LIÈGE université

Activities at the STAR Institute

(Space Sciences and Technologies for Astrophysics Research)

▶ Jean-René Cudell

▷ Atri Bhattacharya

▷ Vincent Boudart

COSPA restart meeting, ULB, 29/10/2021

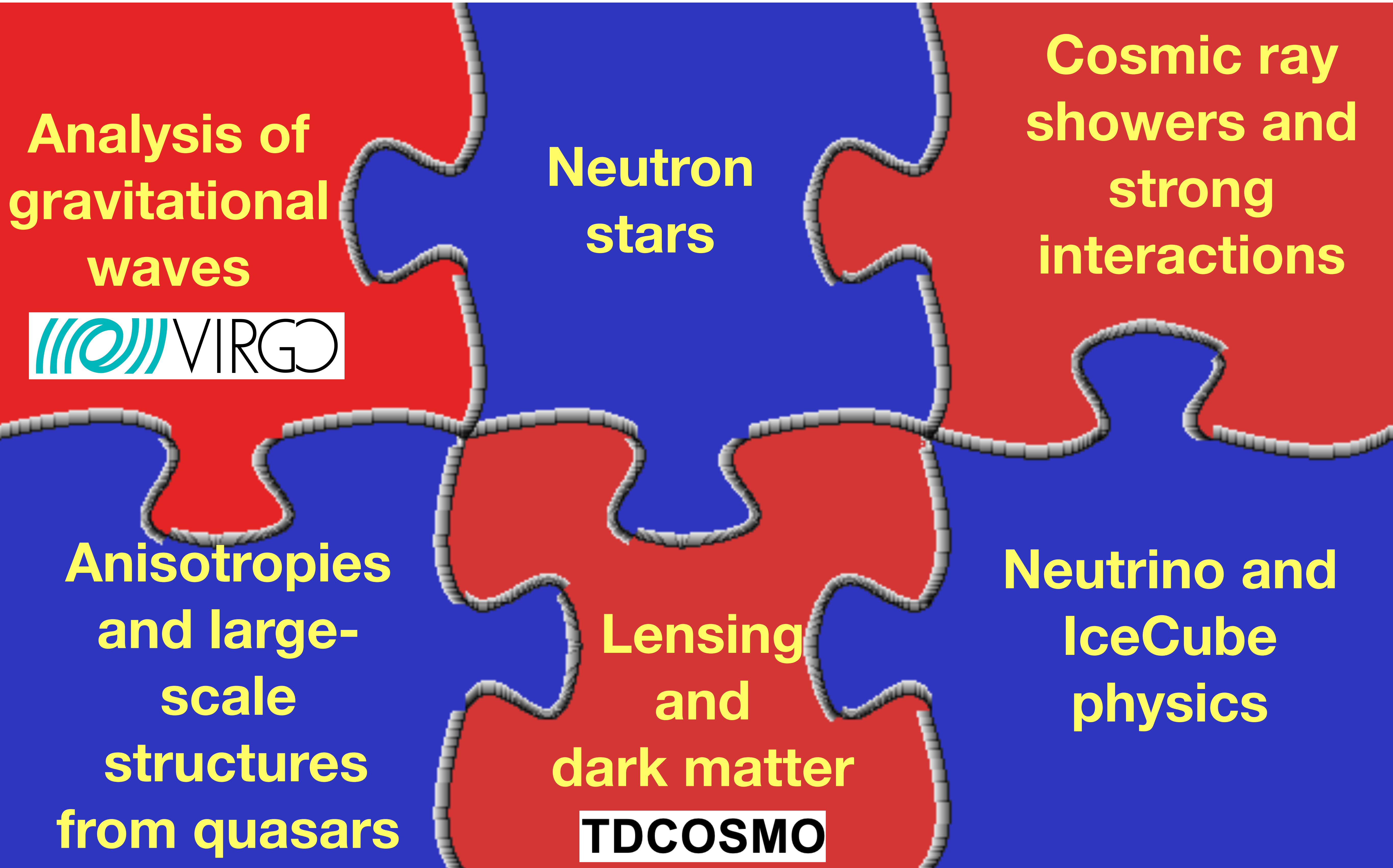
Note: I shall not cover E-Test

See Christophe Collette

Precision Mechatronics Laboratory

http://www.pmlab.be

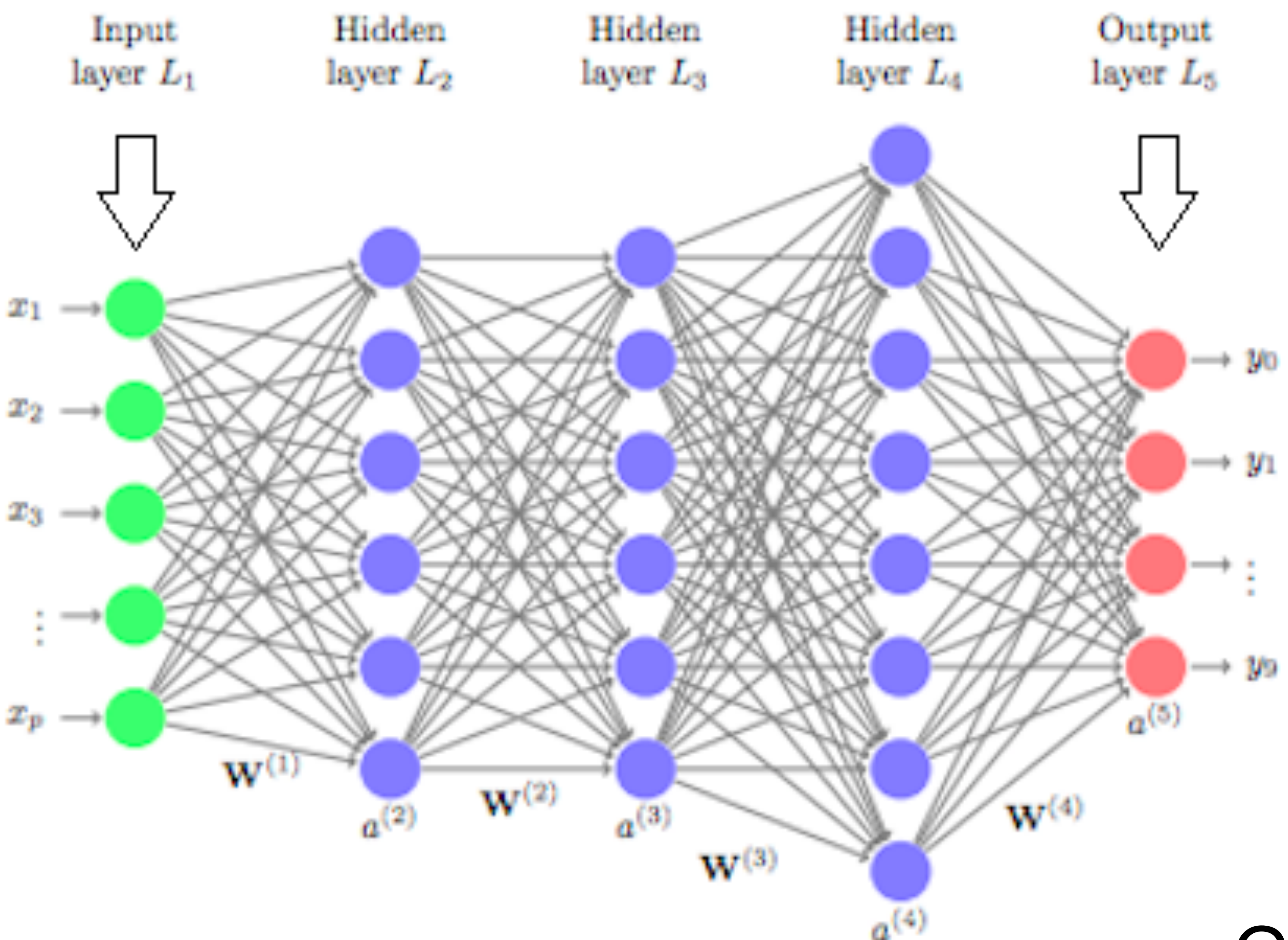
Activities


Analysis of gravitational waves
VIRGO
Neutron stars
Cosmic ray showers and strong interactions
Anisotropies and large-scale structures from quasars
Lensing and dark matter
TDCOSMO
Neutrino and IceCube physics

Gravitational waves

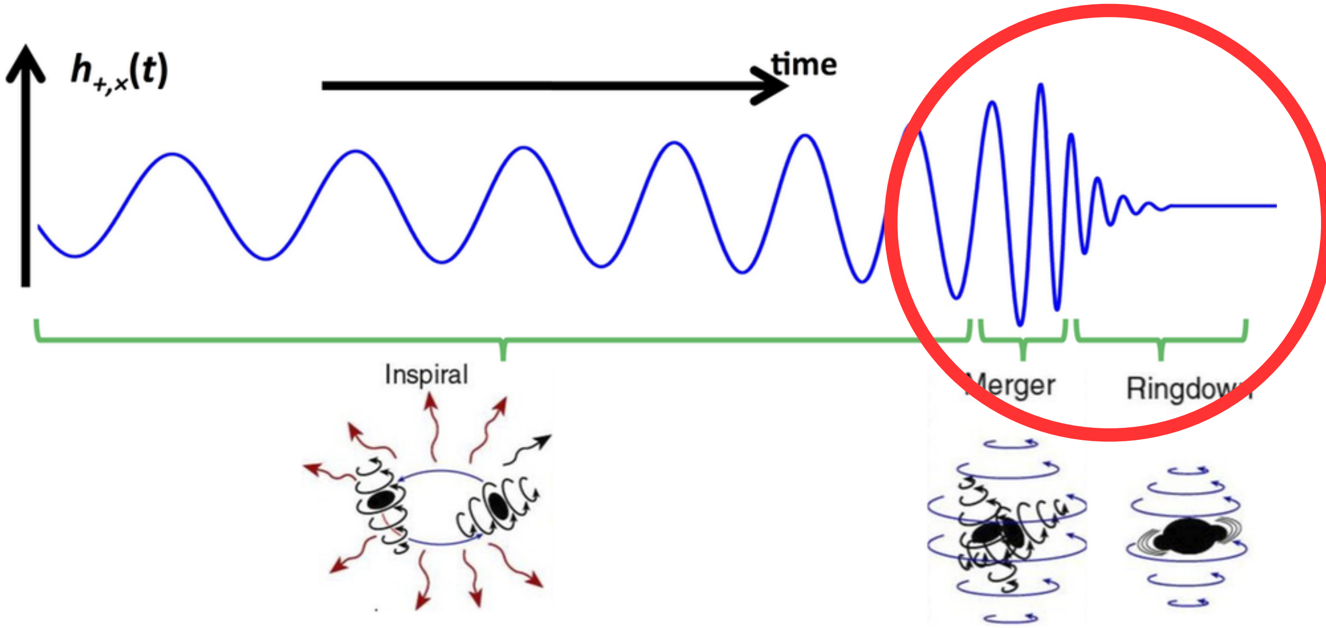
- **Early detection of neutron star mergers**
  Convolutional neural networks for the detection of the early inspiral of a gravitational-wave signal, **G. Baltus**, J. Janquart, M. Lopez, A. Reza, S. Caudill and **J.R.C.**, Phys.Rev.D 103 (2021), 102003
- **Detection of unmodeled signals ➜ Vincent's talk**
- **Search for primordial black holes**
  The hunt for sub-solar primordial black holes in low mass ratio binaries is open, K. S. Phukon, **G. Baltus**, S. Caudill, S. Clesse, A. Depasse, **M. Fays** et al., e-Print: 2105.11449 [astro-ph.CO]
- **New Filter for phase lock loop**
- *IWAVE -- An Adaptive Filter Approach to Phase Lock and the Dynamic Characterisation of Pseudo-Harmonic Waves,* Edward J. Daw, Ian J. Hollows, Elliot L. Jones, Ross Kennedy, Timesh Mistry, **Maxime Fays** et al., e-Print: 2109.00104 [physics.ins-det]

