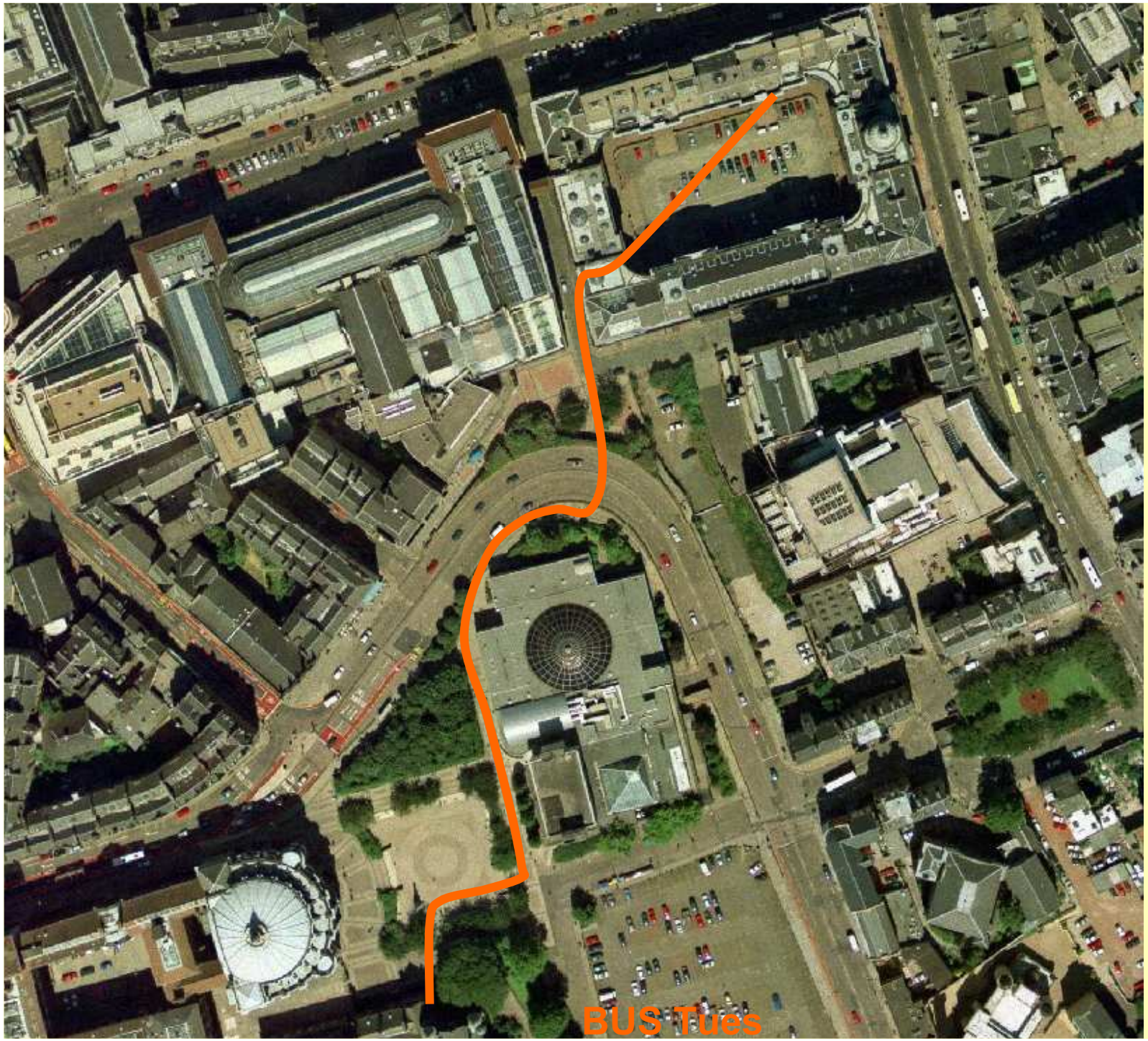
Welcome:

Practical Organisation

What is PPARC?

The Big Questions of PPARC Science

John Peacock University of Edinburgh



There is such a thing as a free lunch –

Teviot House

but not on Friday

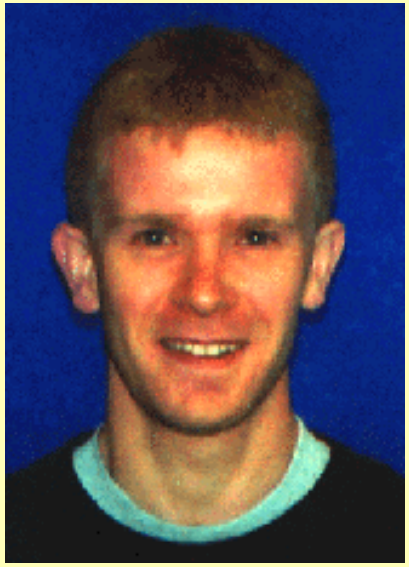
Tuesday afternoon: tour of the Royal Observatory

and some work, with a whisky tasting as reward

Thursday evening: Banquet and Ceilidh at Dynamic Earth

Organisers

John Peacock



David Bacon

Liz Gibson

Nathalie Dupin

Philip Best

Peredur Williams

Tom Targett

Why are you here?

Original idea: teach astronomy to physicists

Now: also learn about the diversity of PPARC Science

- **What is PPARC anyway?**
- **What does it try to achieve?**

PPARC

Until 1994, the Science & Engineering Research Council funded all kinds of scientific research in UK universities - then split up into many independent parts

Particle Physics & Astronomy = not commercial?

Budget £230 Million per year:

- **£120M International Subscriptions (CERN, European Space Agency, European Southern Observatory)**
- **188 X 3 PhD students (£9M)**

Student numbers set to aid 'knowledge economy'

- **cf. 5-10 UK astronomy lectureships in a good year**
- **but many more support jobs and jobs abroad**
- **about 50% of students still 'in astronomy' 8 years post-PhD**

