Unveil Neutrino Multimessenger Astronomy with Super-Kamiokande

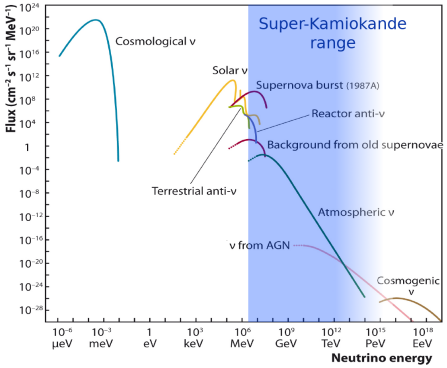
Mathieu Lamoureux

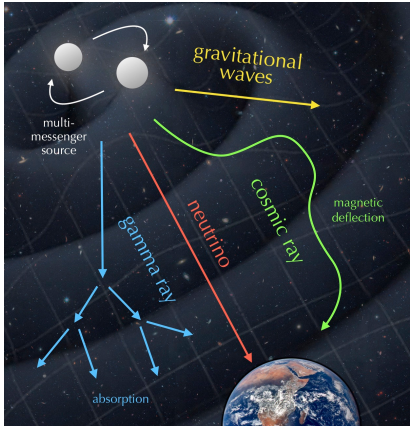
H2020 MSCA COFUND
G.A. 754496

Istituto Nazionale di Fisica Nucleare

What is neutrino astronomy?

- ✔ Neutrinos are very weakly interacting particles, so they propagate in straight line from the source and are almost unabsorbed
- ✖ But they are difficult to detect
  → **need gigantic detectors**



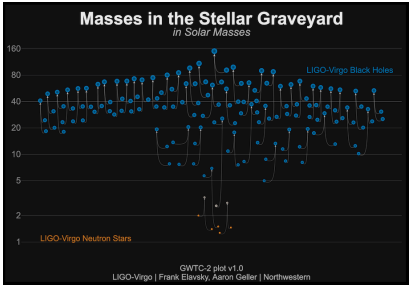


We can probe multi-messenger astrophysical sources using neutrinos.

Gravitational Waves and Super-Kamiokande

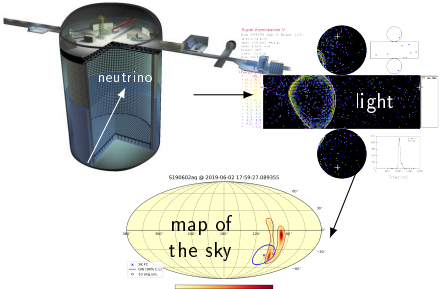
Gravitational Waves

- Emitted from the merging of massive objects (blach holes or neutron stars).
- Alerts are sent publicly by LIGO-Virgo collaborations (~ 5 per month)



Super-Kamiokande

- Huge tank of 50 kilotons of pure water, located in a mine in Japan
- Neutrinos detected by light emission in water



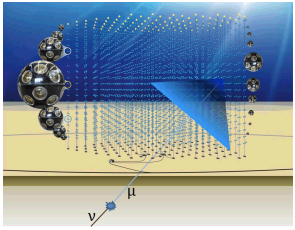
We are looking for common sources of neutrinos and gravitational waves by looking for time/spatial coincidence $\rightarrow$ **preliminary results** were officialised + **publication** under writing.

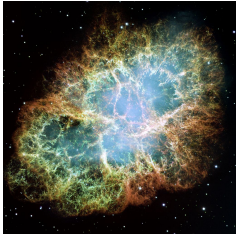
Next steps

- We can use our results to put limits on the different source emission mechanisms (SK+GW)
  → ongoing study
- We can go further by counting in neutrinos from other experiments e.g. ANTARES in the Mediterranean Sea (SK+ANTARES+GW)
  → work during the secondment period in *APC (Paris)* in 2021
- Looking into the future:
  - next-generation detectors will be much bigger: **Hyper-Kamiokande** in Japan, **KM3NeT** in the sea (HK+KM3NeT+GW)
  - more and more sensitive GW detectors

On a different topic:

- Supernovae events: death of the stars emits neutrinos (and potentially gravitational waves) → critical to understand explosion mechanism.
  → project with *LPNHE (Paris)* for precise multi-messenger follow-up.