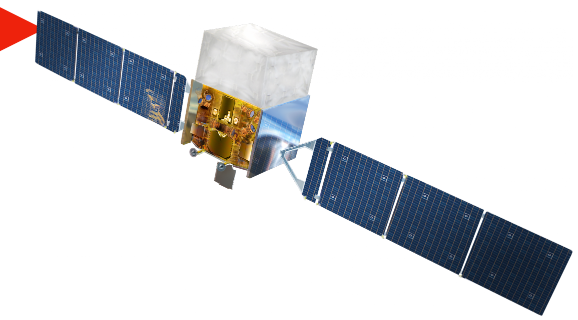
Machine learning



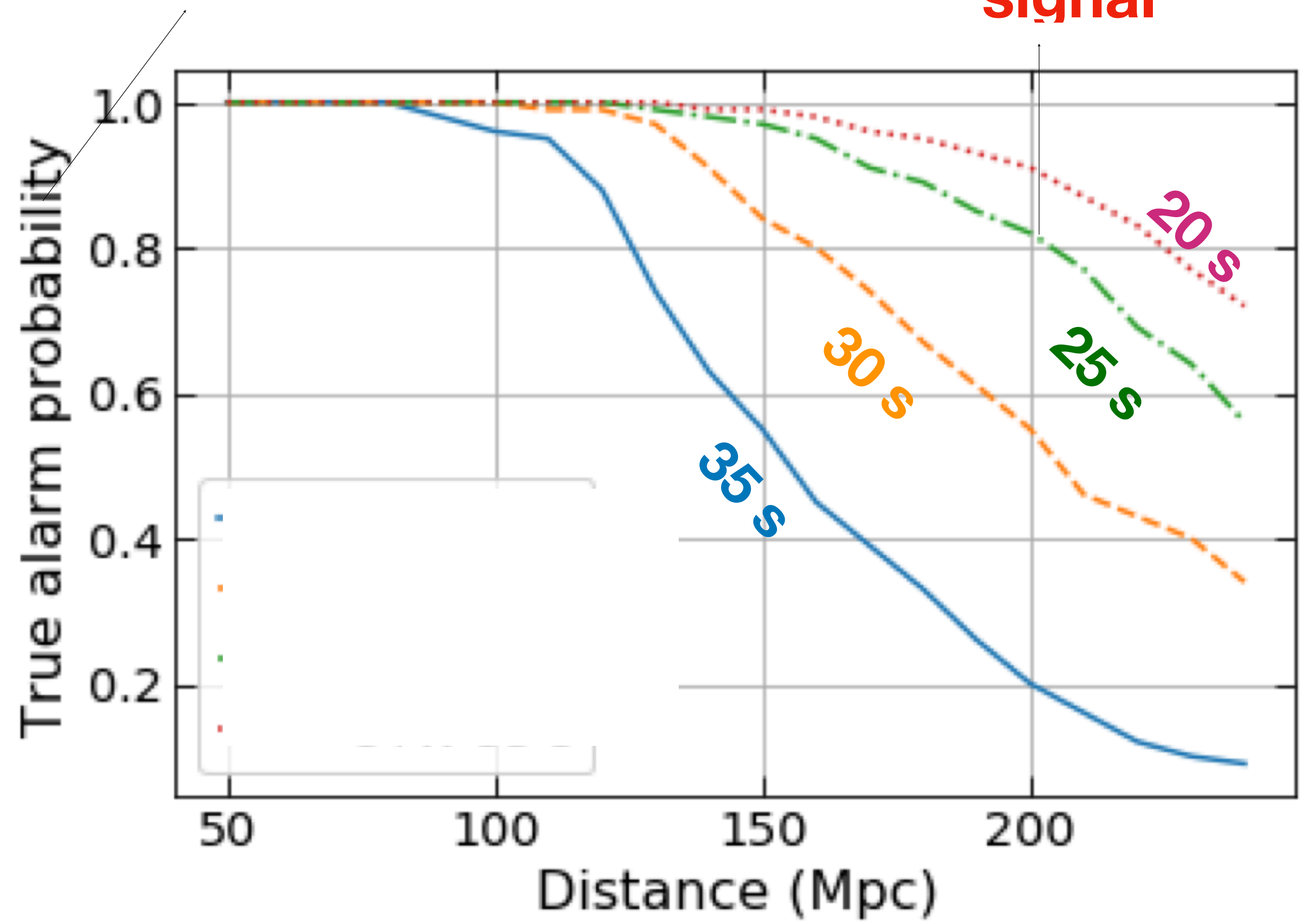
- Good at identifying patterns
- cats/dogs or noise/GWs
- Extremely fast after training
- Massively parallel computing

Convolutional Neural Network for early inspiral detection



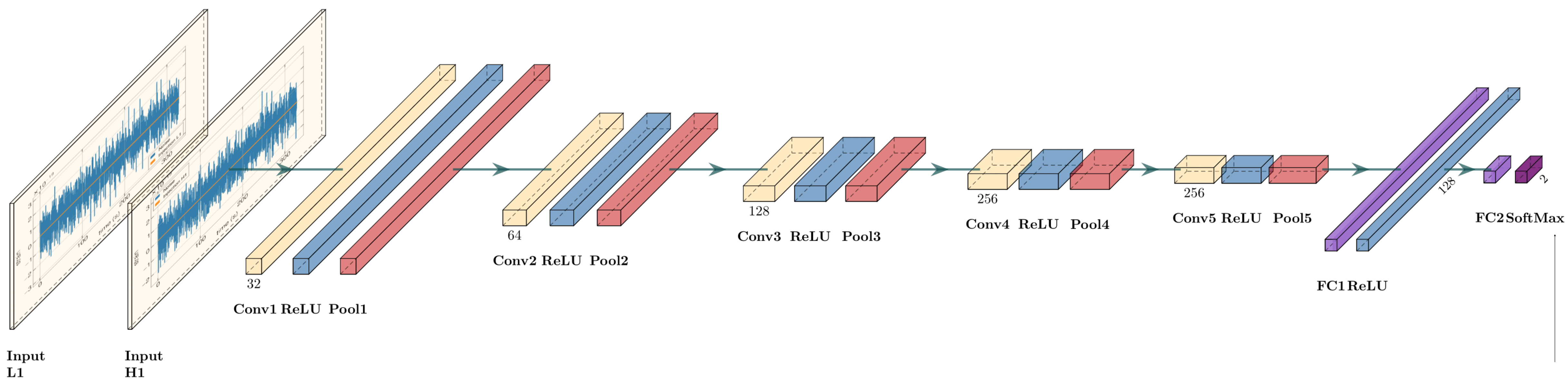


Electromanetic signal



At present, 1st preliminary alert sent 1 minute AFTER MERGER during the last run

A CNN can send an alert BEFORE the merger



In progress:

better training and optimized network

1st preliminary alert

could be sent

2 minutes

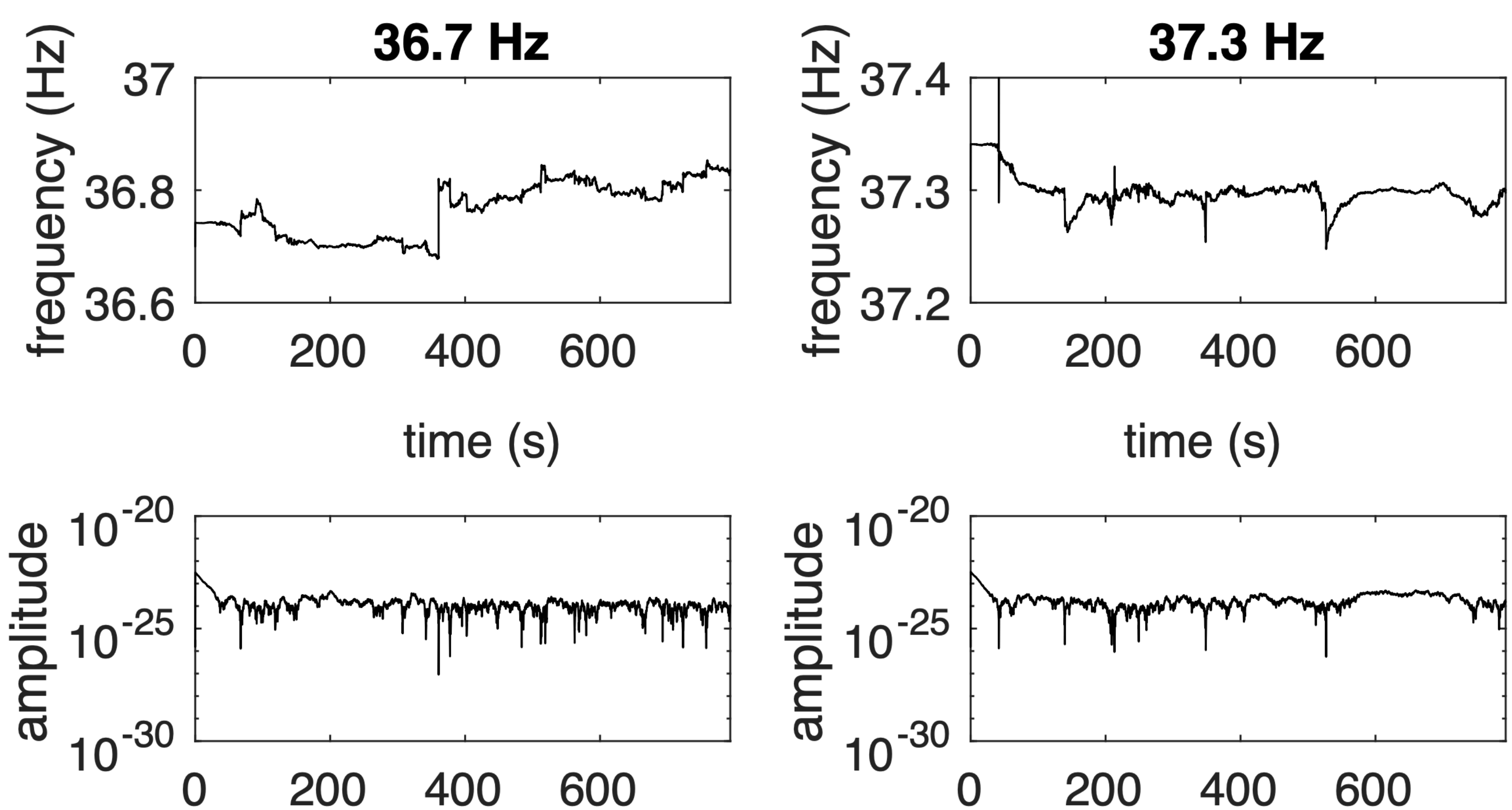
<u>**BEFORE**</u>

<u>**MERGER**</u>

during future runs

IWAVE filter

- Novel adaptive filtering approach to the dynamic characterisation of waves of varying frequency and amplitude embedded in arbitrary noise backgrounds.
- Characterised by single input parameter with low computational load
- Low latency: real-time tracking on single CPU core
  -> Potential for low-latency searches by removing violin modes, 60 Hz power line, etc…

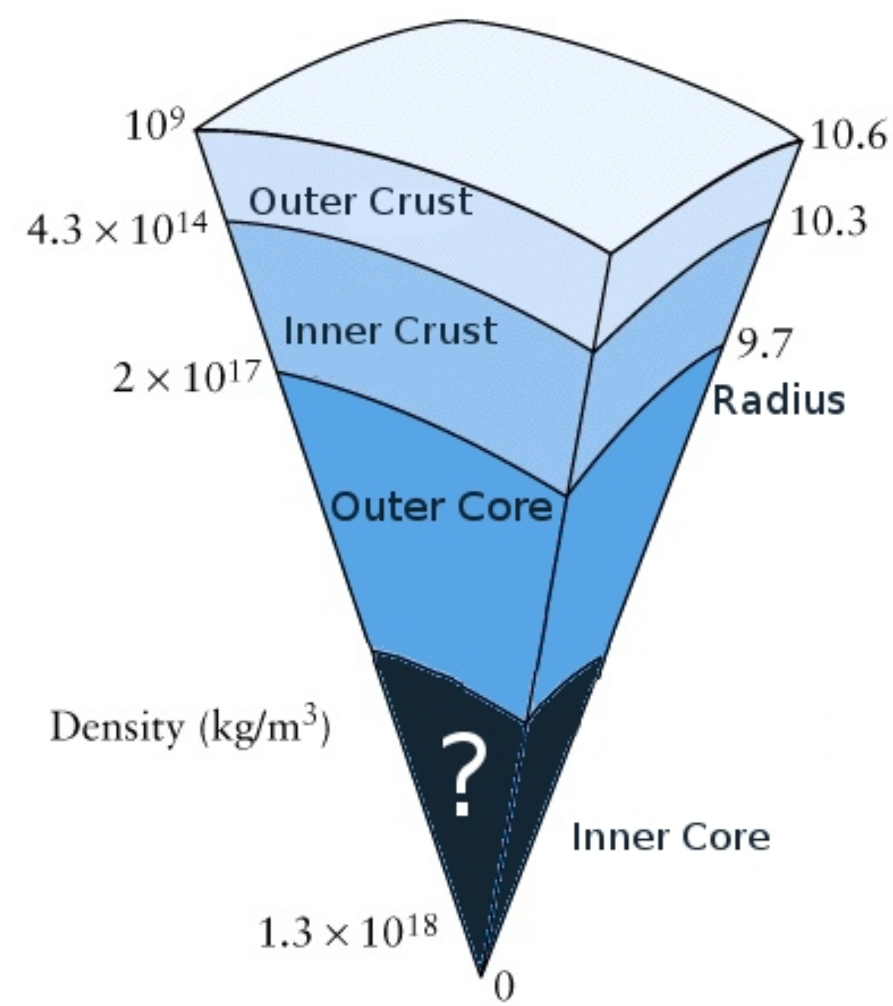


Modeling neutron star matter

B. Biswas, **P. Char**, R. Nandi, and S. Bose, PRD 103, 103015 (2021)

➡ tension between nuclear data and astrophysical observations (large radii)

- Use an EOS from aTaylor expansion around the nuclear saturation density and a phenomenological model (piecewise polytropes $P \propto \rho^{\gamma}$) at high density
- Use Bayesian analysis to determine the transition point.