CERN

from 2007: Large Hadron Collider – Higgs & Supersymmetry search

esa

European Space Agency

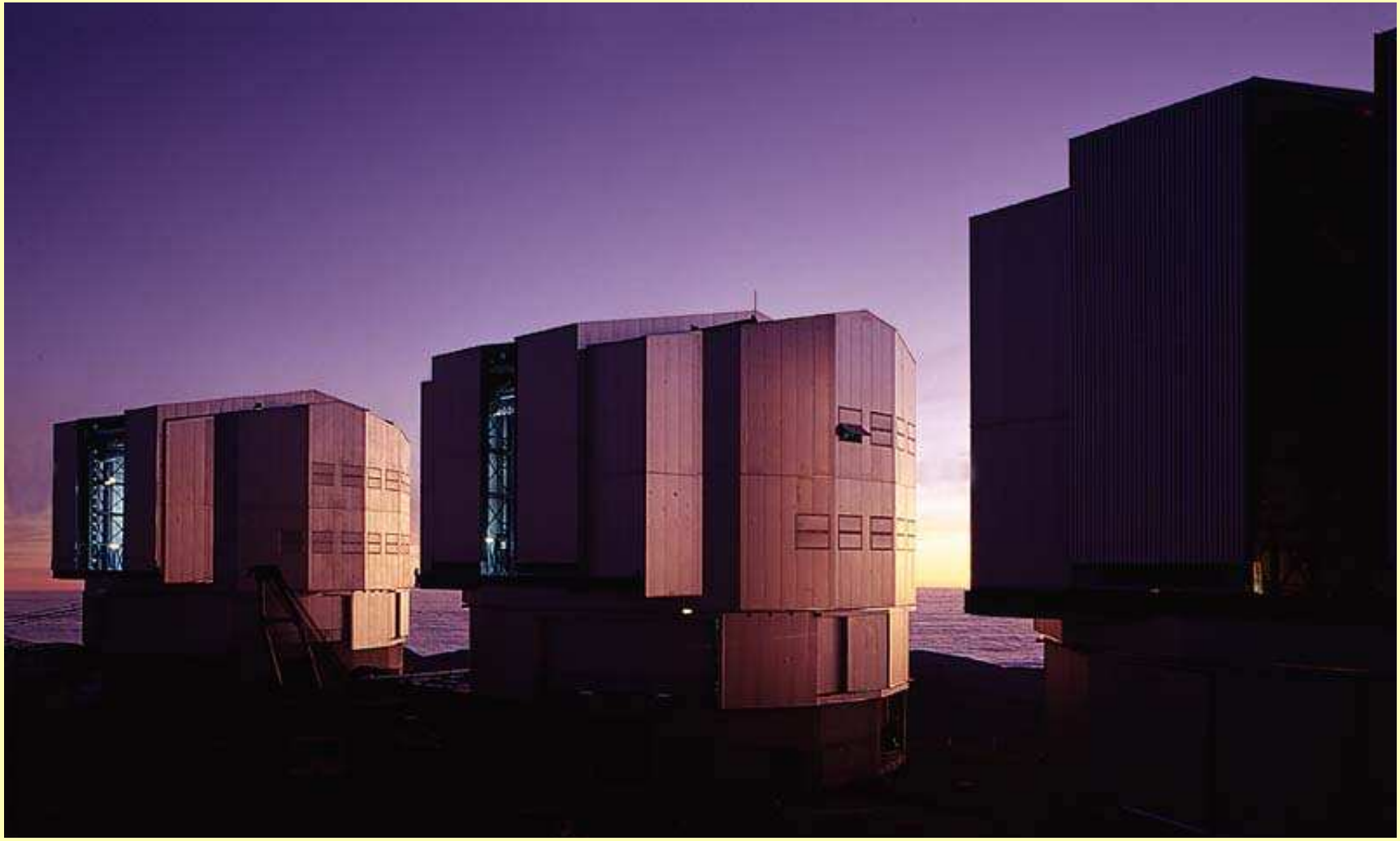
Launchers – Ariane 3

Observatories – e.g. XMM/Newton X-ray

Planetary exploration – e.g. Cassini/Huygens

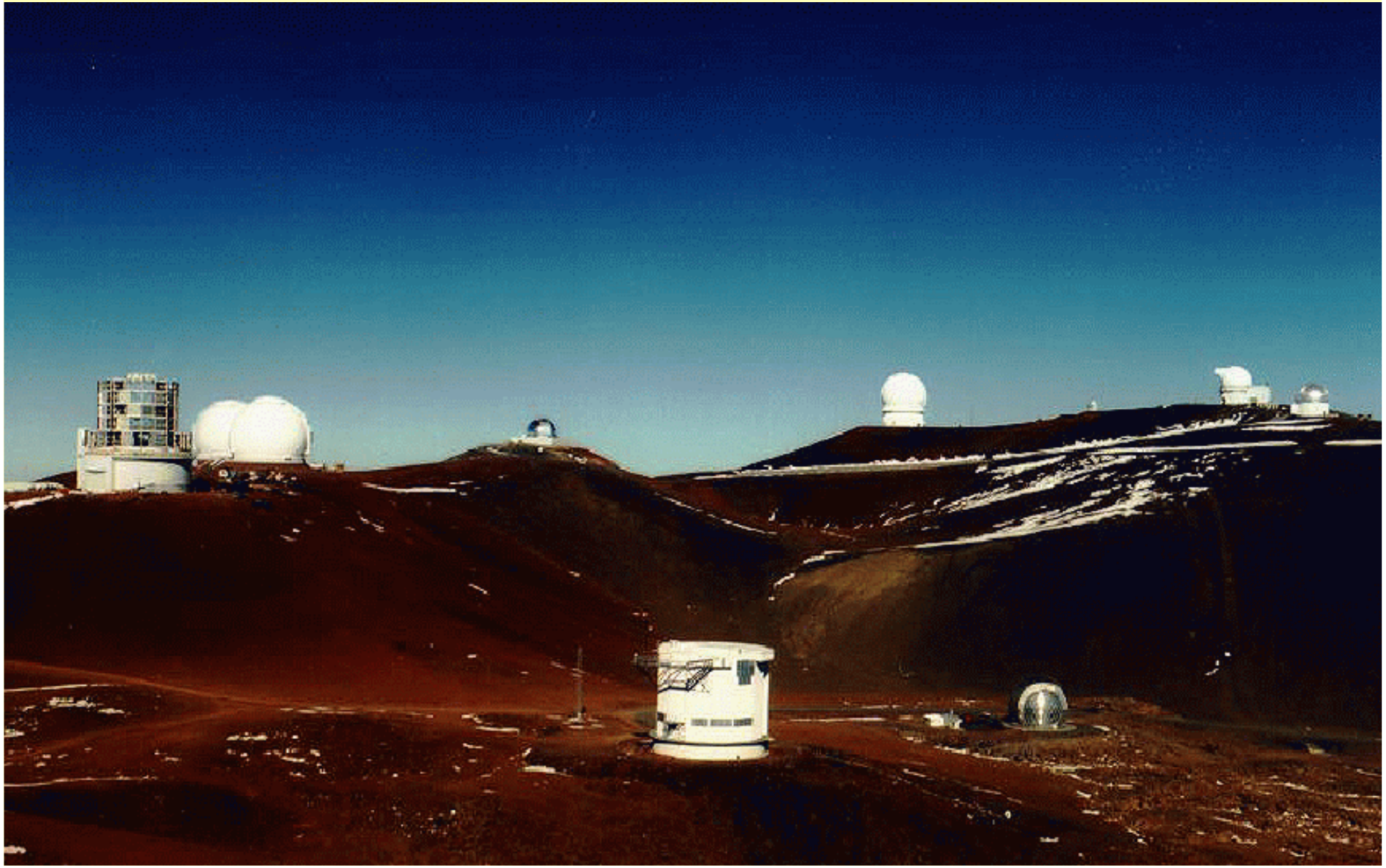
Fundamental physics – e.g. Planck CMB

ESO

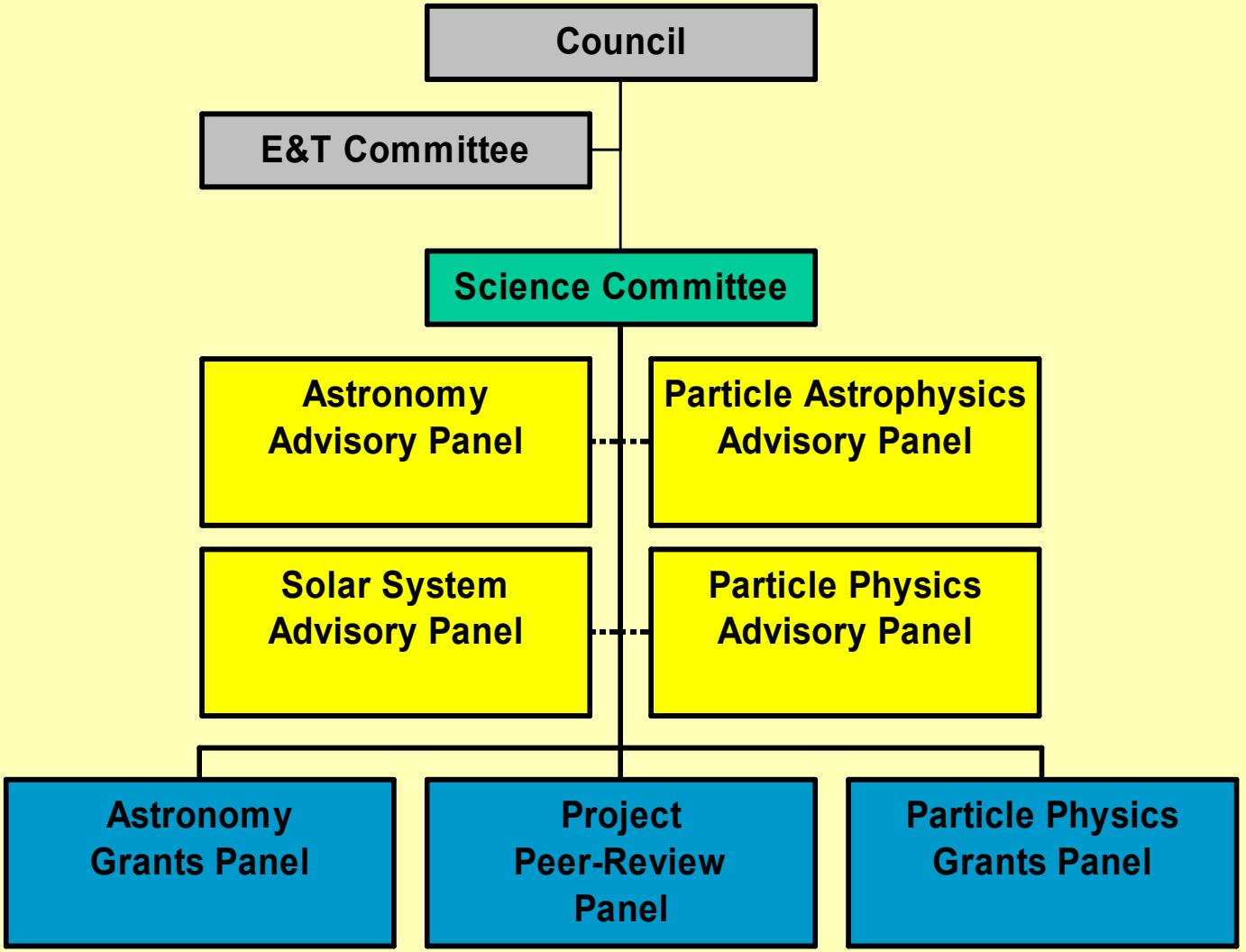


World’s largest optical/IR telescope: 4X8m VLT in Chile

Many other telescopes



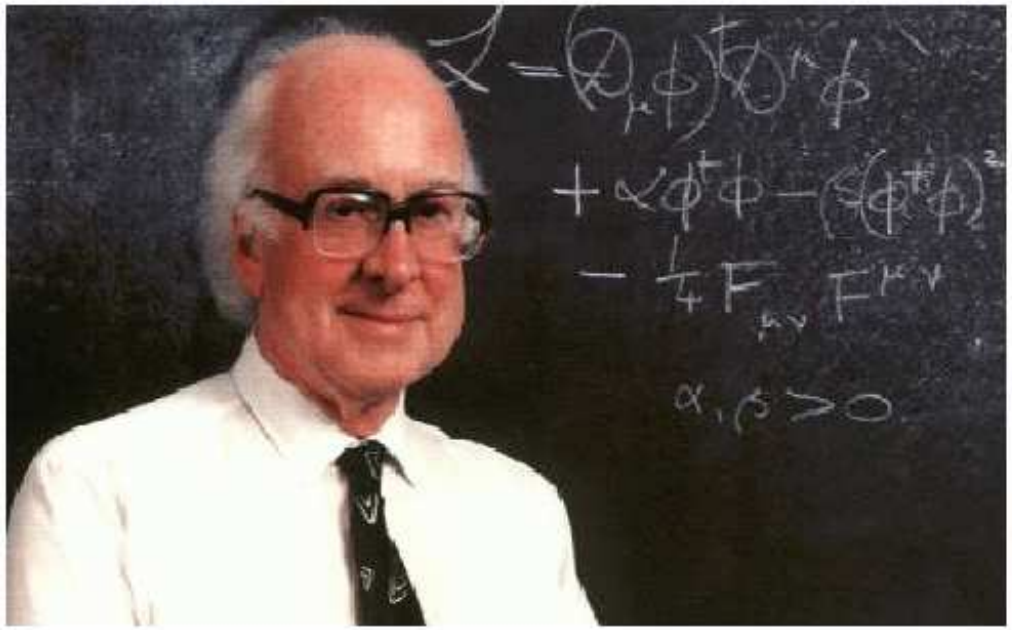
The science: divide & rule



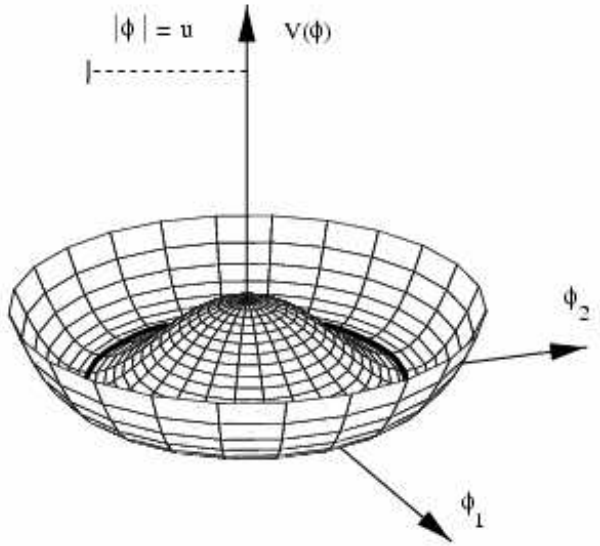
Particle Physics Themes

- The origin of mass
- The properties of neutrinos
- The properties of the strong interaction
- The origin of the matter-antimatter asymmetry in the universe
- The unification of particles and forces including gravity

