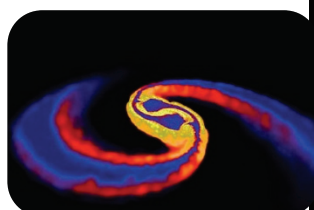
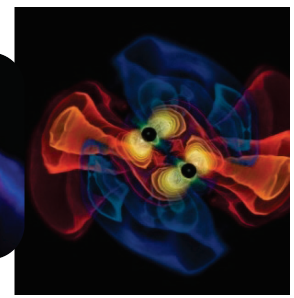
Low latency GW search for electromagnetic follow-ups with Advanced Virgo/LIGO

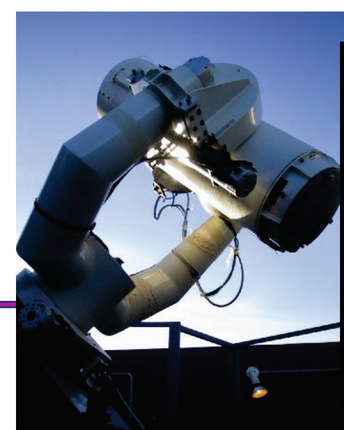


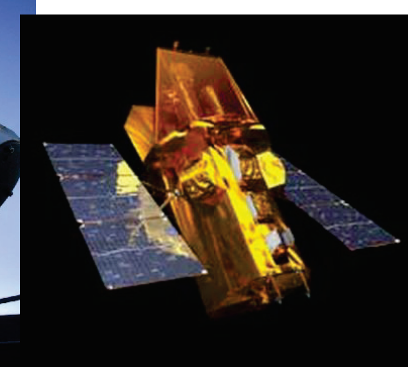


F.Marion

Sélection des projets postdoc ENIGMASS

15 juillet 2013





Ground-based GW detectors

- 1st generation interferometric detectors
  - Initial LIGO, Virgo, GEO600

Unlikely detection

Science data taking
First rate upper limits
Set up network observation

- Enhanced LIGO, Virgo+

VOUS ÊTES ICI

Improved sensitivity

Lay ground for multi-messenger astronomy

- 2nd generation detectors
  - Advanced LIGO, Advanced Virgo, GEO-HF, KAGRA

Likely detection

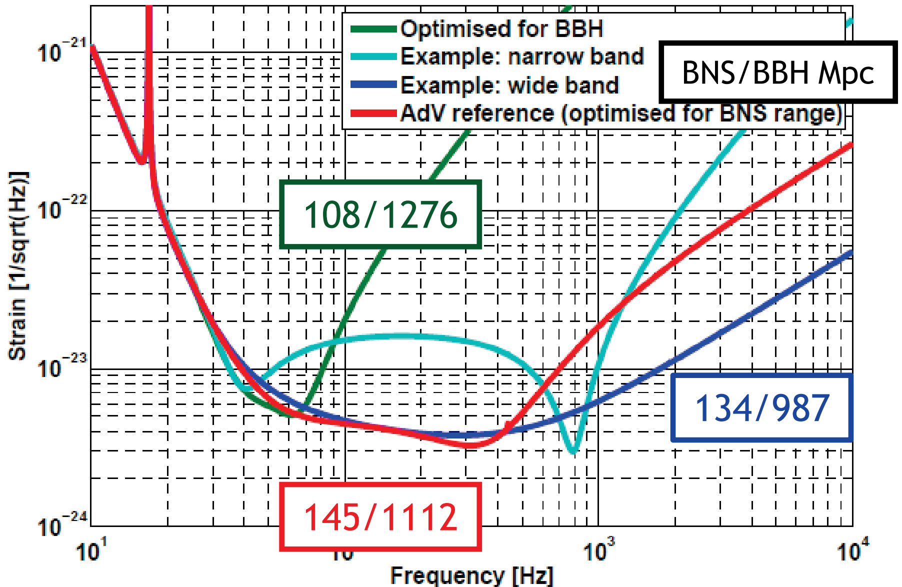
Routine observation
➔ GW astronomy

Thorough observation of Universe with GW

- 3rd generation detectors
  - Einstein Telescope, US counterpart to ET

Advanced detector era prospects

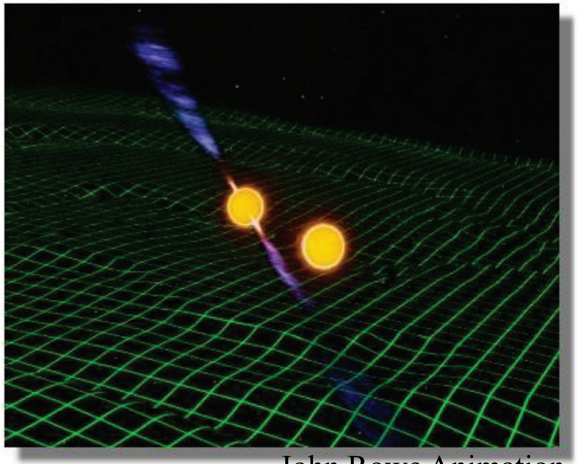
- Experimental challenge
  - ◆ Increase sensitivity by factor 10 over full bandwidth
- Tight schedule driven by Advanced LIGO
  - ◆ First observations as soon as 2015



- LAPP group in charge of big construction responsibilities
  - ◆ Detection system, DAQ system, new vacuum chambers
- First discoveries within reach
  - ◆ Several expected before end of decade
- Multi-messenger astronomy
  - ◆ Extract all the science from observations

