Title: Putting the Astronomy in Gravitational Wave Astronomy

Date: Apr 05, 2011 02:00 PM

URL: http://pirsa.org/11040075

Abstract: One of the great promises of the Advanced LIGO era is the prospect of integrating gravitational wave astronomy into the greater astronomical community. This will allow for measurements that cross spectral bands and provide new paths for insight into some of the most violent processes in the universe. In this talk I'll discuss past and present efforts with Initial and Enhanced LIGO to search for transients with both electromagnetic and gravitational wave signatures, with special focus on electromagnetic followups of inspiral events and an eye towards the advanced detector era. In addition, I'll discuss some work on detecting gravitational waves with pulsar timing experiments, which seeks to bridge the gap between gravitational wave and electromagnetic astronomers in a different way.

Putting the Astronomy in Gravitational Wave Astronomy

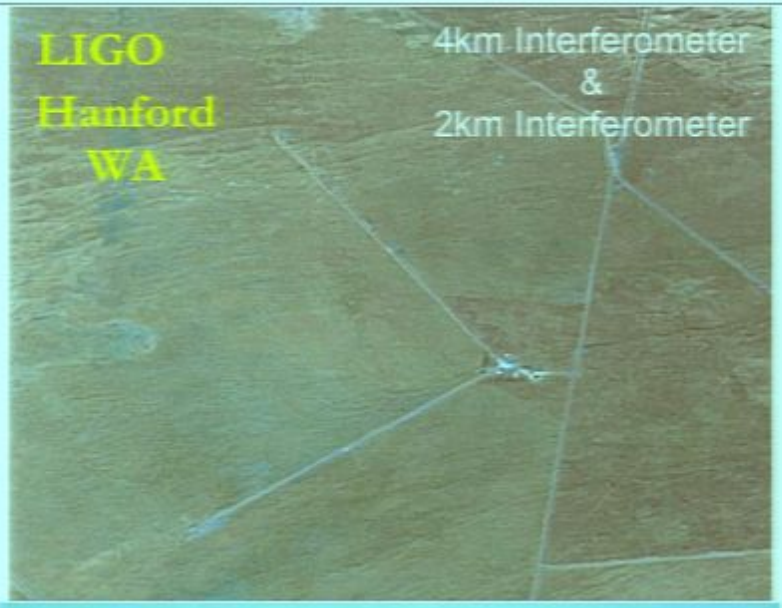
LIGO

Larry Price

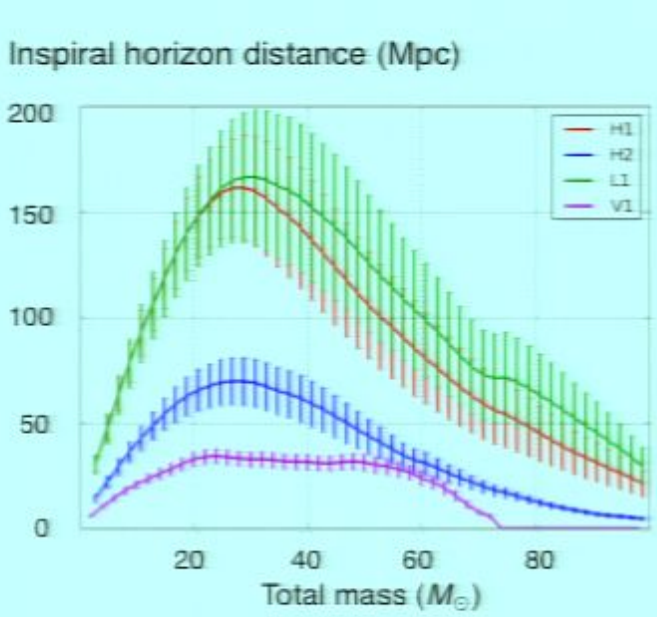
The Plan

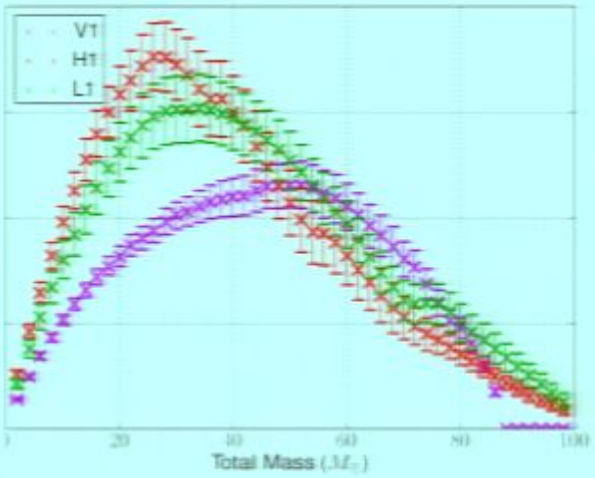
- Introduction
- Past and present multimessenger efforts with LIGO & Virgo
  - ExtTrig
  - LOOCUP
- Looking towards aLIGO

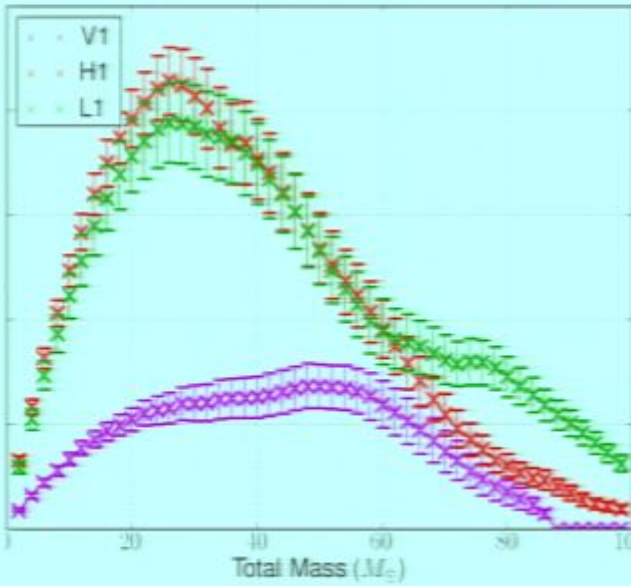
The ground-based scene circa 2010



Sensitivity gains over time







S5/VSR1 Start of S6/VSR2 End of S6/VSR3

Multimessenger Astronomy: An overview

Gravitational wave and electromagnetic signals provide complimentary information about an event.

- GW
  - Progenitor properties, e.g. mass
  - Luminosity distance
  - Bulk motion dynamics
  - Direct probe of the central engine
- EM
  - Sky location
  - Host galaxy
  - Redshift
  - Gas environment

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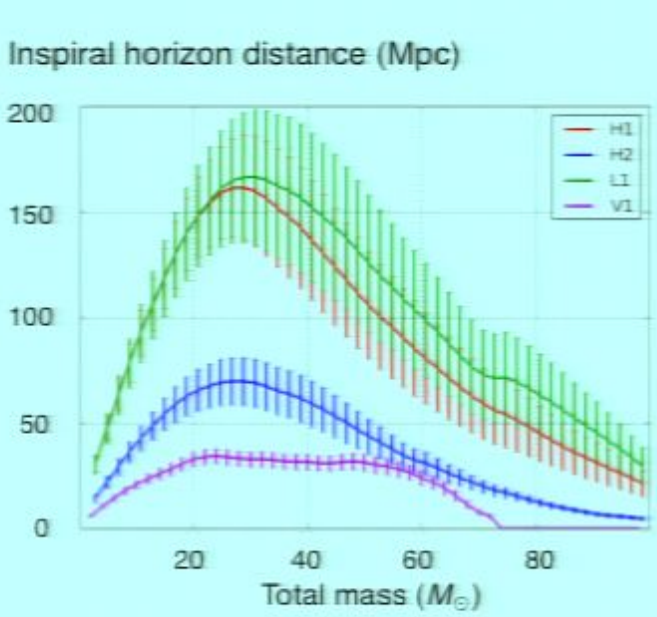

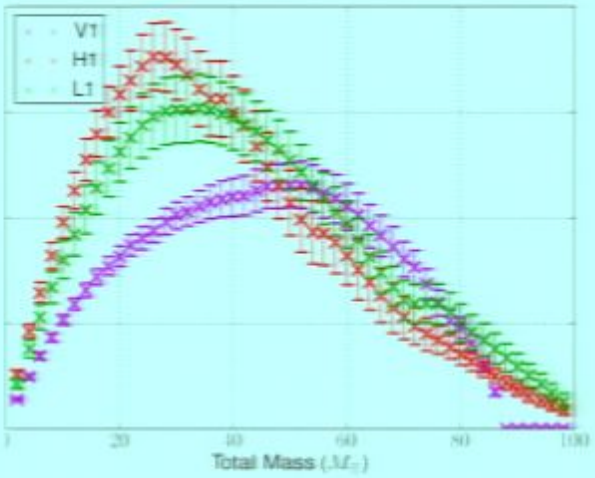

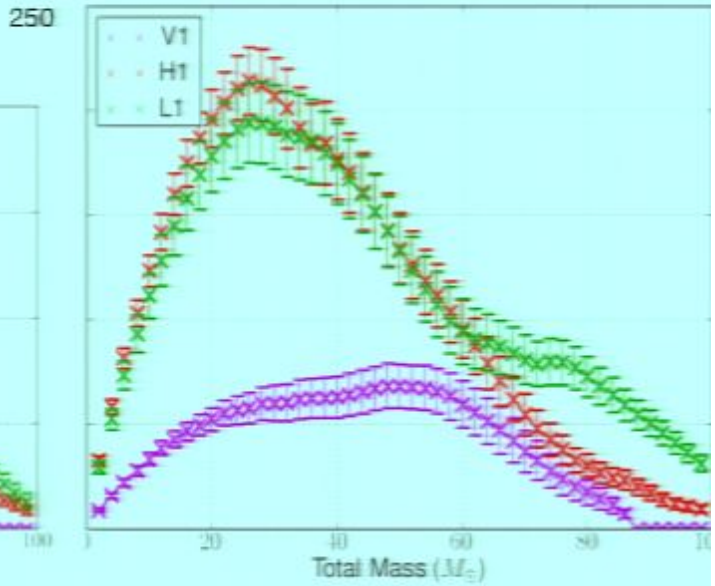

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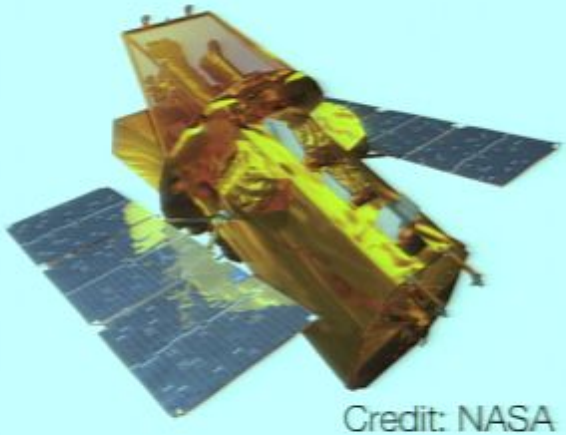
Information from both gives us a more complete picture of the event

Two types of GW+EM searches



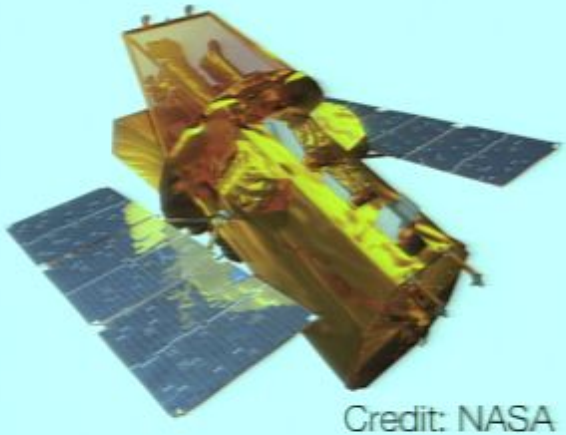
Credit: NASA

Credit: ROTSE

Two types of GW+EM searches

ExtTrig

Allows for a more sensitive search by focusing on a short period of data and a single sky location.



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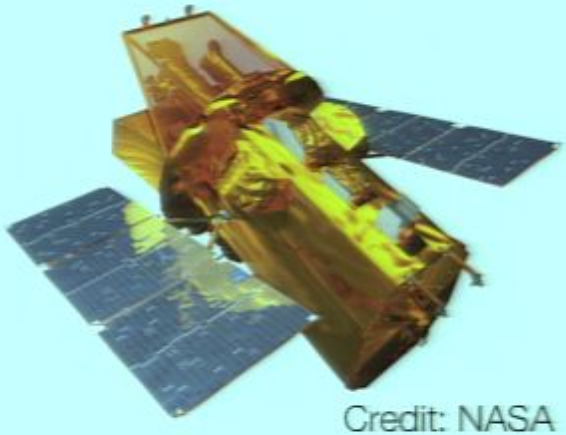

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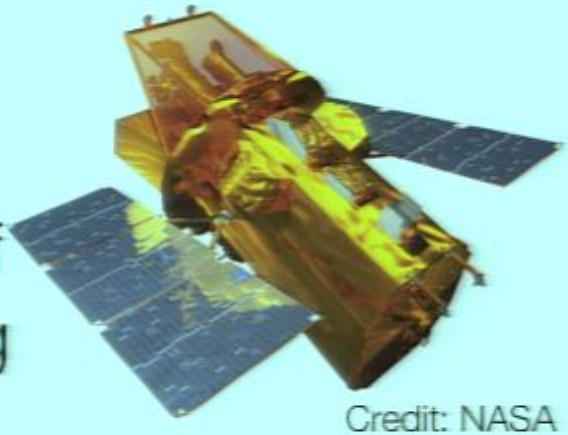
Two types of GW+EM searches

Allows for possibility of imaging corresponding EM signals as they occur.