The origin of mass



Peter Higgs (1929 -)



Unobservability of quantum phase ⇒ no massive particles. Higgs (1964): allowed only if there is a new boson. Key target for LHC (presently m>130 GeV)

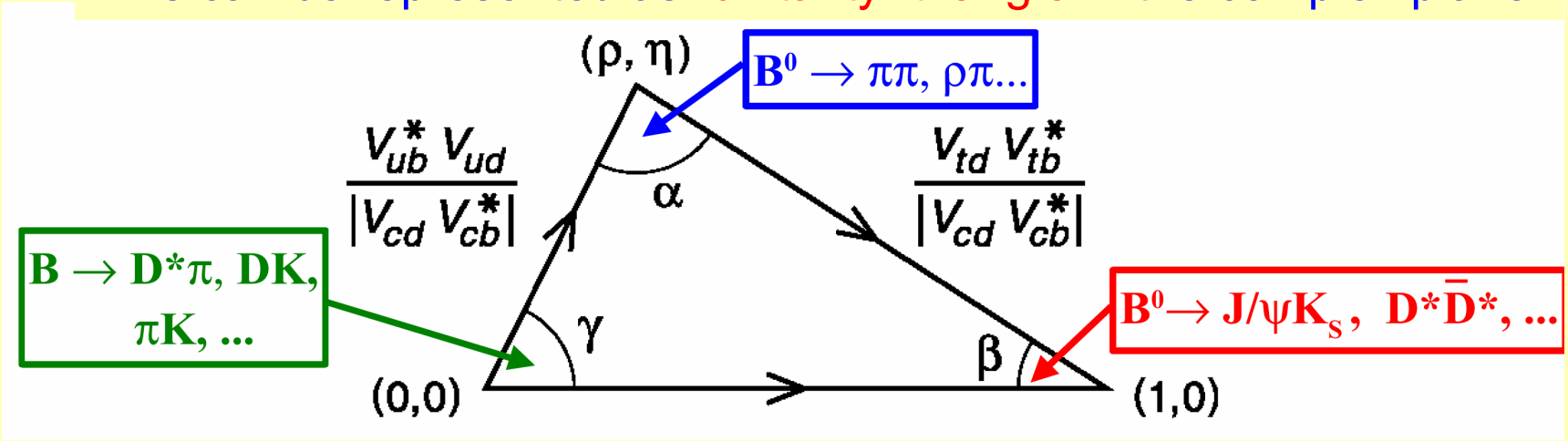
Quark Mixing and CP violation

Quarks are not pure energy states, leading to CP-violation (particle-antiparticle asymmetries). These may be related to the matter – anti-matter asymmetry in the Universe.

$$V = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} = \begin{pmatrix} 1-\frac{1}{2}\lambda^2 & \lambda & A\lambda^3(\rho-i\eta) \\ -\lambda & 1-\frac{1}{2}\lambda^2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + O(\lambda^4)$$

Unitarity of V is required in the Standard Model

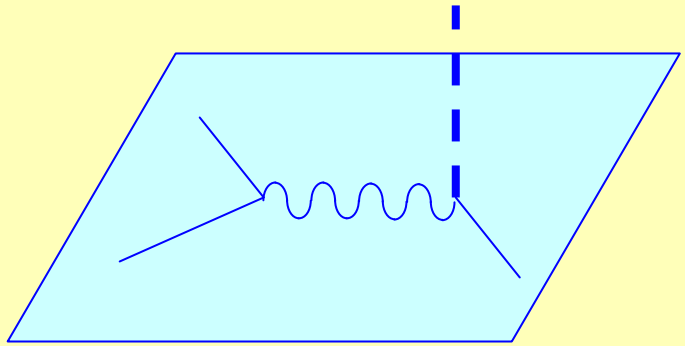
This can be represented as "unitarity" triangle in the complex plane



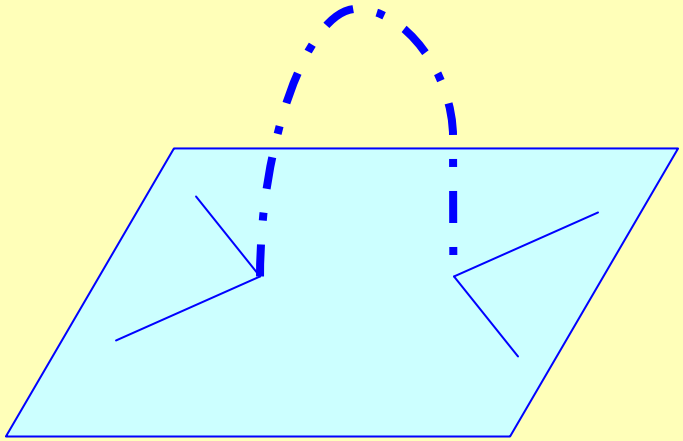
Beyond the Standard Model

- **String theory (or M-theory) provides a framework that unifies gravity with the other 3 forces, naturally incorporating as different facets of the same underlying structure: supergravity, supersymmetric quantum field theory and 'brane' physics.**

- **Quantum gravity / extra dimension effects could even be manifest at the TeV scale.**



Giudice, Ratazzi, Wells
(hep-ph/9811291)



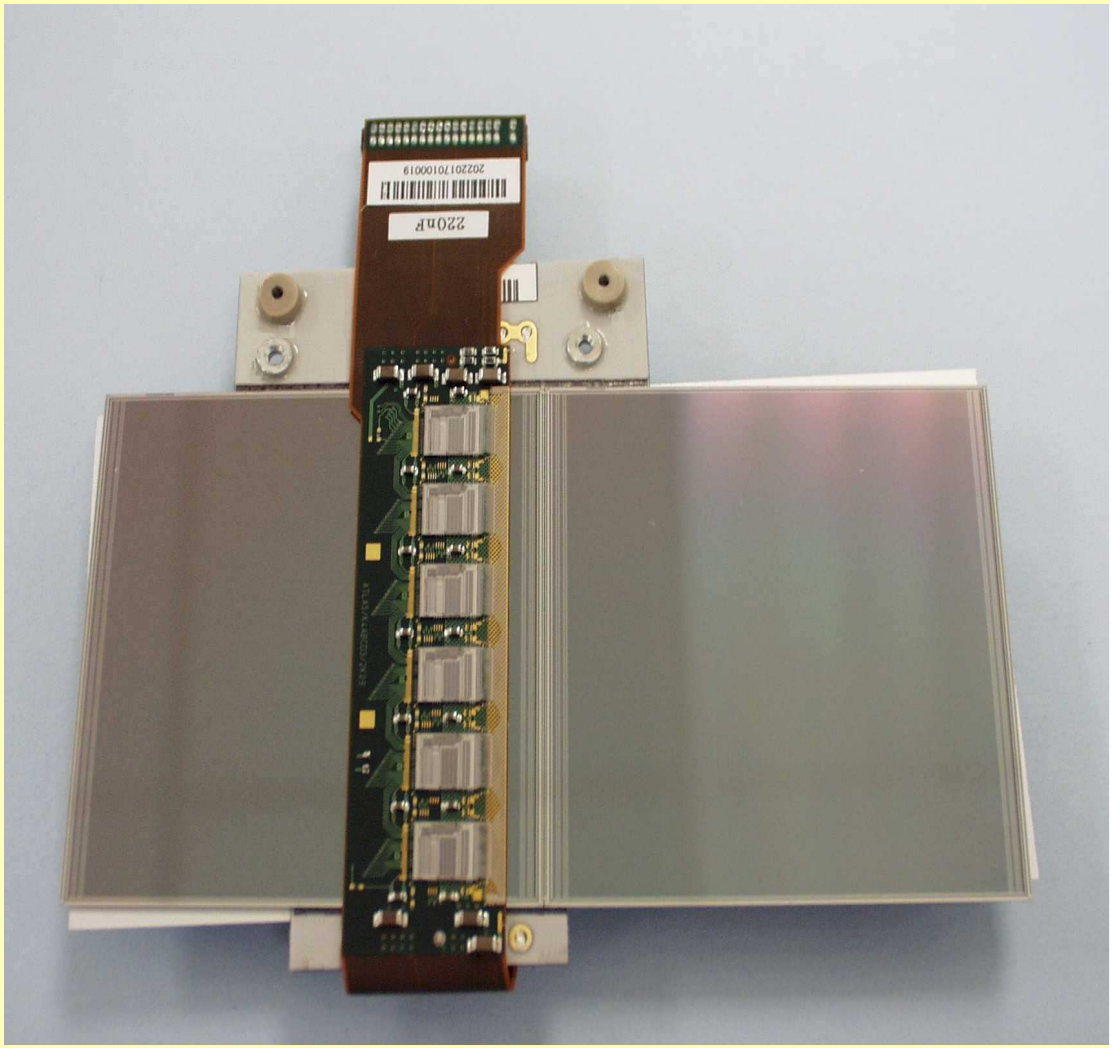
Hewett (hep-ph/9811356)

CERN: Experiments Under Construction

At the Large Hadron Collider, ATLAS and CMS are being built by large international collaborations with the ability to find the Higgs (and much more) in the range 0.1TeV < m_H < 1TeV

The ATLAS experiment, for example, is 46m long, stands 22m high, weighs 7000 tons and has 200 million read-out channels.

The ATLAS collaboration involves 13 UK institutes, with prime responsibility for the silicon detector based central tracking and the event triggers.



The LHC General Purpose Detectors

- The complexity of the accelerator and the experiments is truly unprecedented
- For example, the silicon tracking systems have to be two orders of magnitude larger than those at previous generation experiments
- Irradiation doses will be as high as many tens of Mrads with integrated neutron fluences up to 10^{15}n/cm^2
- The UK is involved in many of the most demanding and high technology sub-systems.

