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

Mark Allen[1]
followed by Peter Jansweijer[2]

[1]*Observatoire astronomique de Strasbourg, Université de Strasbourg, CNRS, FRANCE*
[2]*Nikhef, Amsterdam*

Astronomy ESFRI & Research Infrastructure Cluster

European Commission

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*

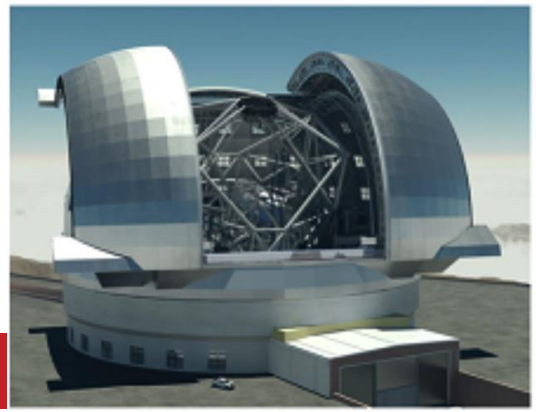
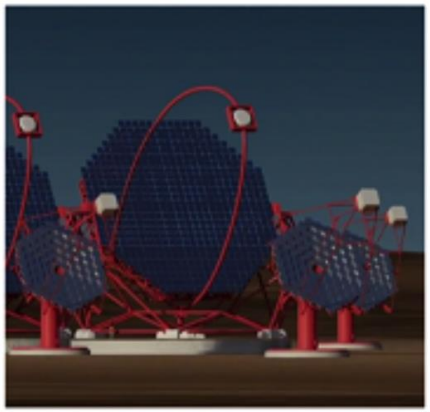
addressing common challenges in astronomy and astroparticle physics

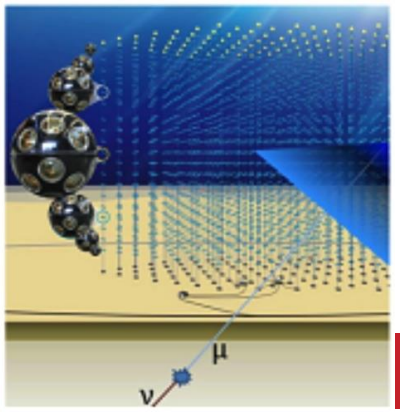
- ***supporting*** and ***accelerating*** the implementation of a new generation of observatories
- ***enhancing performance***
- helping scientists to access data
  - ESFRIs+ interoperating as an integrated multi-λ, multi-messenger facility

concept and approach

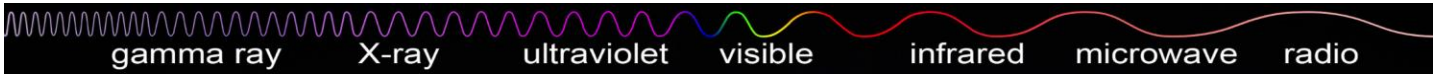
- Supporting the European Strategy Forum on Research Infrastructures (ESFRI)
- Aspiring ESFRI projects + pathfinders
- Other world-class research infrastructures
  - e.g. LOFAR, Euclid, LSST, Virgo

European Strategy Forum on Research Infrastructures



multi-λ, multi-messenger

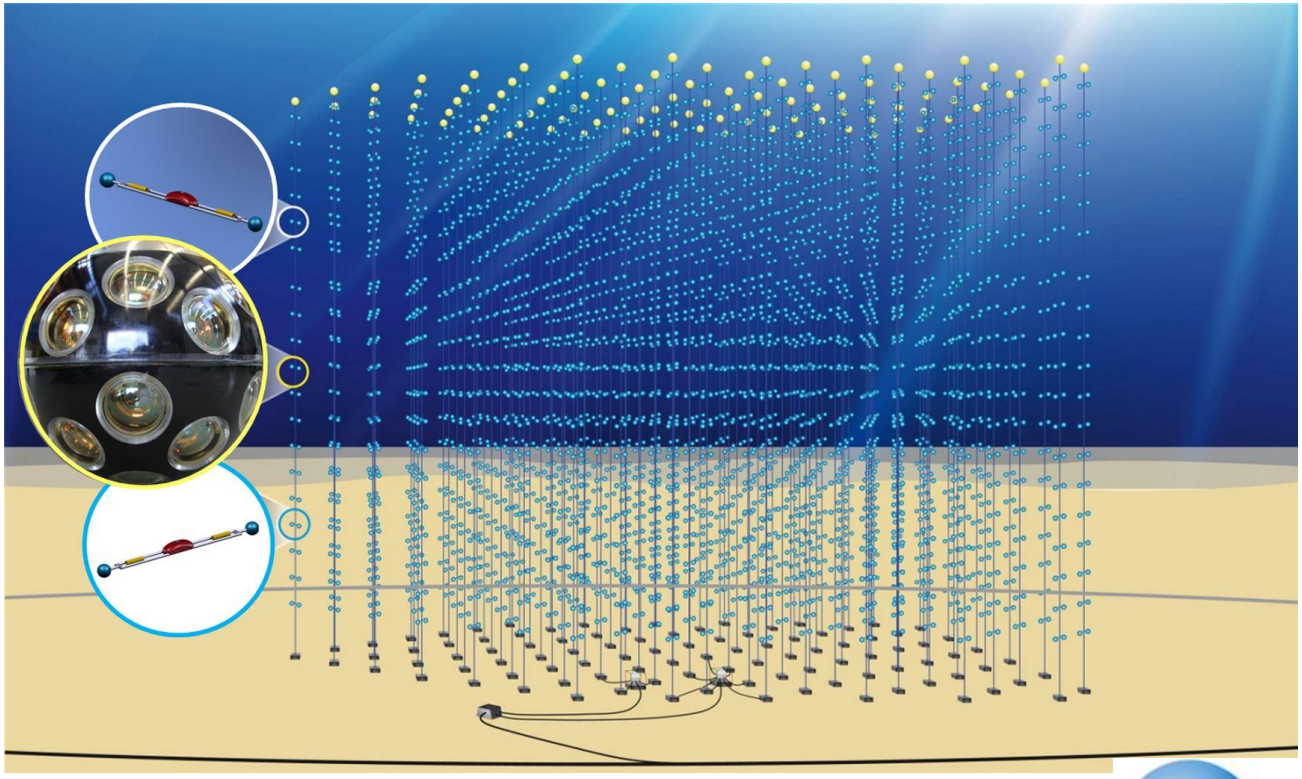
- messengers: **photons, ν, grav. waves, VHEγ**
- multi-λ: 