➡ correctly reproduces neutron star properties along with nuclear matter properties at saturation

Properties of the secondary component of GW190814

Heaviest neutron star (NS) or smallest black hole (BH)?

2.50–2.67 $M_\odot$ "mystery object" with a 22.2–24.3 $M_\odot$ black hole seen in LIGO and Virgo

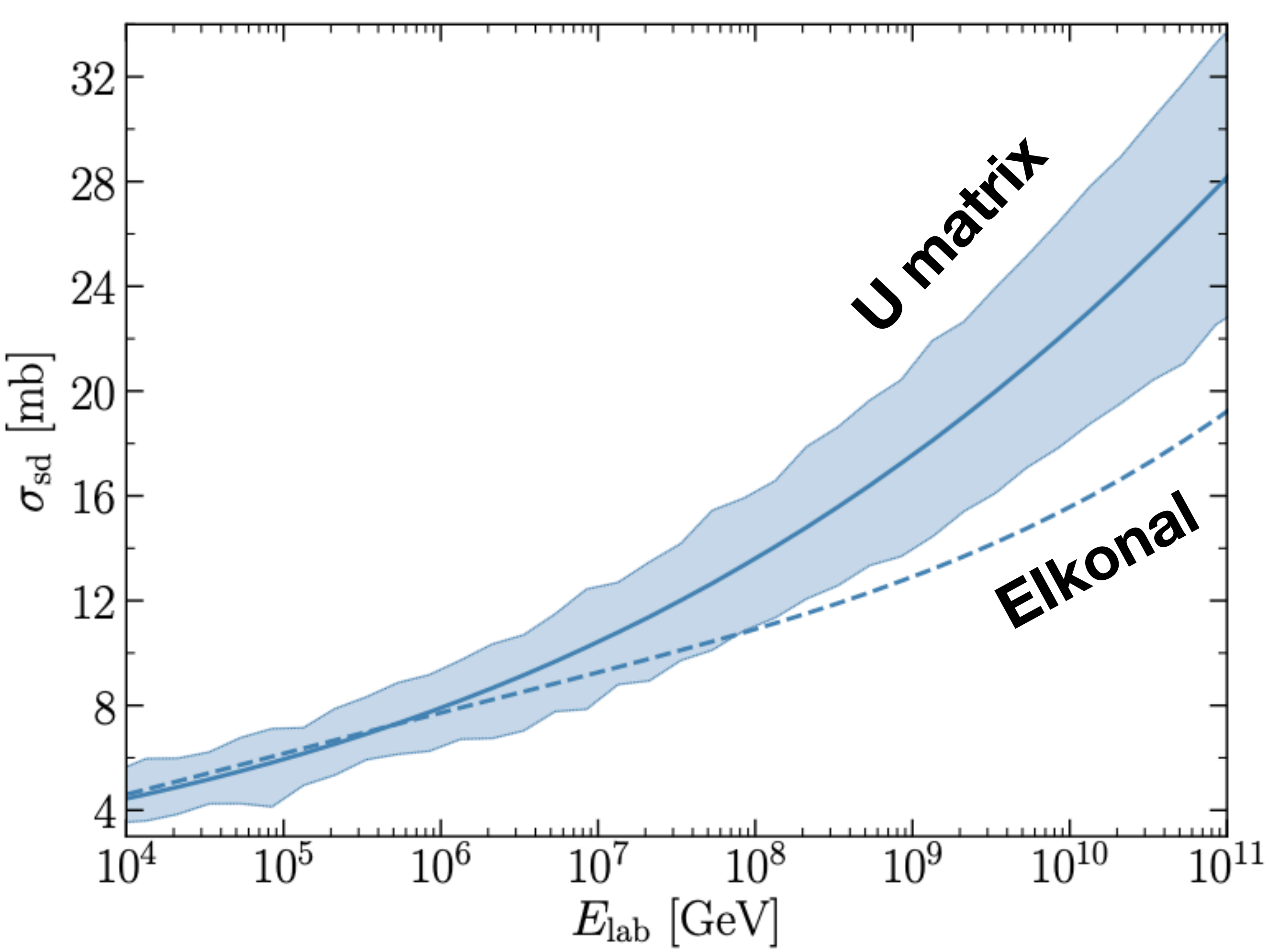
1. Non-rotating NS: We found the probability to be ~ 1%
2. Fast rotating NS: ~ 8% probability being a NS if the highest spinning pulsar has the maximum possible spin in nature.
3. Black hole: It sets an upper bound on the **maximum mass of neutron stars ($2.21_{-0.21}^{+0.19}$ $M_\odot$)** assuming the NS and the BH populations do not overlap.

B. Biswas, R. Nandi, **P. Char**, S. Bose, and N. Stergioulas, MNRAS 505, 1600 (2021)

Cosmic-Ray showers

Unitarisation dependence of diffractive scattering in light of high-energy collider data, A. Vanthieghem, **A. Bhattacharya, Rami Oueslati, J.R.C.,** JHEP 09 (2021), 005

Proton inelastic cross section at ultrahigh energies, **A. Bhattacharya, J.R.C., R. Oueslati,** A. Vanthieghem, Phys.Rev.D 103 (2021) 5, L051502



Overlooked uncertainty

- All Monte Carlos use the eikonal scheme to account for multiple pomeron exchanges
- It is known that this is wrong in QCD

