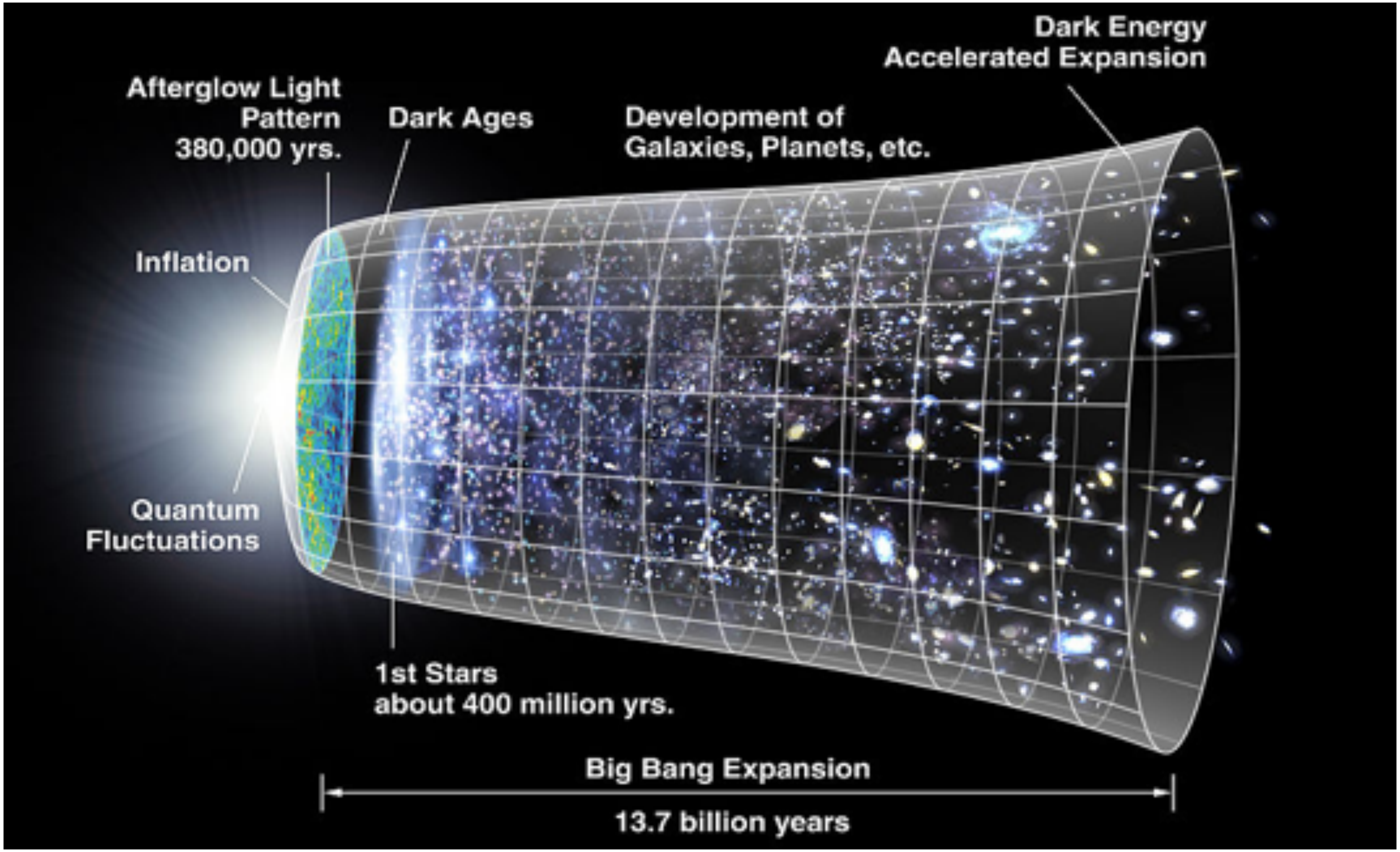


WLCG
Worldwide LHC Computing Grid

HSF
HEP Software Foundation

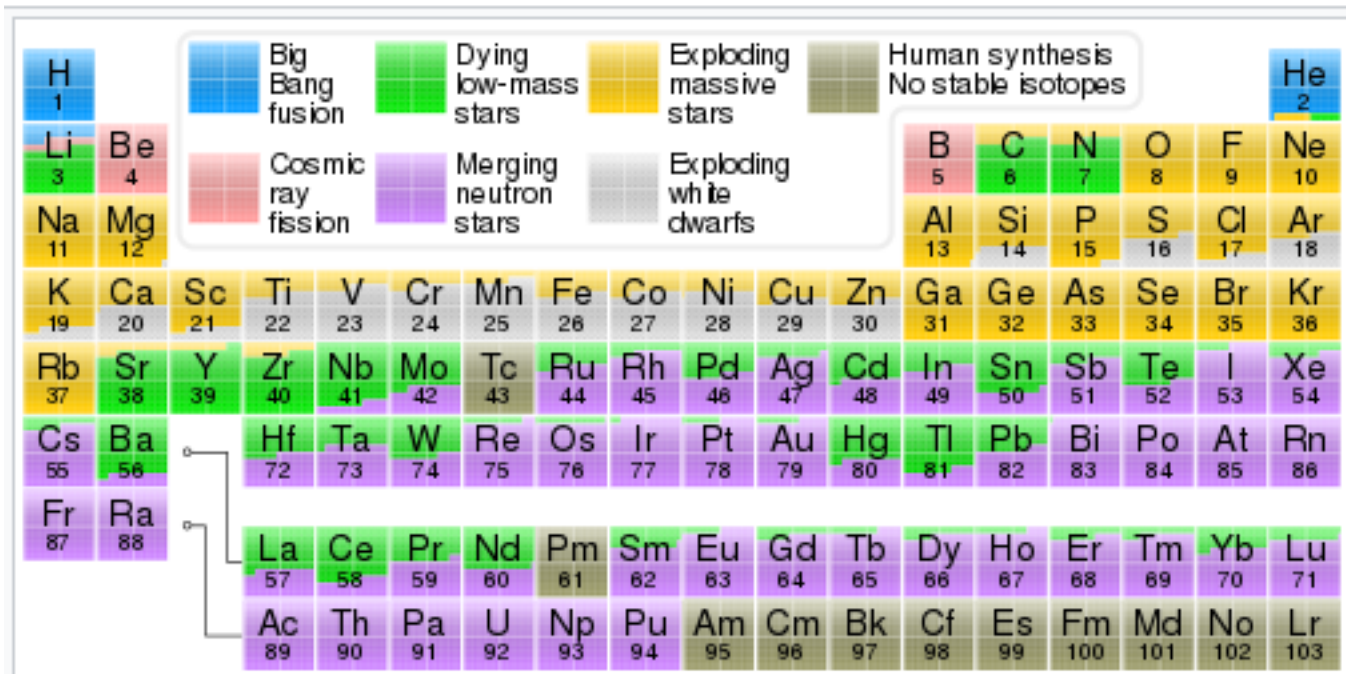
HEP Science Goals for the Next Decade

Liz Sexton-Kennedy

Joint WLCG & HSF Workshop, 26-March-2018

The Big Questions and Where They Lead us Today

- What are we? and How did we get here?
- These questions are at the heart of the sciences. For HEP they are particle, astro-particle, and cosmology questions.
- r-process nucleosynthesis
- cosmic evolution