- transient source astronomy

To make it happen…

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

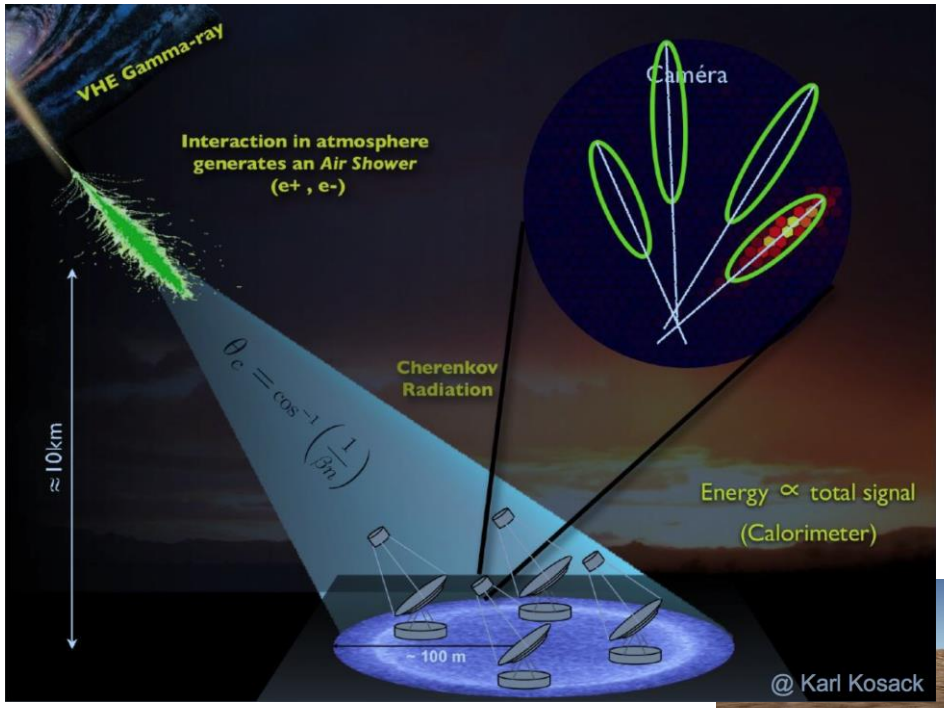
KM3NeT



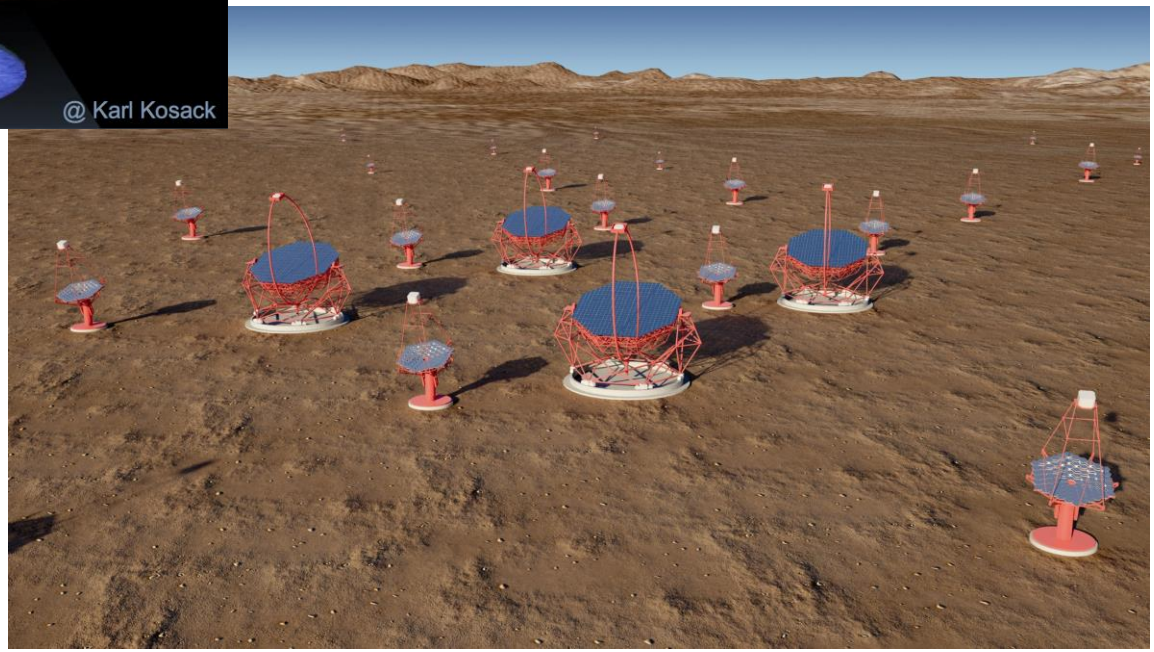
- ***A multi-km³ neutrino telescope***
- Exploring our galaxy for high energy neutrino sources
- KM3Net2 on timescale of 2020

KM3NeT
Opens a new window on our universe

CTA



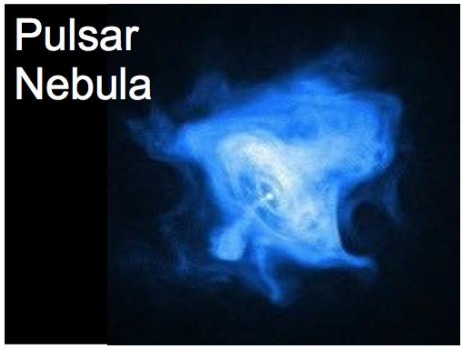
- Very high energy γ-ray observatory
- Two arrays of 100 (N) and 20 (S) telescopes
- Event re-construction
- Complex metadata
- Streaming and processing challenges
- Precursors: MAGIC and HESS



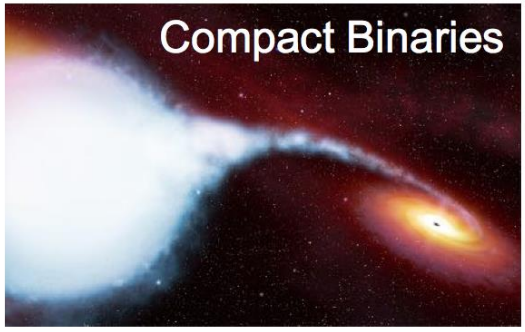
cta
cherenkov telescope array

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

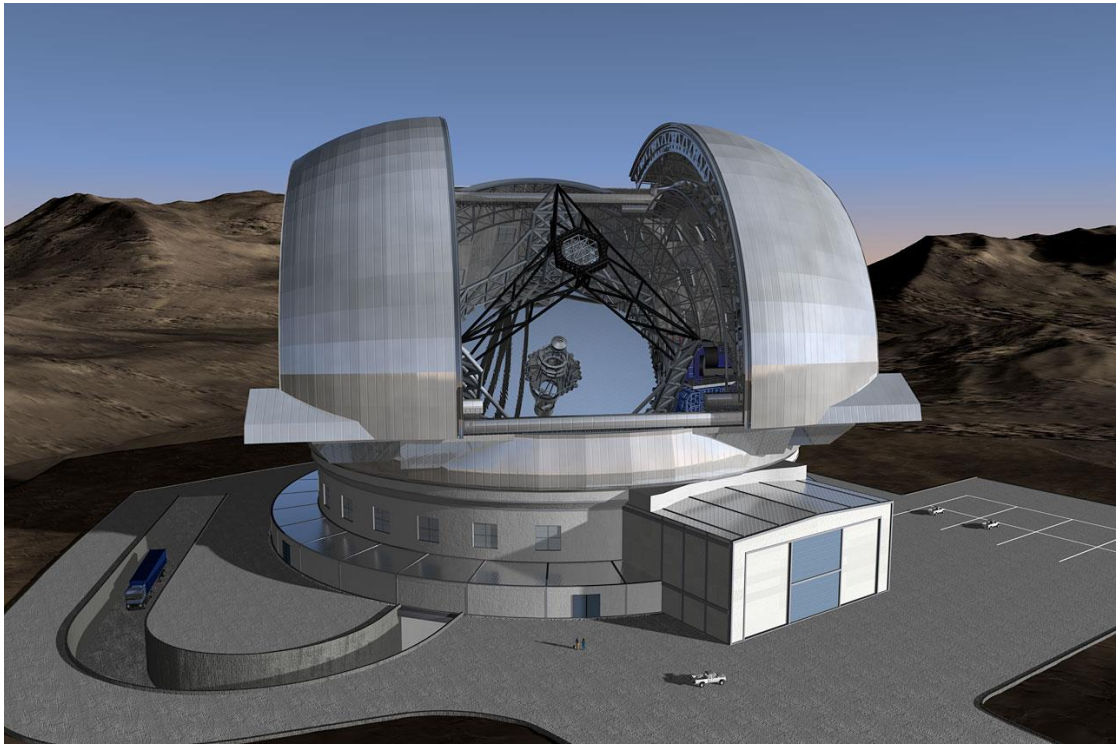
SKA-MID, South Africa

Phase 1: 200 dishes over 150 km
Phase 2: 2500 dishes over 3500 km

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

Challenges everything…

E-ELT



General purpose optical/infrared telescope

- Several scientific instruments (fast switching)

Science areas include:

