Connecting multi-messenger astrophysics R&D in ASTERICS and nanosecond timing in normal life

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Astronomy ESFRI & Research Infrastructure Cluster
what is ASTERICS?

• A €15 million Research Infrastructure funded by EC Horizon 2020 framework (2015-2019)
  – To help solve the Big Data challenges of European astronomy
  – To provide direct interactive access to the best European astronomy data in an international framework
  – Cross-cutting synergies and common challenges
addressing common challenges in astronomy and astroparticle physics

• **supporting** and **accelerating** the implementation of a new generation of observatories

• **enhancing performance**

• helping scientists to access data
  – ESFRIs+ interoperating as an integrated multi-λ, multi-messenger facility
concept and approach

• Supporting the European Strategy Forum on Research Infrastructures (ESFRI)
• Aspiring ESFRI projects + pathfinders
• Other world-class research infrastructures
  – e.g. LOFAR, Euclid, LSST, Virgo
multi-\(\lambda\), multi-messenger

- messengers: photons, \(\nu\), grav. waves, VHE\(\gamma\)
- multi-\(\lambda\):
  - gamma ray
  - X-ray
  - ultraviolet
  - visible
  - infrared
  - microwave
  - radio
- transient source astronomy

To make it happen...

- Interoperability, cooperation, Open Data
- Scalability – processing and analysis
- Big Data, Data mining,
- *Streaming and timing*
KM3NeT

- A multi-km$^3$ neutrino telescope
- Exploring our galaxy for high energy neutrino sources
- KM3Net2 on timescale of 2020
CTA

- Very high energy $\gamma$-ray observatory
- Two arrays of 100 (N) and 20 (S) telescopes
- Event re-construction
- Complex metadata
- Streaming and processing challenges
- Precursors: MAGIC and HESS

Production phase 2018-2023
High Energy Astrophysics

- Violent, transient, non-thermal phenomena
- Matter under extreme conditions
- Particle Acceleration
- Fundamental Physics
- Role of Black Holes in the structuration of the Universe
SKA

SKA-LOW, Australia
Phase 1: 130,000 dipoles over 80 km
Phase 2: 500,000 dipoles over 250 km

SKA-MID, South Africa
Phase 1: 200 dishes over 150 km
Phase 2: 2500 dishes over 3500 km

Phase 1 (2018-2023)
Phase 2 (2025-2033)

Challenges everything...
General purpose optical/infrared telescope
• Several scientific instruments (fast switching)

Science areas include:
• high redshift galaxies
• star formation
• exoplanets
• protoplanetary systems

39m European-Extremely Large Telescope
First Light targeted for late 2024
World class facilities and ESFRI pathfinders

• Connecting real facilities now as path to connected future facilities
**CLEOPATRA:** Connecting Locations of *ESFRI* Observatories and Partners in Astronomy for Timing and Real time Alerts

**DADI:** Data Access, Discovery and Interoperability

**OBELICS:** OBServatory E-environments LInked by common Challenges

**DECS:** Dissemination, Engagement and Citizen Science
ASTERICS connections: gravitational waves

ASTERICS fostered use of VO for gravitational wave EM follow-up
connections & openness

• connecting infrastructures: enhancing individual capabilities - necessary for science!
  – *ICT: high speed data transport/timing*

• Embracing *Open Science, Open Data*
  – many challenges, many opportunities

• Engage with society at large
  – Astro community+, education, public
Strengths from connections

• Enabling data science
  – Training and support
  – Skill sets for astronomy and the market place

Bonus outcomes: beyond Europe
multi-messenger timing and synchronisation

• Building on success of e-VLBI
• EXPReS, NEXPReS

...here comes the White Rabbit
Connecting multi-messenger astrophysics R&D in ASTERICS and nanosecond timing in normal life

Peter Jansweijer

preceded by Mark Allen

1Observatoire astronomique de Strasbourg, Université de Strasbourg, CNRS, FRANCE

2Nikhef, Amsterdam
Timeline

Here we are now:

The connecting strength of Big Science Projects

10 June 2016
Start thinking about timing for the KM3NeT detector
“Measuring propagation delay over a coded serial communication channel using FPGAs”
(P.P.M. Jansweijer, H.Z. Peek)
Joining efforts

“Measuring propagation delay over a 1.25 Gbps bidirectional data link”
(P.P.M. Jansweijer, H.Z. Peek)