Periodic table showing the cosmogenic origin of each element. The elements heavier than iron with origins in supernovae are typically those produced by the *r*-process, which is powered by supernovae neutron bursts

Science Drivers

- Concentrating on the decadal drivers, we have:
  - Fully exploit the Higgs using it as a tool for further discovery, electroweak and flavor physics
  - Investigate the neutrino mass and hierarchy
  - Investigate dark matter and it's role in cosmic evolution
  - Investigate cosmic acceleration, dark energy, quantum gravity
  - Explore the unknown

Instrumentation

- **Large scientific achievements in the past decades have been enabled by large advances in in instrumentation.**
- **Large silicon detectors and cameras with high granularity are driving us to large computing and data challenges.**
- **Large costs of these projects require an international scope.**

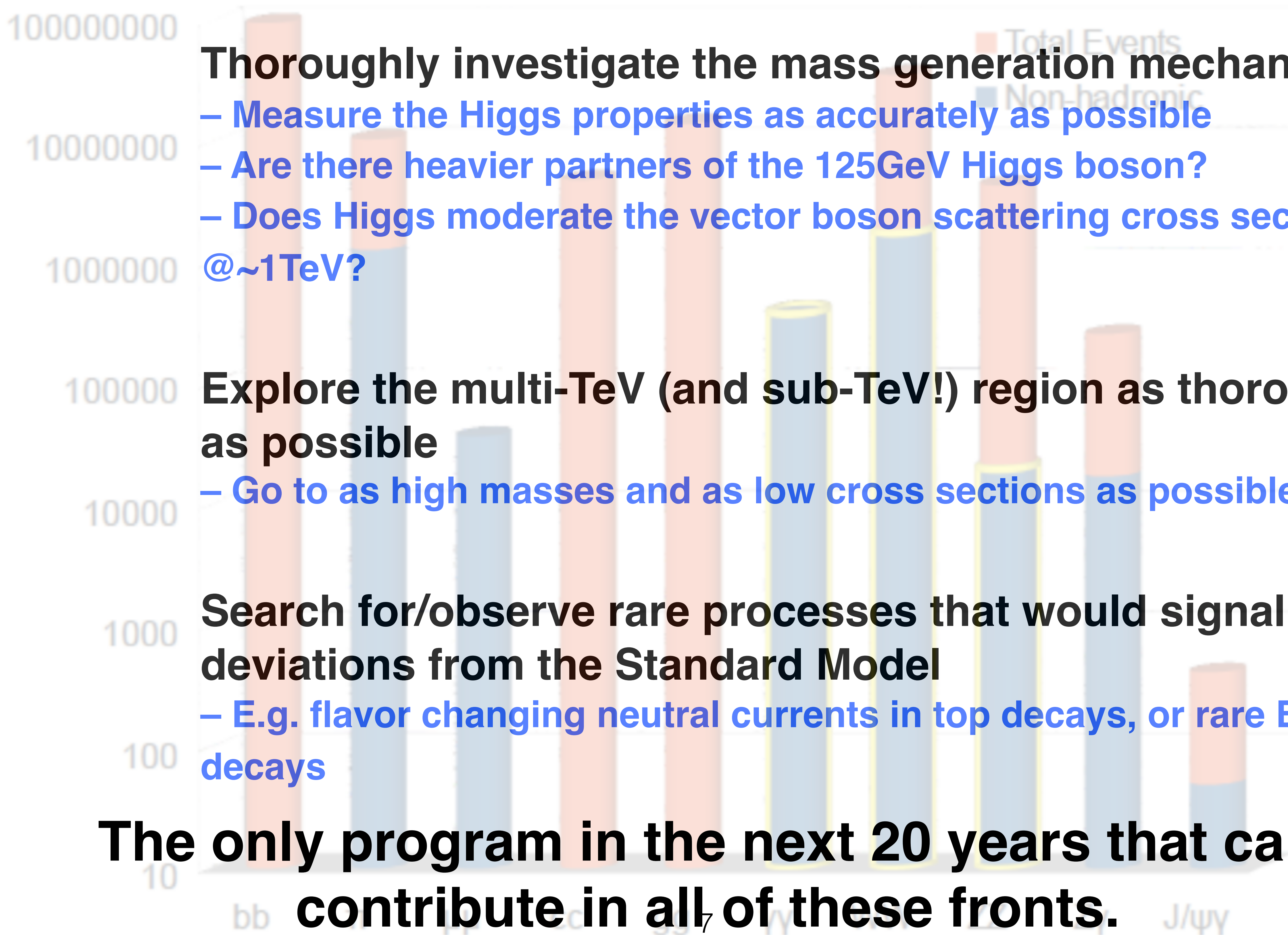
Data Movement

- **International science requirers international data movement and storage.**
- **Going forward the LHC will not be alone in using this infrastructure.**

International Big Data Science

- LHC, SKA, DUNE, LIGO, LSST
    - For each of these I will have one slide on the science case and one slide on the data needs
    - While we know the computing challenges are equally large, others outside of HEP are planing to build exescale compute
    - Most likely our community will have to build exescale data along with our partners.

HL-LHC Science



Thoroughly investigate the mass generation mechanism
- Measure the Higgs properties as accurately as possible
- Are there heavier partners of the 125GeV Higgs boson?
- Does Higgs moderate the vector boson scattering cross section @~1TeV?

