ICCUB

EXCELENCIA MARÍA DE MAEZTU 2020-2023

Institut de Ciències del Cosmos
UNIVERSITAT DE BARCELONA

VIRGO

Past, present and future contributions of ICCUB to Virgo

Jordi Portell i de Mora
Deputy technical director
Institute of Cosmos Sciences
Universitat de Barcelona

Virtual Iberian Gravitational Waves Meeting

9-11 June 2021

UNIVERSITAT DE BARCELONA

ICCUB and Virgo

- **ICCUB joined Virgo on July 2018**
- **Full members of the Virgo Collaboration since July 2019**

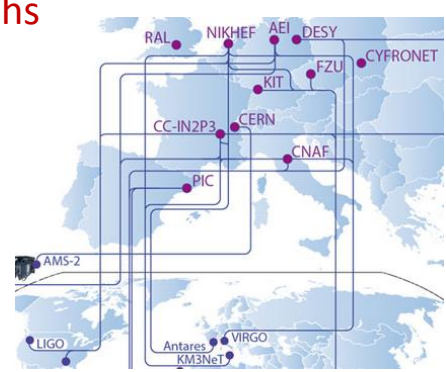
- **Main lines of activity:**
  - **Computing & software**
  - **Instrumentation & electronics**
  - **Data analysis**
  - **Science exploitation**
  - **Outreach**

The ICCUB Virgo team

Name	FTE	Activity
Jordi Portell i de Mora	15%	Group leader, data analysis, computing
Mark Gieles	10%	Science, group co-leader
David Gascón Fora	10%	Instrumentation
Pablo Barneo	100%	Data analysis, outreach (PhD student)
Andreu Sanuy	50%	Instrumentation
Ruxandra Bondarescu	50%	Science, data analysis (contract starting Sept'21)
Tomas Andrade	40%	Science, data analysis
Dani Marín	20%	Science, data analysis (PhD student starting Jul'21, then >50%)
Javier Castañeda Pons	10%	Computing
Joan Mauricio	5%	Instrumentation
Esther Pallarés	5%	Outreach
Pradeep Jasal	*100%*	*Computing (visa and contract much delayed: COVID@India)*
Juan Trenado	*100%*	*TBC; science, data analysis, management (PhD student)*
Arnau Rios	*40%*	*Science, data analysis (dedication and activities TBC, ~Sept'21)*
	3.15 to ≈6 FTEs	

Computing & software engineering

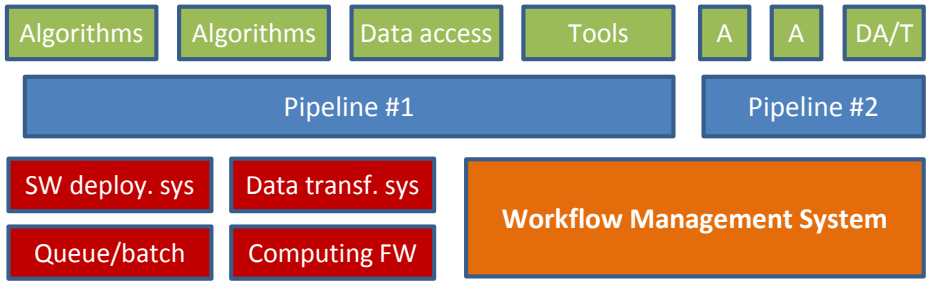
- Virgo Computing is really challenging
  - Continuous, high-throughput data flow (~50 MB/s) during several months
  - Huge data volumes (>1 PB)
  - Complex and CPU-hungry algorithms
  - Heterogeneous and geographically disperse computing resources (grid)

