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Ministero dell'Università e della Ricerca
Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA
ICSC Centro Nazionale di Ricerca in HPC, Big Data and Quantum Computing

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Algorithm optimization to improve continuous gravitational-wave searches WP3 – Flagship Use Case 2.3.1

Lorenzo Pierini

Spoke 2 annual meeting, CINECA, 19/12/2023

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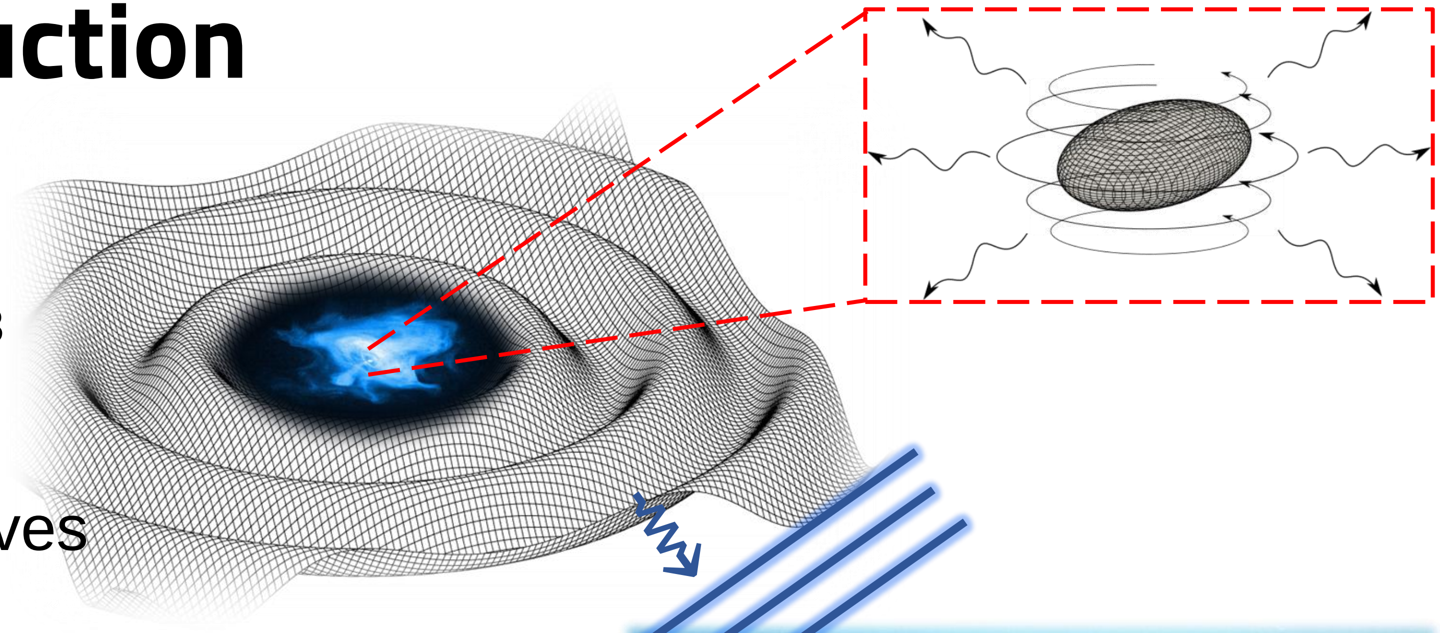
Introduction

About me:

