The Challenges of Big (Science) Data
Evolution of the Universe

SKA – Key Science Drivers:
The history of the Universe

Testing General Relativity
(Strong Regime, Gravitational Waves)

Cradle of Life
(Planets, Molecules, SETI)

Cosmic Magnetism
(Origin, Evolution)

Exploration of the Unknown

Extremely broad range of science!

LHC drivers
Test the Standard Model?
Dark Matter?
Dark Energy?
Anti-matter?
(Gravity?)

Cosmic Dawn
(First Stars and Galaxies)

Galaxy Evolution
(Normal Galaxies z~2-3)

Cosmology
(Dark Energy, Large Scale Structure)

Quantum Fluctuations

Afterglow Light Pattern
380,000 yrs.

Dark Ages

Development of Galaxies, Planets, etc.

Inflation

1st Stars
about 400 million yrs.

13.7 billion years

Big Bang Expansion

Venice, 8 July 2017
The Large Hadron Collider (LHC)

A new frontier in Energy & **Data volumes**:

LHC experiments generate 50 PB/year in Run 2
SKA - HQ in UK; telescopes in AU & SA

- SKA1-LOW: 50 – 350 MHz
- Phase 1: ~130,000 antennas
- across 65km

- SKA1-Mid: 350 MHz – 24 GHz
- Phase 1: 200 15-m dishes across 150 km

Construction Phase 1: 2018 – 2024
Phase 2: mid-2020’s
Tier-0 (CERN and Hungary): data recording, reconstruction and distribution

Tier-1: permanent storage, re-processing, analysis

Tier-2: Simulation, end-user analysis

WLCG: An International collaboration to distribute and analyse LHC data

Integrates computer centres worldwide that provide computing and storage resource into a single infrastructure accessible by all LHC physicists
Worldwide computing

2017:
- 63 MoU’s
- 167 sites; 42 countries
SKA Organisation: 10 countries, more to join

Australia (DoI&S)
Canada (NRC-HIA)
China (MOST)
India (DAE)
Italy (INAF)
Netherlands (NWO)
New Zealand (MED)
South Africa (DST)
Sweden (Chalmers)
UK (STFC)

Interested Countries:
• France
• Germany
• Japan
• Korea
• Malta
• Portugal
• Spain
• Switzerland
• USA

Contacts:
• Mexico
• Brazil
• Ireland
• Russia
SKA Data Acquisition System Overview

8.8 Tbits/s

7.2 Tbits/s

2 Pbits/s

~50 PFlop

~250 PFlop

300 PB/yr

SKA Regional Centres
SKA Observatory

- SKA is a software telescope
  - Very flexible and potentially easy to reconfigure
  - Major software and computing challenge
- Computing challenges are significant
  - Science Data Processor (SDP) needs 25 PetaFLOPS/sec of delivered processing
    - Current estimate is that SDP needs 250 PFLOP/sec peak.
    - Tianhe-2 – 50 PetaFLOPS/sec peak.
    - Memory bandwidth is ~200 PetaBytes/sec
  - Pulsar Search is an additional 50 PFLOP/s of peak processing
  - Power efficiency required is ~40x better than Tianhe-2
- Limitations
  - Because of the bandwidth requirements, have to buy 10x more computing than a pure HPC system would require.

Addressing Power

- Need to achieve a FLOPS/Watt 5-10 times better than current greenest computer.
- Need a three pronged approach:
Data Products from SDP

- Image cubes of sky maps (Continuum) 18PB n*/year
  - Max ~30Gbit/s Mean ~10 Gbit/s
  - SDP Fourier transform of CSP time series
  - Moderate external compute and model fitting
- Epoch of Re-ionisation 1.6PB/6 Hr ~600 Gbit/s
  - Only 11% duty cycle so Mean rate ~ 22 Gbit/s
  - Uses calibrated aperture plane (visibility data)
  - Enormous compute of power spectra
- Relativity Gravitational lensing 70PB/2500Hr 60Gbit/s
  - Uses further processed aperture plane data
  - Considerable compute of galaxy elipsicity
- Pulsars 4-5 PBytes/y ≤10Gbits
  - Discovery and in depth study; timing 10 ns in 10 years
  - Large physics compute
- VLBI 4 beams of 4 Gbit/s (not in the 300PB)
  - Data direct from the correlator, UDP all the way
- PI led projects? Some fraction of observing time
- Discovery science Whatever is available
LHC Schedule

Run 3
Alice, LHCb upgrades

Run 4
ATLAS, CMS upgrades
Future Challenges

- Raw data volume for LHC increases exponentially and with it processing and analysis load
- Technology at ~20%/year will bring x6-10 in 10-11 years
- Estimates of resource needs at HL-LHC x10 above what is realistic to expect from technology with reasonably constant cost

Raw Derived Data estimates for 1st year of HL-LHC (PB)

- Raw 2016: 50 PB → 2027: 600 PB
- Derived (1 copy): 2016: 80 PB → 2027: 900 PB

CPU Needs for 1st Year of HL-LHC (kHS06)

- x60 from 2016
Google searches 98 PB

LHC Science data ~200 PB

Facebook uploads 180 PB

LHC – 2016 50 PB raw data

Google Internet archive ~15 EB

SKA Phase 1 – 2023 ~300 PB/year science data

SKA Phase 2 – mid-2020’s ~1 EB science data

HL-LHC – 2026 ~1 EB Physics data

HL-LHC – 2026 ~600 PB Raw data

Yearly data volumes

10 Billion of these
Optical Private Network
Support T0 – T1 transfers & T1 – T1 traffic
Managed by LHC Tier 0 and Tier 1 sites

Up to 340 Gbps transatlantic
LHCOOne: Overlay network
Allows NREN’s to manage HEP traffic on general purpose network
Managed by NREN collaboration
Provisioning services