- high redshift galaxies
- star formation
- exoplanets
- protoplanetary systems

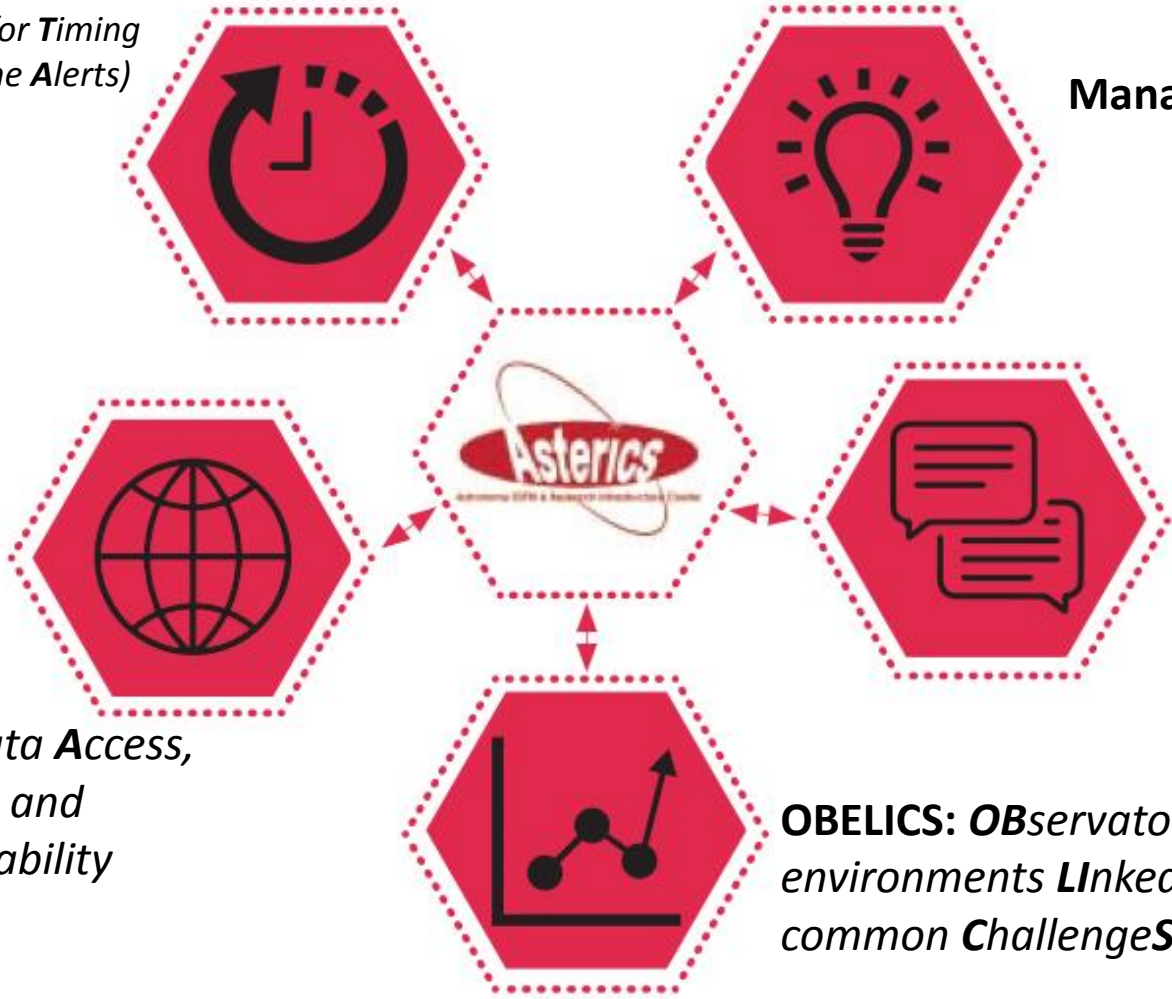
39m European-Extremely Large Telescope
First Light targeted for late 2024

World class facilities and ESFRI pathfinders

- Connecting real facilities now as path to connected future facilities

CLEOPATRA: ***C****onnecting* ***L****ocations of* ***E****SFRI* ***O****bservatories and* ***P****artners in* ***A****stronomy for* ***T****iming and* ***R****eal time* ***A****lerts)*

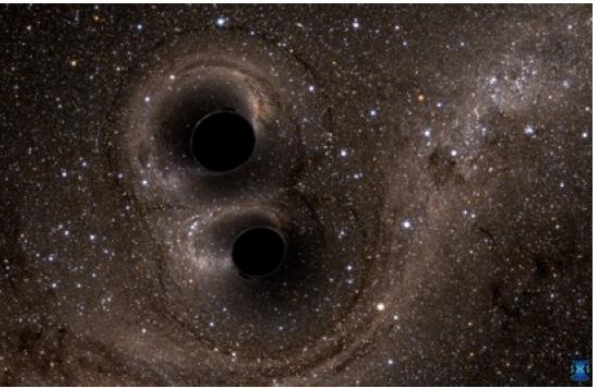
Management



DECS: ***D****isseminaton,* ***E****ngagement and* ***C****itizen* ***S****cience*

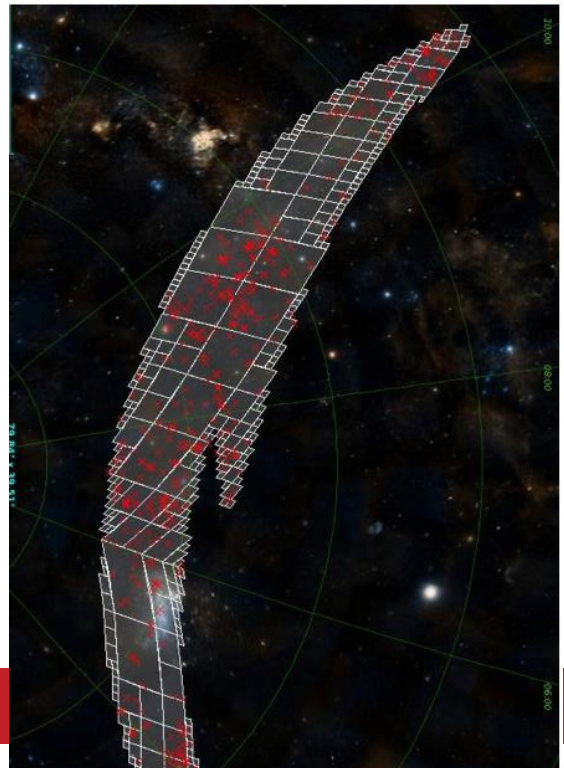
DADI : ***D****ata* ***A****ccess,* ***D****iscovery and* ***I****nteroperability*

OBELICS: ***OB****servatory* ***E****-environments* ***LI****nked by common* ***C****hallenge****S***



ASTERICS connections: *gravitational waves*

ASTERICS fostered use of VO for grav wave EM follow-up



Skymap Viewer

A sky atlas for understanding LIGO-Virgo skymaps. Help here, or watch a video about Skymap Viewer. Plenty simulated skymaps here. If you do not see the big dark sky map, look below and widen your browser. Zoom with the + and - at the right of the sky.

LIGO-Virgo Skymaps

This is skymap GW150914:LALI.
50% area = 149.0 sq deg
90% area = 616.4 sq deg

South ..... North

Show Weighted Galaxies (or table).

Time and Place

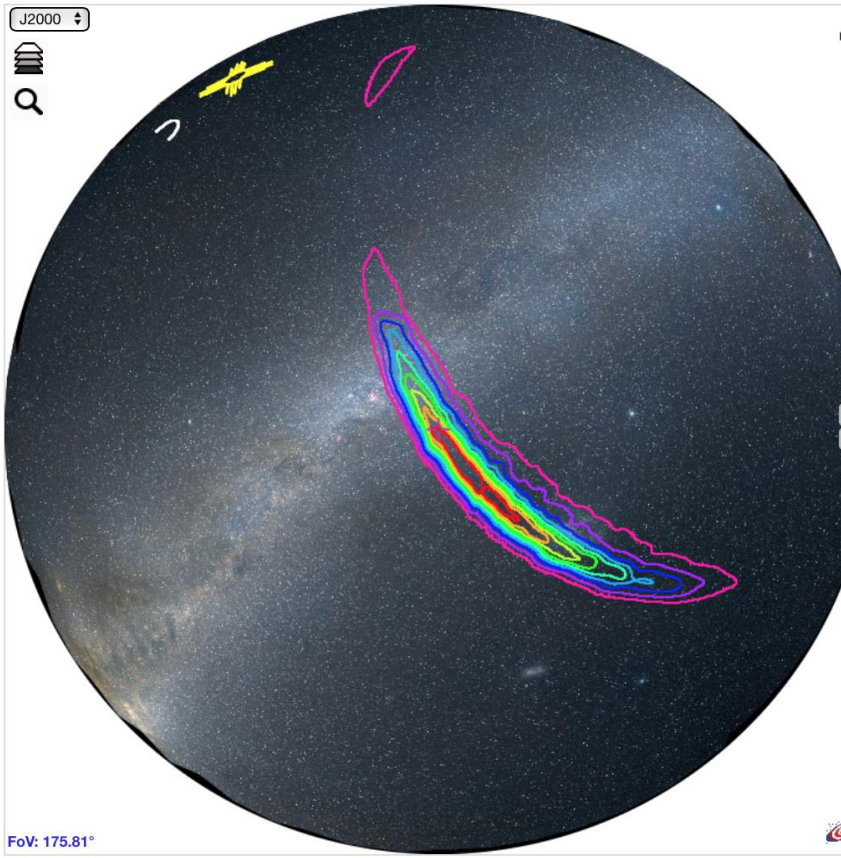
Universal time
2015-09-14T09:50:45 Now
E Longitude east long Latitude latitude
Show Sky
Sun = and = Moon

Catalog Sources

Click the Layers icon to switch on catalogs.
If you click on the sources on the sky, information will appear here with links to Simbad and NED.