Credit: NASA

LOOCUP

Credit: ROTSE

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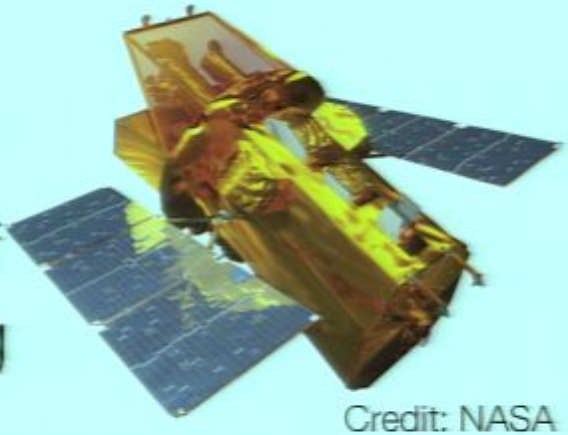

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LOOCUP

Credit: ROTSE

GRB 070201: A success story

LIGO observations ruled out an inspiral progenitor in M31 at >99% confidence.* They allow a soft gamma repeater (SGR) progenitor.†

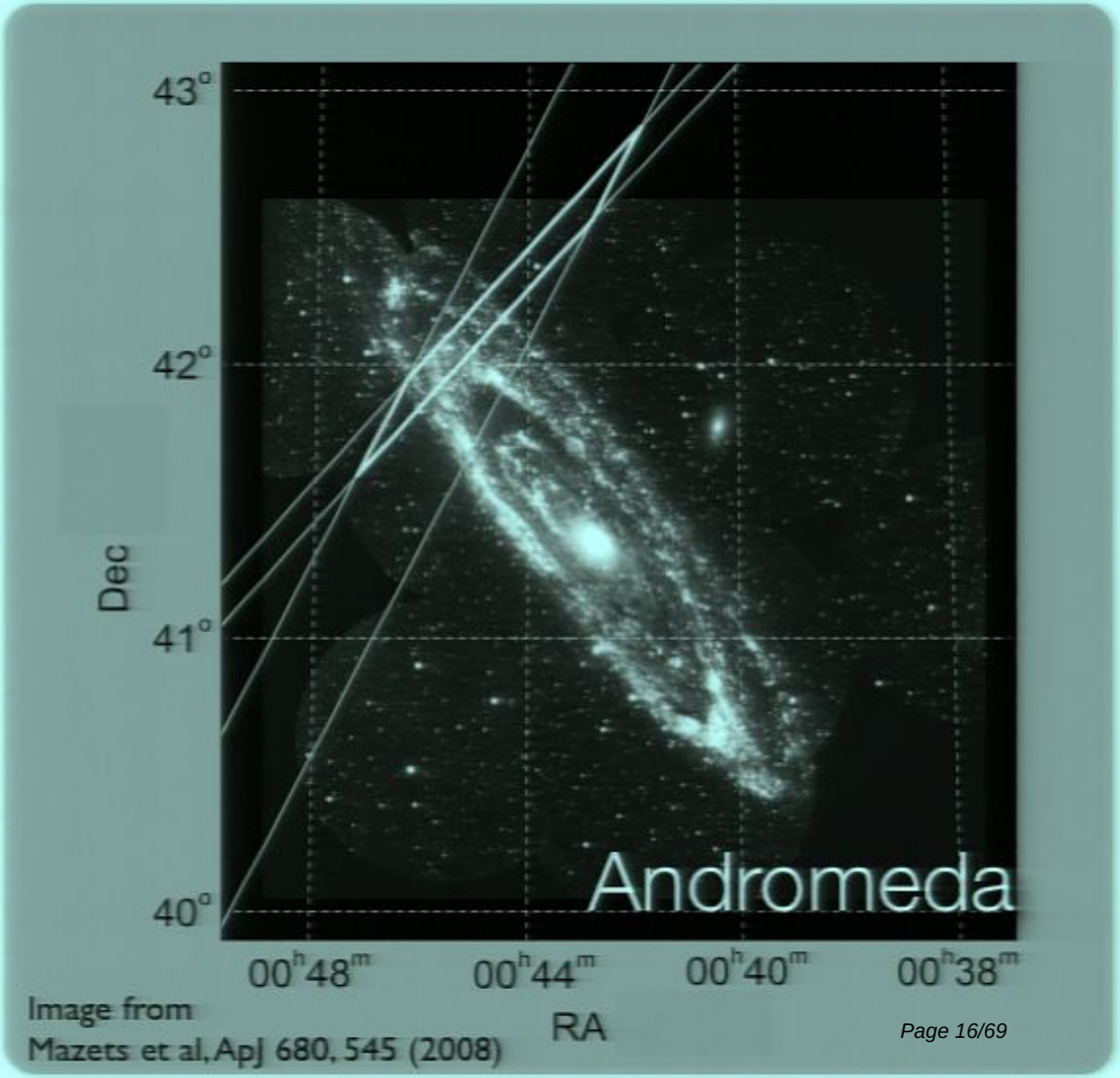

Image from Mazets et al, ApJ 680, 545 (2008)

* Abbott et al, ApJ 681, 1419 (2008)

† Ofek et al, ApJ 681, 1464 (2008); Mazets et al, ApJ 680, 545 (2008)

GRB 070201: A success story

THE ASTROPHYSICAL JOURNAL, 681:1464–1469, 2008 July 10

GRB 070201: A POSSIBLE SOFT GAMMA-RAY REPEATER IN M31[1]

E. O. OFEK,[2] M. MUNO,[2] R. QUIMBY,[2] S. R. KULKARNI,[2] H. STIELE,[3] W. PIETSCH,[3] E. NAKAR,[2]
A. GAL-YAM,[4] A. RAU,[2] P. B. CAMERON,[2] S. B. CENKO,[2] M. M. KASLIWAL,[2]
D. B. FOX,[5] P. CHANDRA,[6,7] A. K. H. KONG,[8,9] AND R. BARNARD[10]
Received 2007 December 13; accepted 2008 February 18

GRB 051103 and GRB 070201 as Giant Flares from SGRs in Nearby Galaxies

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K. Hurley‡, V. Ilinskii*, A. von Kienlin§, E. Mazets* and V. Palshin*

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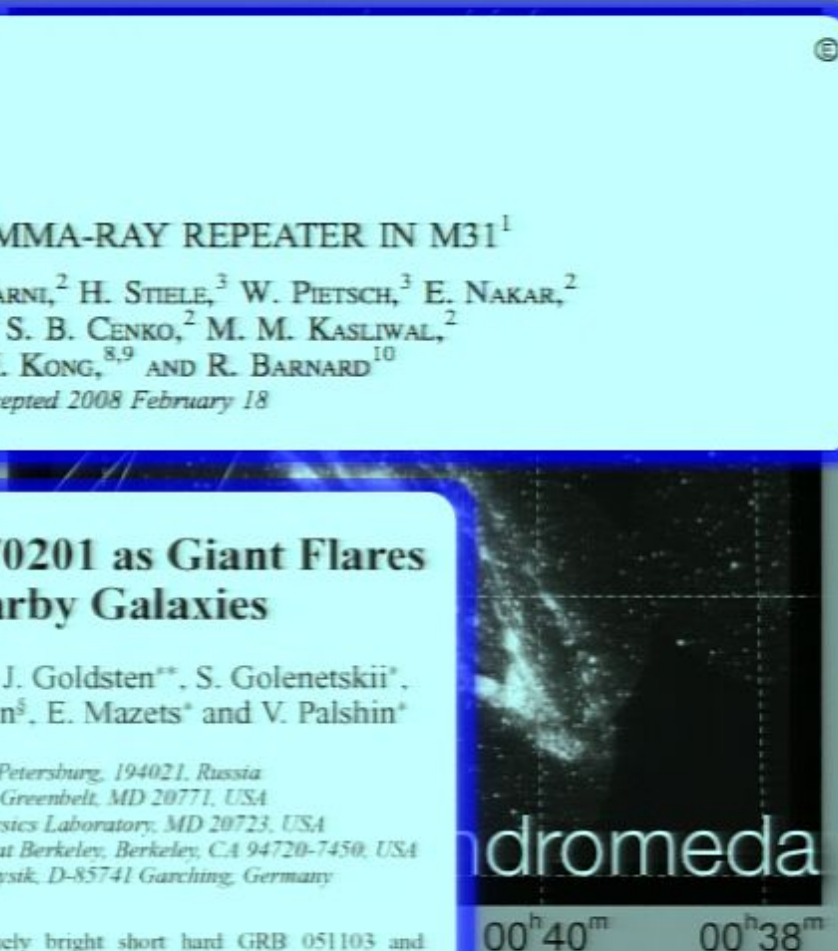
‡Space Sciences Laboratory, University of California at Berkeley, Berkeley, CA 94720-7450, USA
§Max-Plank-Institut für extraterrestrische Physik, D-85741 Garching, Germany

Abstract. The Konus-Wind observations of extremely bright short hard GRB 051103 and GRB 070201 are presented. Results of gamma-ray data temporal and spectral analysis together with IPN sources localization are bringing evidences of the bursts being initial pulses of Giant Flares from Soft Gamma-ray Repeaters in the nearby galaxies M81/M82 and M31.

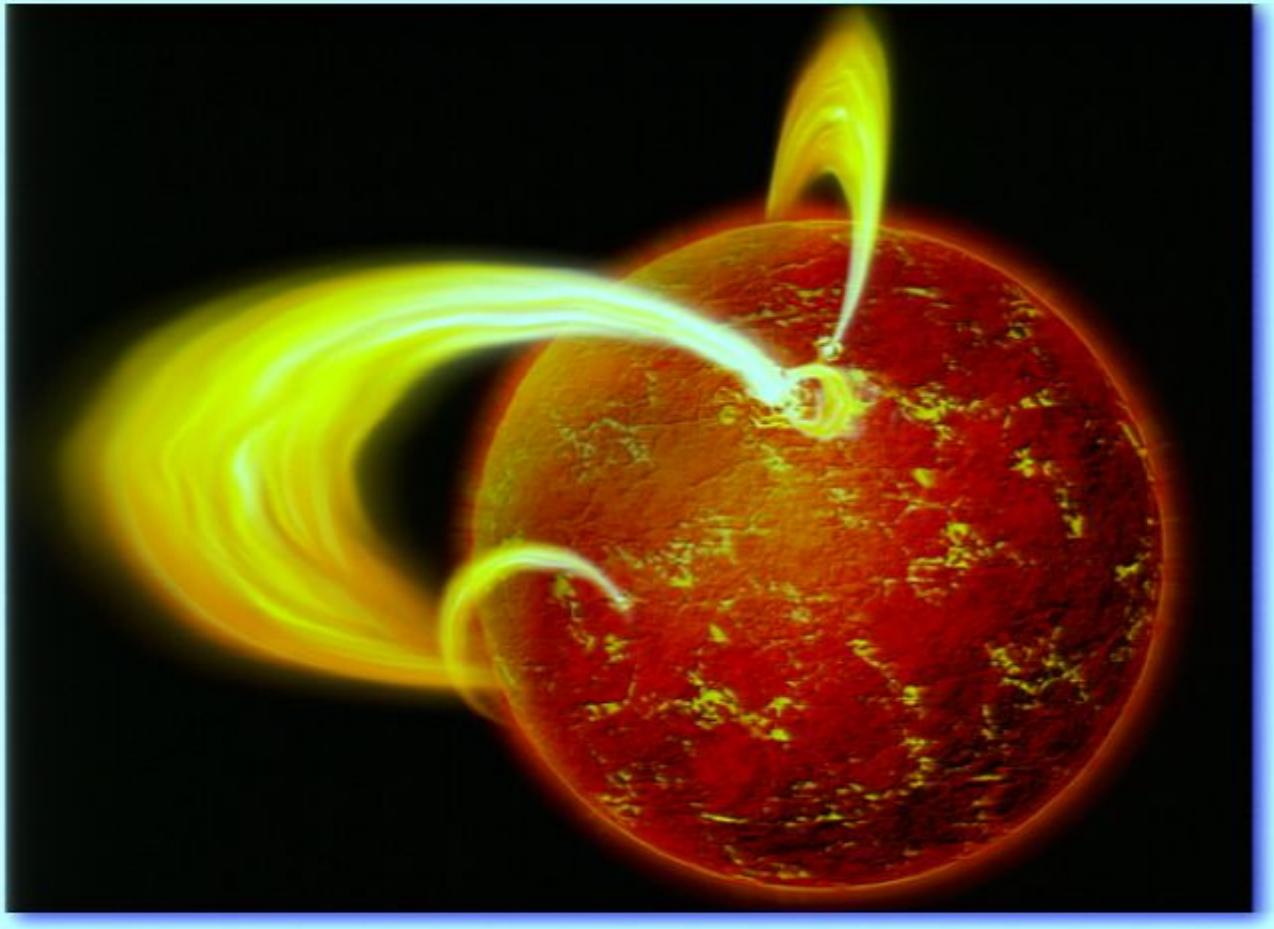
Keywords: gamma-ray bursts, soft gamma-ray repeaters, M31, M81/M82 group



