Past, present and future contributions of ICCUB to Virgo

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Institute of Cosmos Sciences
Universitat de Barcelona

Virtual Iberian Gravitational Waves Meeting
9-11 June 2021
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

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

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
- 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

Credits: A. Sanuy (ICCUB)
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

PCB1 5x5 mm scan @ 0.2 mm step

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

Analysis report

GW150914 waveform
  |
  v
Injection
  |

Noise sample = Tuning data + rROF Tuning software = Optimal rROF parameters

rROF plugin

Credits: P. Barneo (ICCUB)
Data analysis: GW150914 spectrograms

**Without rROF:**

Spectrogram (Normalized tile energy)

**With rROF:**

Spectrogram (Normalized tile energy)

Credits:
P. Barneo (ICCUB)
Data analysis: GW150914 cWB outputs

GW150914 cWB output parameters:

<table>
<thead>
<tr>
<th></th>
<th>SNR</th>
<th>ρ(L1)</th>
<th>ρ(H1)</th>
<th>cc</th>
<th>ED</th>
<th>ϕ</th>
<th>θ</th>
</tr>
</thead>
<tbody>
<tr>
<td>No rROF</td>
<td>25,2</td>
<td>16,7</td>
<td>16,0</td>
<td>0,93</td>
<td>-0,01</td>
<td>356,7</td>
<td>-64,6</td>
</tr>
<tr>
<td>rROF</td>
<td>15,5</td>
<td>9,8</td>
<td>9,5</td>
<td>0,96</td>
<td>-0,05</td>
<td>2,8</td>
<td>-60,8</td>
</tr>
</tbody>
</table>

!? !? !?

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

Credits:
P. Barneo (ICCUB)
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

- **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

Credits: T. Andrade (ICCUB)
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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