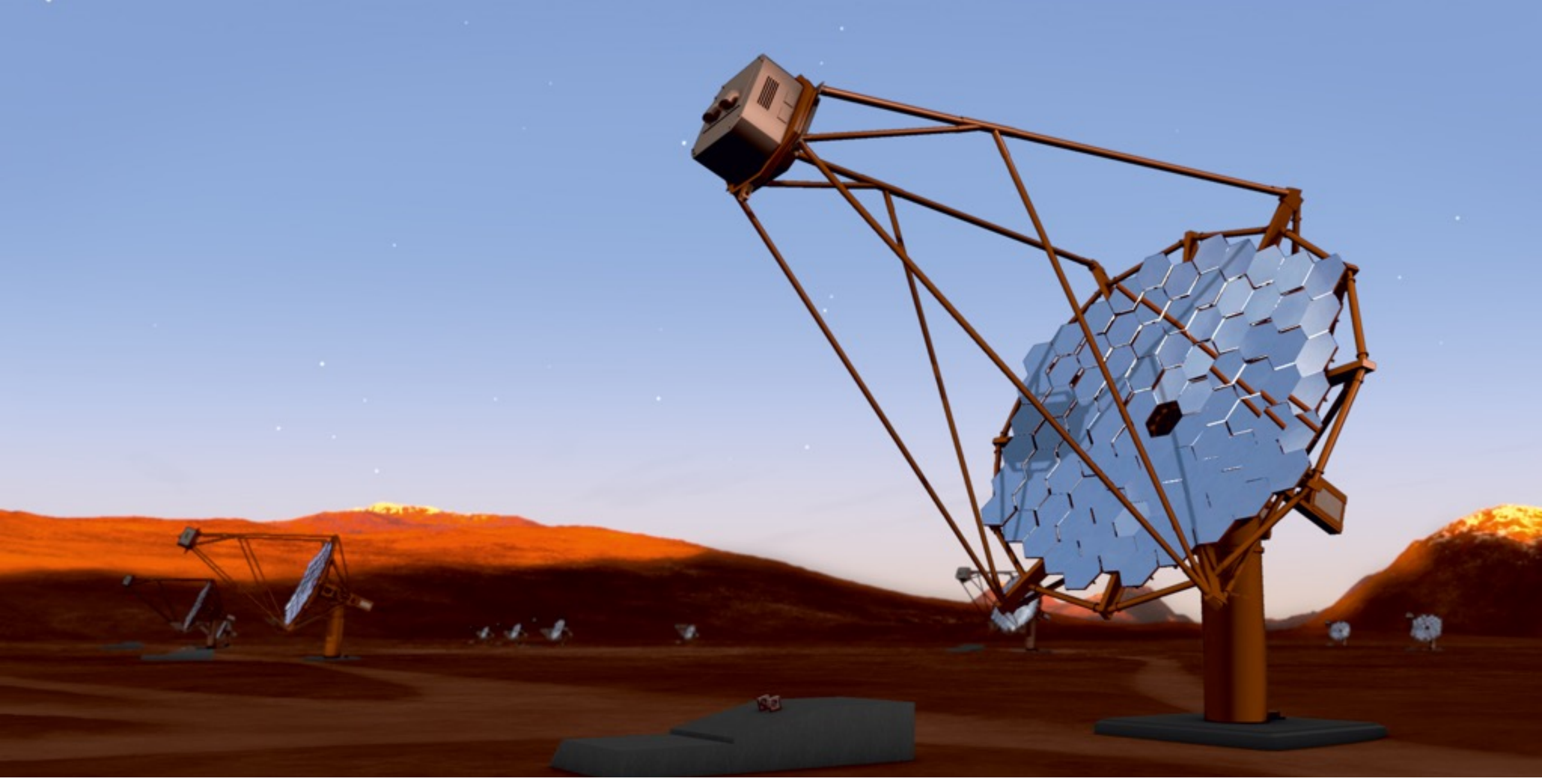