* Abbott et al, ApJ 68
† Ofek et al, ApJ 681,
Mazets et al, ApJ 68

Other ExtTrig efforts

- SGRs
- Supernovae
- Neutrinos
- Radio bursts



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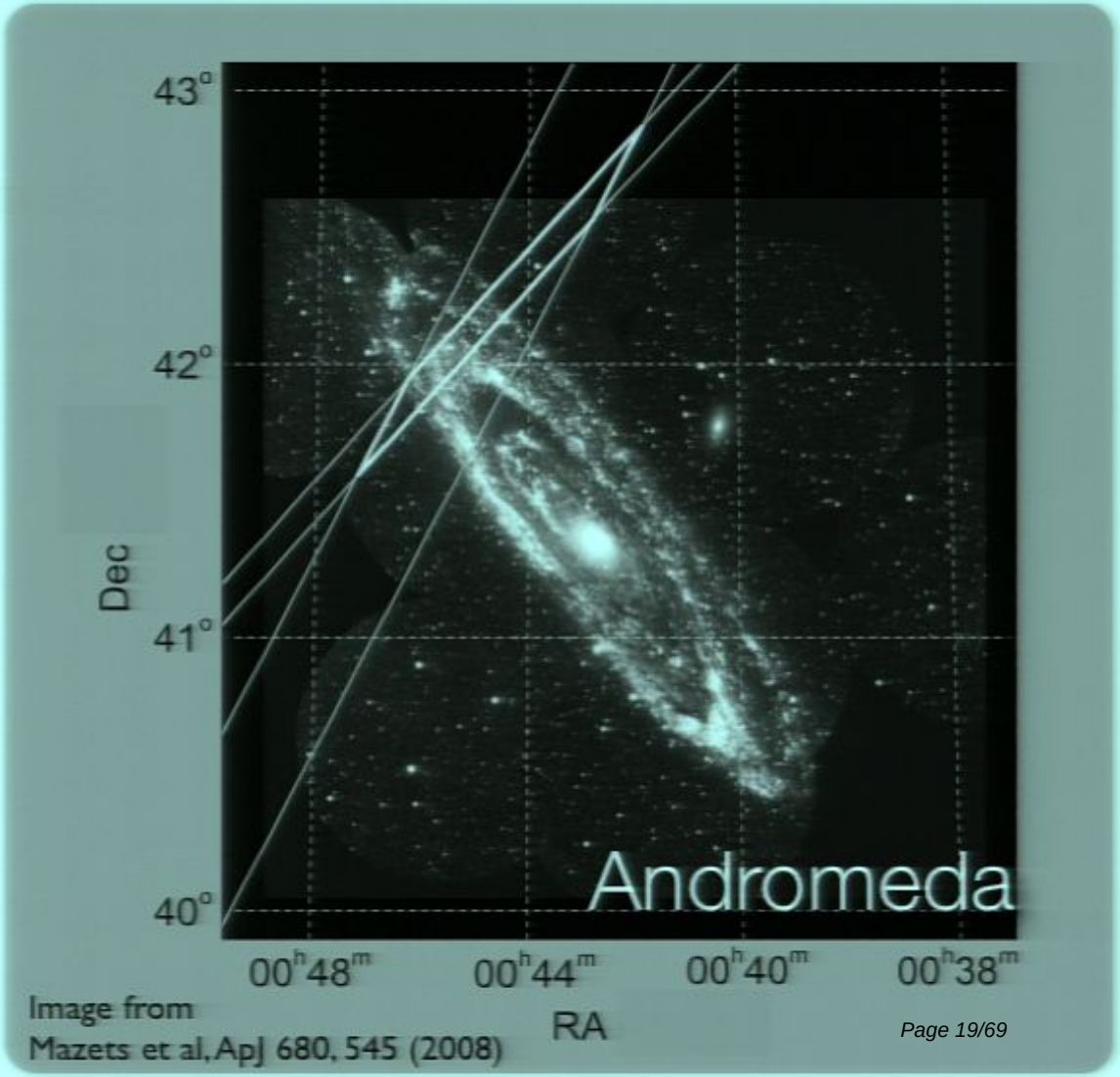

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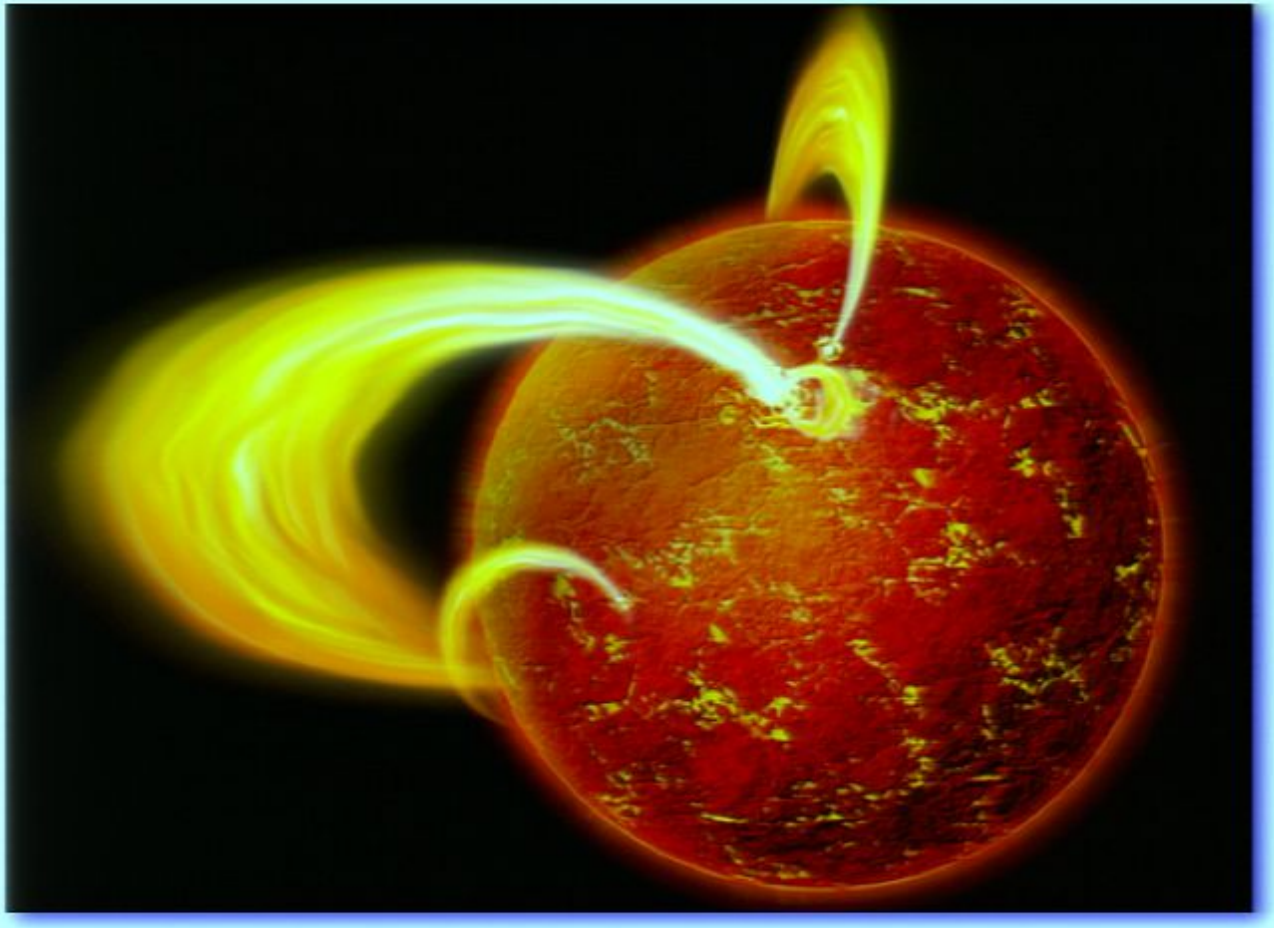
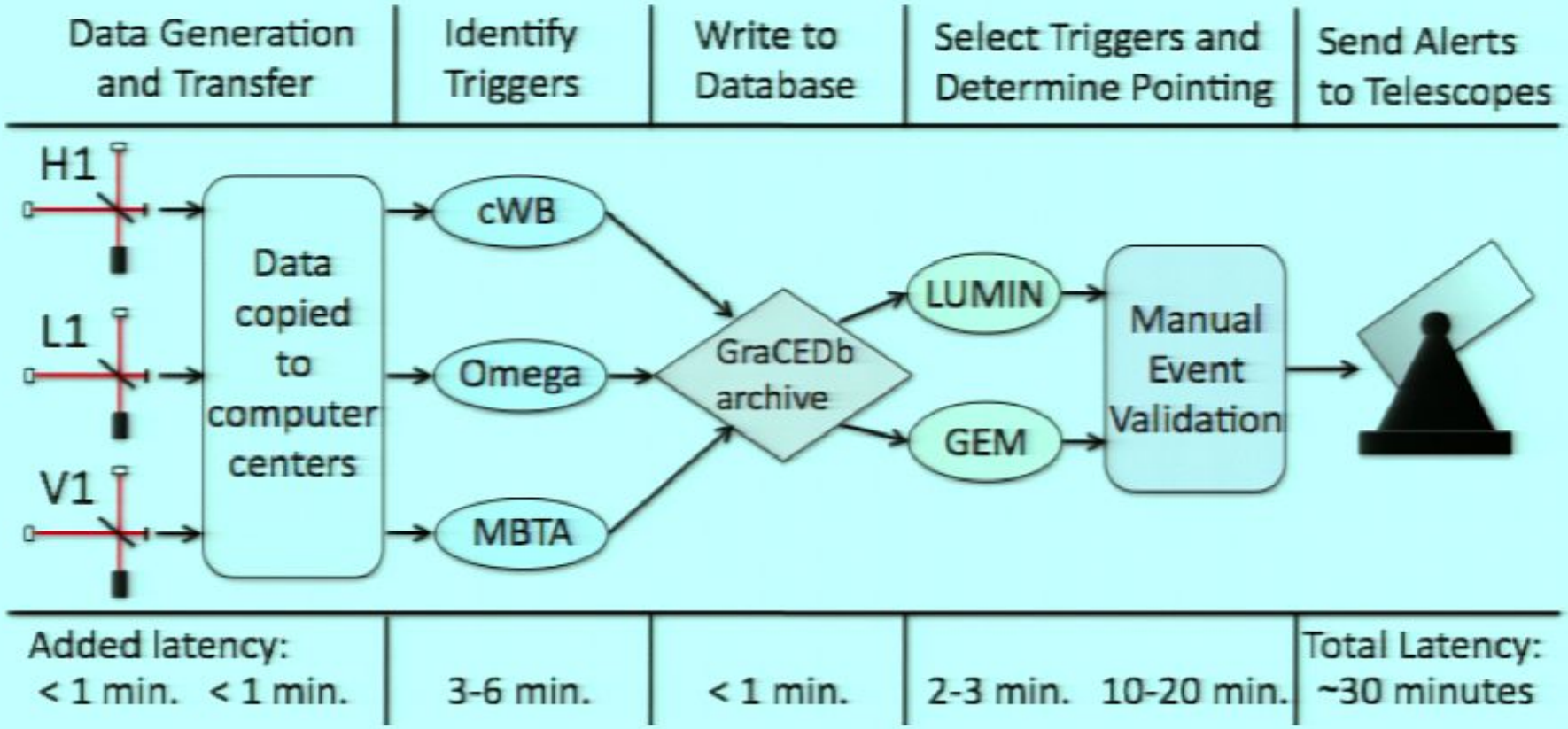


LOOCUP: A work in progress*



Credit: Brennan Hughey and Jameson Rollins

*Final analysis results pending

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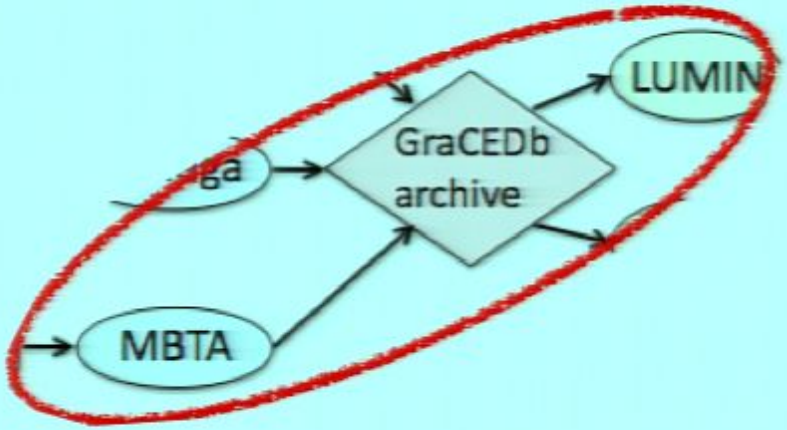

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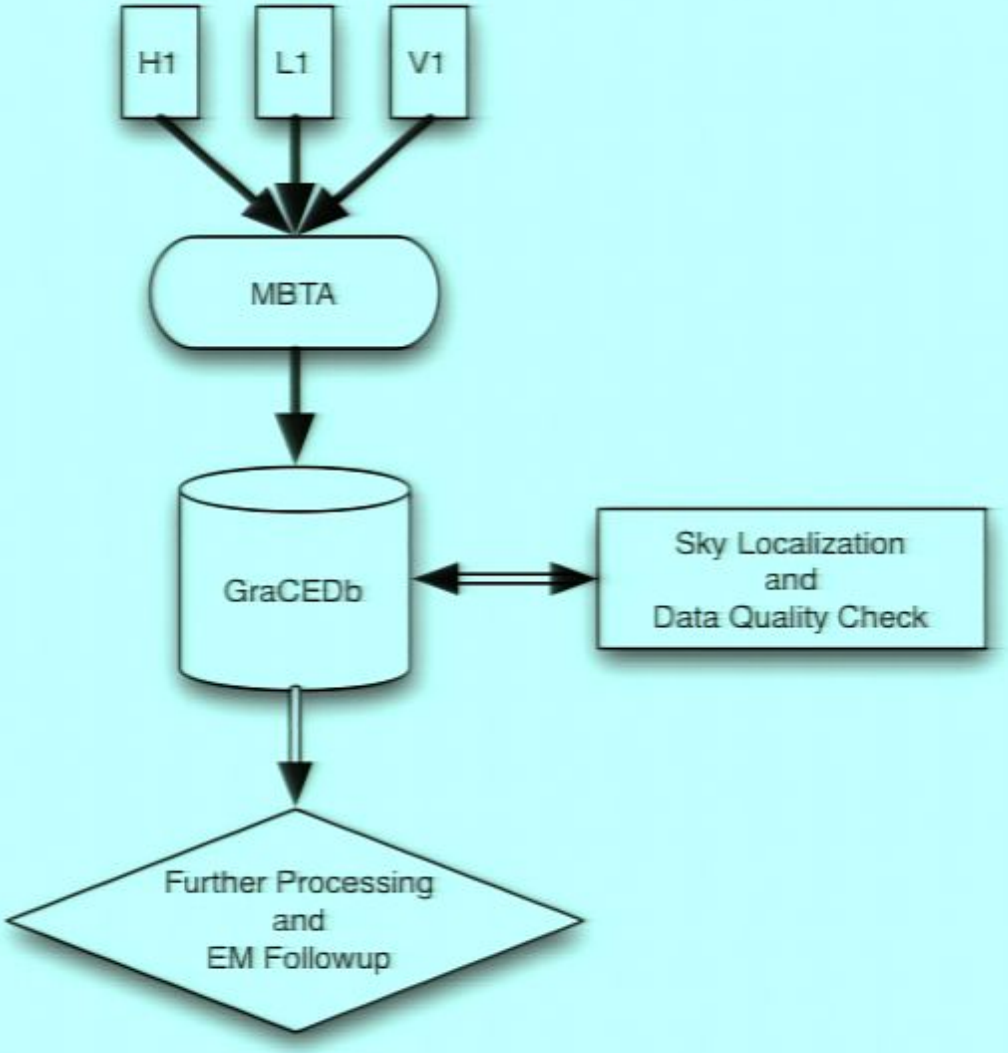
Overview of the pipeline



