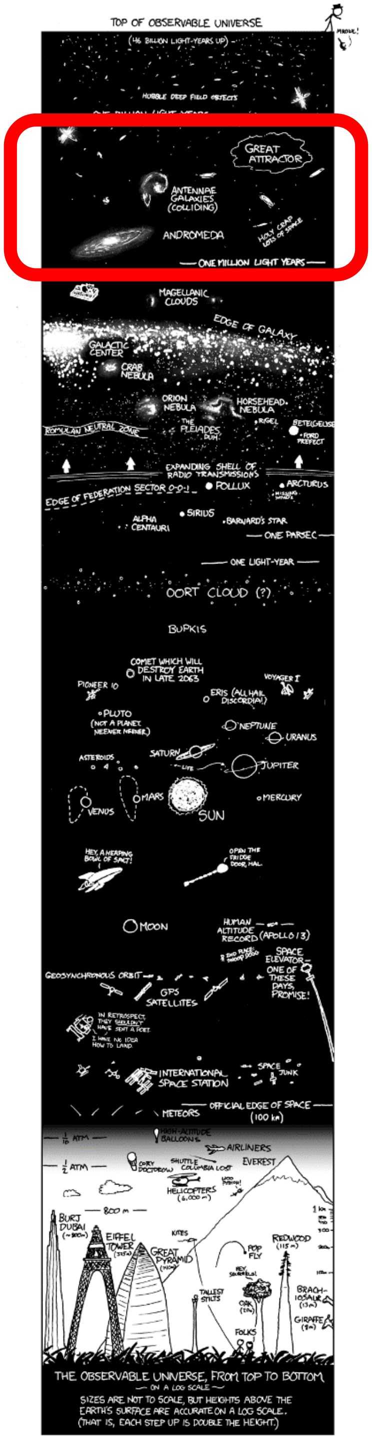
radio and sub-mm measurements

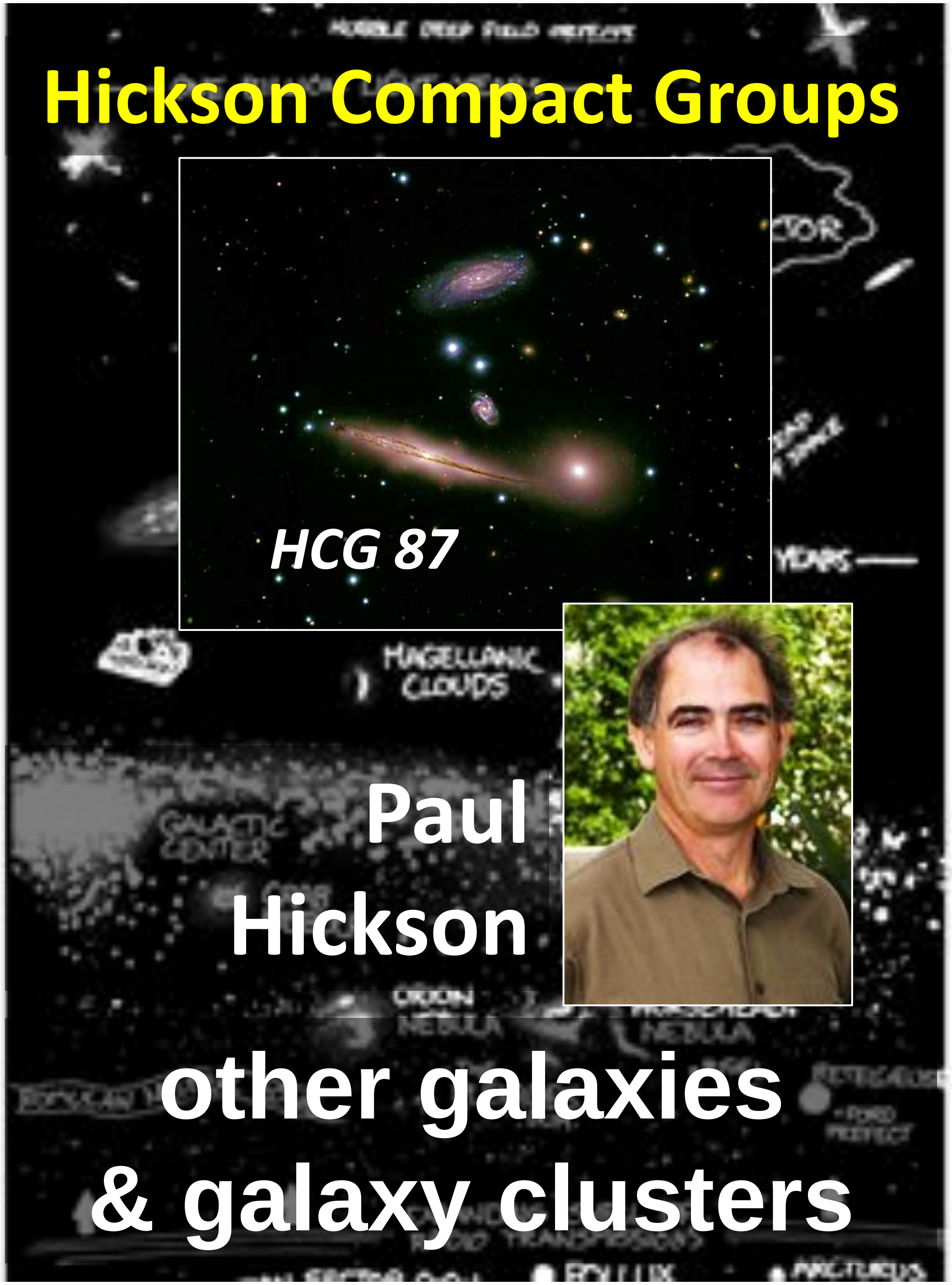
Bill McCutcheon

Milky Way Galaxy
interstellar medium

distance and size scale of the Universe
on a logarithmic scale

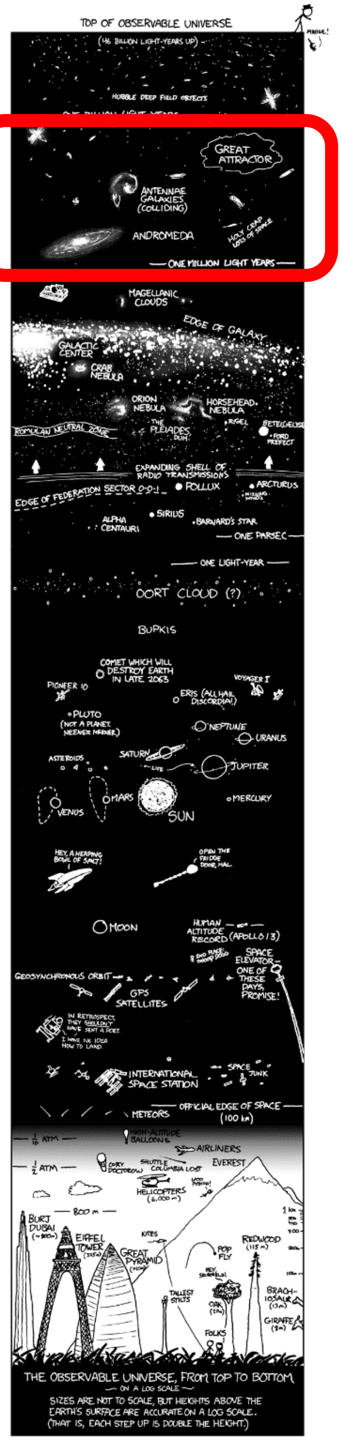
xkcd.com/482/



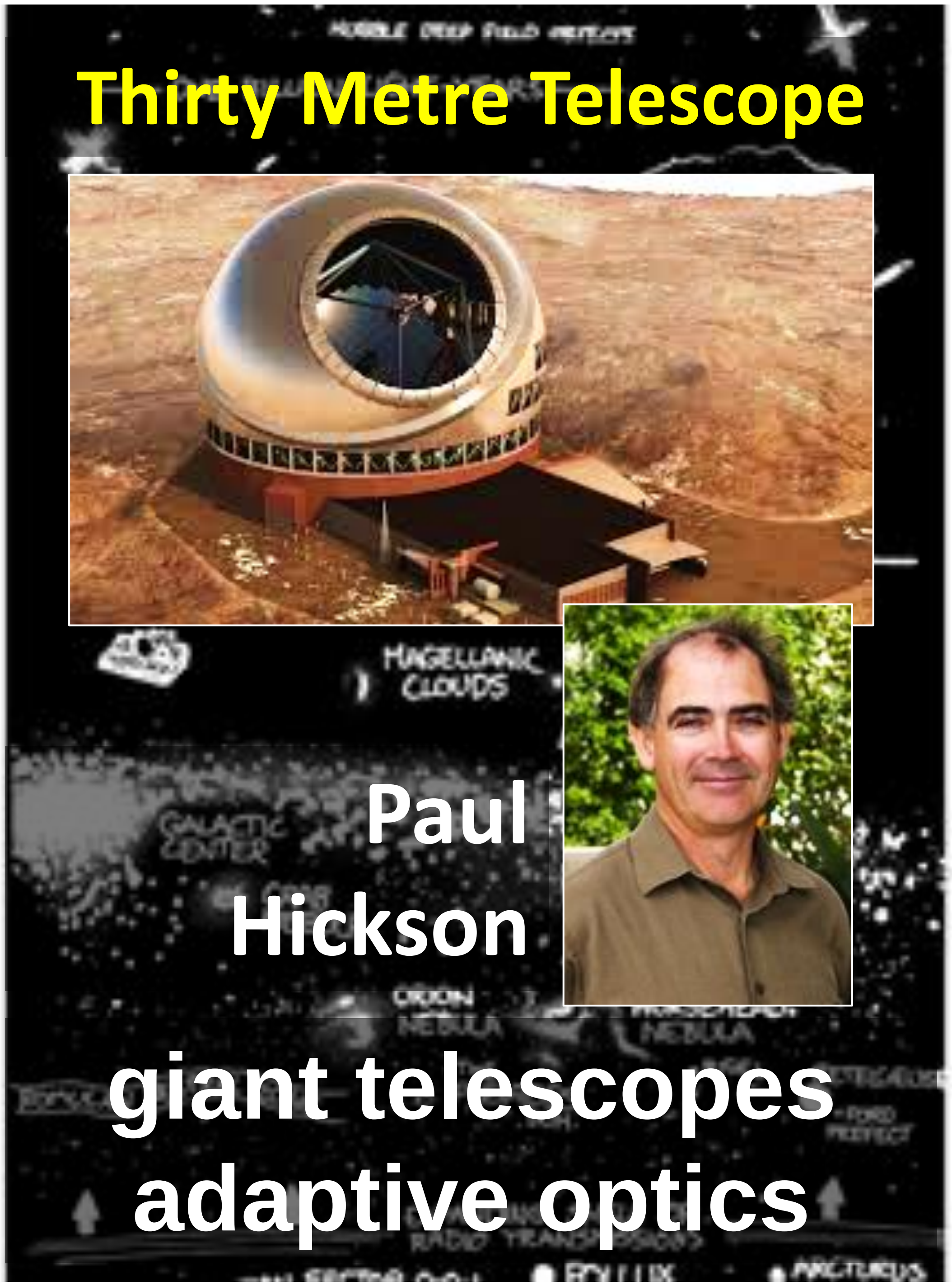


distance and size scale of the Universe
on a logarithmic scale

xkcd.com/482/



Thirty Metre Telescope

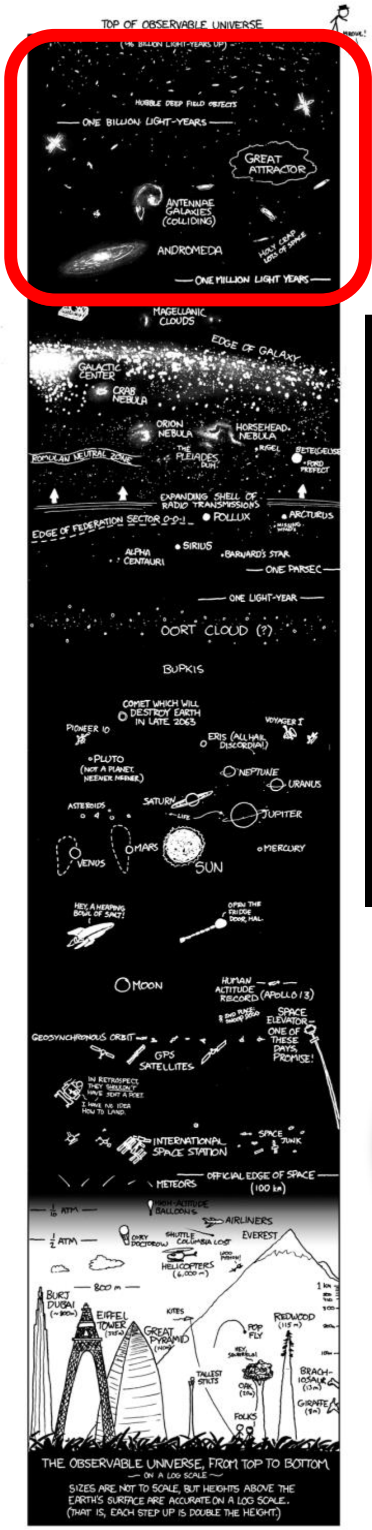


Paul Hickson

giant telescopes
adaptive optics

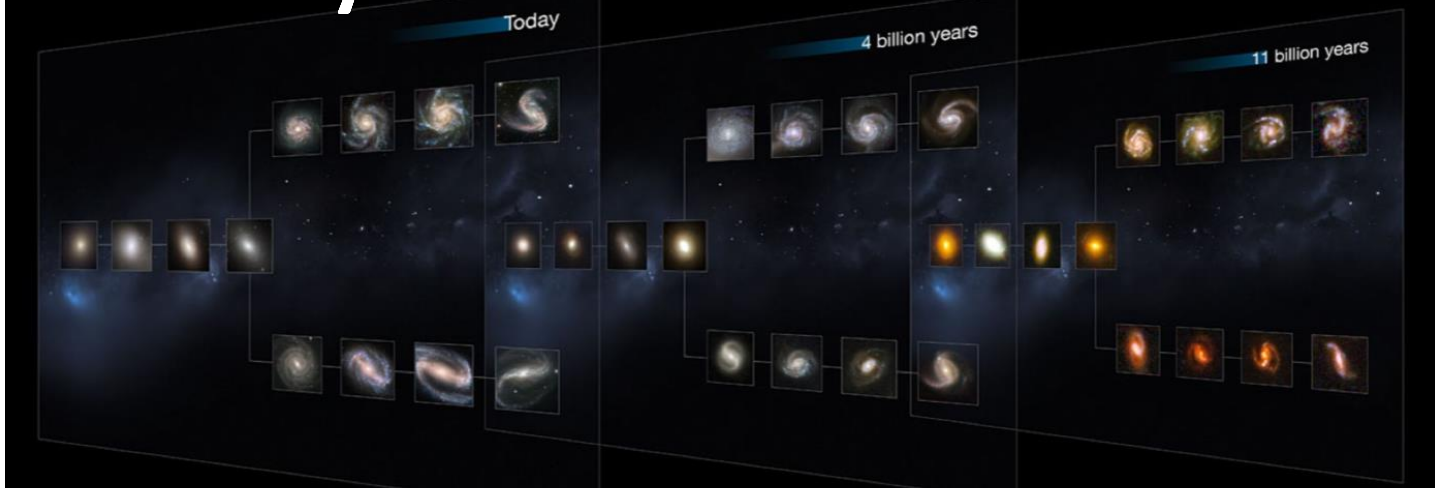
distance and size scale of the Universe on a logarithmic scale

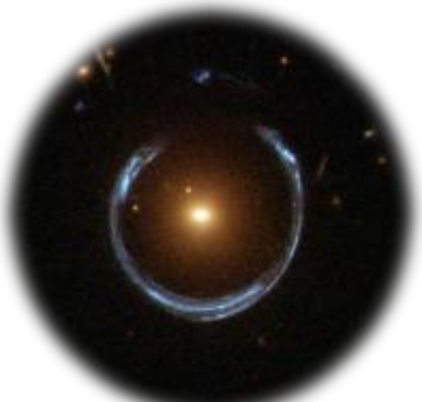
xkcd.com/482/



Allison Man

Galaxy formation & evolution





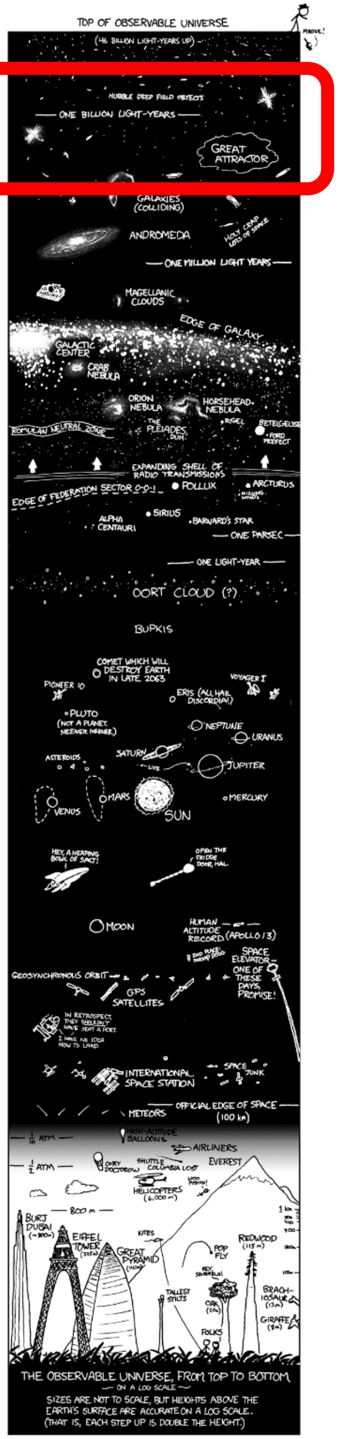
Gravitational lensing

Galaxy mergers & star formation

Active galactic nuclei feedback

distance and size scale of the Universe on a logarithmic scale

xkcd.com/482/



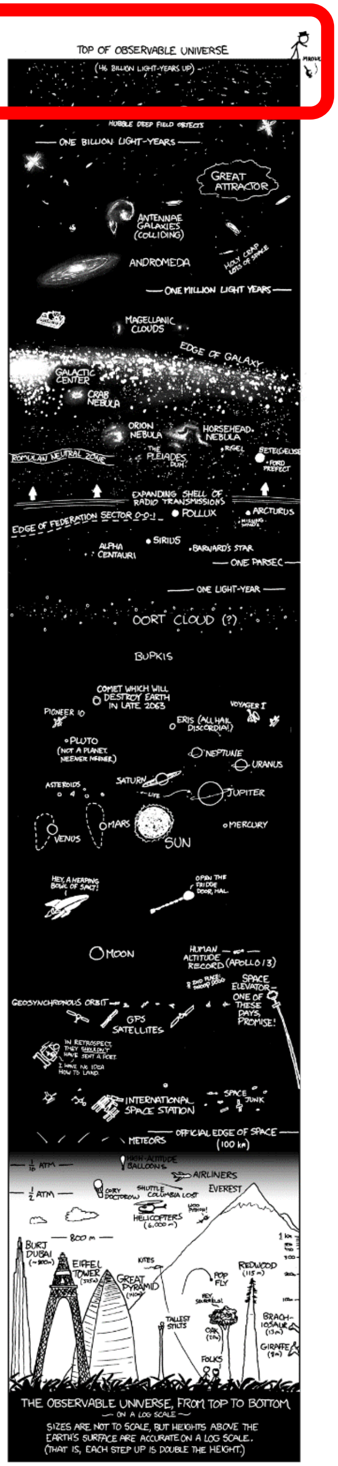
weak lensing surveys

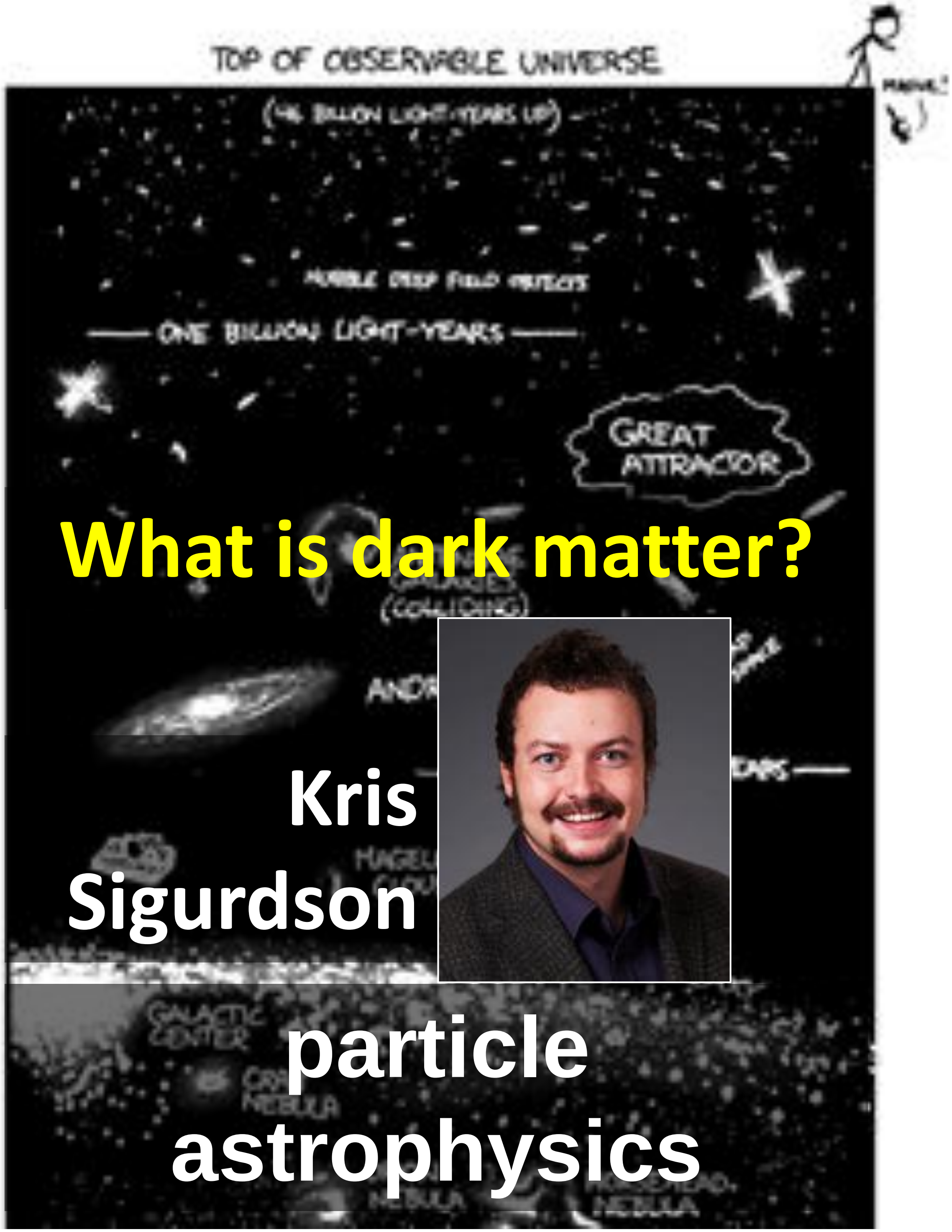
Ludo van Waerbeke

cosmology

Large Scale Structure

distance and size scale of the Universe
on a logarithmic scale
xkcd.com/482/





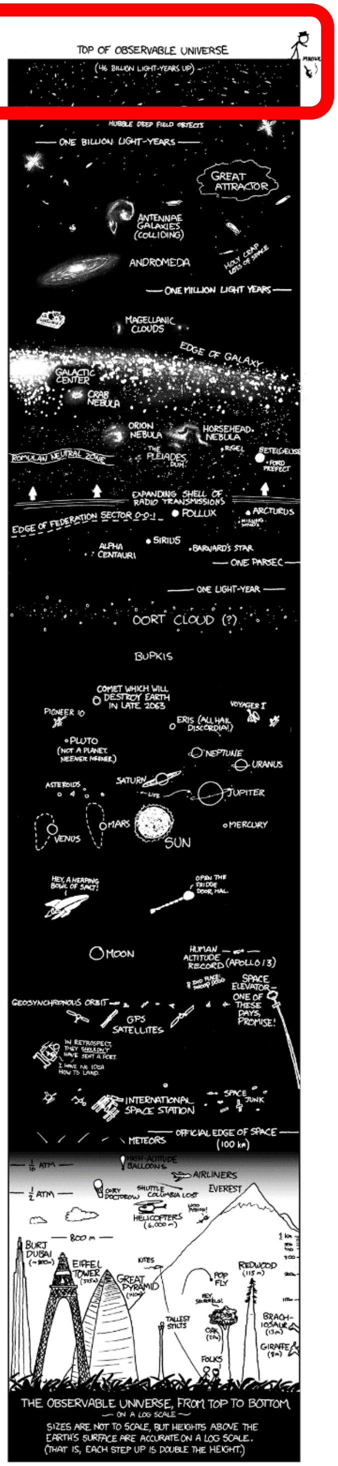
What is dark matter?