Zoomable Multiwavelength Sky

Zoom in on the sky with the mouse or the +/-

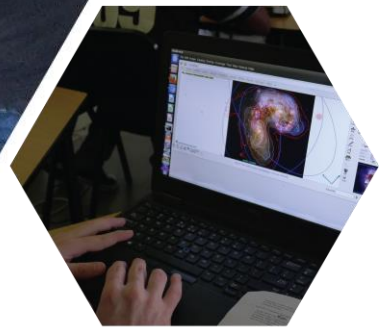


connections & openness

- 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

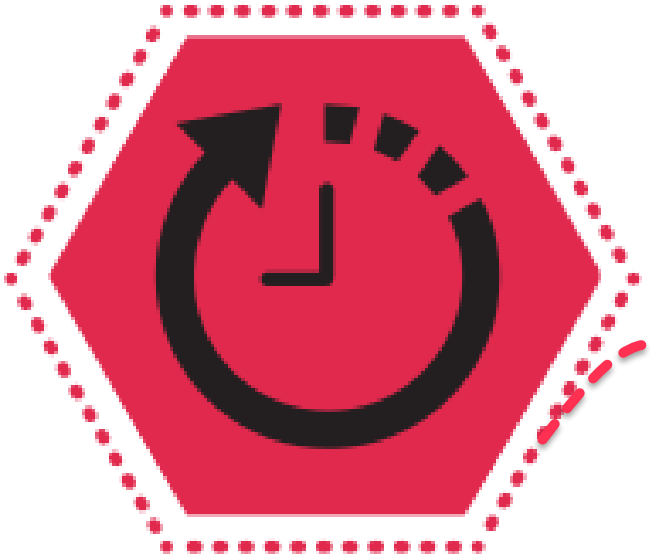
Strengths from connections

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



Bonus outcomes: beyond Europe

multi-messenger timing and synchronisation



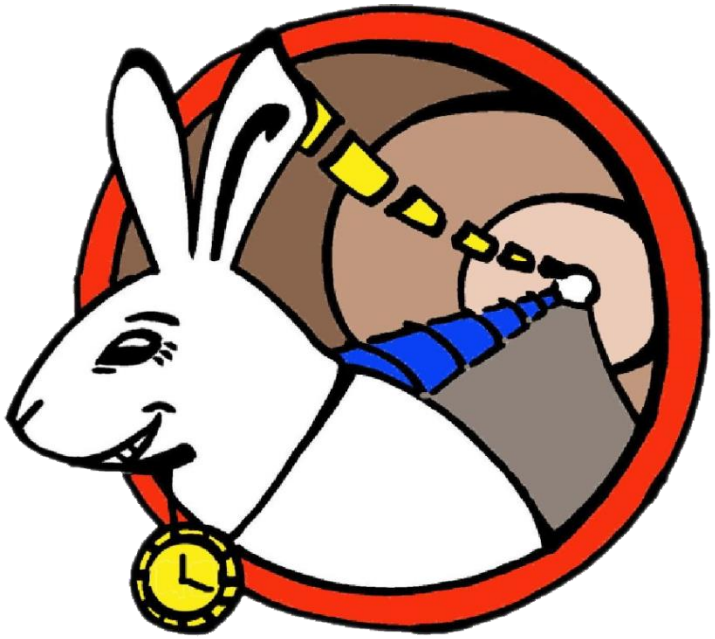
- Building on success of e-VLBI
- EXPReS, NEXPReS

…here comes the White Rabbit

Participating institutions

luster
53477

Supporting organisations and networks



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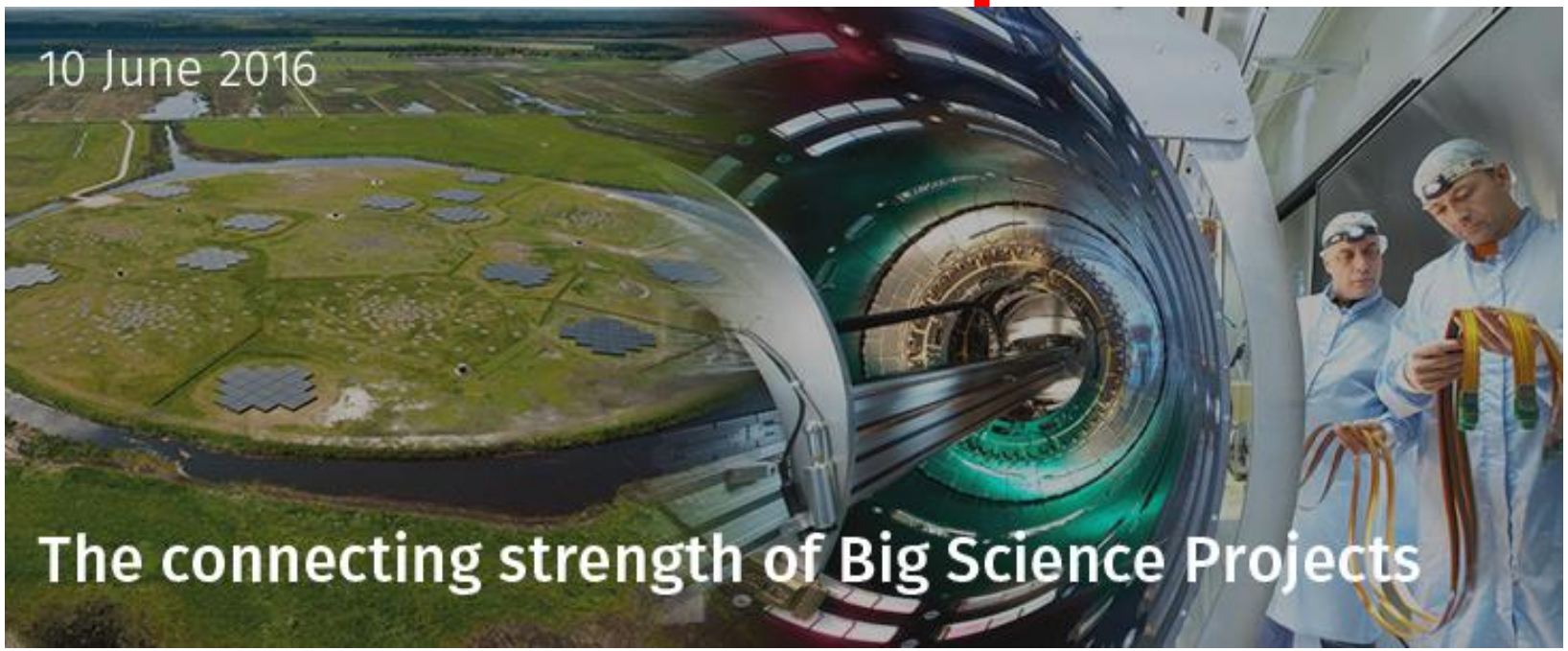
[2]*Nikhef, Amsterdam*

Peter Jansweijer
Nikhef
Amsterdam

Timeline

2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020

Here we are now:



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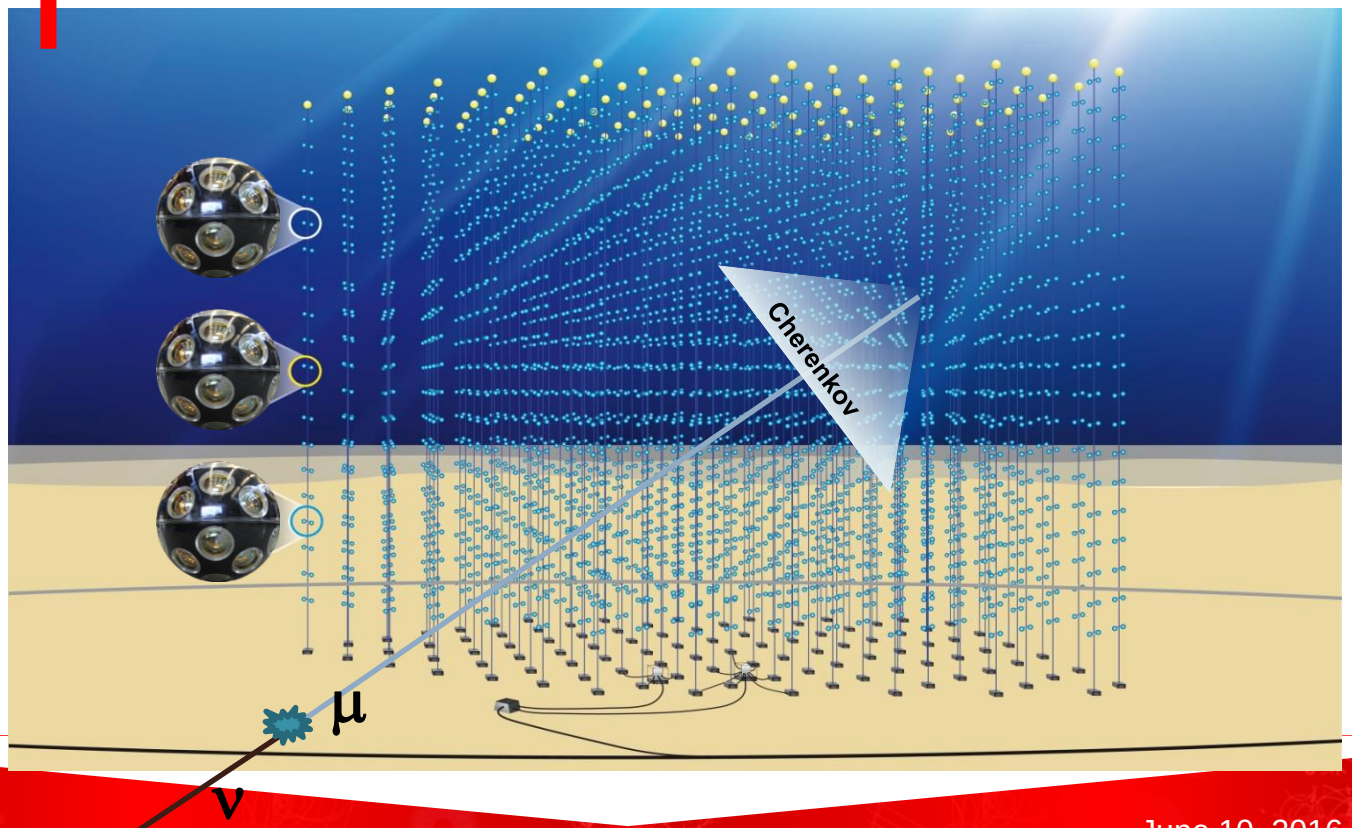
Nikhef
Amsterdam

