MassBus

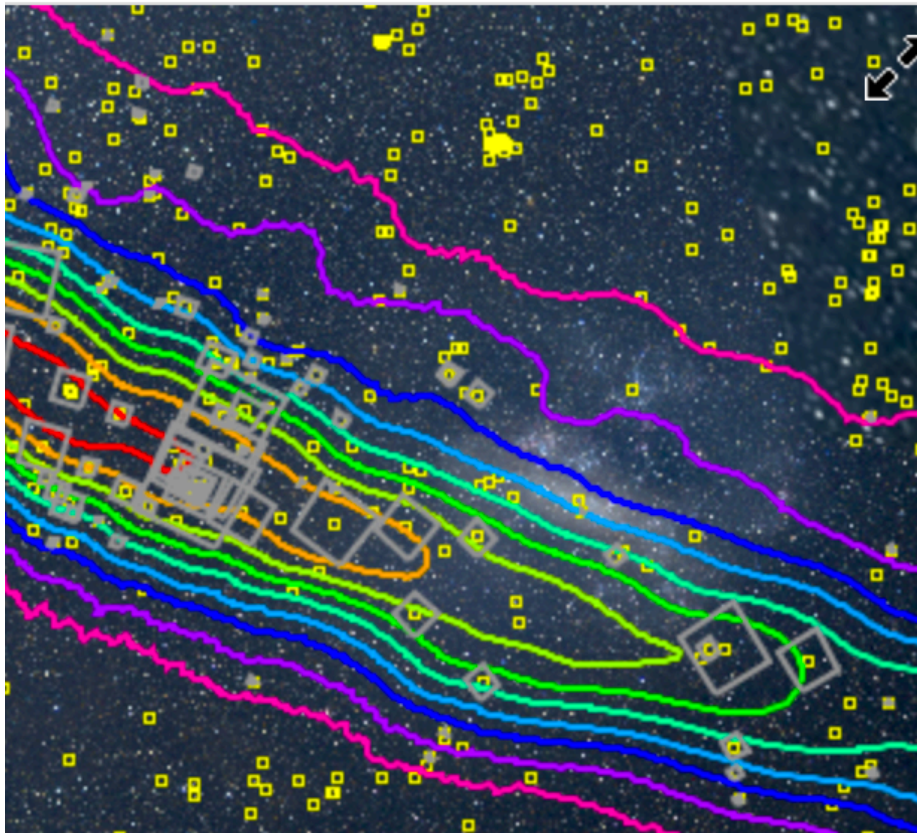
virtual observatory for gravitational-wave follow-up

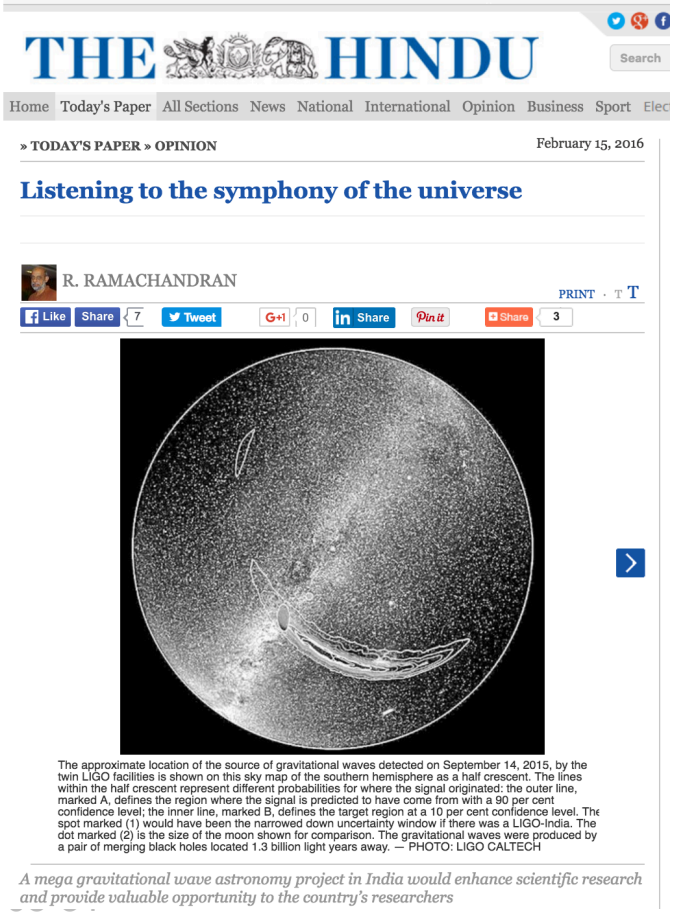
Roy Williams

LIGO Laboratory - Caltech

Thank-you!

Thomas Boch and team for making AladinLite





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February 15, 2016

Listening to the symphony of the universe

R. RAMACHANDRAN

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The approximate location of the source of gravitational waves detected on September 14, 2015, by the twin LIGO facilities is shown on this sky map of the southern hemisphere as a half crescent. The lines within the half crescent represent different probabilities for where the signal originated: the outer line, marked A, defines the region where the signal is predicted to have come from with a 90 per cent confidence level; the inner line, marked B, defines the target region at a 10 per cent confidence level. The spot marked (1) would have been the narrowed down uncertainty window if there was a LIGO-India. The dot marked (2) is the size of the moon shown for comparison. The gravitational waves were produced by a pair of merging black holes located 1.3 billion light years away. — PHOTO: LIGO CALTECH

A mega gravitational wave astronomy project in India would enhance scientific research and provide valuable opportunity to the country's researchers

- Skymap Viewer
- The MassBus
- Sharing footprints

Skymap Viewer

A sky atlas for understanding LIGO-Virgo skymaps. Help here, or watch a video about Skymap Viewer. Plenty simulated skymaps here. If you do not see the big dark sky map, look below and widen your browser. Zoom with the + and - at the right of the sky.