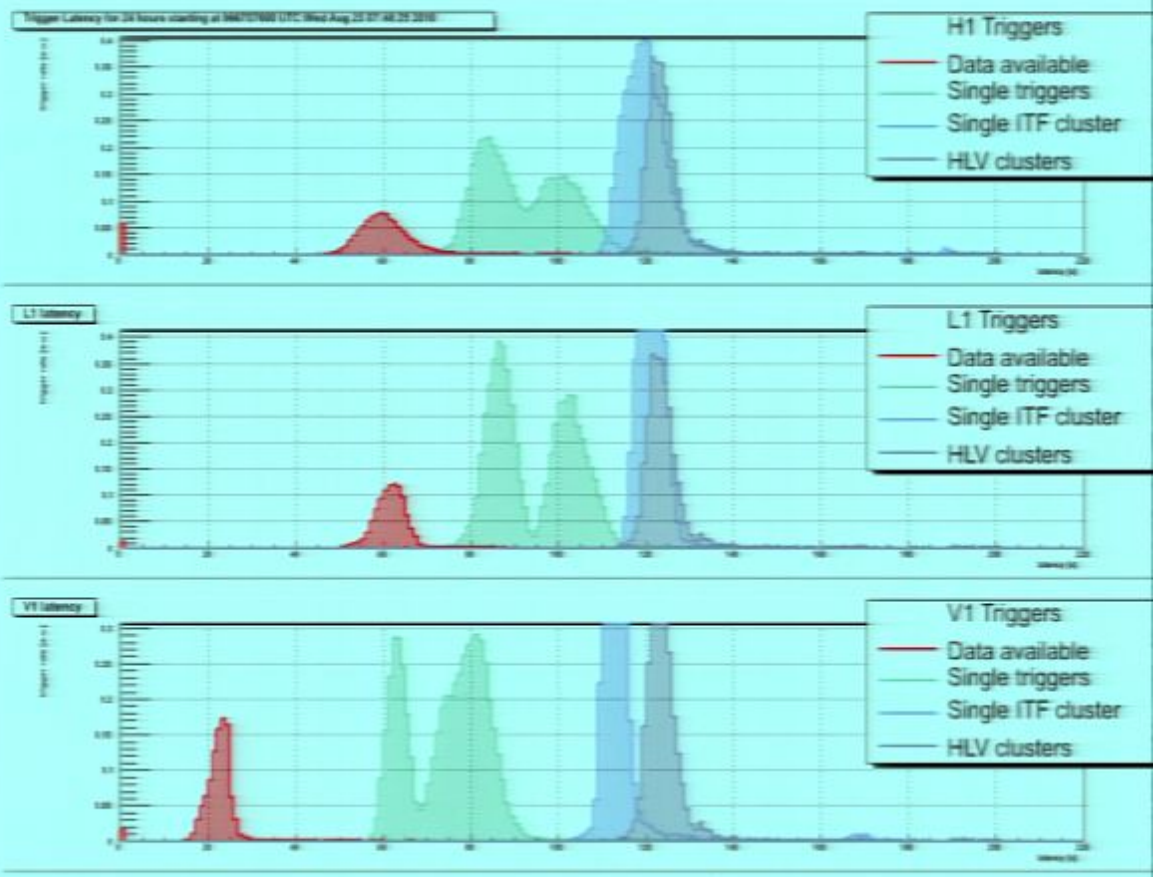
MBTA

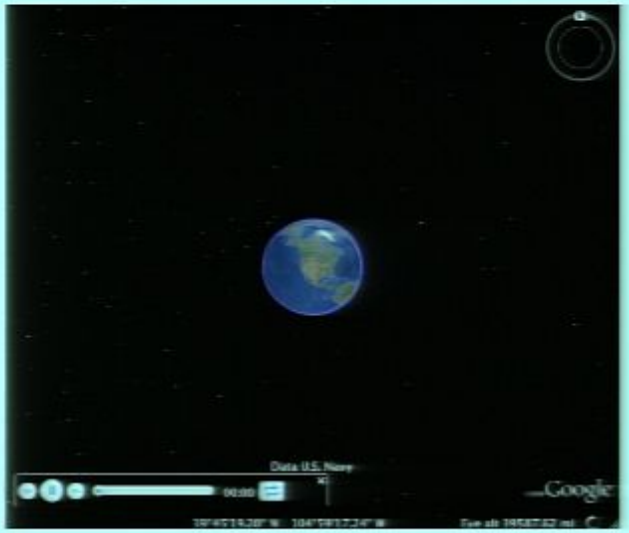
> **M**ulti **B**and **T**emplate **A**nalysis

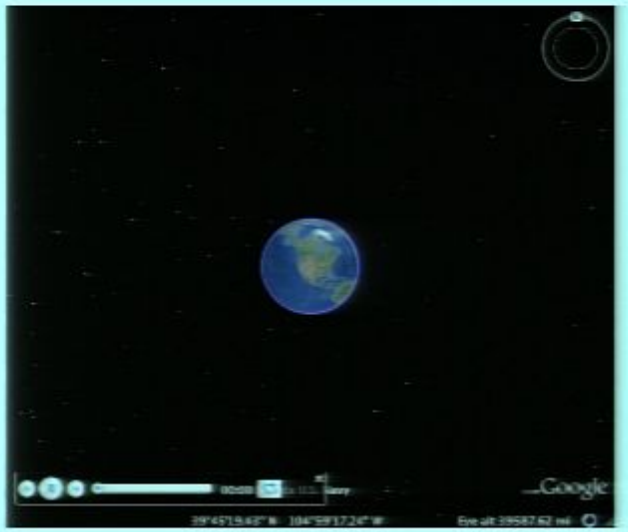
> Matched filter search (2PN)

> Typical latencies ~ a few minutes, including 1 minute to get h(t)!

> Only triple coincident events sent out for followup

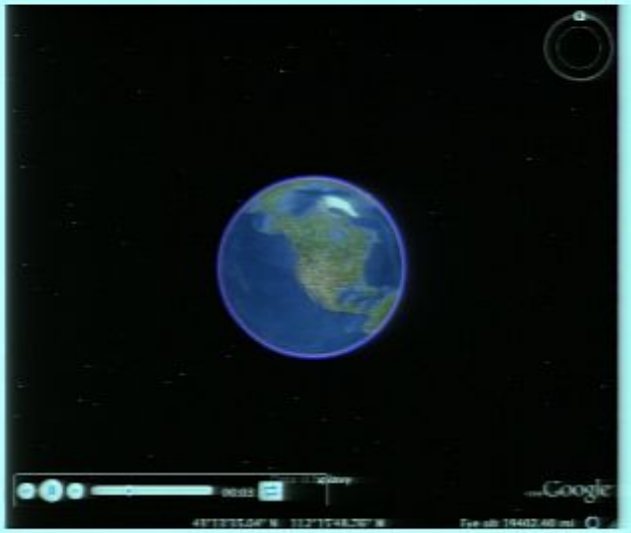


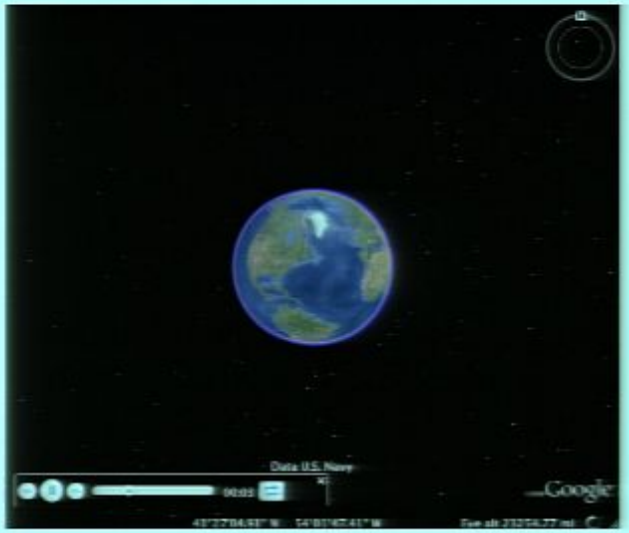


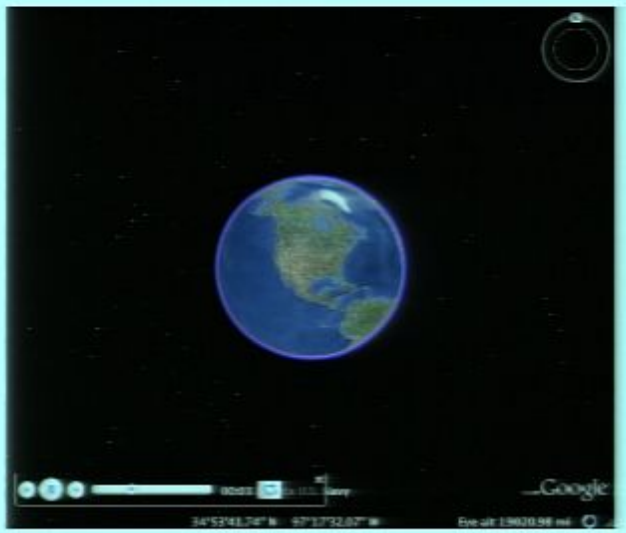


Sky localization

Use the time-delay between detector sites and the amplitude measured at each site to localize sources on the sky.







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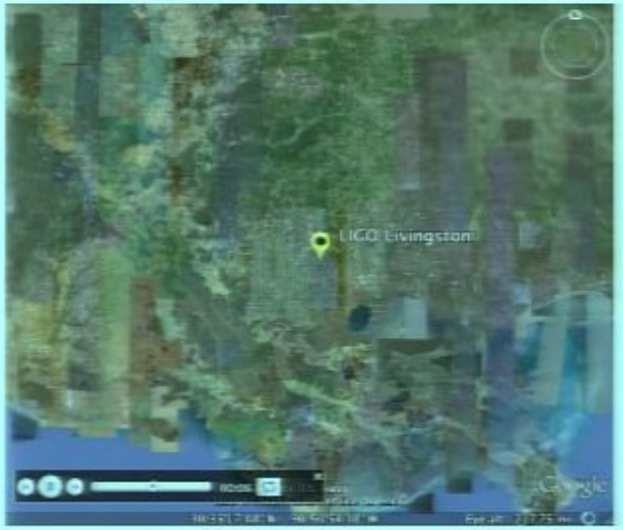

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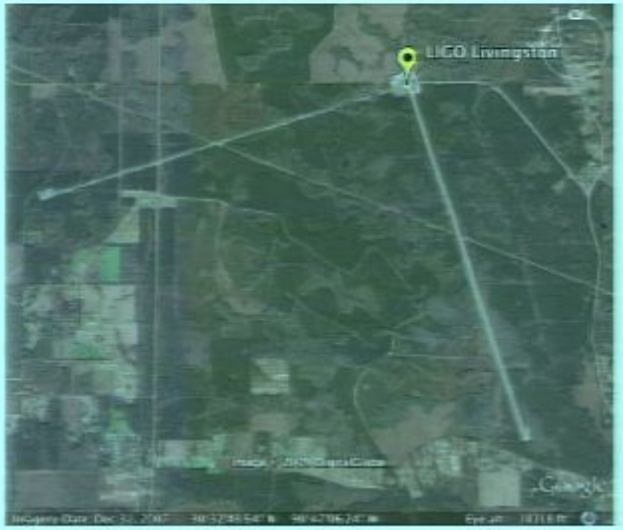

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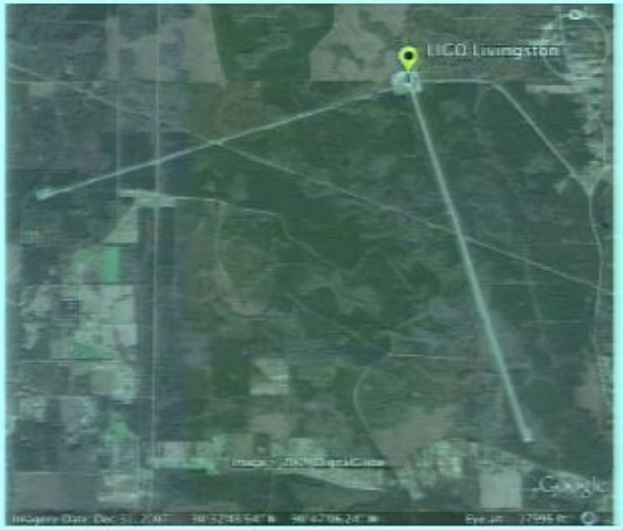

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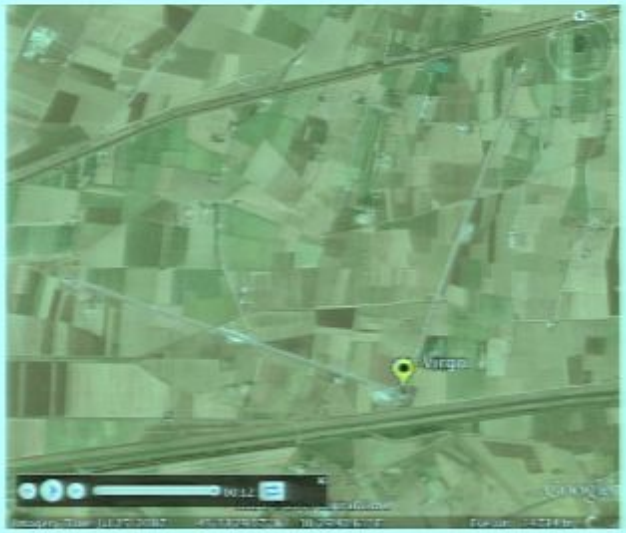