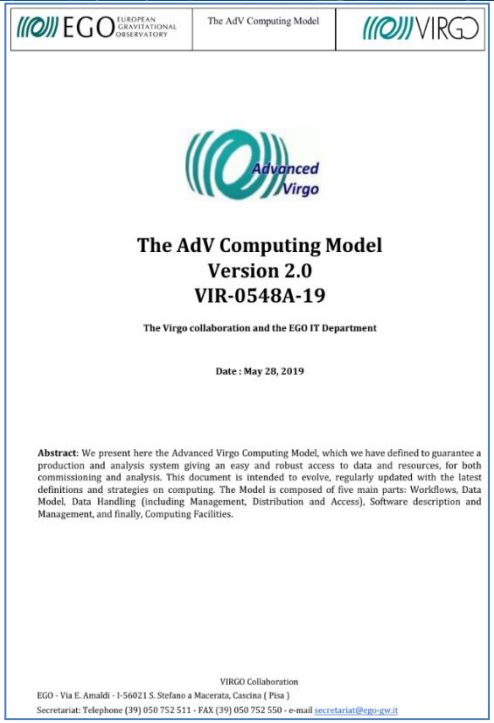


- Low-latency ("online") computing:
  - High availability and reliability
  - High performance, nearly-constant computing load and latency
  - Aiming at prompt alerts → multi-messenger astronomy
  - Mostly on-site (Cascina), at least until O3
- Offline computing:
  - Often towards the end of an observational campaign (or when it has already finished)
  - Massive data access from distributed computing systems
  - Software updates and deployment, user access, execution, monitoring…
- Global effort: **Virgo + LIGO + KAGRA coordination**
  - In low-latency: Cross-check data, candidates and alerts
  - In offline: Share and exchange data, software, computing resources and users
  - **IGWN: International Gravitational-Wave Observatory Network**

ICCUB contributions on Computing

- Initial revision (with other contributors) of the AdV+ Computing Model, revising the actual pipelines, online systems, data and software management, plan for improvements…
- AdV+ Computing Kick-Off Meeting (Barcelona, Feb'19), allowing to better understand the Computing situation at that time (incl. requirements of pipelines to deploy + run them easier), identify tasks + contributors, …
- DIRAC Workshop (Cascina, Nov'18), with ICCUB DIRAC expert, identifying features and tools for the management of data, software and workflows




EGO EUROPEAN GRAVITATIONAL OBSERVATORY | The AdV Computing Model | VIRGO

Advanced Virgo

The AdV Computing Model
Version 2.0
VIR-0548A-19

The Virgo collaboration and the EGO IT Department

Date : May 28, 2019

Abstract: We present here the Advanced Virgo Computing Model, which we have defined to guarantee a production and analysis system giving an easy and robust access to data and resources, for both commissioning and analysis. This document is intended to evolve, regularly updated with the latest definitions and strategies on computing. The Model is composed of five main parts: Workflows, Data Model, Data Handling (including Management, Distribution and Access), Software description and Management, and finally, Computing Facilities.

VIRGO Collaboration
EGO - Via E. Amaldi - I-56021 S. Stefano a Macerata, Cascina (Pisa)
Secretariat: Telephone (39) 050 752 511 - FAX (39) 050 752 550 - e-mail secretariat@ego-gw.it

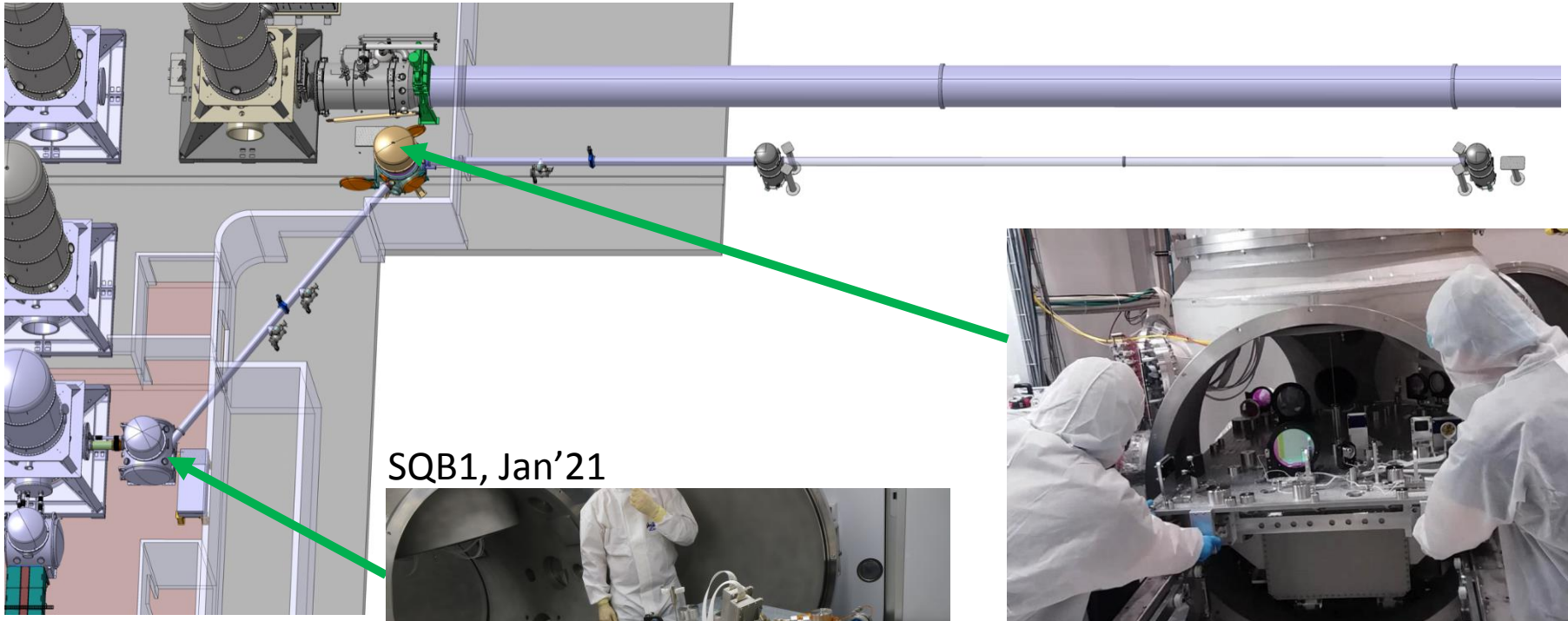
- Migration of some pipelines from CMT (unmaintained) to CMake + Conda (software building and deployment)
- Migration of the Subversion software repository to Git
- *Virgo Computing @ICCUB quite in stand-by for ~2yr now: Experts left, waiting for full-time software engineer to join*

