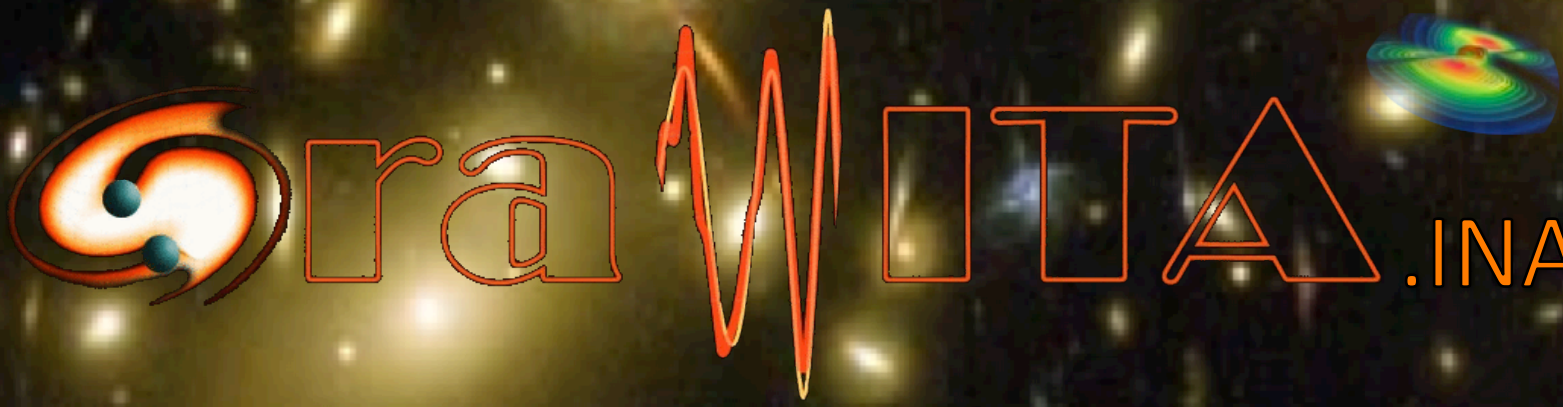
EM follow-up of gravitational waves emitters



Luciano Nicastro
nicastro@iasfbo.inaf.it

GRAWITA: **GRA**vitational **W**ave **I**naf **TeA**m

PI: *Enzo Brocato*

***INAF:* OA Roma, Napoli, Padova, Milano + IASF Bologna**
University of Urbino*, *SNS Pisa*, *ASI SDC

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Gravitown server
(OA-Roma)

CPU: 24 core @ 2.4 GHz
RAM: 256 GB
HDD: 16 + 4 TB (raid 0 + 1)
16 disks bay – LSI card 12GB

analysis tools

MariaDB

Reference catalogues
IGSL v3 (custom, 1.22 G_{obj})
GSC-2.3, TMASS, UCAC4, ...
Objects catalogues
Tools
query, X-match, export, ...