LIGO-Virgo Skymaps

This skymap is from First2Years simulation
F2Y:27544.
Detected by H1,L1
50% area = 61.68 sq deg
90% area = 245.4 sq deg

Show Weighted Galaxies (or table).

Time and Place

Universal time
2010-09-29T10:38:31 Now
E Longitude east lc Latitude latitud
Show Sky
Sun = and = Moon

Catalog Sources

2MASXJ08222592+0409474
BMAG=-17.16, Dist=61.81
Simbad NED

Zoomable Multiwavelength Sky

Zoom in on the sky with the mouse or the +/- icons

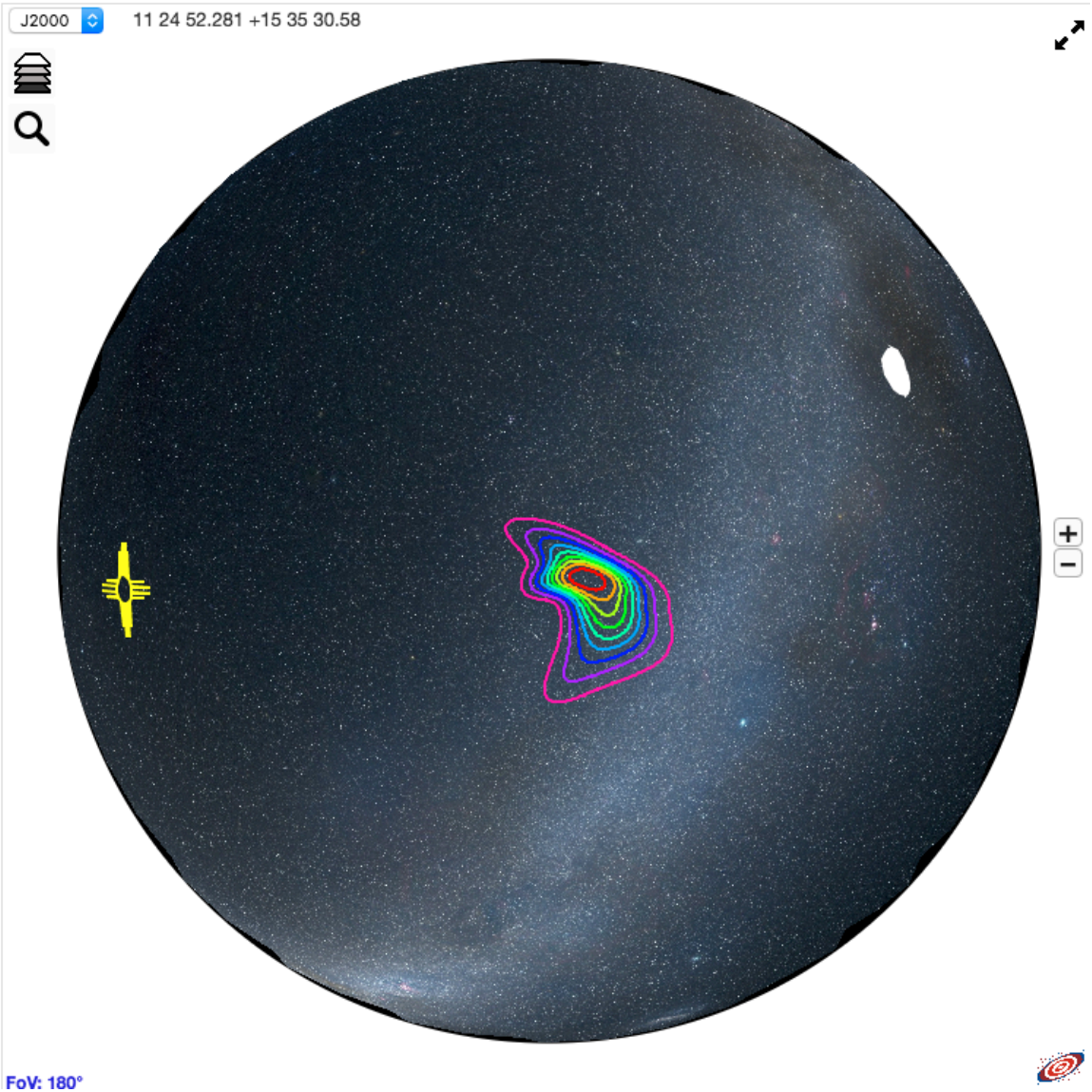
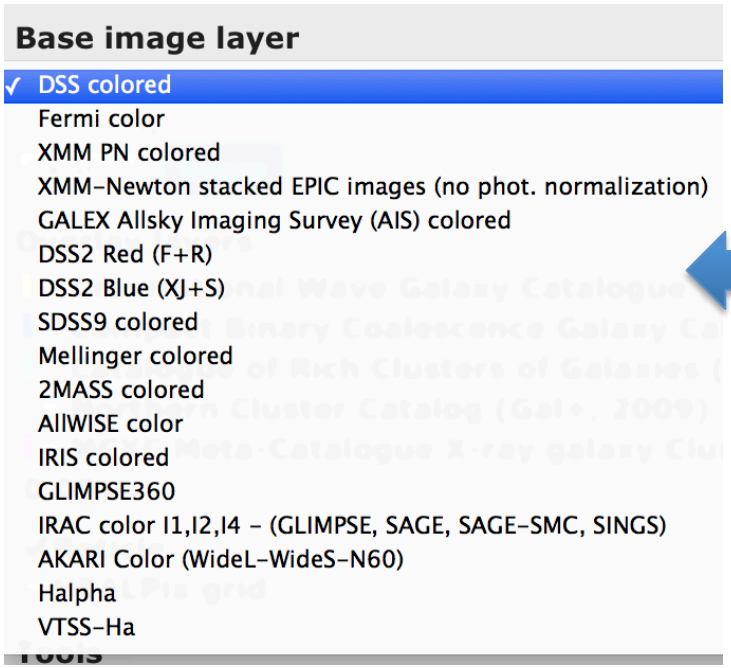
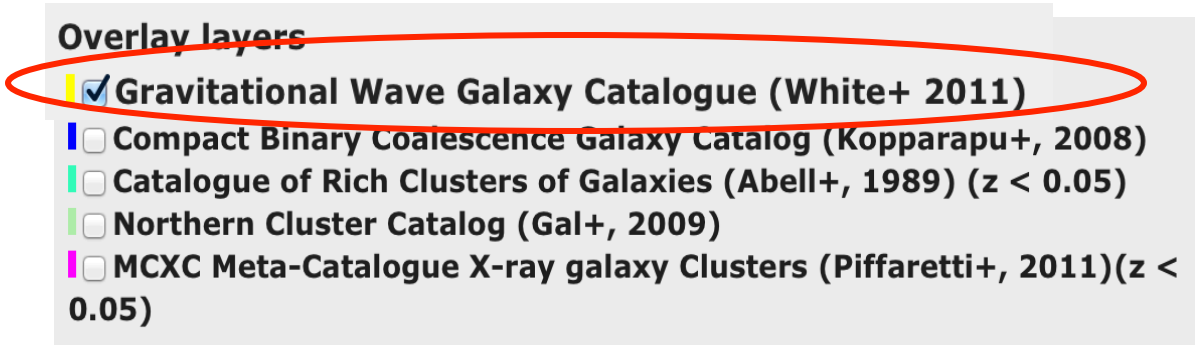