Scientific diffusion of Fellini project and training

Workshops and conferences

- Participation to workshops for training purposes on topic related to astrophysics (NuTel in 03.2019, KM3NeT Town Hall in 12.2019, CR and ν in the Multi-Messenger Era conference in 12.2020).
- Presentation of collaboration or analysis results to conferences on neutrino physics and astrophysics (TAUP in 09.2019, NEUTRINO in 06.2020, another conference in 2021/2022).

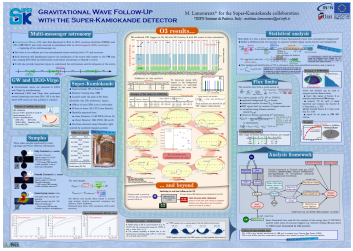
$\Rightarrow$ *using Fellini travel budget for presenting results and training budget for keeping updated on the field*

Collaboration-wide

- Regular video meetings within SK topical groups
- Super-Kamiokande / T2K / Hyper-K collaboration meetings

$\Rightarrow$ *using Fellini travel budget*

(+ work on detectors on-site, required for authorship)



Courses organised by INFN

- Training on Public engagement (online, 09.2020)
- Training on European grants and ERC (online, 12.2020)

Supervision and diffusion

- Co-supervision of Master project on supernova burst detection with Super-Kamiokande (sucessfully defended in October 2020)
- Participation to outreach activities during the next European Researchers' Night (online event, 11.2020)
  - Adaptation of a video already produced by the Japanese TV (subtitled+voiced)
  - Virtual visit of the detector facility in Japan using 360°photos
  - One initial idea was also to build a small model of the detector, with LEDs to illustrate neutrino interactions (use of Fellini budget to buy components) → *cancelled because of COVID*
- Member of the Local Organising Committee of the Neutrino Telescope 2021 (online event, 02.2021).

UNIVERSITÀ DEGLI STUDI DI PADOVA

Dipartimento di Fisica e Astronomia "Galileo Galilei"

Master Degree in Physics

Final Dissertation

Low-Energy Neutrino Astrophysics with Super-Kamiokande

Thesis supervisor	Candidate
Prof. Gianmaria Collazuol	Marco Mattiazzi
Thesis co-supervisor	
Dr. Mathieu Lamoureux	

Main objective

Broaden skills on neutrino astrophysics, source models and statistical combination. Develop network to aim for future permanent position in France (e.g. CNRS).

- **Main institution:** APC, U-Paris 7
- **Local group:** KM3NeT, ANTARES
- **Goal:** thematical continuity of Fellini
- **Scientific targets:**
  - join astrophysical studies there, in particular ANTARES analyses of archival data and real-time studies in KM3NeT
  - perform combined analysis with SK
  - study sensitivity of future facilities (initiate studies within Hyper-Kamiokande)

- **In parallel:** LPNHE, U-Paris Sorbonne
- **Local group:** Hyper-Kamiokande
- **Goal:** collaboration continuity
- **Scientific target:**
  - work on a GPS system to be deployed in Hyper-Kamiokande, useful for time sync. of astrophysical signals, **critical** for supernovae
  - potentially initiate collaborations between APC and LPNHE

- **Hard skills:**
  - *Neutrino detection:* event reconstruction methods, analysis techniques
  - *Astrophysics:* astronomical considerations, source modeling
  - Development of full flexible framework to *handle realtime* alerts (different formats and systems)
  - *Statistical methods* to extract emission limits and combine observations
- **Soft skills:**
  - *Supervision* of a Master student for his thesis (SN-related project)
  - Work with *groups of various scales* (collaboration of > 100 people, small topical group of ~ 10, few international Master/PhD students or researchers)
  - Communication:
    - presenting at *conferences and meetings* (8 collaboration meetings since the beginning of Fellini, 2 international conferences, 1 topical workshop)
    - outreach activity at European Researchers' Night
    - publication of results (two under writing, few others scheduled by end of the project)