ET EIB Div4 status and tasks:

multimessenger alerts and low-latency infrastructure

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The ET multi-messenger challenge

- Right now, multi-messenger astrophysics is a sparsely data-populated domain
  - There have only been a handful of multi-messenger observations to date
  - Of those observations, only one involved a GW signal (GW170817)

- By the time of ET, this will have completely changed
  - GW alert rates are increasing in LVK O4 and beyond, especially when we reach ET
  - Other messenger types are also dramatically increasing their rates
    - Example: Vera Rubin Observatory will generate millions of alerts per night, starting soon

- Increasing individual rates on multiple sides will lead to a huge increase in MM events
  - New tools and alert distribution infrastructure are needed to work in this environment
  - This is not an ET-only challenge: requires close cooperation with the wider community

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Design and develop the infrastructure needed for low-latency data analyses, and for multi-messenger triggers management and distribution. Follow the development of software tools for low-latency computing.

- Coordinate the development of the tools for the low-latency analysis and alert generation
- Participate in the technical development of the alert distribution infrastructure, by liaising with the wider astrophysical community

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  - We are instead working to prepare for this stage by identifying what will be needed
- Participate in the technical development of the alert distribution infrastructure, by liaising with the wider astrophysical community
  - There is a lot to do here - the MM community is active now, and we have to be a part of it!
  - This is where we have focused our efforts so far

Div4 and the M2Tech proposal

- The main focus of Div4 so far has focused on an EU funding request
  - M2Tech is a proposed multimessenger consortium: CTAO+LST, KM3NeT, Virgo+ET
  - Targets the EU INFRA-TECH funding instrument
  - Planned budget of roughly 10M€ over four years
- There is a work package on computing for multimessenger astronomy
  - Largest single work package, and led by ET (Stefano), with all RIs involved
  - One of the three tasks is dedicated to MM tools+infrastructure, led by ET (Steven)
- **A successful M2Tech proposal would be a major source of support for Div4**
  - Multiple people would work full-time on different pieces of MM tools+infrastructure
  - Would establish a present-aware but future-oriented multimessenger consortium
  - Would ensure that ET needs and uses are considered when building MM infrastructure

M2Tech revisited

- Unfortunately, the M2Tech submission (March 2022) was above-threshold but not funded
  - Criticisms of various aspects, including specific weaknesses of the computing work package
- The next INFRA-TECH call deadline is March 2024
  - Intend to submit the M2Tech project again to the next call
  - The work package leaders have been meeting ∼monthly since fall 2022 to revise the proposal
- As before, ET is leading the computing work package
  - This time, Stefano+Steven are sharing the work package coordination role
- We have made a high-level proposal on how to restructure the computing tasks
  - **The new structure focuses even more on multimessenger tools and infrastructure**
  - This was welcomed and supported by the other M2Tech coordinators
  - We are now discussing with the RI contacts, then will work on the specific details
- Activities will continue, ensuring ET remains a key player in designing the future of MM

ACME

- Beyond INFRA-TECH, the EU also has an INFRA-SERV funding implement
  - In the context of astronomy, this mostly focuses on trans-national access to observing facilities, access to data archives, and supporting the training of the community
- An MM-related proposal was submitted to the call (closed March 2023)
  - ACME, Astrophysics Center for Multimessenger studies in Europe
- We tried to have ET participate directly in ACME, but ultimately it was not possible
  - The call description required the involved RIs to have real data, which excludes ET
  - Instead, ET will be included in the ACME RI Forum, which will assess the current models for access to data in a MM context, and discuss possible new collaboration models for the future
- While not ideal, it is good that ET will be included in ACME strategic discussions
  - **Important for ET to already be involved in multimessenger community planning**

Revisiting the Div4 mandate

Design and develop the infrastructure needed for low-latency data analyses, and for multi-messenger triggers management and distribution. Follow the development of software tools for low-latency computing.

