Multiwavelength studies of fast transients: GRBs, FRBs and GWs

OAS DAYS
Bologna, 17-18 dicembre 2018

GRBs and FRBs

The OAS GRBs and FRBs member team:

L. Amati, M. Dadina, G. De Cesare, E. Maiorano, N. Masetti, L. Nicastro, E. Palazzi, E. Pian, A. Rossi, G. Stratta

Gamma Ray Bursts

SHORT HARD GRBs

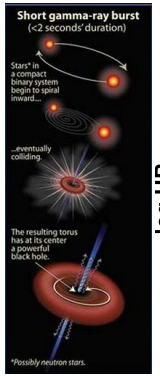
LONG SOFT GRBs

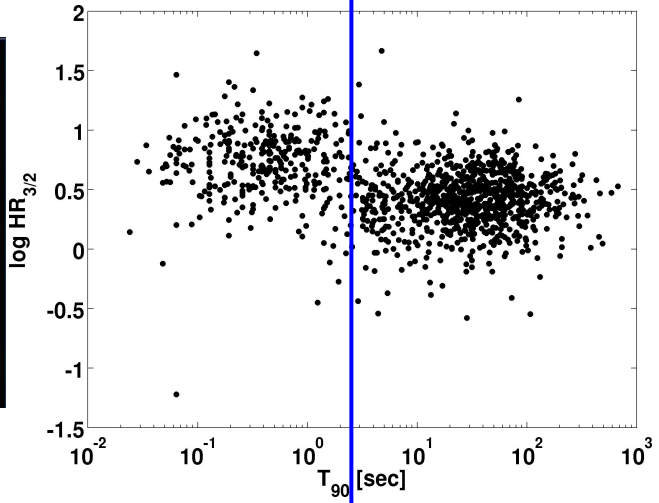
~ 2 seconds

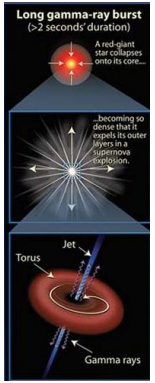
Merger of NS-NS / NS-BH

Progenitor indications:

- GW/GRB170817
- lack of observed SN
- association with older stellar population
- larger distance from the host galaxy center (~ 5-10 kpc)







Progenitor strong evidence:

- observed Type Ic SN spectrum
- close to the center of the host galaxy
- hosted in star-forming galaxies

Kilonovae
(Optical/IR, radio remnant)

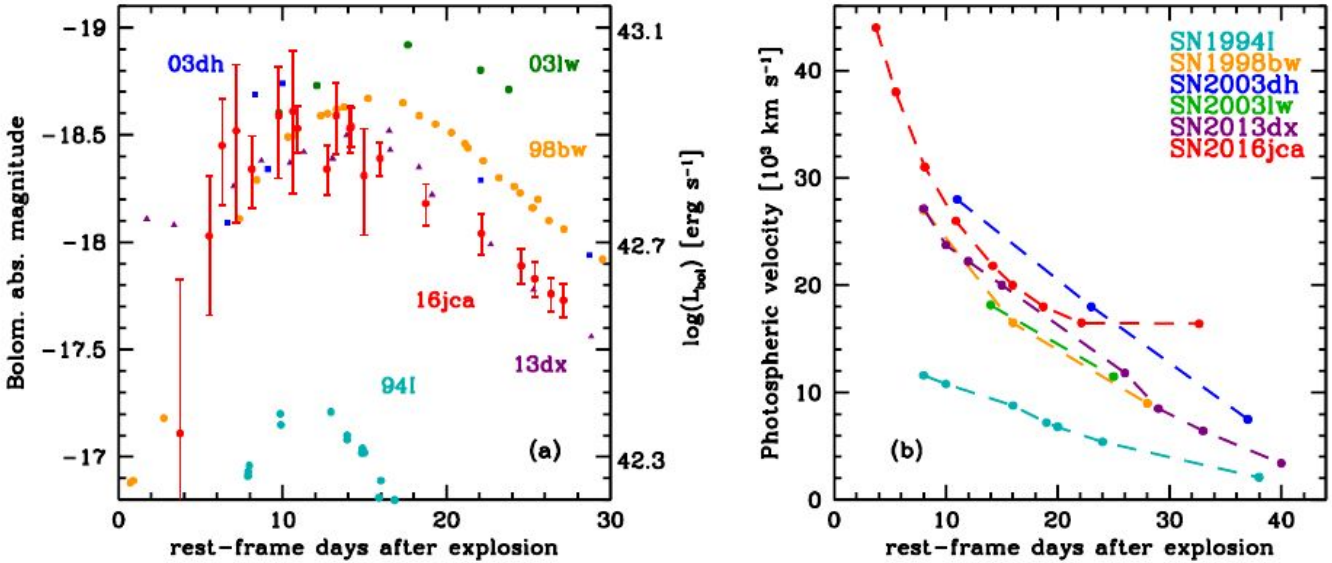
Supernovae Type Ib/c

GRB-related works @ OAS

- Active members of the national CIBO (Coordinamento Italiano Burst Ottici) and the European STARGATE collaborations for the search and follow-up GRB afterglows at the INAF and ESO Telescopes respectively
- GRB-SN connections
- Host galaxies multiwavelength observations and studies
- Studies of the high energy prompt GRB emission and of the X-ray afterglow properties
- Use of GRBs as cosmological probe

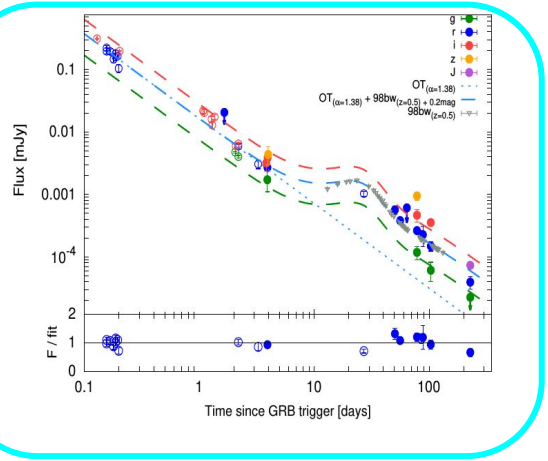
GRB-SN connections

- **All the observed GRB-SNe are type Ic**: their ejecta contain no H and no He.
- Estimated **progenitor** masses are in the range **30-50 $M_\odot$** and **ejecta** masses in the range **8-12 $M_\odot$**
- Their **kinetic energy** after correction for asymmetry is still **one order mag larger than typical SNe Ic.**
- Two contending scenarios for the powering mechanism: **collapsar or magnetar**?
- Both scenarios may contribute → more GRB-SN data needed.



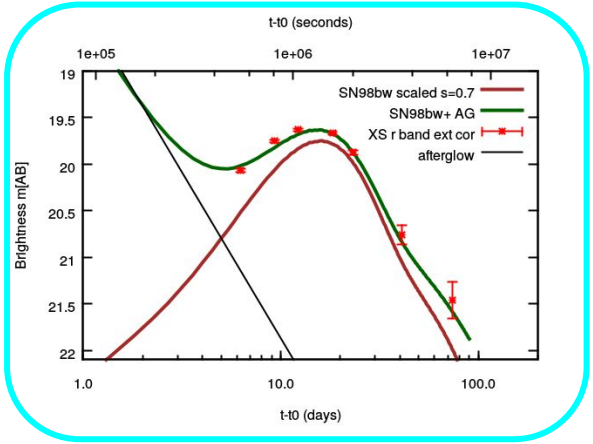
Adapted from Ashall, Pian et al., arXiv: 170204339

GRB-SN connections



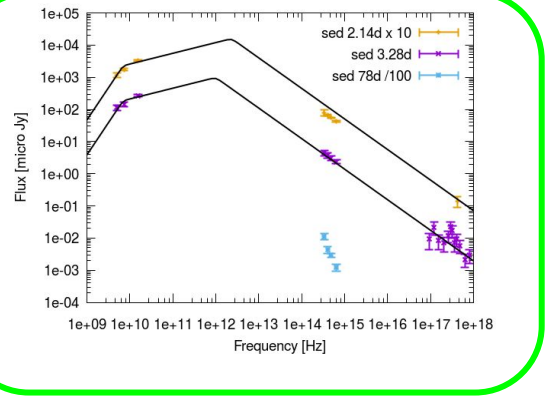
light-curve modeling:

- GRB afterglow
- SN

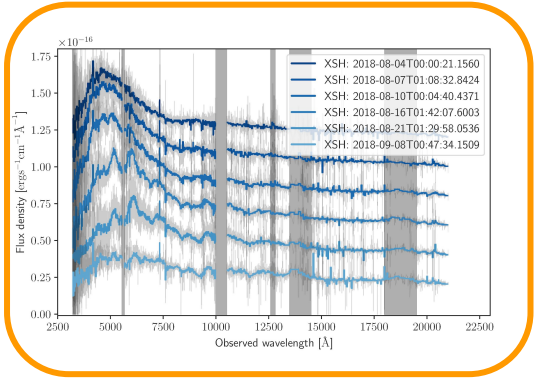


Multiband SED modeling of afterglows:

- double broken power-law
- synchrotron emission



Spectroscopic follow-up of GRB-SNe

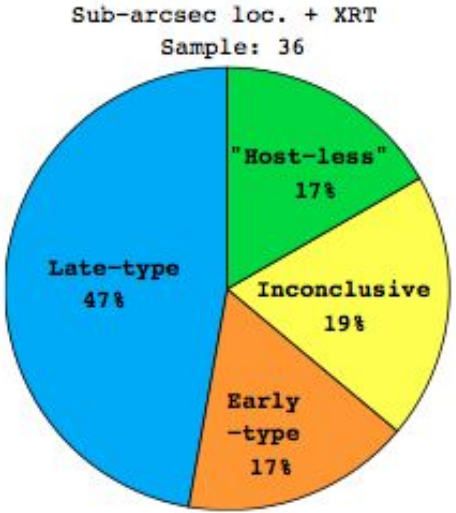


GRB170105A/ATLAS17aeu
Melandri et al., 2018, arXiv:1807.0368, A&A accepted

GRB180728A, the closest high-luminosity GRB ever
Rossi et al., in prep.