➡ Use another scheme to describe soft forward interactions

➡factor 2 uncertainty in single diffractive @ultrahigh energy

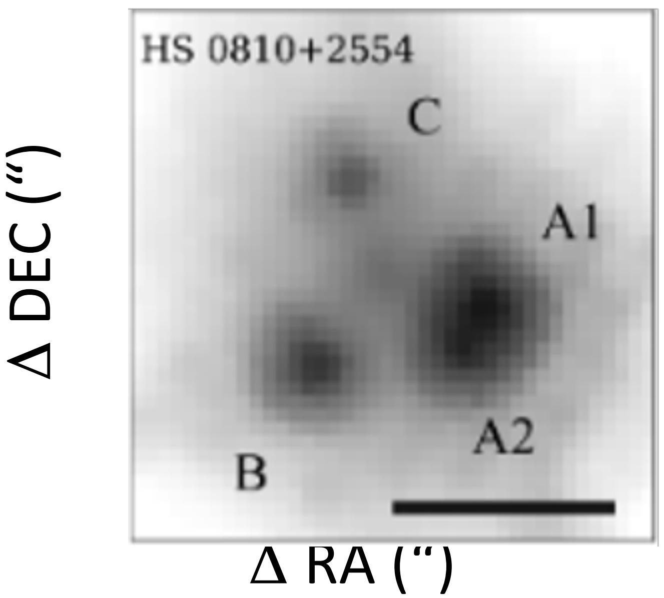
➡same for muons

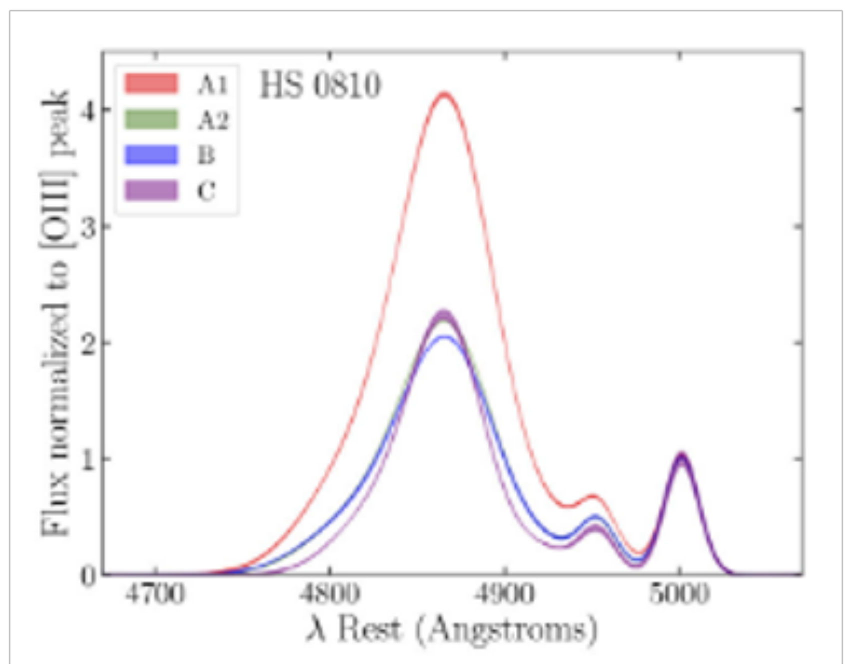
IceCube physics
➜ see Atri's talk

Gravitational lensing and dark matter

Double dark matter vision: twice the number of compact-source lenses with narrow-line lensing and the WFC3 grism, A.M. Nierenberg, … **D. Sluse** et al,, Mon. Not. Roy. Astron. Soc. 492 (2020) 4, 5314-5335

Narrow lines from the diffuse matter around quasars enable the detection of so far undetected subhalos



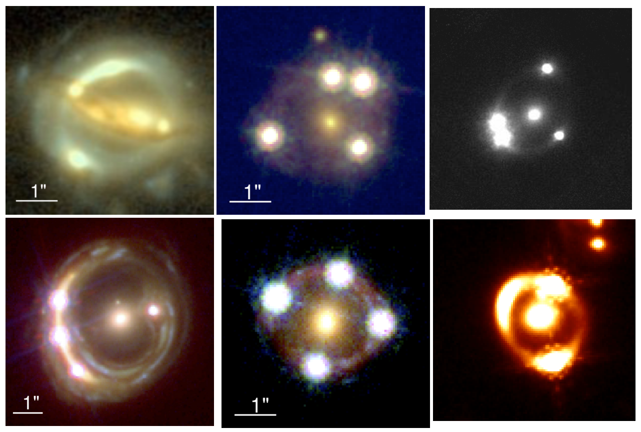


Flux anomalies among images come from dark matter substructures and can give a probability for their mass: data from 11 lensed events from the Hubble Space telescope

Coming soon: data for 31 lensed quasars from the James Webb Space Telescope approved

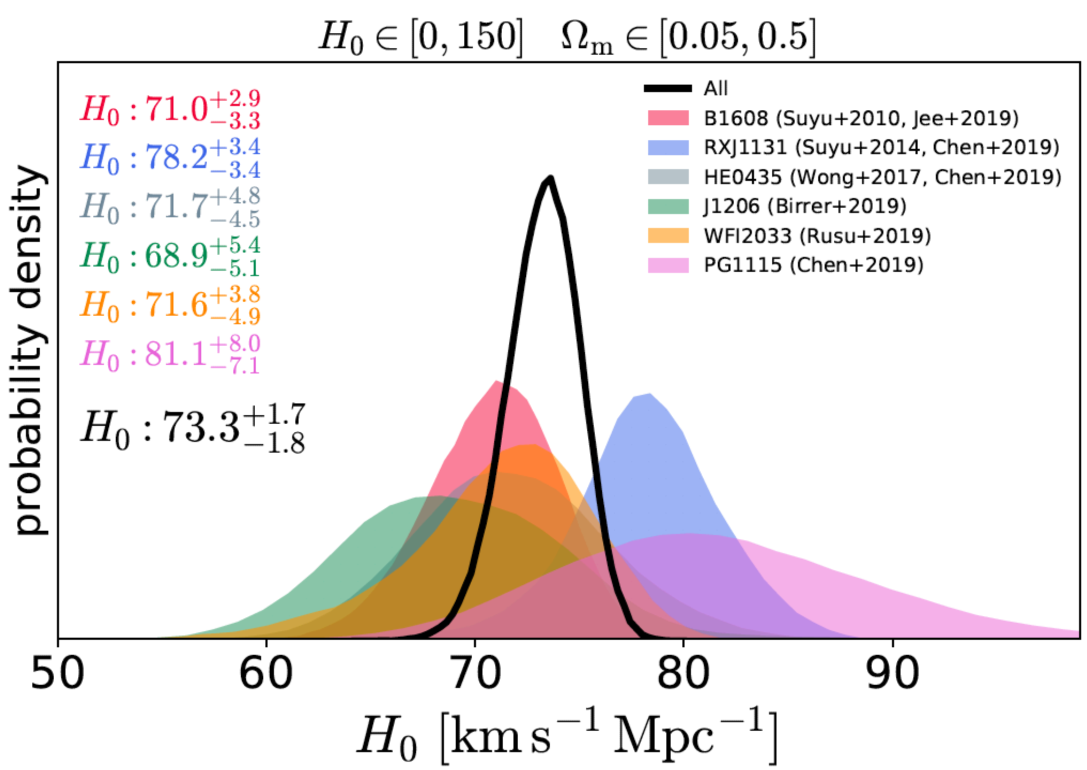
Strong lensing and the Lemaître constant H_0