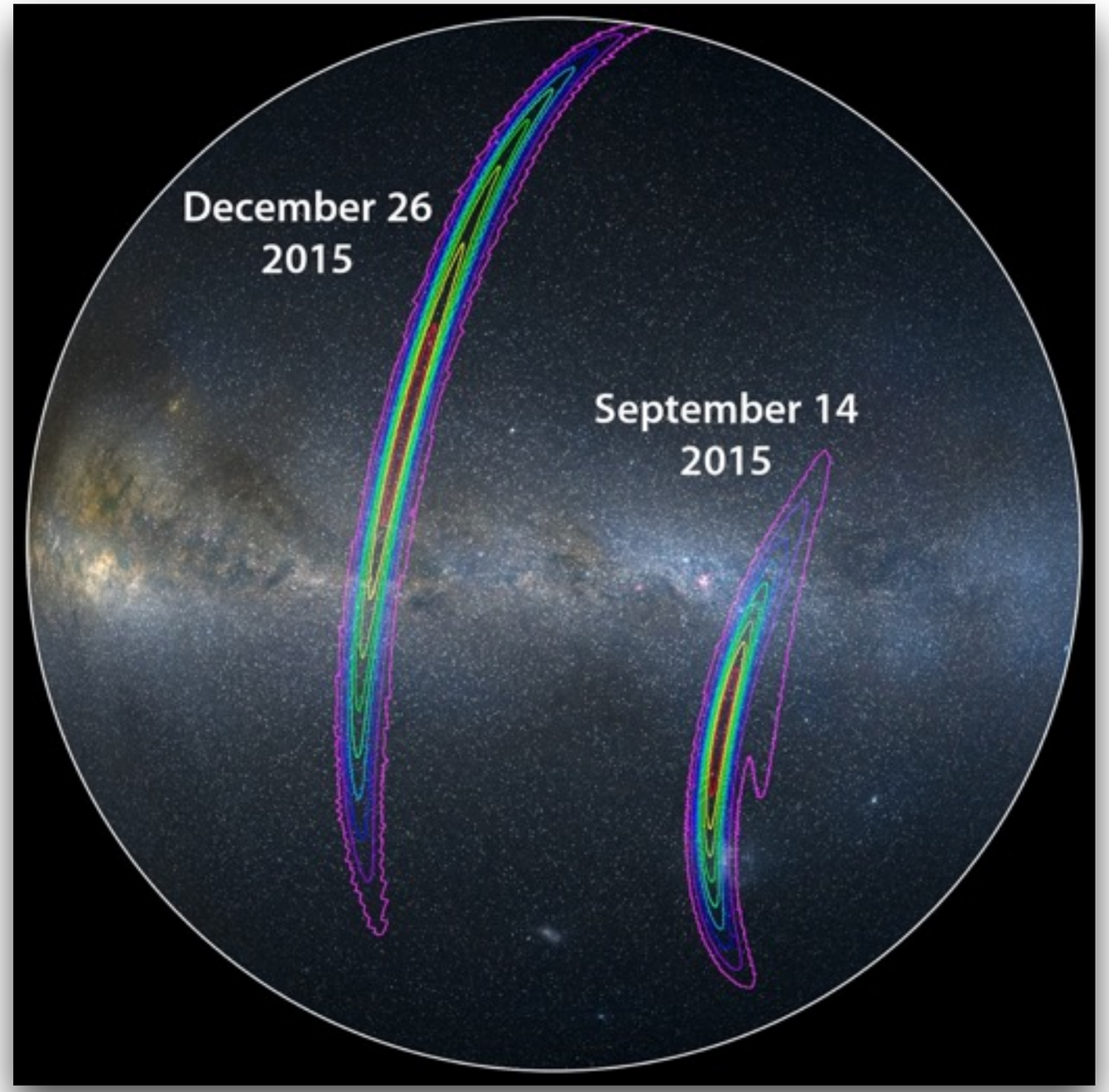