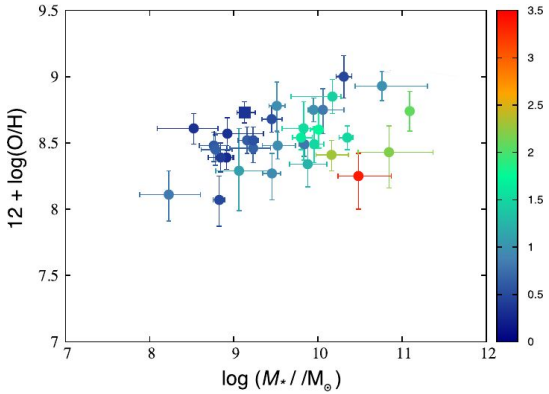
GRB Host galaxies

- Short GRBHs
  - Short: both quiescent and star forming, generally more massive

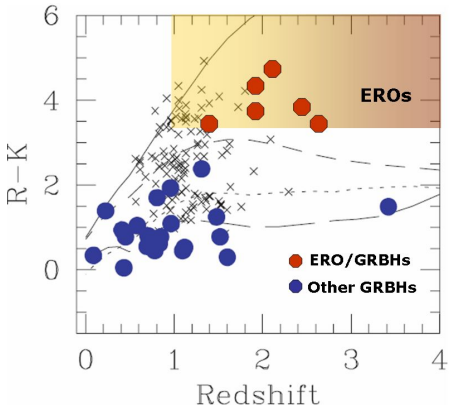


Fong et al., 2014

- Long GRBHs
  - star forming galaxies, with preference for low metallicity blue dwarf galaxies at low redshift
  - 30-40% of all long GRBs are dark Half of them may be host by extremely red objects



Arabsalmani et al., 2018

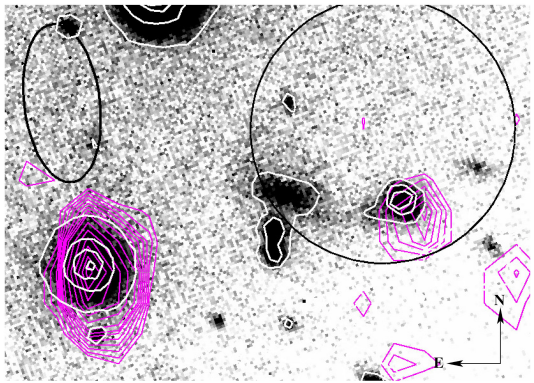


Rossi et al., 2012

GRB Host galaxies

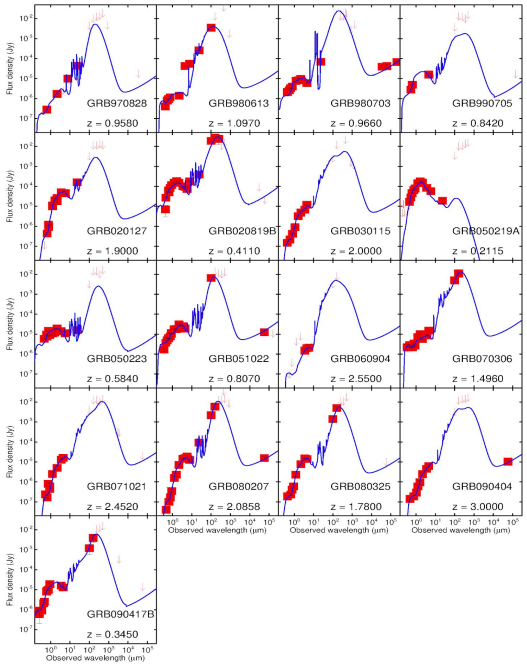
Missing host problem:

- high-z?
- low-luminosity HG?
- Kicked progenitor



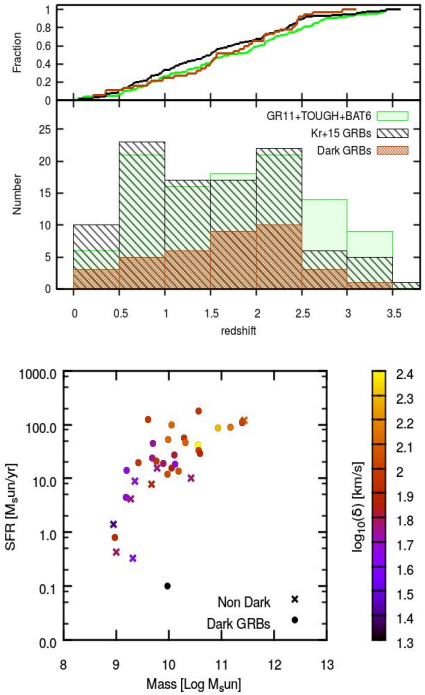
Nicuesa et al., 2015

Multiband SED modeling



Hunt et al. 2014

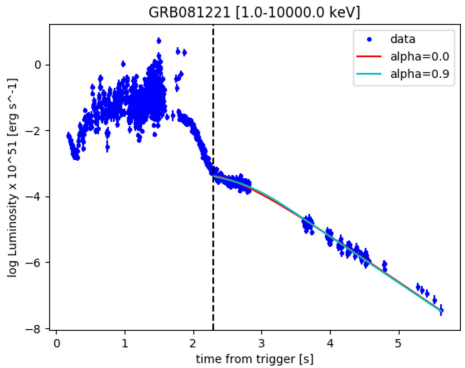
Long GRB host properties

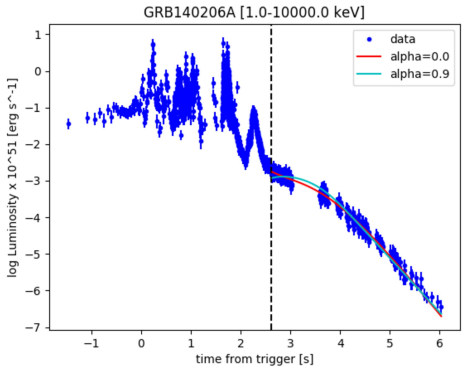


Rossi et al., in prep

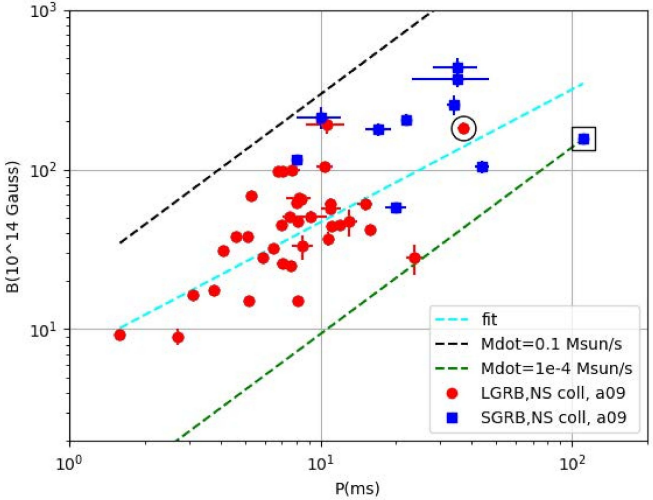
X-ray Afterglows

X-ray afterglow light curves from Swift/BAT+XRT data





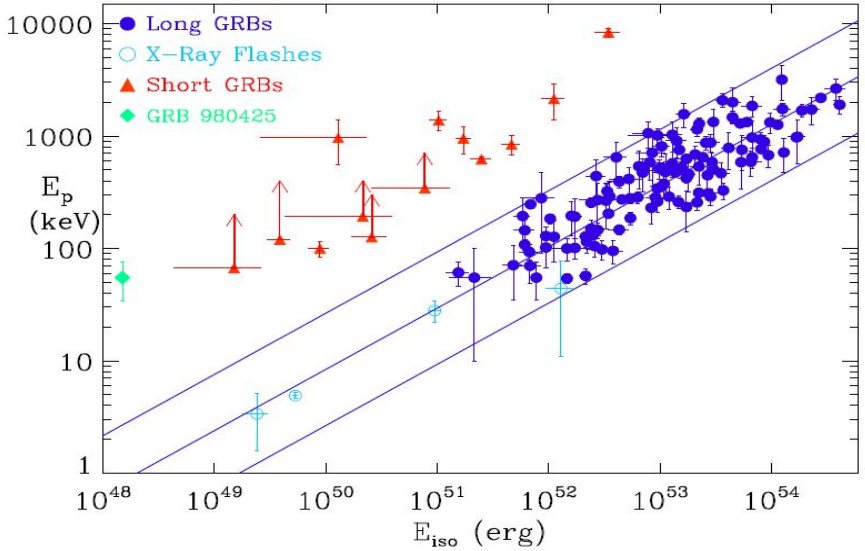
Long and short GRBs seem to follow the same well known B vs P correlation of accreting PSR



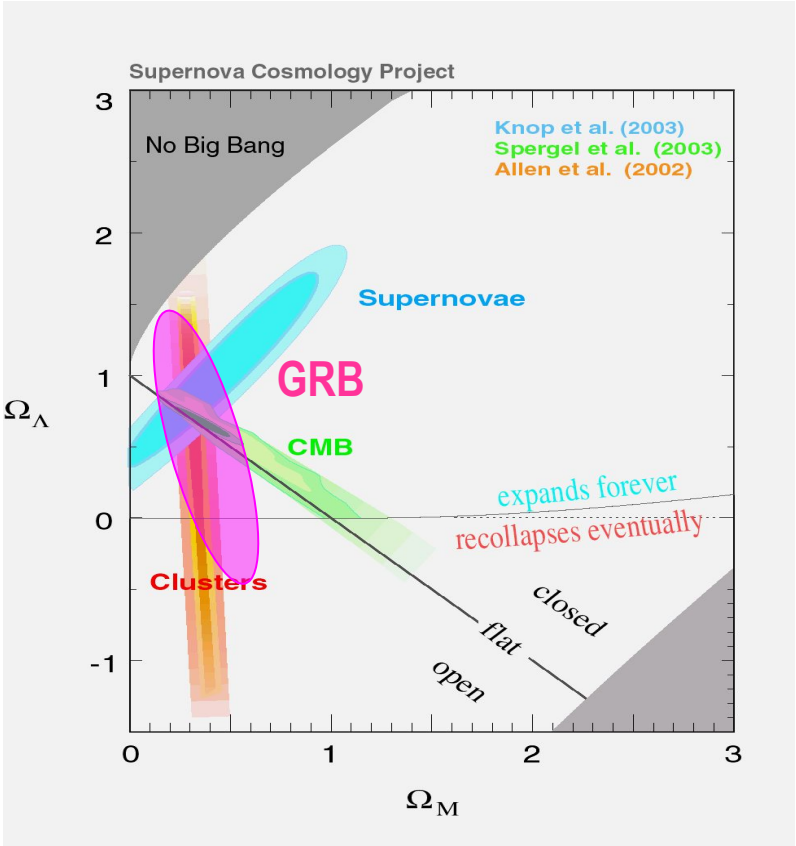
1) Confirmation of past evidence on the presence of a central magnetar injection power into the afterglow
2) Evidence that long GRB have faster spinning magnetar w/r to short GRB possibly due to larger accreting matter

Stratta et al. 2018, ApJ in press

GRB as cosmological probes



193 long GRBs as of 2015



Amati et al, 2002…2016

Fast Radio Bursts

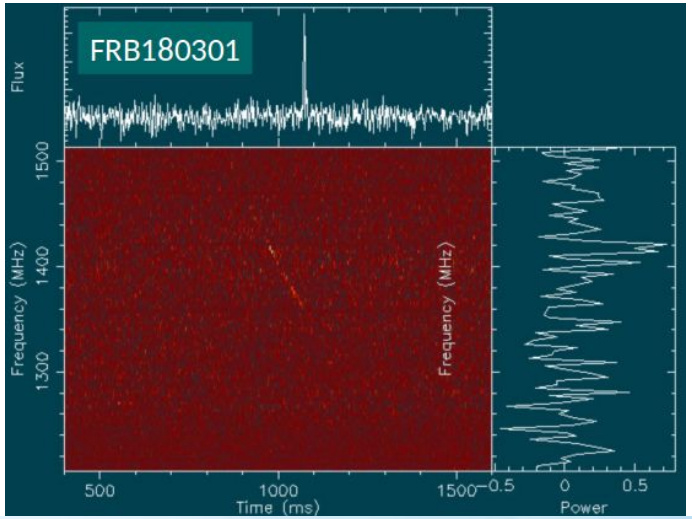
Mysterious radio transients with ms duration ⇒ must be compact