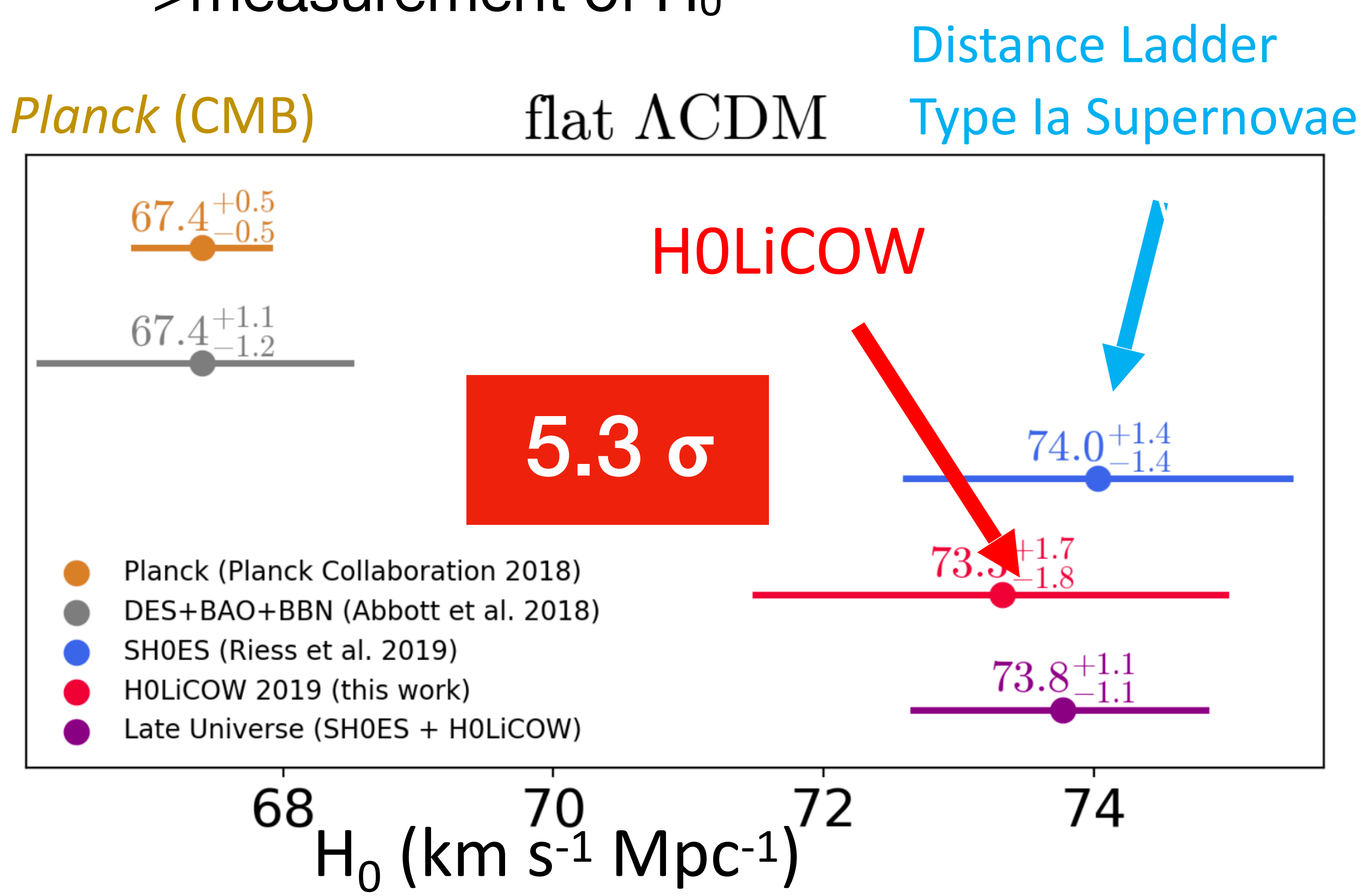
H0LiCOW - XIII. A 2.4 per cent measurement of H0 from lensed quasars: 5.3σ tension between early- and late-Universe probes, K.C. Wong… **D. Sluse** et al., Monthly Notices of the Royal Astronomical Society, 498 (2020) 1420-1439



Time-Delay Cosmography

6 strongly-lensed quasars
Measure time delays between images
using the variability of the quasar as a clock
->measurement of H_0





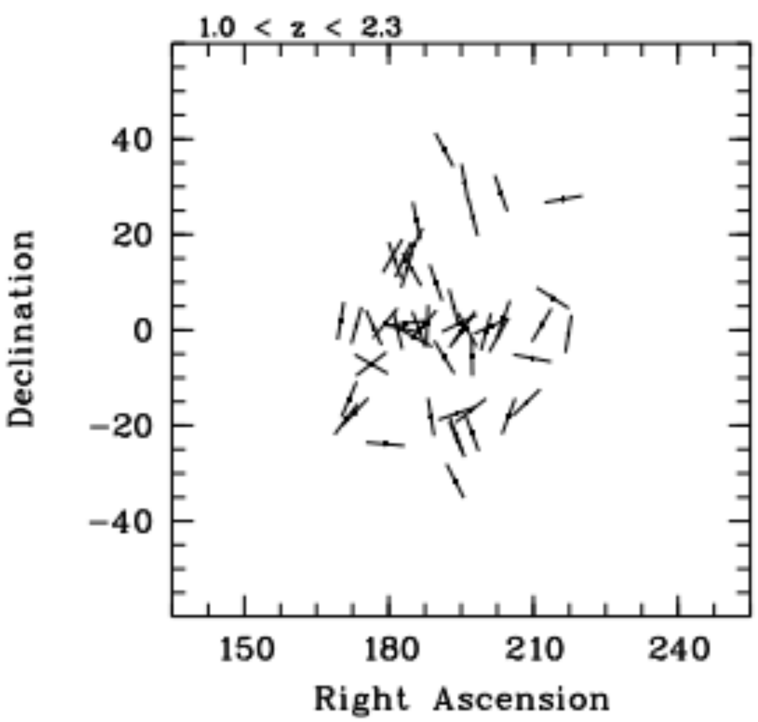
H0LICOW accretes researchers and becomes **TDCOSMO** (http://tdcosmo.org)