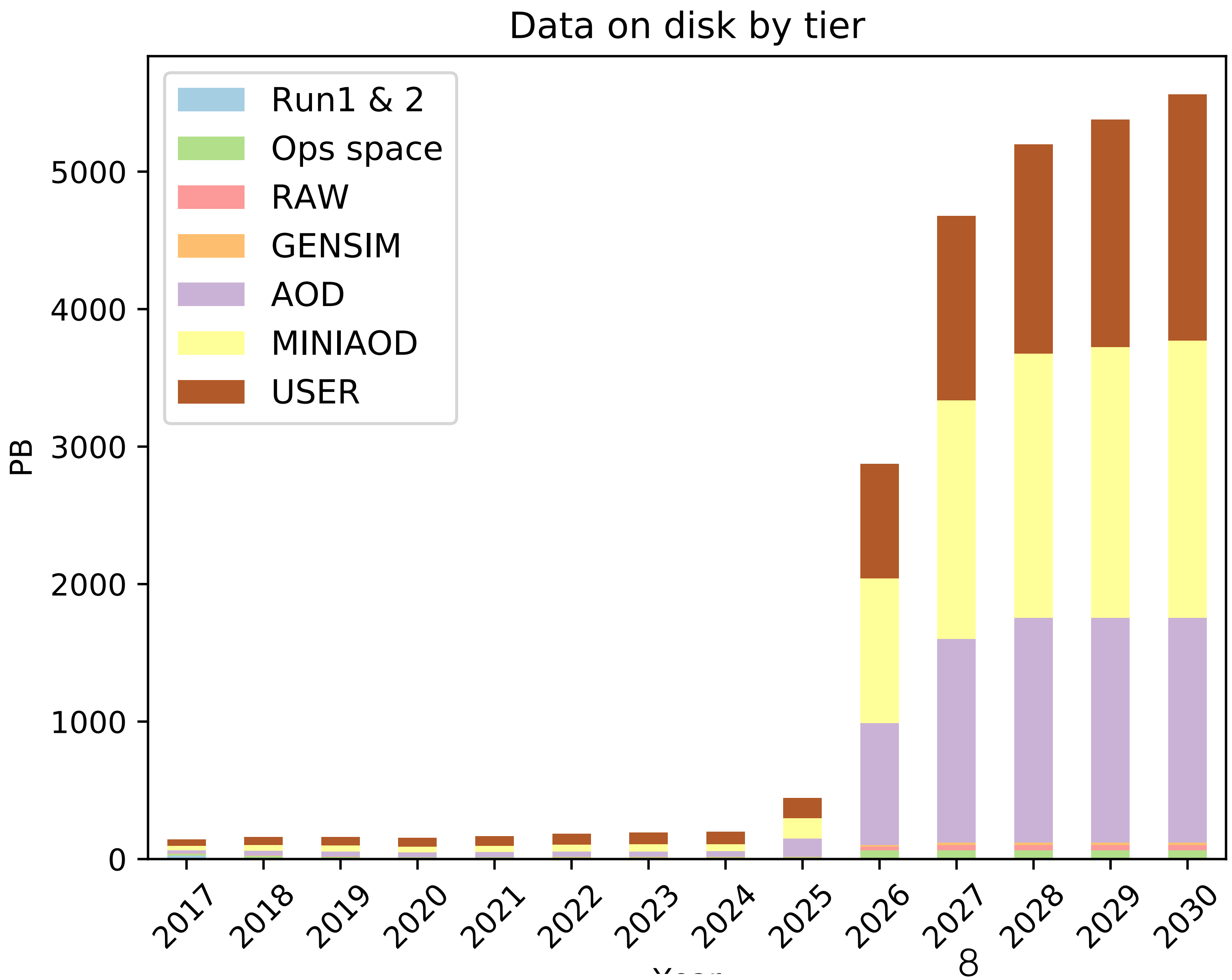
Explore the multi-TeV (and sub-TeV!) region as thoroughly as possible
- Go to as high masses and as low cross sections as possible

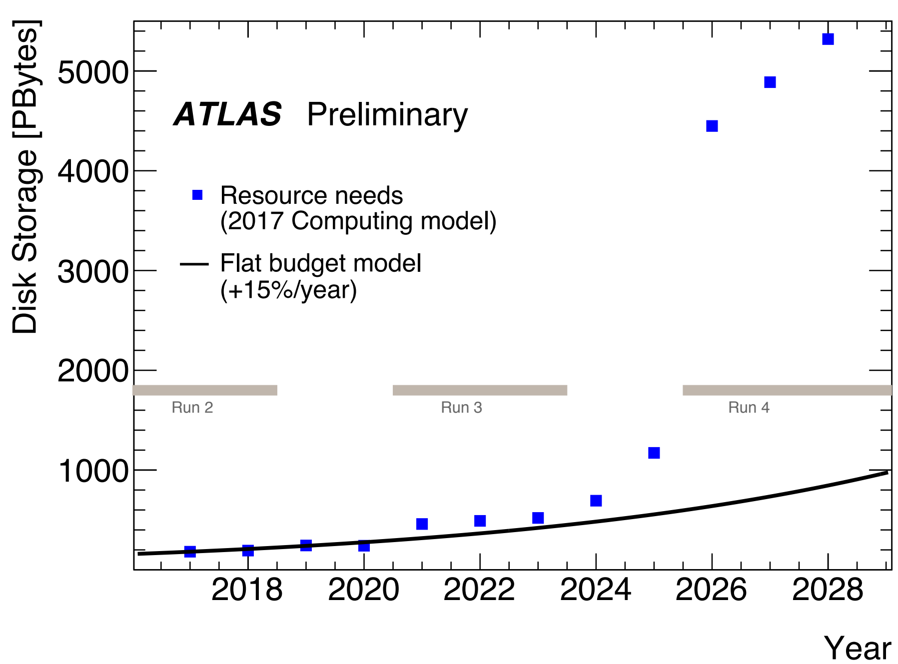
Search for/observe rare processes that would signal deviations from the Standard Model
- E.g. flavor changing neutral currents in top decays, or rare B decays

The only program in the next 20 years that can contribute in all of these fronts.

LHC Current Data Projections

- From the CWP; the plots themselves show that data models have to change.
- The concept of cold storage for RAW is already embedded in CMS

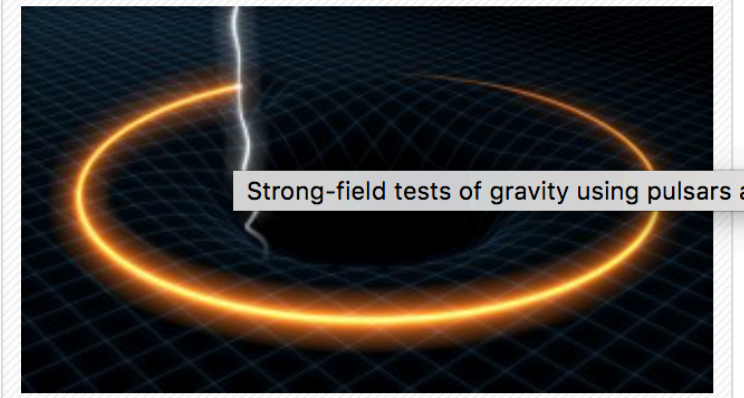




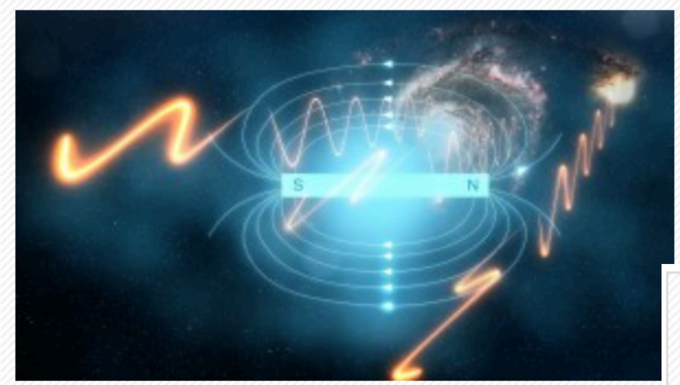
SKA Science

- The SKA will investigate this expansion after the Big Bang by mapping the cosmic distribution of hydrogen.
- SKA will investigate the nature of gravity and challenge the theory of general relativity
- SKA will create three-dimensional maps of cosmic magnets to understand how they stabilize galaxies, influence the formation of stars and planets, and regulate solar and stellar activity.
- SKA will look back to the Dark Ages, a time before the Universe lit up, to discover how the earliest black holes and stars were formed.
- SKA will be able to detect very weak extraterrestrial signals and will search for complex molecules, the building blocks of life, in space.