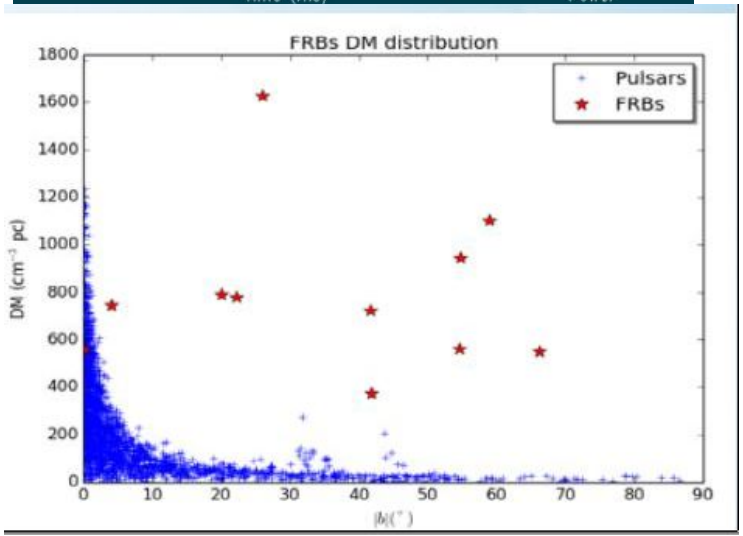
Mostly detected around 1GHz

High Dispersion Measure, greater than local Galaxy value ⇒ extragalactic

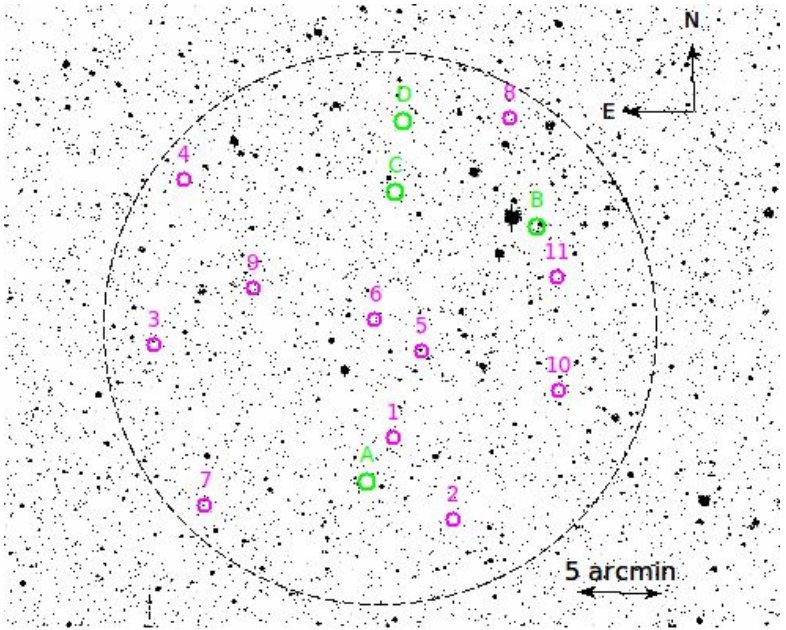
Possibly two types: repetitive vs non repetitive

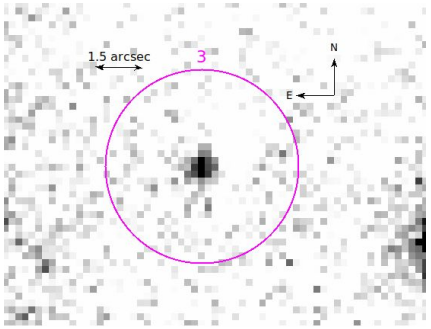
Unknown origin; there are still more models that detected FRBs

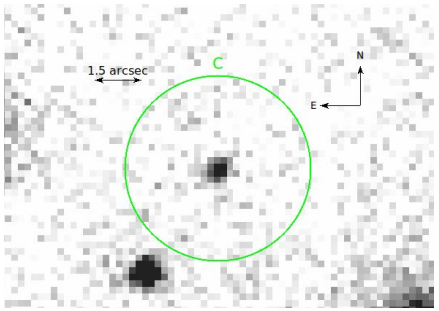




FRBs-related works @ OAS







Lorenzo Milizi Master Thesis

FRB 180301. Zoom-in on the FRB error circle observed with **VST**, i band. ESFgalaxies (green peas), variable sources within 1 day (magenta)

Follow-up of FRB 180301, 180309, 180311

Search of the candidates:

- Large FOV instruments: OMEGACAM/VST and VIRCAM/VISTA
- Swift/XRT

Methods:

- photometric relative variability
- image subtraction.

Characterization of candidates with VLT-X-Shooter

Gravitational Waves: Activities on the electromagnetic follow-up

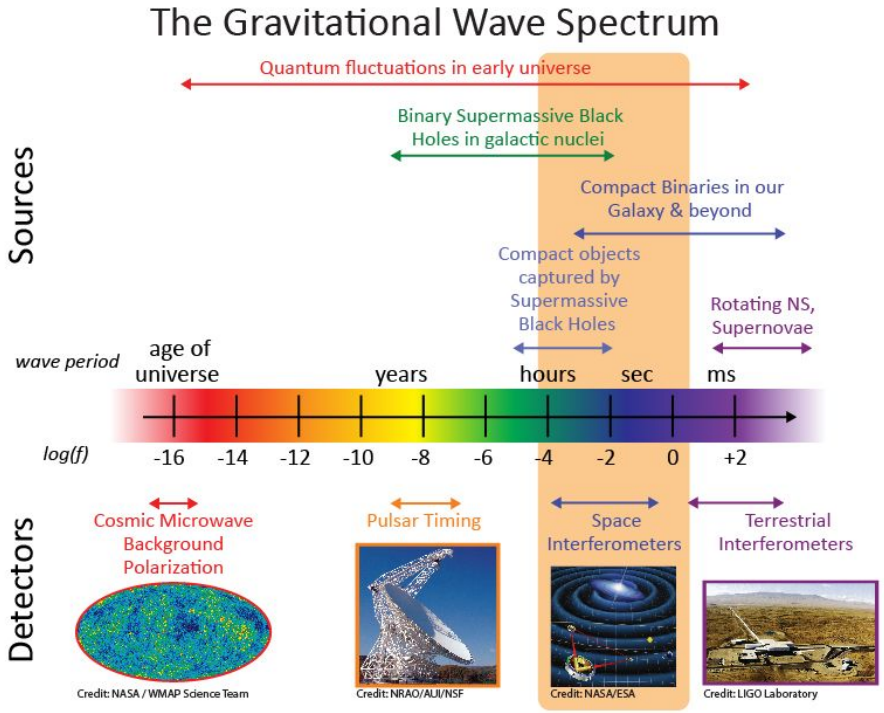
The OAS GW member team:

L. Amati, A. Bulgarelli, F. Cusano, A. De Rosa, M. Dadina, G. De Cesare, V. Fioretti, G. Lanzuisi, E. Maiorano, N. Masetti, L. Nicastro, E. Palazzi, N. Parmiggiani, E. Pian, A. Rossi, G. Stratta, E. Torresi, D. Vergani (+ DIFA and IRA colleagues)

High Frequency (10-1000 Hz) GW sources

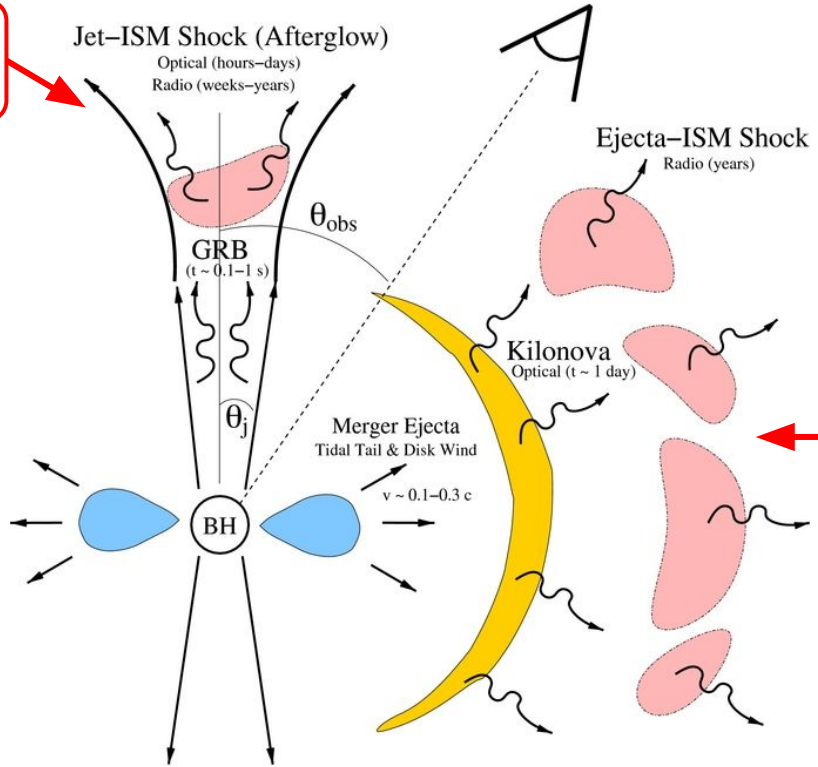
- The frequency range at which GW detectors are sensitive tell us type of sources we can observe

- **At high frequencies we expect to see**
  - **Compact-binary coalescences**
  - core-collapsing stars
  - instability phenomena on NSs



Expected e.m. counterparts

Short GRB+afterglow



Metzger & Berger 2012

GW170817 → first GW source associated with an EM counterpart!

+1.7 s → short GRB (Fermi+INTEGRAL)

+ 11 hrs → optical counterpart (Swope + many others and REM!)

+1.5 days → optical spectrum (VLT/X-shooter, GMOS, Soar Magellan Telescope)

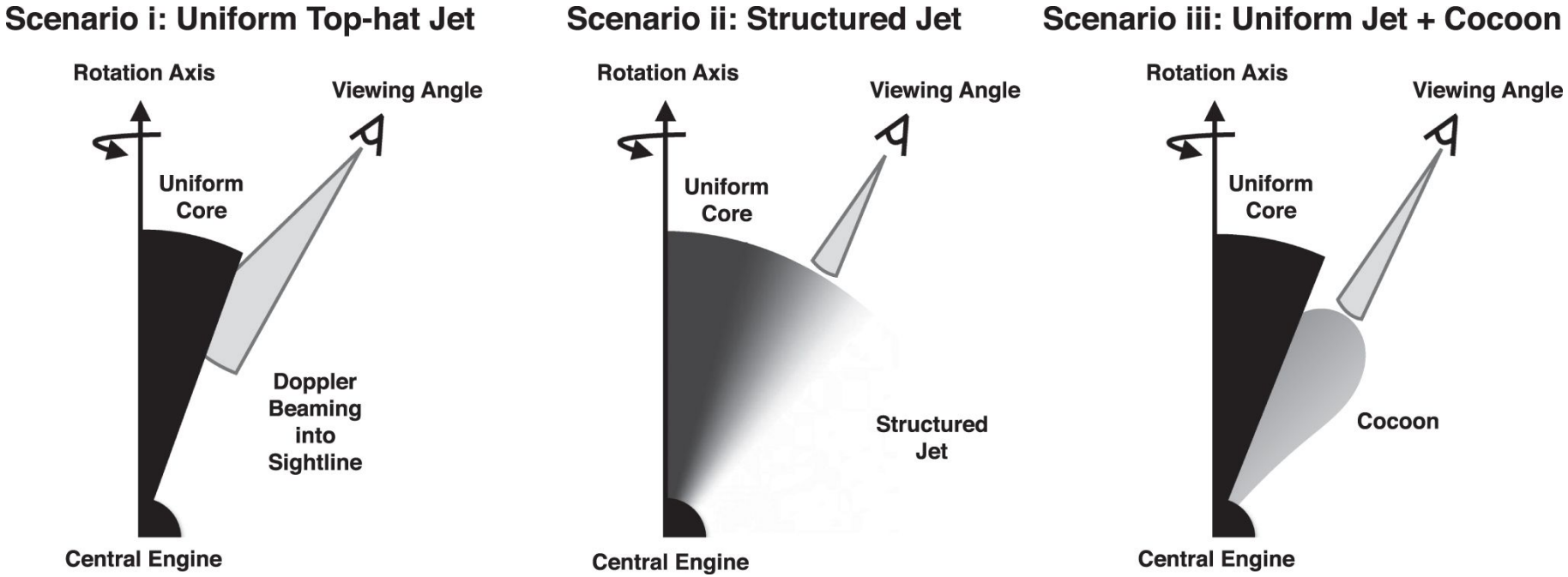
+ 9 days → X-ray counterpart (Chandra)