Computing: looking ahead

- AdV+ Computing in general (coord. F. Carbognani + S. Bagnasco):
  - Many tasks identified on coordination and planning, platforms and services, low-latency alerts and data distribution, bulk data handling, software management, offline computing, R&D, …
  - Efforts on Computing have significantly increased during the last 3 years:
    ICCUB (just ~2018-19), Torino, Louvain, NIKHEF, PIC, ...
  - Improvements on data handling and bookkeeping (Kafka, Rucio), computing resources (better HTCondor usage in Europe), low-latency services, high availability systems, accountability, tests (e.g. O3 end-to-end data replay exercise), virtualization…
  - However: "*Available personpower clearly inadequate*"
    "*Need to find additional skilled personpower for Computing within the Virgo Collaboration*"
    → ICCUB's forthcoming software engineer should help here!
- **ICCUB plans towards O4 and beyond**:
  - End-to-end test facility, mainly for low-latency (in Cascina + Cloud)
  - Port some low-latency components off-site (incl. Cloud)
  - Review Git merge requests, support to software and pipelines development
    (*data scientists are not software engineers!*)
  - (Study the) deployment of some offline pipelines in HPC systems (e.g. MareNostrum)
  - (Study the) migration of raw frames to HDF5
  - (Study the) improvement of raw frames data compression

Instrumentation and electronics

- Work on SIN/QNR:
  - **Quantum Noise Reduction / Squeezing Injection**
  - Development of Quadrant Photodetectors (Position Sensitive Sensors, PSDs) and associated instrumentation



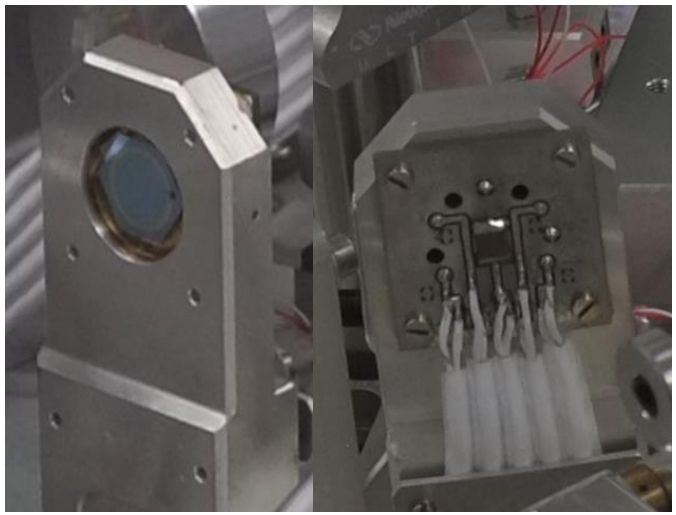
SQB1, Jan'21

SQB2, Apr'21

PSDs for Quantum Noise Reduction

SQB1 & SQB2 laser calibration systems

- Selection of DC quadrants for green laser beam (532 nm), operated at low frequency
- Development of low-noise electronics to interface with the ADC designed by Annecy
- Devices to be operated in vacuum; outgassing control as in Space projects