KM3NeT

Start thinking about timing for the KM3NeT detector



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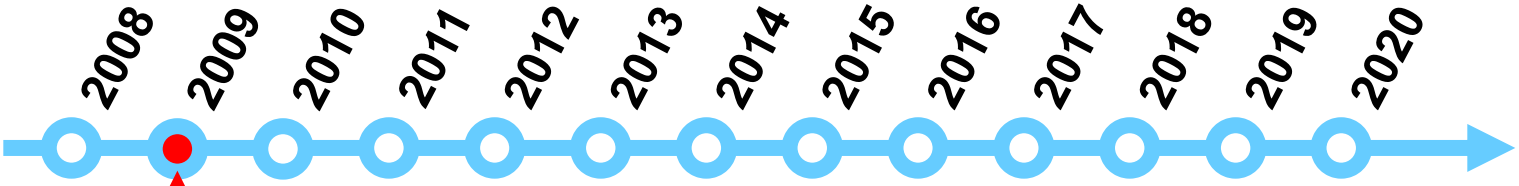
VLVνT 09 in Athens



"Measuring propagation delay over a coded serial communication channel using FPGAs"

(P.P.M. Jansweijer, H.Z. Peek)

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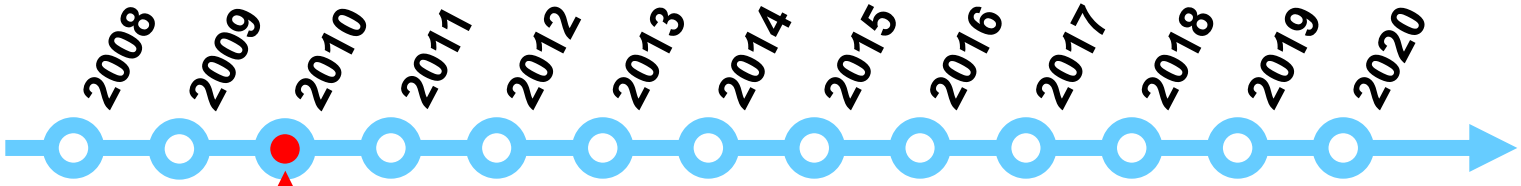
Amsterdam

Joining efforts



Nikhef

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

1st White Rabbit Developer meeting @ CERN

CERN

GSI Helmholtzzentrum für Schwerionenforschung

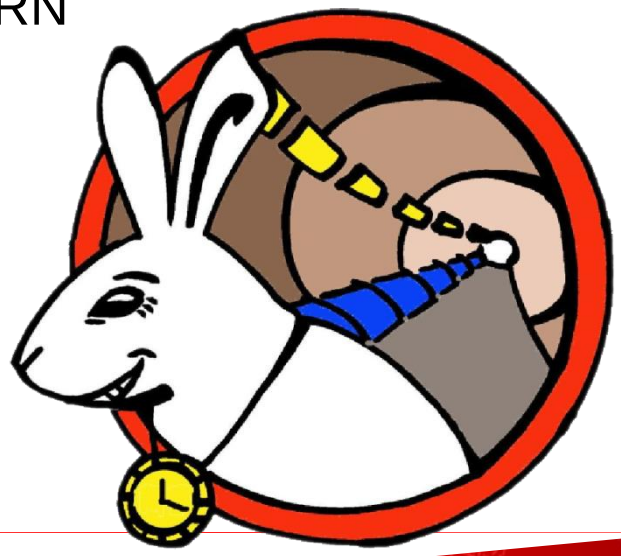
FAIR

GNU device drivers embedded systems

creoTECH Instruments S.A.

COSYLAB

INTEGRASYS Building Success from Innovation



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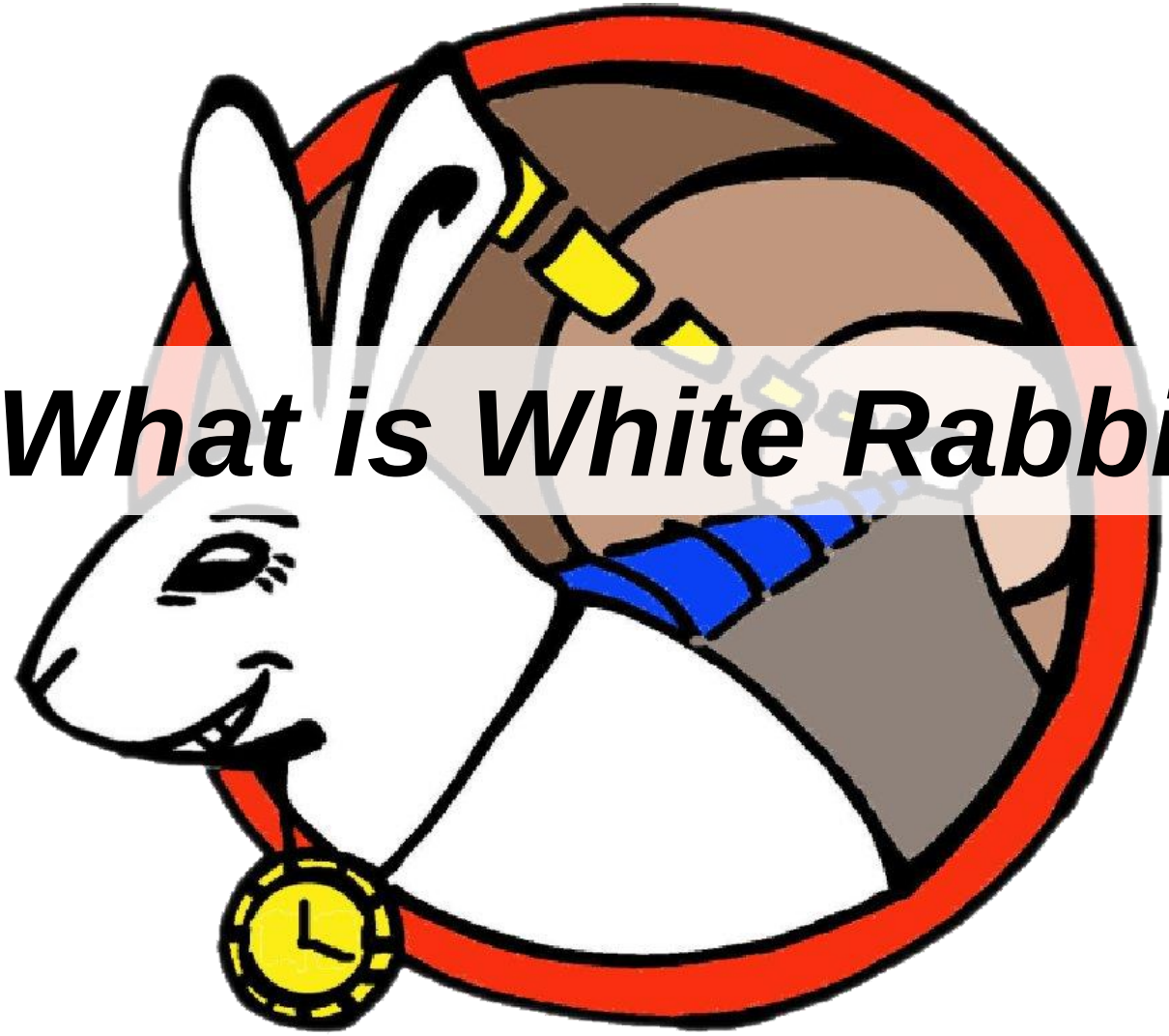

What is White Rabbit?