- Coordinate the development of the tools for the low-latency analysis and alert generation
  - Hopefully the next M2Tech submission will be successful, in which case people would be hired to start working, full-time and long-term, on these tasks
  - **Others are also very welcome to work on such tools; there is lots to do!**
- Participate in the technical development of the alert distribution infrastructure, by liaising with the wider astrophysical community
  - If the next M2Tech submission is successful, people will also be hired to work in this direction
  - Involvement in M2Tech, ACME, etc is just the start - we need to remain proactive
  - **Lots of potential for others to get involved here, also with small time commitments**

Liaising with other research infrastructures

- Lots of short-term yet ongoing tasks to liaise with other RIs
  - Understand their plans and how they intend to generate/consume MM alerts
  - Form connections to develop in common directions or common software
  - Form consortia to identify support for common infrastructure
  - ...
- Examples of such links include:
  - Those who inform ET: LISA
  - Those who are roughly in parallel to ET: CE, 2nd gen GW
  - Those who may react to ET: EM observatories, especially those with ToO programmes
  - Those who may after-the-fact correlate with ET: neutrino observatories, full-sky EM surveys
- **Concretely, we need people to form or act as bridges to these other communities**
  - If you are also active in another community, should be easy!
  - If you are interested in learning about another community, great way to do so!

Liaising with the multi-messenger community

- The MM community is already very active external to specific RIs
  - Several different alert brokers, distributors, etc; also the Virtual Observatory
  - Vera Rubin will be generating many more alerts than us; the community is already preparing
- It is important that we interface with the MM community
  - They are building software infrastructures that we should integrate with
  - Need to inject our needs and use cases into these discussions
- So far, ET participating through the MM astrophysics workshops and their follow-ups
  - Low-latency alerts & Data analysis for Multi-messenger Astrophysics: Jan 2022
    - Resulted in INFRA-TECH proposal, as previously discussed
  - Multi-Messenger Astrophysics Workshop: Oct 2022
    - Resulted in INFRA-SERV proposal, as previously discussed
- **Concretely, we need to define our future needs and use cases**
  - We have started to identify key ET needs, but only preliminarily; more input is welcome
  - Need to understand how this fits with the wider community needs/goals

Identifying developments of future relevance to alert infrastructure

- Alert infrastructure is needed many years from now, and we have to be prepared to evolve
- MM alerts will need to be fast, automated, findable, and efficiently communicated
  - Fast: heterogeneous computing, which is likely to only get more heterogeneous
  - Automated: fully automated pipelines, such as wavefier
  - Findable: dynamic databases supporting updatable alerts, integrated in brokers, etc
  - Efficiently communicated: time-sensitive networking, such as White Rabbit
  - Machine learning likely has a role to play in many places, thus we need to track ML tools
- The above is only the start - we are likely missing important developments
  - **We need people to think about bottlenecks in the current alert systems**
- We also need to understand how our current approaches scale to ET challenges
  - **We need to integrate accuracy-vs-speed metrics into ET mock data challenges**
  - **We should support the creation of MDCs targeting early warnings (pre-merger alerts)**

Summary

- Most of the division 4 activities are oriented towards longer-term efforts
  - Liaising with the wider community requires time, as does developing infrastructure
  - Major focus so far has been the MM workshops, and resulting M2Tech and ACME proposals
- There are also ways to contribute on a shorter term:
  - Defining the MM needs and use cases of ET, to inject into MM community discussions
    - Requires moderate knowledge, but should be feasible in a few dedicated brainstorming events
  - Starting discussions with other RIs on how they plan to interact with ET alerts
    - Requires some knowledge, but may require months of iterations (+ ideally ongoing availability)
  - Identifying bottlenecks in the current GW alert systems, thus necessitating developments
    - Requires substantial knowledge, but could be done with a few dedicated brainstorming events
  - Integrating alternative alert-related metrics + benchmarking into mock data challenges
    - Requires minimal previous knowledge, but timescale is unclear (not entirely our control)
- This is a list of selected topics, and feedback is very welcome!

Please get in touch if you are interested in getting involved!