The CMS Experiment Under Construction at CERN

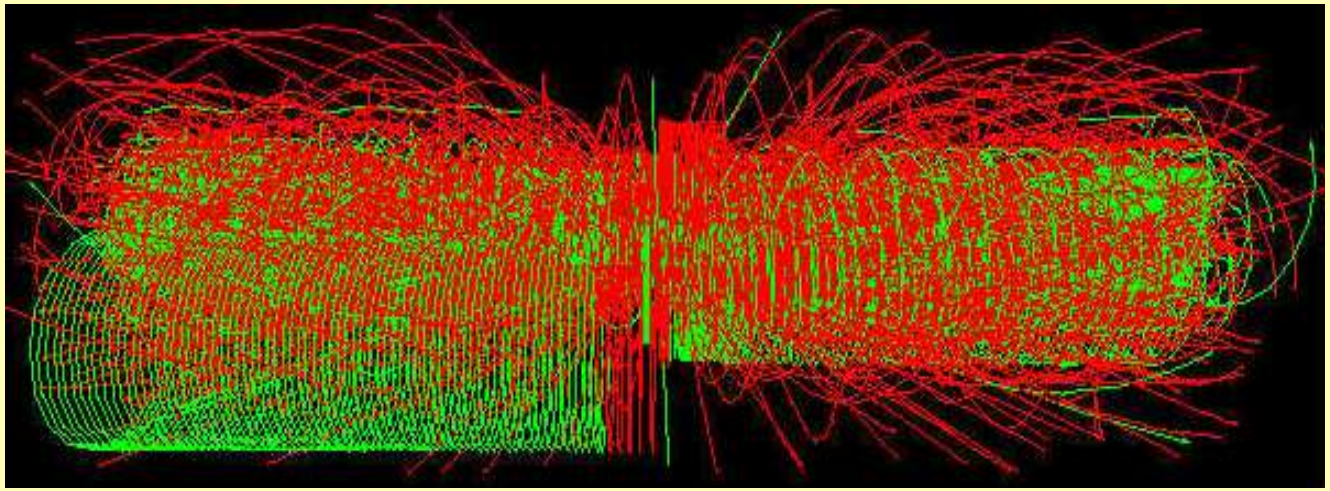
LHC pp collisions at 14 TeV

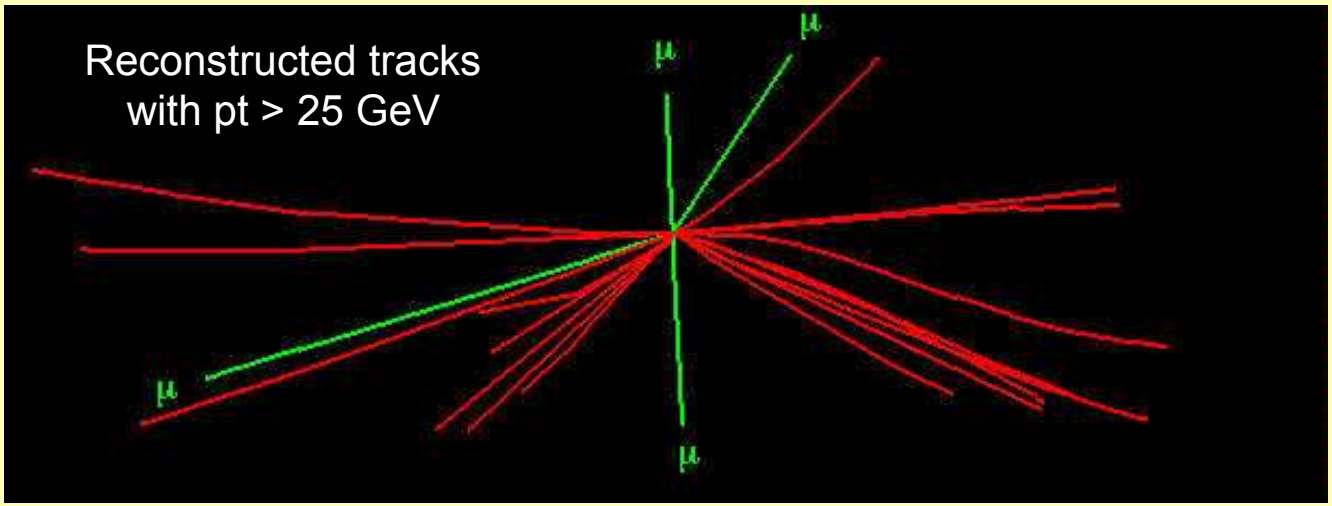
- 20 events overlapping in each beam-crossing
- $H \rightarrow ZZ \quad Z \rightarrow \mu\mu$

$H \rightarrow$ 4 muons:

the cleanest ("golden") signature

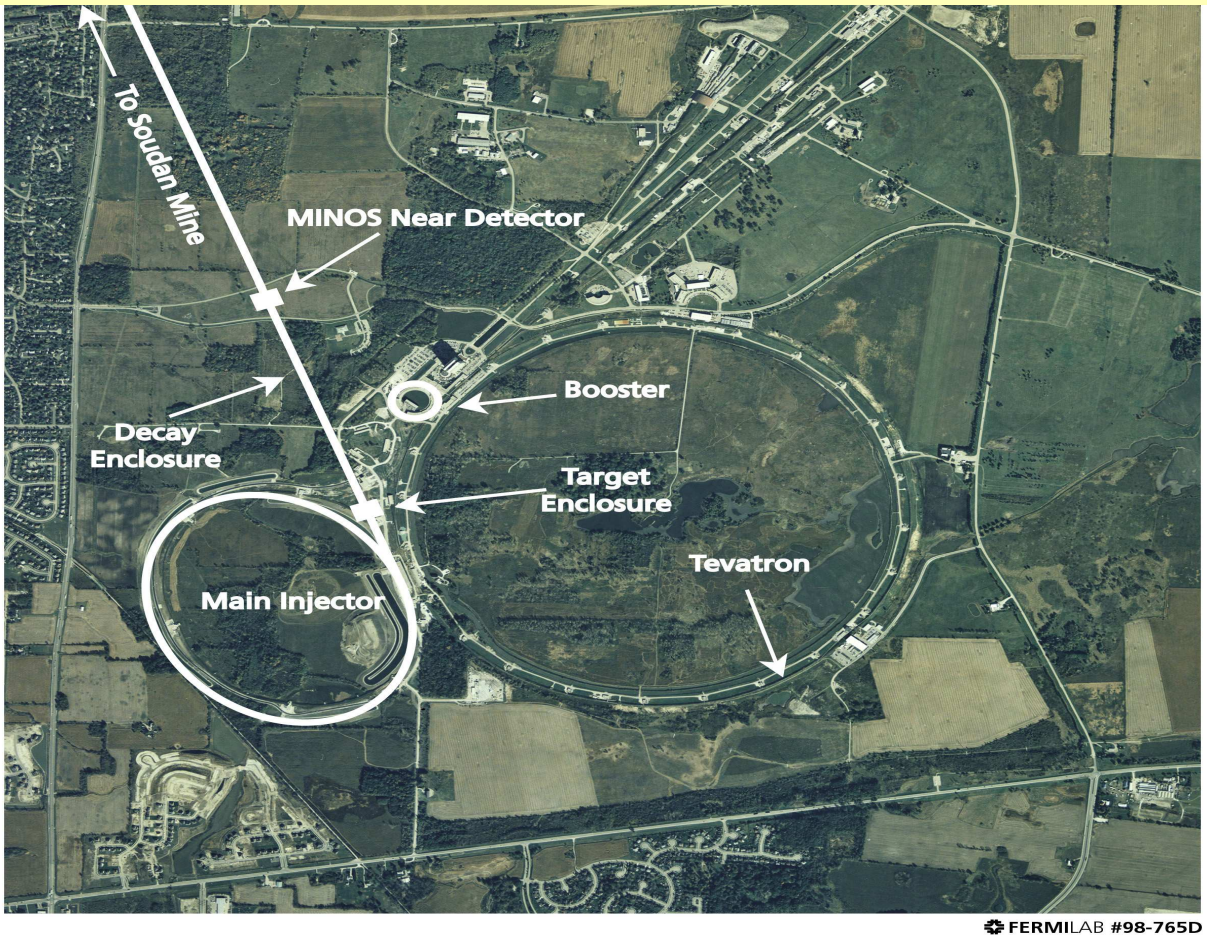
And this (not the H though…) repeats every 25 ns…





Neutrino mixing

Like quarks, neutrinos mix. Over large baselines, neutrinos ‘oscillate’ in type - seen in neutrinos from the sun and terrestrial experiments