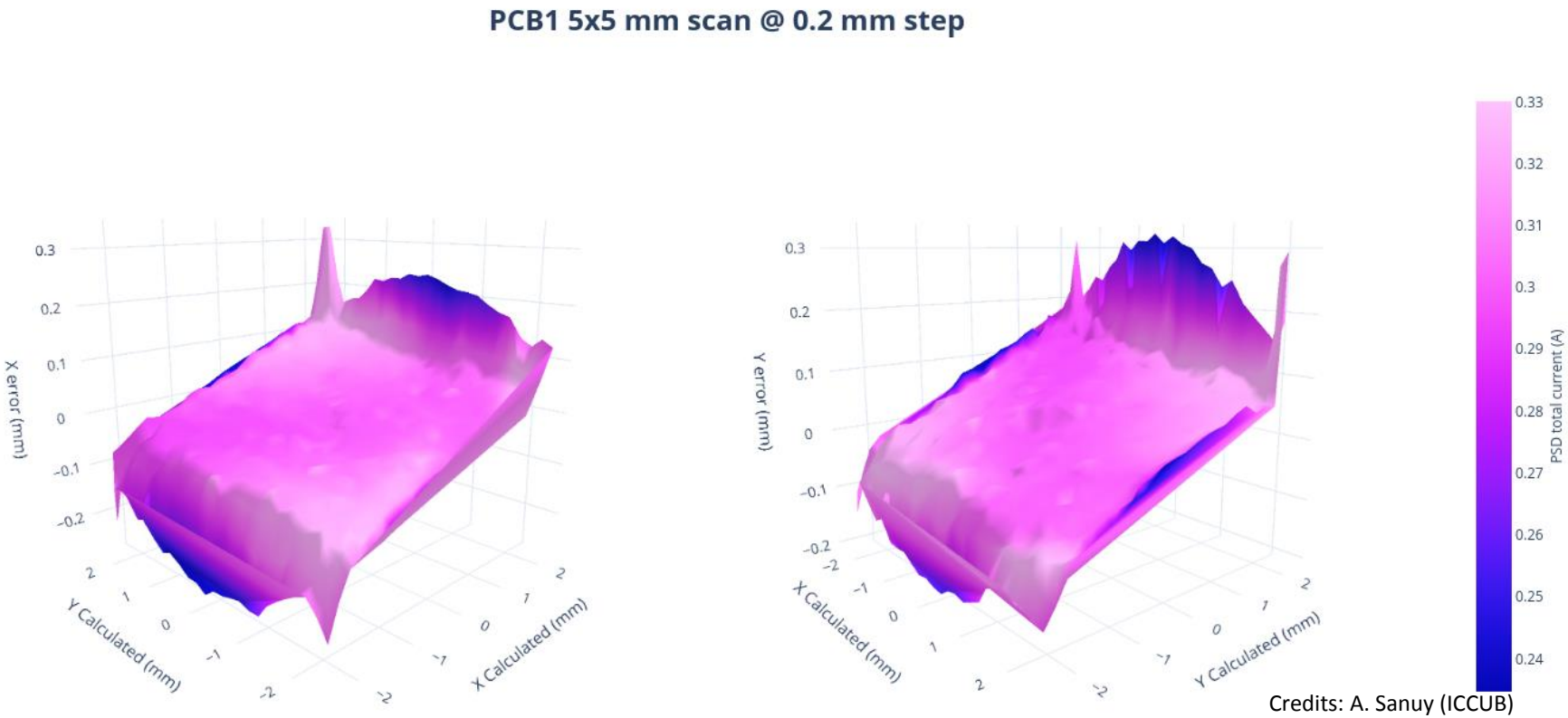


Old design with Excellitas YAG444 Silicon PIN Quadrant Detector

ICCUB development with two-dimensional PSD model S2044 from Hamamatsu and front-end electronics specially designed to operate in vacuum