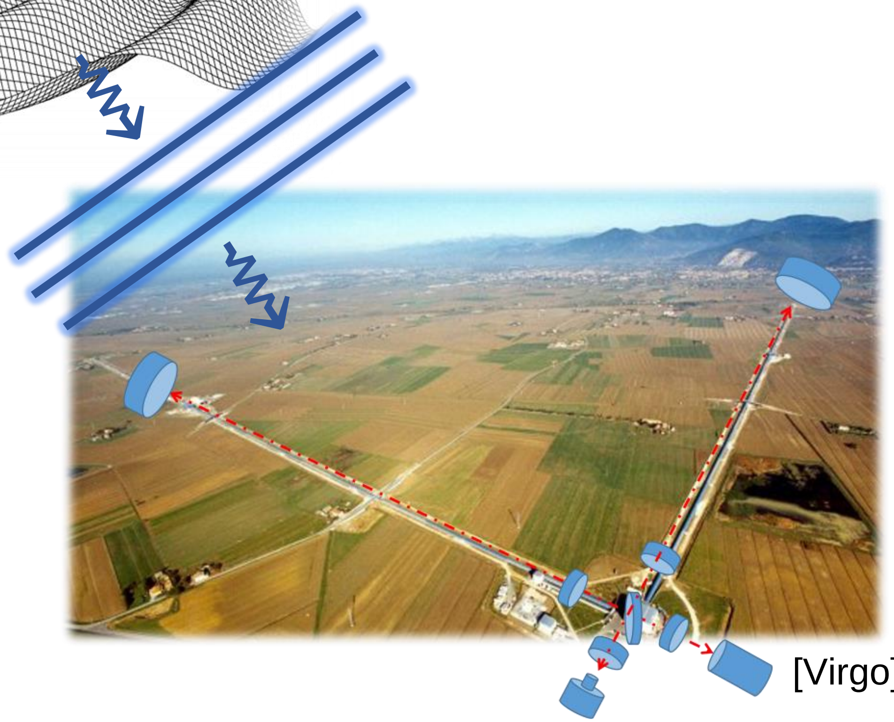
Lorenzo Pierini
PhD in physics, defended in May 2023
INFN technologist 100% ICSC since May 2023



About us: Virgo Rome group

Topic: Continuous gravitational waves

- Perturbations of the space-time, predicted by General Relativity.
- Emitted by rotating, deformed neutron stars (and more exotic sources).
- Can be detected by Earth-based detectors: LIGO, Virgo, KAGRA.