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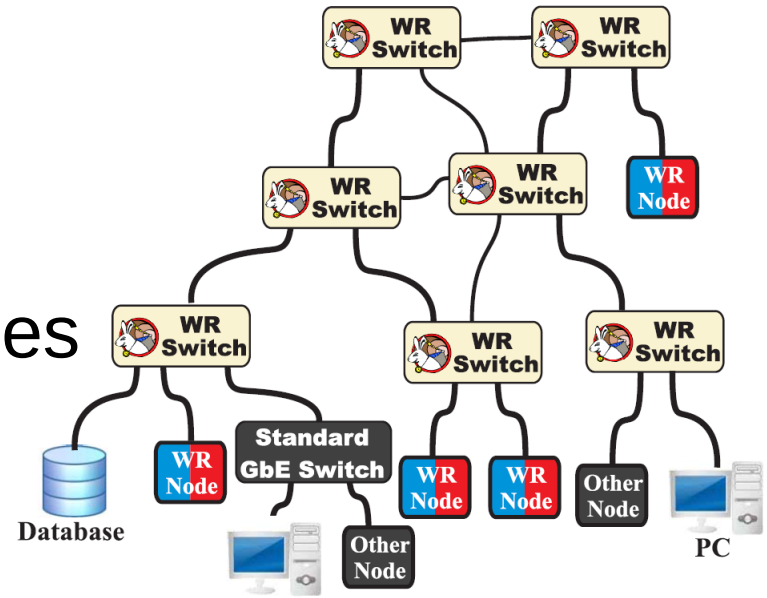
Amsterdam

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)



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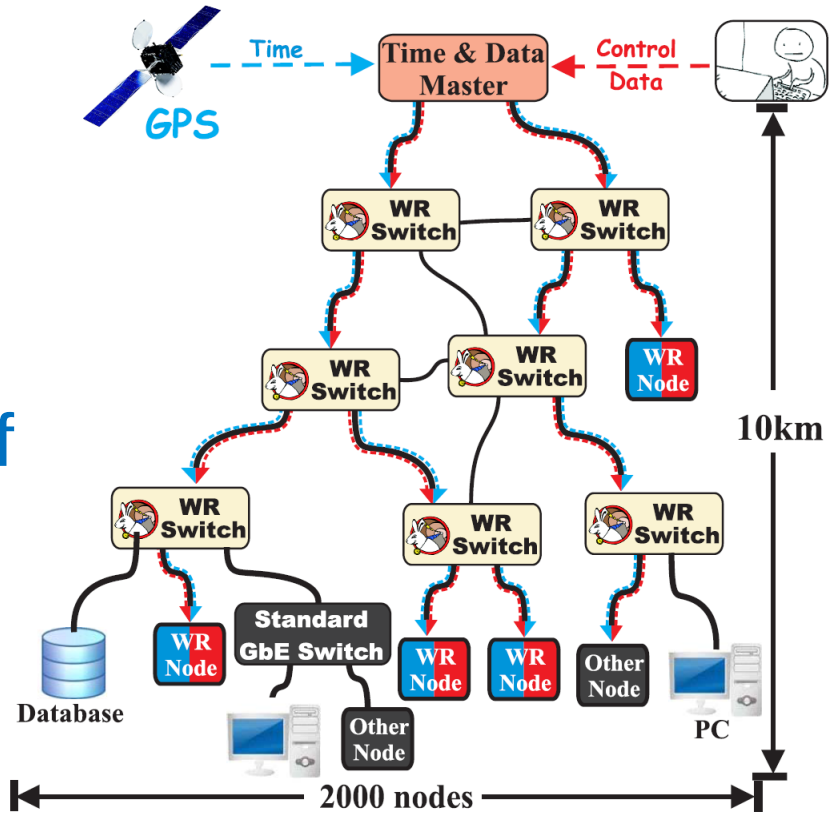
White Rabbit
an *extension* of Ethernet

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



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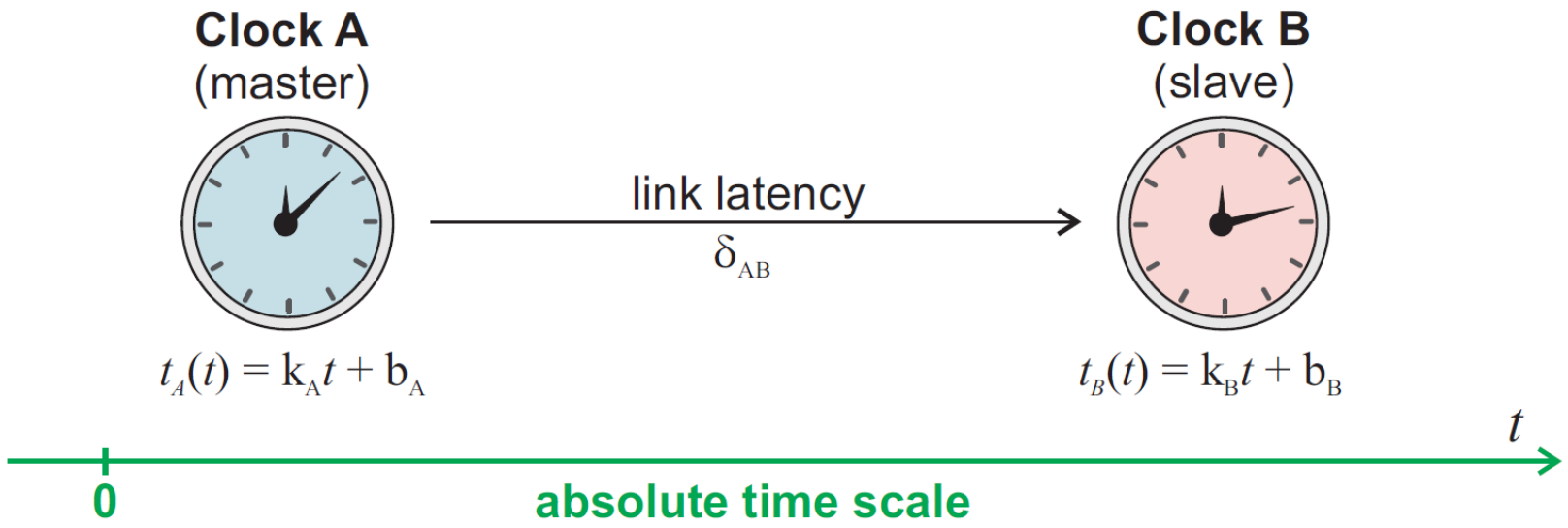
Timing over Ethernet



$k_A = k_B$ Syntonization	Synchronous Ethernet
$b_A = b_B$ synchronisation	Precision Time Protocol (PTP)

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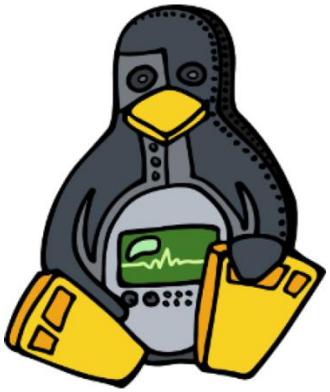
Open Hardware Repository

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



http://www.ohwr.org/

	Commercial	Non-commercial
Open	**Winning combination. Best of both worlds.**	Whole support burden falls on developers. Not scalable.
Proprietary	Vendor lock-in.	Dedicated non-reusable projects.

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4th and 5th WR workshop

2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020

Number of participants and companies grow

Picture taken @ 4th WR workshop (2011), GSI Darmstadt

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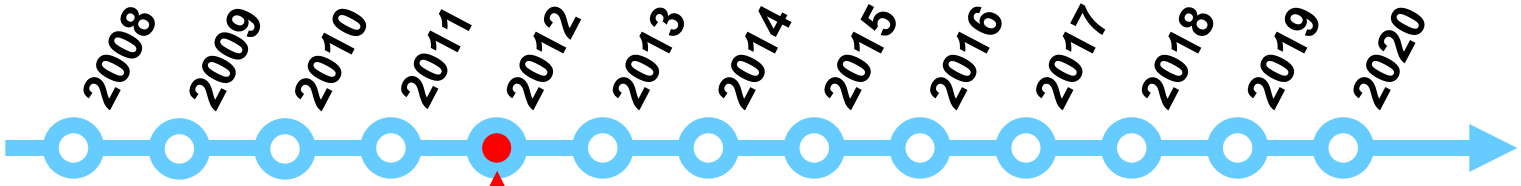
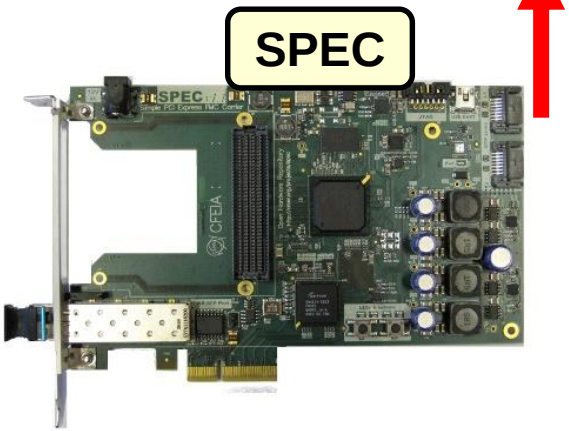
First open hardware, start standardization