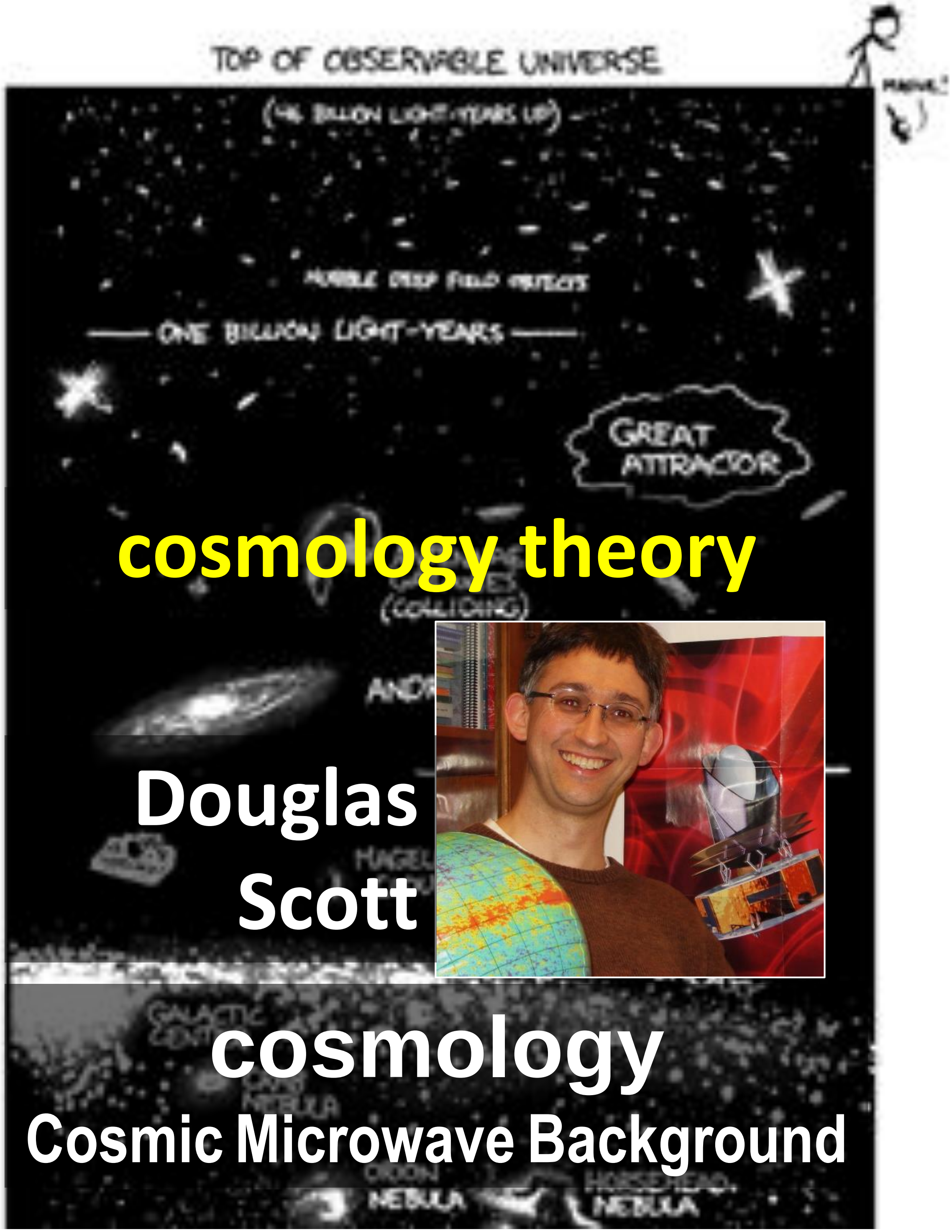
Kris Sigurdson

particle astrophysics

distance and size scale of the Universe on a logarithmic scale

xkcd.com/482/





cosmology theory

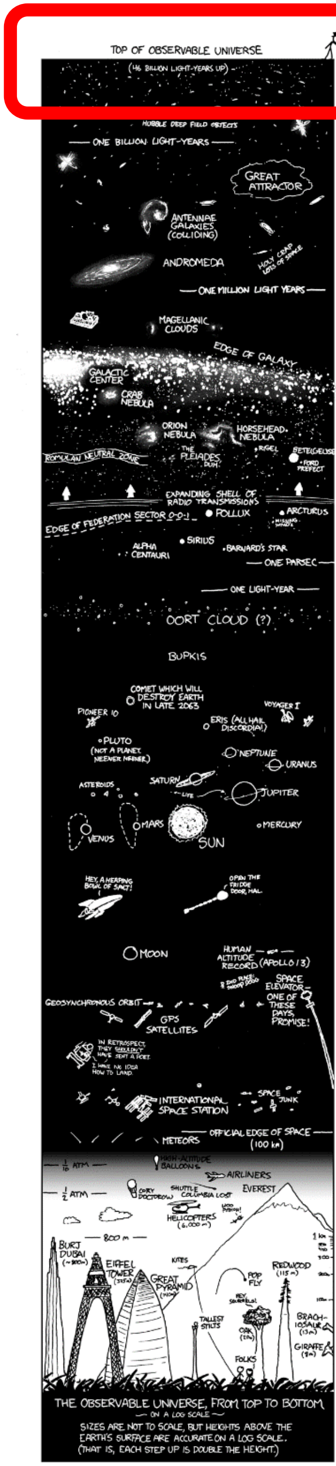
Douglas Scott

cosmology

Cosmic Microwave Background

distance and size scale of the Universe
on a logarithmic scale

xkcd.com/482/



Gary Hinshaw

instruments & data

Mark Halpern

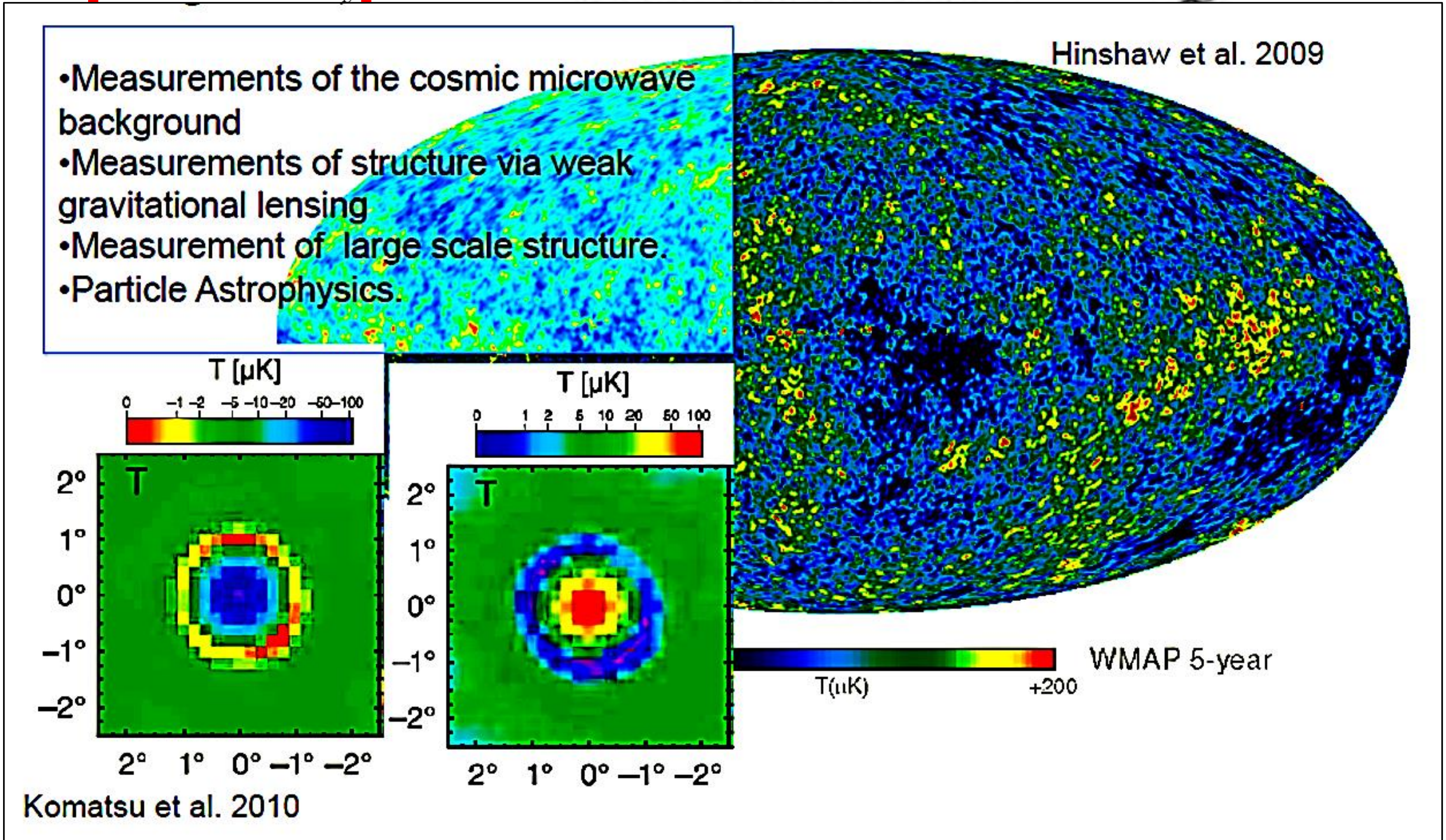
cosmology

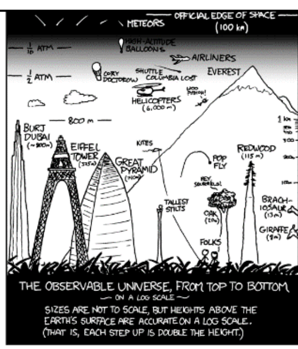
Cosmic Microwave Background

distance and size scale of the Universe

xkcd.com/

- Measurements of the cosmic microwave background
- Measurements of structure via weak gravitational lensing
- Measurement of large scale structure.
- Particle Astrophysics.

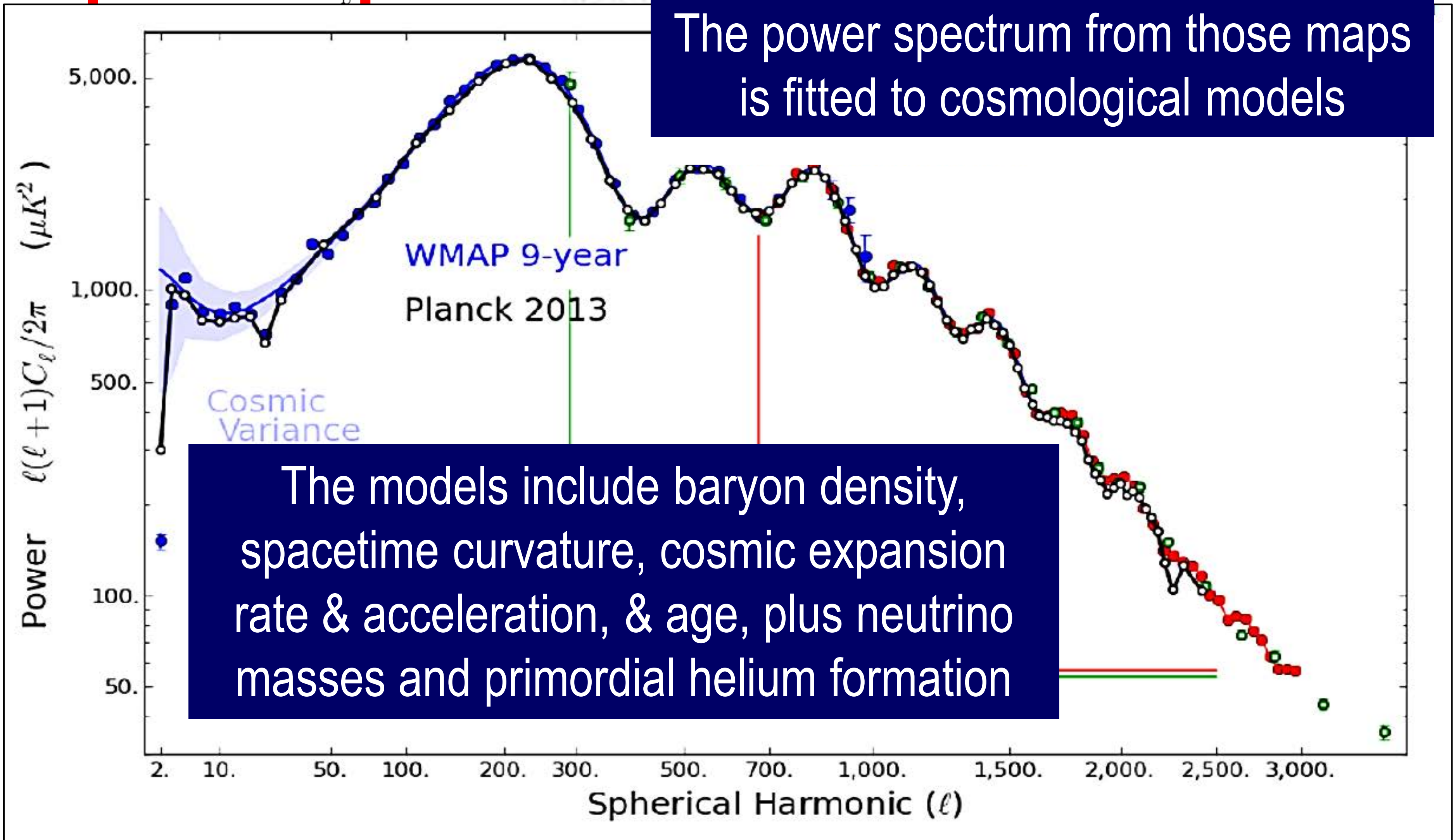




cosmology

Cosmic Microwave Background

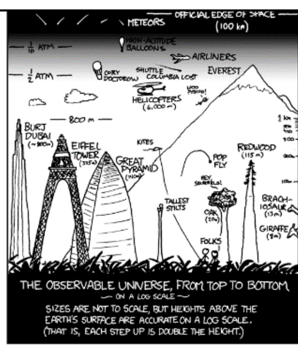
The power spectrum from those maps is fitted to cosmological models



The models include baryon density, spacetime curvature, cosmic expansion rate & acceleration, & age, plus neutrino masses and primordial helium formation

