Multi-Messenger Astronomy

Schools Masterclass

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Workshop aims

Workshop aimed at age 14+ students. Based loosely on CERN masterclasses.

Contributors: Cardiff, Glasgow, LIGO-Hanford, Sonoma, ESO

Delivered with online and hands-on materials

Involves groups working to find details of event based on data they detect

3-intervention activity:

- Day 1: Introductions to material
- Day 2: Workshop
- Day 3: presentations

Local, regional and international workshops planned.

Teams

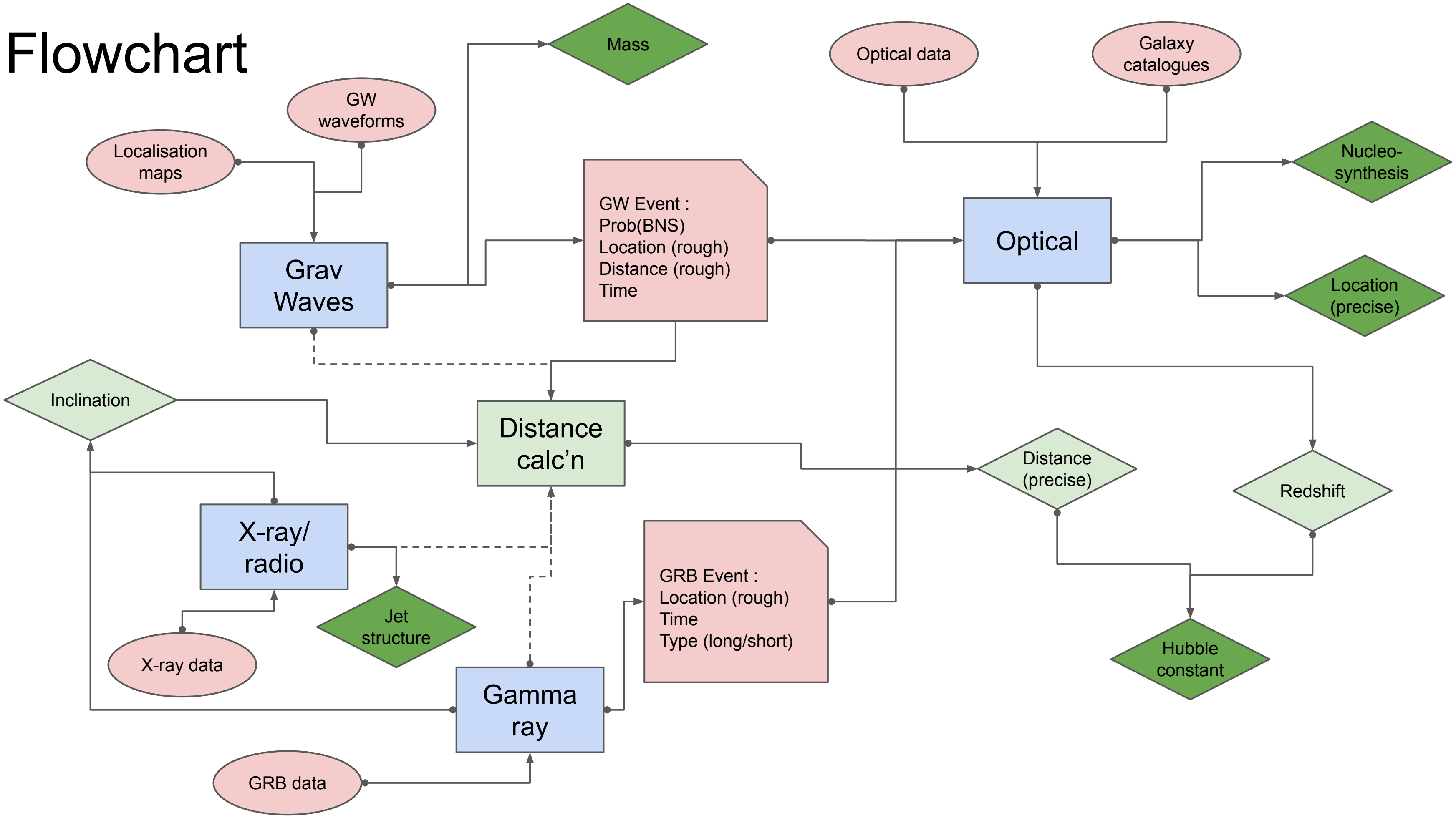
Grav Waves

Gamma Rays

X-ray/radio

Optical

Flowchart



Mass
Optical data
Galaxy catalogues
GW waveforms
Localisation maps
Nucleo-synthesis
GW Event :
Prob(BNS)
Location (rough)
Distance (rough)
Time
Optical
Grav Waves
Location (precise)
Inclination
Distance calc'n
Distance (precise)
Redshift
X-ray/ radio
GRB Event :
Location (rough)
Time
Type (long/short)