Compact binary coalescences as sources of gravitational waves

- Final stage of evolution of binary systems containing compact objects
  - Driven by gravitational radiation
  - Predictable waveform



John Rowe Animation

- Systems containing
  - Binary neutron stars
  - Neutron stars and black holes
  - Binary black holes

- Ground-based detectors bandwidth
  - ➔ Sensitivity to stellar mass to intermediate mass black holes

Science with GW from compact binaries

- General Relativity
  - Test theory in strong field
  - Test/constrain alternative gravity theories
- Astrophysics
  - Measure merger rates
  - Inform source distribution
  - Study effect of matter in BNS waveform
  - Progenitors of short, hard GRBs ?
- Cosmology
  - CBC inspirals as standard sirens
    - » Independent measurement of Hubble constant

IFO	Source[a]	$\dot{N}_{\rm low}$ yr^{-1}	$\dot{N}_{\rm re}$ yr^{-1}	$\dot{N}_{\rm pl}$ yr^{-1}	$\dot{N}_{\rm up}$ yr^{-1}
Initial	NS-NS	2×10^{-4}	0.02	0.2	0.6
	NS-BH	7×10^{-5}	0.004	0.1	
	BH-BH	2×10^{-4}	0.007	0.5	
	IMRI into IMBH			$< 0.001^b$	0.01^c
	IMBH-IMBH			$10^{-4\,d}$	$10^{-3\,e}$
Advanced	NS-NS	0.4	40	400	1000
	NS-BH	0.2	10	300	
	BH-BH	0.4	20	1000	
	IMRI into IMBH			10^b	300^c
	IMBH-IMBH			0.1^d	1^e

Many of these require combining information from gravitational wave, electromagnetic and/or particle observations
➔ Multi-messenger astronomy