+ 16 days → radio counterpart

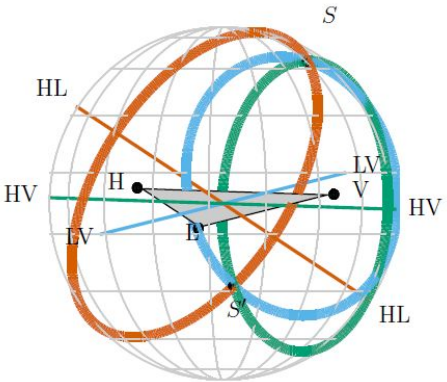
kilonova

Expected e.m. counterparts

Abbott et al. 2018 ApJL 848, L13

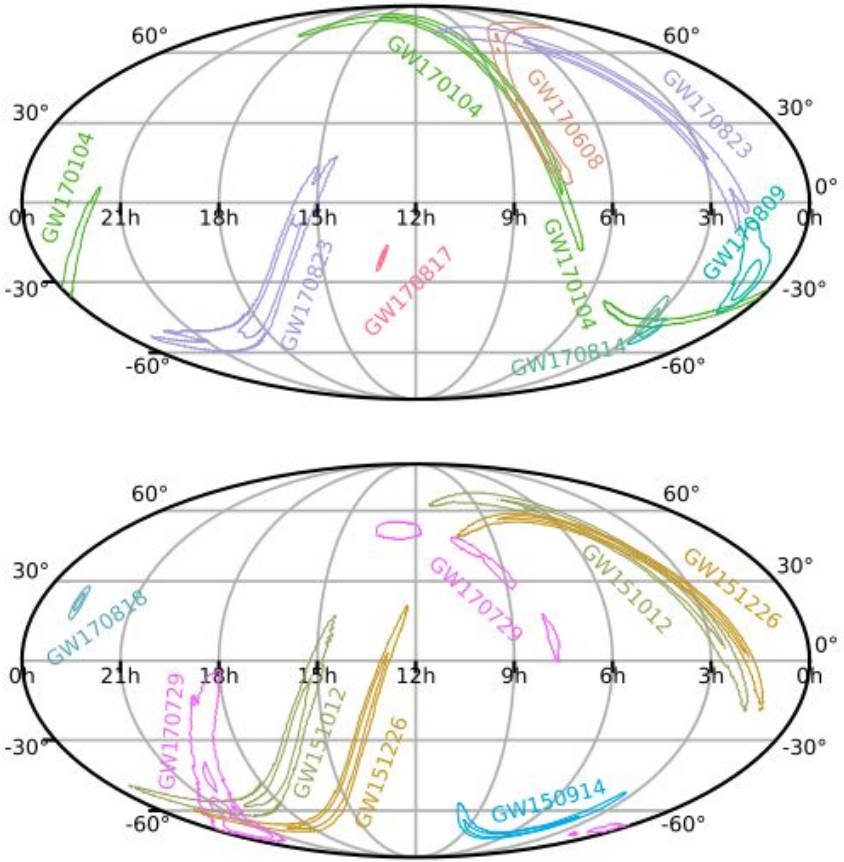


GW source localization



Triangulation → 100-1000 deg^2 with 2 detectors, 10-100 deg^2 with 3 detectors

10 BH-BH and 1 NS-NS localization at 90% CL in the range 1500-16 deg^2



1st GW transient catalog, Abbott+2018, https://arxiv.org/abs/1811.12907

GW-related expertises @ OAS

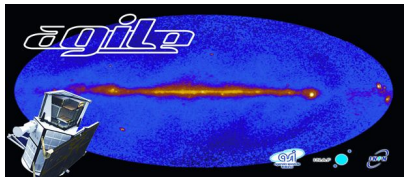
Kilonova + afterglow

short Gamma Ray Bursts

premio INAF!

- **Transient sources observational strategies and follow-up (GRBs and FRBs)**
- **High energy (keV, MeV GeV) data analysis**
- **Multi-wavelength data analysis**
- **Photometry + Spectroscopy**
- **GW data analysis**
- **Infrastructure and outreach**

cta cherenkov telescope array



L.Amati-oo, A.Bulgarelli-o, F.Cusano-o, A.De Rosa-o, M.Dadina-oo, G.De Cesare-oo, V.Fioretti-oo, G.Lanzuisi-o, E.Maiorano-oo, N.Masetti-oo, L.Nicastro-oo, E.Palazzi-ooo, E.Pian-ooo, A.Rossi-ooo, G.Stratta-ooo, E.Torresi-o, D. Vergani-o

premio “Occhialini”!

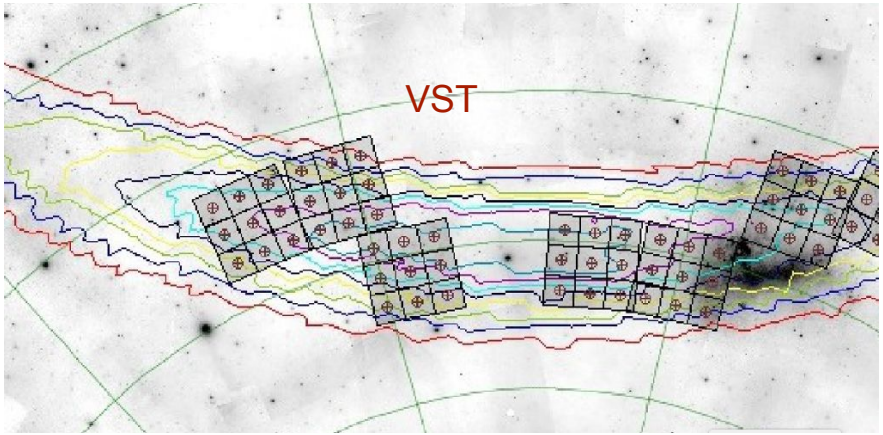
Follow-up results during the O1 & O2 LVC runs

OAS members participated to the e.m. follow-up campaigns during the first two LVC observational runs O1 (Sept-Dec 2015) and O2 (Jan-Aug 2017)

Large FoV telescope = VST
→ *tiling strategy → candidate list*

Small FoV telescopes = Asiago, REM, Loiano, TNG, Campo Imperatore
→ *candidate characterization*

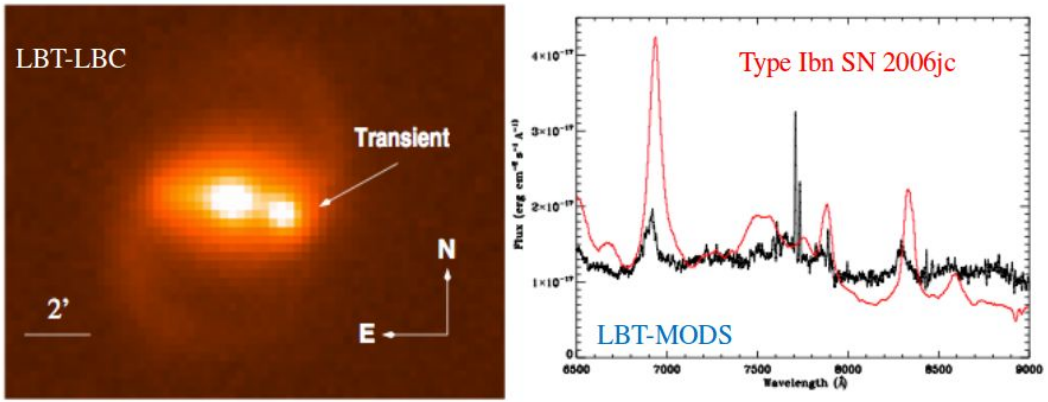
GW150914, GW sky localization: 600 deg^2 at 90% CL
VST tiling (90 deg^2) +2.9 days (23hr after the alert)



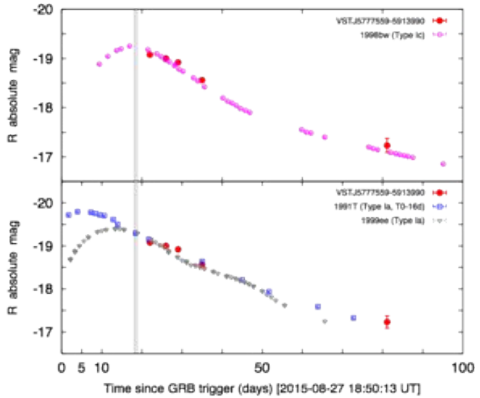
Brocato et al. 2018, MNRAS 474, 411
Abbott et al. ApJL 826, L13

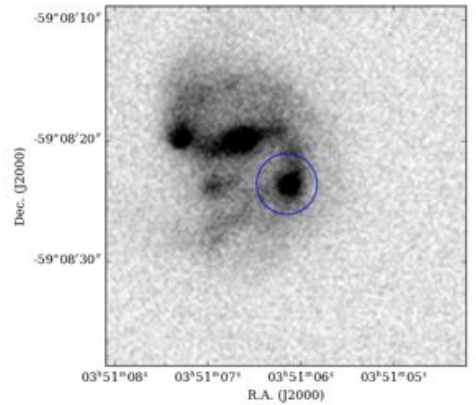
Follow-up results during the O1 & O2 LVC runs

- Several e.m. candidates have been characterized via spectroscopic and photometric observations
- Results have been published in a number of papers (e.g., Melandri et al. 2018, Grado et al. 2018, Pian et al. 2017)



SN Ibn discovered during follow-up of GW151226, (*Piranomonte et al. in prep.*)





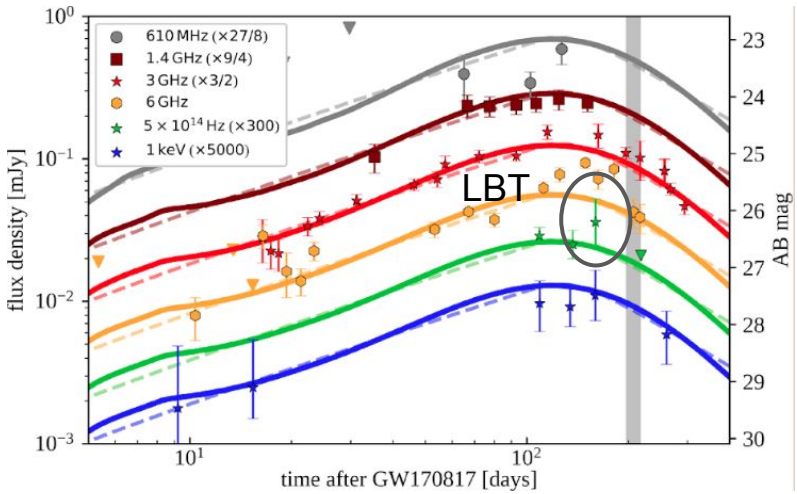
SN candidate in GW150914 survey (*Brocato et al. 2018*)

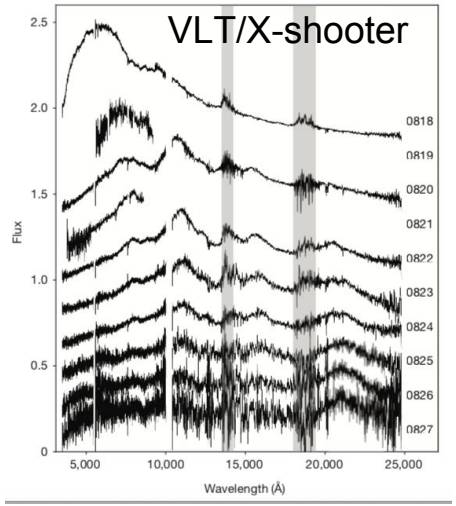
OAS observational contribution to GW 170817

GW170817 is associated with the merger of two NSs and is the only GW source with e.m. counterpart so far.