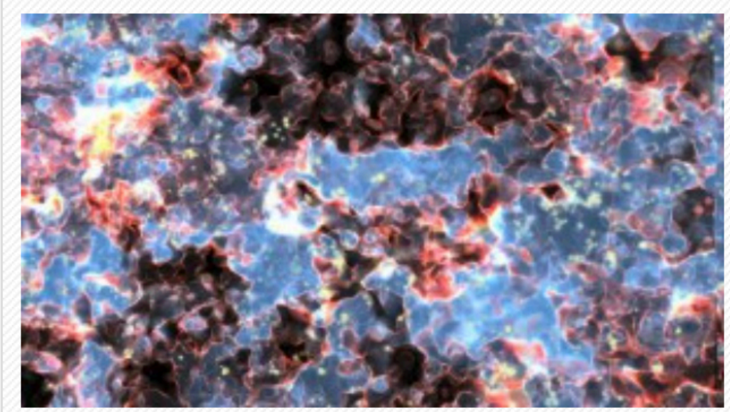
Galaxy evolution, cosmology and dark energy



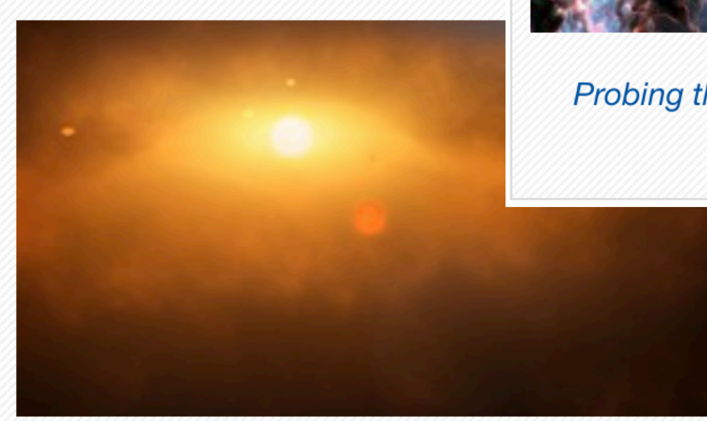
Strong-field tests of gravity using pulsars and black holes



Investigating the origin and evolution of cosmic magnetism



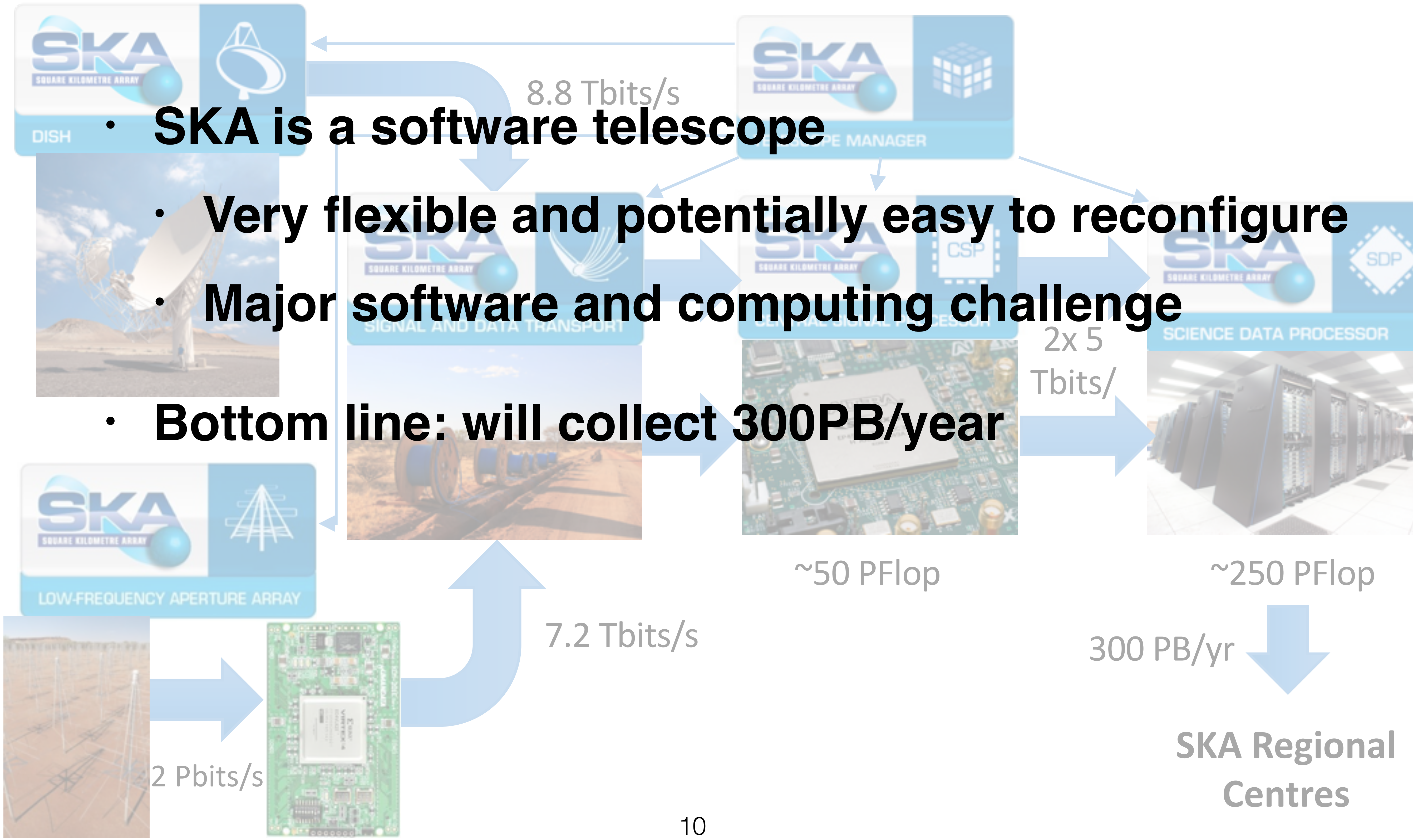
Probing the dark ages – the first black holes and stars



The cradle of life searching for life and planets

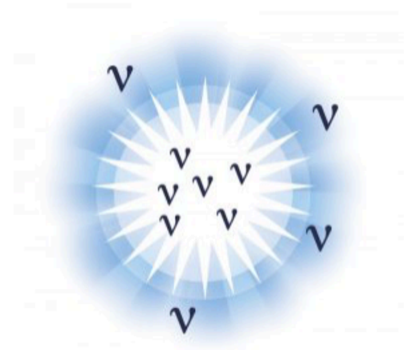
SKA Data

- **SKA is a software telescope**
  - **Very flexible and potentially easy to reconfigure**
  - **Major software and computing challenge**
- **Bottom line: will collect 300PB/year**



DUNE Science

Aiming for groundbreaking discoveries



Origin of Matter Neutrino Oscillations

Could neutrinos be the reason that the universe is made of matter rather than antimatter? By exploring the phenomenon of neutrino oscillations, DUNE seeks to revolutionize our understanding of neutrinos and their role in the universe.

Unification of Forces Proton Decay

With the world's largest cryogenic particle detector located deep underground, DUNE can search for signs of proton decay. This could reveal a relation between the stability of matter and the Grand Unification of forces, moving us closer to realizing Einstein's dream.