Many TDcosmo papers studying the systematic uncertainties in the extraction of H0

Quasars for cosmology and fundamental physics

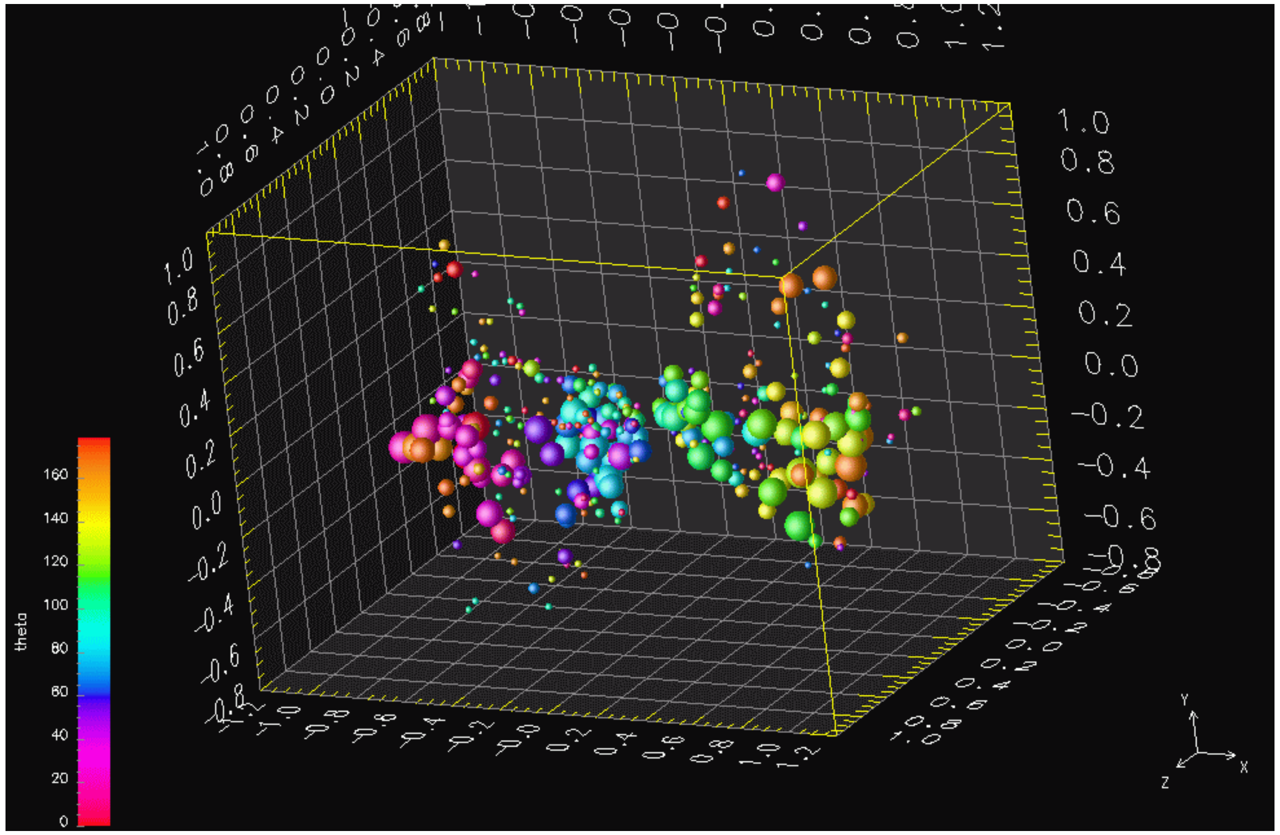
- Bounds on the circular polarisation lead to bounds on Axion-Like Particles

- **Hutsemekers effect**: systematic alignment of light polarisation for large-scale clusters of quasars

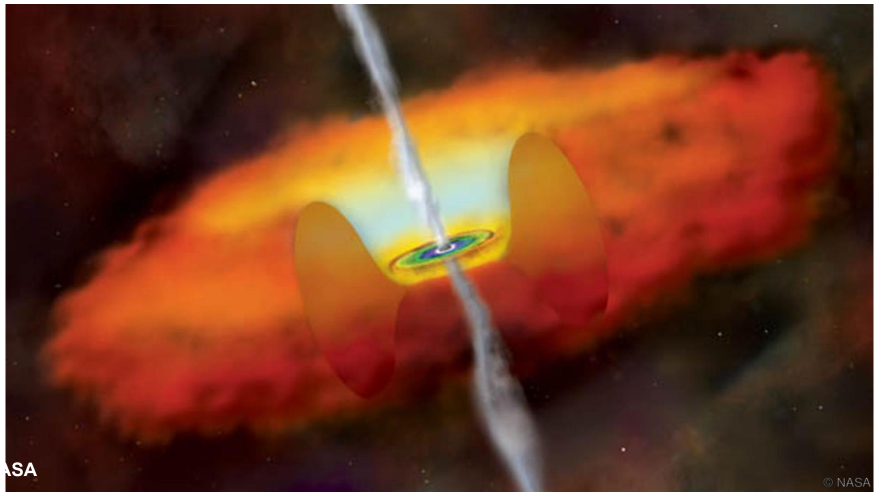


Alignments with large-scale structures? Dipole? Failure of the cosmological principle?

Rotation of the polarisation of electromagnetic waves from quasars with cosmological distance along a preferred axis



In progress



Understanding the quasar internal structure with polarimetry and microlensing:
- relation between polarization and SMBH spin axis
- orientation versus evolutionary effects

Developing wide field polarimetry to measure the polarization of 10^4 quasars :
- large-scale structures
- CMB foreground correction

Preparing future X-ray polarimetry:
- study of the SMBH immediate vicinity
- testing ALPs with high-energy photons