Jet structure
Hubble constant
X-ray data
Gamma ray
GRB data

Gravitational Waves

Knowledge required:

Types of merger (BBH, BNS etc.)

Gravitational wave analysis

Information transfer:

In:

- Gamma/X-ray: inclination

Out:

- Localisation & distance (rough) -> optical
- Time -> Gamma Ray & x-ray
- Distance -> analysis (all)

Data Inputs:

Gravitational wave waveforms for events

Localisation maps for events (based on relative detector arrival times)

Outputs:

Event notification:

- Probability of being BNS
- Distance to event (rough)
- Localisation of event (rough)
- Time of event

Mass of black holes

Precise distance (with inclination)

Gravitational Waves - team process

Day 1:

- Calculations/methods for (rough) distance and mass based on waveform properties (from day 1)
- Mapping between signal duration and probability of being BNS
- Inclination calculation

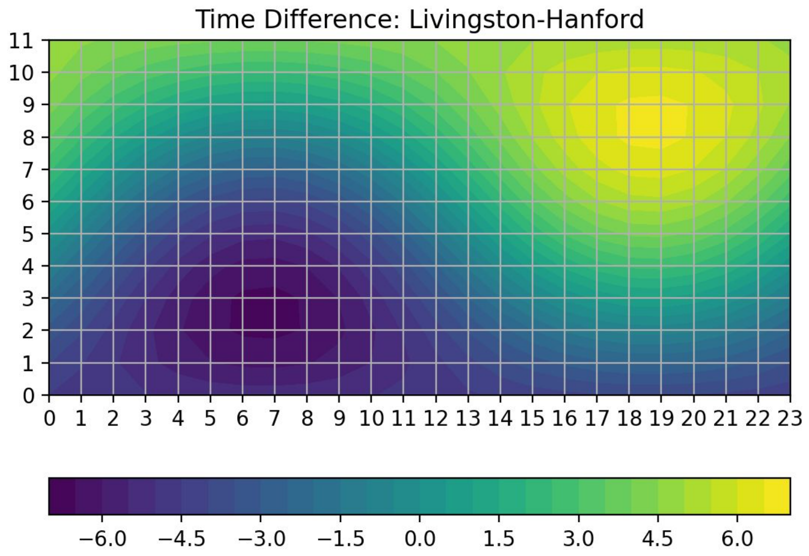
Provided with:

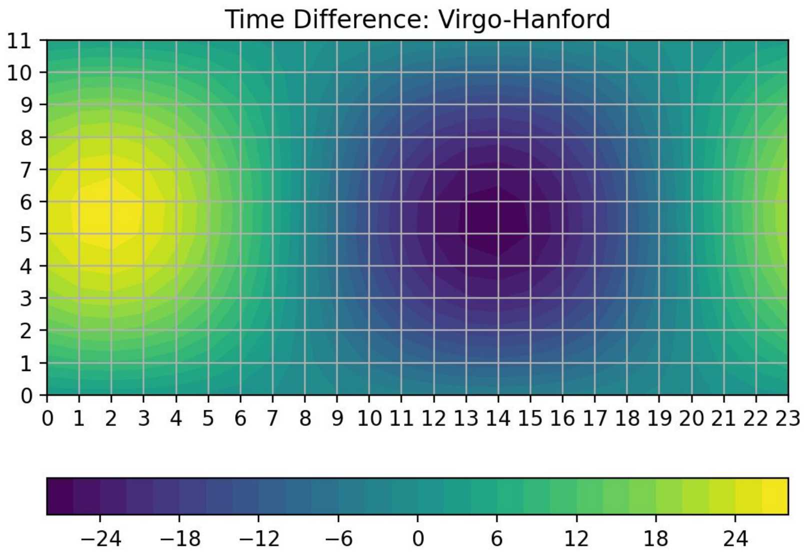
- Waveforms for 3 events (different “zoom” levels in time)?
- Location maps for 3 events with time differences - use grid system based on RA/Dec
  - gives two possible locations (gamma ray will eliminate one of them)
- [Calculation for precise distance from inclination]

They need to:

- Immediately:
  - Use duration of signal to calculate probability of BNS
  - Identify the event that they should pass on (e.g. find BNS)
  - Create “event notification” with: time, rough location, distance and mass, probability of BNS
- Medium-term:
  - Calculate mass from waveform
- With inclination:
  - Use inclination to calculate precise distance

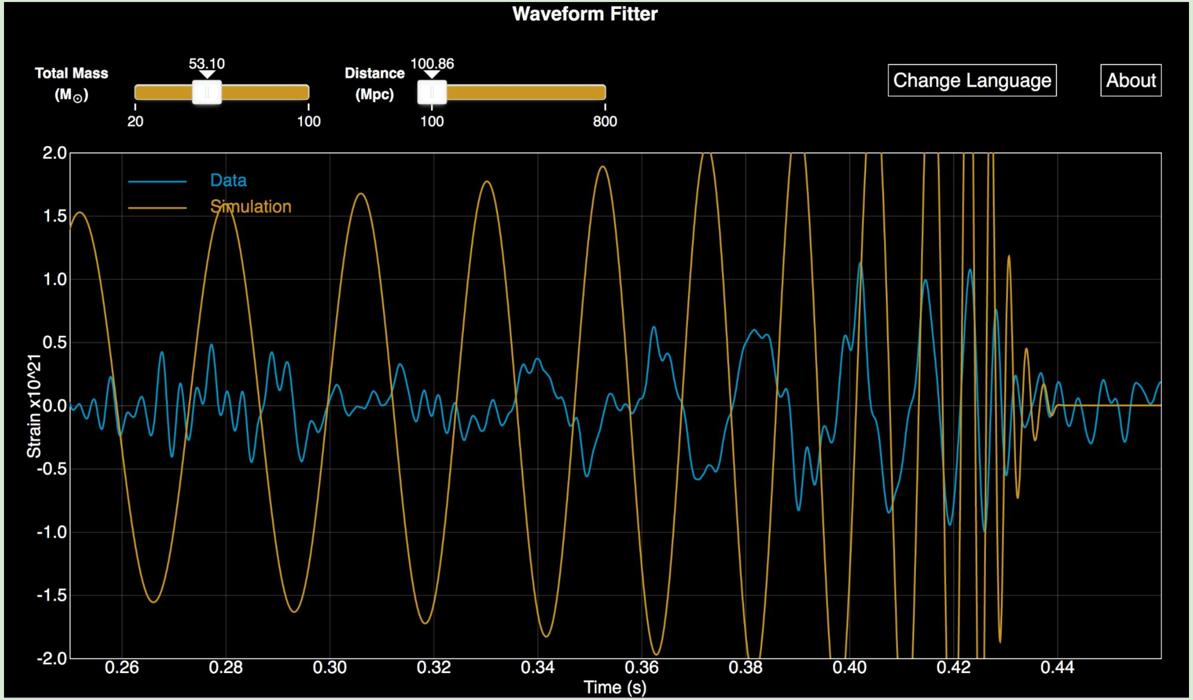
Gravitational Waves - Location Maps





Gravitational Waves - Mass/Distance

http://data.cardiffgravity.org/waveform-fitter/



Gamma Ray

Knowledge required:

Types/properties of GRBs (short, long etc.)

Gamma ray analysis

Information transfer:

In:

- GW Event Notification: timing

Out:

- Localisation (rough) -> optical
- Inclination -> GW

Data Inputs:

Gamma ray data and timing

Gamma ray localisation for events

Outputs:

Event notification:

- Localisation of event (rough)
- Time of event
- Event classification

Inclination of event

Gamma Ray - team process

Day 1:

- Properties of different types of events (short vs long)

Provided with:

- Times and characteristics (short vs long) of selection of events
- Location maps for events (use grid system based on RA/Dec?) - eliminate one of two GW patches
- Information on calculating inclination from distance and gamma-ray brightness (graph of probability)

They need to:

- Immediately:
    - Characterise the event of interest
    - Use localisation maps to identify rough localisation
    - Create “event notification” with rough localisation, GRB characteristics (long/short), time of event
- Use time & location from Grav Waves team to identify the event of interest
- Provide inclination to GW team

Optical astronomers

Knowledge required:

Types/properties of kilo/supernova(?)

Optical spectrum analysis

Nucleosynthesis models

Information transfer:

In:

GW & Gamma: Localisation (rough)

Out:

Redshift -> Analysis (all)

Data Inputs:

Event location maps

Galaxy redshift catalogues

Outputs:

Redshift of source

Localisation of event (precise)

Nucleosynthesis constraints

Optical astronomers

Day 1:

- Properties of supernovae vs kilonovae
- Spectral signatures of nucleosynthesis?

Provided with:

- Time series (images) of a range of events all over the sky with locations (grid squares?)
    - NB: include something in location excluded by gamma ray
- Galaxy redshift catalogues
- Spectra of selected events

They need to:

- Use rough locations and timings from GW/Gamma ray teams' "event notifications" to identify candidates
- Select event in grid square to identify kilonova event and check distance (other are more distant supernovae)
- Determine which event is the kilonova from images and lightcurves
- Use redshift catalogues to identify redshift
- Constrain nucleosynthesis models

X-ray/radio

Knowledge required:

Types/structure of BNS jet models

X-ray analysis

Information transfer:

In:

GW & Gamma: timing & localisation

Out:

Inclination -> GW

Jet structure/type

Data Inputs:

X-ray/radio time evolution for different models

Outputs:

Type/structure of jet

Inclination of jet

X-ray/radio

Day 1:

- Dependence of jet structure on time evolution

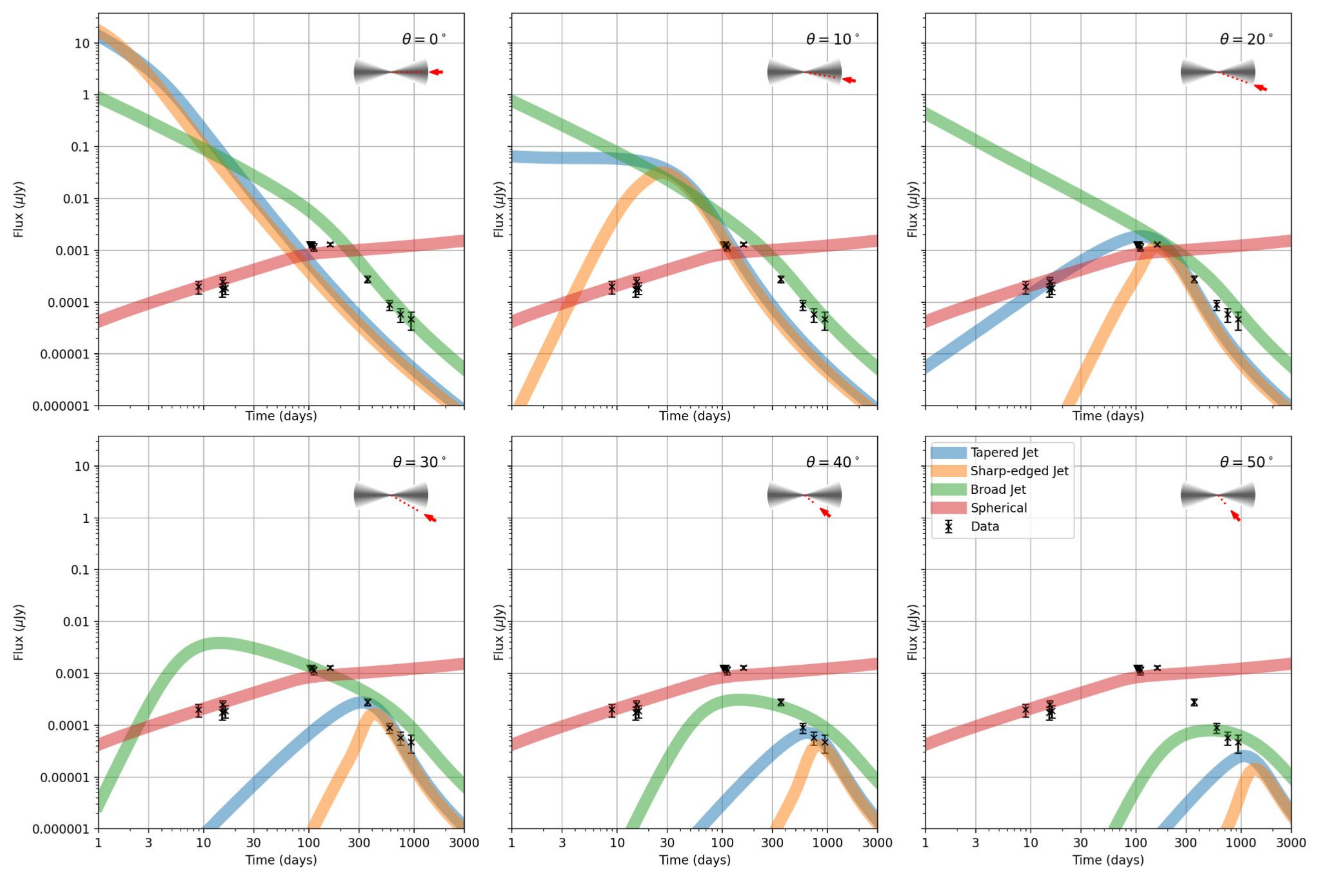
Provided with:

- Time series of a range of events at different times/locations

They need to:

- Use rough location and time from GW/Gamma ray teams' event notification to identify candidates
- Use time evolution to determine jet structure of event
- Use time evolution to determine inclination
- Provide inclination to GW team

X-ray content (models)



Analysis (everyone)

Knowledge required:

Hubble constant calculation

Information transfer:

In:

Optical: redshift

GW: Distance (precise)

Out:

Hubble constant

Data Inputs:

Outputs:

Hubble constant

Analysis (everyone)

Day 1:

- Calculations of Hubble constant from redshift and distance

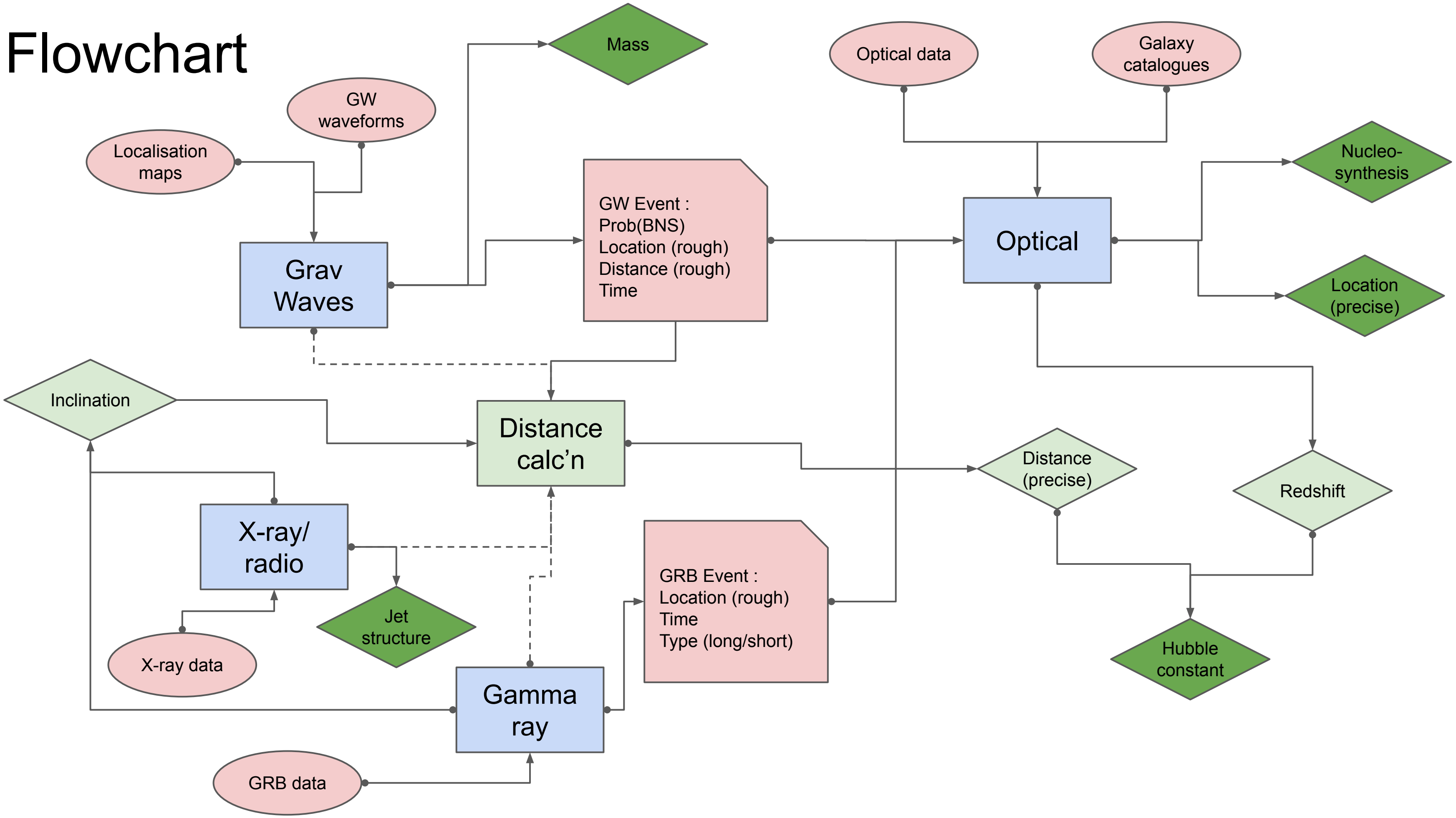
Provided with:

- Reminder of H0 calculation

They need to:

- Use precise distance from GW team and redshift from Optical team to calculate Hubble constant
- Use uncertainty on distance to calculate uncertainty on H0

Flowchart



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