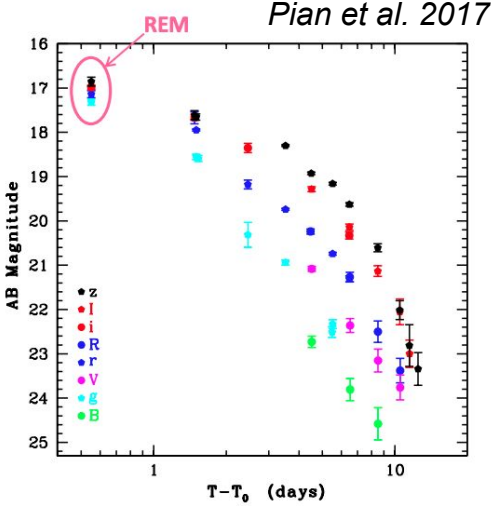
- **REM**: optical transient early observations at ~11 hrs
- **VLT-X/shooter**: kilonova KN 170817 follow-up and high quality spectra
- **LBT/LBC**: Unique ground-based detection of the afterglow of GRB 170817A

Ghirlanda et al. 2018





Pian et al. 2017

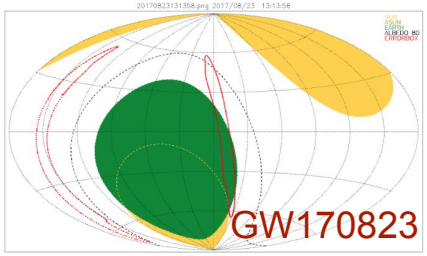


AGILE Real Time Analysis for GW Alerts during O1 and O2

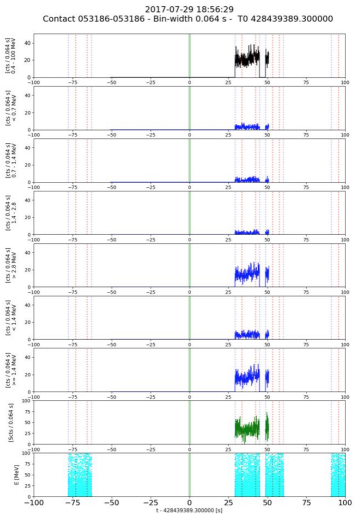
- AGILE system reacts to LIGO/VIRGO GW Alerts sending notifications to the AGILE Team and performing a real-time analysis of AGILE data to detect possible EM counterparts
- **The full AGILE pipeline has been developed and is running @OAS Bologna**
- **OAS Bologna has also the responsibility of the follow-up operations**
- Results also accessible through a mobile App (AGILEScience)

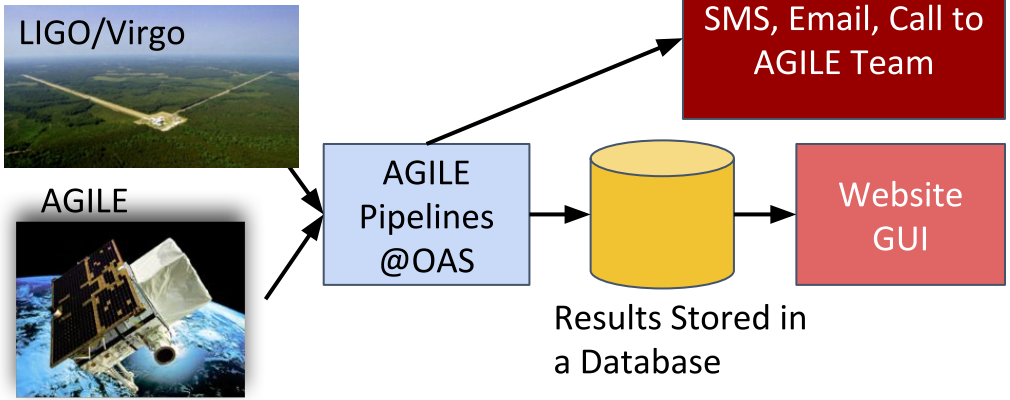
Instrument	LIGO
Triggerid_seqnum	298936_10
Event T0 (UTC)	2017-08-23T13:13:58.500
Event T0 (MJD)	57988.551371528
Event T0 (TT)	430578838.5

Visibility



MCAL PLOT ± 100s
GW170729





A. Bulgarelli, N. Parmiggiani, V. Fioretti, L. Baroncelli, M. Trifoglio, F. Gianotti

The case of GW170817

GW170817 → first GW source associated with an EM counterpart!

- +1.7 s → short GRB (Fermi+INTEGRAL)
- + 11 hrs → optical counterpart (Swope + many others and REM!)
- +1.5 days → optical spectrum (VLT/X-shooter, GMOS, Soar Magellan Telescope)
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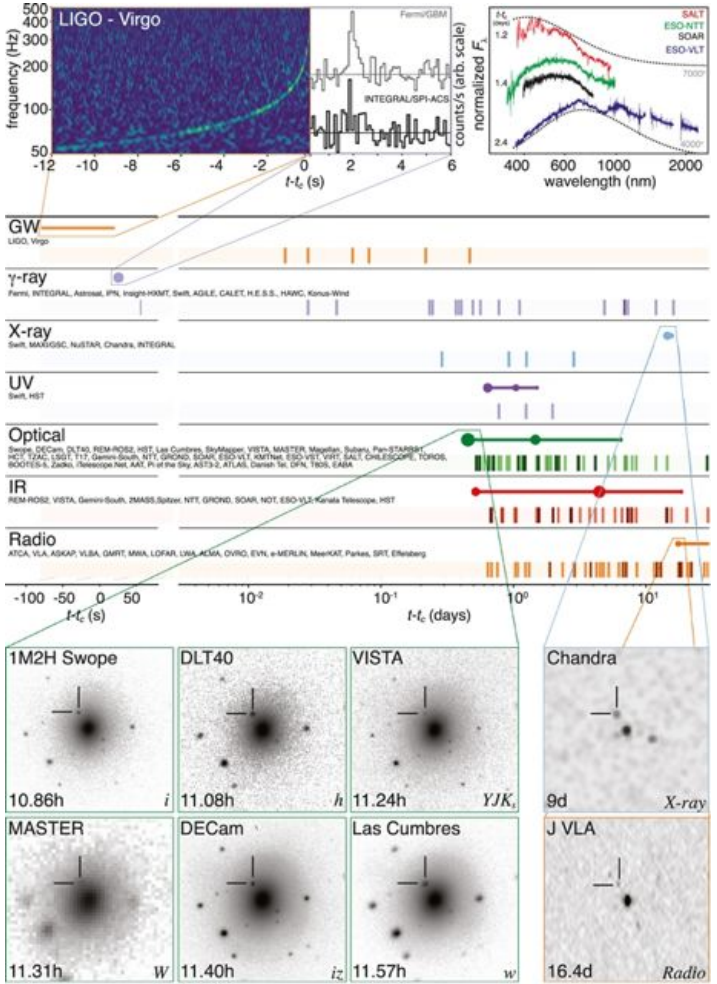


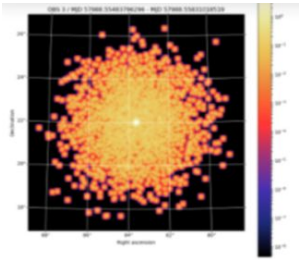
Multi-band campaign for GW170817 (Abbott et al. 2017 ApJL, 848, L12)

GW-related ongoing works @ OAS

- **Kilonova 170817:**
  - Could we had seen a kilonova like KN170817 in past short GRB afterglows?
  - Which chemical abundances of freshly synthesized heavy elements are shaping the spectra?
- **Host galaxy NGC4993:**
  - How peculiar is it (w/r to e.g. short GRB hosts)?
  - Optimization of galaxy target strategies

- **DB of nearby galaxy reference images** for small telescopes as Savelli, REM, ITM

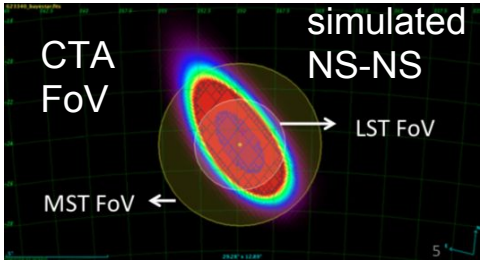
GW-related future works @ OAS



GRB simulated with CTA

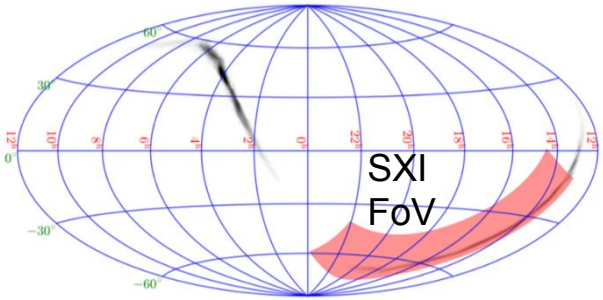
SoXS(+2021)@ESO-NTT followup+characterization of GW e.m. candidate counterparts + host galaxies
(https://www.eso.org/sci/facilities/develop/instruments/SoXS.html)

ELT(2025+) science case on characterization of GW e.m. candidate counterparts + host galaxies



Cherenkov Telescope Array (2025+):

- **Science Alert Generation System**
- **Instrumental response** for transient sources
- **Simulations** of scientific observations in different modes



THESEUS (2032+): sky localization of GW sources detected but very poorly localized with 3G interferometers

THESEUS GW source localization capabilities (Amati et al. 2018, Stratta et al. 2018)