distance and size scale of the Universe

xkcd.com/

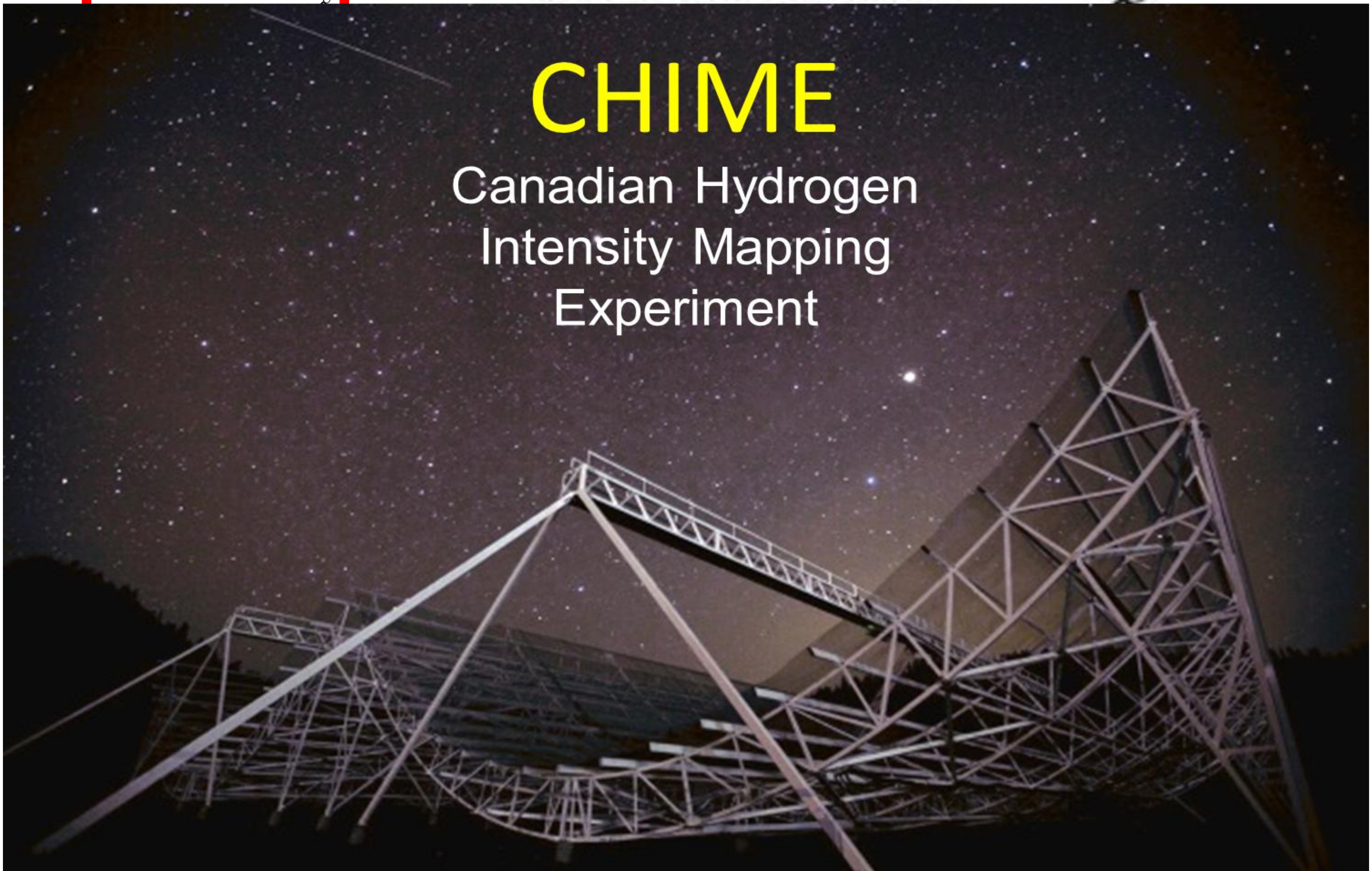


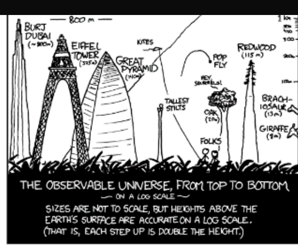
cosmology

Cosmic Microwave Background

distance and size scale of the Universe

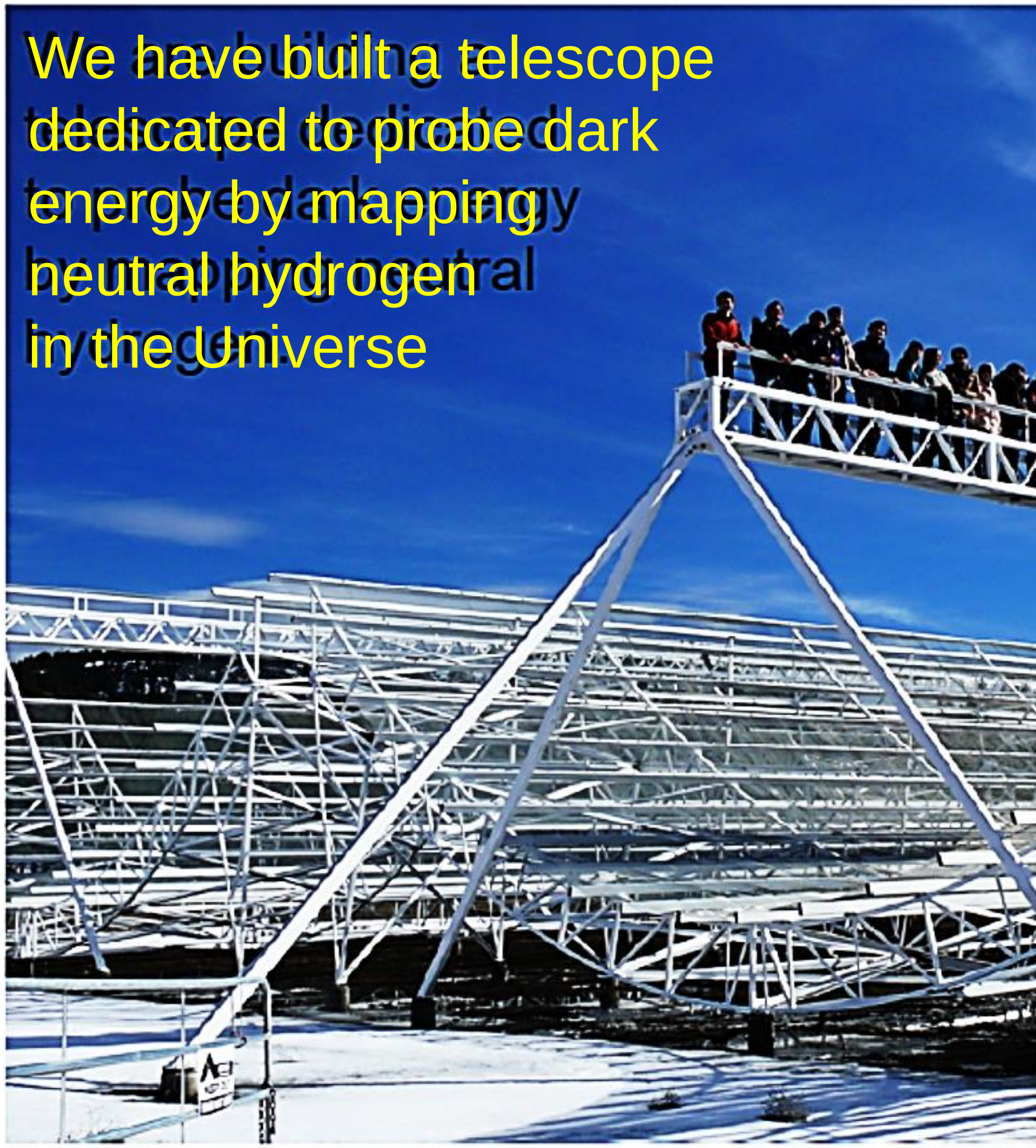
xkcd.c

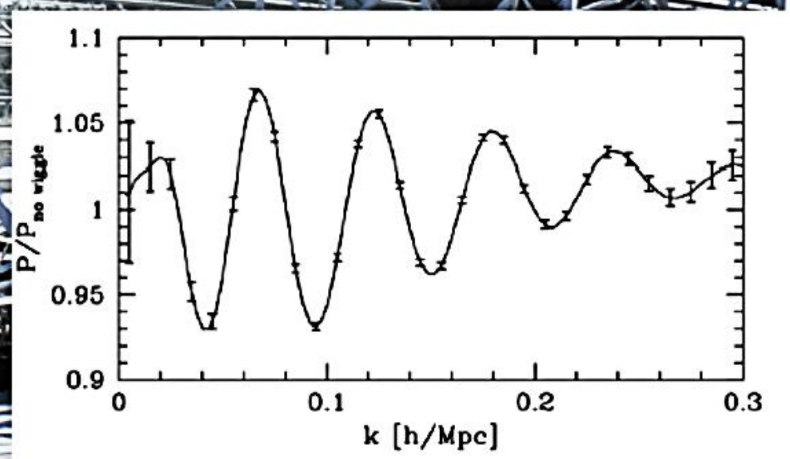


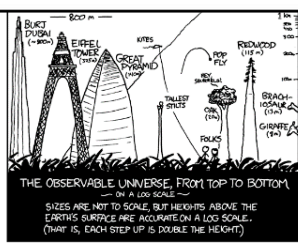


distance and size scale of the Universe

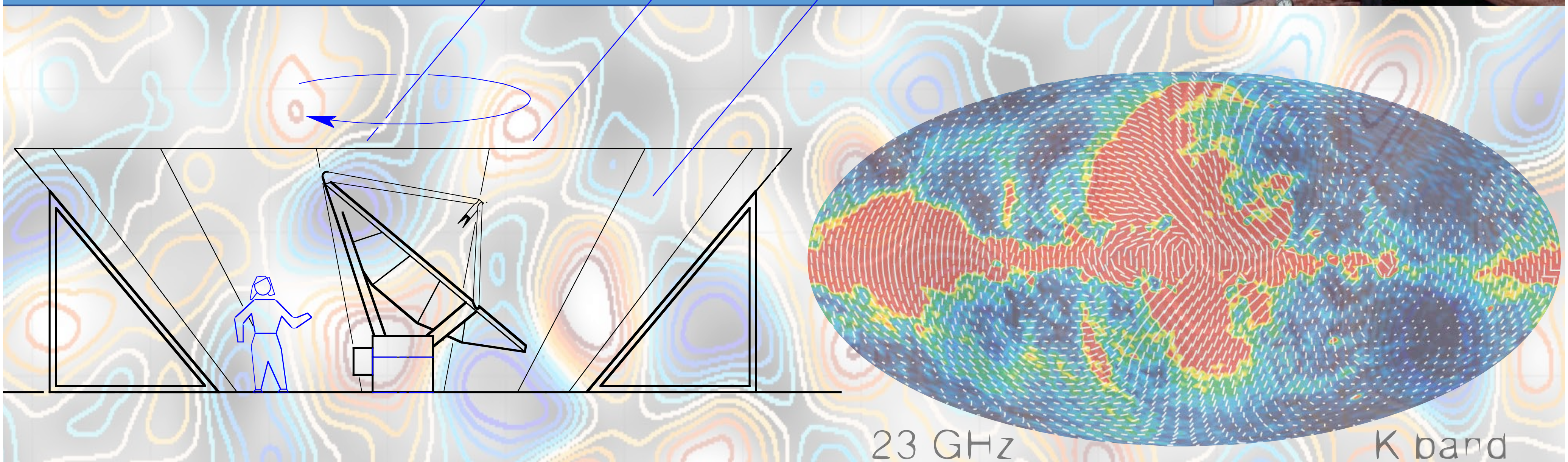
xkcd.c







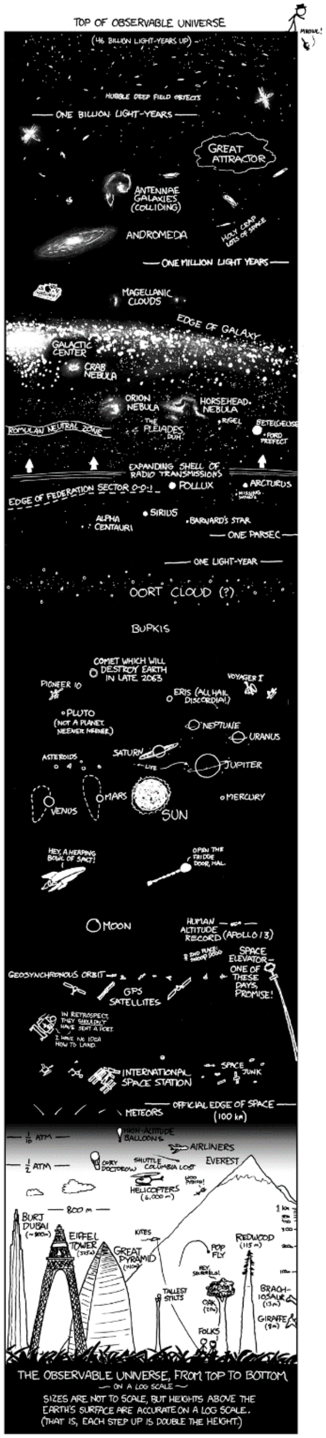
The Canadian Galactic Emission Mapper (CGEM)



The **Canadian Galactic Emission Mapper** is a new telescope we are building at the DRAO to map polarized emission of the entire Northern sky at 10 GHz. These data on galactic foregrounds are an important part of the effort to find primordial gravitational radiation from inflation, lurking in the background CMB polarization.

distance and size scale of the Universe
on a logarithmic scale

xkcd.com/482/



CMB (Cosmic Microwave Background)

Other galaxies   Large Scale Structure

Local Group of Galaxies

Milky Way

Star clusters and star/planet formation

Stars   Exoplanets

Trans-Neptunian Objects

Planets, dwarf planets, moons, asteroids

Sun

Moon

space telescopes

high-altitude balloons

surface of Earth   Largest telescopes

distance and size scale of the Universe
on a logarithmic scale

xkcd.com/482/

Scott, Halpern, Hinshaw
Sigurdson

Hickson

van Waerbeke   Man

McCutcheon   McIver

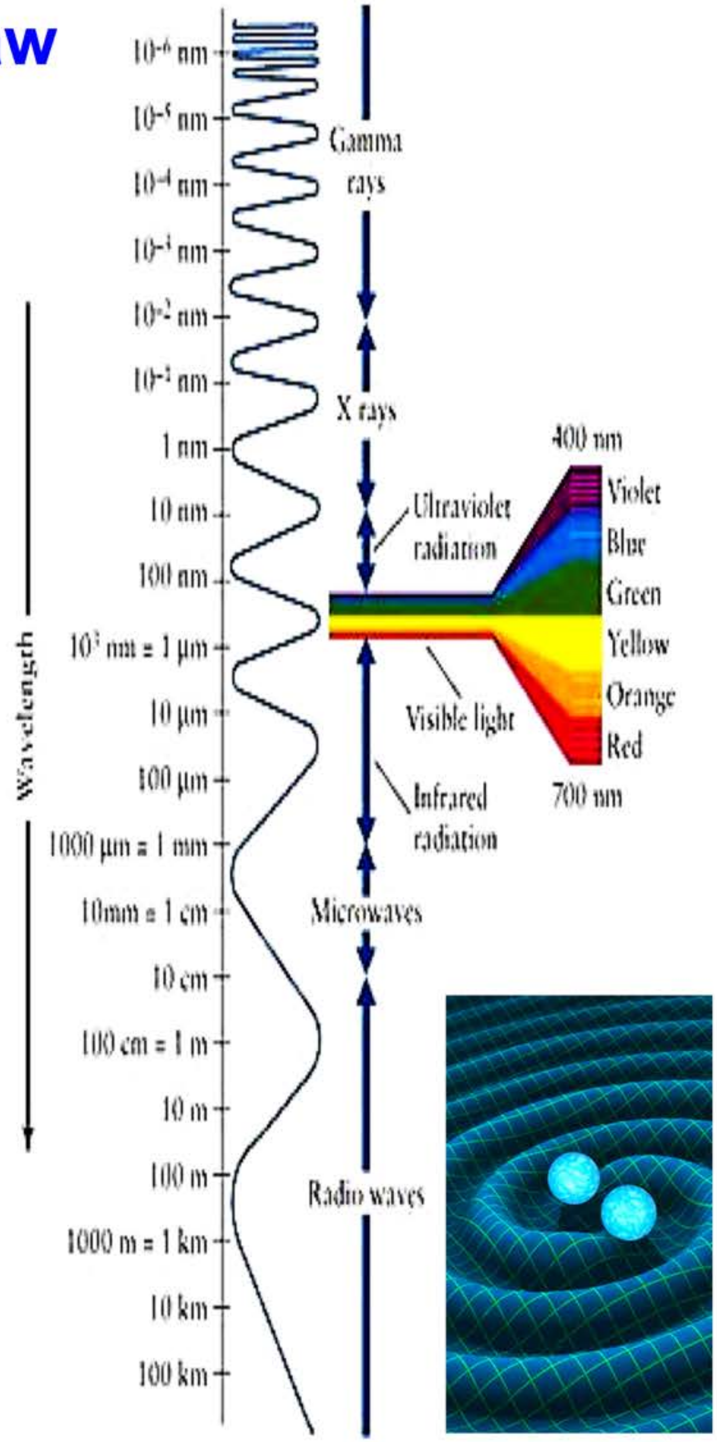
Richer, Heyl, Stairs

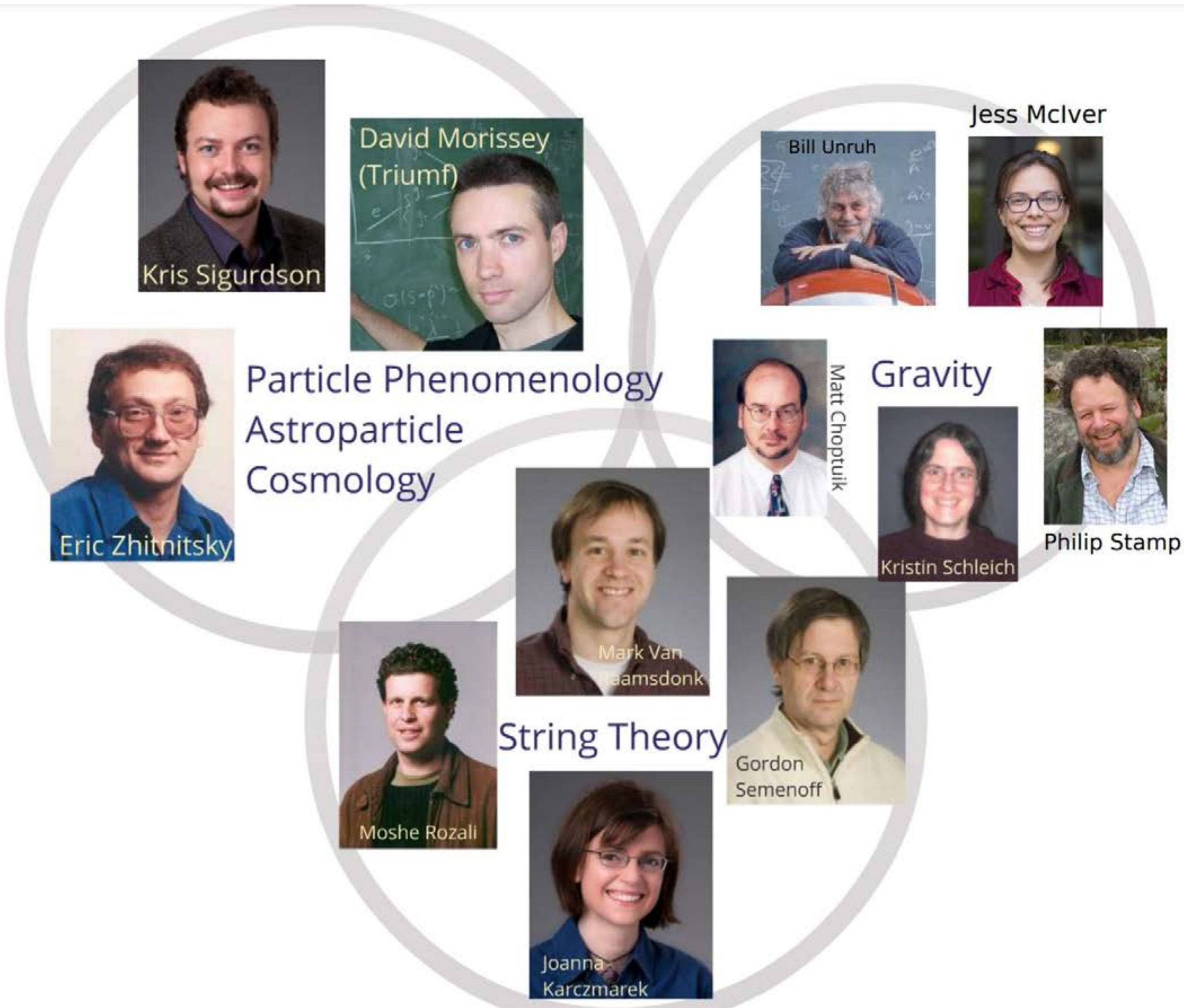
Boley, Matthews

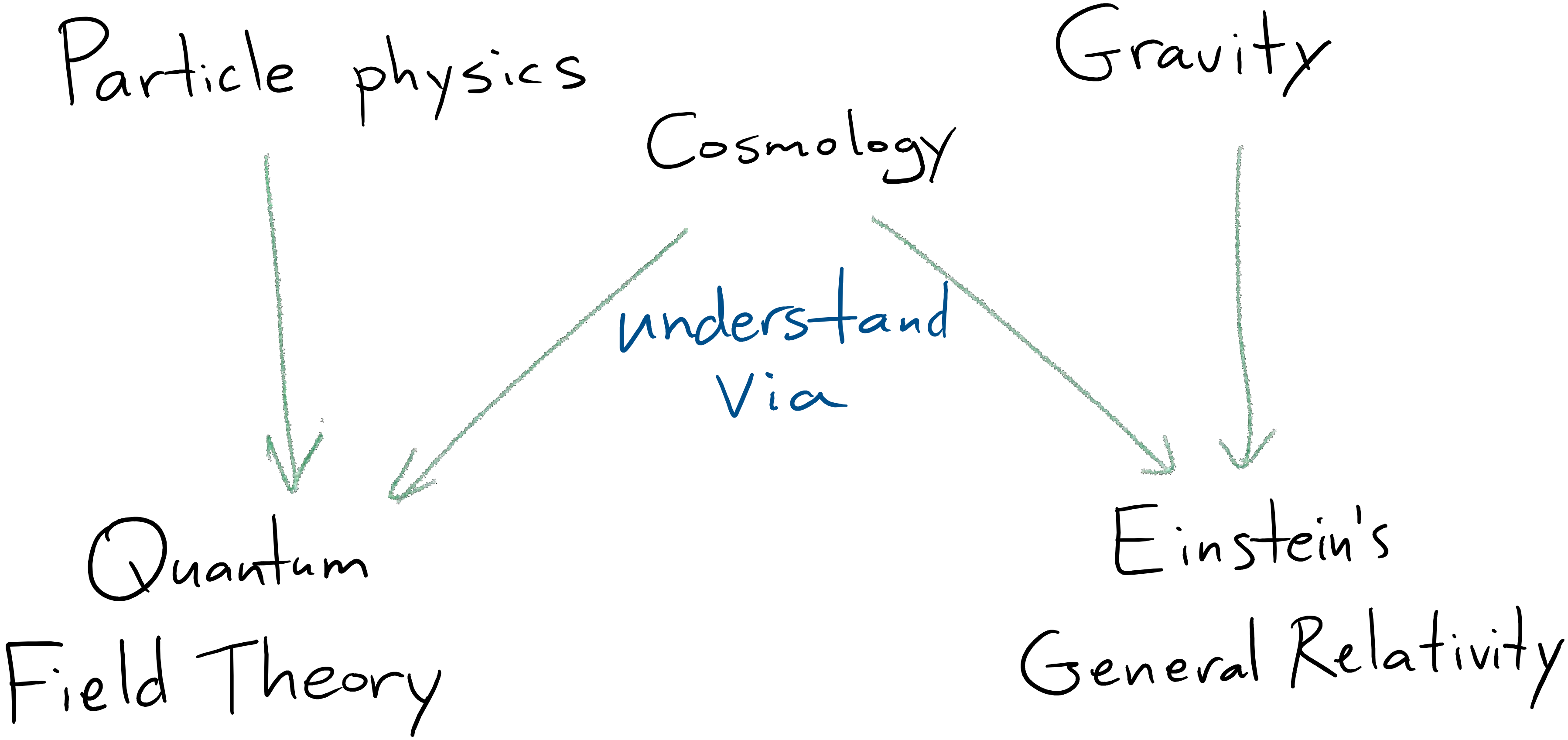
Gladman

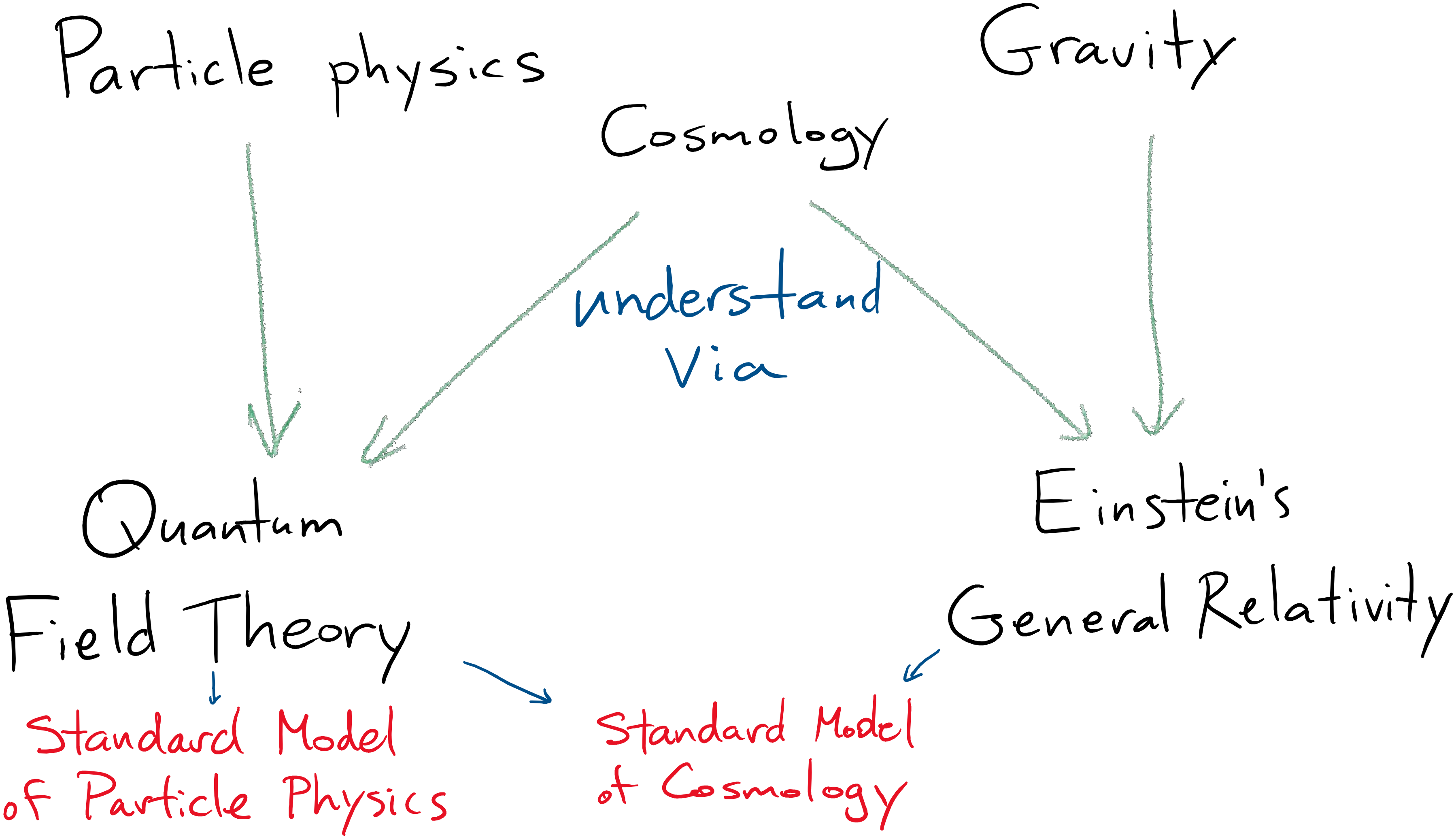
Richer, Scott
Matthews

Hickson
Halpern, Hinshaw




Kris Sigurdson
David Morissey
(Triumf)
Eric Zhitnitsky
Particle Phenomenology
Astroparticle
Cosmology
Bill Unruh
Jess McIver
Matt Choptuik
Gravity
Philip Stamp
Kristin Schleich
Mark Van
Raamsdonk
String Theory
Gordon
Semenoff
Moshe Rozali
Joanna
Karczmarek


Particle physics
Cosmology
Gravity
understand
via
Quantum
Field Theory
Einstein's
General Relativity


Particle physics
Cosmology
Gravity
understand Via
Quantum Field Theory
Einstein's General Relativity
Standard Model of Particle Physics
Standard Model of Cosmology

Particle physics

Cosmology

Gravity

understand via

Quantum Field Theory

Einstein's General Relativity

Standard Model of Particle Physics

Standard Model of Cosmology

Extremely successful, accurately predict/explain experiments e.g.