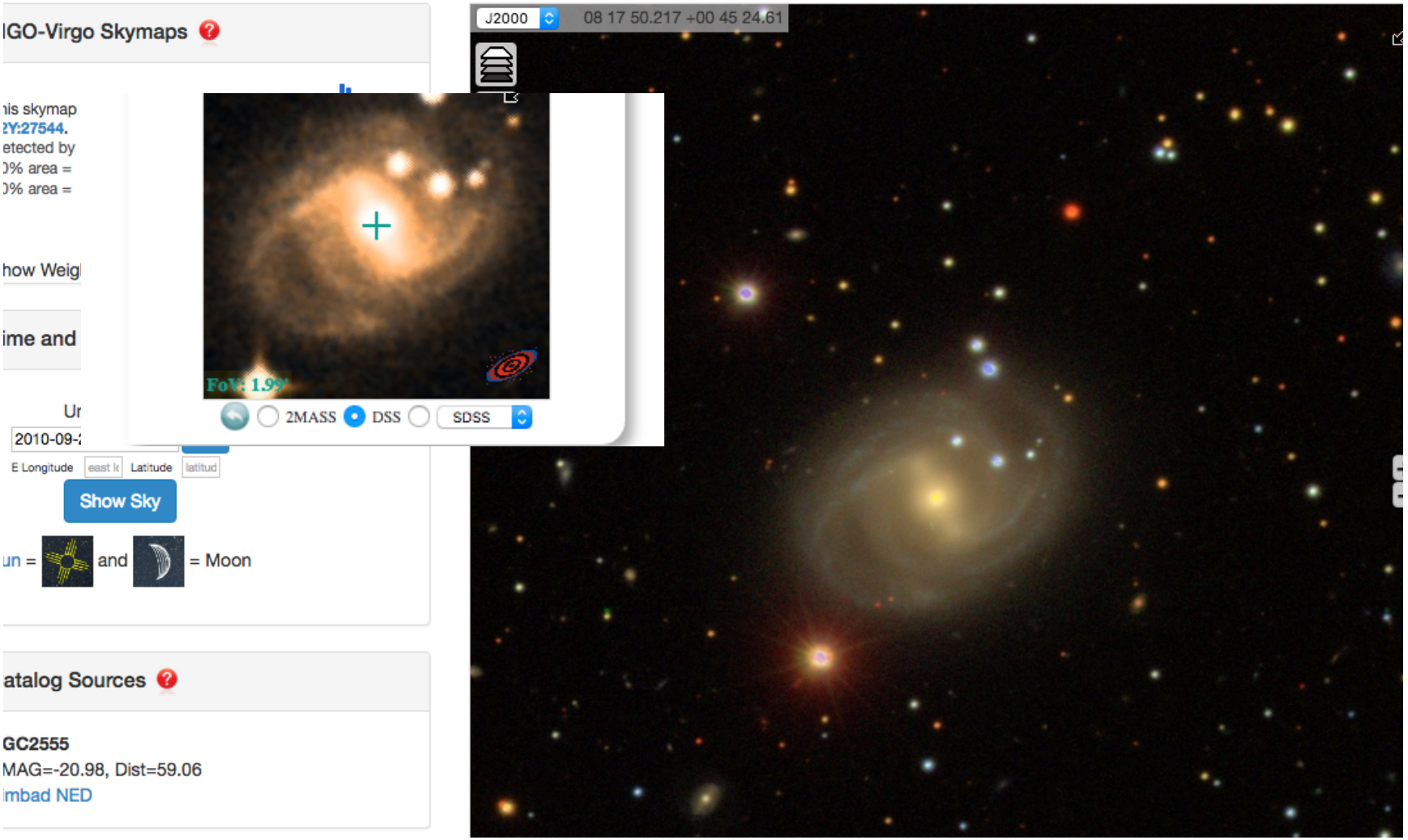
Image and Catalog



Click on the Layers icon



Simbad/DSS and Aladin/SDSS9



Observation Priority

LIGO-Virgo Skymaps

This skymap is from First2Years simulation
F2Y:27544.
Detected by H1,L1
50% area = 61.68 sq deg