Images archive
Ref. catalogues
Extracted cats
Products

Website
(wordpress)
Public info
Images & Products
Blog
References

GraWITA
computational resources

Cloud
(owncloud)
Products
Previews
Biblio
Misce

Google
Drive (proposals)
Group emails - blog
Forms
Misce

+ other stuff

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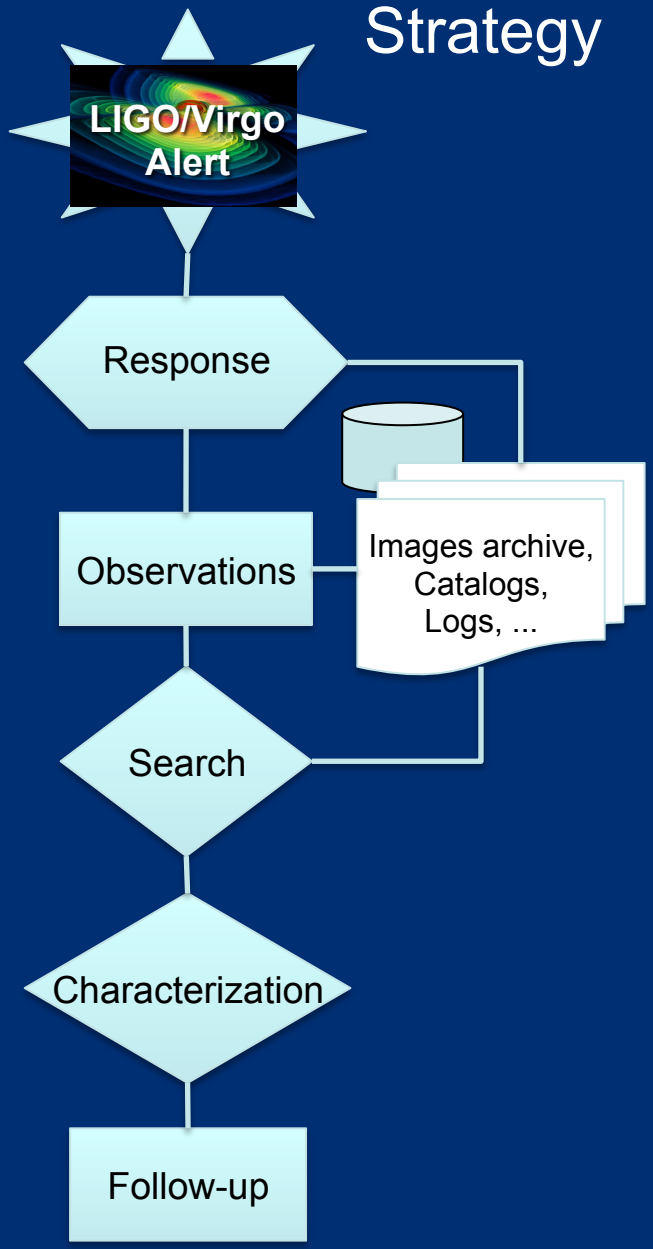
Strategy



Telescopes with large FoV distributed at different latitudes/longitudes

Computing Facilities with fast and smart software to select a handful of transients

Telescopes with large collecting area to obtain light curves and spectral features of transients

STEP 1

Search & Detect

Transients in the error box provided by LVC have to be discovered and measured *as soon as possible*

STEP 2

Observe & Characterize

The detected transients have to be observed to infer their nature

STEP 3

Follow & Study

Follow-up at all observable λ for an adequate time to study the physical properties of the **EM counterparts of GW**

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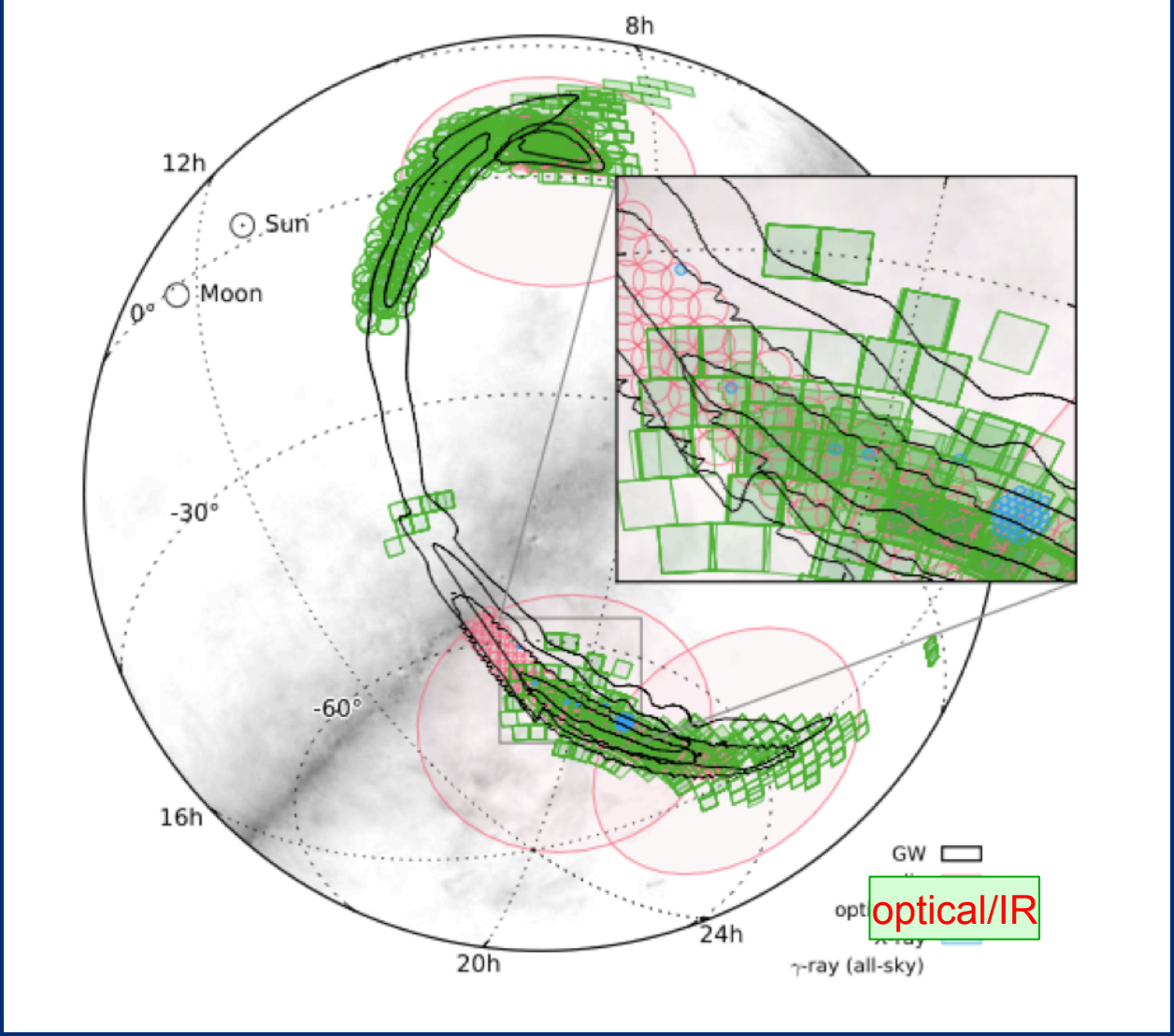
GW150914 : EM follow-up