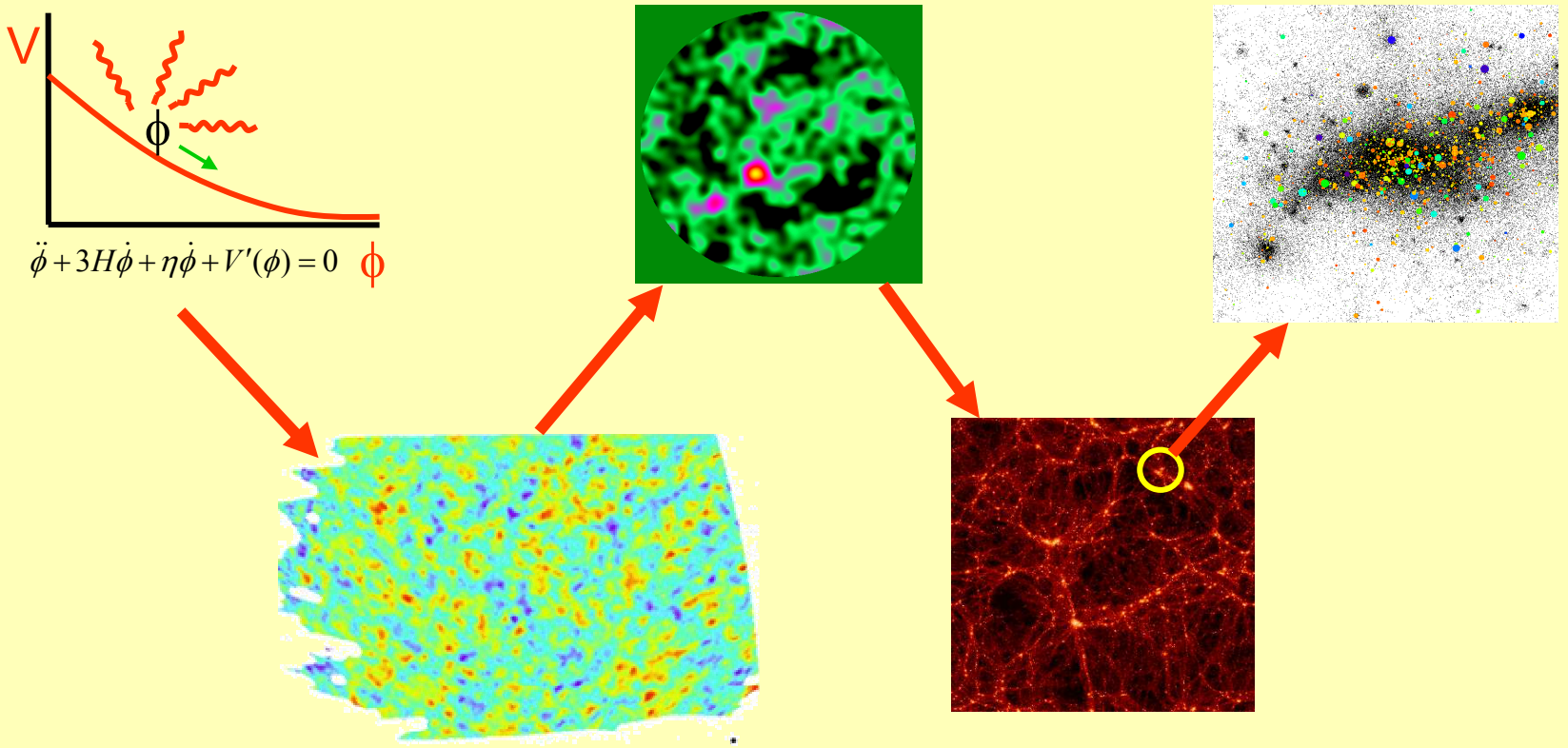


MINOS

Astronomy Themes

- Cosmology
- The formation and development of galaxies
- The formation of stars and planetary systems
- Extreme environment astrophysics

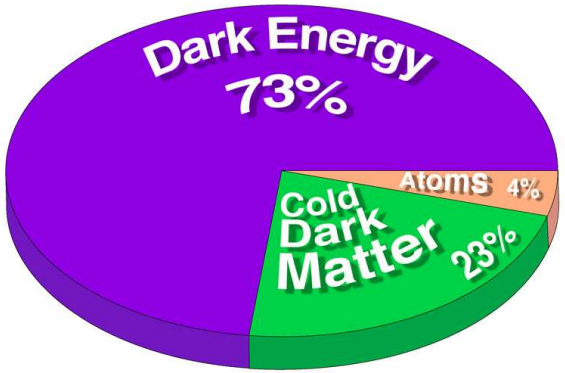
Cosmology



A standard model: early quantum fluctuations perturb a universe containing 5:1 Cold Dark Matter : baryons plus vacuum energy

Testable by observing microwave background, high-redshift galaxies, large-scale clustering, local galaxy systems

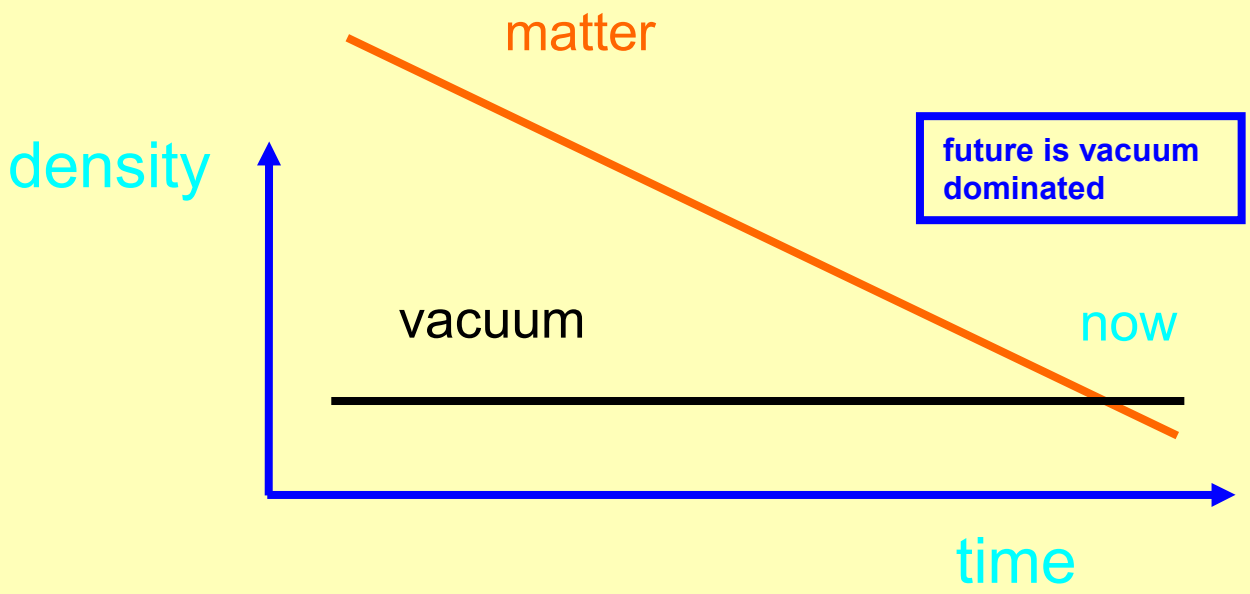
The cosmic puzzle



Why so many constituents at similar level?

What is the DM & DE?

Vacuum energy: why now?

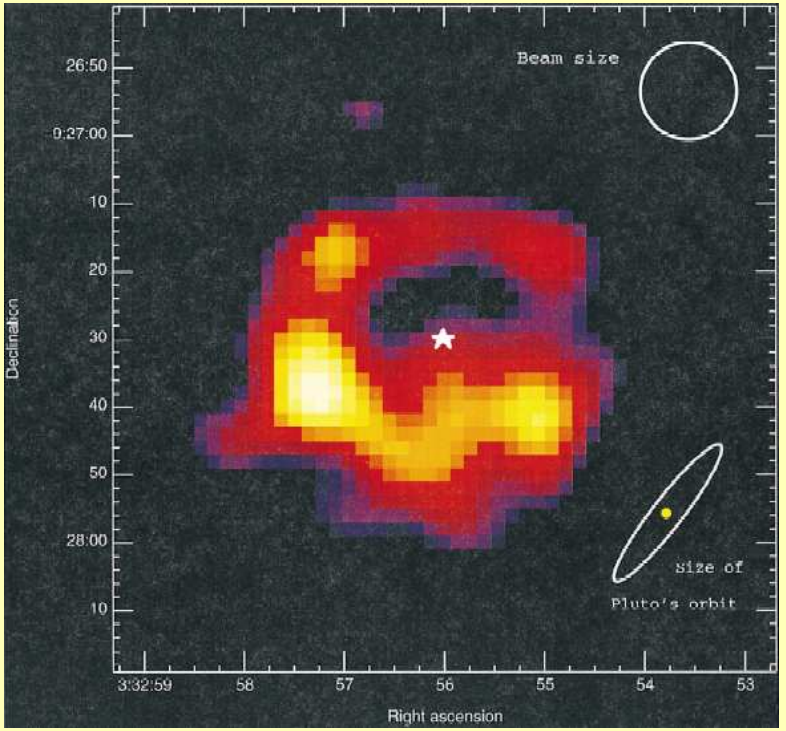


Forming Stars & Planets

Needs long-wavelengths, to pierce ubiquitous dust. Complex problem, where magnetic fields, turbulence and radiative transfer all important

Orion near-IR

Fomalhaut 850-micron disk



ALMA

The ultimate tool: 30-50 dish mm interferometer array at 5000m in the Chilean Atacama