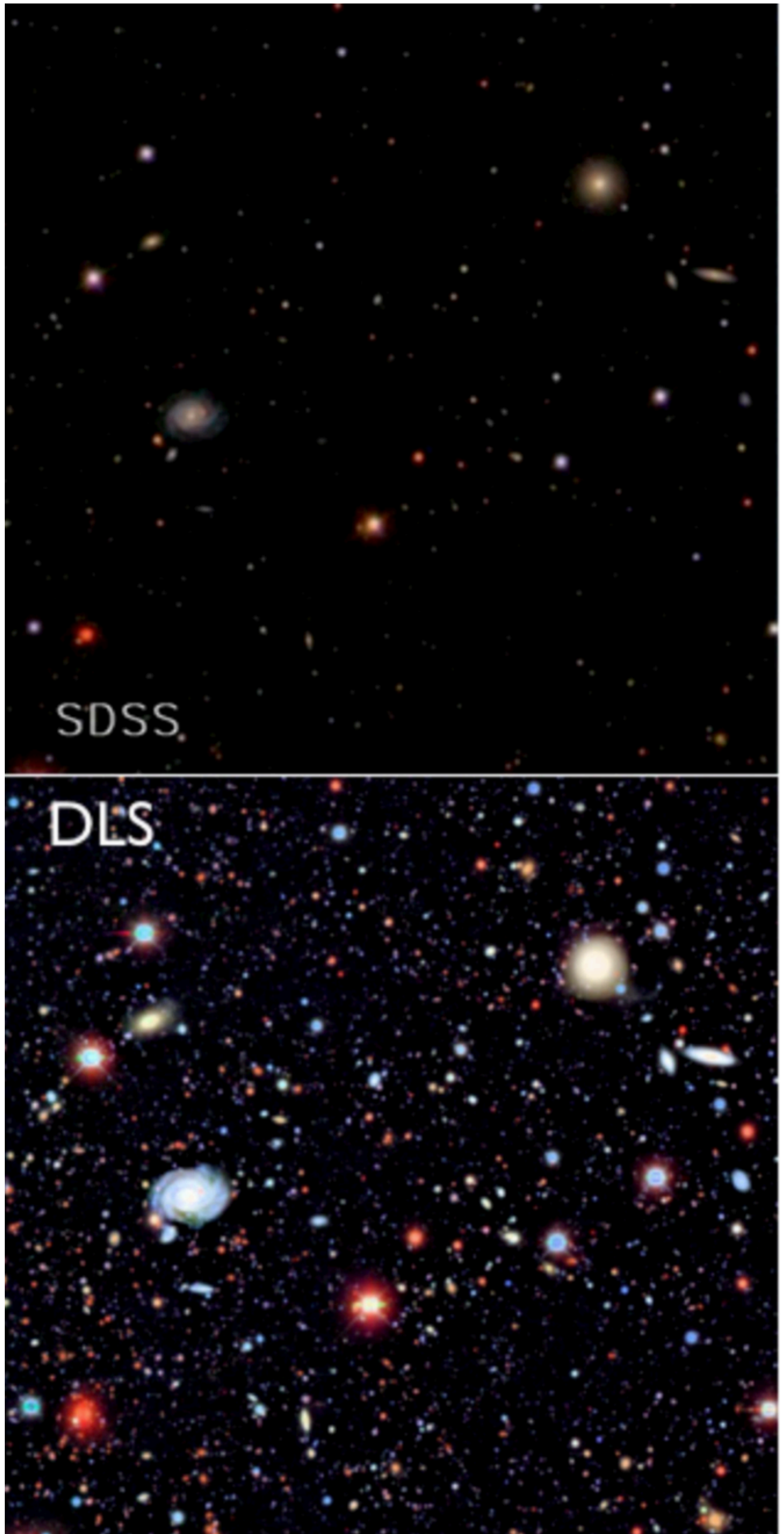
Black Hole Formation Neutrino Astrophysics

DUNE's observation of thousands of neutrinos from a core-collapse supernova in the Milky Way would allow us to peer inside a newly-formed neutron star and potentially witness the birth of a black hole.

DUNE Data

- Full Stream Data for DUNE is impossibly large, order 150EB/year
    - Much of the detector research will go into reducing that to reasonable levels
    - suppression of ^{39}Ar decay, cold electronics noise, space charge effects, argon purities all play a role
    - above means that most challenging data needs for DUNE are during it's prototyping phase - now untill 2020
    - Needs proposed at review: low/high = 4/59 PB, most probable 16PB

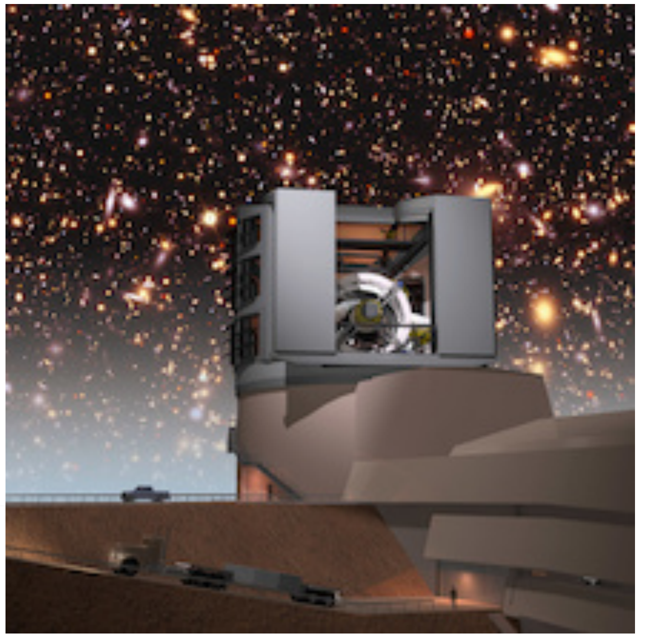
Year	CPU (10^6 Hr)	Storage (TB)	Tape (PB) low/high
FY18	9.25	703	0.8/5.9
FY19	28.6	1938	3/49.8
FY20	12.5	237	0.04/3.4