LHC

Planck

LIGO

Still many open questions:

What is dark matter?

What is dark energy?

Is there new physics beyond the standard model?

Why is there more matter than antimatter?

What is the origin of the CMB?

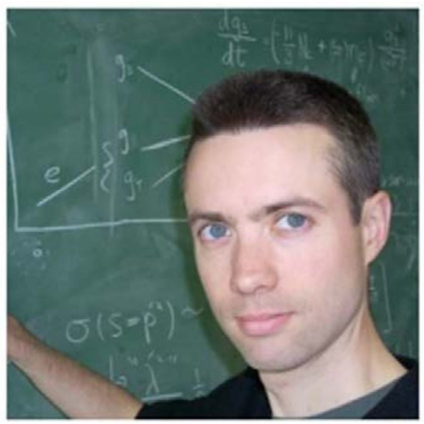
Kris Sigurdson

My theoretical research interests span **cosmology and its connections to fundamental particle physics and string theory**.

What physics do we need to explain **Dark Matter? Dark Energy? Inflation?**

David Morissey

Elementary Particle Physics



- **New particles and interactions** (e.g. supersymmetry, extra dimensions, strong forces)
- Interpretation and explanation of **LHC data**
- Candidates for **dark matter**
- Origin of the **matter-antimatter asymmetry**
- Ways to test this stuff **experimentally**

What is the physics of the strong force in extreme situations?

QCD

quark-gluon plasma
(e.g. heavy ion collisions at RHIC
early universe)

relevant to dark matter?

Eric Zhitnitsky

I work on **Quantum Chromodynamics (QCD)** in the unusual environment when **temperature, chemical potential**, the so-called **theta parameter are non-zero**. Such a study is important in the area where the **particle physics / nuclear physics / astrophysics / cosmology** are overlapped.

What is the physics of black holes?

origin, distribution

black hole merger physics

Jess McIver

Gravitational wave experiment with LIGO

- **Large-scale instrumentation**: improving the performance of the Advanced LIGO detectors
- **Noise characterization** and modelling
- Use GWs to explore **new tests of general relativity,** cosmology, and astrophysics

Part of team UBC at LIGO-Livingston

Jess

Matt Choptuik

Numerical relativity at UBC:
see **http://laplace.phas.ubc.ca** for more info.

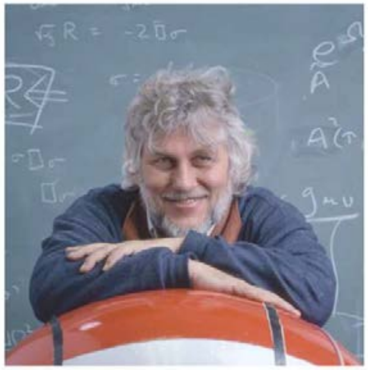
Theoretical aspects of gravity:

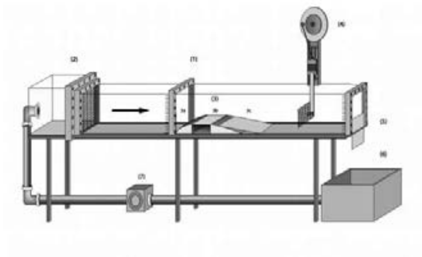
- intersections between quantum mechanics & gravity

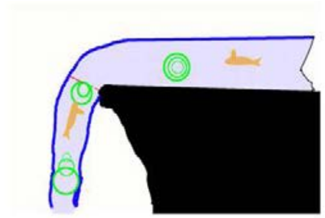
- physics of black hole evaporation

- can exotic objects e.g. wormholes exist?

Bill Unruh







Black Hole analogy: (above) Model black hole quantum emission in fluids
(water waves, BEC, optical)

Kristin Schleich

Classical relativity and quantum gravity, especially the role **topology** plays in the classical and quantum dynamics of our universe.
General relativity in **higher dimensions**, with a focus on problems related to **M-theory and string theory**.

Quantum Cosmology

+

Foundations of Quantum Mechanics:

PHILIP STAMP

Decoherence in quantum gravity

Alternatives to standard quantum mechanics + gravity

Can we understand quantum gravity?

string theory

AdS / CFT correspondence

Where do time + space come from?

What is the big bang?

What's inside a black hole?

- also alternative approaches

Joanna Karczmarek

also:
simple models
for low D
gravity

Moshe Rozali

quantum
chaos
& black holes

Connections
to quantum
information

Mark Van Raamsdonk

connections to
condensed matter
physics

Gordon Semenoff

I work on **theoretical elementary particle physics, quantum field theory and string theory**:

Atomic, Molecular and **Optical** (AMO) Physics

The **study and control**
of **individual atoms, molecules and photons**,
and their **interactions** with one another.

Extreme Frontiers of AMO!

Ultra-cold Atoms

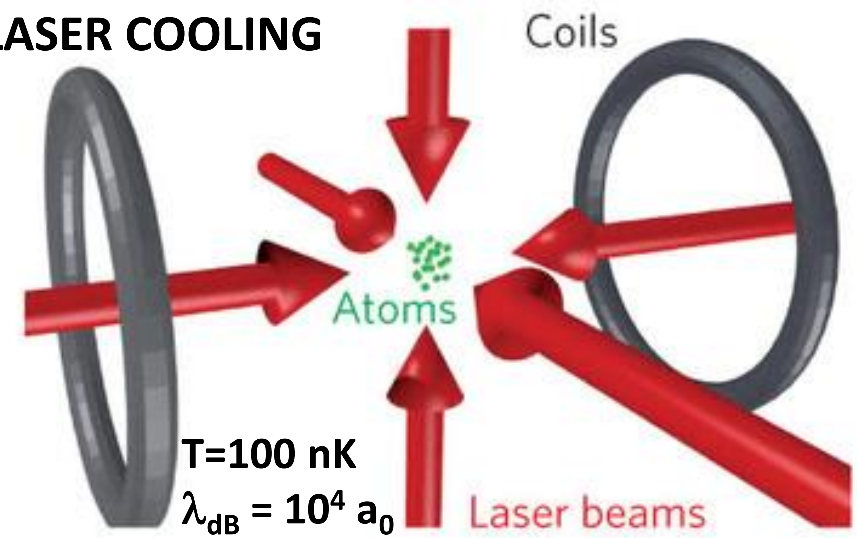
Molecular Super-Rotors

Extreme UV, Single photons

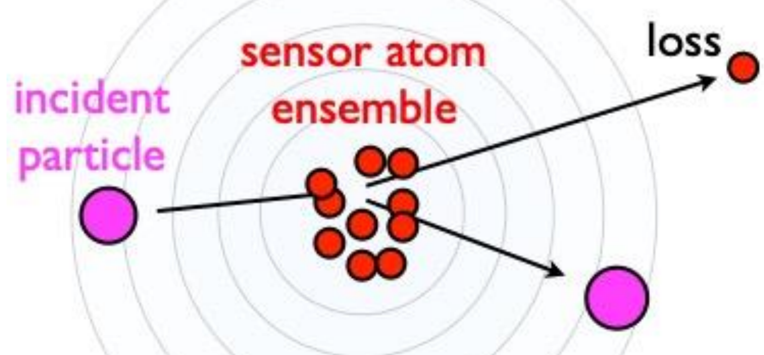
Madison Research Group

Ultracold Atoms and Molecules

LASER COOLING



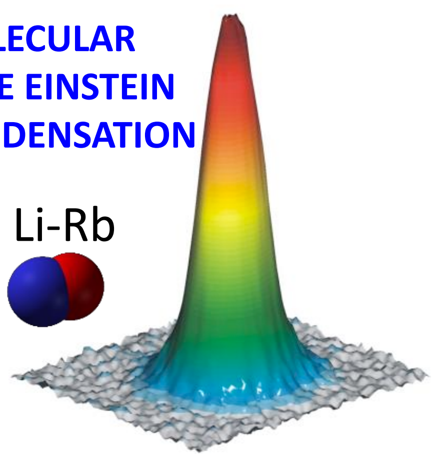
QUANTUM SENSORS



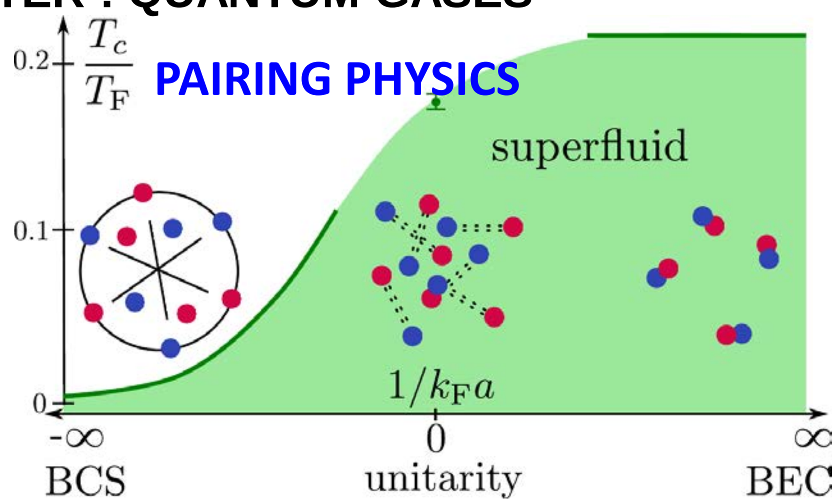
We have used laser cooled atoms to realize the first ***quantum pressure standard*** for ultra-high vacuum.