Baselines up to 18km 0.3-9 mm.
Best resolution 0.01 arcsec

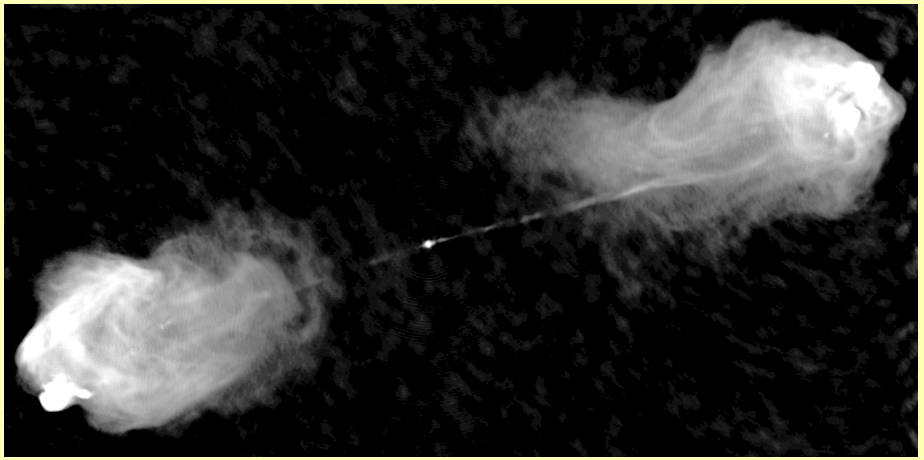
Commissioning 2007 - 2012

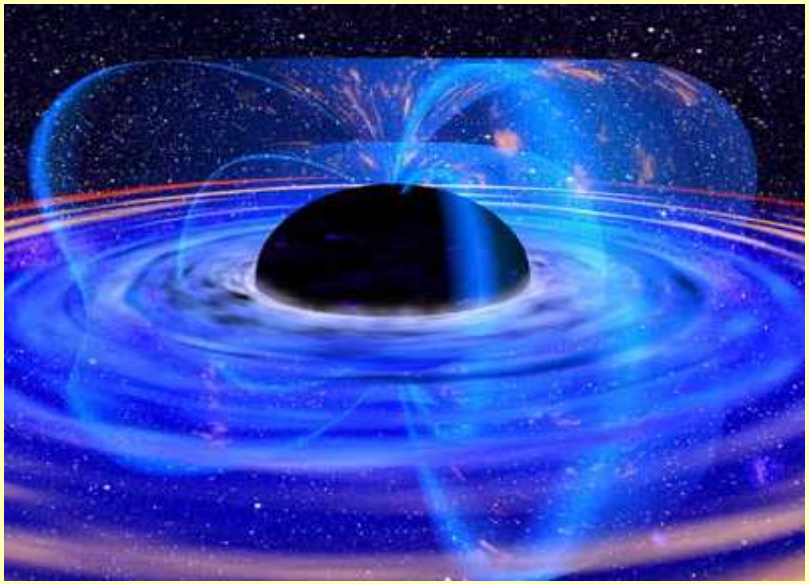
Extreme environments – black holes

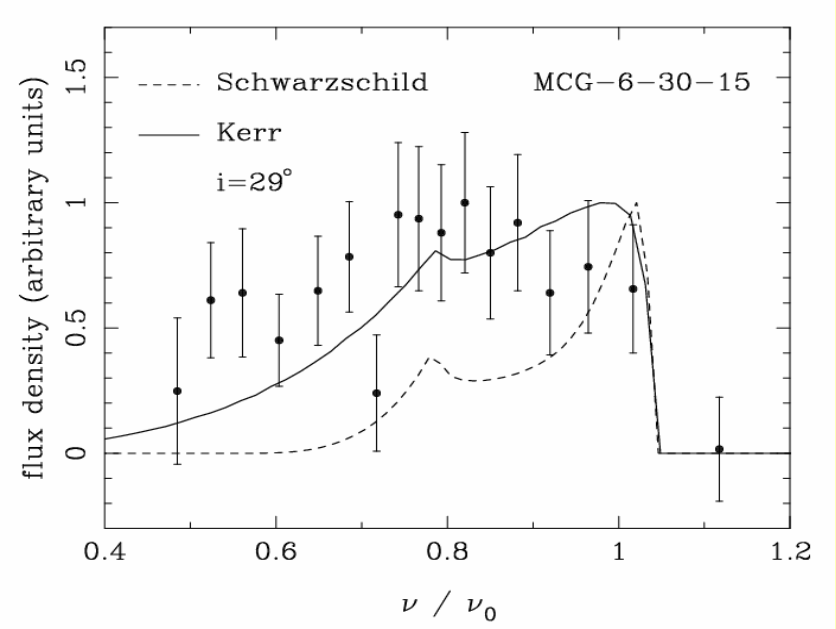
Gravity power implicated in sustaining active galaxies.

(1) Understand energy generation

(2) Probe strong gravity



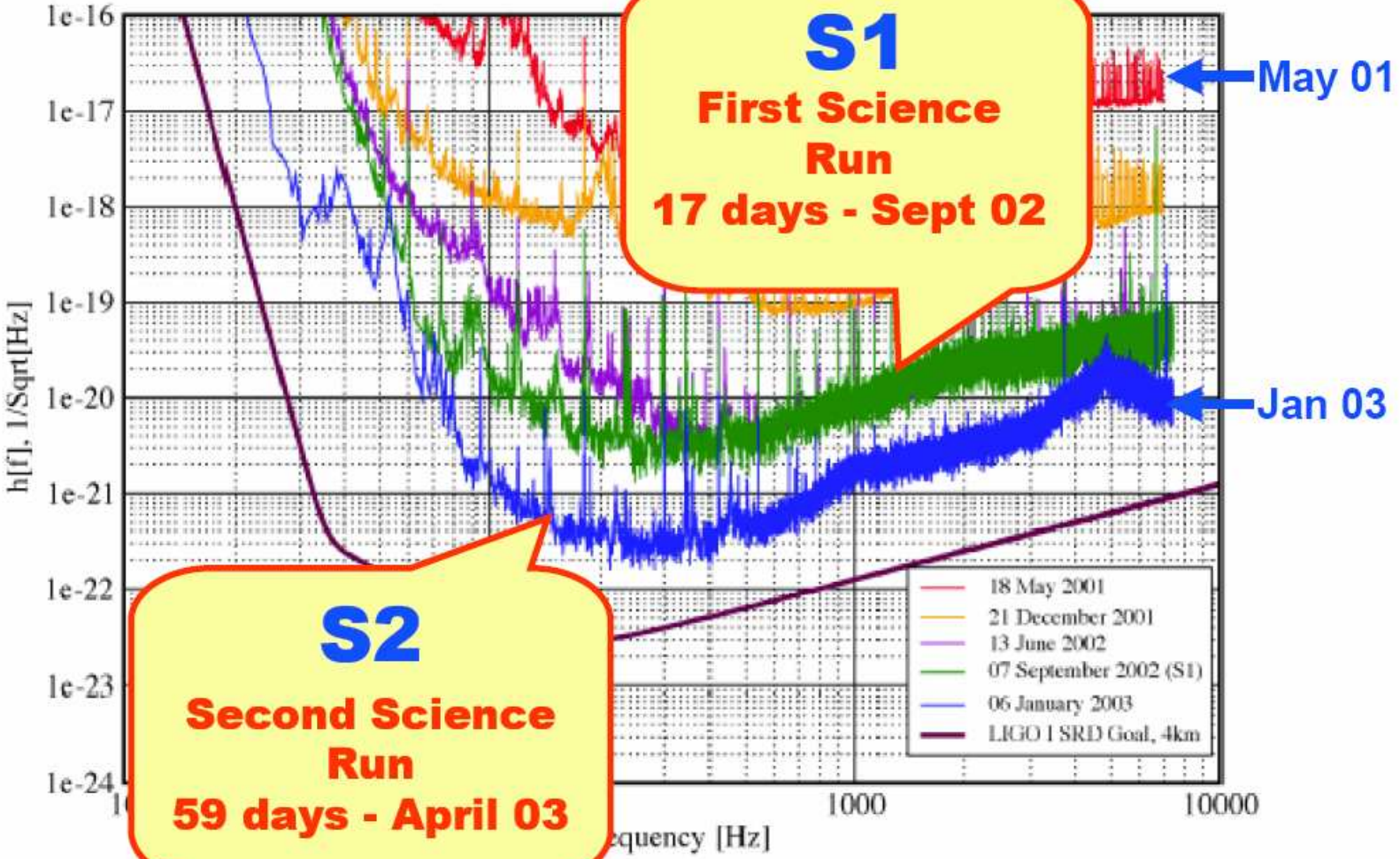




Particle Astrophysics Themes

- Gravitational waves
- Dark matter
- Cosmic microwave background radiation
- Neutrino astrophysics
- Cosmic and gamma rays
- Fundamental physics in space