1st White Rabbit Developer meeting @ CERN

The connecting strength of Big Science Projects
What is White Rabbit?

http://www.ohwr.org/projects/white-rabbit/wiki
White Rabbit
an *extension* of Ethernet

- Bandwidth: 1 Gbps
- Single fiber medium
- Up to 10 km links
- WR Switch: 18 ports
- Allows non-WR Devices
- Ethernet features (VLAN) & protocols (SNMP)
White Rabbit
an *extension* of Ethernet

Two separate services (enhancements to Ethernet) provided by WR:

- **Synchronization:** accuracy better than 1 ns precision (tens of ps sdev skew max)
- **Deterministic, reliable and low-latency Control Data delivery**
Timing over Ethernet

Clock A (master)

\[ t_A(t) = k_A t + b_A \]

Clock B (slave)

\[ t_B(t) = k_B t + b_B \]

link latency

\[ \delta_{AB} \]

0

absolute time scale

<table>
<thead>
<tr>
<th>Syntonization</th>
<th>Precision Time Protocol (PTP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>[ k_A = k_B ]</td>
<td>[ b_A = b_B ]</td>
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Synchronous Ethernet
Open Hardware Repository

- Estimation: White Rabbit up to now (2016): 100..120 man years of work!

http://www.ohwr.org/

<table>
<thead>
<tr>
<th>Commercial</th>
<th>Non-commercial</th>
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<tbody>
<tr>
<td>Open</td>
<td></td>
</tr>
<tr>
<td>Winning combination. Best of both worlds.</td>
<td>Whole support burden falls on developers. Not scalable.</td>
</tr>
<tr>
<td>Proprietary</td>
<td></td>
</tr>
<tr>
<td>Vendor lock-in.</td>
<td>Dedicated non-reusable projects.</td>
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</table>
The connecting strength of Big Science Projects

4th and 5th WR workshop

Number of participants and companies grow

Picture taken @ 4th WR workshop (2011), GSI Darmstadt
First open hardware, start standardization

- Now, many people start to play with WR!
- Process of standardization is initiated.
Many use cases…

… also means many bug reports

1000 Km link in Finland (Anders Wallin)

- 100 times longer than the original 10 Km specification
- 2 ns error over 60 days
Many new users

08 09 10 11 12 13 14 15 16 17 18 19 20


HiSCORE
LHAASO
VLBI

Picture SKA website: https://www.skatelescope.org/

Courtesy Paul Boven

Peter Jansweijer
Nikhef
Amsterdam

The connecting strength of Big Science Projects

June 10, 2016

ASTRON Dwingeloo, the Netherlands
SuperGPS

- Optical methods to **backup GNSS timing** via fiber
- Next-generation positioning (optical/radio)

**Pictures**: Jeroen Koelemeij

http://www.ohwr.org/attachments/1753/Jeroen-superGPS.pptx
Metrology institutes discover potentials

international optical clock
Comparisons using optical fibers

See also presentations at the Third International VLBI Technology Workshop
9th WR workshop hosted by Nikhef

Participants: 66
Institutes: 30
Universities/Companies: 30
Countries Worldwide: 9

(14-16 Mar 2016) @ Nikhef Amsterdam
Now and the Future

The connecting strength of Big Science Projects

10 June 2016

Future: Standardization

- Jan 2017: Draft version of IEEE1588 rev. 3 (PTP)
  - White Rabbit => High Accuracy profile
- Publish Mid 2018

More about the standardization procedure and the current status:
http://www.ohwr.org/attachments/4249/WRworkshop-P1588-HA.pdf
Future? Timing is Booming Business

- Once standardized as IEEE1588 High Accuracy profile more users are to be expected.
- KM3NeT, CTA, SKA, VLBI will complete
- Pico second accuracy, 10 Gbps networks
- SuperGPS
  - Next-generation positioning => Autonomous driving cars
  - Power plant synchronization
  - Time stamping financial transactions
- Telecom 4G, 5G,… networks
  - "Synchronization Standards Towards 5G“
  - Smart antenna
- ? Anything we didn’t think of yet…
Thank you

And:

thanks to all WR developers / contributors
(also for re-using many of the White Rabbit slides)

all WR users

https://www.asterics2020.eu/

European Commission grant no 653477