DILUTE QUANTUM MATTER : QUANTUM GASES

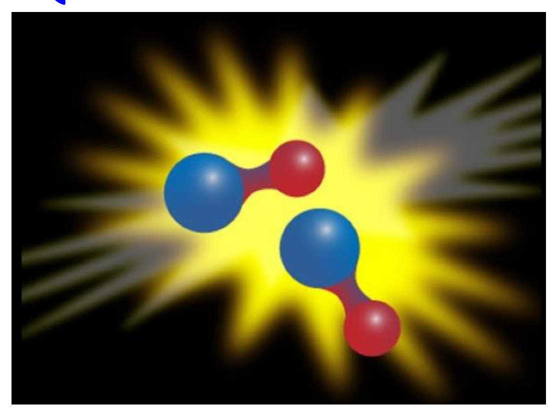
MOLECULAR BOSE EINSTEIN CONDENSATION



PAIRING PHYSICS



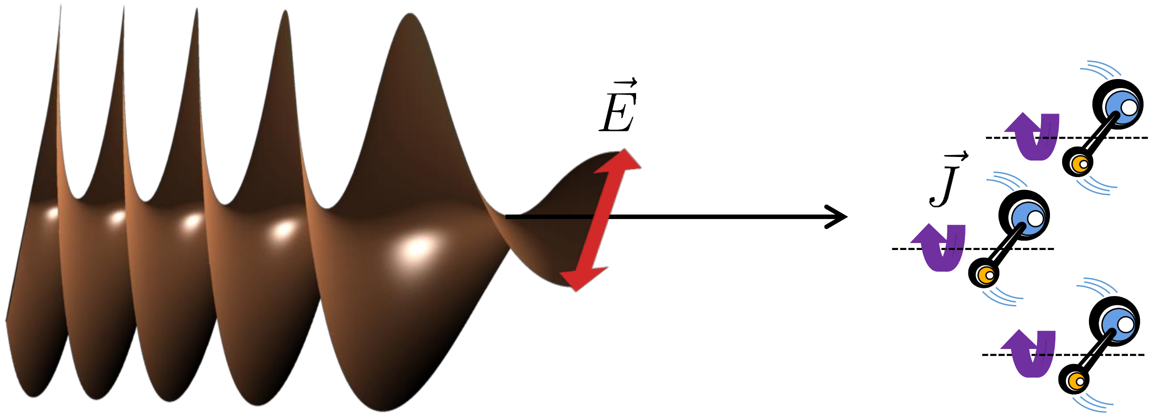
QUANTUM CHEMISTRY



Milner Research Group

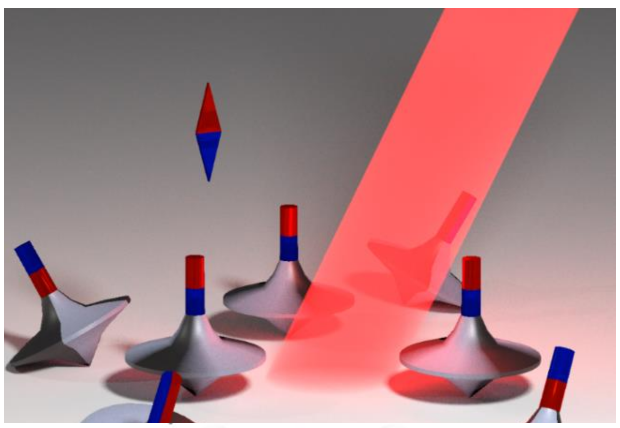
Molecular Super-Rotors

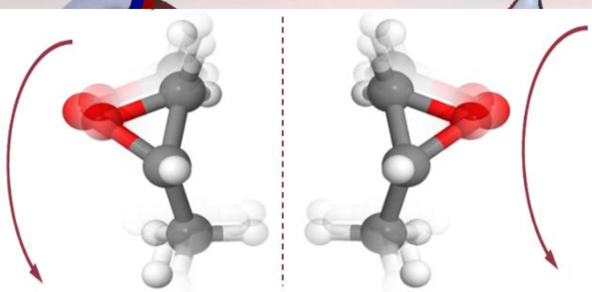
Optical Centrifuge



Ultra-fast *(10 THz)*
Uni-directional
Coherent
Controlled
Selective

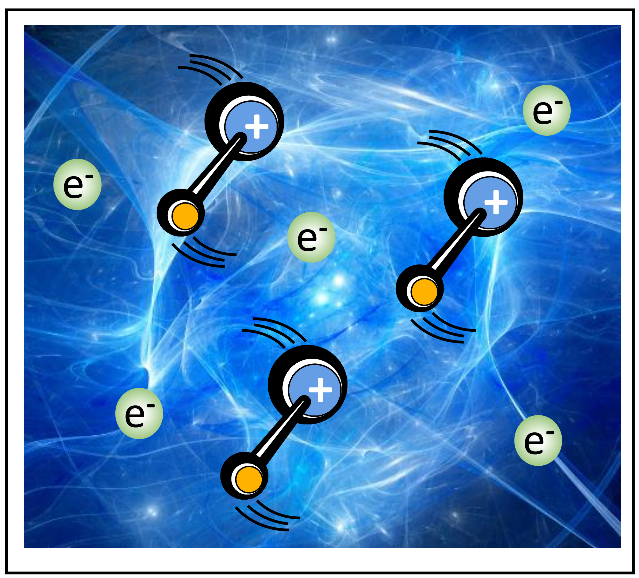
1. Non-interacting GAS



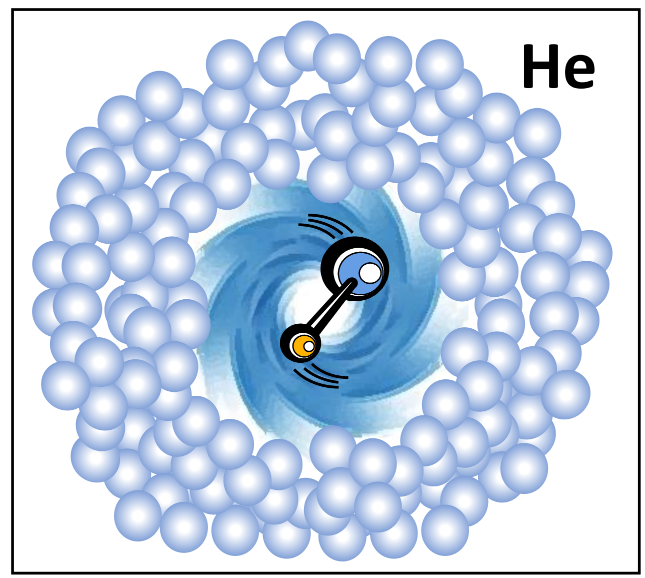


…of chiral super-rotors

2. Weakly interacting Ultra-Cold PLASMA

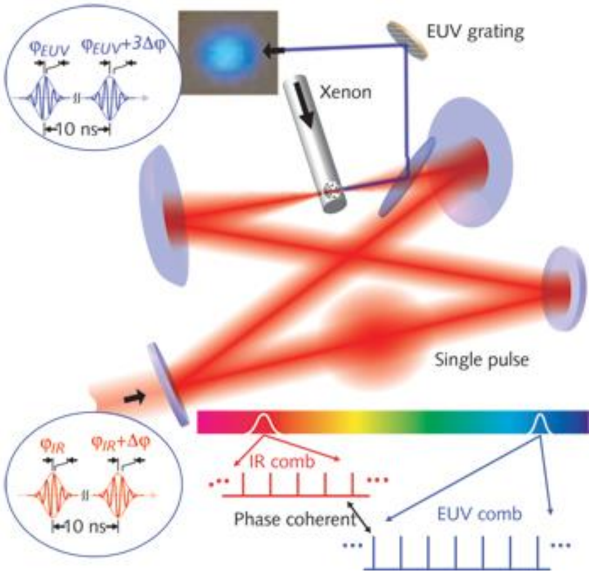


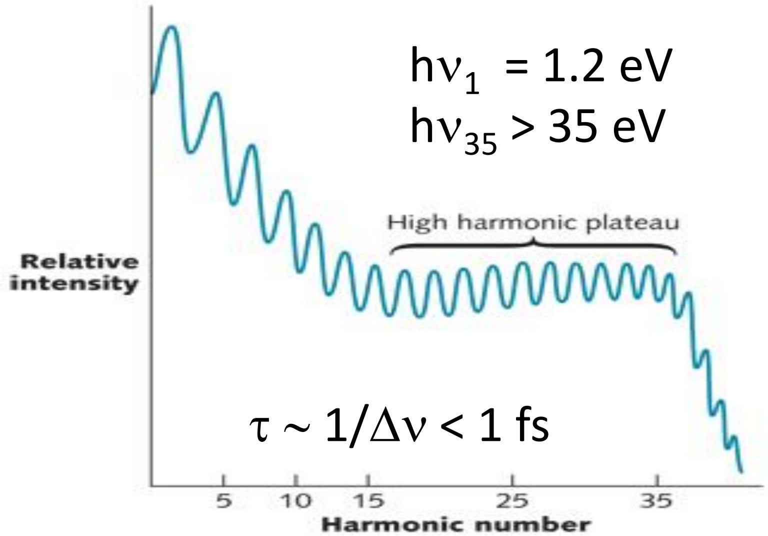
3. Strongly interacting SUPERFLUID

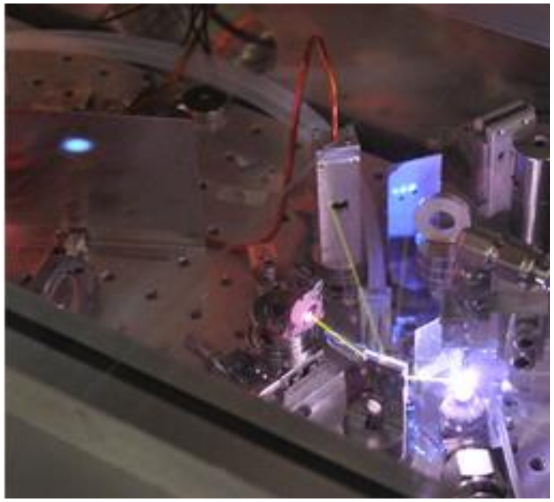


Jones Research Group

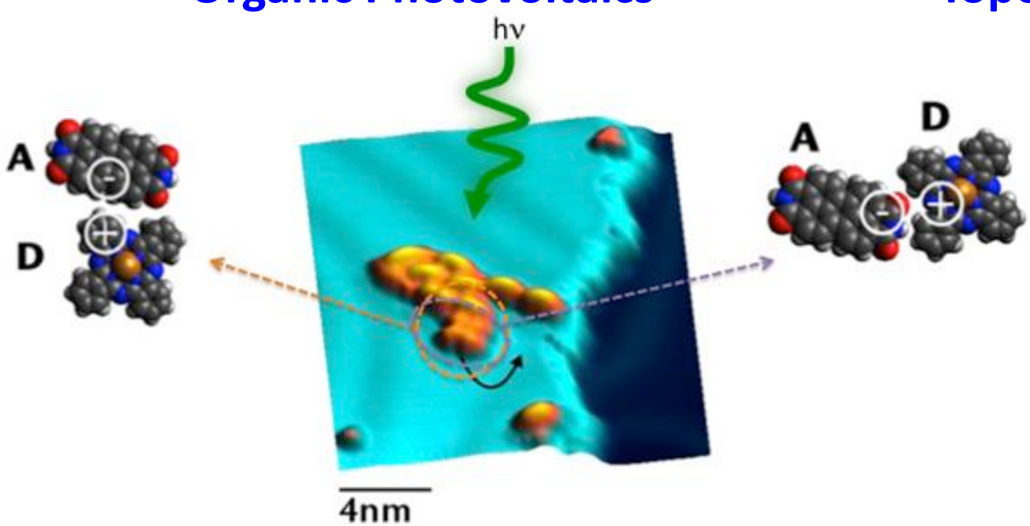
Extreme UV



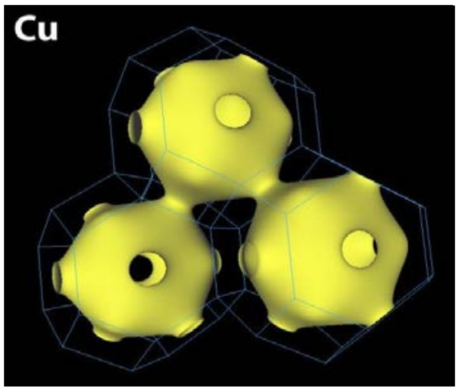


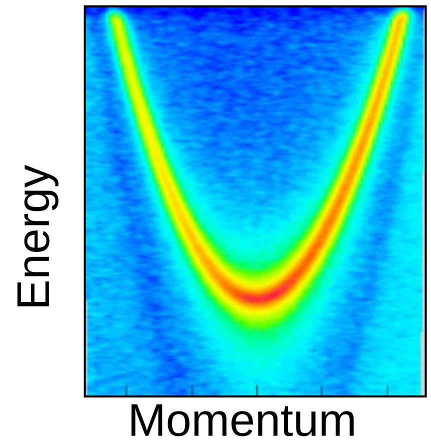


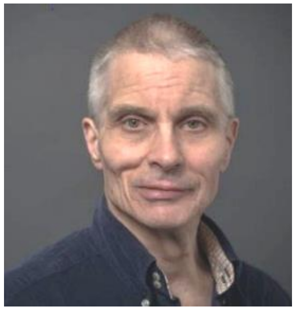
Organic Photovoltaics



Topological insulators and High-T_c superconductors



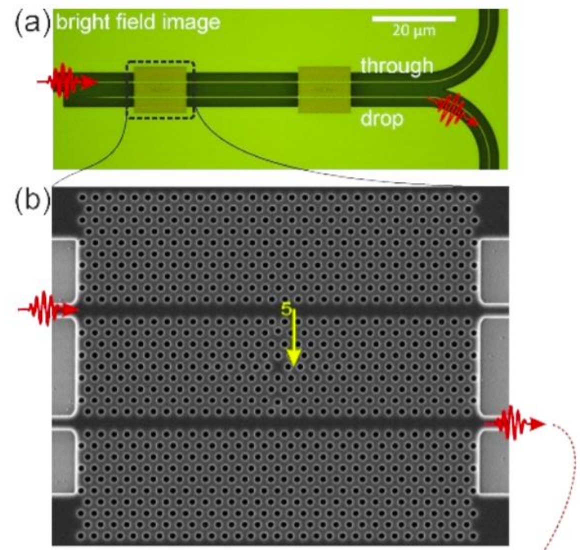




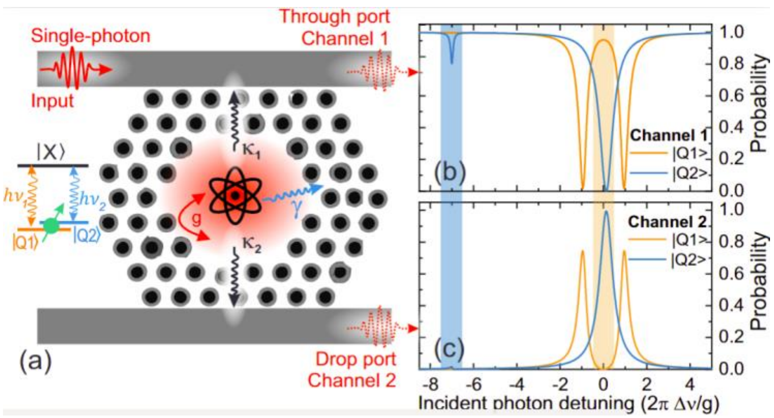
Young Research Group

Nano-photonics and Quantum Optics

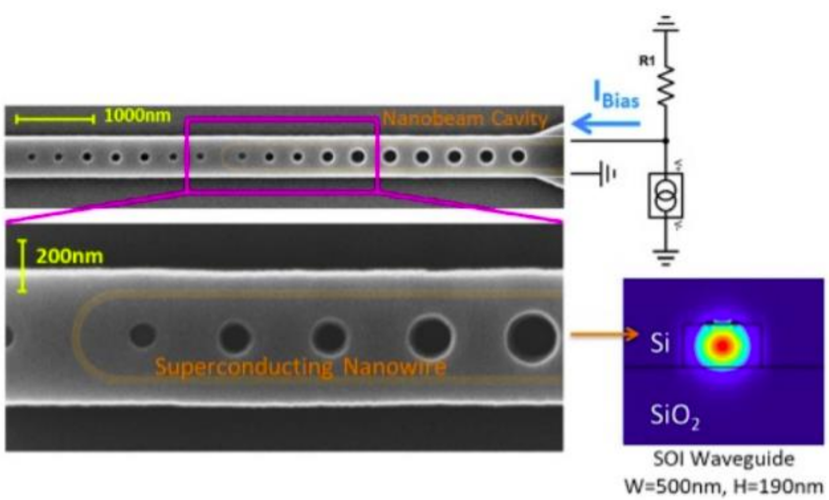
Integrated Silicon Photonic Circuitry

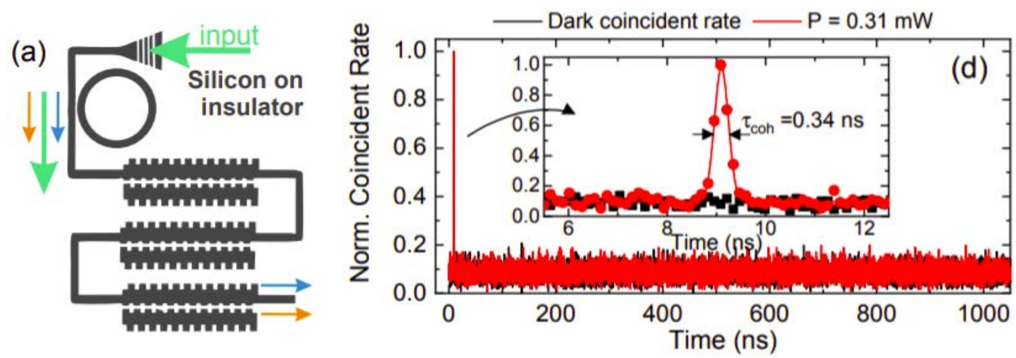


Cavity Quantum Electrodynamics



Single Photon Detectors





Single Photon Sources

Two Centers for **AMO** Physics at UBC

CRUCS — Canadian Centre for Research on Ultra-Cold Systems

CHIROS — Chirality Research On Origins and Separation

Chirality Reseacrh On Origins and Separation

AMO @ UBC	Department of **PHYSICS**	Department of **CHEMISTRY**
EXPERIMENTAL STUDIES	David Jones Kirk Madison Valery Milner Jeff Young	Takamasa Momose Edward Grant Keng Chou
THEORETICAL STUDIES	Fie Zhou Mona Berciu	Roman Krems

Biophysics: the Physics of the 21st century

UBC PHAS, with Michael Smith Labs, SBME, GSAT, BIONF, Nanomedicine, Mathematical Biology, Chemistry, Zoology...

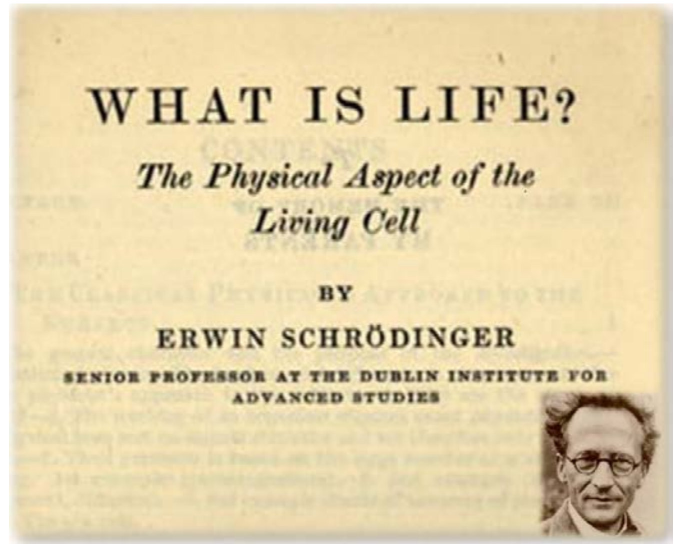
UBC PHAS Colloquium Sept 16, 2021

Working at the Interface of Physics, Biology, and Medicine

There's Plenty of Room at the Bottom

An invitation to enter a new field of physics.

by Richard P. Feynman


WHAT IS LIFE?

The Physical Aspect of the Living Cell

BY

ERWIN SCHRÖDINGER

SENIOR PROFESSOR AT THE DUBLIN INSTITUTE FOR ADVANCED STUDIES

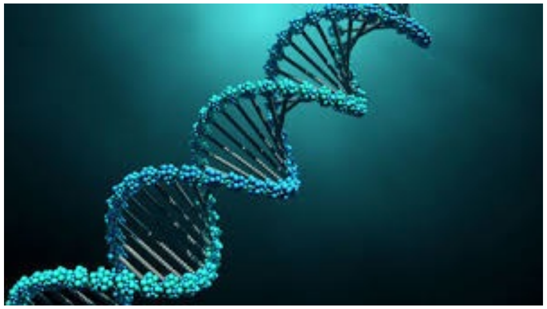
1978

1944

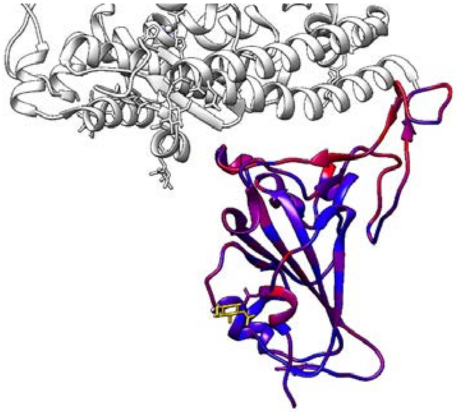
New biophysical tools, and new ideas, enable new discoveries

"..It is very easy to answer many of these fundamental biological questions; you just look at the thing! You will see the order of bases in the chain; you will see the structure of the microsome. Unfortunately the present microscope sees at a scale which is just a bit of information.."

– Richard Feynman, 1978



DNA



Part of spike protein on SARS-COV-2

Biophysics subgroup

Sabrina Leslie
sabrinaleslie@phas.ubc.ca

Single-molecule microscopy, applications to DNA, RNA, therapeutics, mRNA vaccines

Steven Plotkin
steve@phas.ubc.ca

Molecular genetic origins of multi-cellular animals, Protein misfolding, SARS-CoV-2 vaccine/Ab development

Carl Michal
michal@phas.ubc.ca

NMR and MRI, brain research, spider silk, synthetic materials

Joerg Rottler
jrottler@physics.ubc.ca

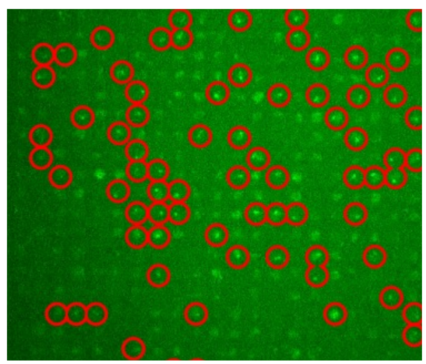
Material properties from an atomistic perspective, machine learning, polymers, biomaterials

In common: Understand biological systems
Innovating instrumentation, analysis, theory

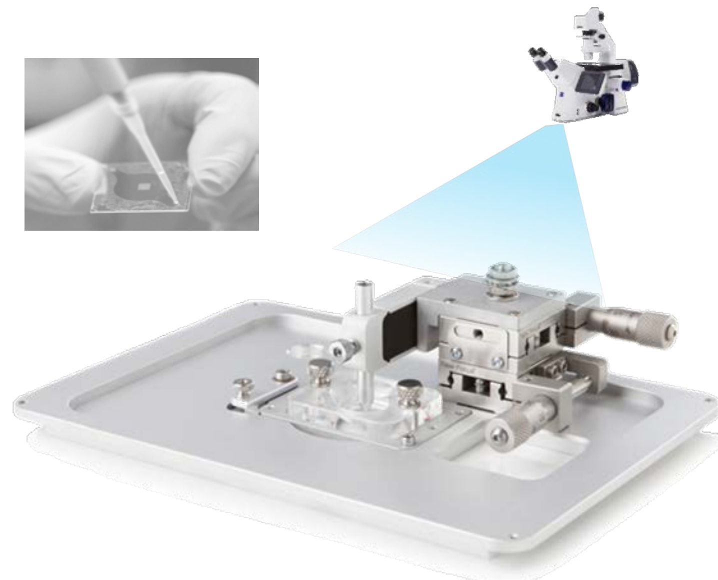
NMR and other microscopies

Can we democratize boutique technologies to accelerate science?

AI to assist data analysis

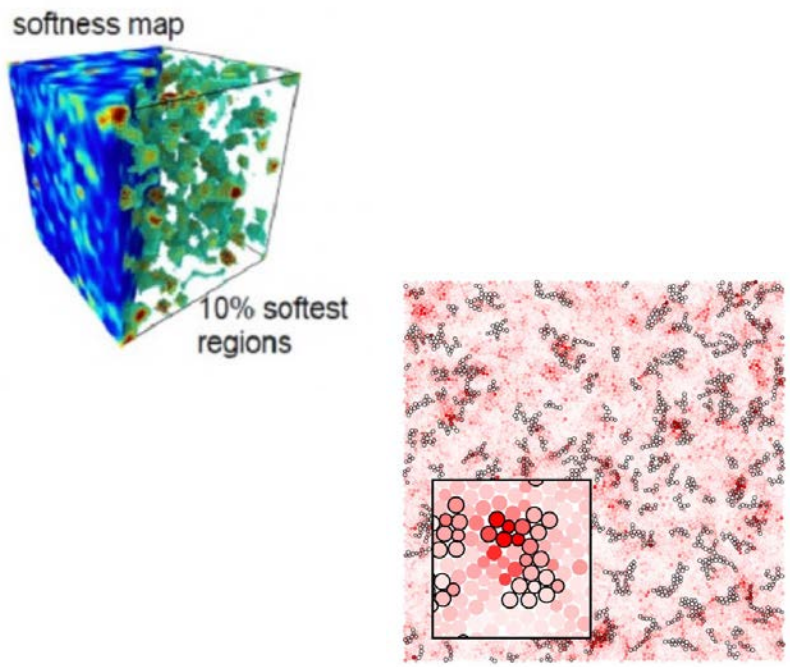


Single-molecule and single-cell microscopy
of molecules, particles, cells, tissues, ..

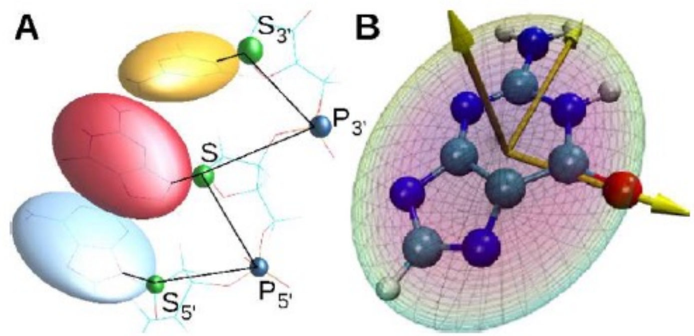


Biophysics skill sets through research:
Instrumentation, microscopies, optics, theory, computation, AI, machine learning, fabrication, wet sample handling, biotechnology

Rottler Lab



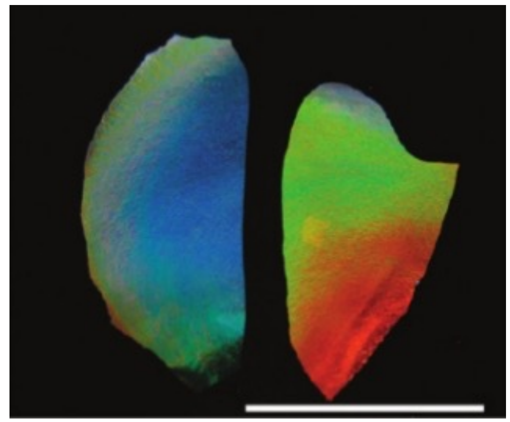
Towards an atomistic understanding of materials



Biopolymers, biomechanical response, AI, ..

Michal Lab

Brain research

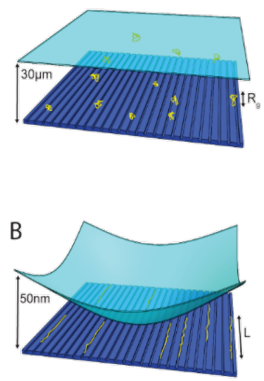


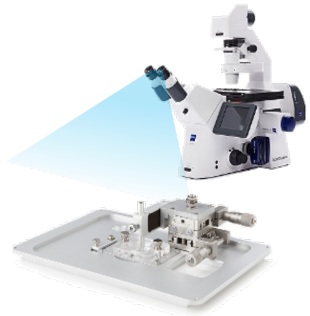
Spider silk and synthetic materials

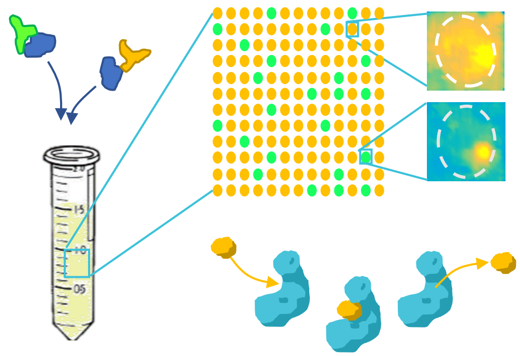
NMR

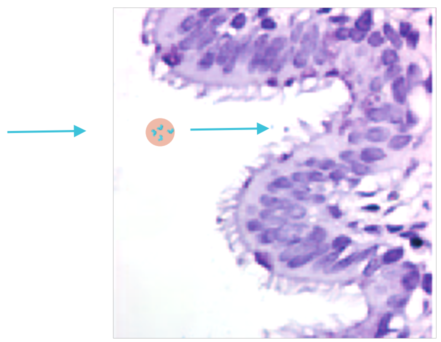
New investigations of bio materials using NMR and MRI; further innovating these tools to democratize their use

Leslie Lab









Isolating and imaging DNA in nano-grooves

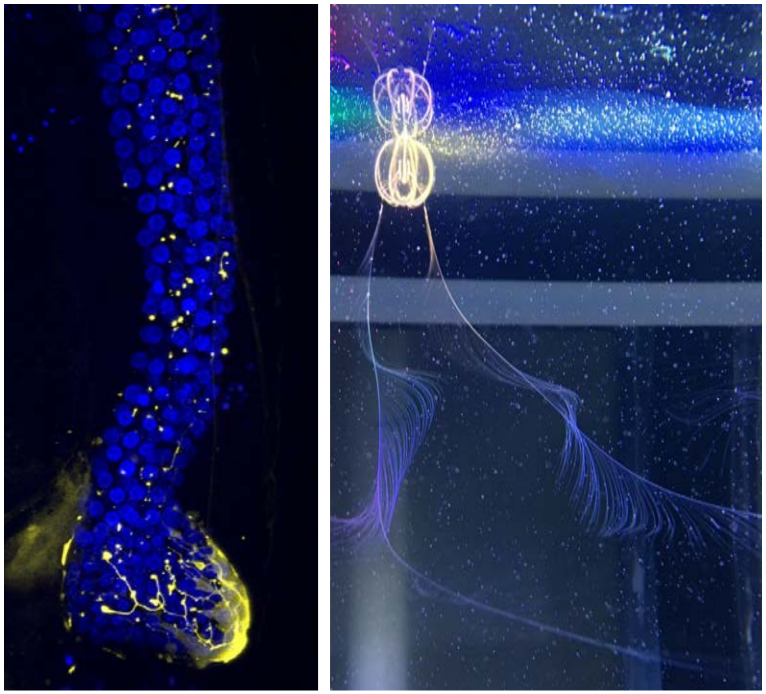
Enabling single-molecule visibility

Capturing drug/target interactions (and other molecules)

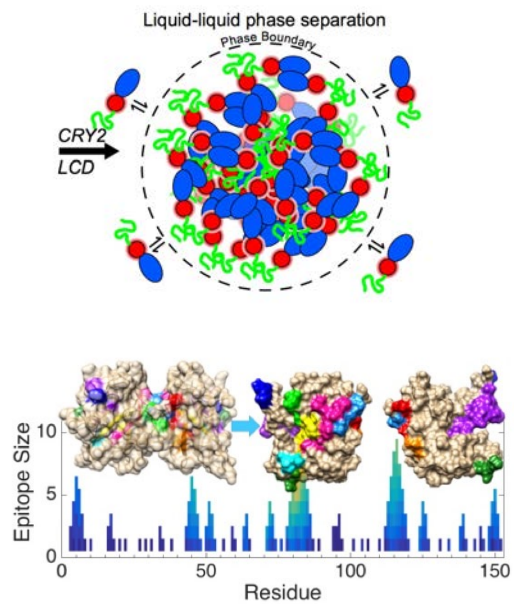
Understanding delivery dynamics in cells

Single-molecule (SM) and single-cell platform for therapeutics discovery and development

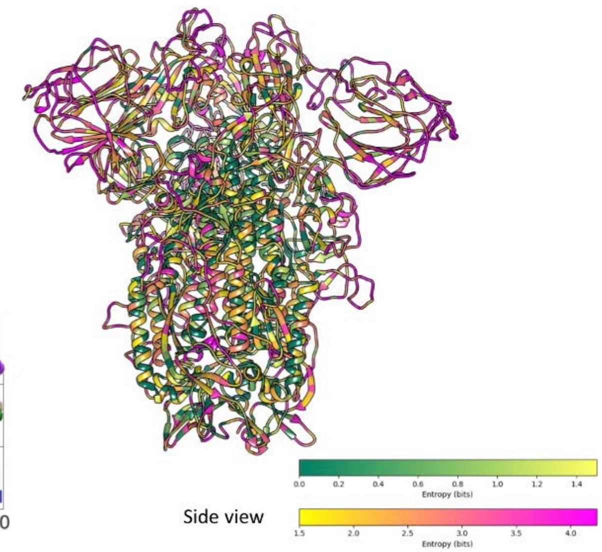
Plotkin Lab



Molecular genetic origins of multicellular animals



Protein misfolding and aggregation



Molelular design of therapeutics for SARS-CoV-2

Thanks and happy to meet: looking for great students!

Sabrina Leslie
sabrinaleslie@phas.ubc.ca

Single-molecule microscopy, applications to DNA, RNA, therapeutics, mRNA vaccines

Steven Plotkin
steve@phas.ubc.ca

Molecular genetic origins of multi-cellular animals, Protein misfolding, SARS-CoV-2 vaccine/Ab development

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NMR and MRI, brain research, spider silk, synthetic materials

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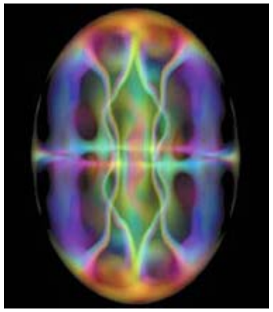
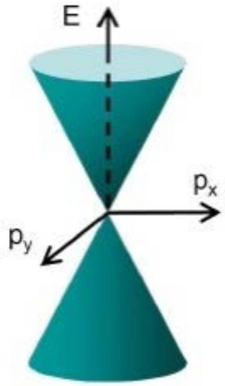
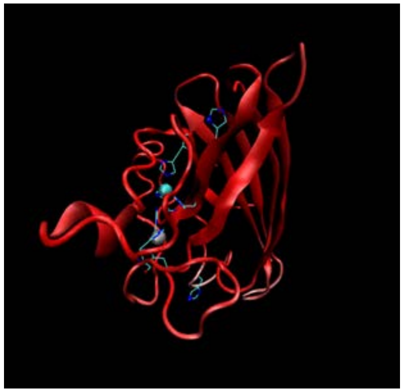
Material properties from an atomistic perspective, machine learning, polymers, biomaterials

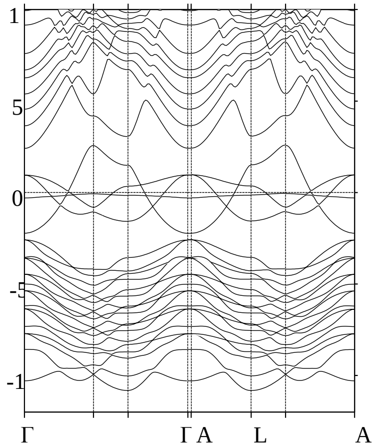
(Quantum) CONDENSED MATTER THEORY at UBC

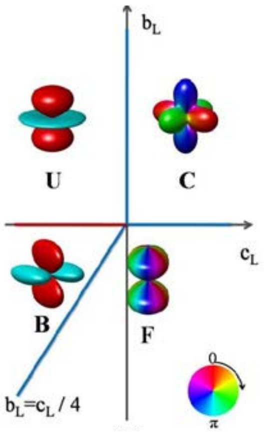
Fei Zhou











Interacting quantum many-body systems:

"emergent phenomena"

More Is Different

Broken symmetry and the nature of the hierarchical structure of science.