- Not yet detected so far.



[Virgo]

People involved:

- Pia Astone (**PI**) (INFN Roma)
- Lorenzo Pierini (INFN Roma)
- Marco Serra (INFN Roma)
- Stefano Dal Pra (INFN CNAF)
- Cristiano Palomba (INFN Roma)

How do we search those signals?

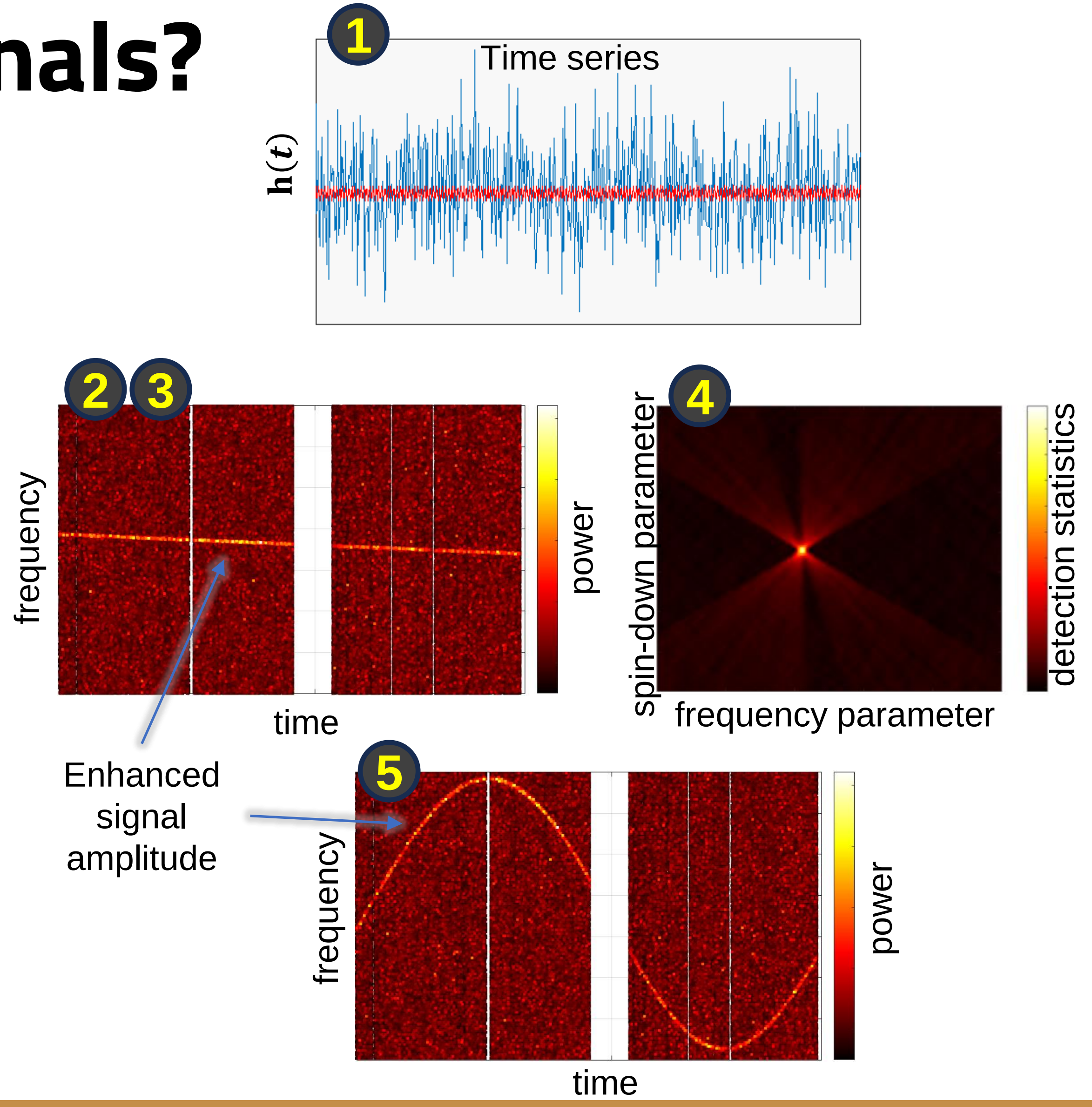
1) Detector output: calibrated time series. Weak signals deeply embedded in noise.