Observe a ToO following an alert from gravitational wave observatories

Fabian Schüssler (IRFU/CEA-Saclay) on behalf of the WG
2nd Top Level Use Case meeting, Bologna, 2016-06-22

Overview + Introduction

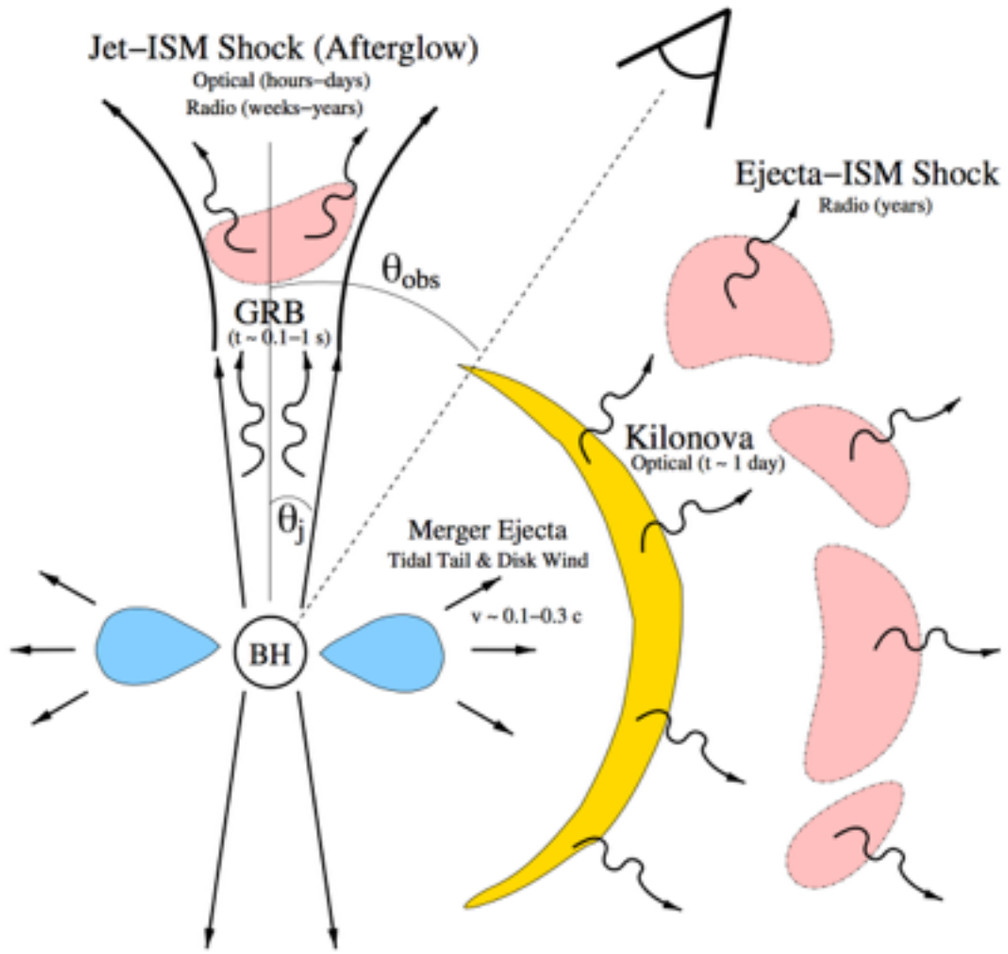
- Working group
  - Angelo Antonelli
  - Andrea Bulgarelli
  - Alessandro Carosi
  - Stefano Covino
  - Diego Götz
  - Antonio Stamerra
  - Fabian Schüssler
  - Paul O'Brien
  - Susanna Vergani
- Use Case template:
  - Link: Gravitational Waves
- Modifications marked in red



Gravitational Waves: Introduction

"Transient KSP"

- alerts from Advanced LIGO + Advanced Virgo
  - currently shared under MoUs (signed by CTA)
  - may become public (after O2 in 2017 ?)
- source candidates
  - NS-NS / BH-NS mergers
    - sGRBs
    - Kilonovae
    - …
  - …