P. W. Anderson

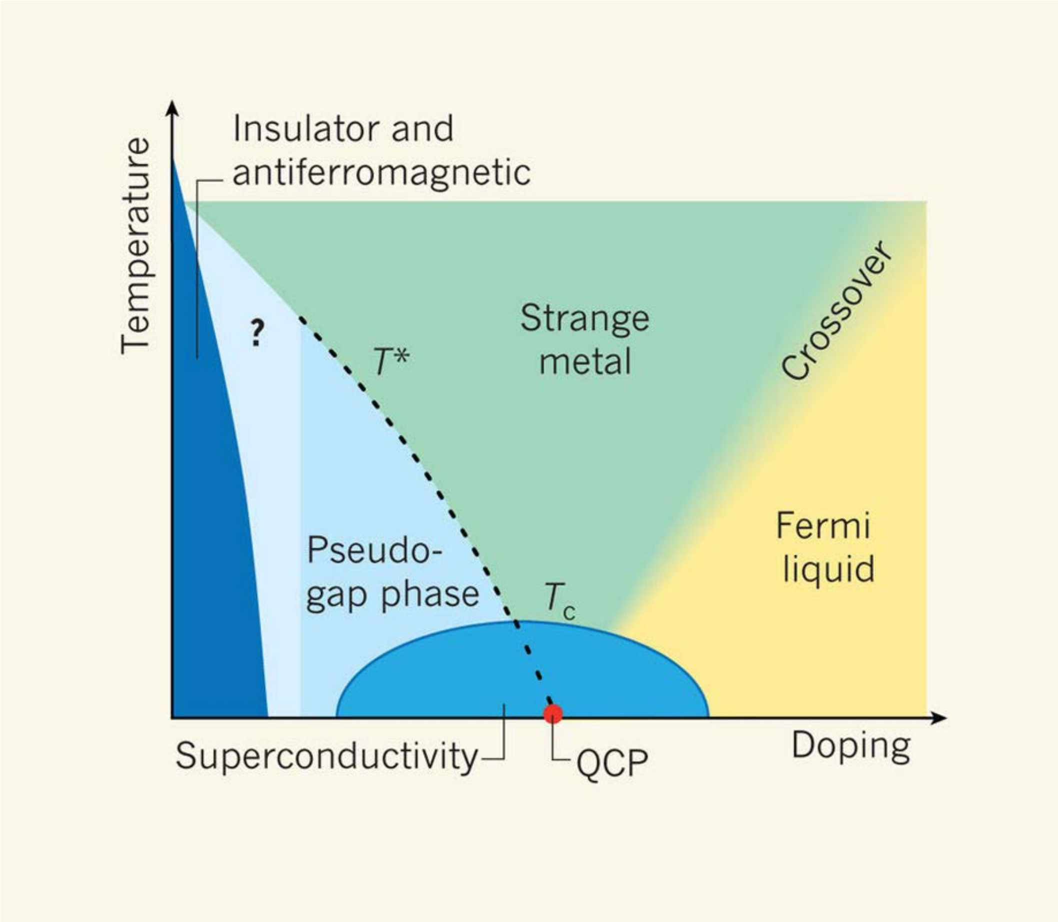
The reductionist hypothesis may still be a topic for controversy among philosophers, but among the great majority of active scientists I think it is accepted

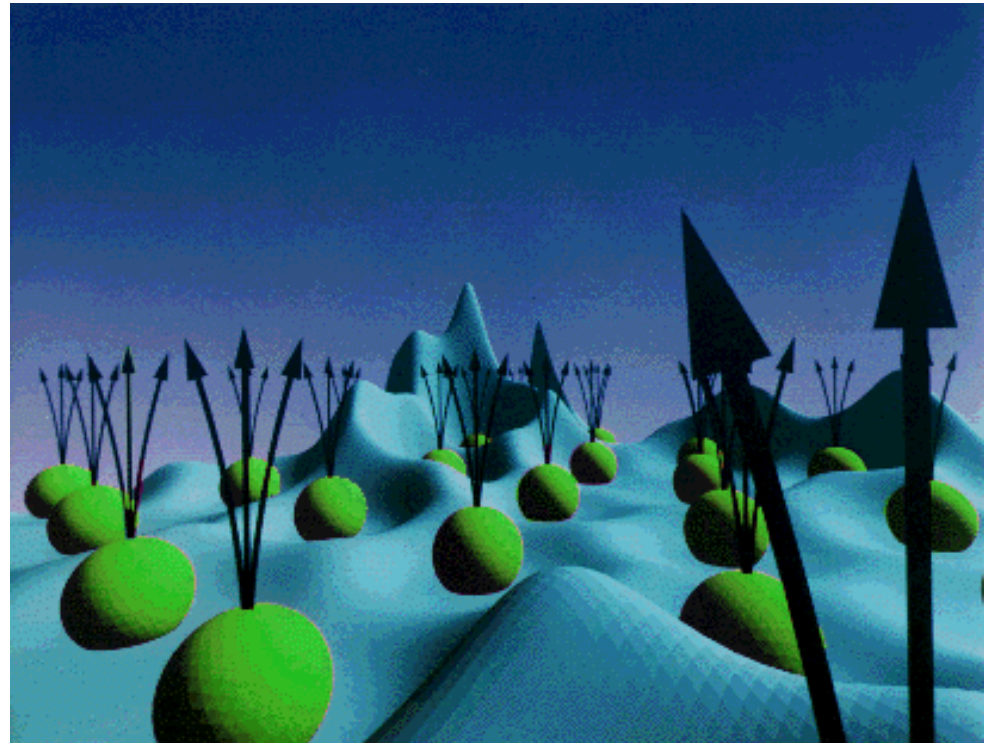
planation of phenomena in terms of known fundamental laws. As always, distinctions of this kind are not unambiguous, but they are clear in most cases. Solid state physics, plasma physics, and perhaps

less relevance they seem to have to the very real problems of the rest of science, much less to those of society.

The constructionist hypothesis breaks down when confronted with the twin difficulties of scale and complexity. The behavior of large and complex aggregates of elementary particles, it turns out, is not to be understood in terms of a simple extrapolation of the properties of a few particles. Instead, at each level of complexity entirely new properties appear, and the understanding of the new behaviors requires research which I think is as fundamental in its nature as any other. That is, it seems to me that one may array the sciences roughly linearly in a hierarchy, according to the idea: The elementary entities of science X obey the laws of science Y.

Large scale quantum phenomena can't be understood as a simple extrapolation of microscopic individual particles. Strong interactions lead more exotic phenomena.





Superconductor (HTcS)
1) electrons can condense and super-flow!
2) strongly interacting electron can super-conduct at high T.

Fractional Quantum Hall (FQH): a topological liquid

Laughlin state with 1/3 electron per flux in B-field
Quasi- particles carrying 1/3 of electron charges.

Why “emergent phenomena” surprising?

A) Quantum matter can break the symmetries of the microscopic interactions (Superconductor/superfluid, ferromagentic-anti-ferromagentic etc)

B) Strong interactions/high “degeneracy” due to either quantum or classical configurations leading to fractionalization and non-local ”topological order”, an open area (various FQHs, Non-Abelian electronic or spin liquids and topological quantum computers etc).

C) Strong interactions fine tuned to certain critical values lead scale/ conformal symmetries emergent at large scale quantum phenomena. They represent singularities making it impossible to extrapolate (from individual constitutes) and are pivotal to emergent physics.

Condensed Matter Theory (more info at www.physics.ubc.ca/cmt)

Ian Affleck

Mona Berciu

Marcel Franz

Philip Stamp

Fei Zhou

Quantum CMT GROUP

others with overlap in CMT

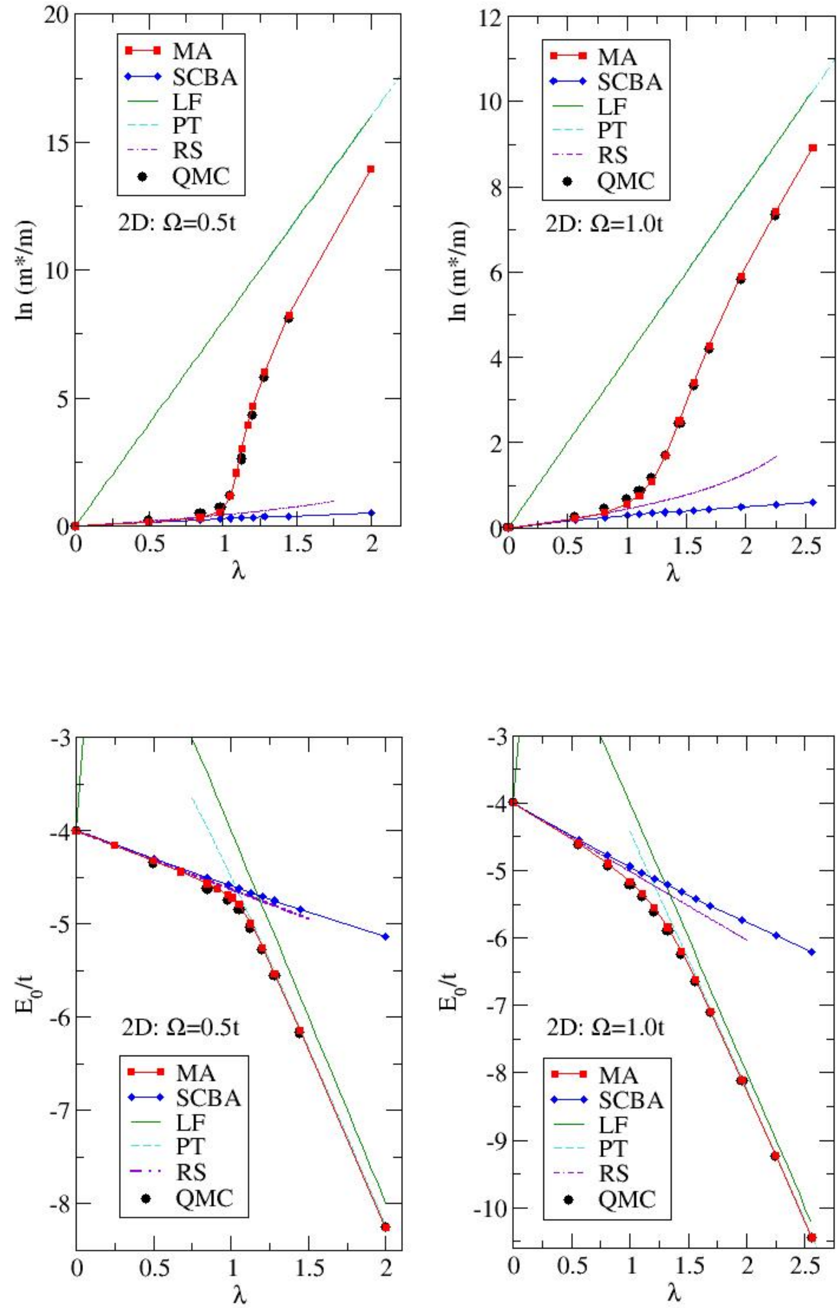
Robert Raussendorf

Bill Unruh

Gordon Semenoff

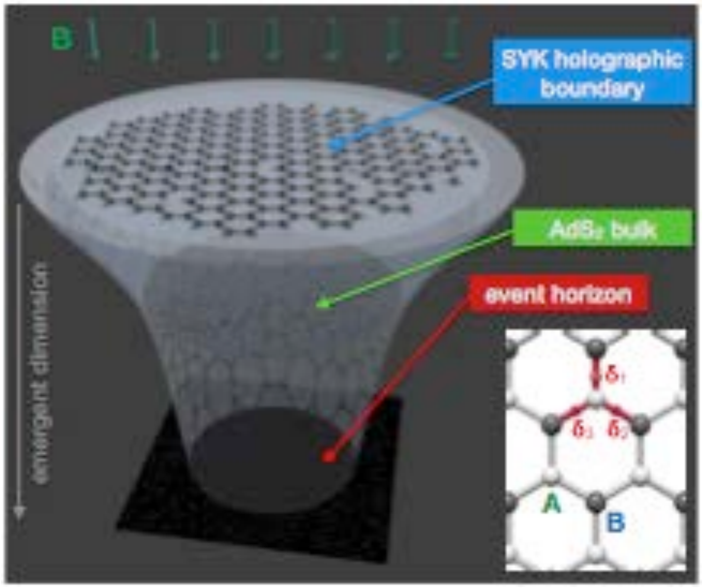
Mona Berciu:

→ I work on finding accurate variational approximations for systems with strong electron-phonon coupling and/or strong correlations. We use these methods to study certain properties of high-temperature cuprates, rare-earth nickelates, bismuthates, etc.



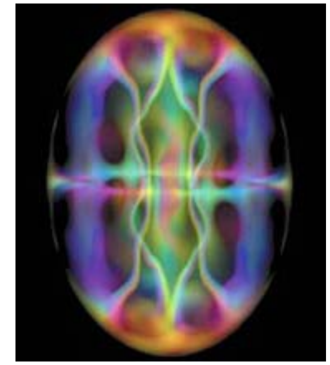
Marcel Franz:

→ I specialize in topological states of quantum matter, superconductivity, systems with strong interactions and anything else out of the ordinary.



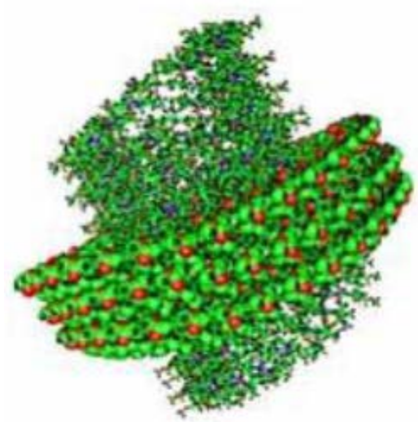
PHILIP STAMP

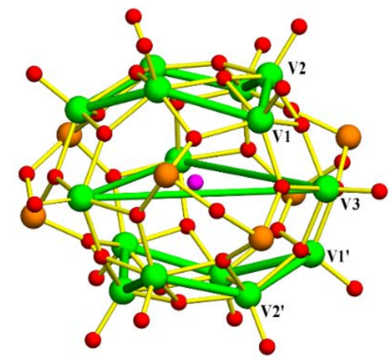
Black Hole: where GR confronts QM



Vortices in rotating superfluid

chlorosome (green sulfur bacteria)





Magnetic molecules: Qubits for a Q computer

<u>Large-Scale Quantum Phenomena</u>: Decoherence in Nature. Building a Quantum Computer. **Large-scale coherence in biological systems.** Large-scale quantum phenomena in spin systems; Quantum spin glasses & quantum glasses; Dynamics of superfluids & vortices

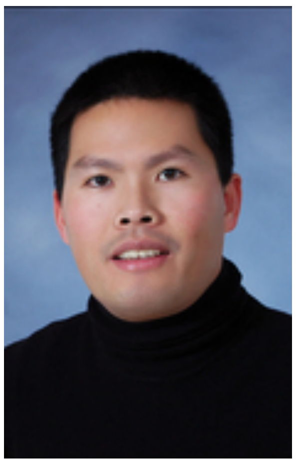
<u>Quantum Mechanics & General Relativity</u>; Breakdown of QM caused by gravity; Gravitational Decoherence (project with WG Unruh)

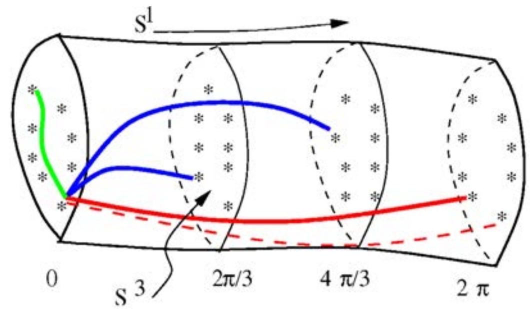
Fei Zhou:

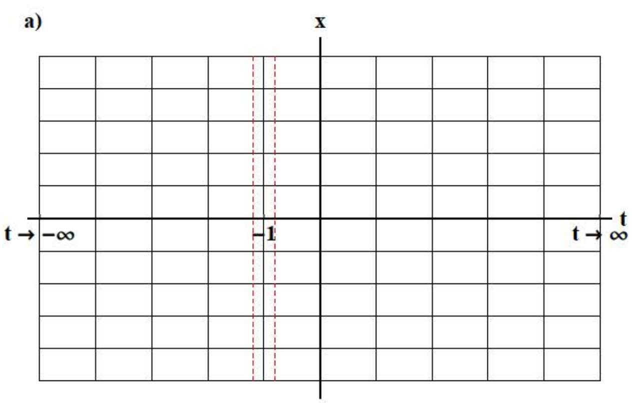
→ Quantum Criticality in Symmetry Protected/Enriched Topological States and Emergent Gapless topological states;

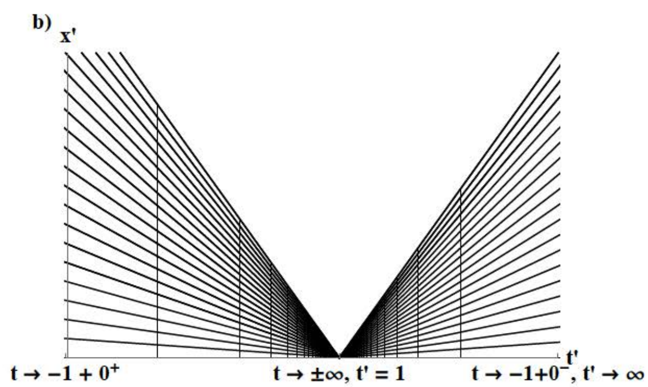
→ Non-equilibrium Quantum Dynamics in Strongly Interacting Systems;

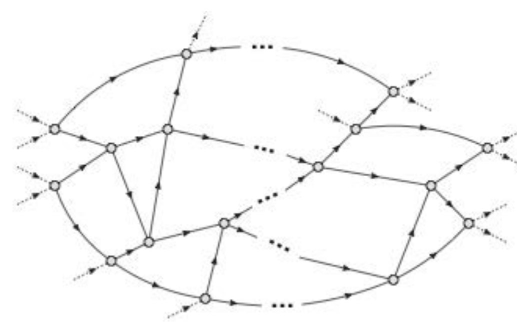
→ $\hbar$-Bounded Planckian Dynamics and Emergent holographic/ Ads/CFT-related quantum matter in CMP.





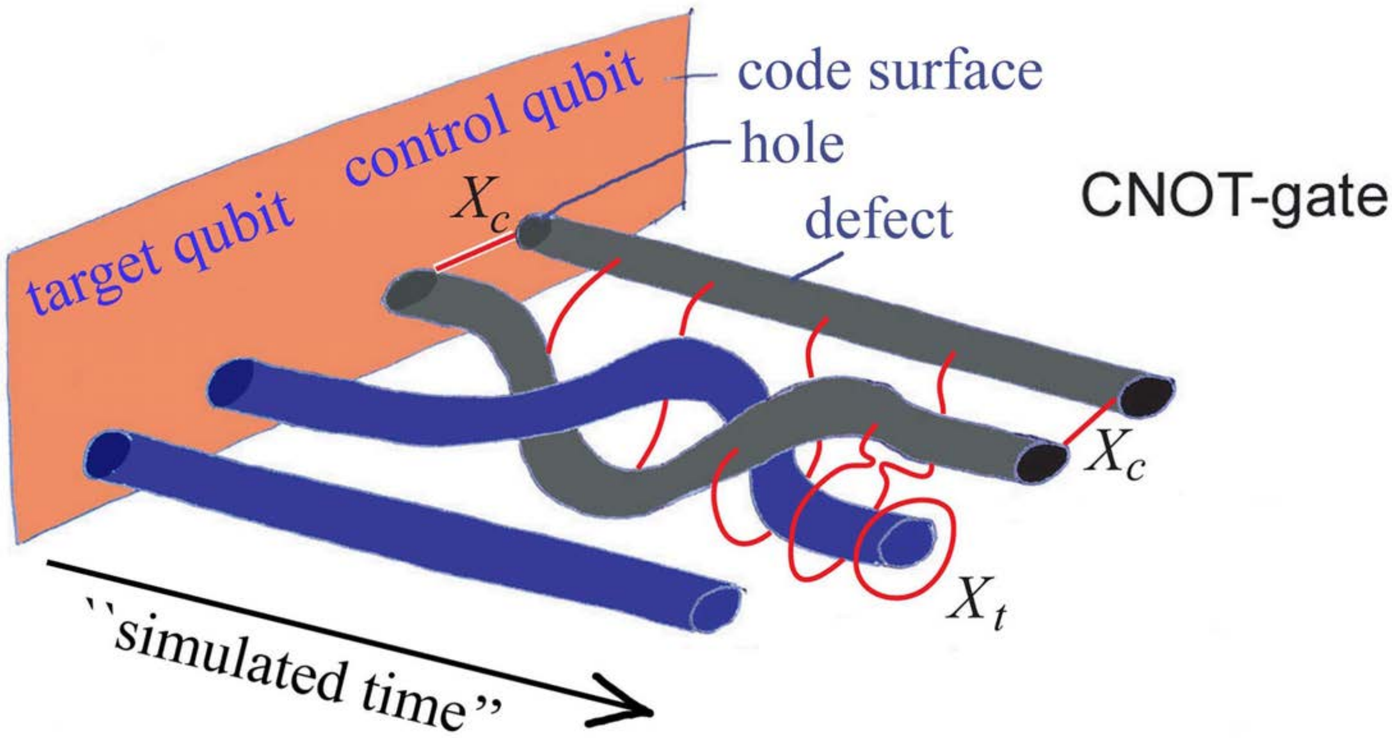






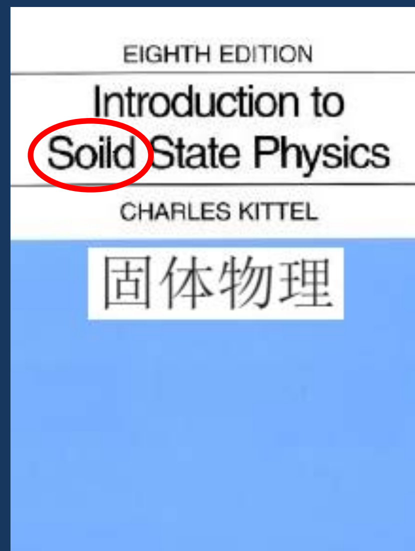
Robert Raussendorf:

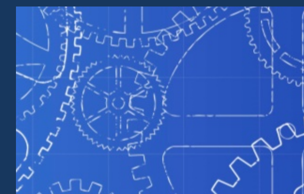
→ My research is in quantum computation. I am particularly interested in computational models, such as computation by measurements, and in making quantum computers stable against the effects of noise and decoherence.