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

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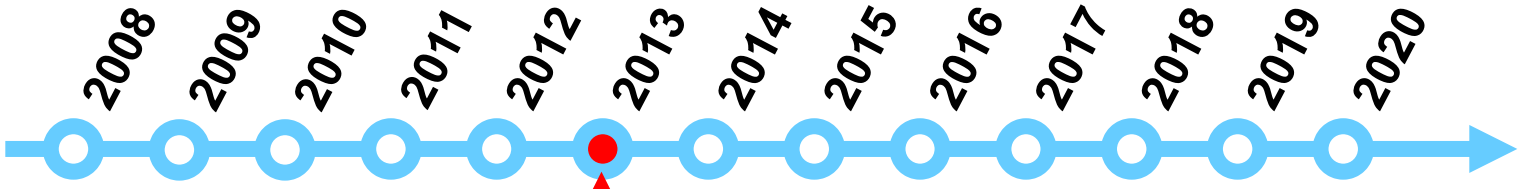
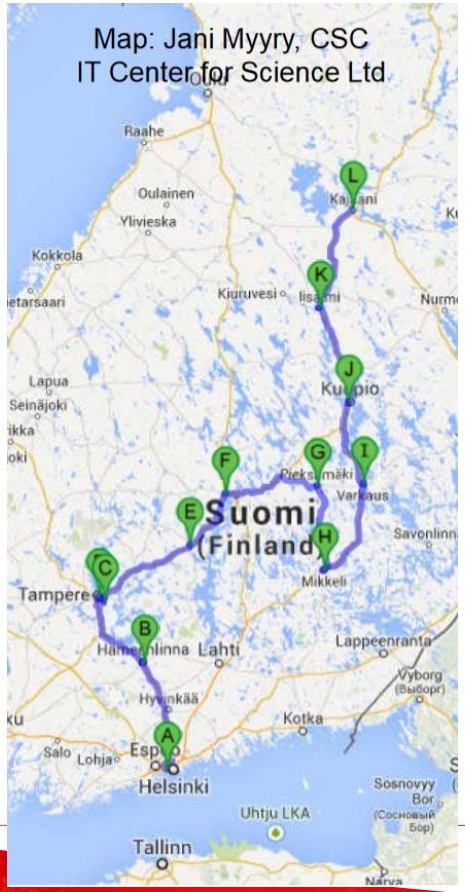
Many use cases…



… also means many bug reports



MIKES METROLOGIA

1000 Km link in Finland (Anders Wallin)

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

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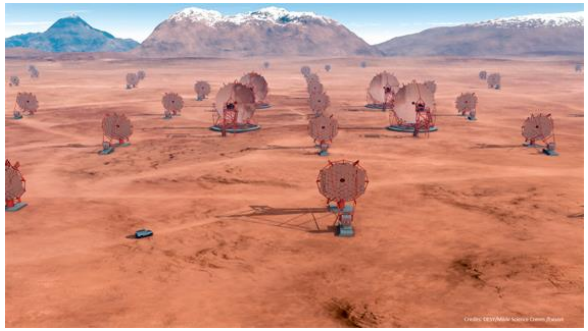
Many new users

2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020

DESY

HUMBOLDT-UNIVERSITÄT ZU BERLIN

HiSCORE



cta cherenkov telescope array

TSINGHUA UNIVERSITY 1911

LHAASO

SKA SQUARE KILOMETRE ARRAY

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

VLBI

jive JOINT INSTITUTE FOR VLBI IN EUROPE

Courtesy Paul Boven

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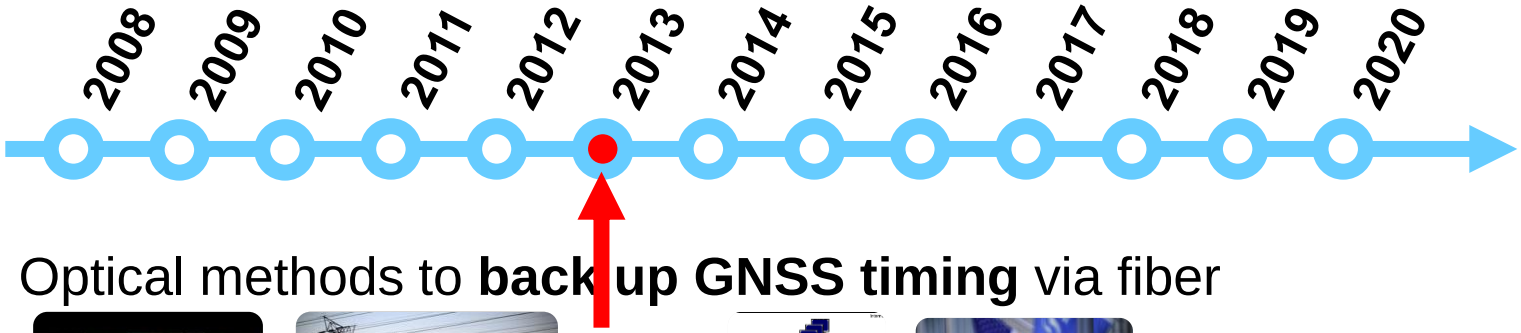
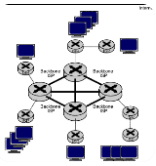
Nikhef
Amsterdam

SuperGPS

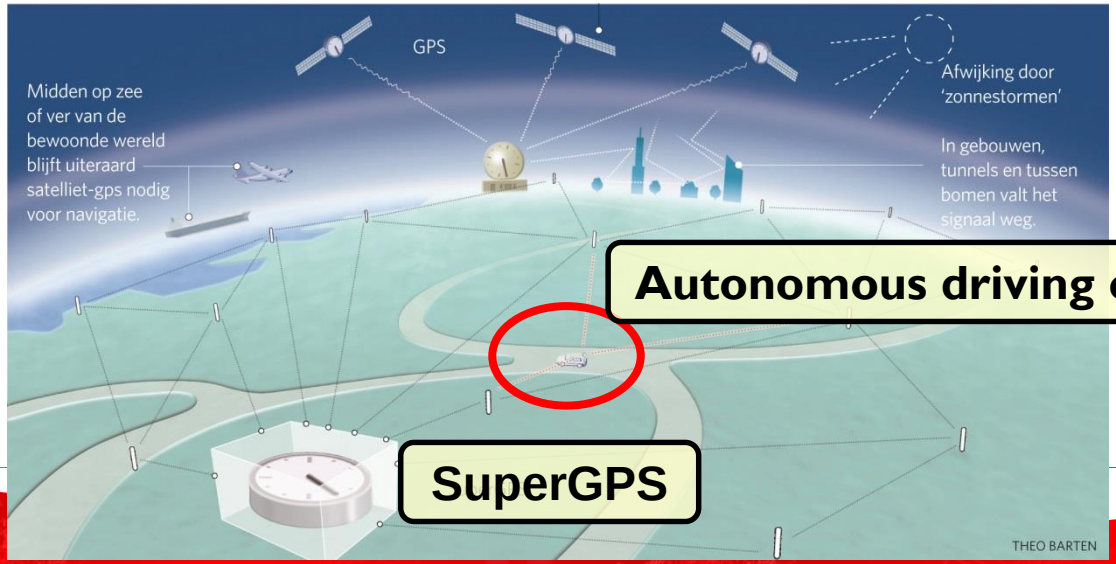


- Optical methods to **back up GNSS timing** via fiber




- **Next-generation positioning** (optical/radio)



VU VRIJE UNIVERSITEIT AMSTERDAM

TU Delft

Pictures: Jeroen Koelemeij
http://www.ohwr.org/attachments/1753/Jeroen-superGPS.pptx