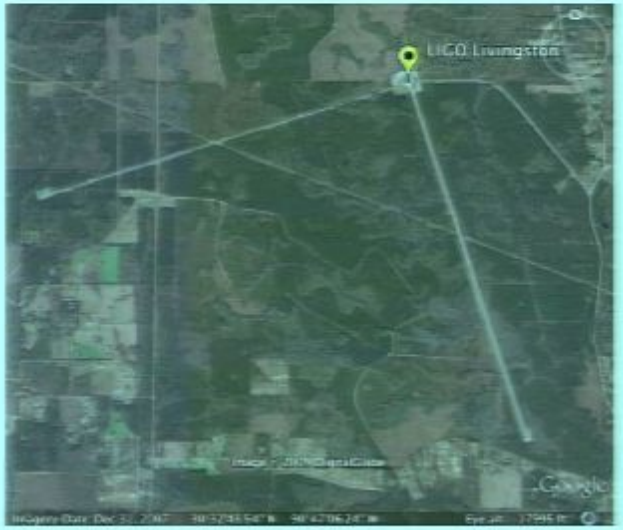

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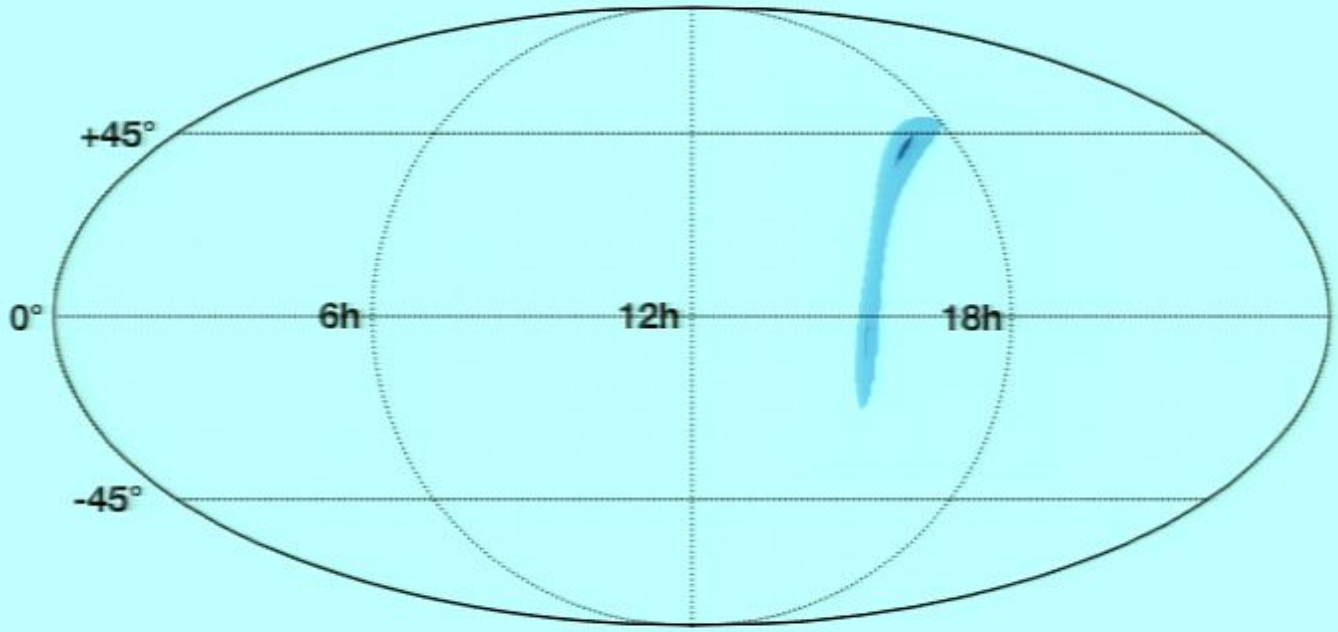
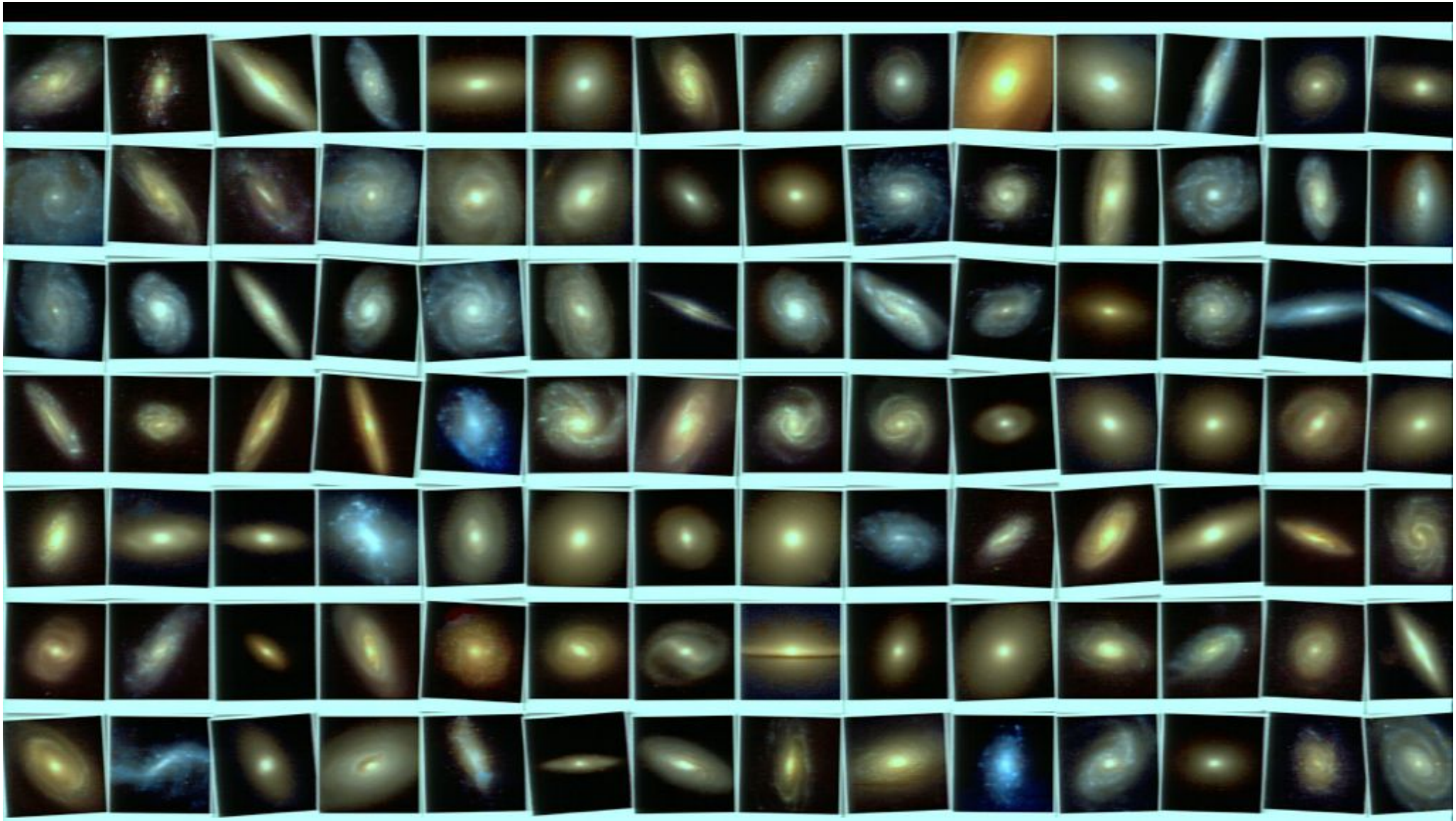
One big problem

Poor sky localization. Optimistically **tens** of square degrees, even for advanced detectors*.





Credit: Zsolt Frei et al (1995

Incorporating Astrophysical Priors

Kopparapu, Hanna, Kalogera, O'Shaughnessy, González, Brady & Fairhurst (2008)

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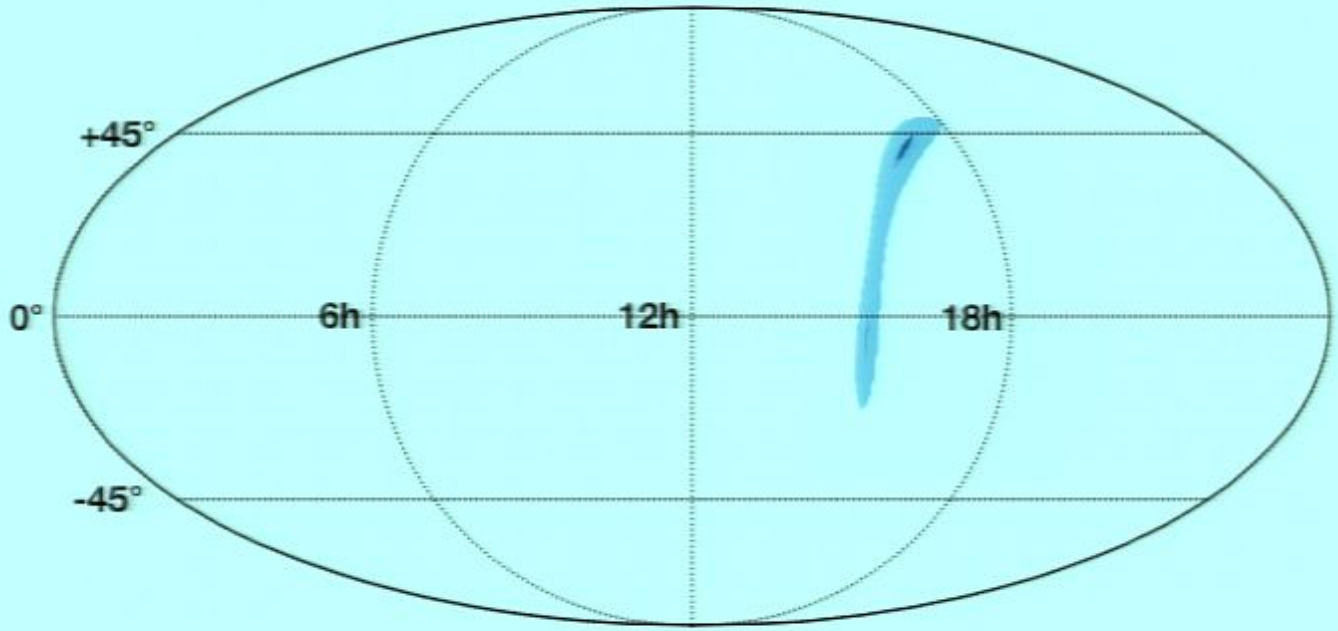