90% area = 245.4 sq deg

South ..... North

Show Weighted Galaxies (or table).

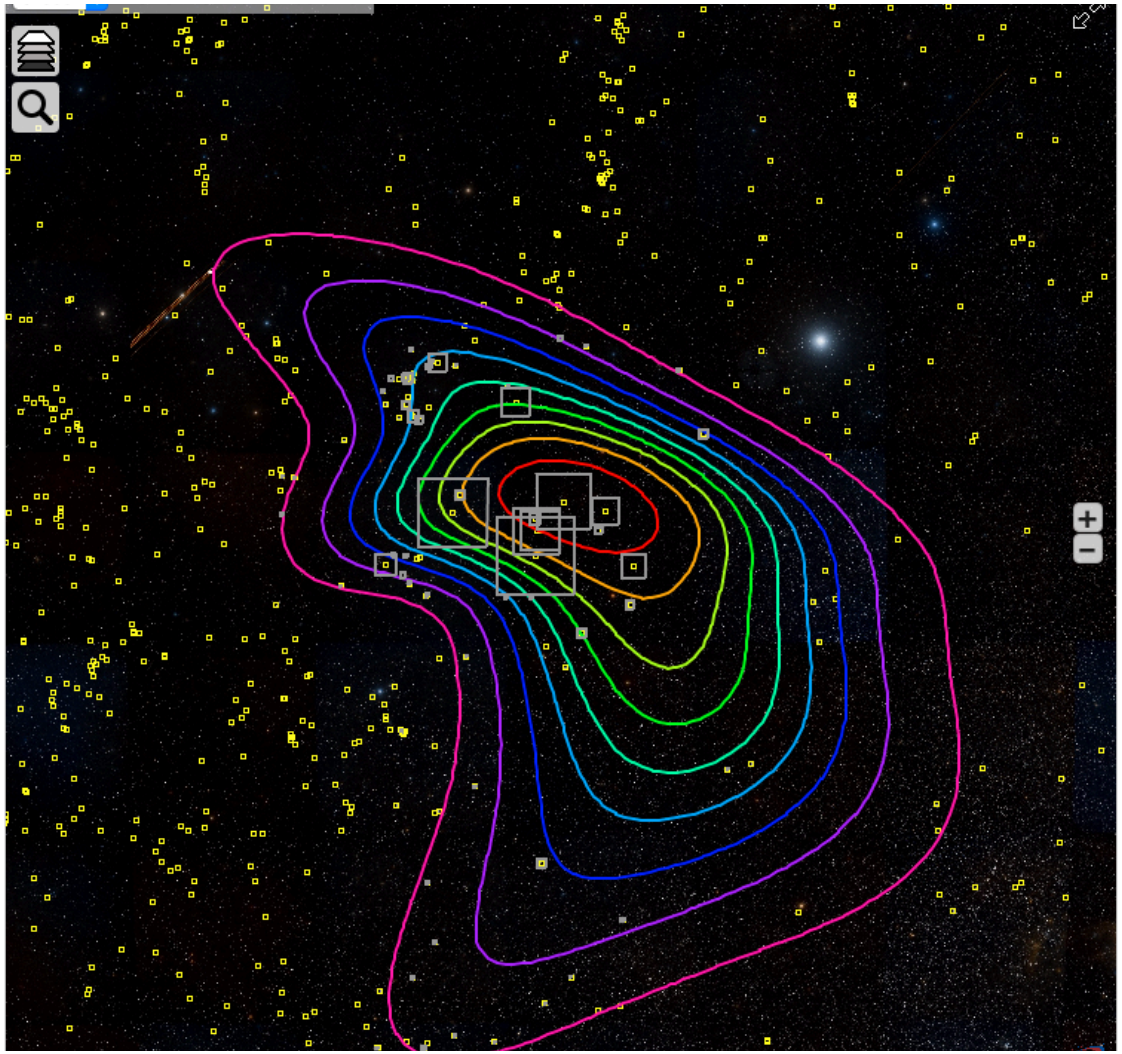
Time and Place

Universal time
2010-09-29T10:38:31 Now
E Longitude east lc Latitude latitud
Show Sky
Sun = and = Moon