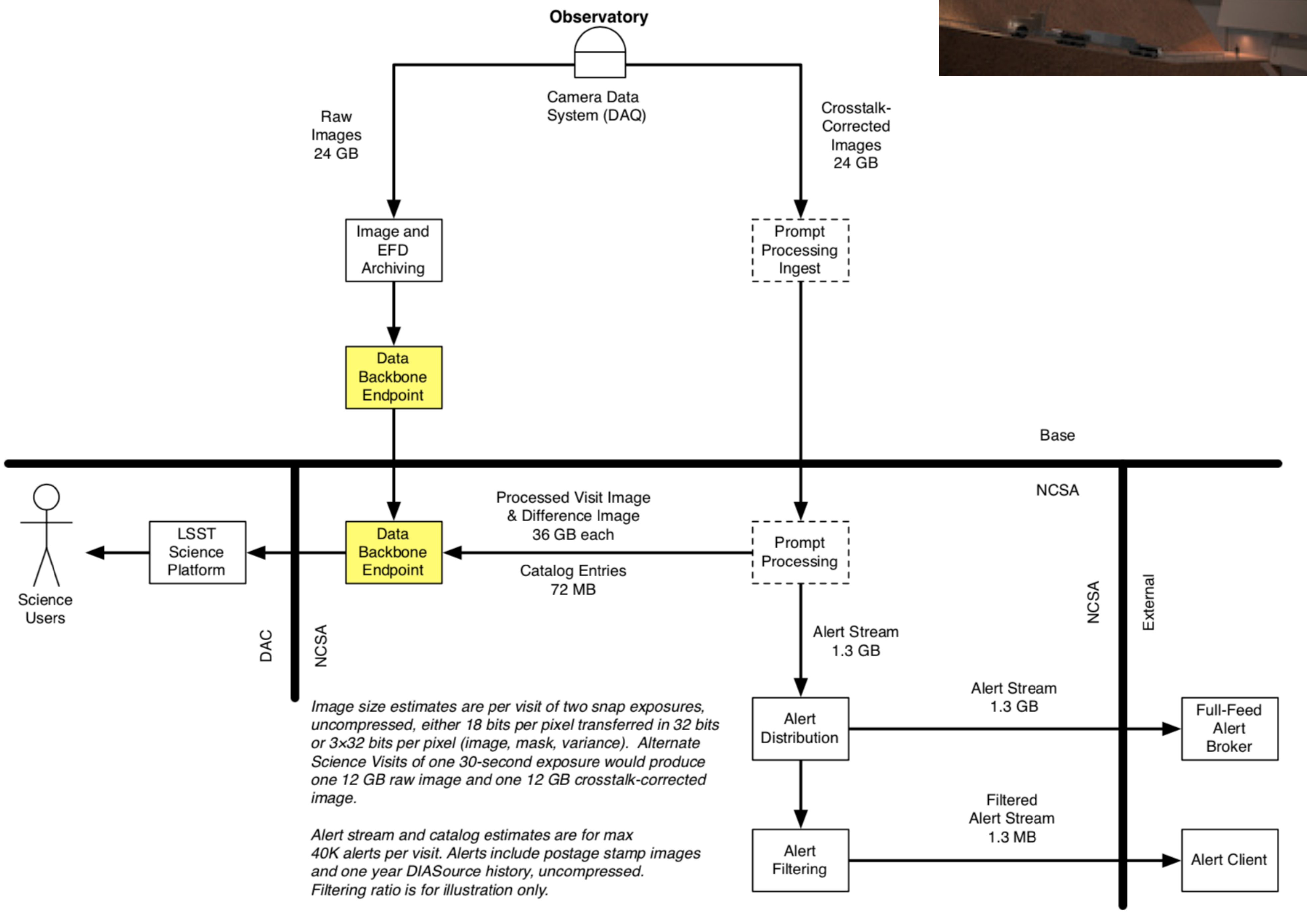
LSST Science

- LSST will conduct a deep survey with a frequency that results in taking repeat images of every part of the sky every few nights in multiple bands for ten years.
    - Milky Way Structure & Formation: by creating a map 1000 times the volume of past surveys, cataloging the colors and brightnesses of billions of new stars.
    - Probe the nature of dark matter and dark energy using several billion galaxies
    - Exploring the Changing Sky and Cataloging the Solar System