Why condensed matter experiment?

observation
↓
discovery
↓
understanding



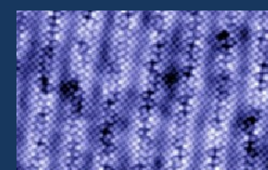


design

creation

understanding

observation



Design/Create: Molecular beam epitaxy, crystal growth, organic self-assembly

Observe/Understand: STM, ARPES, REXS, transport, optics, μSR, NMR

Understand/Design: Band structure computation, modelling of interactions, connect structure & properties

Quantum Matter Institute

Quantum
Matter
Institute

Rapid growth & new opportunities:

2010: cluster of 15 faculty groups spanning physics, chemistry, engineering, with common interest in quantum materials

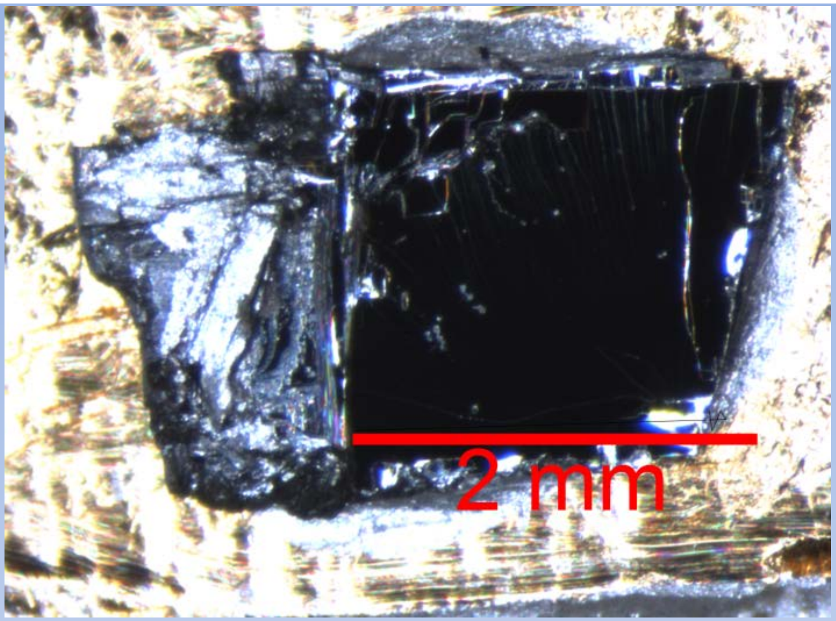
2010: joined with Max Planck Institute

2014: QMI extension started

2015: $66.5M Canada First Excellence Research Fund (CFREF) with new faculty hires planned

2017: Moved into new Building

2021: Finish cluster of new faculty hiring

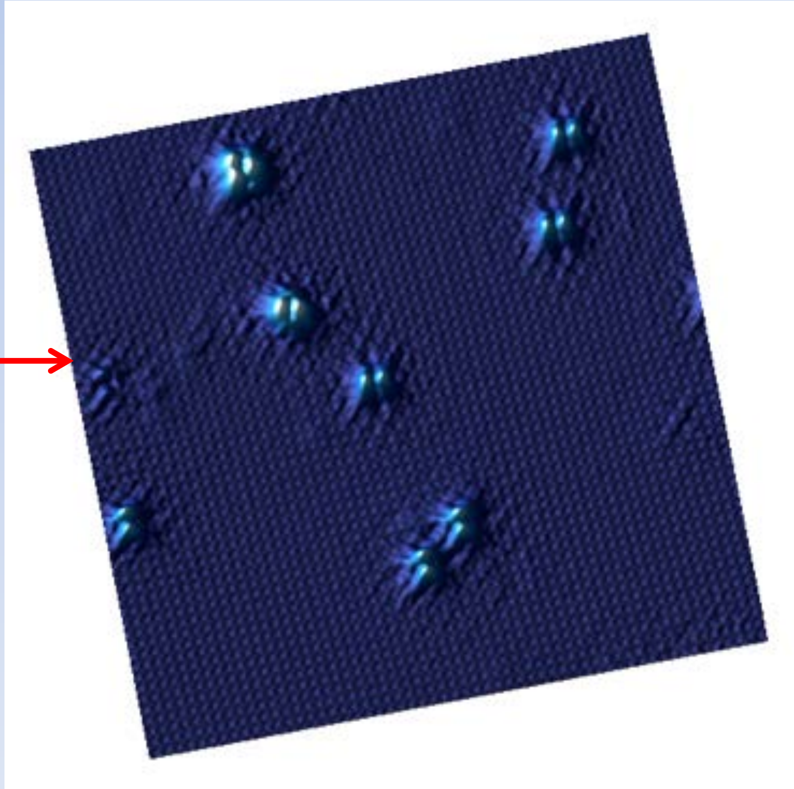


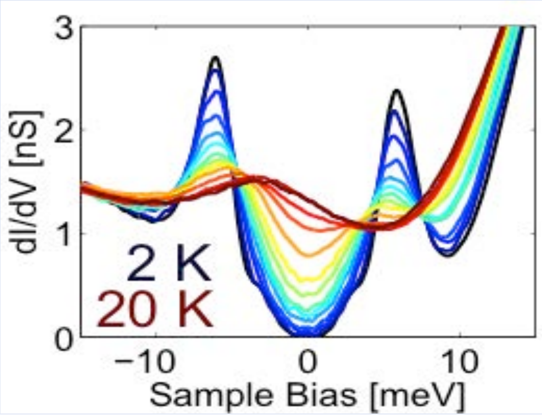
Doug Bonn
Superconductivity Group

Single crystal growth and characterization of cuprates, Fe-based superconductors, and other strongly-correlated materials.

Measurement facilities

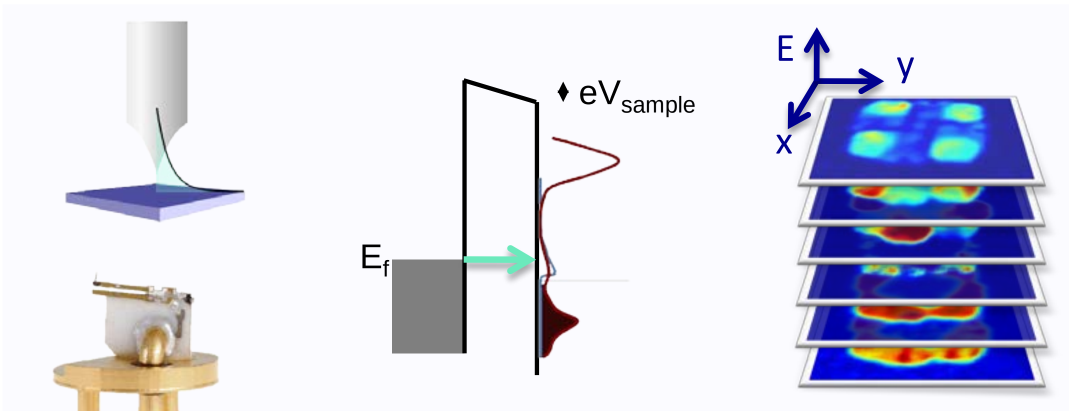
- Magnetic susceptibility
- DC resistivity
- High magnetic field measurement
- microwave spectroscopy
- Scanning Tunneling Microscopy and Spectroscopy



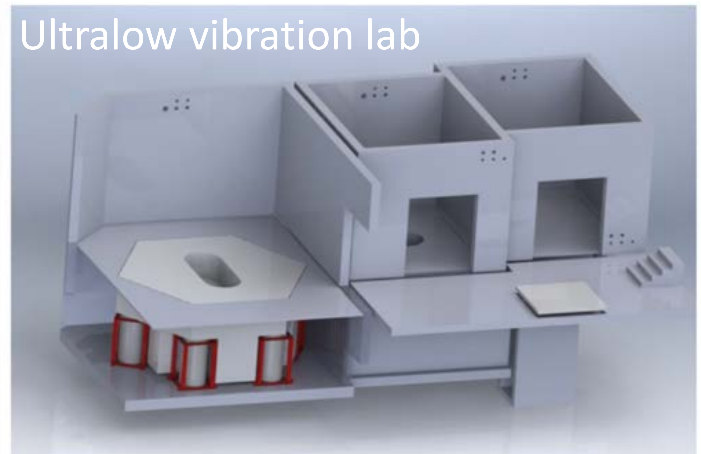


Sarah Burke
Laboratory for Atomic Imaging Research

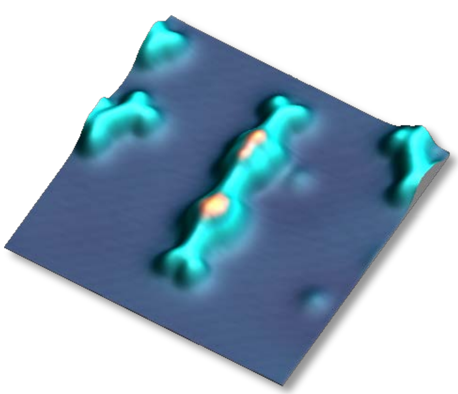
UBC LAIR

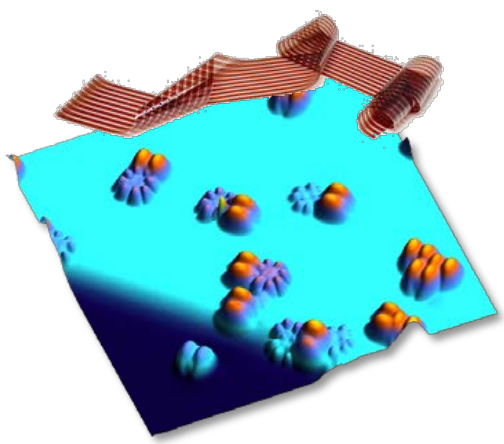


STM & AFM: local probes of structure & properties

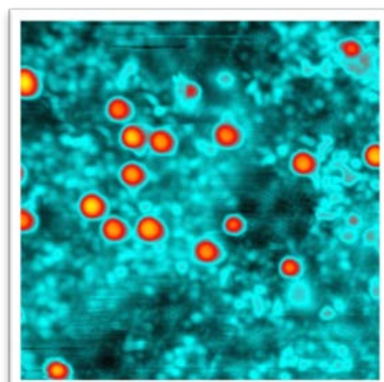


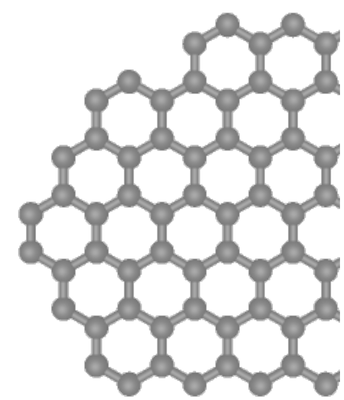
Organic materials for photovoltaic energy conversion





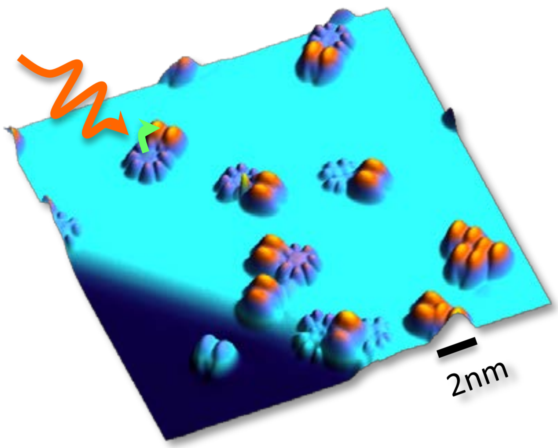
Exotic electronic materials: Superconductors & graphene



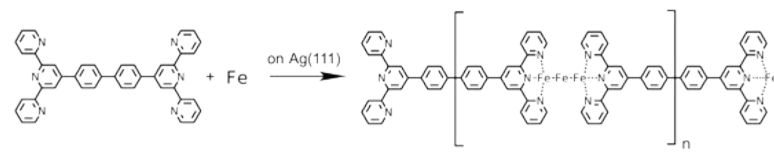


Laboratory for Atomic Imaging Research
Burke lab project highlights

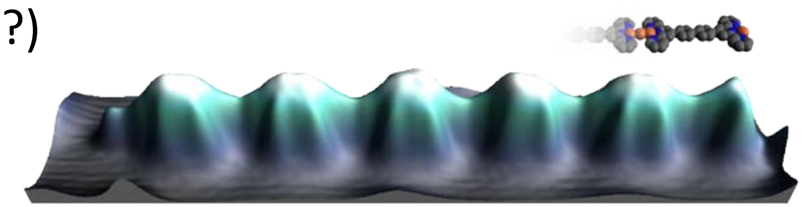
UBC LAIR

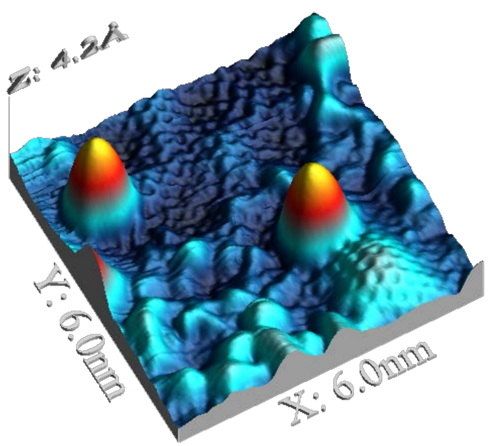


Photoinduced charge transfer for photovoltaic systems



Self-assembly for control of nanoscale systems
(photovoltaics, catalysis, electronics & spintronics… ?)



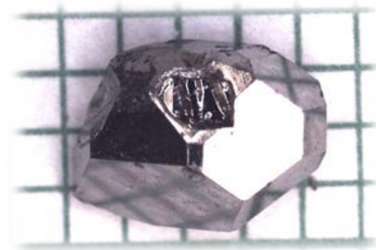


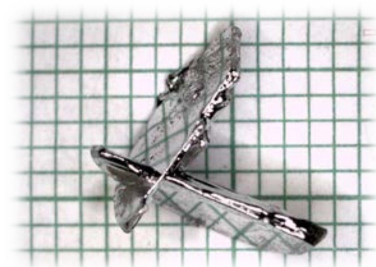
Using adatoms to modify and probe electronic structure

The Hallas Group
Quantum Materials Design Lab

We discover new quantum materials that exhibit remarkable magnetic and electronic behaviors. You will:

- ❖ Grow crystals using state of the art synthesis techniques (high pressure and floating zone)
- ❖ Solve crystal structures using x-ray crystallography
- ❖ Perform property measurements down to 50 mK and up to 14 T.
- ❖ Travel to international facilities to perform experiments (neutron scattering and muon spin relaxation)



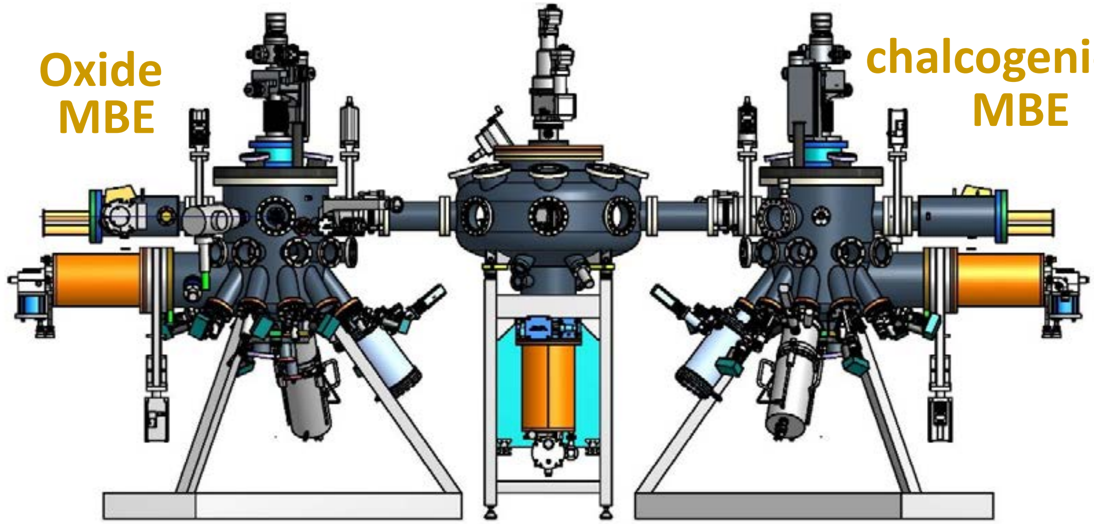


Learn more: https://hallas.phas.ubc.ca
Get in touch: alannah.hallas@ubc.ca

2-dimensional crystal materials with novel electronic properties

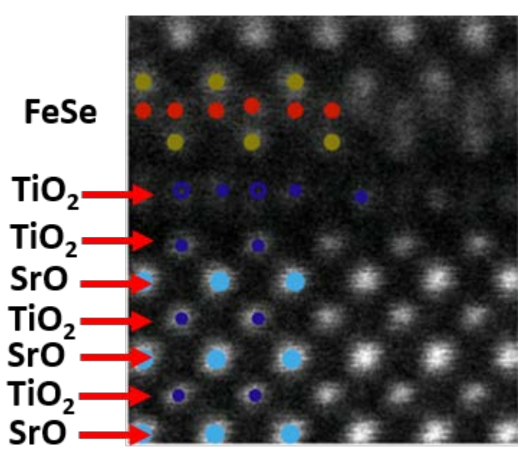
Molecular beam epitaxy:

- Synthesizing crystals in UHV
- With atomic level of precision and control
- Minimum impurities and defects
- Ideal for high-quality 2D materials with nm thickness



To study 2D materials with novel electronic properties: Superconductors, topological insulators, Weyl semimetals, …

TEM of high-Tc superconductor monolayer $FeSe/SrTiO_3$



Integrate MBE synthesis with other characterization tools:

XRD, TEM, AFM, Nanofabrication, electrical transport, and *in situ* ARPES (with Damascelli group)

Ke Zou

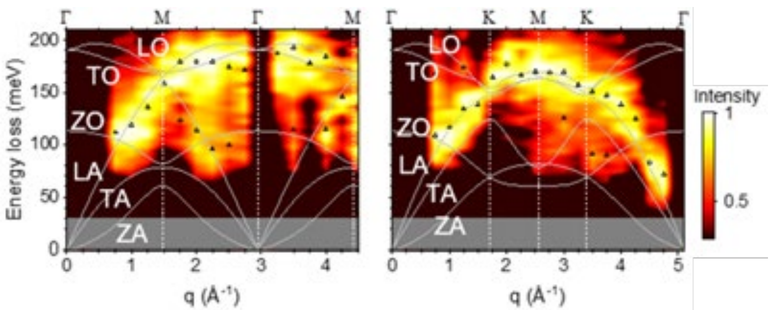
kzou@phas.ubc.ca

Brimacombe 476

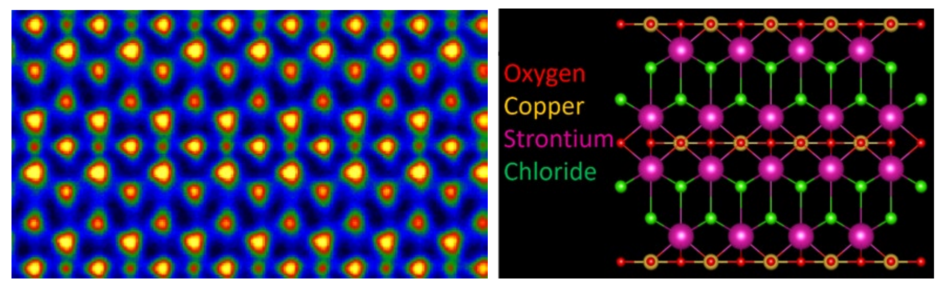
Steve Dierker

I. Quantum Materials Electron Microscopy Center

- Two state of the art electron microscopes:
  - atomic imaging and characterization of materials
  - momentum resolved electron energy loss (EELS) measurements with unprecedented energy resolution
- Research Topics
  - Momentum dependence of the dielectric function of quantum materials
  - Collective excitations in inhomogeneous strongly correlated matter
  - Confined optical modes in polaritonic media



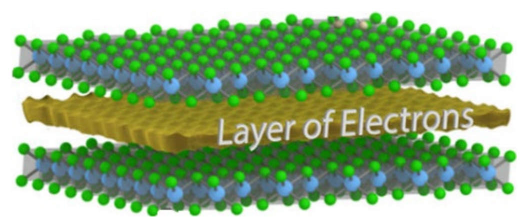
Momentum resolved EELS measurements of phonon dispersion curves in monolayer graphene



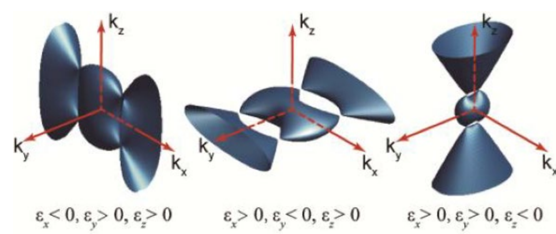
TEM image of $Sr_2CuO_2Cl_2$ along the [100] axis (left) and atomic model (right)

II. Nanospectroscopy Laboratory

- Optical spectroscopy with ~ nm spatial resolution at low temperatures and large magnetic fields
- Research Topics
  - Nanophotonic devices based on polaritons in 2D electrides and layered transition metal oxides
  - Controlling them by integration with quantum materials