2) Data processed to obtain time-frequency maps.

3) The expected signal is nearly monochromatic, with a slow frequency variation (spin-down).

4) To recover the signal parameters, we apply the Hough transform to the map. Most significant outliers identify a possible signal.

5) However, the observed signal is distorted by the Doppler effect due to the Earth motion! This distortion changes for any sky location.



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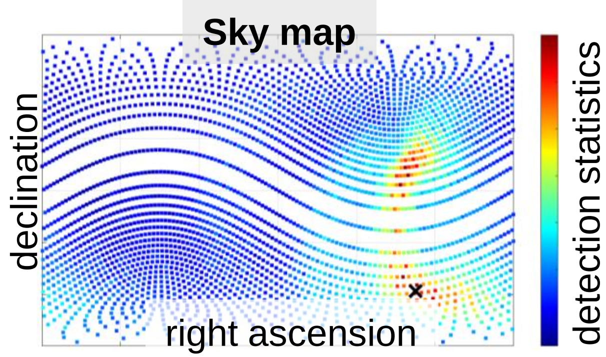
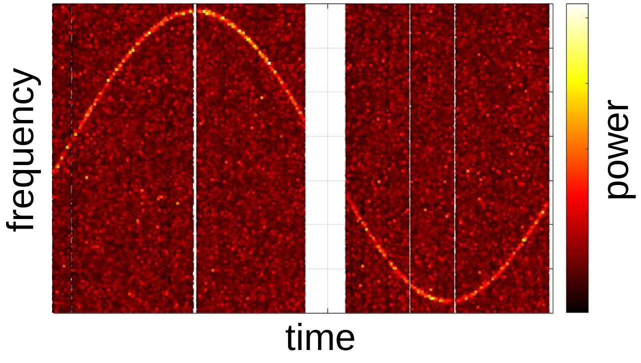
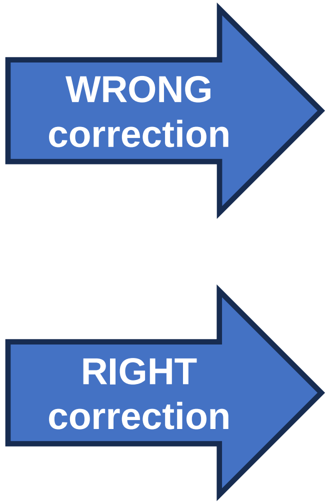
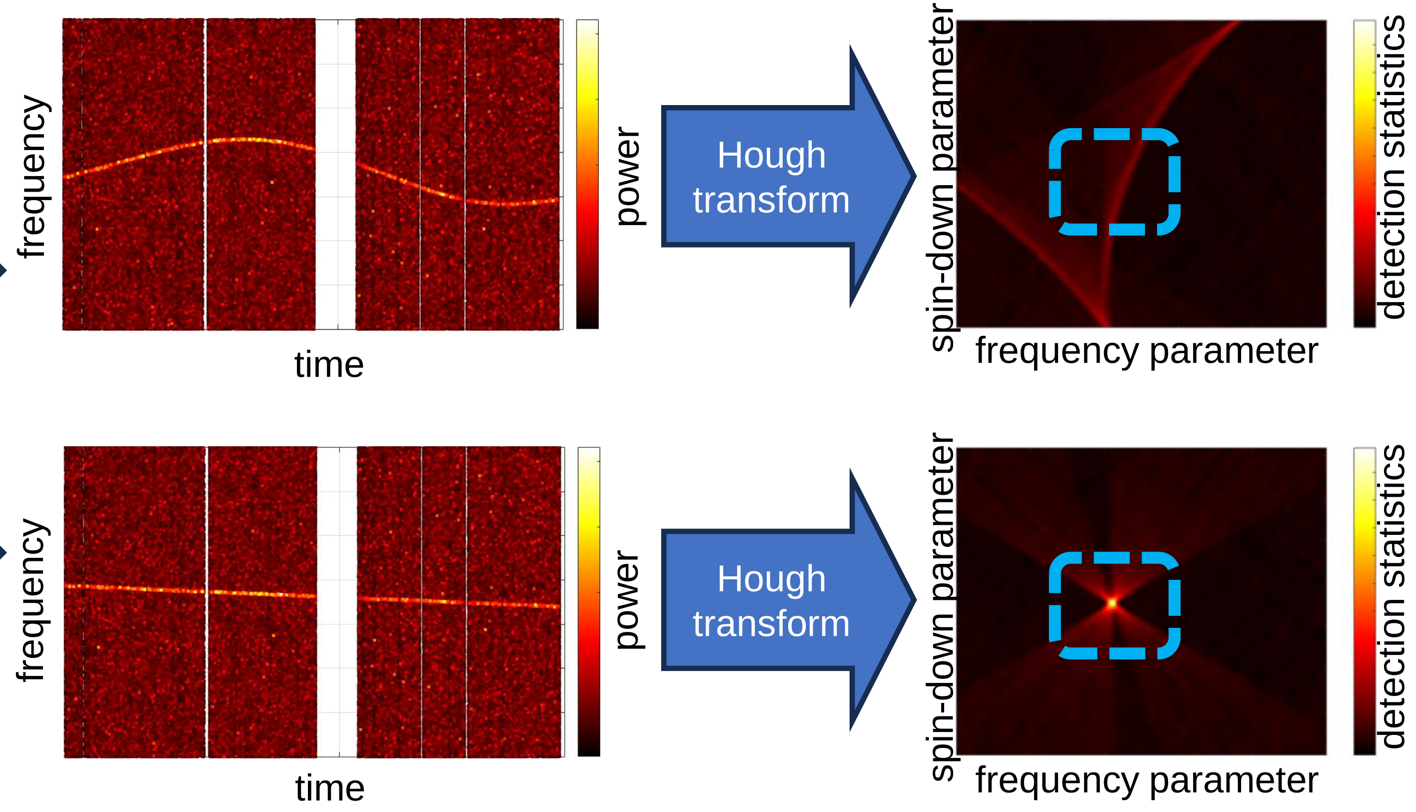
The computational problem



1) According to a discretized sky map, we correct the Doppler effect for ANY POINT in that map.
2) Only the correction that matches the right position of the source maximizes the detection statistics.
3) The number of sky patches is up to $\mathbf{10^5}$!
4) To cover the full parameter space, we need **$\sim 10^7$ core-hours for 1-year data for each detector (3-4)!**