PSDs for Quantum Noise Reduction

- Performance evaluation:
  - Error in the position determination is well within requirements
- 8 complete units delivered to EGO early May'2021
  - 3 units + 1 spare for each of the two benches



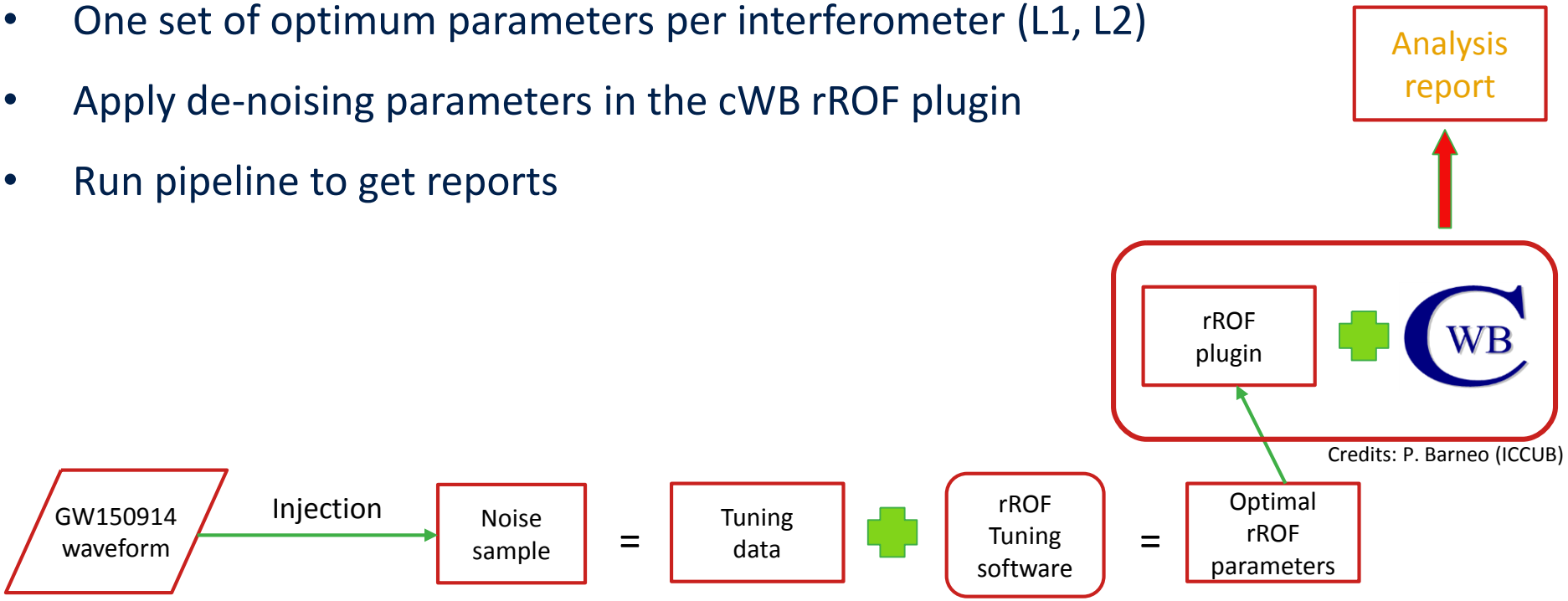
Credits: A. Sanuy (ICCUB)

Data analysis: De-noising plugin for cWB

- Method proposed to de-noise gravitational data (with Valencia Virgo group): **regularized ROF** (**rROF**), based on Total Variation minimization (where noise is supposed to be the main contribution)
- It needs a hyper parameter tuning using a GW template as reference
- Quality evaluation: scale based on the 1st Wasserstein Distance that indicates the amount (%) of noise left after de-noising
- Test rROF de-noising in the **coherent wave bursts** (**cWB**) pipeline
  - Implementation of rROF as a cWB plug-in (ROOT macro)
  - Application of rROF de-noising after whitening (in the data conditioning stage)
  - Code development complete and functional

Data analysis: GW150914 de-noising with rROF

- Parameter tuning
  - Reference: GW150914 waveform from cWB without de-noising
  - Reference noise: 212 s data before merger time
- One set of optimum parameters per interferometer (L1, L2)
- Apply de-noising parameters in the cWB rROF plugin
- Run pipeline to get reports