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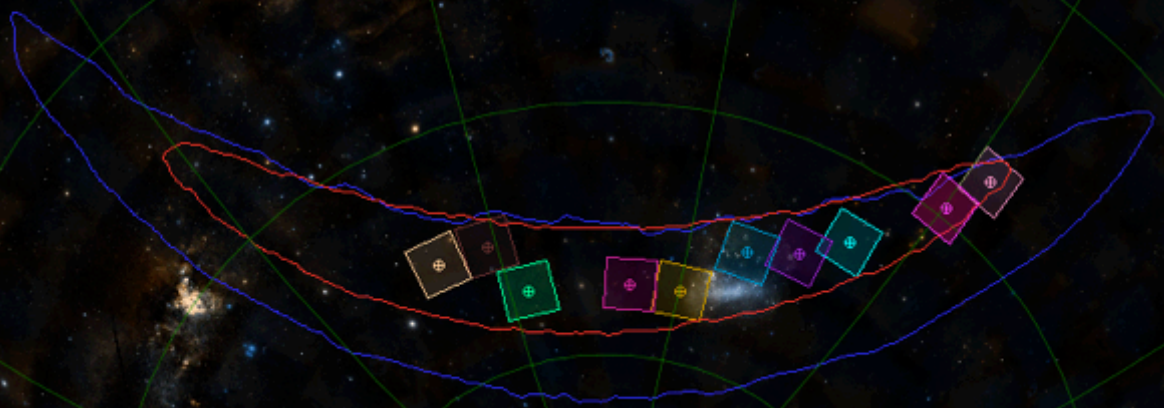
VST campaign on GW150914

- 90 deg^2 (3°x3°) to be repeated at six epochs:
  t_0 , t_0+1d, t_0+5d, t_0+8d, t_0+15d, t_0+ 60d [t_{REF}]
- Filters: r
- 2 dithered exposure per pointing, 40 s each, limiting mag r ~ *22.4*



- Number of images: ≥ 200 images
  (~18000×18000 px to map 1 deg^2)
- Image size: ~ 1.3 GB / image
- Calibration time: ~ 6.5 hrs for a set of ~ 200 images