Anionic electrons (yellow) in between the layers of the 2D electride Ca_2N



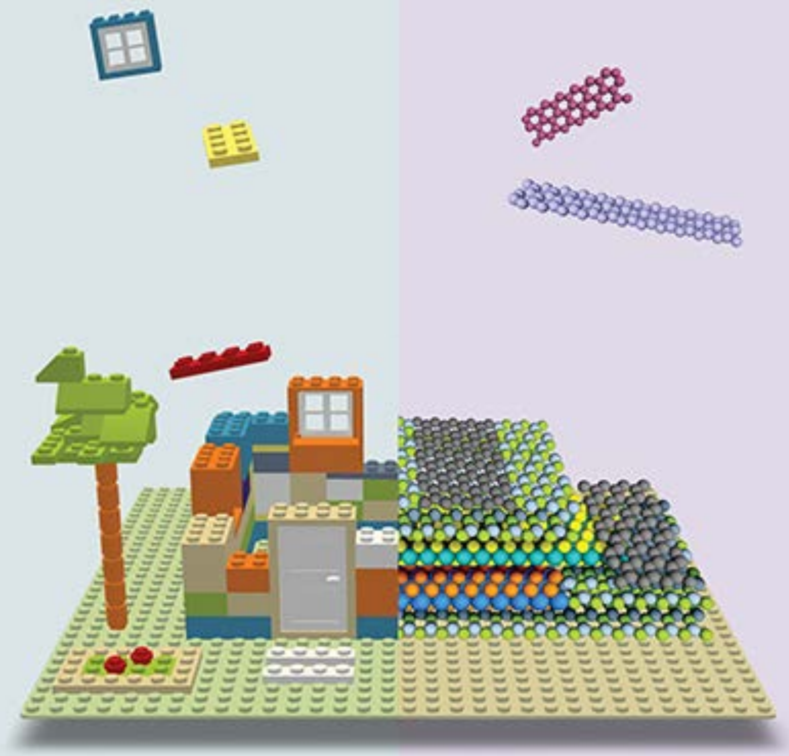
Anisotropic hyperbolic polaritons in MoO_3

Optical spectrscoy
2D materials and their heterostructures

Ziliang Ye
AP in Physics and Astronomy and
Quantum Matter Institute since 2017

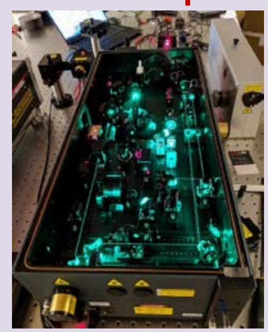
Fundamentals:

- Topological superconductivity in twisted heterostructures
- Simulating many-body physics in Moire superlattice
- Excitonic BEC condensate

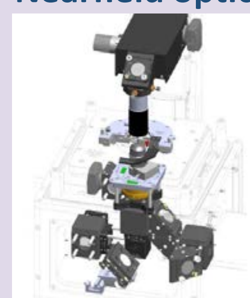


Exp techniques:

Ultrafast optics



Nearfield optics

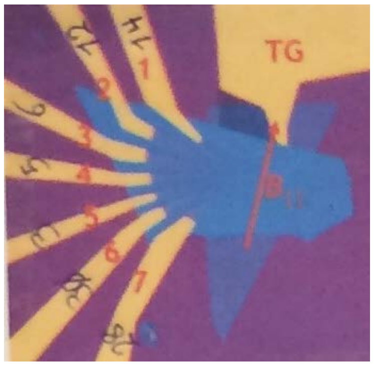


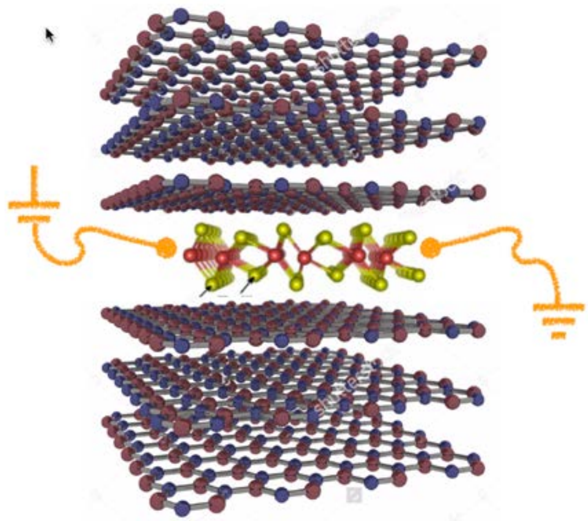
Applications:

- Bulk photovoltaic effect (photodetector without pn junction)
- Flexible optoelectronic devices

Josh Folk: Quantum Devices Group:

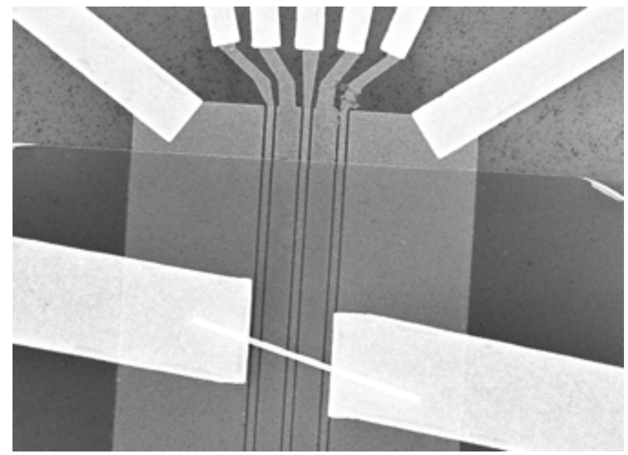
(Nano)Electronics to probe new materials,

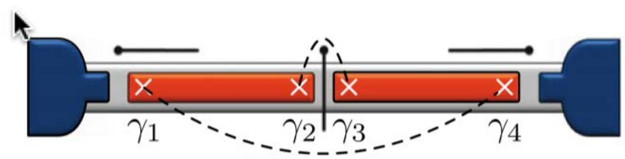




Exotic properties of monolayer WTe_2 encapsulated with boron nitride layers.

InAs nanowire device for probing Majorana fermions at the wire ends.



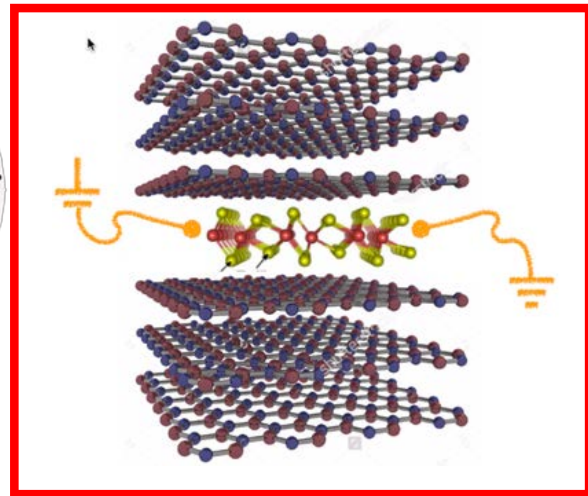


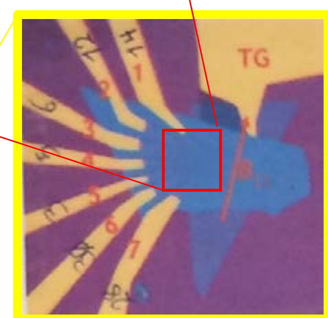
$$|0_{14}, 0_{23}\rangle = \frac{1}{\sqrt{2}}\left(|0_{12}, 0_{34}\rangle + |1_{12}, 1_{34}\rangle\right)$$

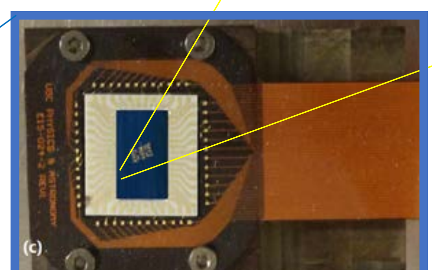
Aasen, JF et al, PRL 2016

Measuring quantum electronics

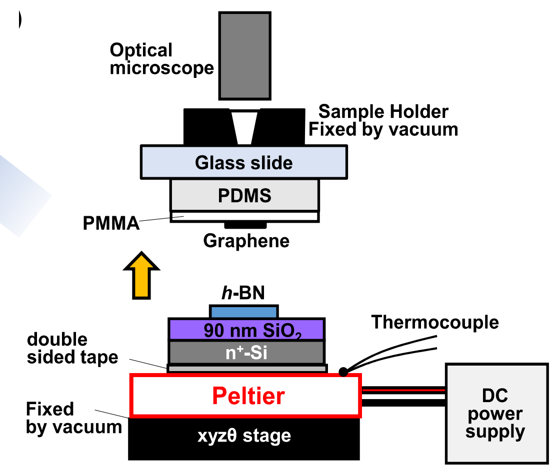
10mK







Ebeam Litho (the new JEOL)



Dry transfer technique for 2D materials

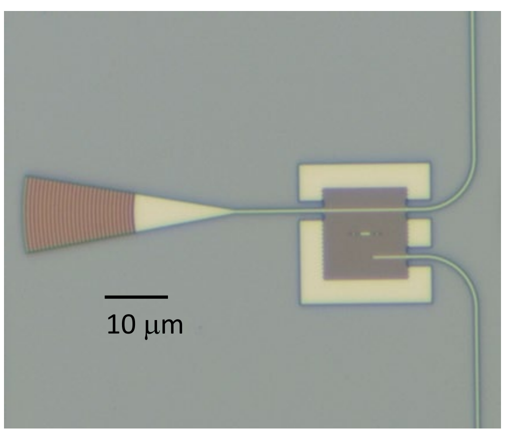
(Uwanno et al, 2D Materials, 2015)

Quantum Information Processing using Spin Qubits Embedded in Silicon Photonic Circuits: *Jeff Young (young@phas.ubc.ca)*

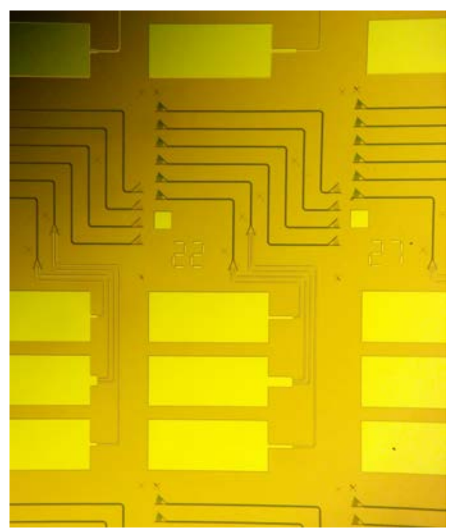
Photons used to read out and control/couple material qubits

- Direct electronic coupling of atomic-scale qubits non-trivial, especially for electrons in silicon
- Photons are “bigger”, whether localized or “flying”, so relax fabrication tolerances to 10’s of nm range
- Photons almost immune to stochastic noise (though they can be lost)

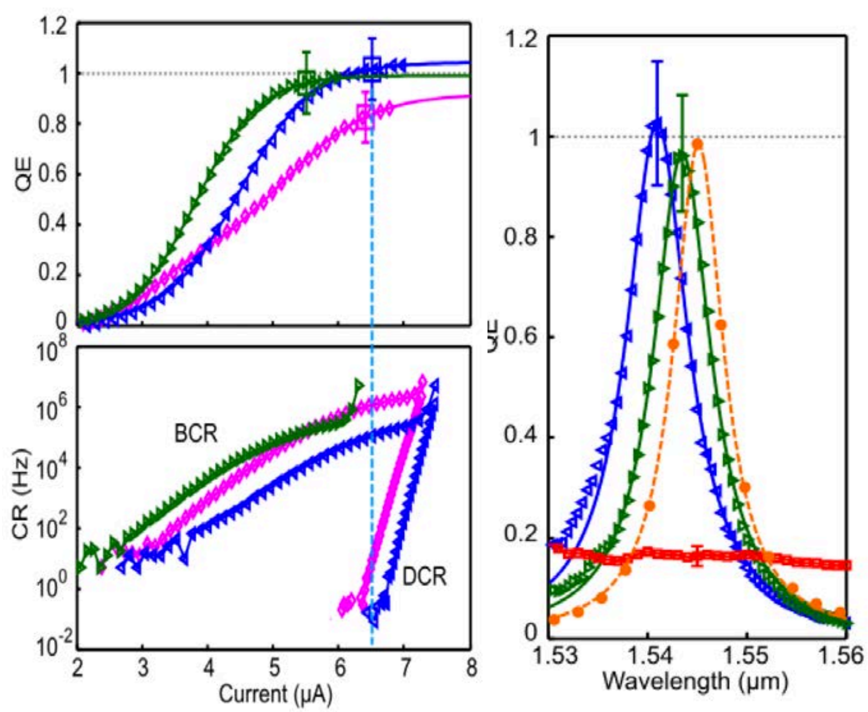
Component Design and Nanofabrication



Circuit Design and Fab

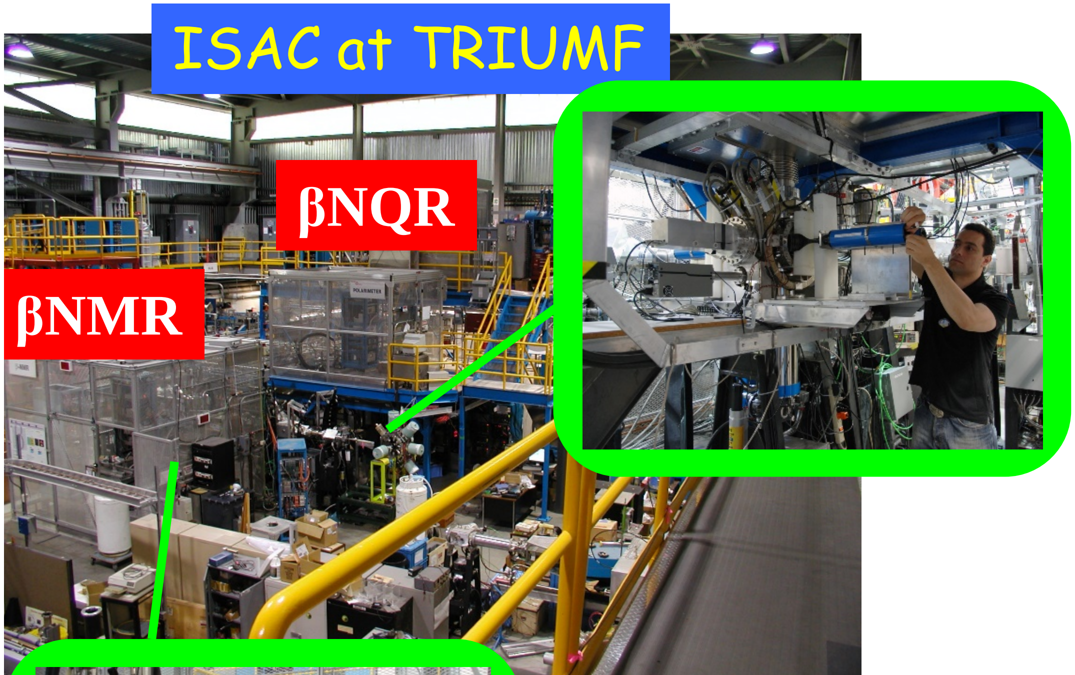


Quantum Optical Measurements



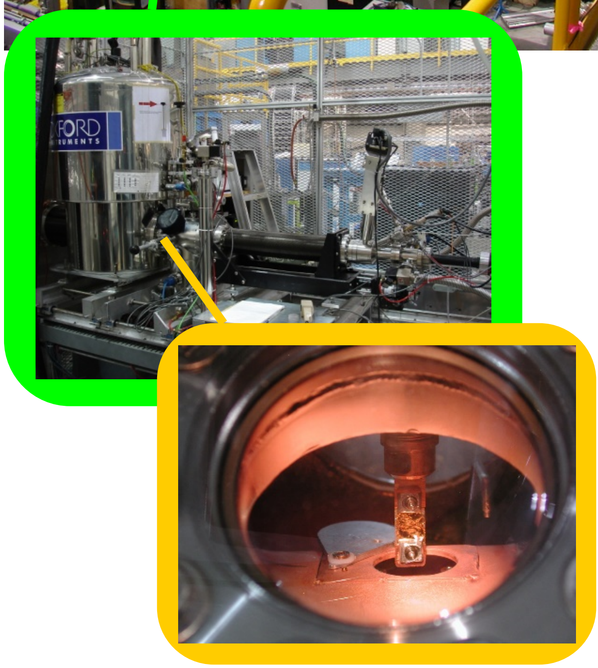
β-detected Nuclear Magnetic Resonance and μSR: Interface Effects in Solids

Andrew MacFarlane, Rob Kiefl



Electronic, magnetic and structural properties of thin films and interfaces are often very distinct compared to the bulk. Highly sensitive radioactive spin probes (β-NMR at TRIUMF, low energy μSR at PSI) are being used to explore this behaviour in:

- superconductors
- magnetic materials
- ionic conductors
- polymers
- topological insulators
- correlated electron
- catalysts …

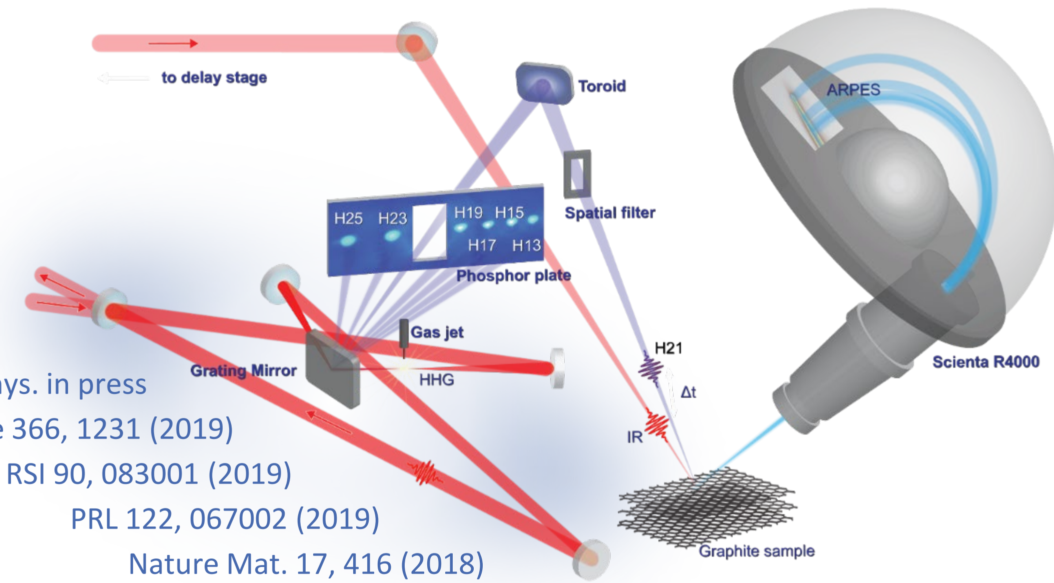


Also using the low energy muon facility at Paul Scherrer Institute (PSI) . near Zurich

QUANTUM MATERIALS IN THE TIME DOMAIN

Quantum Materials in the Time Domain

Jones-Damascelli's groups



Nature Phys. in press

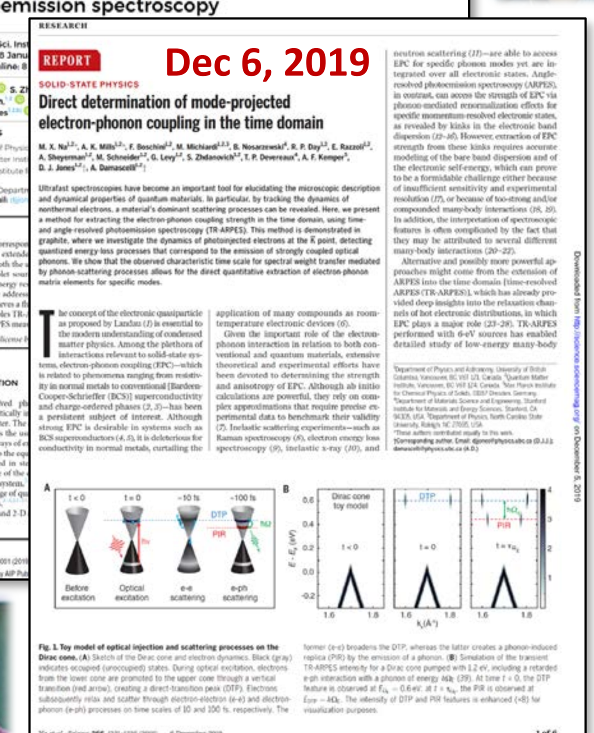
Science 366, 1231 (2019)

RSI 90, 083001 (2019)

PRL 122, 067002 (2019)

Nature Mat. 17, 416 (2018)

Meng Xing (Ketty) Na


Review of Scientific Instruments
ARTICLE
scitation.org/journal/rsi
Cavity-enhanced high harmonic generation for extreme ultraviolet time- and angle-resolved photoemission spectroscopy

RESEARCH
REPORT
SOLID-STATE PHYSICS
Direct determination of mode-projected electron-phonon coupling in the time domain

Dec 6, 2019

Art Mills

CFI FCI

GORDON AND BETTY MOORE FOUNDATION

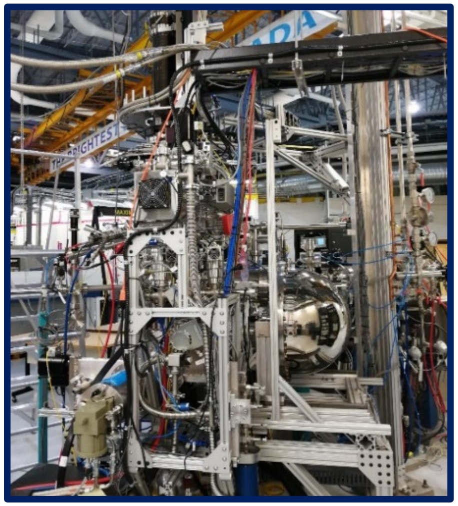
CIFAR

Stewart Blusson Quantum Matter Institute

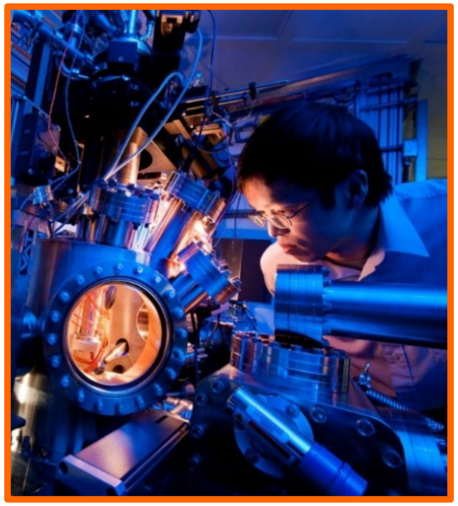
UBC

ARPES AND REIXS USERS' FACILITIES

SBQMI Beamlines @ Canadian Light Source



QMSC: Quantum Materials Spectroscopy Centre



REIXS: Resonant Elastic & Inelastic X-ray Scattering

Sawatzky-Damascelli-Zou-Green-Keimer's groups

CFI FCI

Canadian Light Source