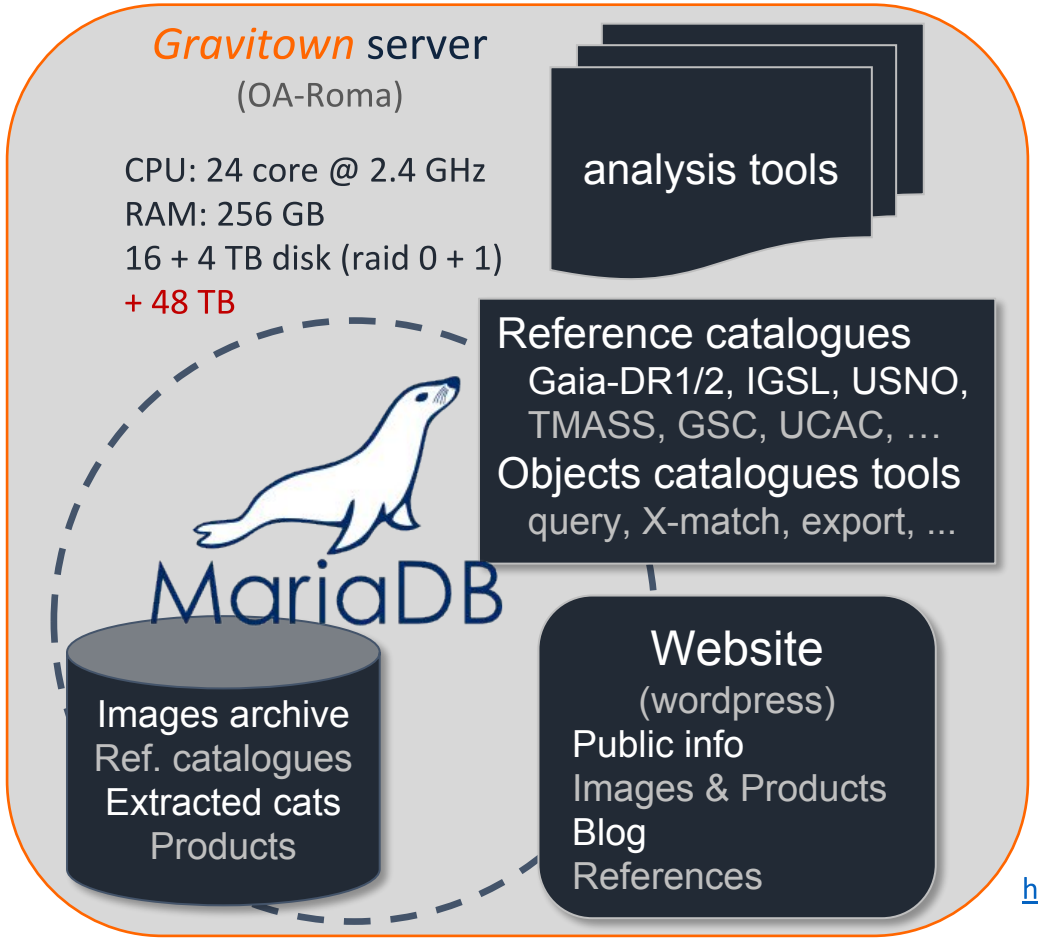
Infrastructure & tools

The OAS member team:

L. Nicastro

Infrastructure & tools

grawita.inaf.it



OAS resources

- **5** rack servers + backup + edu.inaf
  - ross, ross2, luna, cats, oastrodb1
- ~ 25 TB RAID1
- Use: storage + computing + Web server + DB server
- Projects: REM, QSFit, Gaia + AstroCats, X-ray + Optical/IR data analysis, BeppoSAX-GRBM, etc.
- S/W: public + Custom s/w
- Access: ssh, web, db

https://owncloud.iasfbo.inaf.it/owncloud/

https://grawita.inaf.it/VSTbrowse/GW170814/

Infrastructure & tools

engrave-eso.org

Data
(ERDA)
Computing
Turku (Finland)

Electronic Research Data Archive
University of Copenhagen

http://erda.dk/

Data analysis teams

- ESO Tools: ESOREX, IFUANAL, …
- IRAF (various flavours), DAOPHOT, SExtractor
- Custom s/w

Website
(Git + Jackall)
Public info

Wiki
(MediaWiki)
Private docs

Blog
(Slack)
Discussion

Papers
(overleaf)

DB & Web tools

- MCS: https://github.com/gcalderone/MCS
- DIF / SID: https://github.com/lnicastro/DIF – https://github.com/lnicastro/SID
- Spectra: http://qsfit.inaf.it/
- DB course: http://ross2.iasfbo.inaf.it/wp/imprs18/

- Catalogues: http://cats.iasfbo.inaf.it – http://cats.iasfbo.inaf.it/TOCatsweb/
- Images: http://ross.iasfbo.inaf.it/REMDBdev/ – https://grawita.inaf.it/VSTbrowse/GW170814/
- Spectra: http://qsfit.inaf.it/

Ingredients:

- DB server ⇒ MySQL/MariaDB
- Web server ⇒ Apache
- Language ⇒ HTML5, CSS3, PHP, JavaScript

Main JS packages: *AladinLite, JS9, amCharts*

QSFit

Calderone et al., MNRAS, 72, 4 (2017)

QSFit

About » Who we are » Composite spectra

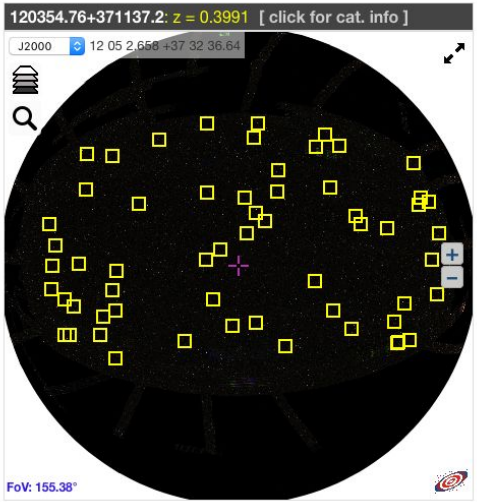
Catalogue of spectral properties of Type 1 AGN (observed with SDSS DR10)

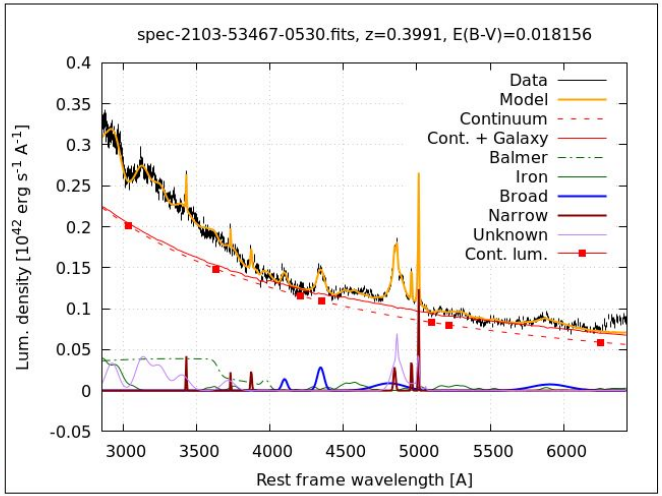
Version 1.2.4

http://qsfit.inaf.it/

Select by: ○ Plate-MJD-Fiber ○ SDSS name ◉ Redshift ○ Coords

☑ ☆ .4 +/- 0.001 Submit Reset





Toggle column <– **REDSHIFT** – **PLATE** – **MJD** – **FIBER** – **GALAXY__LUM** – **CONT1450__LUM** – **CONT3000__LUM** – **CONT5100__LUM** –>

Show 25 entries Search:

	SDSS_NAME	RA	DEC	REDSHIFT	PLATE	MJD	FIBER	GALAXY__LUM
🔍	003719.84+011114.6	9.332694	1.187396	0.4004	1494	52937	570	272.569
🔍	005205.56+003538.1	13.023187	0.593939	0.3993	1132	52903	510	1045.57

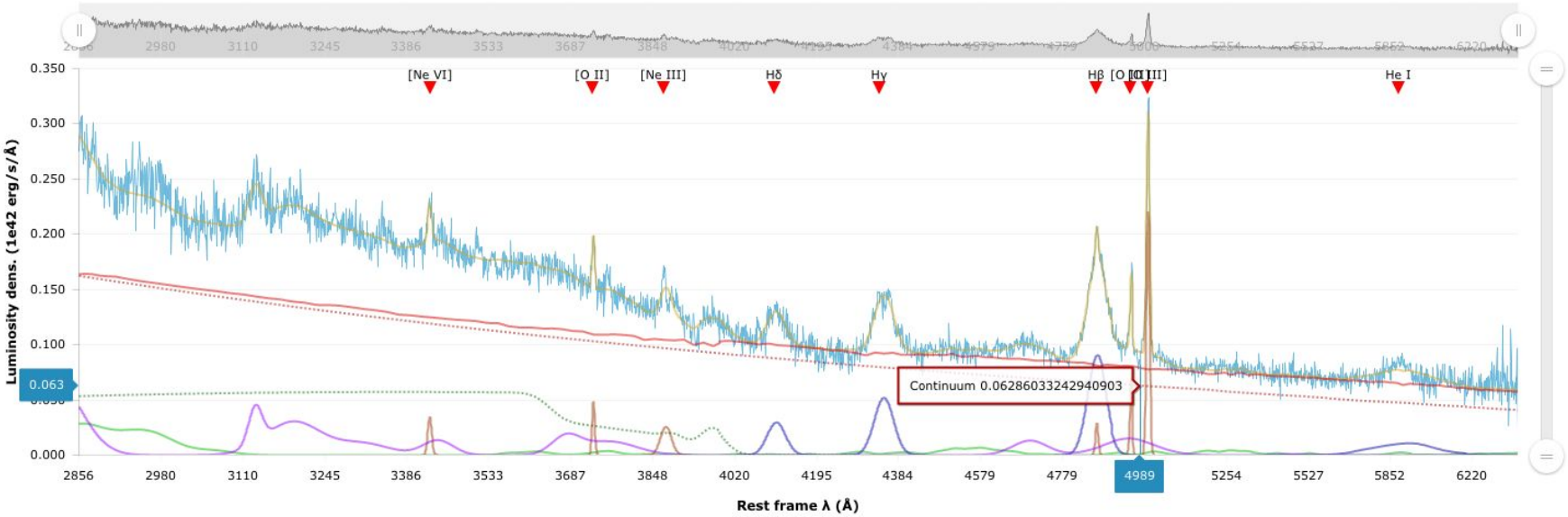
QSFit

Catalogue of spectral properties of Type 1 AGN (observed with SDSS DR10)

Version 1.2.4

Show: (•) Emitted luminosity ( ) De-reddened flux **File:** spec-0890-52583-0557 **X range (Å):** 2856 to 6432 Rebin fac.: 1 **Get data**

SDSS J075651.50+321007.6 [z = 0.3999]



Data	0.08269830793142319	Model	0.09296241402626038	Continuum	0.06286033242940903
Cont.+Galaxy	0.07877817749977112	Iron lines	0.0008982812869362533	Balmer comp.	
Broad lines		Narrow lines		Unknown lines	0.01328595448285341
Reference lines		Residuals (σ data−model, outliers marked) -2.1105			

Disable balloons | Hide lines | Show all components | Hide all components | click on legend items to show / hide components – plot made using amCharts

QSFit

Catalogue of spectral properties of Type 1 AGN (selected from SDSS DR10)

Version 2.0.0

Drag & drop your spectral file here... or Browse ...