Catalog Sources

J0823.1+0421
ZwCl1665 ZwCl1665 z=0.0293
Simbad NED

Zoomable Multiwavelength Sky

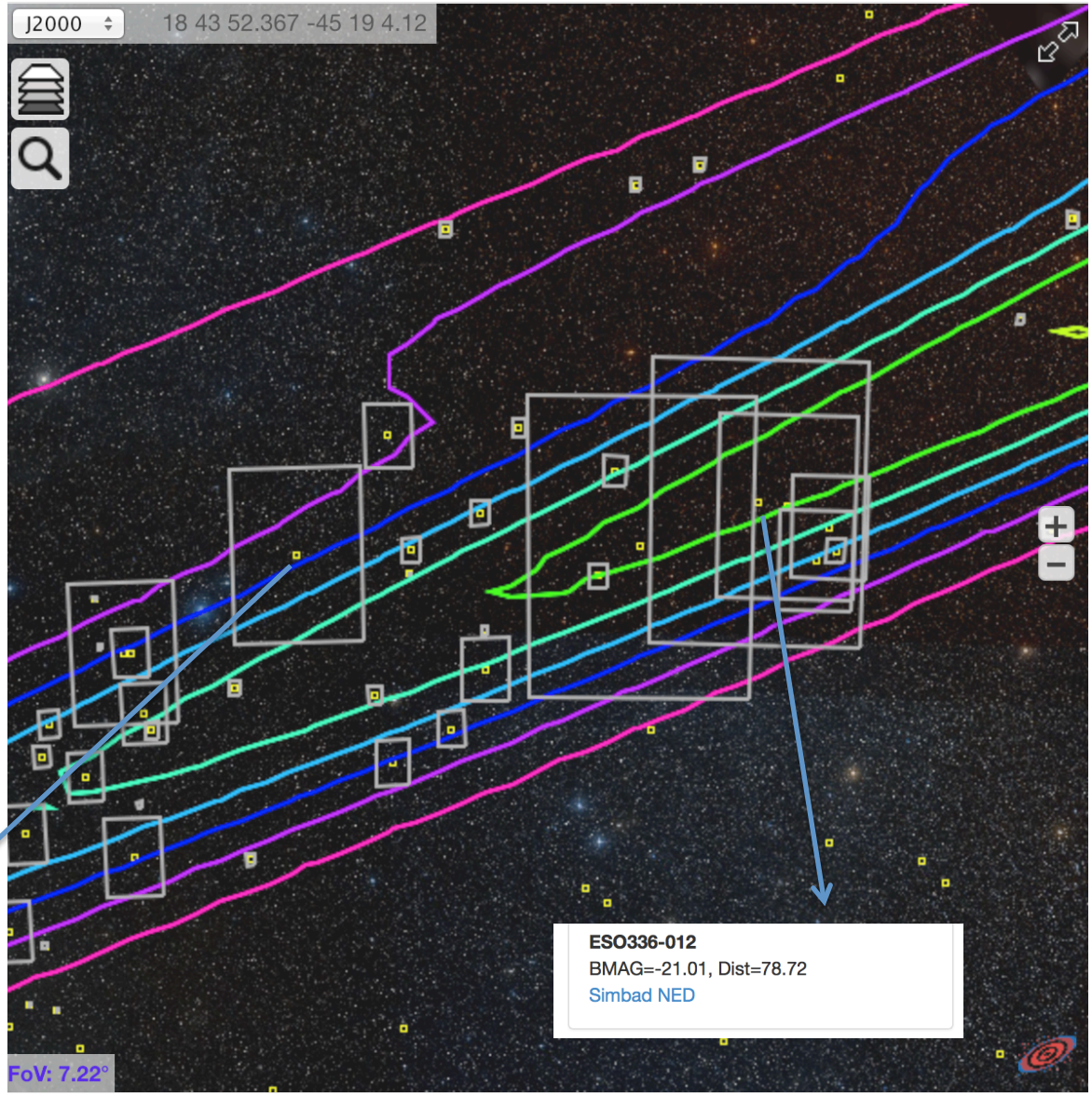


Show Weighted Galaxies

size of square is ~galaxy mass * skymap

From one catalog:
GWGC
vizier VII/267

click the center to get Simbad and NED



Catalog Sources

ESO336-016
BMAG=-21.11, Dist=70.26
Simbad NED

Instead of using 1 special catalog --

-- use many catalogs!

MassBus

- EM followup of GW event
  - Suppose we ***select sources from catalogs***
  - Compute ***observation priority***
  - Start with the highest priority
- Premise:

  Observation priority for a source depends on:

  mass of the source

  multiplied by

  probability the GW came from its position

MassBus

The MCXC: a Meta-Catalogue of X-ray detected Clusters of galaxies

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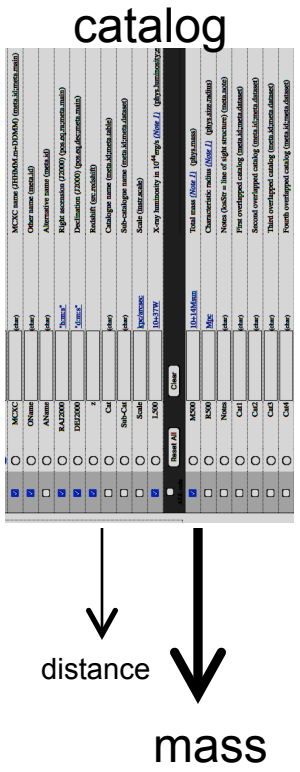
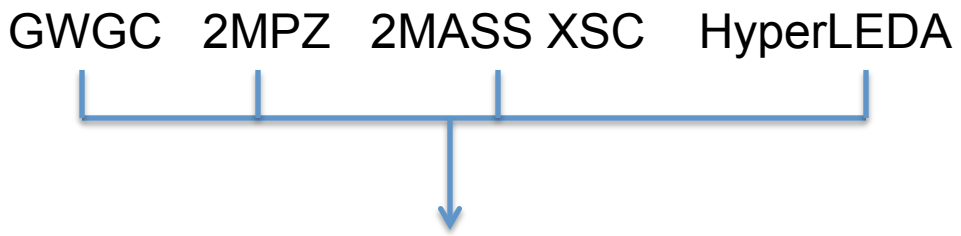
[3] DSM/Irfu/SPP, CEA/Saclay, F-91191 Gif-sur-Yvette Cedex, France