GW151226

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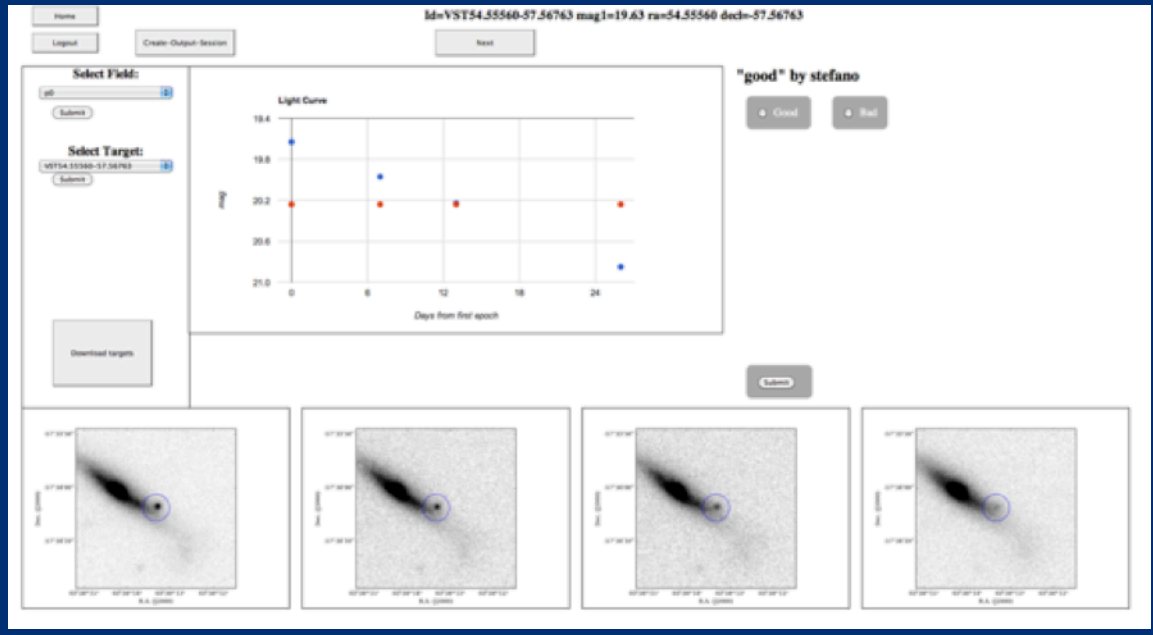
Search:

I. Comparison of catalogs

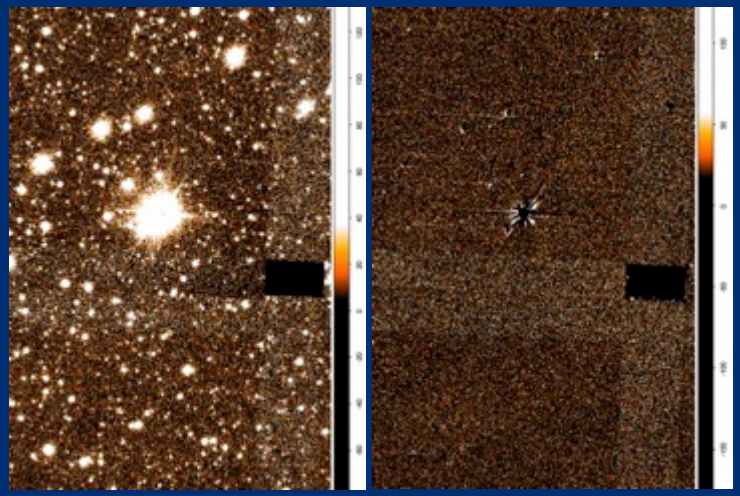
- Sextractor -> object ident.
- mag_{diff} @ each epoch (7σ)
- check with available catalogs
  (IGSL, Simbad, Minor Planet Center)
- PSF fitting single object
- Check by eye (LC + images)

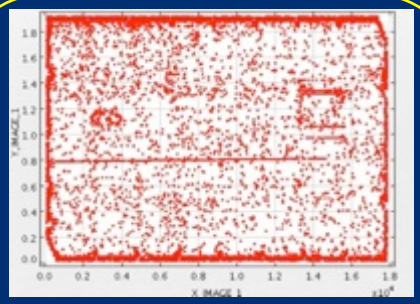


II. Image subtractions

IIa. SUDARE@VST
Cappellaro et al. 2013

IIb. TAC/RMN algorithm
(coll. INFN – Ge)





~10^4 transients in 1 deg^2

~10 transients in 1 deg^2

Server for data analysis: Gravitown@OARoma

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Main computing tasks:

- VST-tube (Napoli)
  - Astromatic tools (Scamp, SWarp, SExtractor, ...): *clean images, extracted objects catalogs*
  - 6.5 hr, 10 TB

- Catalogs pipeline (Bologna)
  - Filtering, Xmatch, ...
  - 5 min, ~ 1 GB
- Custom image reprocessing pipeline (Merate)
  - Filtering, PSF photometry, Xmatch, LC
  - ~45 hr, 300 GB
- Hotpants, SUDARE@VST (Padova)
  - Images subtraction, LC
  - ~50 hr, 2 TB