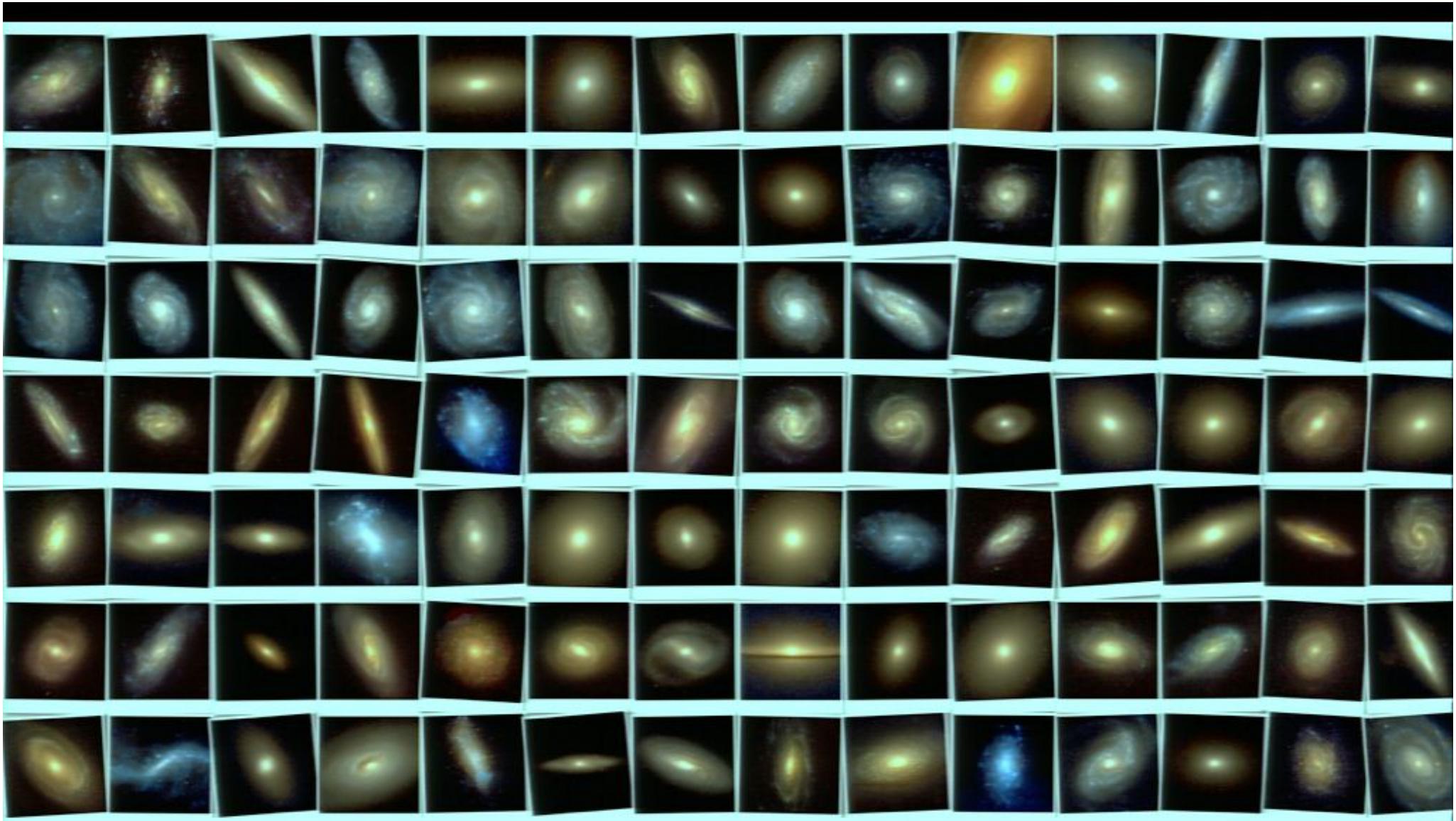

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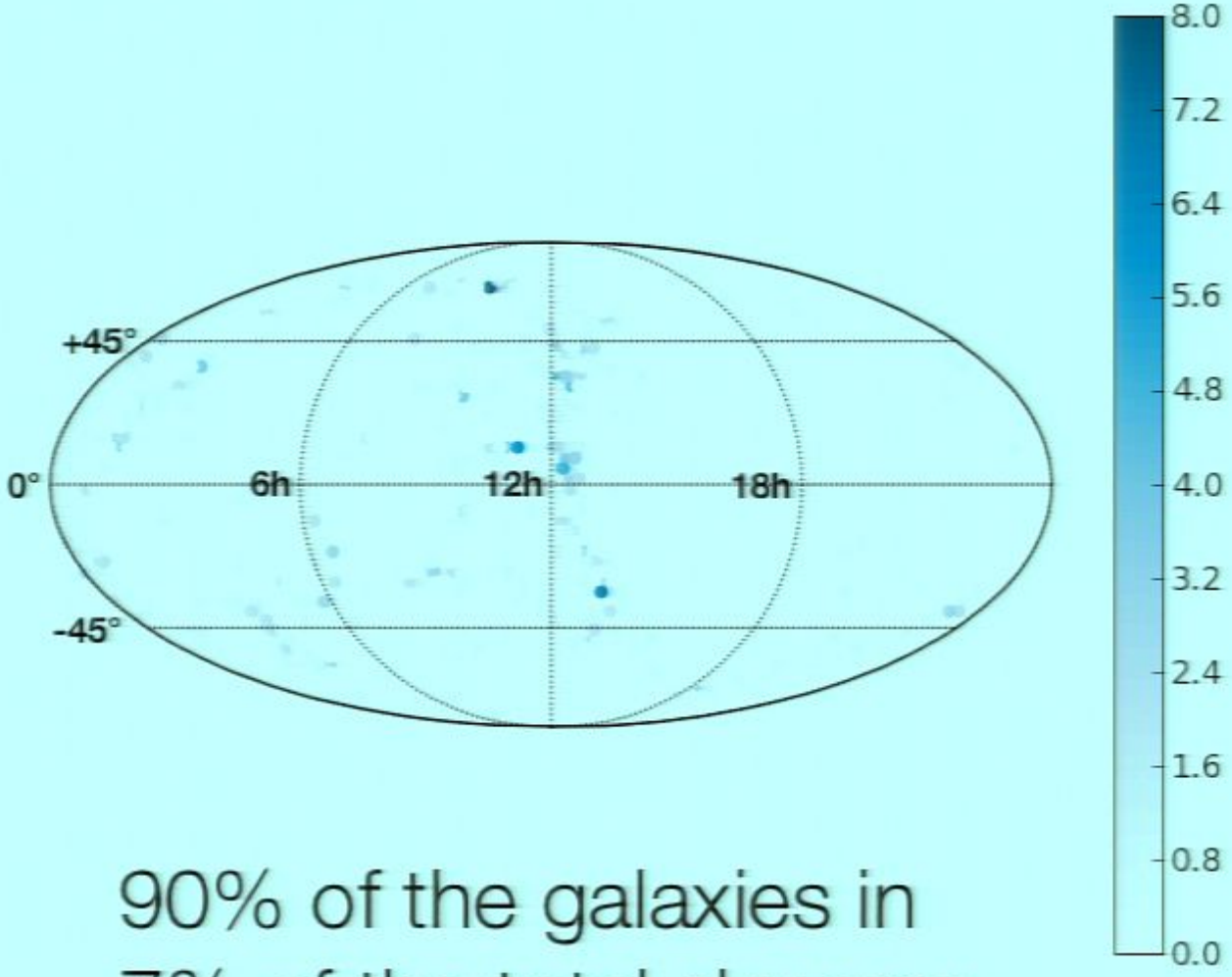
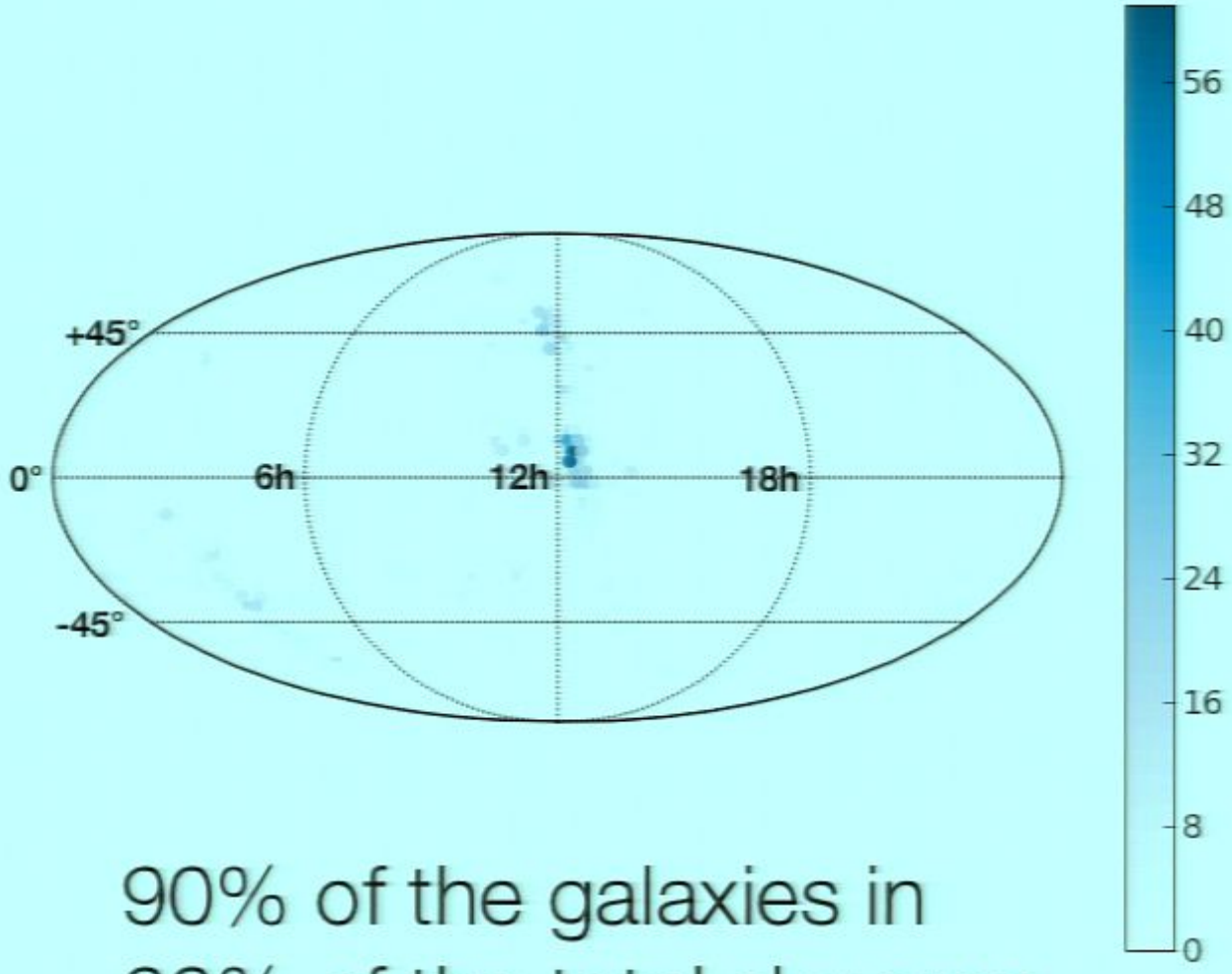
Number of galaxies at 10Mpc



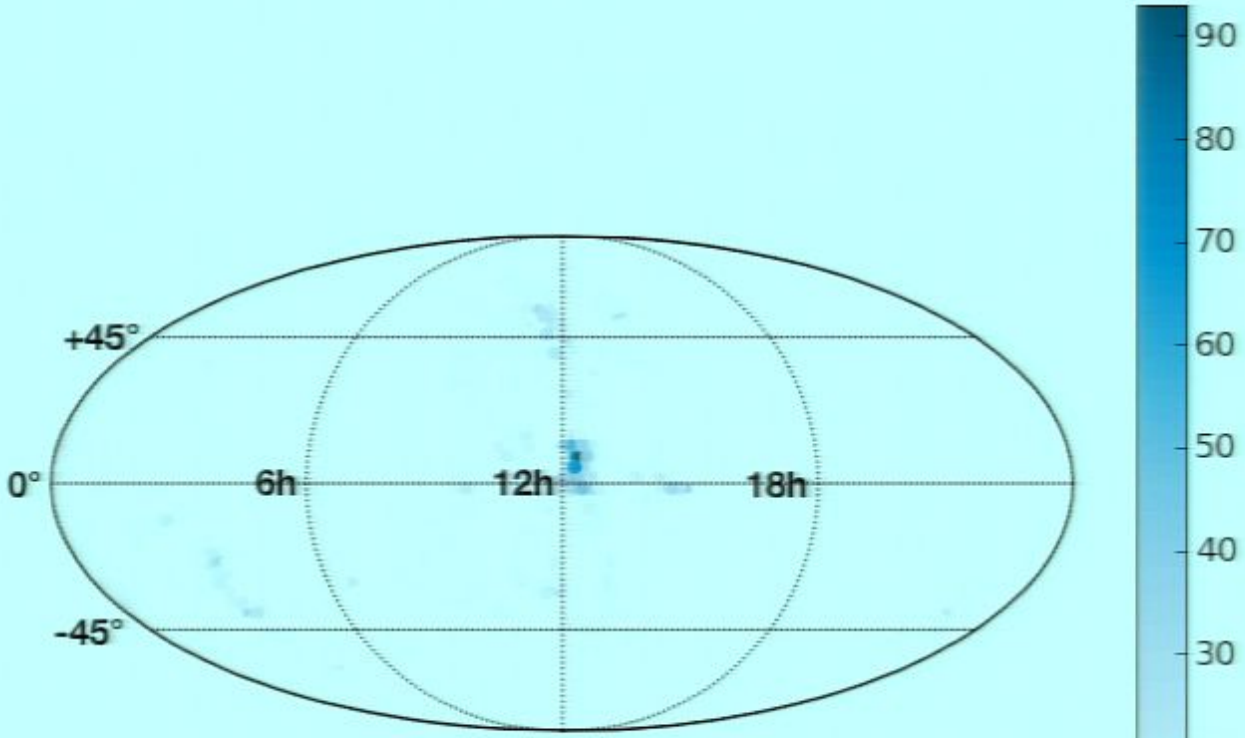
90% of the galaxies in
7% of the total sky area

Number of galaxies at 20Mpc



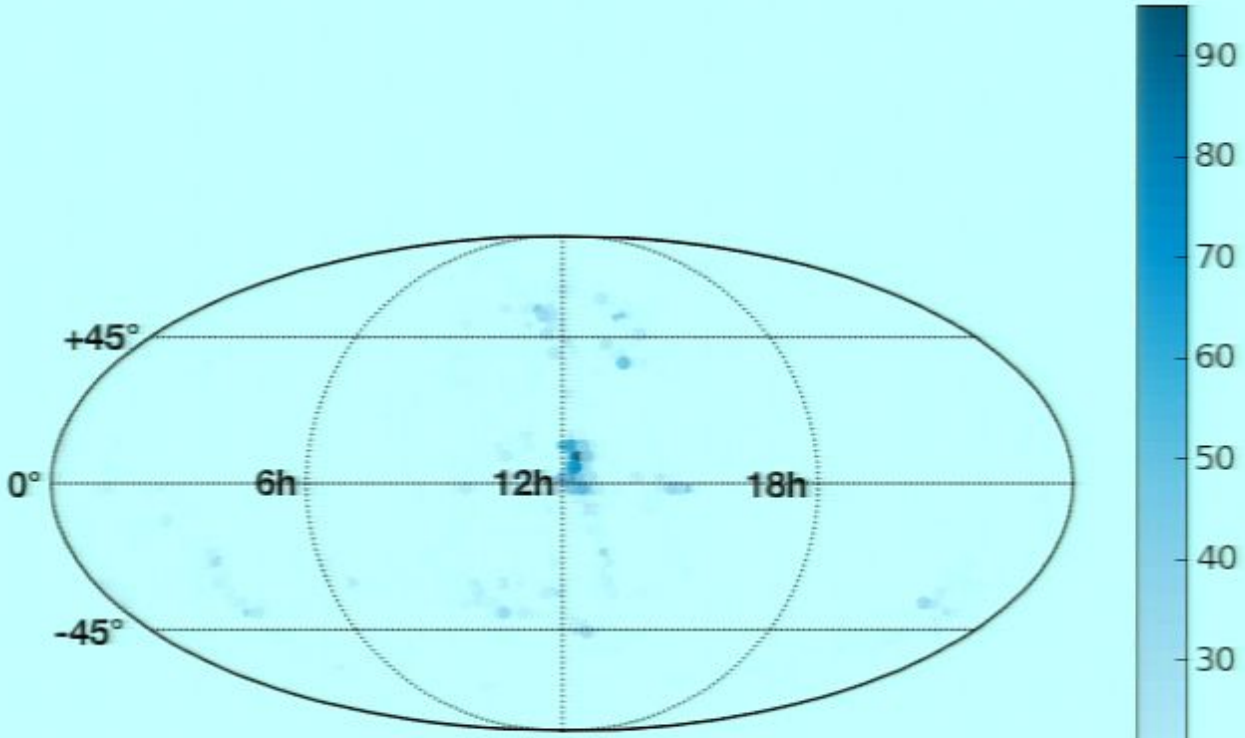
90% of the galaxies in
20% of the total sky area

Number of galaxies at 30Mpc



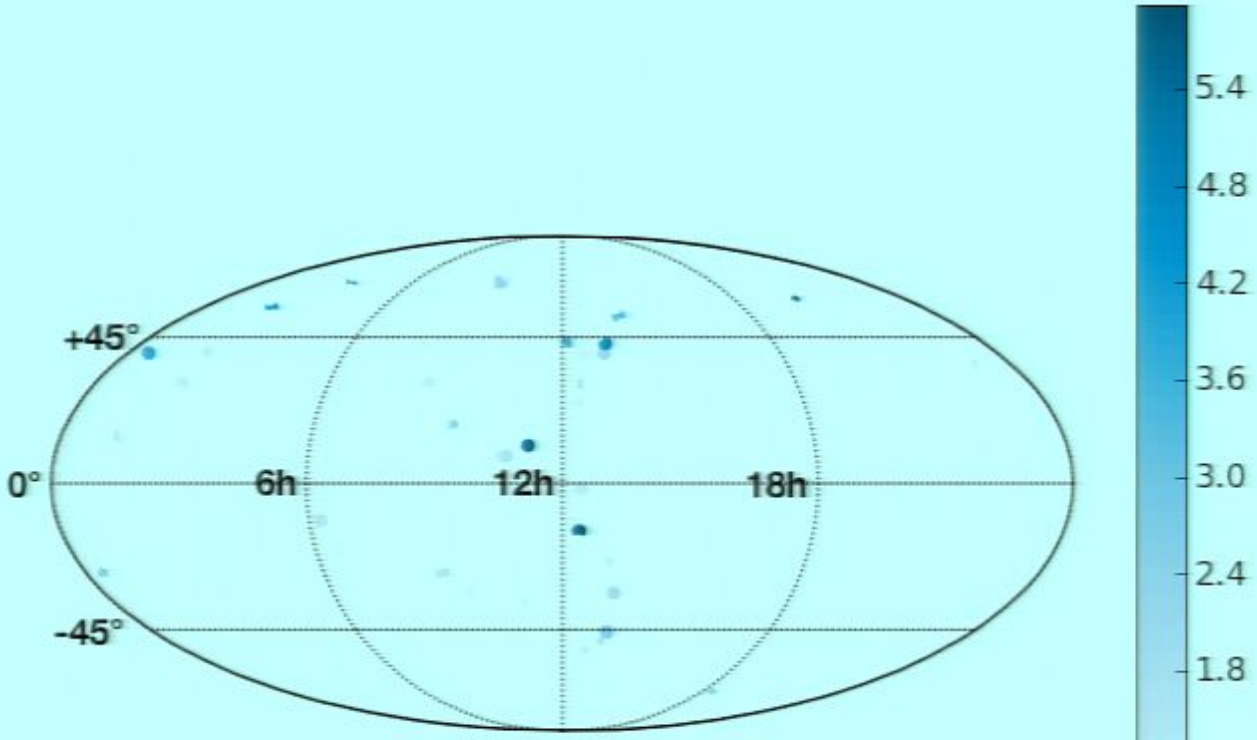
90% of the galaxies in
27% of the total sky area