LSST Data



- LSST will collect 50PB/ year of data



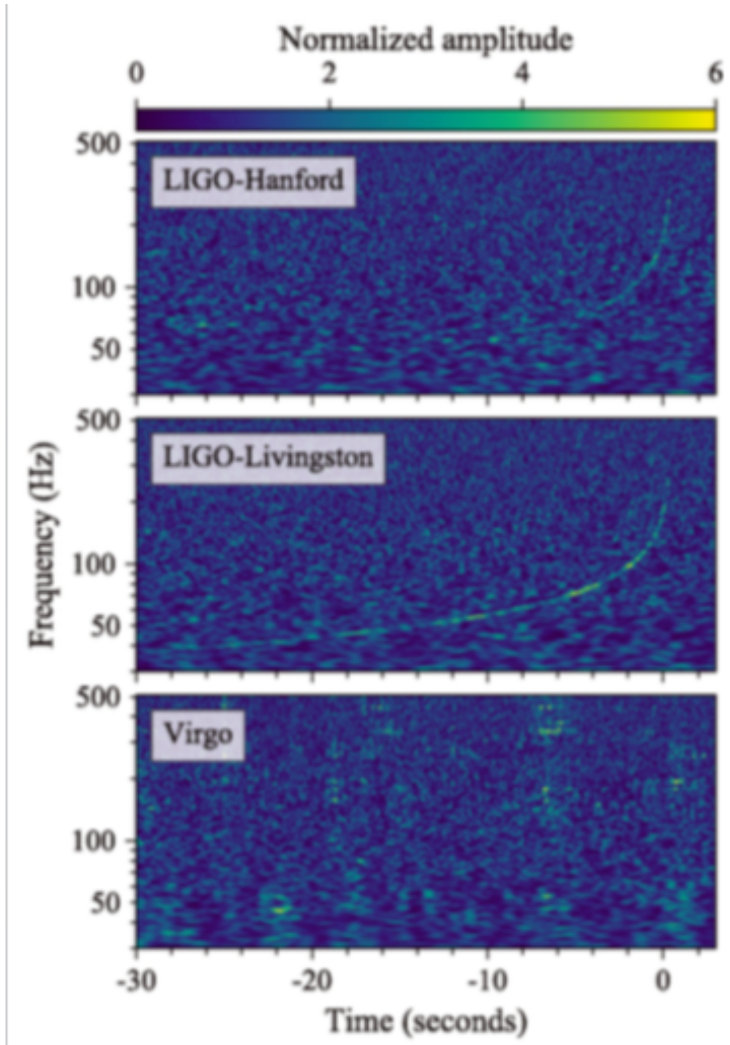
LIGO Science

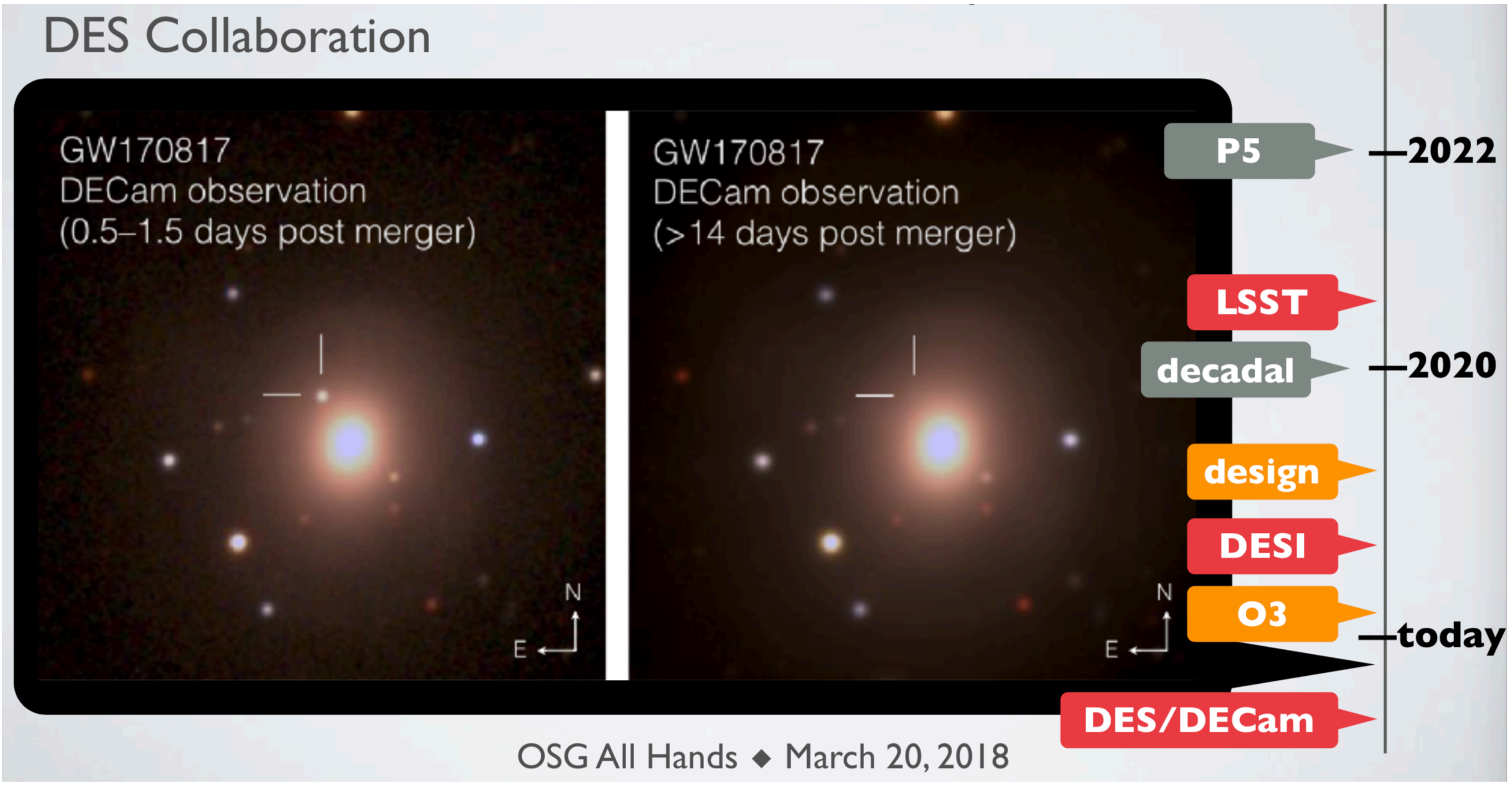
Is general relativity the correct theory of gravity?
How does matter behave under extreme densities and pressures?
How abundant are stellar-mass black holes?
What is the central engine driving gamma ray bursts?
What happens when a massive star collapses?

- With the discovery of gravitational waves LIGO has ushered in a new branch of astronomy

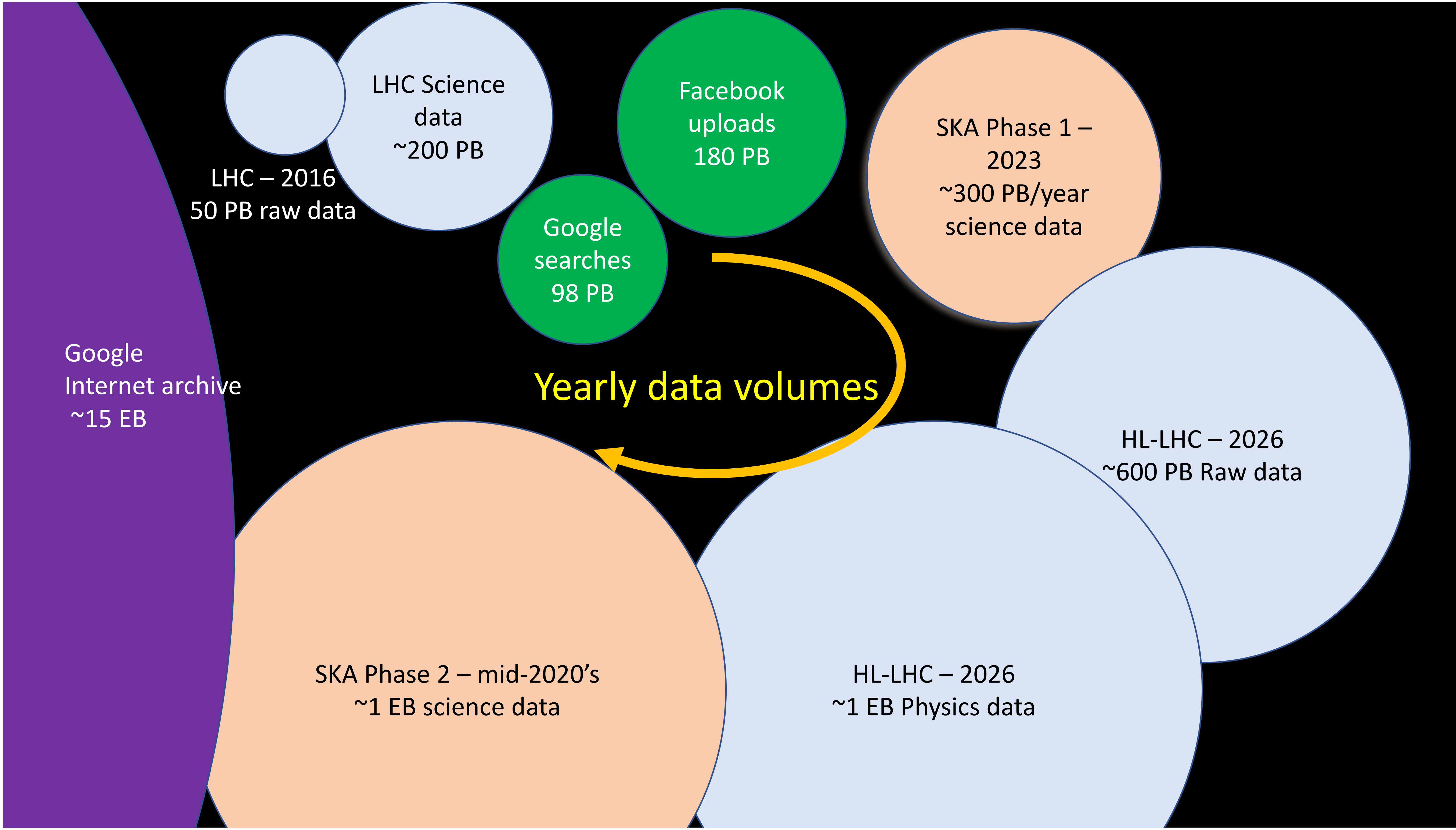
MULTI-MESSENGER ASTRONOMY

- Data science is not just about the large size of datasets it is also about the needed velocity of processing.
- Grid resources were used to search for the EM counterparts of GW events enabling the witnessing of r-process nucleosynthesis