☑	○	MCXC		(char)	MCXC name (JHHMM.m+DDMM) (meta.id;meta.main)
☑	○	OName		(char)	Other name (meta.id)
☐	○	AName		(char)	Alternative name (meta.id)
☑	○	RAJ2000		"h:m:s"	Right ascension (J2000) (pos.eq.ra;meta.main)
☑	○	DEJ2000		"d:m:s"	Declination (J2000) (pos.eq.dec;meta.main)
☑	○	z			Redshift (src.redshift)
☐	○	Cat		(char)	Catalogue name (meta.id;meta.table)
☐	○	Sub-Cat		(char)	Sub-catalogue name (meta.id;meta.dataset)
☐	○	Scale		kpc/arcsec	Scale (instr.scale)
☑	○	L500		10+37W	X-ray luminosity in 10^{44}erg/s *(Note 1)* (phys.luminosity;e
☐ ALL cols	Reset All		Clear		
☑	○	M500		10+14Msun	Total mass *(Note 1)* (phys.mass)
☐	○	R500		Mpc	Characteristic radius *(Note 1)* (phys.size.radius)
☐	○	Notes		(char)	Notes (losStr = line of sight structure) (meta.note)
☐	○	Cat1		(char)	First overlapped catalog (meta.id;meta.dataset)
☐	○	Cat2		(char)	Second overlapped catalog (meta.id;meta.dataset)
☐	○	Cat3		(char)	Third overlapped catalog (meta.id;meta.dataset)
☐	○	Cat4		(char)	Fourth overlapped catalog (meta.id;meta.dataset)

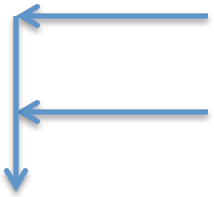


MassBus

- GLADE catalog



Column no.	Name	Description
1	RA	Right ascention [deg]
2	dec	Declination [deg]
3	Dist	Distance [Mpc] See column 47 whether its val
4	Bmag	Apparent B magnitude [mag] See column 47 whether its val