LIGO Sensitivity -- L1



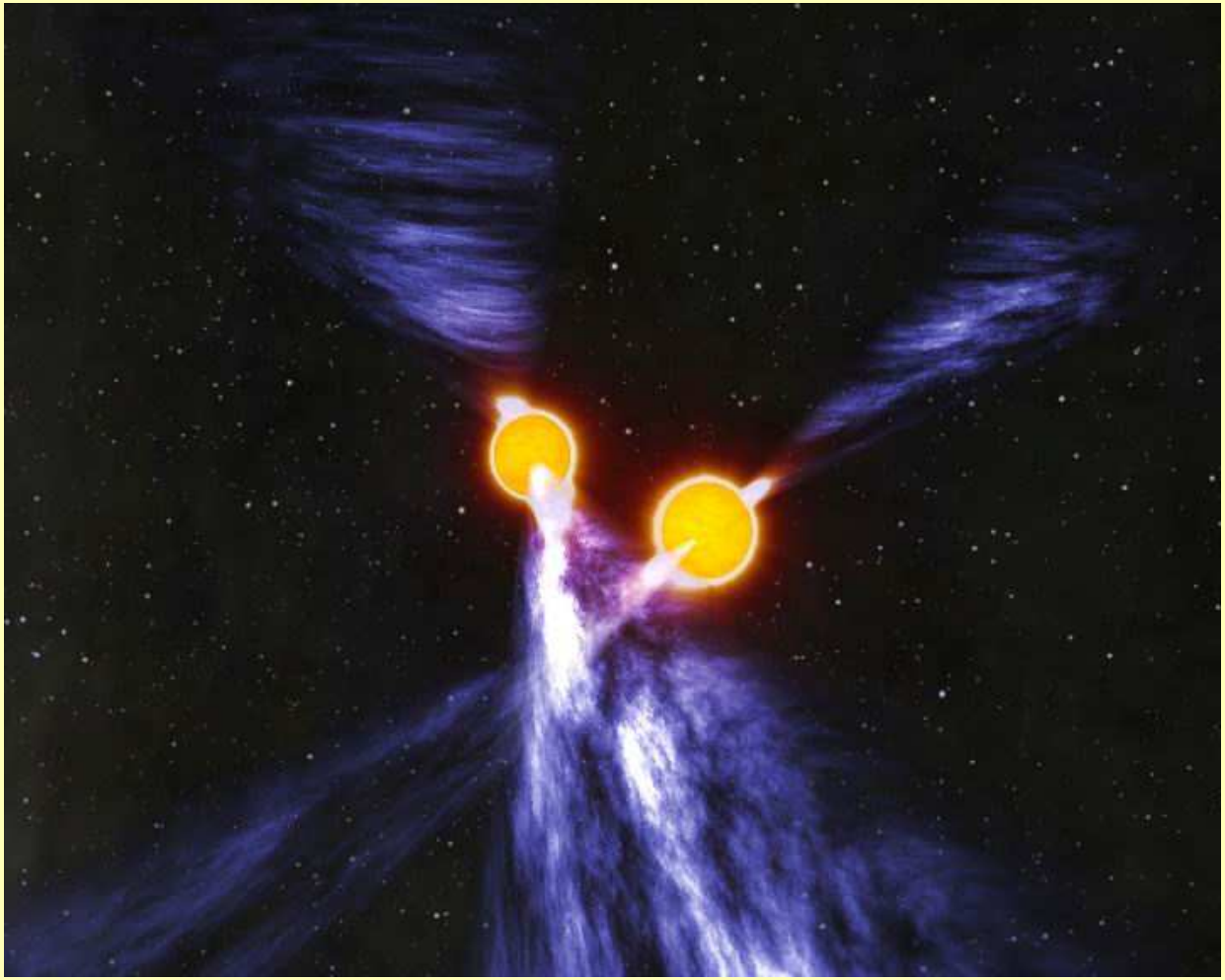
S1
First Science Run
17 days - Sept 02

May 01

Jan 03

S2
Second Science Run
59 days - April 03

Gravitational waves seen indirectly



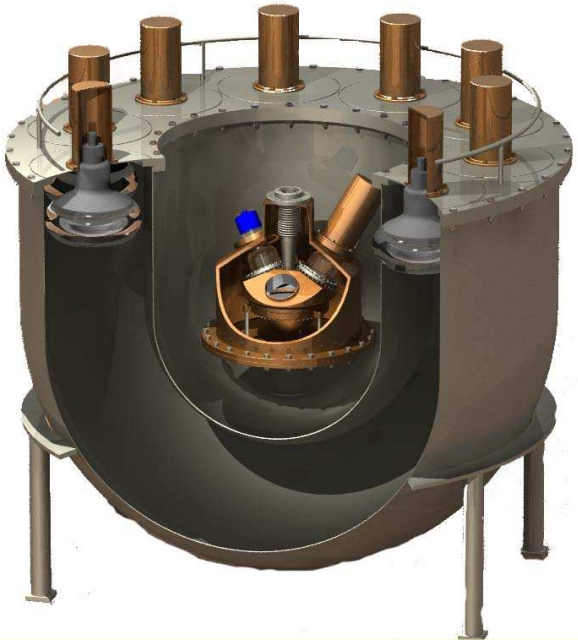
Double pulsar J0737-3039A

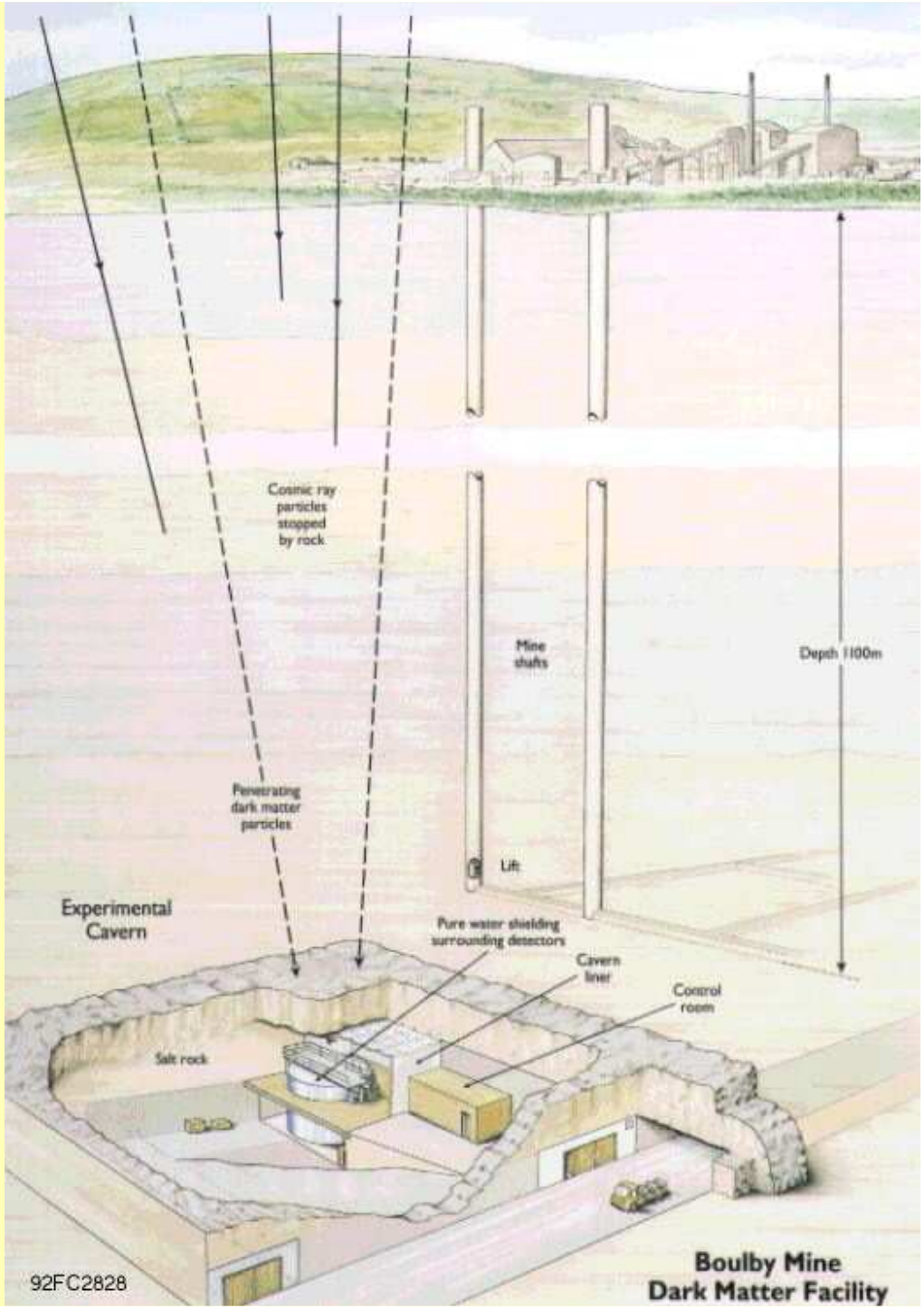
Found 2004

Joint orbital period 2.4 hours. Decay time 85Myr, as expected from GW loss

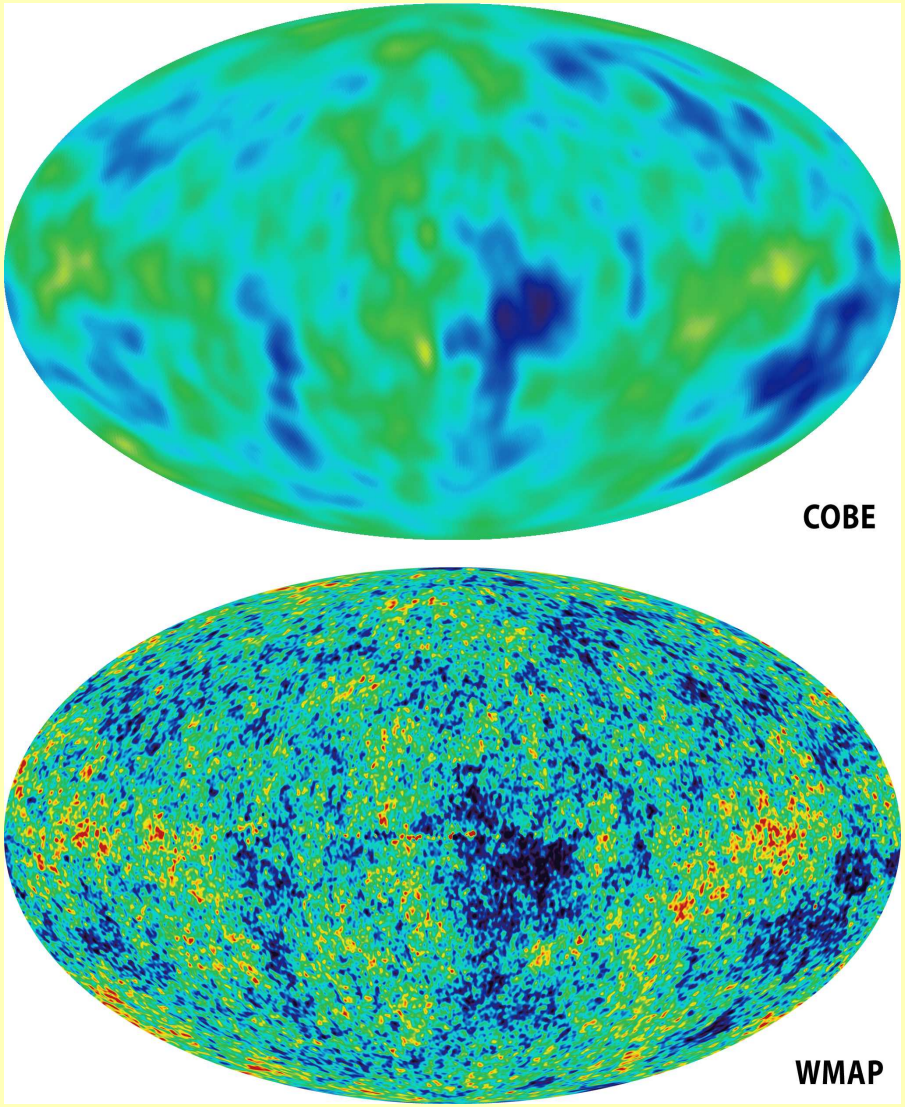
Dark matter searches

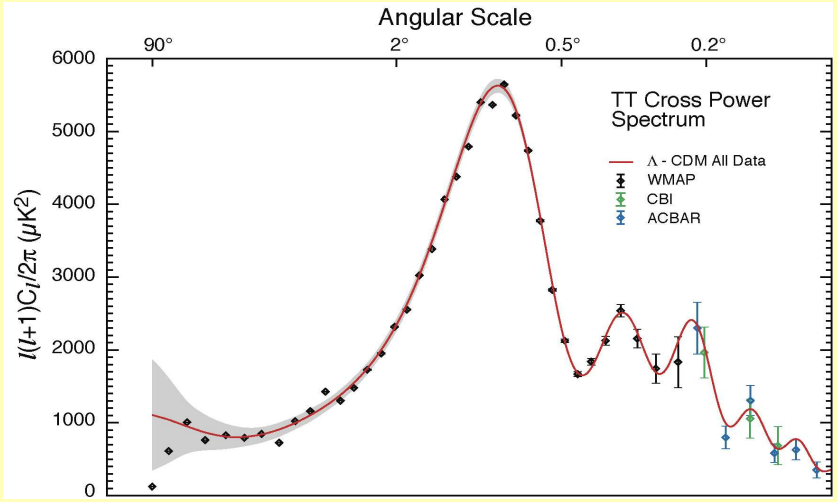
Look for nuclear recoil events in shielded deep mine environment – e.g. UKDM at Boulby