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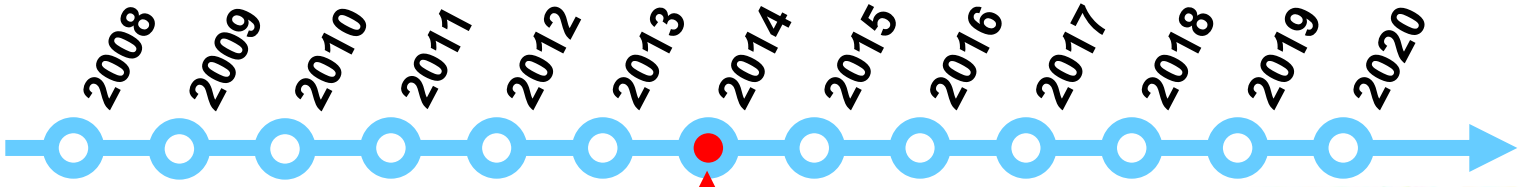
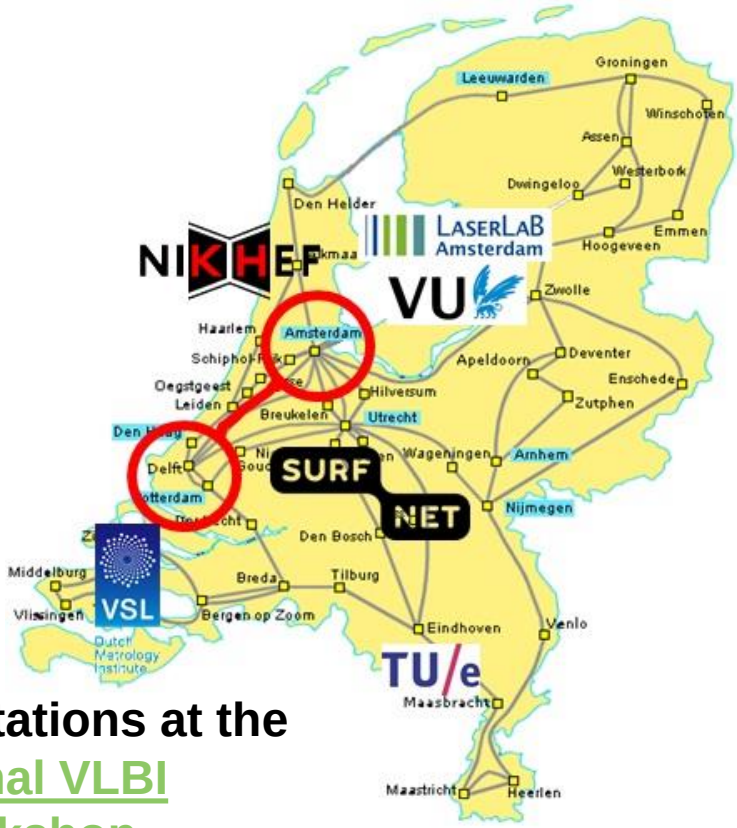
Metrology institutes discover potentials



international optical clock
Comparisons using optical fibers



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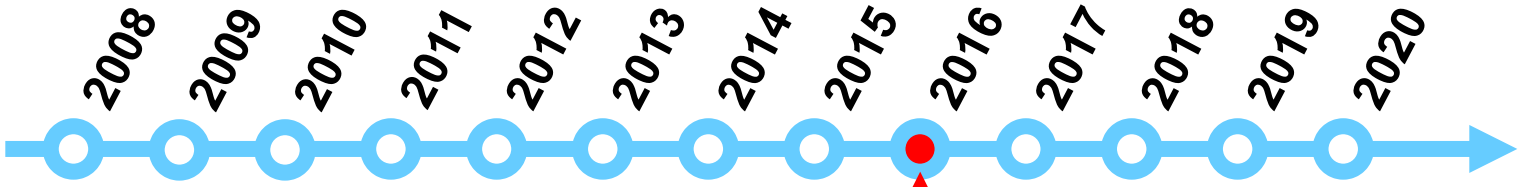
Amsterdam

See also presentations at the
Third International VLBI Technology Workshop

9th WR workshop hosted by Nikhef



66	Participants
30	Institutes Universities Companies
9	Countries Worldwide

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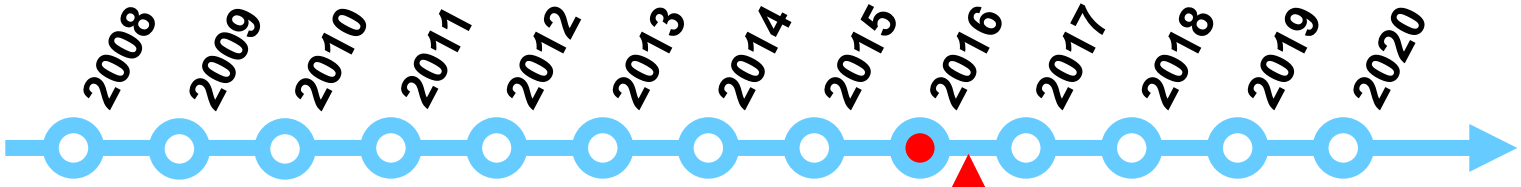
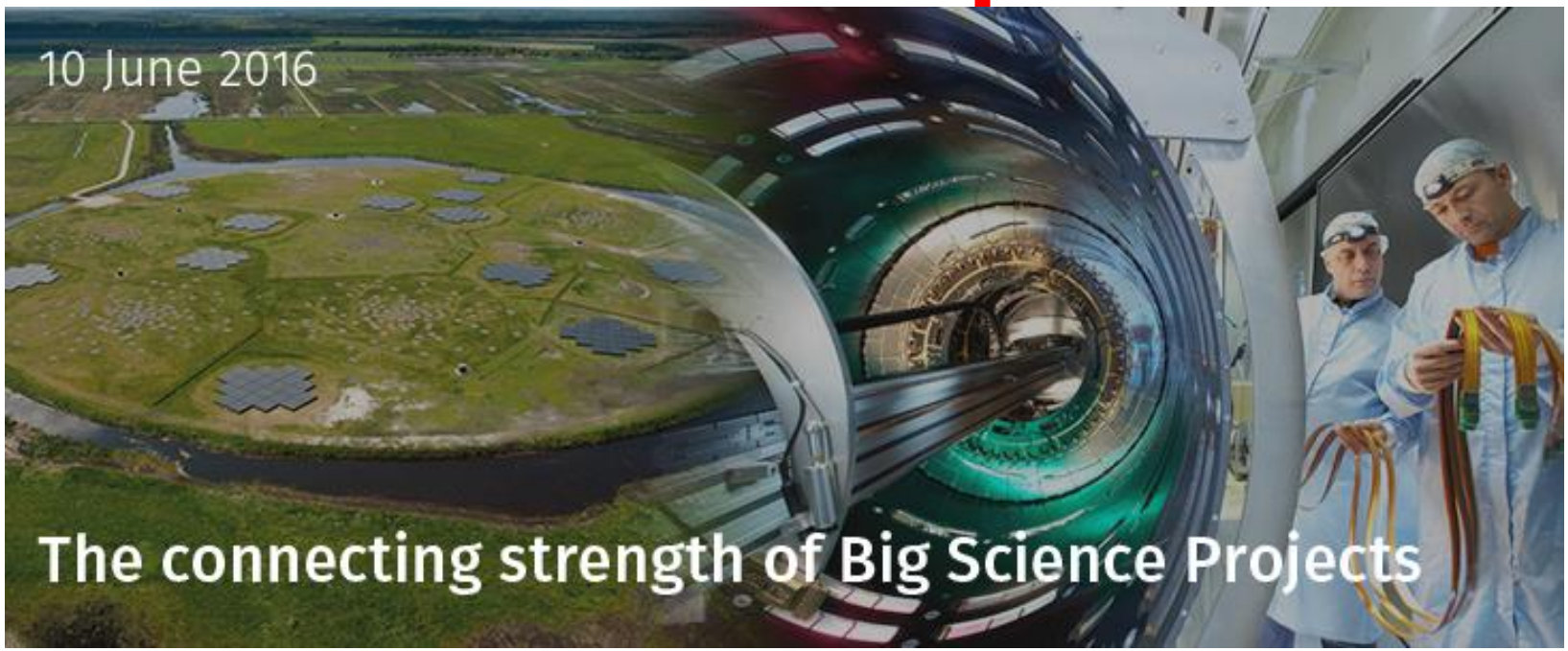
Now and the Future





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Amsterdam

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

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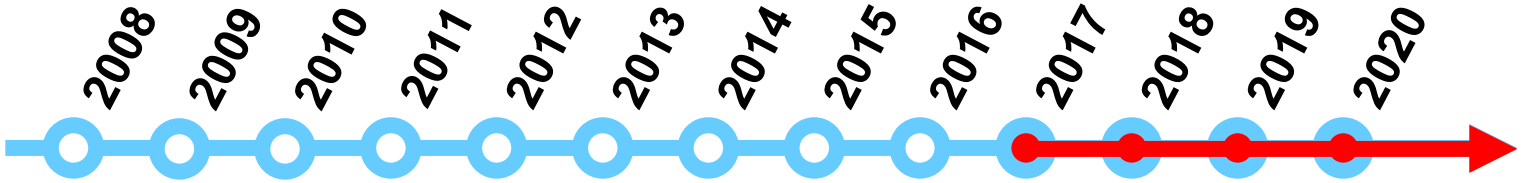
Future? Timing is Booming Business



- 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…

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Thank you

And:

thanks to all WR developers / contibutors

(also for re-using many of the White Rabbit slides)

all WR users

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