- **spettro-loiano_ncg4051_e-17.txt** (type: text/plain) - 36814 bytes

Redshift: 0.00234 E(B-V): 0.011 **Process this file >**

Customize analysis

NO	Use a separate component for the [OIII]5007 blue wing
YES	Use the Balmer continuum component
YES	Use a Lorentzian profile for the emission lines (instead of a Gaussian one)
7590, 7618, 6859	Comma separated list of rest frame wavelengths of the absorption lines
free	Fixed continuum slope (leave blank for free parameter)
1000	Minimum line resolution (in km/s) to fit the line
SWIRE_ELL5	Host galaxy template

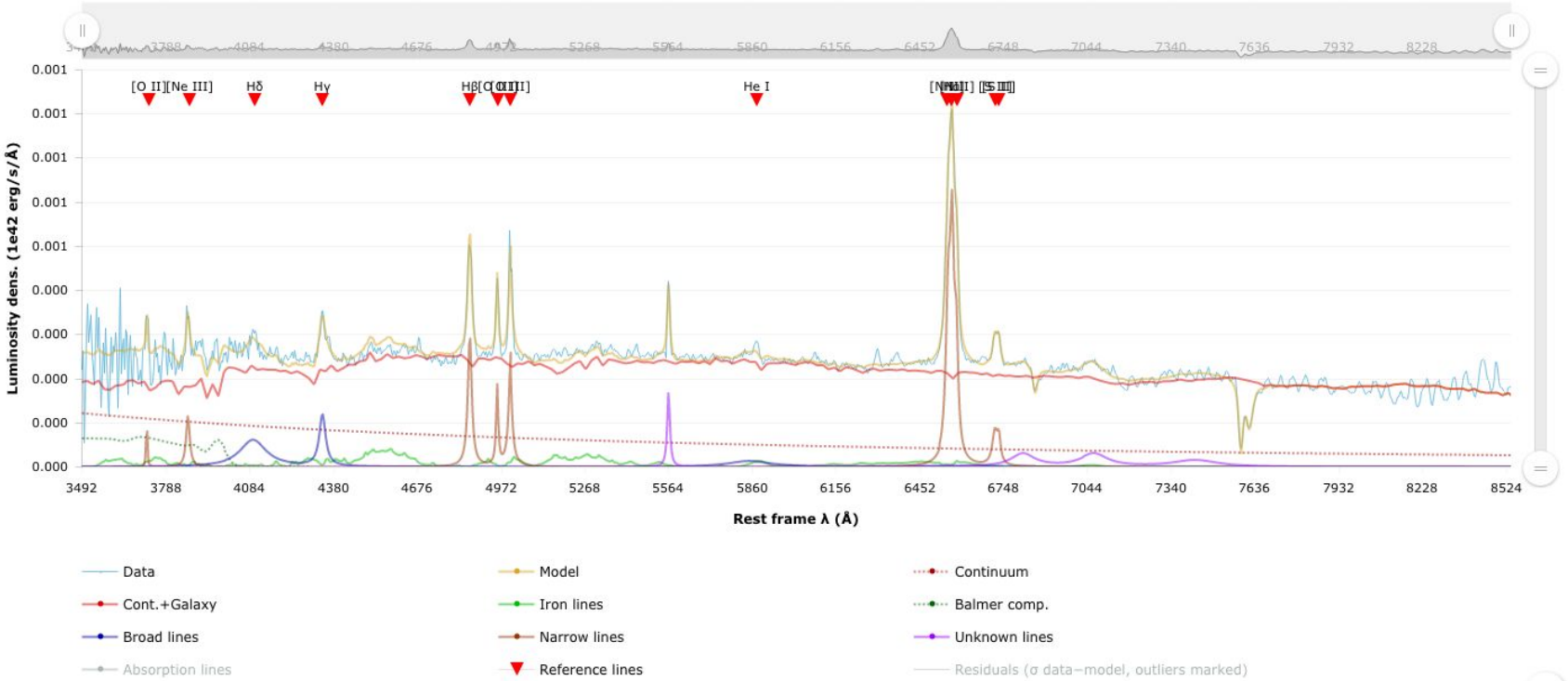
QSFit

Catalogue of spectral properties of Type 1 AGN (selected from SDSS DR10)

Version 2.0.0

Show: (•) Emitted luminosity ( ) De-reddened flux File: spettro-loiano_ncg4051_e- X range (Å): 3488 to 8544 Rebin fac.: 1 Get data

Uploaded by user luciano.nicastro@inaf.it (ID 0) on MJD 58466.6960 (2018-12-14 16:42:17 UT) [z = 0.00234, E(B-V) = 0.011]



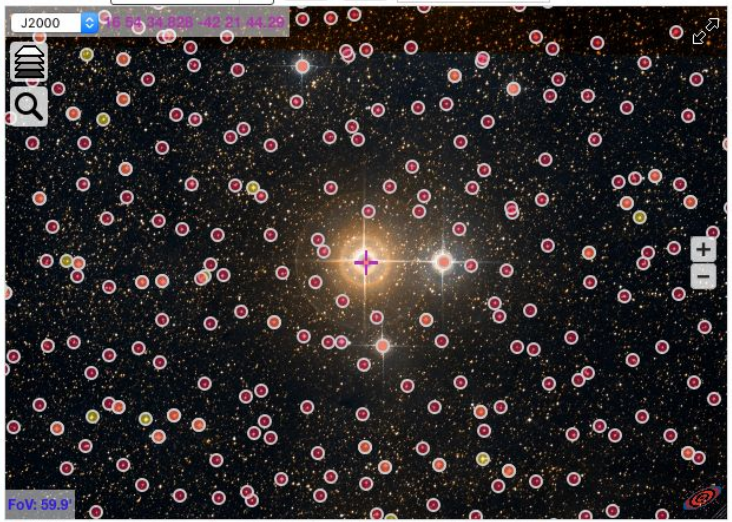
☐ Y log ☐ Disable balloons ☐ Hide lines Show all components Hide all components click on legend items to show / hide components – plot made using amCharts

http://cats.iasfbo.inaf.it/TOCatsweb/

TOCats - HiPS cats browser - Version 1.0 - Developed using DIF / SID.

Remove all | Hide all | Show all | Go to start | Enlarge | Shrink | Max objects: 10000 | **gaiadr2_mini_hips10** – HPX order: 10 – c.: 253.645,-42.362 – r.: 32.95'

Catalogue: Gaia DR2 | Draw | Clear | View single cat



DSS color | SDSS9 color | 2MASS | AllWISE | GLIMPSE 360 | Pan-STARRS DR1 | Spitzer

Objects density map:

Gaia DR2 | Gaia DR1 | PanSTARRS1 | 2MASS | GSC 2.3 | USNO-B1.0 | UCAC4 | SDSS DR9

Overlay Simbad objects 3582 objects

Toggle column [Mag – Nobjs – HPXid] Draw objs when entries shown

Show 10 entries Search:

RA	Dec	Mag	Nobjs	HPXid
253.645118	-42.362302	3.00723	454	10850256
253.498862	-42.362044	4.48535	491	10850247
253.612254	-42.478925	5.63661	371	10850244
253.495218	-41.994337	6.09274	472	10853003
253.76387	-42.09084	6.12814	524	10852910
253.582076	-41.819879	6.54054	657	10853017
253.369236	-42.121411	7.10097	369	10850289
253.481694	-41.880981	7.50988	625	10853006
253.555103	-41.842374	7.80896	745	10853016
253.46523	-41.842429	8.32829	570	10853029
RA	Dec	Mag	Nobjs	HPXid

Showing 1 to 10 of 291 entries Previous 1 2 3 4 5 … 30 Next

There are **126,147** objects in the field. Got **291** brightest.

VO Cone Search link (e.g. for use in TOPCAT - URL **http://cats.iasfbo.inaf.it/gaiadr2_mini_hips10/**) - size in degrees - add `&json=1` to get a JSON structure:

http://cats.iasfbo.inaf.it/gaiadr2_mini_hips10/size=0.5492&ra=253.645&dec=-42.362

https://grawita.inaf.it/VSTbrowse/GW170814/

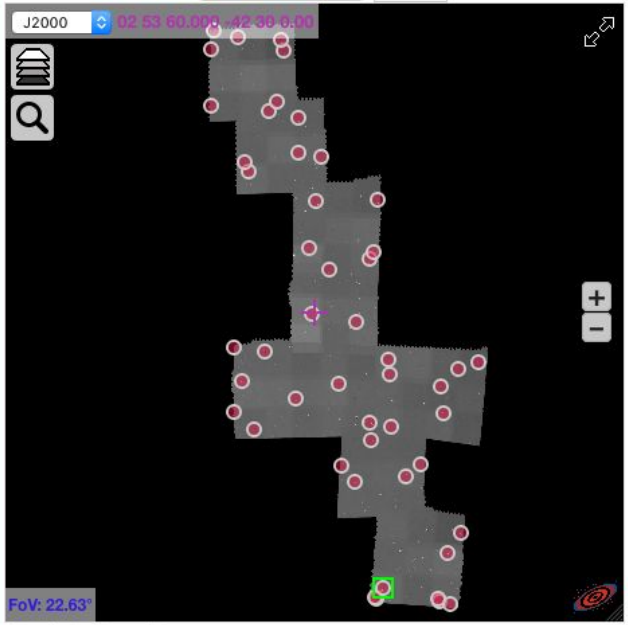
GraWITA

VST variable sky browser - Version 0.2a - Developed using DIF

Catalog: VST_r_20170814_mrg - 233957 objs | Filter cats: Filter list string | Filter | HPX order: 5 – c.: 43.5,-42.5 – r.: 16.46°

WHERE ex. mag_auto < 19 | Max objs: 1000 | Overlay | Clear | Hide all | Show all | Go to start | Enlarge | Shrink | Remove all

VST20170814 | Get FITS of FoV | 300 pix



You clicked in void

Overlay Reference Catalogue | Overlay Simbad objects

Gaia DR2 | Show | Clear

Toggle column [eMag – Area – a – b – FWHM – Ellip – Flags] Draw objs when entries shown

Show 10 entries

N.	RA	Dec	Mag	eMag	Area	a	b	FWHM	Ellip	Flags
1563	39.35211	-52.54124	6.38	0	110091	275.223	15.208	388.4	0.945	52
734	40.52736	-38.38173	6.511	0	66563	145.239	17.704	304.43	0.878	22
716	43.39342	-38.43452	6.675	0	66264	119.567	14.758	252.19	0.877	22
1284	40.53501	-46.52223	6.741	0	70023	127.727	14.518	258.53	0.886	22
2387	45.98008	-43.89757	7.03	0	55073	99.404	12.851	214.58	0.871	22
948	44.20168	-35.37821	7.039	0	56571	104.522	13.551	225.94	0.87	20
2321	35.72726	-51.08877	7.085	0	41204	77.613	11.195	176.97	0.856	23
1071	40.83443	-40.52745	7.216	0	49020	57.19	13.655	167.77	0.761	20
1121	44.90945	-32.50722	7.237	0	54263	69.627	14.409	190.16	0.793	20
3	39.78182	-52.93406	7.317	0	44049	71.892	11.778	174.7	0.836	20