Microwave Background



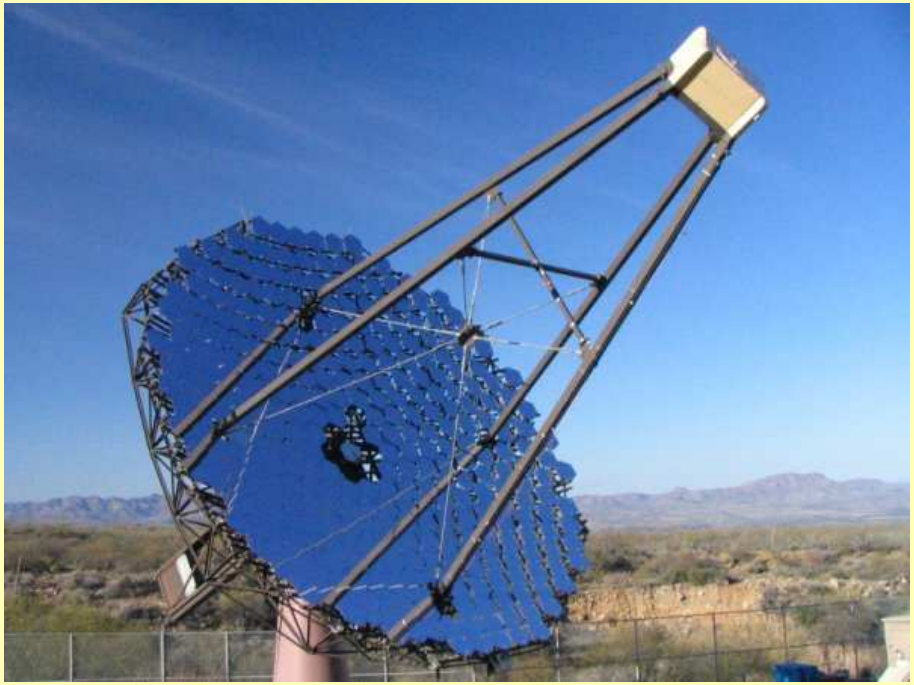


NASA's COBE & WMAP satellites mapped the young hot universe. ESA's Planck will do even better in 2007

Cosmic rays

Detect charged particles and gamma rays up to 10^{20} eV by Cerenkov light (triangulation) and shower products. New probe of acceleration mechanisms in active galaxies

Auger, Veritas, Hess



Solar System Themes

- Energy flow in the Solar System
- Understanding fundamental plasma processes
- How the interior of the Sun couples with the solar surface and atmosphere
- Formation and evolution of planets, satellites and small bodies
- The conditions that can sustain life

The active Sun

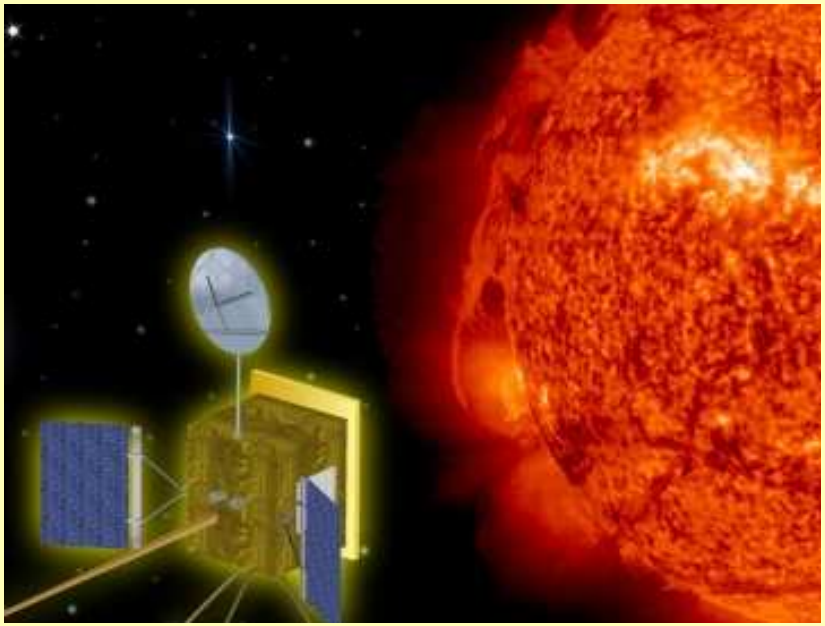
Open puzzles:

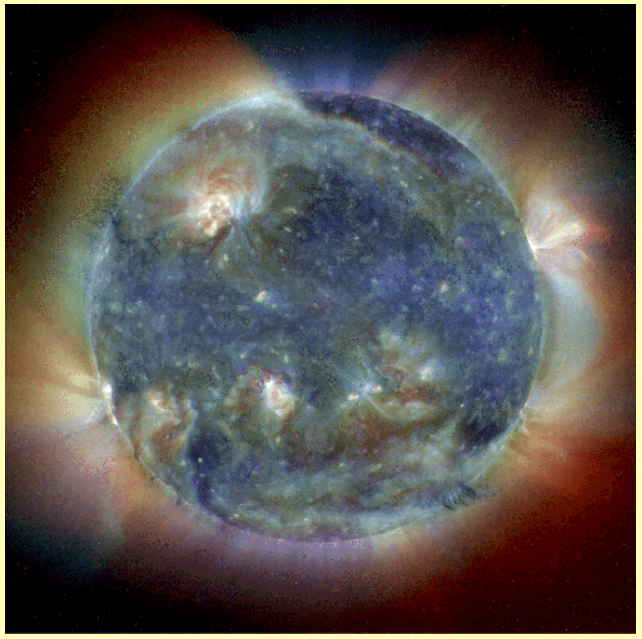
Origin of B field; 11-year cycle; heating of chromosphere; generation of solar wind

Now: SOHO

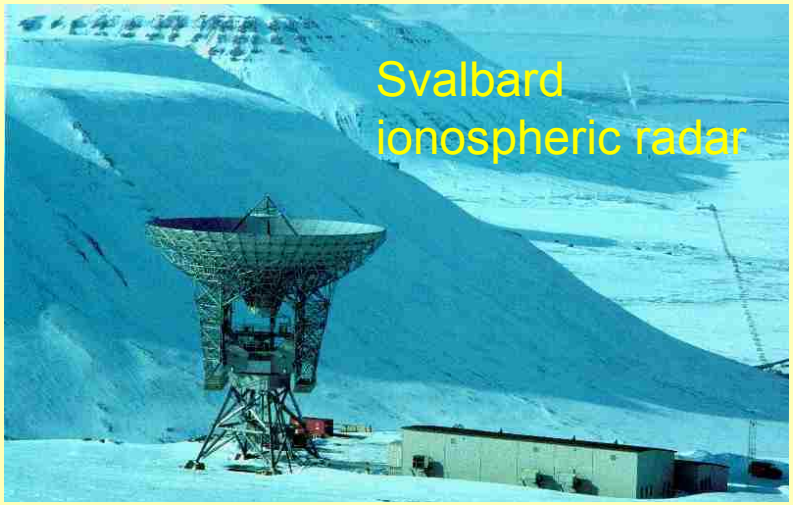
2005: STEREO

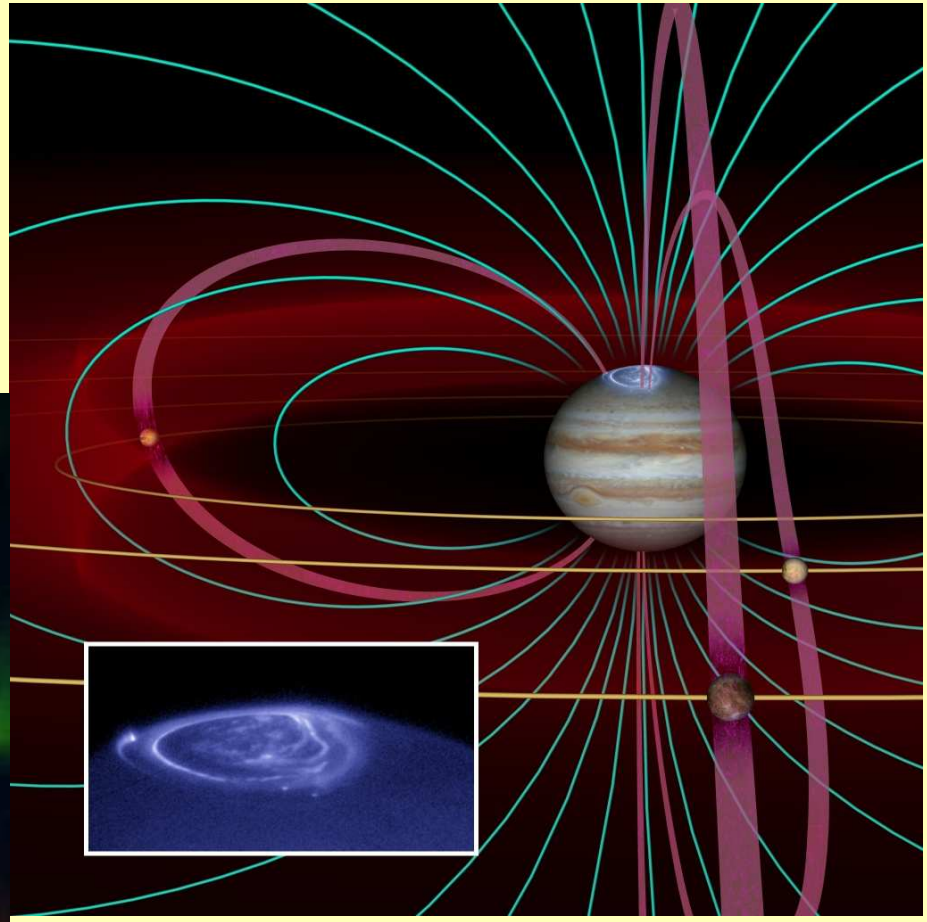
2012: Solar Orbiter





The interacting solar system





Conditions for life

Did life form on Earth or elsewhere?

Analyse meteorites, measure conditions in situ, sample returns

Beagle 2, Huygens, Rosetta (launch 2004; comet rendevous 2014)

Aurora programme: robots to Mars

Common themes

The grand vision:

The route from cosmological initial conditions to life

Turf wars:

Baryogenesis, extra dimensions, CMB, planet formation

Common techniques:

Supercomputing

The Grid (the petabyte virtual observatory)