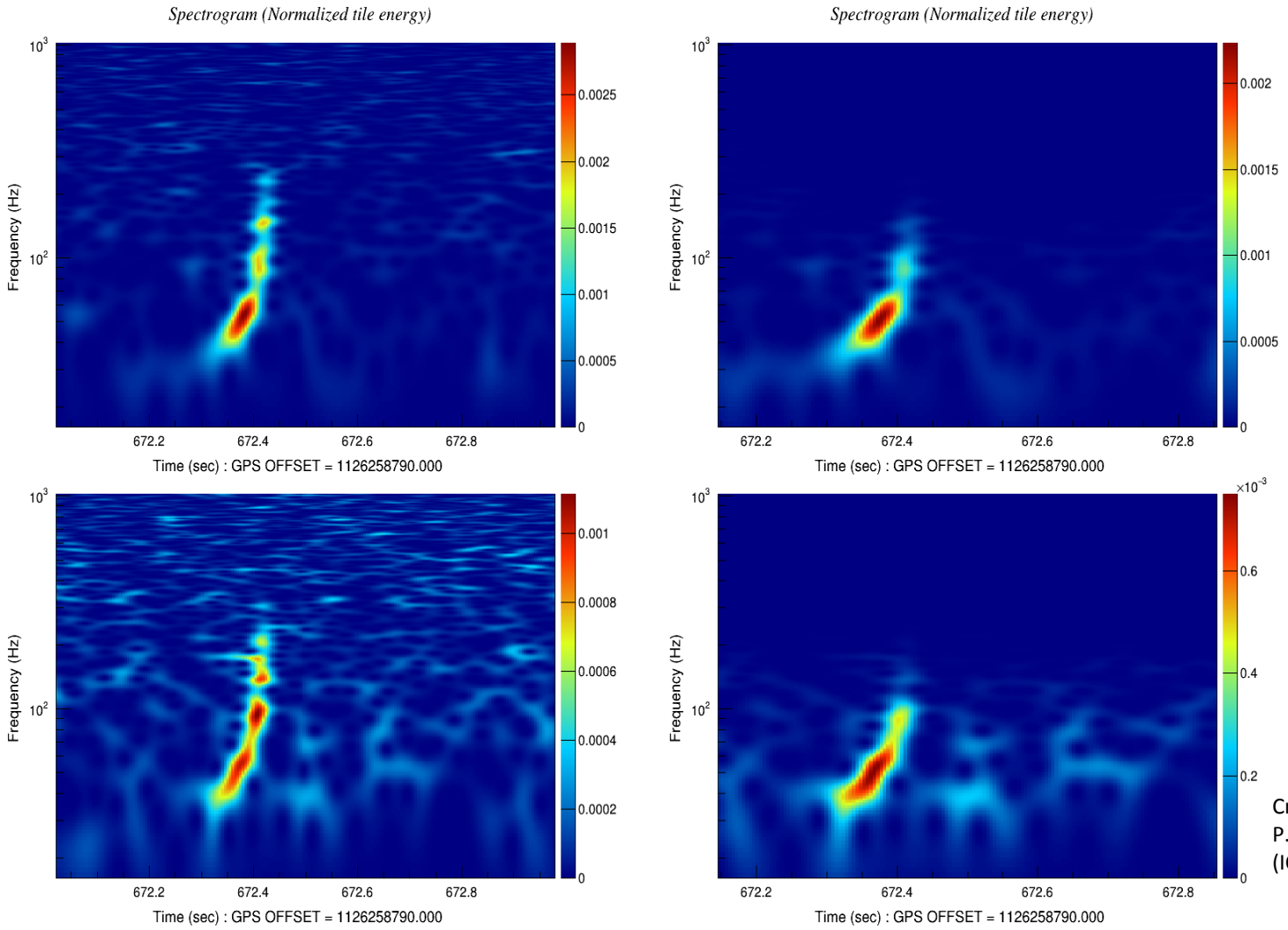
Data analysis: GW150914 spectrograms

Without rROF:

With rROF:

L1

H1

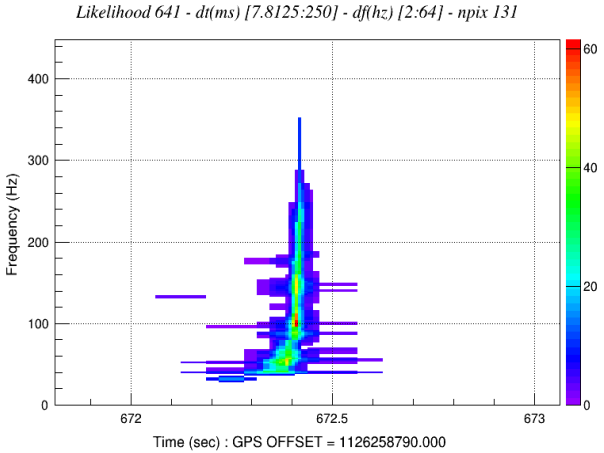


Credits:
P. Barneo
(ICCUB)

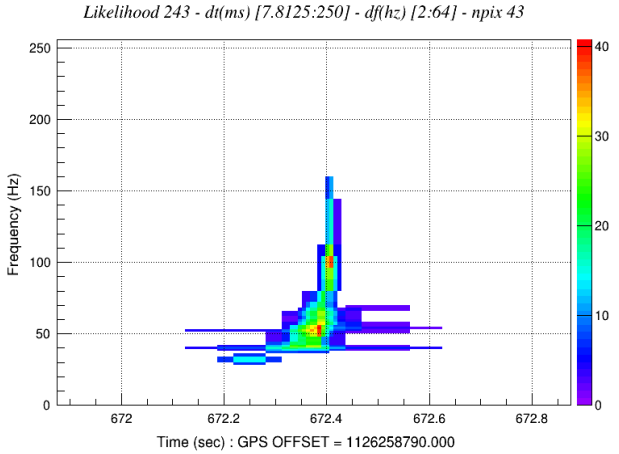
Data analysis: GW150914 cWB outputs

L1

Without rROF:



With rROF:



GW150914 cWB output parameters:

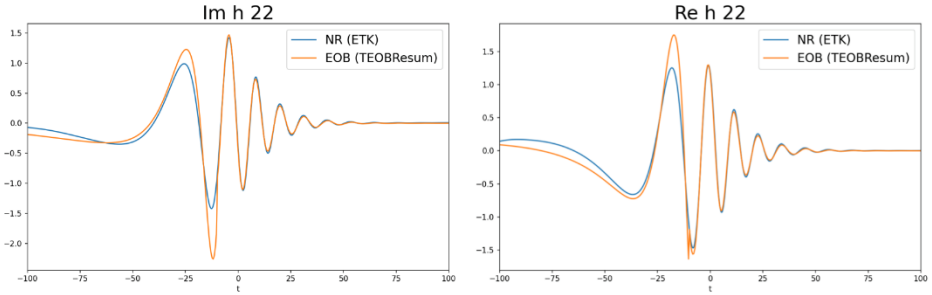
	SNR	ρ(L1)	ρ(H1)	cc	ED	φ	θ
No rROF	25,2	16,7	16,0	0,93	-0,01	356,7	-64,6
rROF	15,5	9,8	9,5	0,96	-0,05	2,8	-60,8
	!?	!?	!?	🙂			

Credits:
P. Barneo
(ICCUB)

Coherence Coefficient improves → good!
SNR decreases → it *could* make sense, but not good. Still investigating...

Further data analysis & Science

- T. Andrade:
  - Contributing to development & calibration of **TEOBResum** code: Waveforms in broad range of parameters for BBH in Effective One Body framework
  - This allows for accurate & efficient computation, necessary for data analysis
  - Main goal: accommodate for effects of **eccentricity**, believed to be an important physical parameter in the determination of the origin of coalescing binaries



Credits: T. Andrade (ICCUB)

- M. Gieles:
  - See his talk tomorrow!
- A. Rios (RyC research fellow, Sept'21),
  R. Bondarescu (postdoc, Sept'21):
  - Neutron star EoS and crust
- D. Marín (PhD, Jul'21)
  J. Trenado (PhD, Sept'21 - TBC):
  - Details being defined

Summary

- ICCUB Virgo group growing:
  14 people, ~6 FTE by the end of this year
- Computing + instrumentation + data analysis + science
- Science case becoming well defined
- Collaborations with Univ. Valencia (rROF, science case)
- Funding:
  - Currently María de Maeztu (ICCUB frame program)
  - Application next year to national program

Thank you

Jordi Portell (jportell@icc.ub.edu)

on behalf of the Virgo ICCUB group

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