Showing 1 to 10 of 49 entries | Previous | 1 | 2 | 3 | 4 | 5 | Next

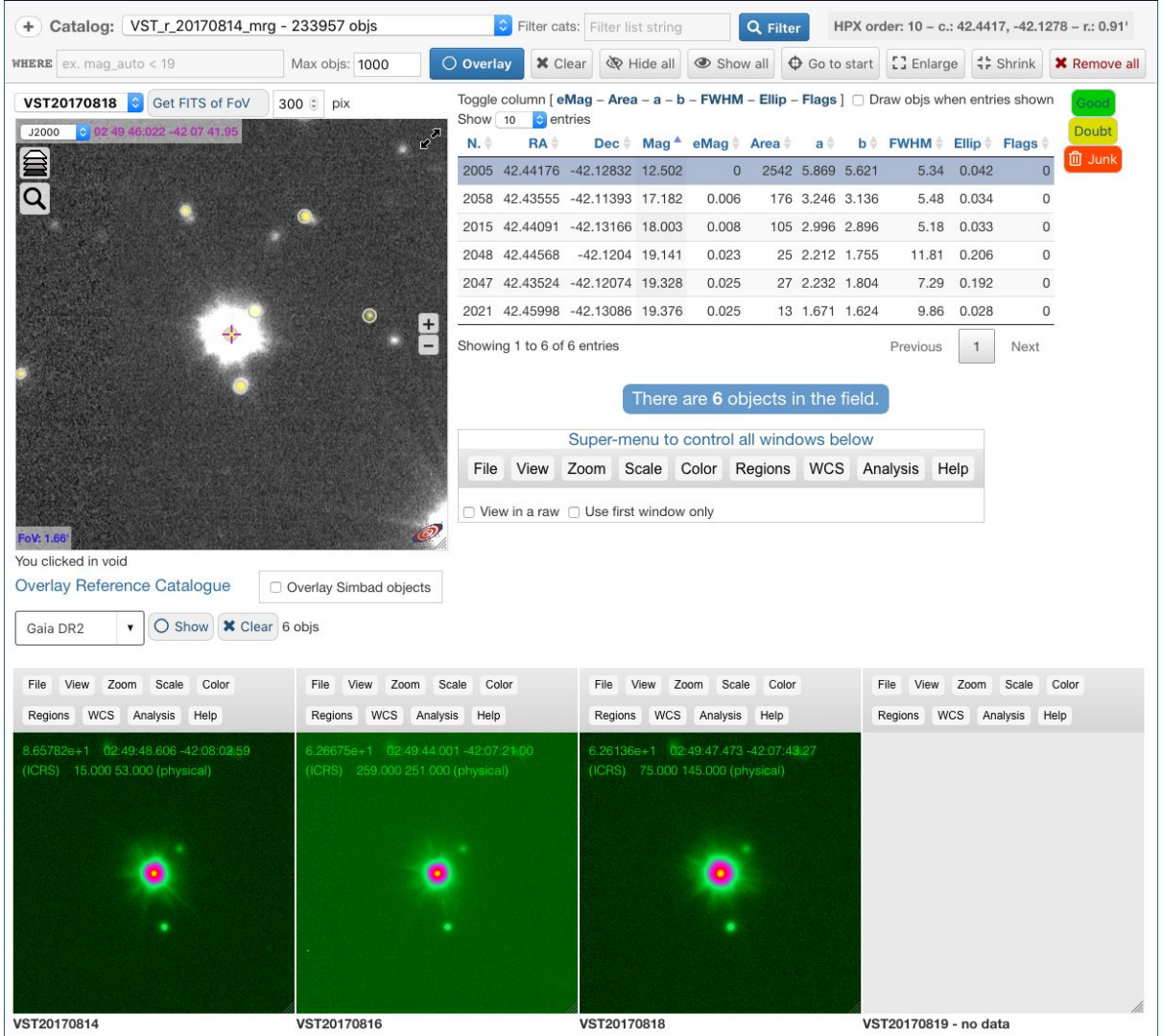
Good | Doubt | Junk

There are **49** objects in the field.

Super-menu to control all windows below

File | View | Zoom | Scale | Color | Regions | WCS | Analysis | Help

View in a raw | Use first window only



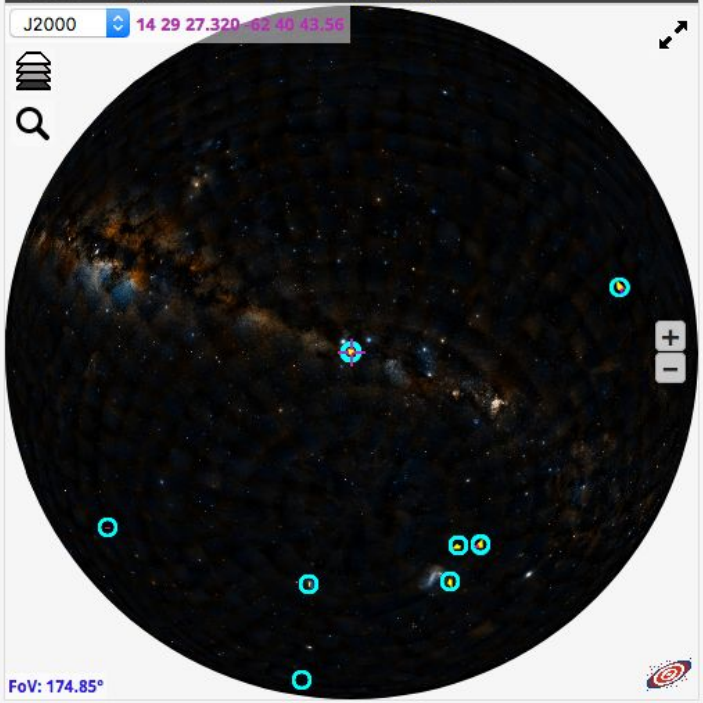
https://grawita.inaf.it/VSTbrowse/GW170814/

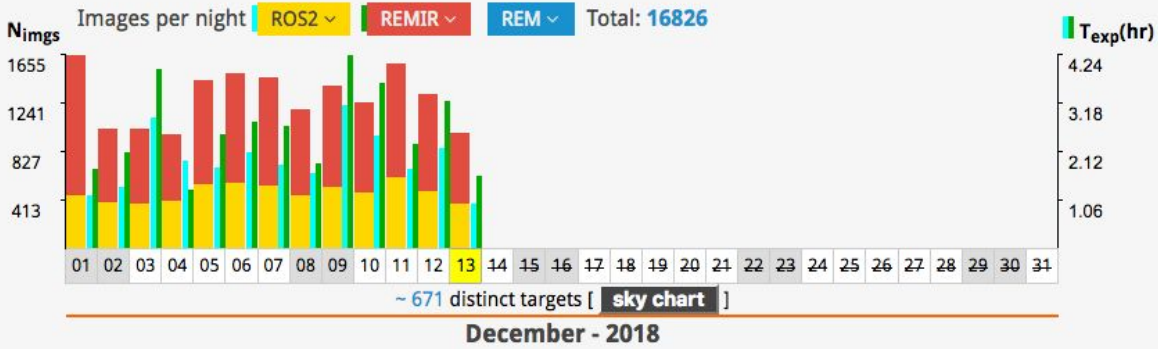
http://ross.iasfbo.inaf.it/REMDBdev/

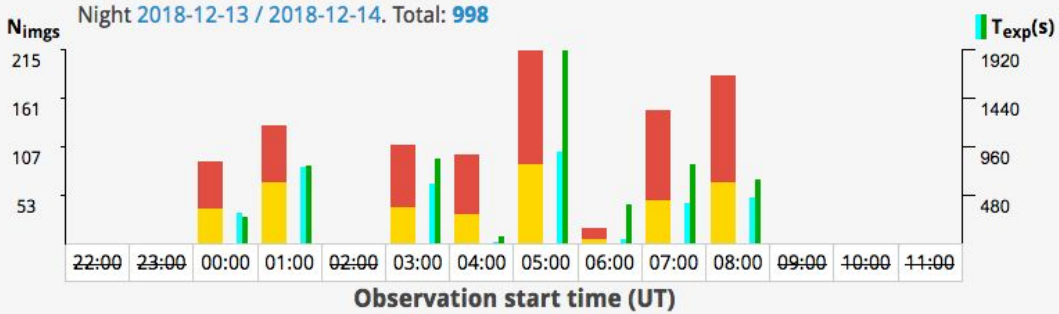
Select ALL WHERE ImgNight ≥ 2018-12-13 ≤ 2018-12-13 More options Submit REM

« 2017 | August | September | October | November | December ?

238 pointings - Cursor on pointing for Object info

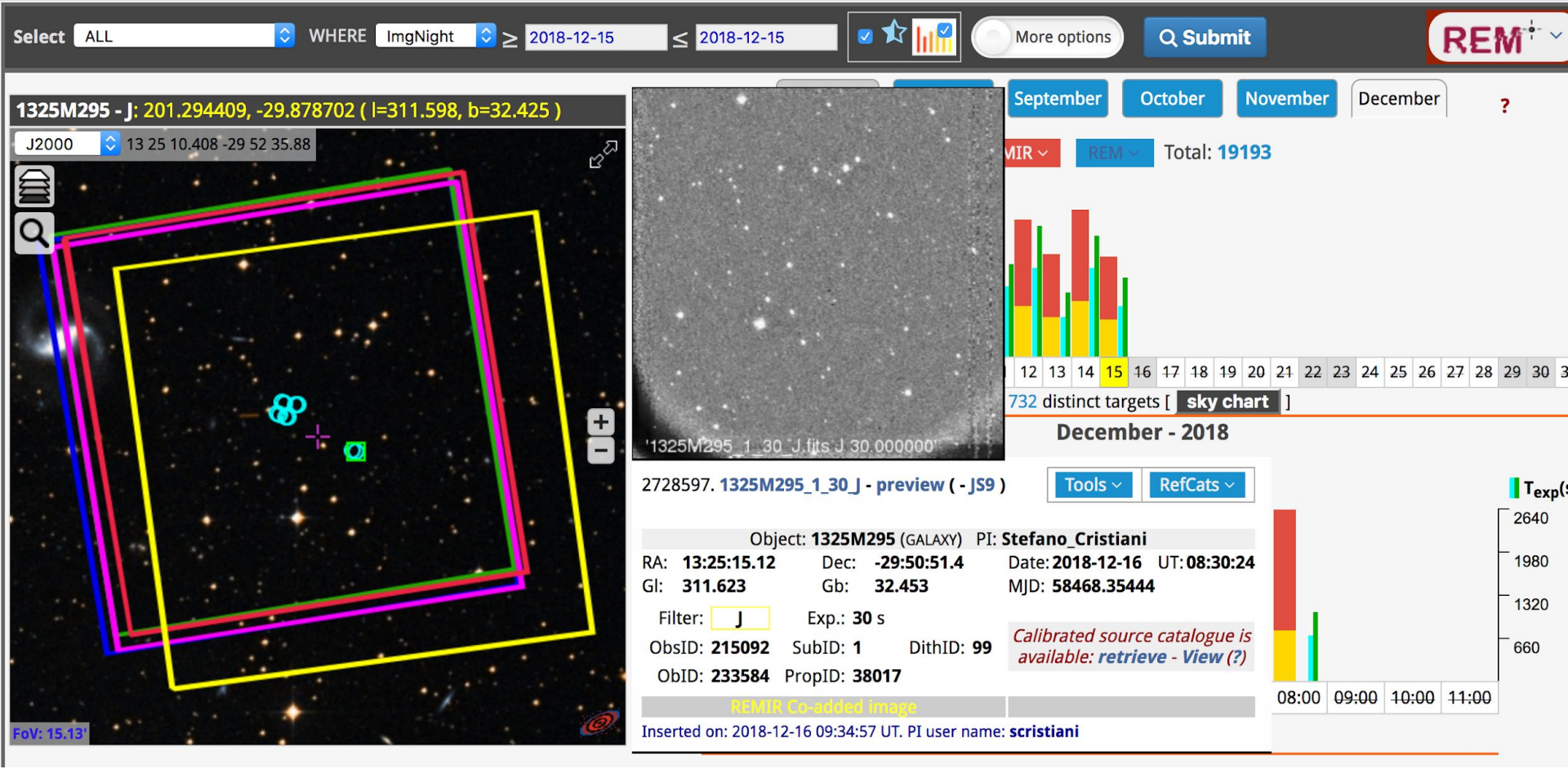






?	Filename	Object	RA	Dec	Date	Time	PI-CoI	Texp	Filter	ObsType	uniqueID	MJD
⊕	ProximaCenb_15_2_K_5	**ProximaCenb**	14:29:42.96	-62:40:45.8	2018-12-14	08:40:40	**Red_dots**	**2**	**K**	GENSTAR	2150180105	58466.36157
⊕	ProximaCenb_15_2_K_4	**ProximaCenb**	14:29:42.96	-62:40:45.8	2018-12-14	08:40:29	**Red_dots**	**2**	**K**	GENSTAR	2150180104	58466.36145
⊕	ProximaCenb_15_2_K	**ProximaCenb**	14:29:42.96	-62:40:45.8	2018-12-14	08:40:19	**Red_dots**	**2**	**K**	GENSTAR	2150180199	58466.36133

http://ross.iasfbo.inaf.it/REMDBdev/



Perspectives

Fast transients work continues as usual, but...

- Personnel: no “full time” appointed ⇒ investment/support from OAS
  - About 15 people involved ⇒ relevant resources (internal + external) are required
- HW / SW packages / algorithms - in particular ML
  - Expertise scarce at the moment - people involvement always welcome
- New requirements / challenges in view of future facilities like LSST, CTA, ET, THESEUS, SKA, etc.