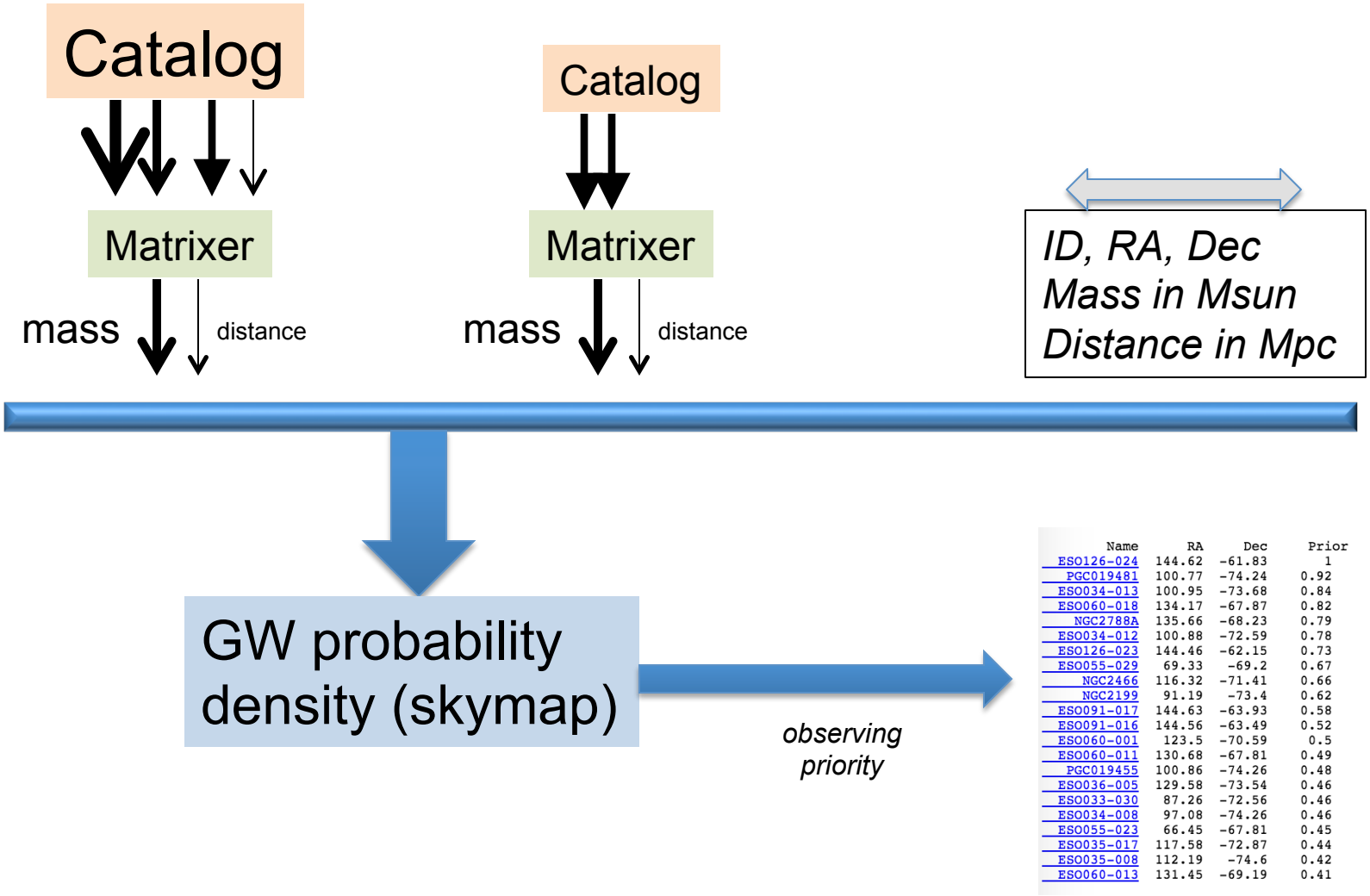


absMag = Bmag + 25 - 5 log (Dist)

$M/M_{sun} = L/L_{sun} = 10 \wedge [0.4*(4.77 - absMag)]$

http://aquarius.elte.hu/glade/Download.html

MassBus



Name	RA	Dec	Prior
ESO126-024	144.62	-61.83	1
PGC019481	100.77	-74.24	0.92
ESO034-013	100.95	-73.68	0.84
ESO060-018	134.17	-67.87	0.82
NGC2788A	135.66	-68.23	0.79
ESO034-012	100.88	-72.59	0.78
ESO126-023	144.46	-62.15	0.73
ESO055-029	69.33	-69.2	0.67
NGC2466	116.32	-71.41	0.66
NGC2199	91.19	-73.4	0.62
ESO091-017	144.63	-63.93	0.58
ESO091-016	144.56	-63.49	0.52
ESO060-001	123.5	-70.59	0.5
ESO060-011	130.68	-67.81	0.49
PGC019455	100.86	-74.26	0.48
ESO036-005	129.58	-73.54	0.46
ESO033-030	87.26	-72.56	0.46
ESO034-008	97.08	-74.26	0.46
ESO055-023	66.45	-67.81	0.45
ESO035-017	117.58	-72.87	0.44
ESO035-008	112.19	-74.6	0.42
ESO060-013	131.45	-69.19	0.41

MassBus

- Its not just mass
  - specialized matrixer for your choice of:
    - Dark Matter, Globular clusters, Galactic BH mass ...
- MassBus can consume
  - GLADE and CLU catalogs
  - Galaxy cluster catalogs eg Abell
  - X-ray catalogs
  - Anything you like if you can make the function

    (RA,Dec,Mass,Distance) = matrixer(catalog record)