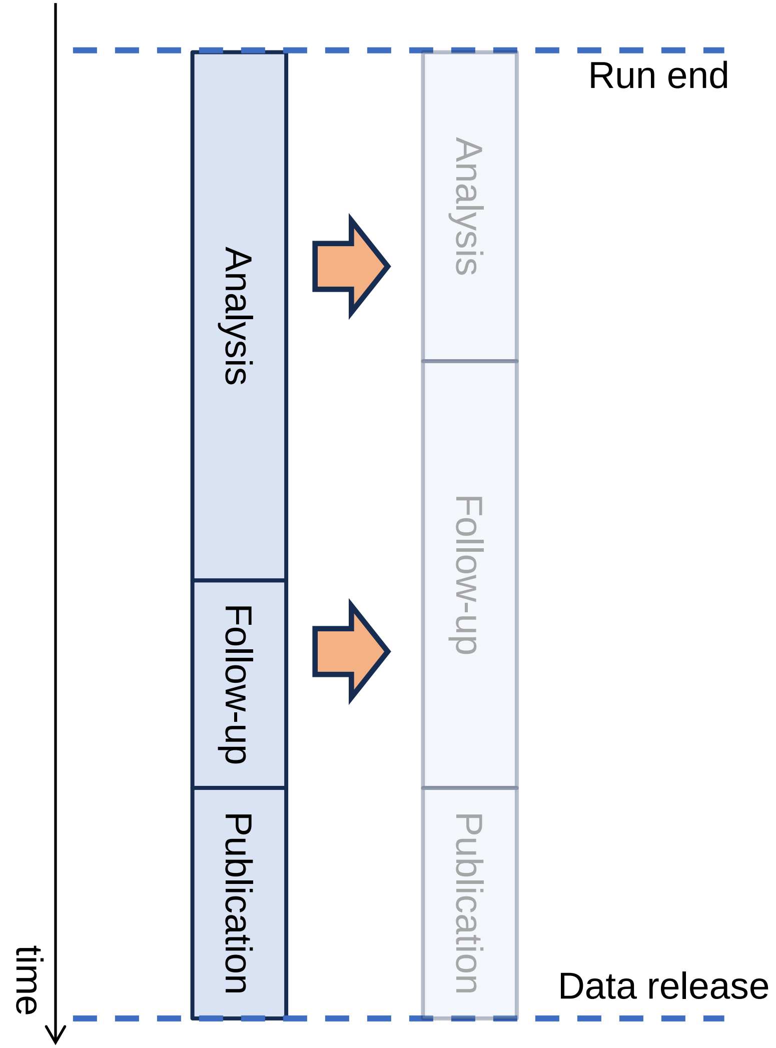






The computing bounds

1) An all-sky & all-frequencies search on 1-year data for 3 detectors requires $\sim 30 \cdot 10^6$ core hours.
   (A typical 10-14 HS06/core is considered)
2) Follow-up: the goal is to select up to 10^9 signal candidates from the Hough maps, to be further processed and verified.
3) The follow-up itself is a refined search based on the Hough transform: another computationally heavy step!
4) There is a tight schedule to publicly release the data too: long computing time limits the number of signal candidates that we are able to verify.
5) Optimizing the algorithm is crucial: shortening the computing time leaves room to analyze a higher number of candidates, thus increasing the overall search sensitivity.



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The opportunity of ICSC

- First part: code optimization.
  - The heavy part of the algorithm is the calculation of the Hough transform.
  - The Hough transform is implemented and optimized in a serial code that avoids parallelization.
  - The main goal is to implement different versions of the Hough transform that exploit parallel architectures, in particular GPU devices.
  - Then, to adapt the analysis code to fully run on GPUs and CPUs.

- Second part: extensive tests.
  - The large scale of ICSC is an exceptional opportunity to test the new algorithms: the amount of available resources matches the typical infrastructure needed to obtain results according to out tight time scales.
  - Extensive tests: perform long timescale analysis to test the stability of the code running on a high number of cores and for long jobs.
  - We hope that in future the ICSC resources will be available for next years research: gravitational wave searches are planned to go on with new detectors!

Thank you for your attention!