Number of galaxies at 40Mpc



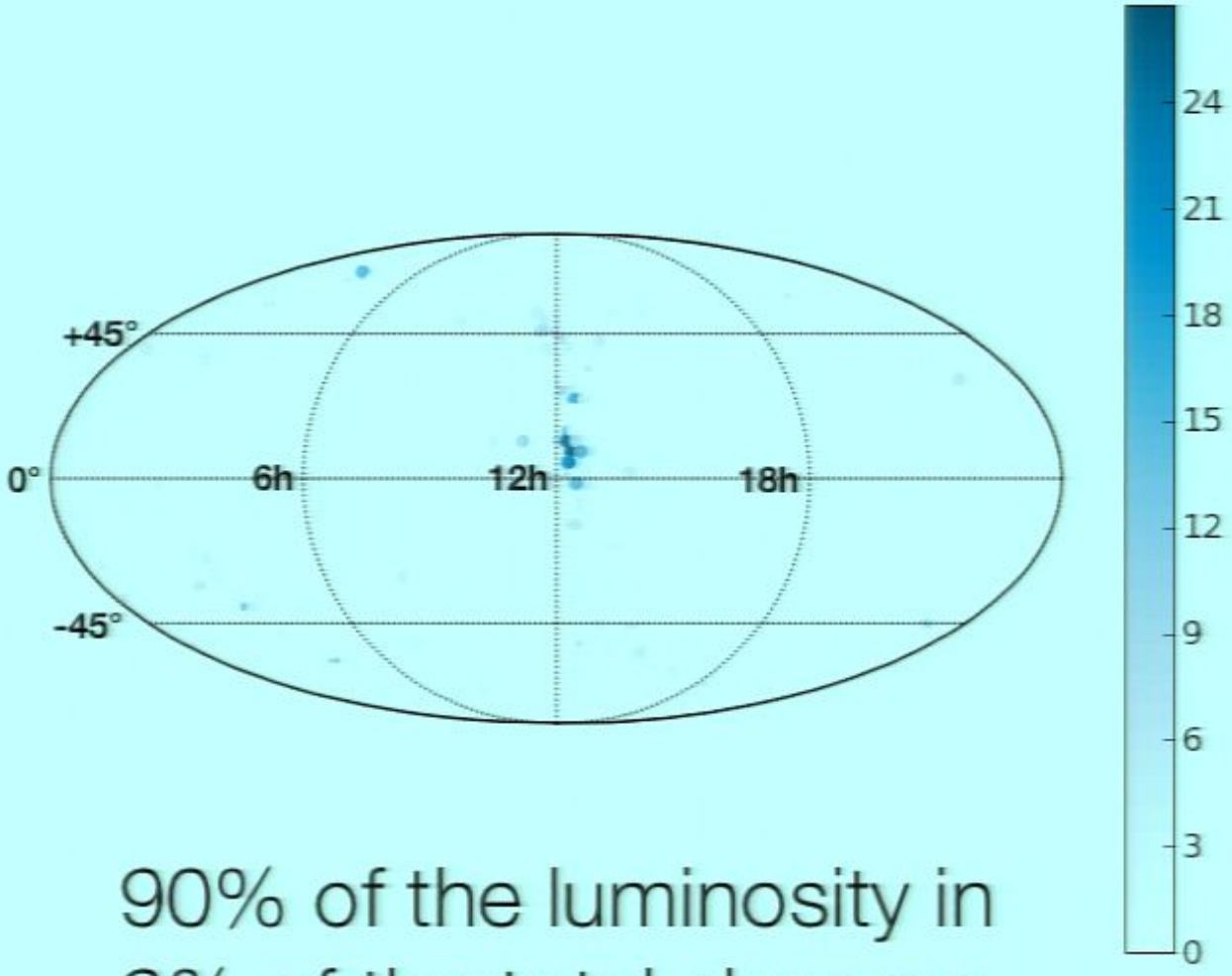
90% of the galaxies in
31% of the total sky area

Blue luminosity at 10Mpc



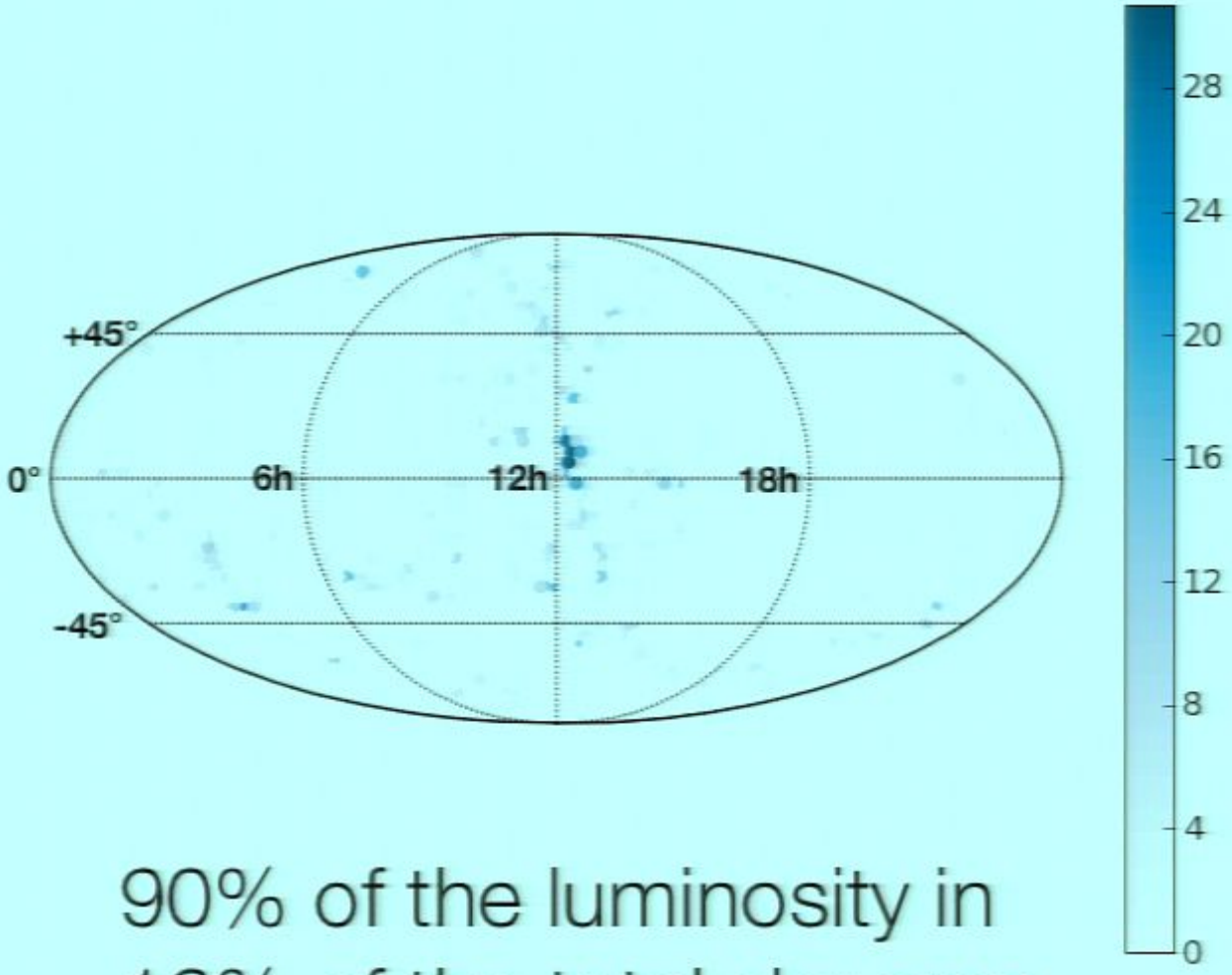
90% of the luminosity in
2% of the total sky area

Blue luminosity at 20Mpc



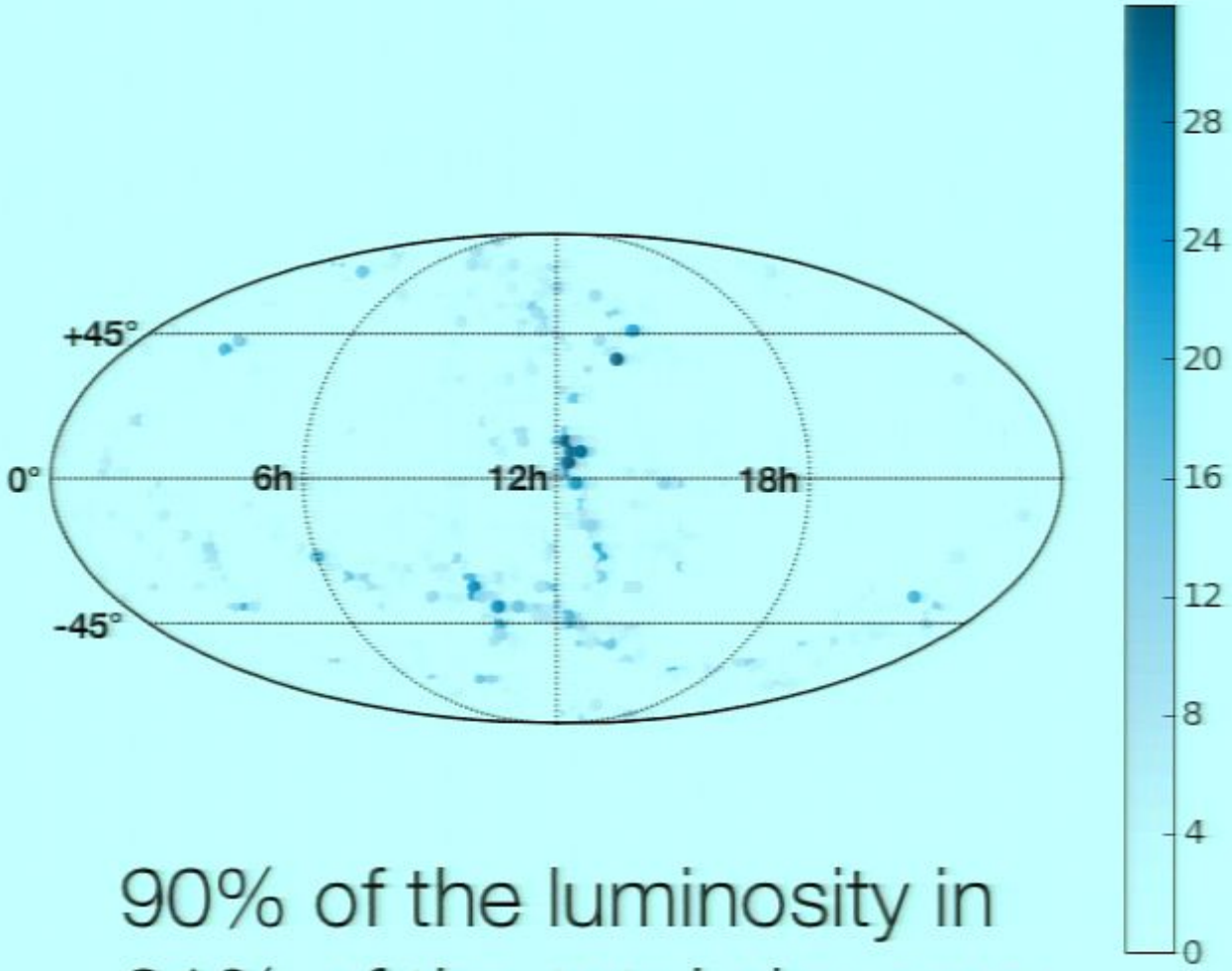
90% of the luminosity in
9% of the total sky area