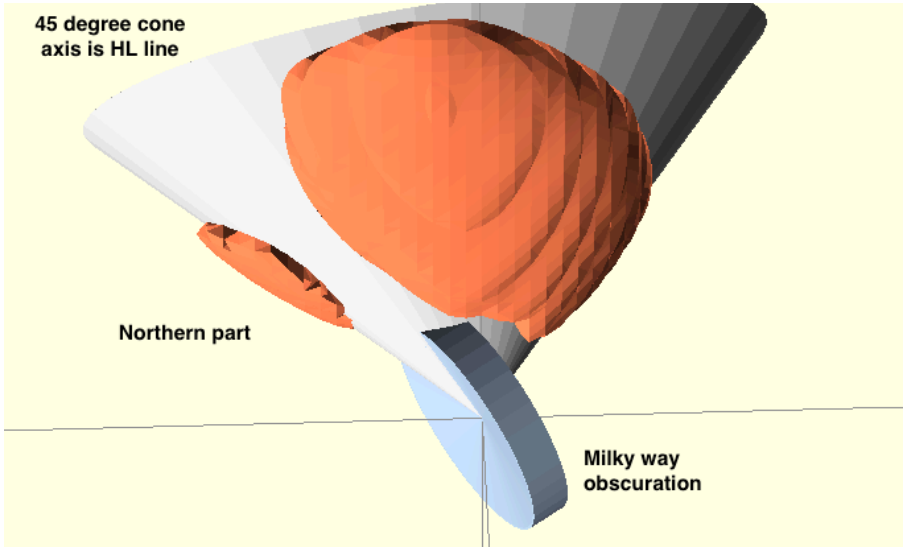
MassBus

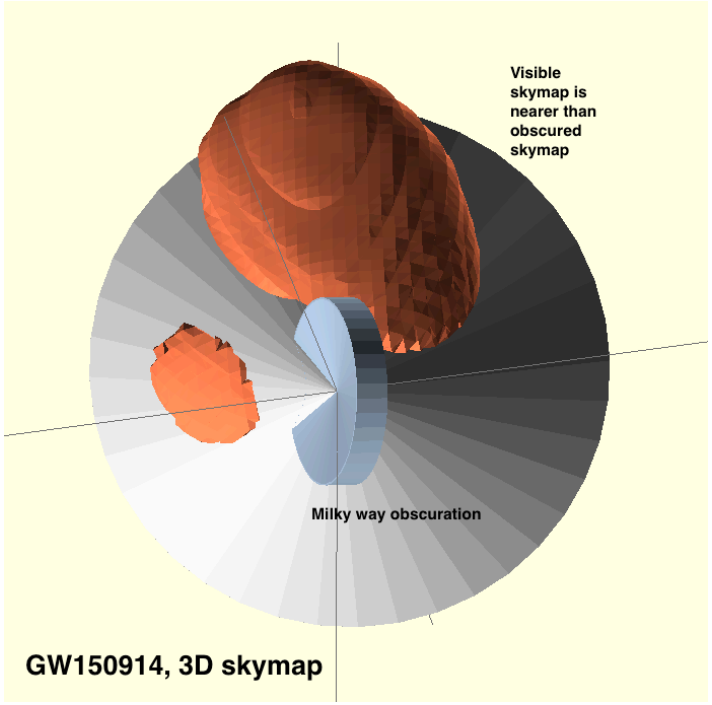
- For all sources:
  - compute mass × skymap
  - take top 100
- Future:
  - 3D skymaps
  - Bigger catalogs (PanStars, DES, LSST)
  - Smaller skymaps (HLVKI)

- Can we use HiPS, MOC etc?

3D Skymaps

This is why distance is in the MassBus



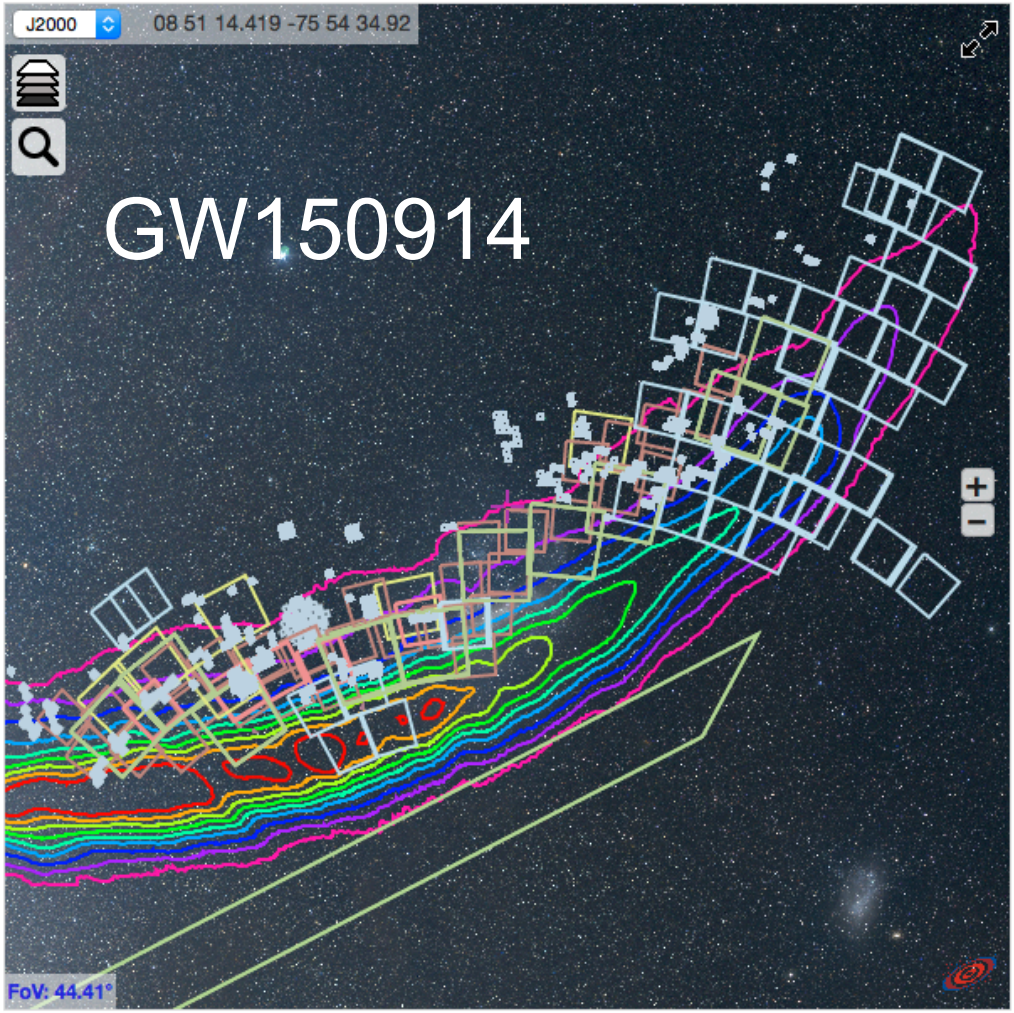


Sharing Footprints

Show Bulletin Board

Bulletin Board

	Group	Comment *click for full*
☑	Swift	
☑	Swift	
☑	Swift	
☑	Swift	
☑	Swift	
☑	INAF	- exptime 80 s - total observ
☑	ZTF	Note that observation location
☑	ZTF	?Note that observation locatio
☑	Pan-STARRS	i,z, y filters in 3 x 3 pointi
☑	ISDC	No excess in the all-sky API/A
☑	TZAC	
☑	TZAC	Filter C
☑	TZAC	Full obs. report below Letter
☑	Swift	Tiling of part of the GW proba
☑	INAF	- exptime 80 s - total observ
☑	SkyMapper	mag_i~19.7
☑	LOFAR-TKSP	
☑	LOFAR-TKSP	



Minor Planet Center