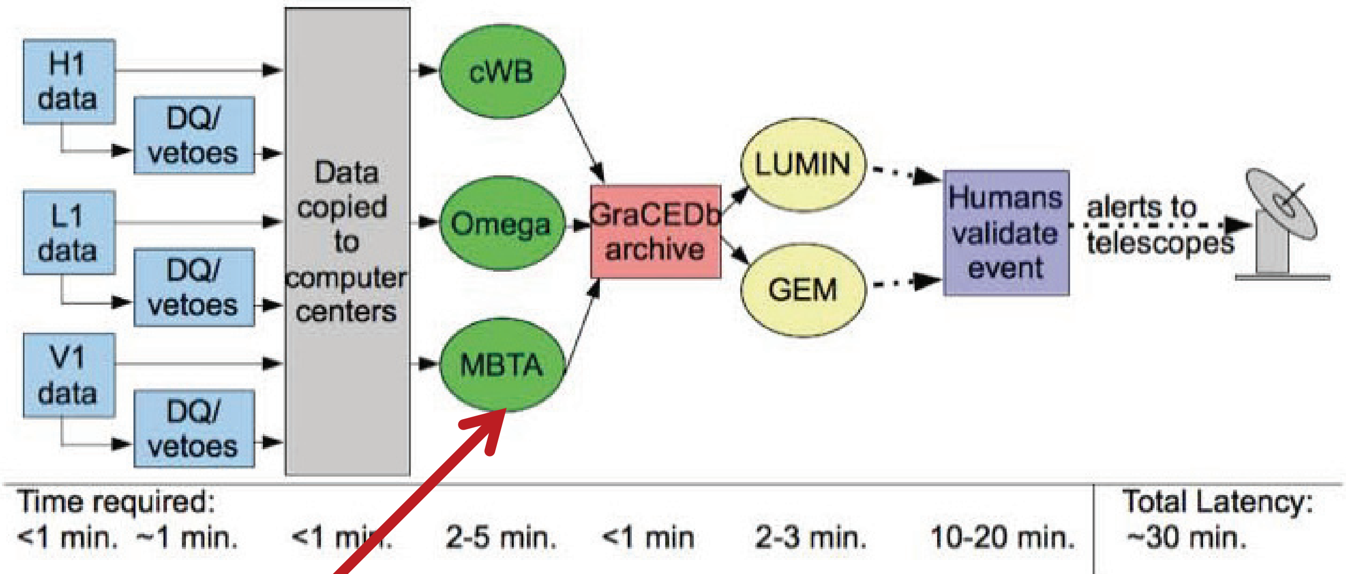
Multiple messengers

- Electromagnetic counterparts to compact binary mergers
  - Require matter, so not always expected: none for BBH ➘ but worth checking!
  - Beamed emissions: γ, X-ray, optical, radio
    - » Afterglows expected to be less beamed than GRB ➘ more likely to detect
  - Isotropic emission
    - » Faint transient powered by radioactive decay
- Neutrinos
- Benefits from multi-messenger astronomy
  - Increase confidence in GW detection
  - Improve sensitivity of GW detectors
  - Get astrophysical context
  - Pinpoint source location
  - Break parameter degeneracy

Multi-messenger astronomy with initial detectors

- Externally triggered GW searches
  - GRB, HE neutrinos, pulsar glitches, SGR flares…
- Search for electromagnetic counterparts associated to GW triggers

S6/VSR3



Developed @ LAPP

[First low-latency LIGO+Virgo search for binary inspirals and their electromagnetic counterparts, LIGO & Virgo, A&A 541, A155 (2012)]

EM follow-up in advanced detector era

- Actively prepared right now
- Continue with MoU model for first detections
  - May issue open alerts later, in routine detection era
- Make sure all relevant partners join the fun
  - From big telescopes/satellites to dedicated, medium-size robotic telescopes
  - Open call has been issued, LoIs due soon, discussion will follow
- Deal with poor sky localization from GW

Network	Sources localized within				Worst Area (deg^2) (SNR>8 per ITF)
	1 deg^2	5 deg^2	10 deg^2	20 deg^2	
HHLV	0.5%	6%	15%	42%	150

Adapted from Fairhurst arXiv/1010.6192

- Get everyone interested, without raising unrealistic expectations
  - First data in 2015-2016, final sensitivity reached ~2020, unpredictable rate of progress in between

Work plan (I)

- Upgrade pipeline for advanced detector era
  - Latency
    - » Keep it low, even when decreasing the search low frequency cutoff (longer signals)
  - Efficiency
    - » Target sources with spin as well
    - » Deal with instrumental/environmental artifacts
      - – LAPP involved in *Virgo Data Quality* group
    - » Pipeline parameters tuning
  - Reliability
    - » Measure false alarm rate of triggers
- Participate in engineering runs and mock data challenges

Work plan (II)

- Pointing
  - Source localization accuracy
    - Typically poor: several tens of deg^2 ☹
  - Fast method relies primarily on triangulation based on timing information in different detectors, ~minutes
  - Slow Bayesian methods scanning all parameter space, ~days
  - Two step hierarchical approach?
    - Can the sky location be refined in a few hours?
    - Possibly using GPUs?

Why is ENIGMASS funding crucial?

- Was outlined in the ENIGMASS program
  - Sections 1.2.1.D, 1.2.1.E & 1.2.2.C
- Institutional funding focused on Advanced Virgo construction
  - An obvious priority!
  - An ENIGMASS postdoc would give us the resources to go on with data analysis preparation and keep the visibility acquired during S6/VSR3
    - Hot topic, competitor pipelines showing up!
- In the long run, connection to follow-up partners within the labex
  - HESS, CTA, LSST