Transient Source Search within Gravitational Wave Events

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Introduction

The first gravitational waves(GW) detection by the Laser Interferometer Gravitational-wave Observatory(LIGO) on September 15, 2015 is the merger of a binary back-hole(BBH)[1]

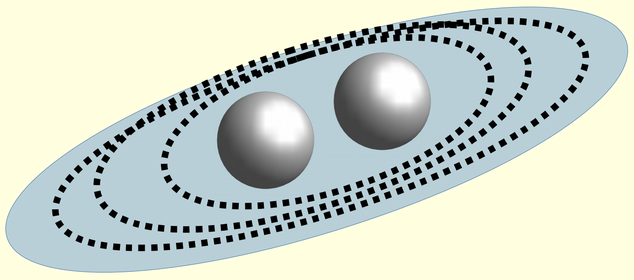

Figure 1: Cartoon of BBH

What does we expect from the BBH collision?
The transient events is what we are looking for, but non transient detection is reported[2].

No detected evidence in these wavelength:
Radio, Microwave, Infrared, Visible light, Ultraviolet, X-ray, Gamma-ray.

Why are there any evidence of detection in other wavelength coming from GW event?
Maybe the BBH merger does not produce the Electromagnetic waves or we could not detect a transient source emitted after the merger on the conditions[3]. There are possible reason as:

I. The map of localization gravitational wave event is very large and telescopes could not covers all possible area in time of event.
II. Duration of event is very short, a few second.
III. Transient source is too faint to detect.

A very wide field of view telescope is the best choice for optical counterpart of gravitational Events.

Télescope à Action Rapide pour les Objets Transitoires (TAROT)

Is the network of automated telescopes which is for the counterpart gamma ray burst, Asteroid, debris, GW event and other that are suitable for these robotic telescopes[4] shown in figure 2.

- The counterpart time is less than 20 seconds.
- It has a very large field of view 3.24 to 17.98 deg^2 .
- It is located at southern and northern hemisphere in a different continent.
- It has a hight sensitivity.
- Automated observation.
- No human interacting.

Figure 2:TAROT telescope

Telescope	Diameter(m)	Focal ratio	Sensitivity*
TCA[1]	0.25	f/3.2	18
TCH[2]	0.25	f/3.2	17
TRE[3]	0.18	f/3.2	16
ZDK[4]	1.00	f/8.0	20

*Measure in Rmag with 1 minute exposure.
[1]Calern Observatory, France. [2]Les Makes Observatory, France.
[3]La Silla Observatory, Chile. [4]Gingin Observatory, Australia.

Transient search method

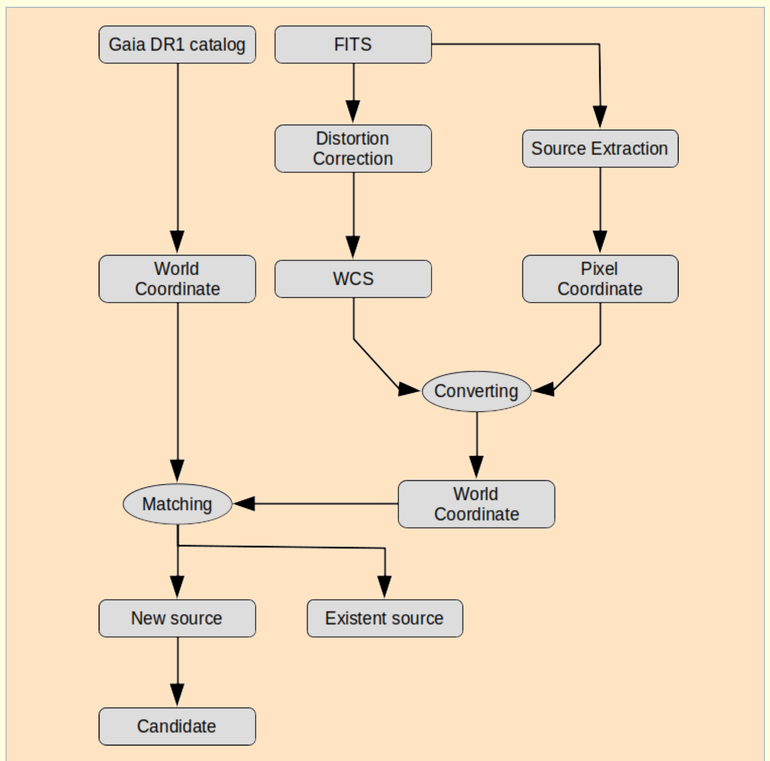

Figure 3: Transient search diagram

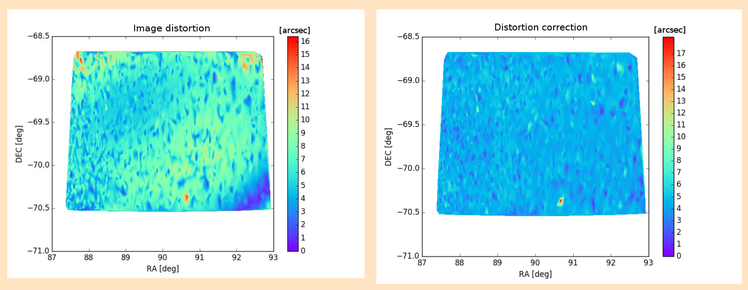

Figure 4: Image distortion in TAROT and after correction

Search for a transient source in scientific image stand on the following 5 basic steps show in figure 3:

1. we corrected a distortion in image with Astrometry package[5] to obtain the World Coordinate System (WCS).
2. Source Extractor[6] was used to extract sources in image with informations, specifically pixel coordinate.
3. Pixel coordinate is converted to world coordinate by using WCS obtain from previous step.
4. The next step was to match data with catalog Gaia Data Release 1 by using search algorithm[7] with machine learning to compare data sources against catalog. The result provided an angular separation of each source. If data source had a high angular separation than median then it was treated as a mismatch with catalog and classified as a new source.
5. New source was flagged as a possible candidate if it was not in other standard catalogs.

Optical counterpart of gravitational wave events

The first optical counterpart for TAROT is GW150914 and continue observation for 16 days and again with GW170104 on January 4, 2017. In total TAROT had counterpart two from six GW events. Data was processed though the transient search method and search algorithm.

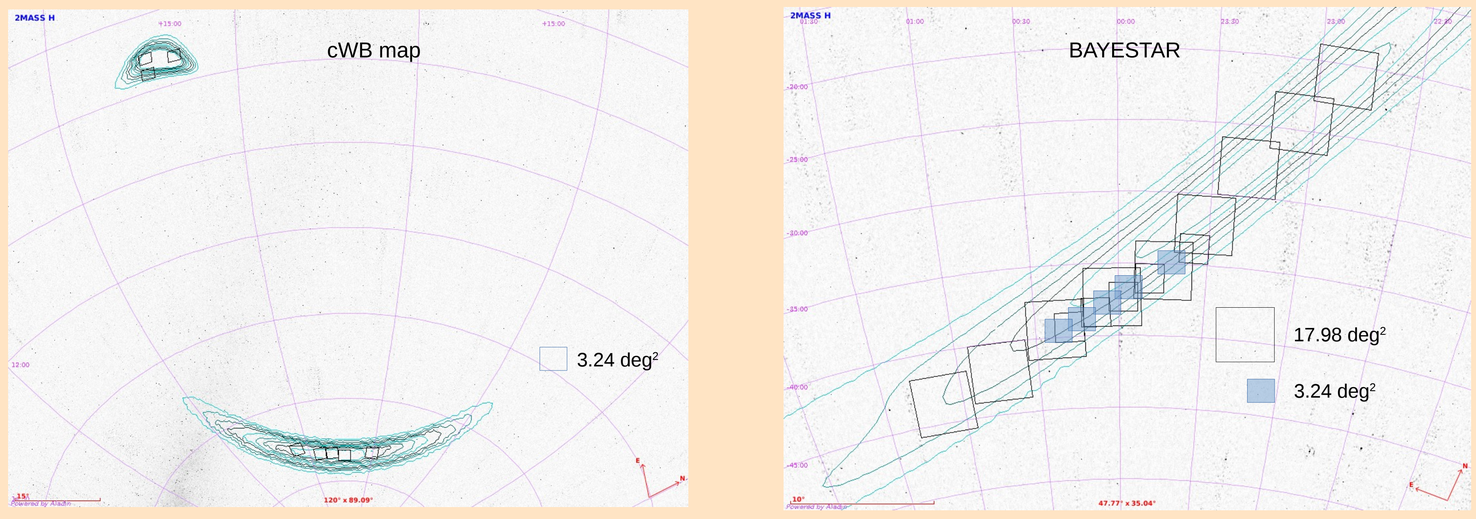

Figure 5: TAROT's footprint over the contours of the initial distributed localization GW map of GW150914 of 308.2 deg^2 (right) and GW170104 of 1632 deg^2(left) only in southern hemisphere, Images generated by Aladin software.

Conclusion

The transient search algorithm has a very high efficiency with searching a candidate in TAROT images. As long as an image is able to correct distortion with simple imaging polynomial convention at order 5th, the transient search algorithm always provides a possible candidate. The result from searching a candidate from two optical counterpart of GW events, GW150914 and GW170104, was satisfied as possible candidates had been detected but no potential candidate was confirmed with photometry.

References

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*All work have been done on Ubuntu operation and permission license; LibreOffice, Python packages, Latex, Gimp, Spyder, DS9, Aladin and other GNU general public licenses.