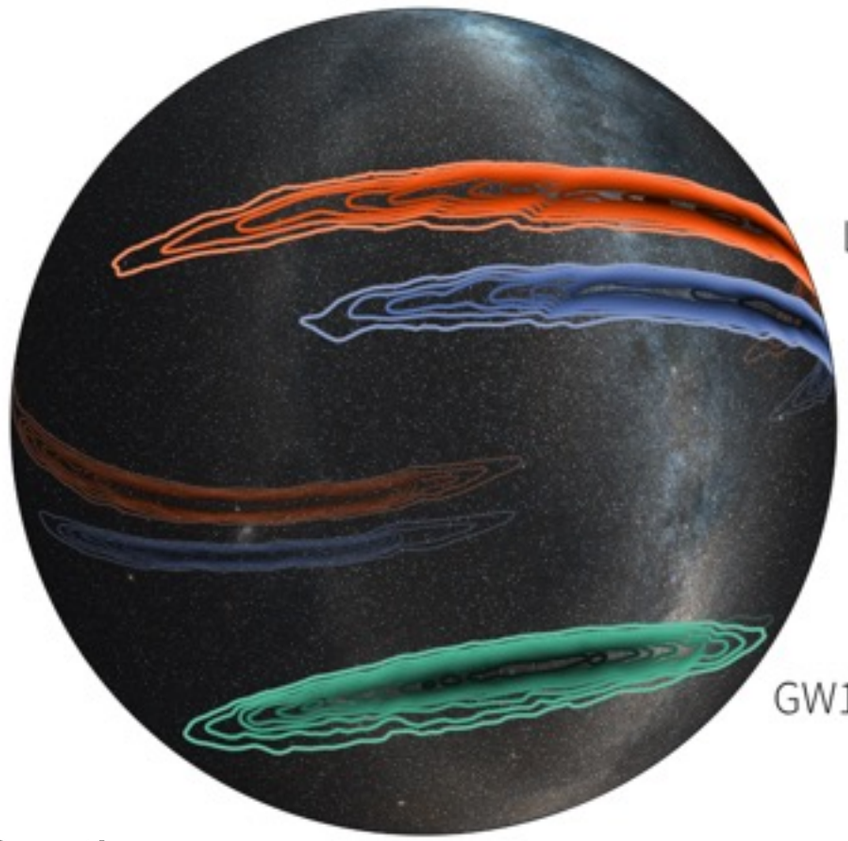


Metzger&Berger, 2012

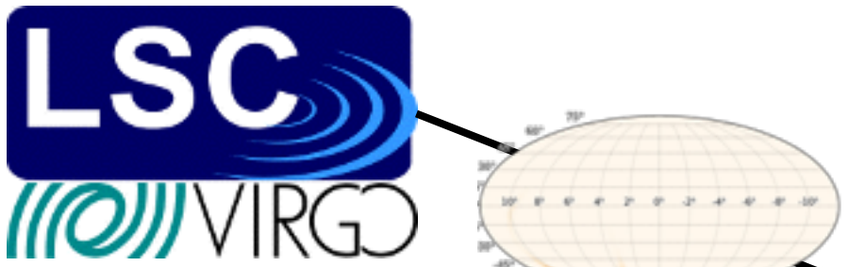
Gravitational Waves: Introduction

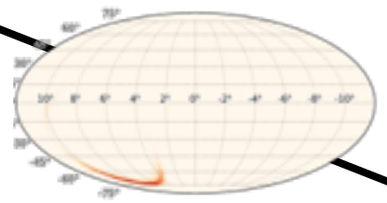
"Transient KSP"

- alerts from Advanced LIGO + Advanced Virgo
  - currently shared under MoUs (signed by CTA)
  - may become public (after O2 in 2017 ?)
- source candidates
  - NS-NS / BH-NS mergers
    - sGRBs
    - Kilonovae
    - …
  - …
- error regions > CTA-FoV
  - typically both hemispheres: CTA-North + CTA-South
  - scanning necessary
    - tiling vs. divergent pointing needs further investigations



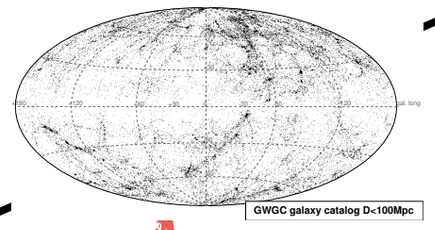
Gravitational Waves: Observation Strategy I





3D uncertainty region
(in preparation)

Galaxy catalog(s)
caveat: completness



correlation of new sources with galaxies within the GW error-box

cta
cherenkov telescope array

Global CTA scheduler (??)

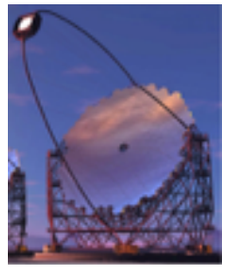
- Highly beneficial for optimizing the follow-up
- Important implications for ACTL implementation
- required for other UCs/ KSPs ?

Discussion tomorrow (!?)

GW-Scheduler

pointings, priorities, etc.

Observation Mode #1



- **FULL ARRAY** for at least 2h
  - **Observation mode #1**
- To O: divergent mode of LSTs/MSTs ?
- RTA searching for new sources

End of GW follow-up

Gravitational Waves: Observation Strategy II

Observation Mode #1

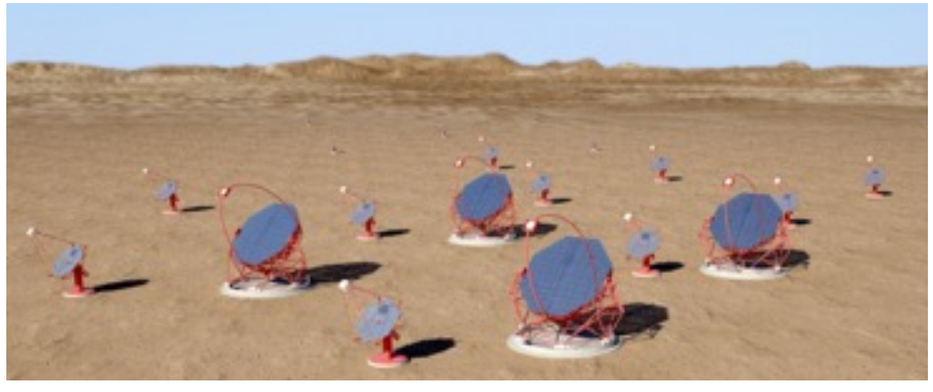
RTA source detection

LSC EM-follow up: counterpart detection

Discussion on prioritization and ranking of detected transients

- GRB-like LC
- new source => serendipitous UCs
- flaring AGN => AGN monitoring
- …