Moving towards Elastic Hybrid IaaS model:
• In house resources at full occupation
• Elastic use of commercial & public clouds
  • Assume “spot-market” style pricing
Commercial Clouds

Open Telekom Cloud

ATLAS
LHCb
ALICE

CMS global pool

300k

Google

Via Fermilab HEPCloud:
CMS Amazon Web Services (AWS) Usage

Fermilab Tier-1

Running by Site

ATLAS
LHCb
ALICE
SKA Regional Centres

- SKA envisage a network of regional centres
- Modelled on the LHC Tierw
- Not part of SKA, or funded by SKA, but:
  - Essential to generate science
  - Coordinated with assistance from SKAO and accredited with SKAO
- Principle functions
  - Take data products generated by SDP and turn them into science
  - Support regional astronomers with their data processing.
  - Act as centres for domain expertise.
Regional Centre Concept:

Science Processing Centre

Regional Centre 1
Users

Regional Centre 2
Users

Regional Centre N
Users

Observatory

User Community

RSA

AUS
Regional Centre Network

Fibre Cable Systems – SKA relevant
Major NREN Paths – SKA relevant

US$1-3M/Year
US$1-3M/Year
US$1-3M/Year
US$0.2-.5M/Year
US$0.2-.5M/Year
US$0.1-.2M/Year
US$0.1M/Year
US$0.1M/Year
US$0.2-.5... NREN Paths – SKA relevant

Exploring the Universe with the world's largest radio telescope
10-year challenges

- HL-LHC will be a multi-Exabyte challenge
  - Storage and compute needs x10 above what naïve technology extrapolation will bring
  - Need to drive down costs: focus on performance, efficiency, operations, etc.
    ⇒ changes in computing and infrastructure models are necessary

- SKA will have similar data volumes on the same time-scale

- Opportunity for synergy – in particular in large scale facilities
  - SKA and LHC likely to be co-located in major facilities

- But there is experience:
  - ~15 years of grid development and successful operation for science
  - CERN has been operating a distributed DC for ~5 years
  - Large internet companies provide tools and experience that did not exist when we started WLCG
    - Tools for managing interconnected DCs, cloud provisioning, etc.
    - Starting to prototype federated structures for the future
HL-LHC computing cost parameters

Business of the experiments: amount of Raw data, thresholds; Detector design long term computing cost implications

Business of the experiments: reconstruction, and simulation algorithms

Performance/architectures/memory etc.; Tools to support: automated build/validation Collaboration with externals – via HSF

New grid/cloud models; optimize CPU/disk/network; economies of scale via clouds, joint procurements etc.
Software

- Not just a HEP problem
- Transistors go into many cores, co-processors, vector units, etc.
- Memory access and I/O paths also become problematic
- Getting performant software requires significant investment in skills
Possible Model for future HEP computing infrastructure

HEP Data cloud
Storage and compute

HEP Data lake
Storage and compute

Cloud users: Analysis

Simulation resources

A data lake is a place to put all the data enterprises (may) want to gather, store, analyze and turn into insights and action, including structured, semi-structured and unstructured data
Hadoop and Analytics

- Hadoop Production Service
  - New scalable data services
    - Scalable databases
    - Hadoop ecosystem
    - Time Series databases

- Big Data Analytics

- Activities and objectives
  - Develop projects and services with/for users
  - Support of Hadoop Components
  - Further value of Analytics solutions
  - Define scalable platform evolution based on requirements
Machine Learning

ML in Atlas

- Machine Learning (or rather Multivariate Analysis as we used to call it) used almost since first data taking (2010) for reconstruction and analysis
- In most cases, Boosted Decision Tree with Root-TMVA, but recent explosion of usage and studies (see later)

- Data taking
  - Real time event categorization
  - Data monitoring & certification robot

- Data Reconstruction
  - Calorimeter reconstruction
  - Boosted object jet tagging

- Data Processing
  - Computing Resource Optimization
  - Predicting data popularity
  - Intelligent networking

- Data Analysis
  - CMS assistance service
  - Big data reduction and analysis
  - Model independent search

Machine learning and data analytics are hot topics at CERN openlab workshop

- Last week, CERN openlab held a workshop on machine learning and data analytics. The event, which took place on Friday 29 April, saw experts from both research and industry gather in the CERN IT Department for a full day of presentations and lively discussion.

- The morning featured presentations from representatives of the four large LHC experiments: ALICE, ATLAS, CMS, and LHCb, on their current projects and future challenges in these areas.

- During the afternoon, representatives from industry were also invited to give their perspectives. This included presentations from CERN openlab partner companies [insert names here], as well as contributions from other companies and researchers. The discussions. Over the course of the day many commonalities and areas of potential collaboration emerged.

- “The event provided a great opportunity for experts from both industry and the LHC experiments to discuss their activities — as well as the challenges they face — in the exciting area of machine learning and data analytics,” says Maria Giromini, CERN openlab coordinator. “It also underscored the need to keep the engagement of all participants in lively and constructive discussions.”
SWAN

- Provides a web-based analysis facility – via notebooks
- Transparent access to scalable back-end analysis infrastructure
  - Clouds, Spark, Hadoop, ML, etc.
- Performance is defined by the infrastructure
- Provides the analysis portal in a “data cloud” or “data lake” model
Conclusions

- In the next decade HL-LHC and SKA will be the leading Exabyte-scale scientific big data challenges.
- Computing & software challenges and concerns are often similar or complementary.
- Evolution of computing models must be very agile to be able to adapt to a rapidly evolving landscape of new technologies & funding opportunities.
- Many opportunities for synergy, collaboration, and leadership in scientific big data.
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