Gravitown @ OA-Roma

Totals: ~100 hr, 14 TB, Key point: data throughput

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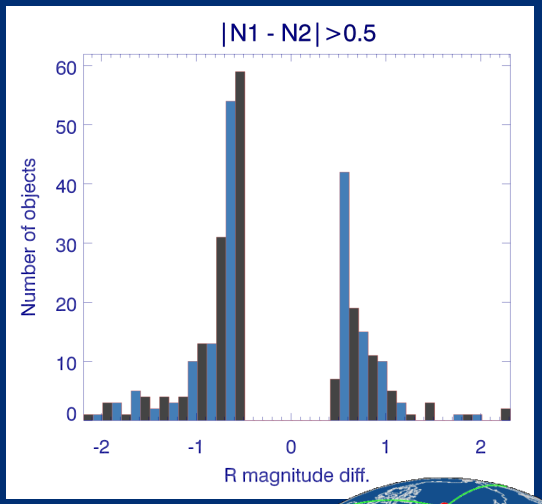
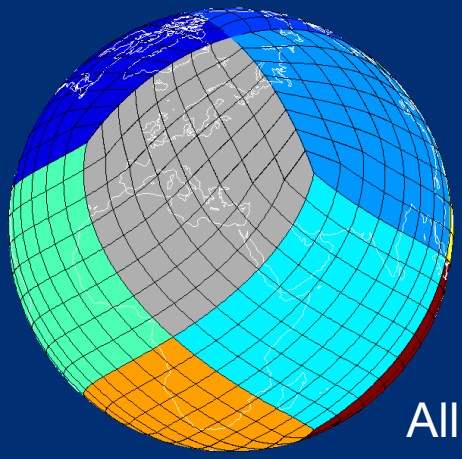
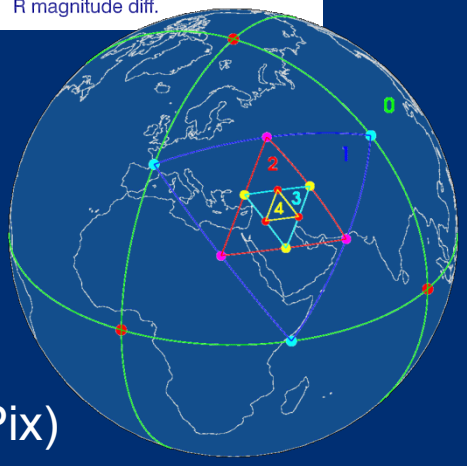
DB main usage:

- Reference catalogues
  - IGSL, 2MASS, UCAC4, GSC2.3
  - GWGC
- SExtracted objects catalogs
  - Statistics, Flagging, LCs
- Images log
  - Observation info
  - Image sky footprint





- X-match
  - Sphere-match: 1-1 1-N
  - SQL Join



All use sky pixelization indexing (HTM, HEALPix)

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Main optimization tasks:

- Machine learning algorithms
  - PTF, VISTA
- Parallelization
  - Single multi-core, OpenStack, Julia (julialang.org)...
- Uniform pipelines architecture to use DB
  - All the advantages of DBs
- Write new s/w
  - Mainly for images managing and processing, LC analysis
  - See https://goo.gl/8I9TPL (UC1)
  - C/C++, Python, ..., **Julia** ?
- Use the web (browser) to get (easy) access to the computational resources (HTML5/JS, NodeJS, Redis, MongoDB, OpenCL, OpenGL, ...)

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GRAWITA and the next LVC runs:

- Prepare to Virgo impact
- Faster alerts from LVC
- Faster data analysis of VST images
  (catalogs pipeline + image subtraction)
- Make agreements with other groups

Web-tools demo links

- https://sadira.iasfbo.inaf.it/~indy/gc5/interface.8.html
- http://ross.iasfbo.inaf.it/~rossusr/BSC-web-example/
- http://ross.iasfbo.inaf.it/~rossusr/DBcross/
- https://sadira.iasfbo.inaf.it/~indy/gc5/interface.2.html
- https://sadira.iasfbo.inaf.it/~indy/gc5/interface.6.html

- https://goo.gl/8I9TPL (UC1)

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HEALPix

N_{obj} = 113,780,000
K = 8 N_{pix}= 786,432 Ω_{pix} ~ 14’