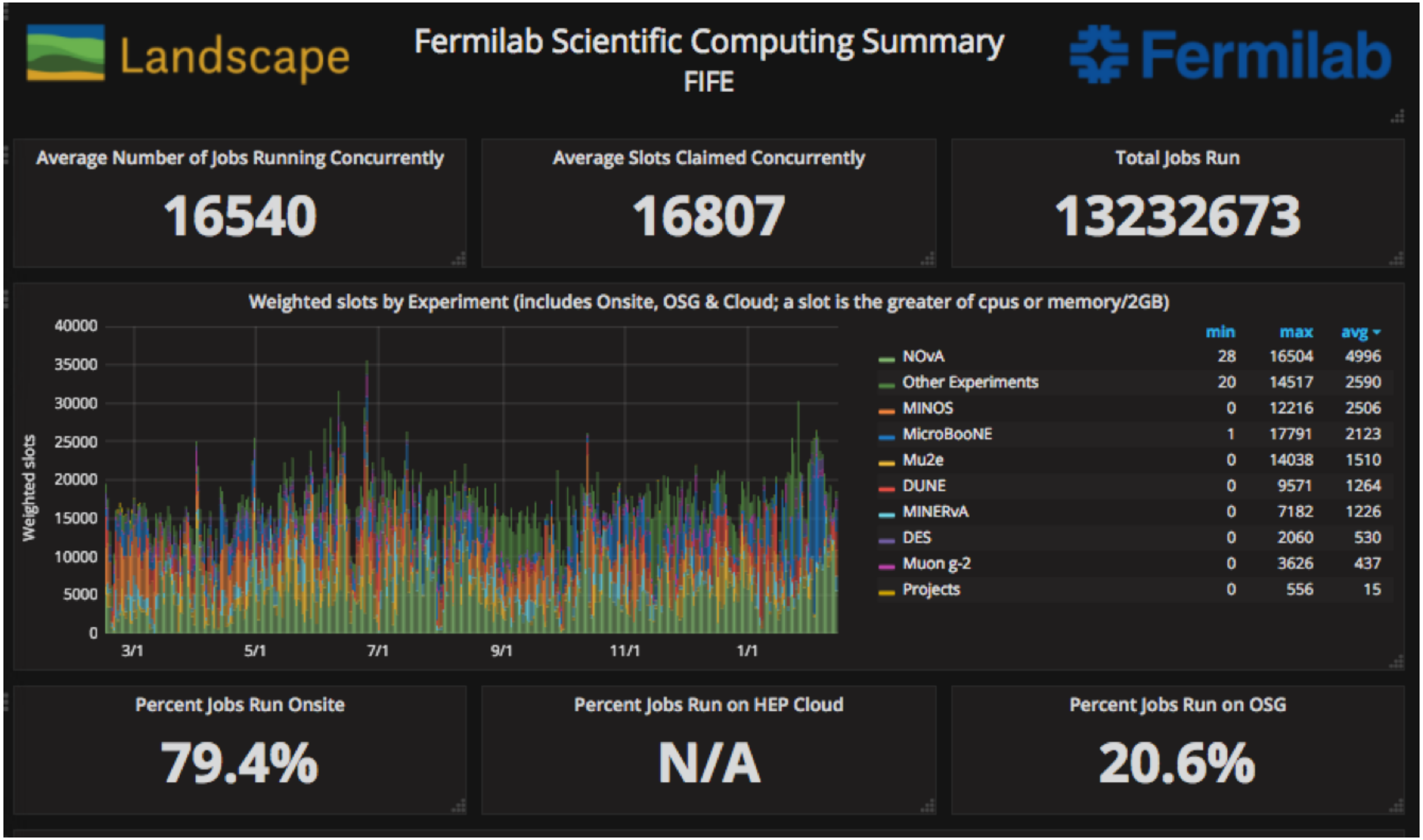




International Data Needs

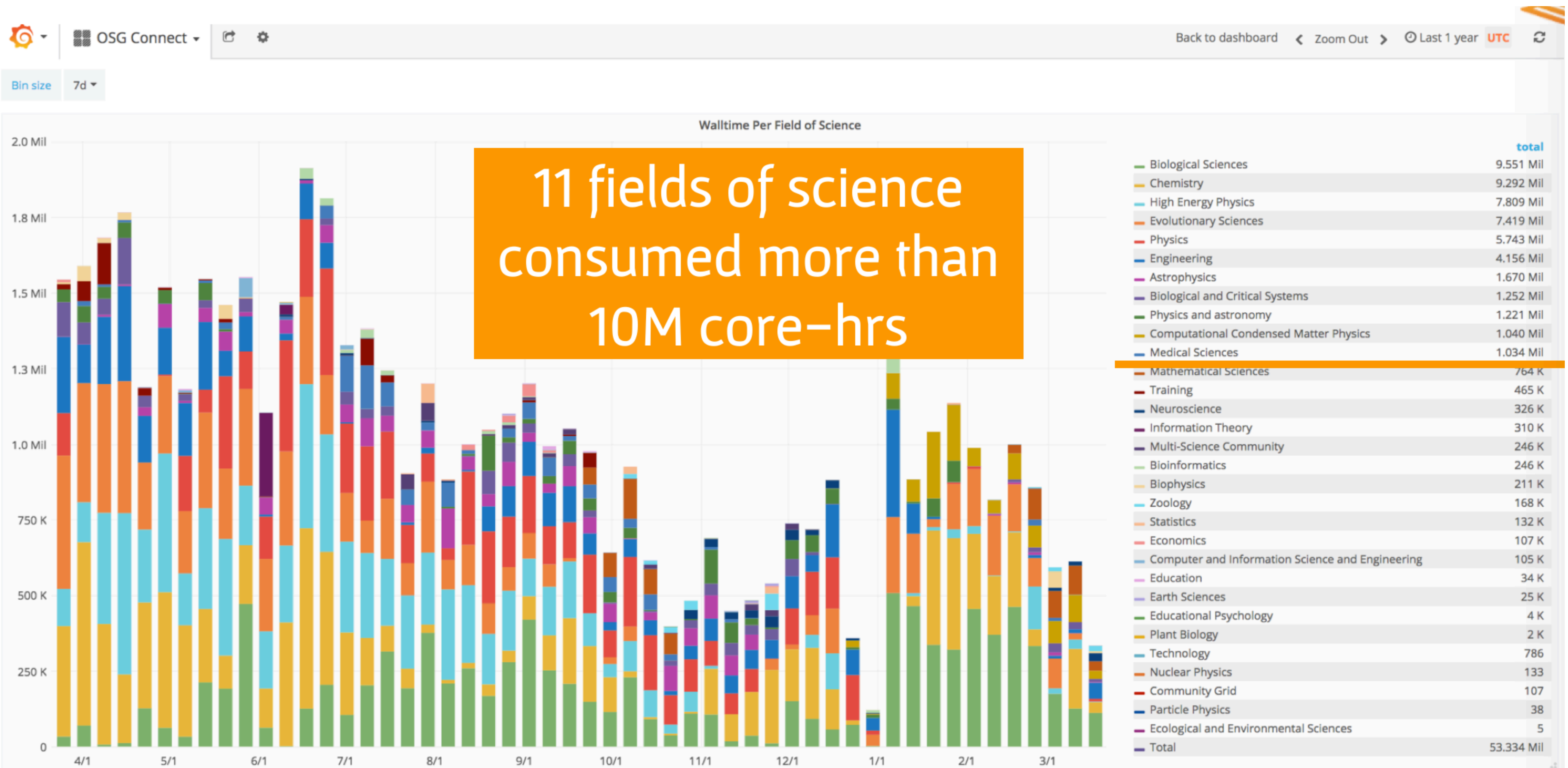


Sharing Infrastructures



- Most science needs are spiky, a large number of users keeps utilization high.

Long Tail of Science



- Allowing opportunistic use of our large facilities is powerfully enabling

Conclusions

- The data and compute challenges of the next decade are large, even daunting.
- In order to satisfy the scientific needs, we will need to build unprecedented scientific facilities and capabilities
- The scientific harvest that is arriving with this new era of big data science, is extremely compelling.

Special thanks to Ian Bird, Rob Gardner, Ken Herner, Marcelle Soares-Santos, and others who contributed to the slide content