- at least 2h of additional follow-up with the full array (confirm source detection, study variability, etc.)
  - start source follow-up right away (**#2a and #2b**)
  - **sub-array to follow-up right away (#4a and #4b)**
  - start source follow-up at the end of #1 (**#3a and #3b**)
- RTA searching for variability of source(s)



End of GW follow-up

Outgoing alerts non-public within LSC-EM (until 4 GW detections)

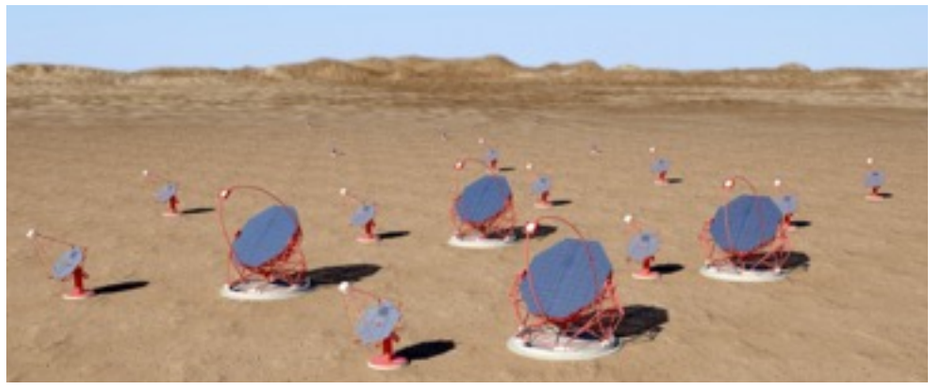
Gravitational Waves: Observation Strategy III

Outside GW follow-up

Level B: source detection

LSC EM-follow up: counterpart detection

- Notification + discussion within the CTA-GW team
  - might trigger follow-up with full array for 2h
    - Observation modes **#3c and #3d**
- RTA searching for variability of source(s)



End of GW follow-up

Gravitational Waves: Overview + open points

Observation modes

- #1: initial scanning of the GW error region
- #2a: full-array follow-up of a new source detected by the CTA-RTA during #1
- #2b: full-array follow-up of an EM counterpart detected during #1
- #3a: delayed, full-array follow-up of a new source detected by the CTA-RTA during #1
- #3b: delayed, full-array follow-up of an EM counterpart detected during #1
- #3c: delayed, full-array follow-up of a new source detected by the CTA-Level B analysis
- #3d: delayed, full-array follow-up of an EM counterpart
- #4a: sub-array follow-up of a new source detected by the CTA-RTA during #1
- #4b: sub-array follow-up of an EM counterpart detected during #1

Open points

- Need to decide whether to use parallel or divergent pointing. Most of the above assumes multiple convergent pointings (i.e. tiling the sky)
- Need to decide what exposure times to use. Short exposures will allow a large sky coverage quite quickly.
- Need to decide between Observation modes #2 or #3 (direct or delayed follow-ups) for CTA-RTA sources and EM counterparts. Maybe this has to be done on a case-by-case basis (e.g. hints of fading in RTA, etc.) and may require ranking of multiple detections
- Need to define the integration times for the RTA search for variability (closely related to GRB-UC, focus on short GRBs)

Observation parameters (GW + neutrinos)

- General assumptions: discovery observations, follow-up as many triggers as possible => as little constrains as possible
- N + S arrays
- parallel pointing (efficiency of divergent mode needs additional studies)
- coordinates: tiling for large uncertainties
- minimum telescopes: 2 MSTs or 1 LST
- marginal sky quality + 1/2 moon light
- zenith < 70deg
- no precision pointing
- ToO time delays
  - <2-3h for GW (similar GRBs, late follow-up after decision by GW-team)
- prioritization to be done (false alarm rate, time delay, error box, correlation with galaxies within 3D error-box, etc.)

Data products

- RTA/Level A analysis: for all gamma-ray sources within the ROI
  - position
  - light-curve with RTA integration time binnings
  - flux estimate
  - correlation with galaxies or other objects
- Level B/C analysis: for all gamma-ray sources within the ROI
  - position
  - light-curve (finer binning than Level A)
  - energy spectrum
  - correlation with galaxies or other objects
- Level B/C: flux upper limits might be requested for particular regions/sources (e.g. an EM counterpart detected by another observatory taking part in the GW follow-up)