Blue luminosity at 30Mpc



90% of the luminosity in
16% of the total sky area

Blue luminosity at 40Mpc



90% of the luminosity in
21% of the total sky area

Sky localization performance

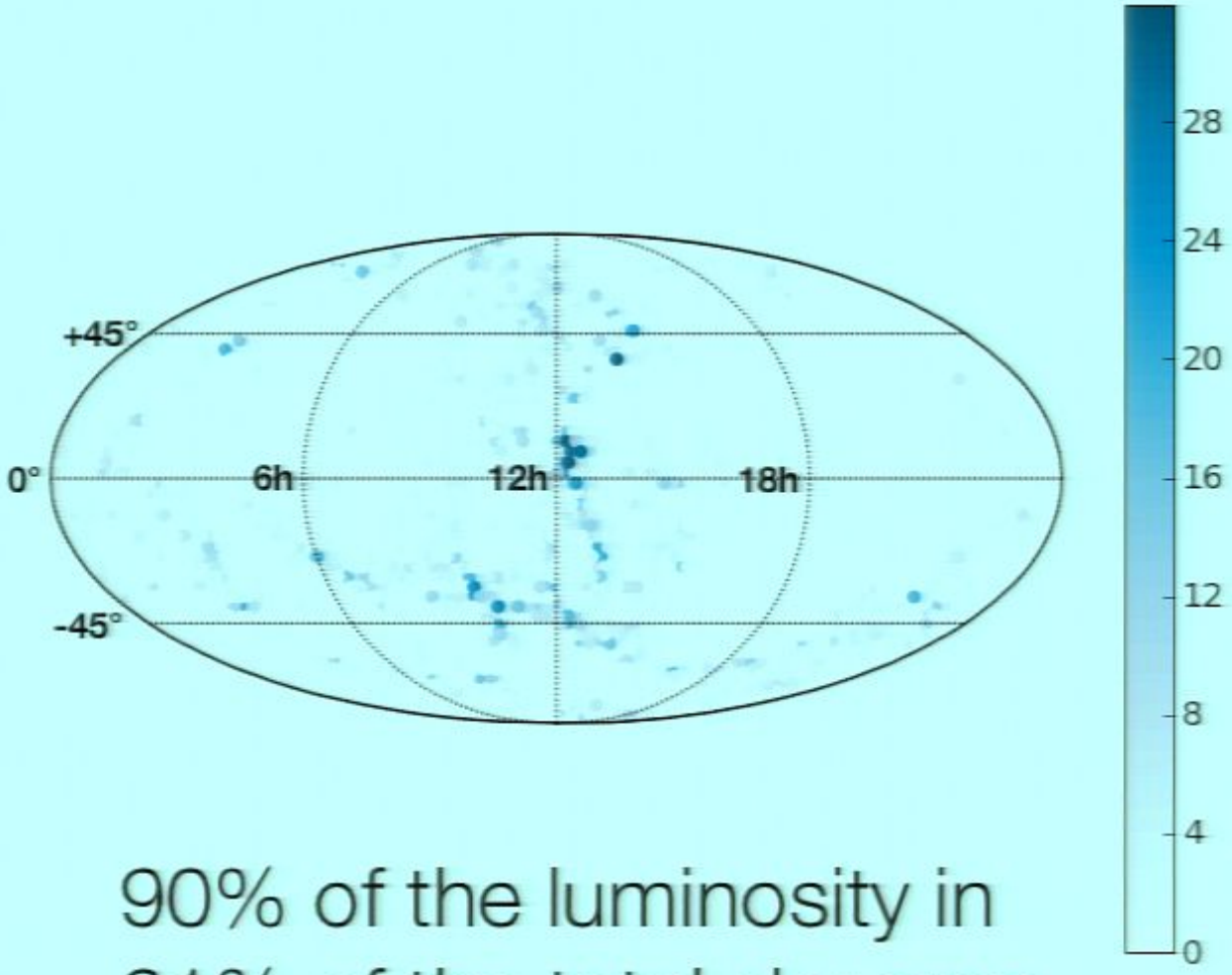
> Simulated signals (injections) put into real detector noise from week 6 of S6/VSR2

> Injection parameters taken from the low mass region of parameter space (systems more likely to contain a neutron star component)

> Focus on low signal-to-noise ratio (SNR) injections

> Characterize performance by the area contained in the pixels ranked above the true location ("Searched Area")

Blue luminosity at 40Mpc



90% of the luminosity in
21% of the total sky area

Sky localization performance

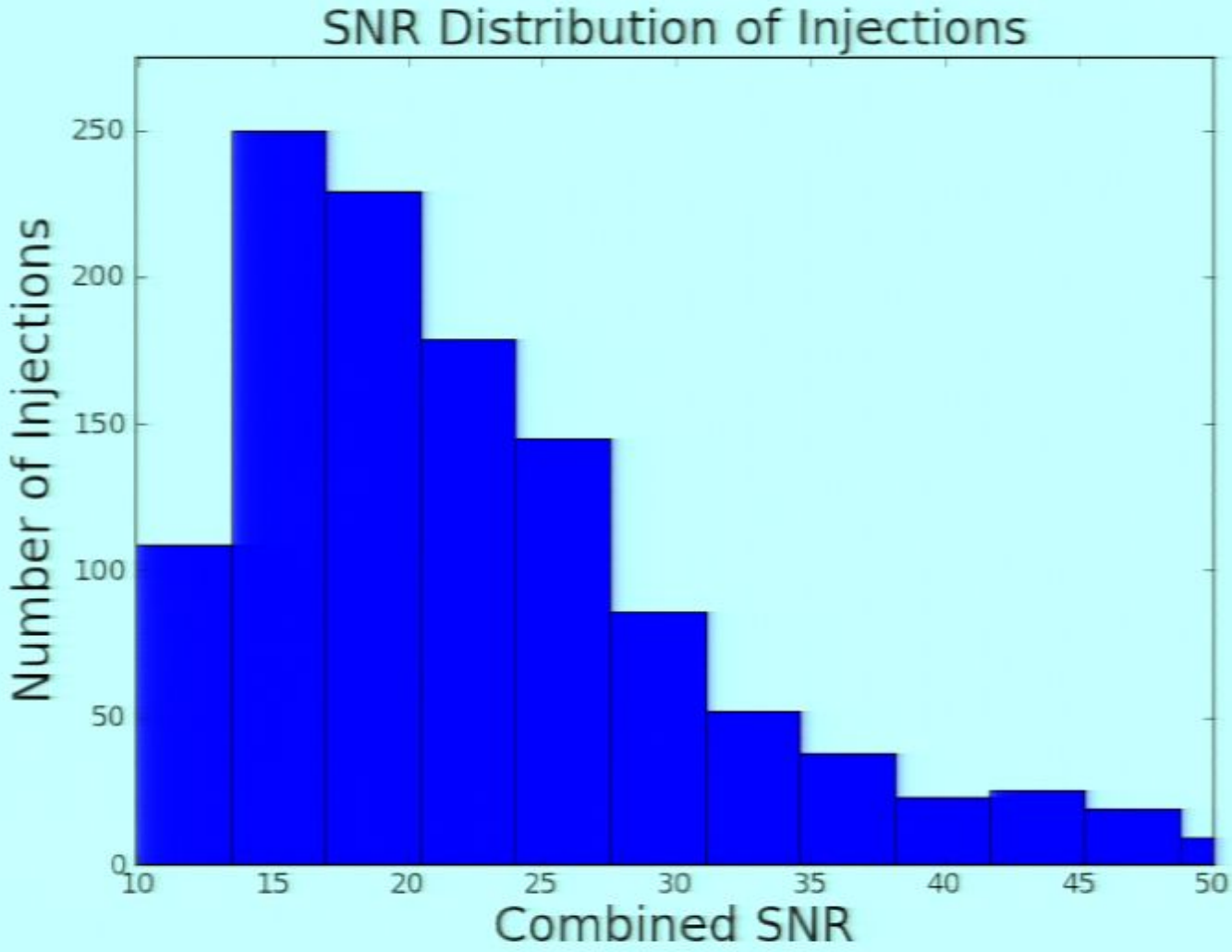
> Simulated signals (injections) put into real detector noise from week 6 of S6/VSR2

> Injection parameters taken from the low mass region of parameter space (systems more likely to contain a neutron star component)

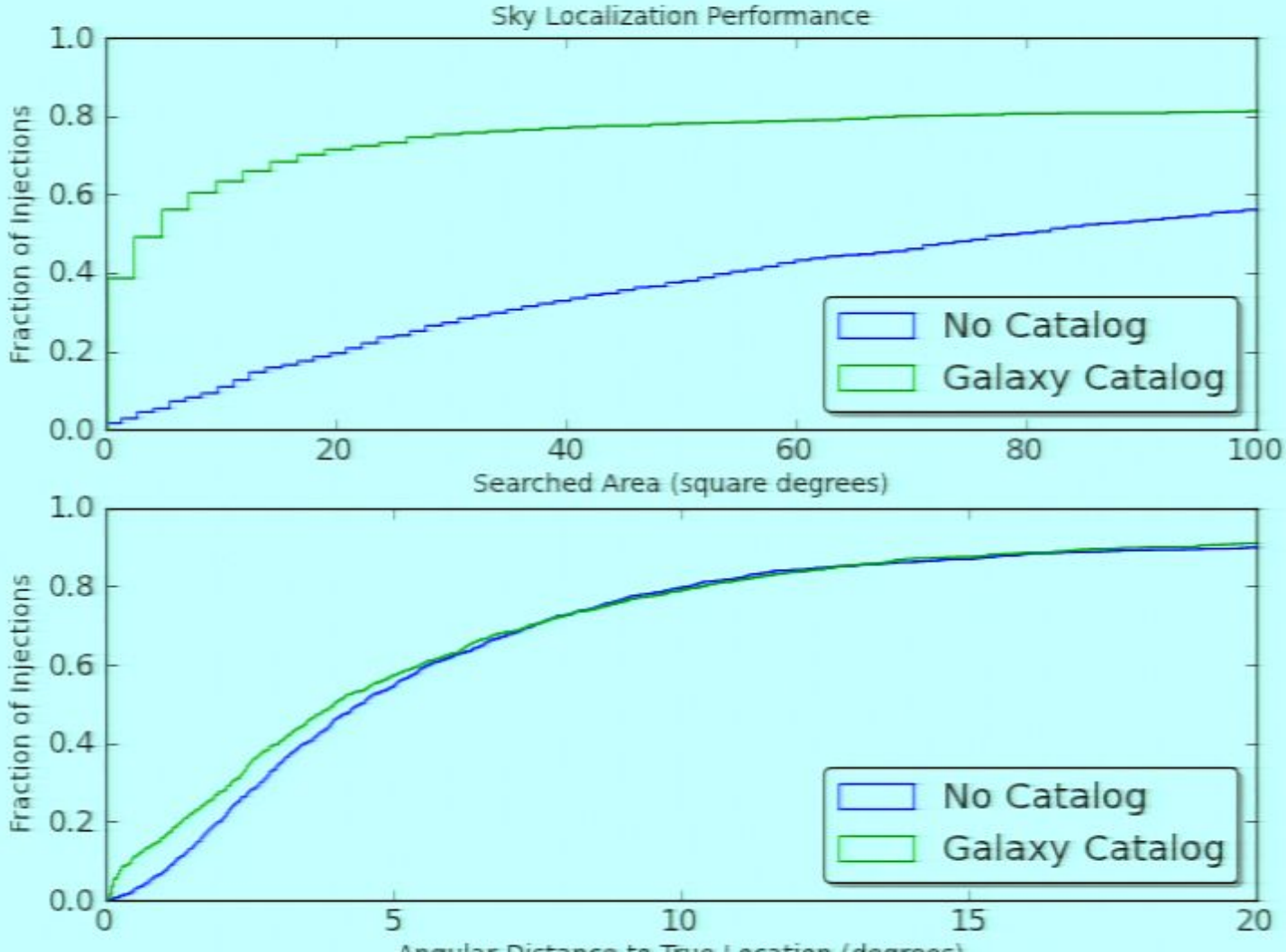
> Focus on low signal-to-noise ratio (SNR) injections

> Characterize performance by the area contained in the pixels ranked above the true location ("Searched Area")

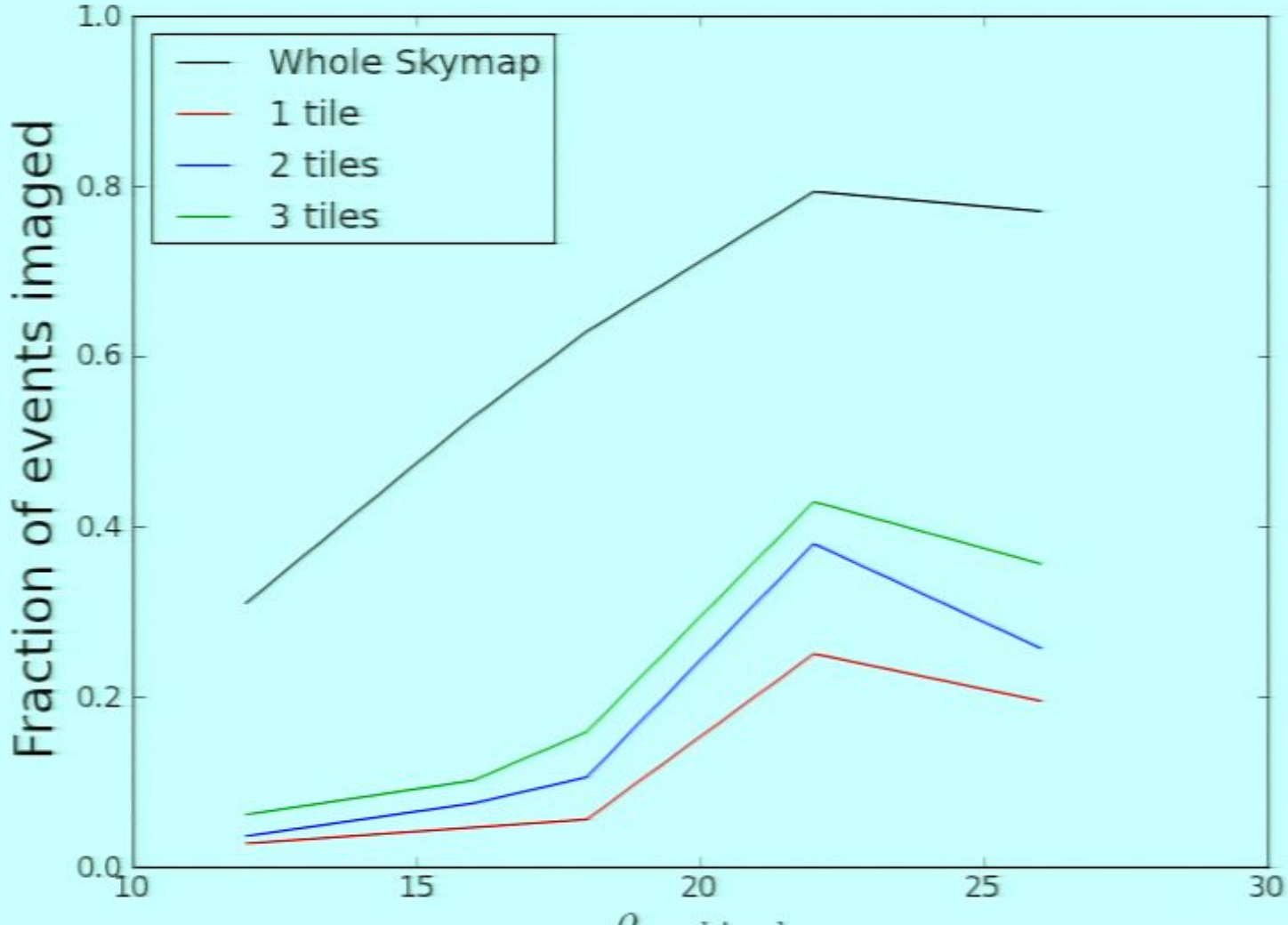
Sky localization performance



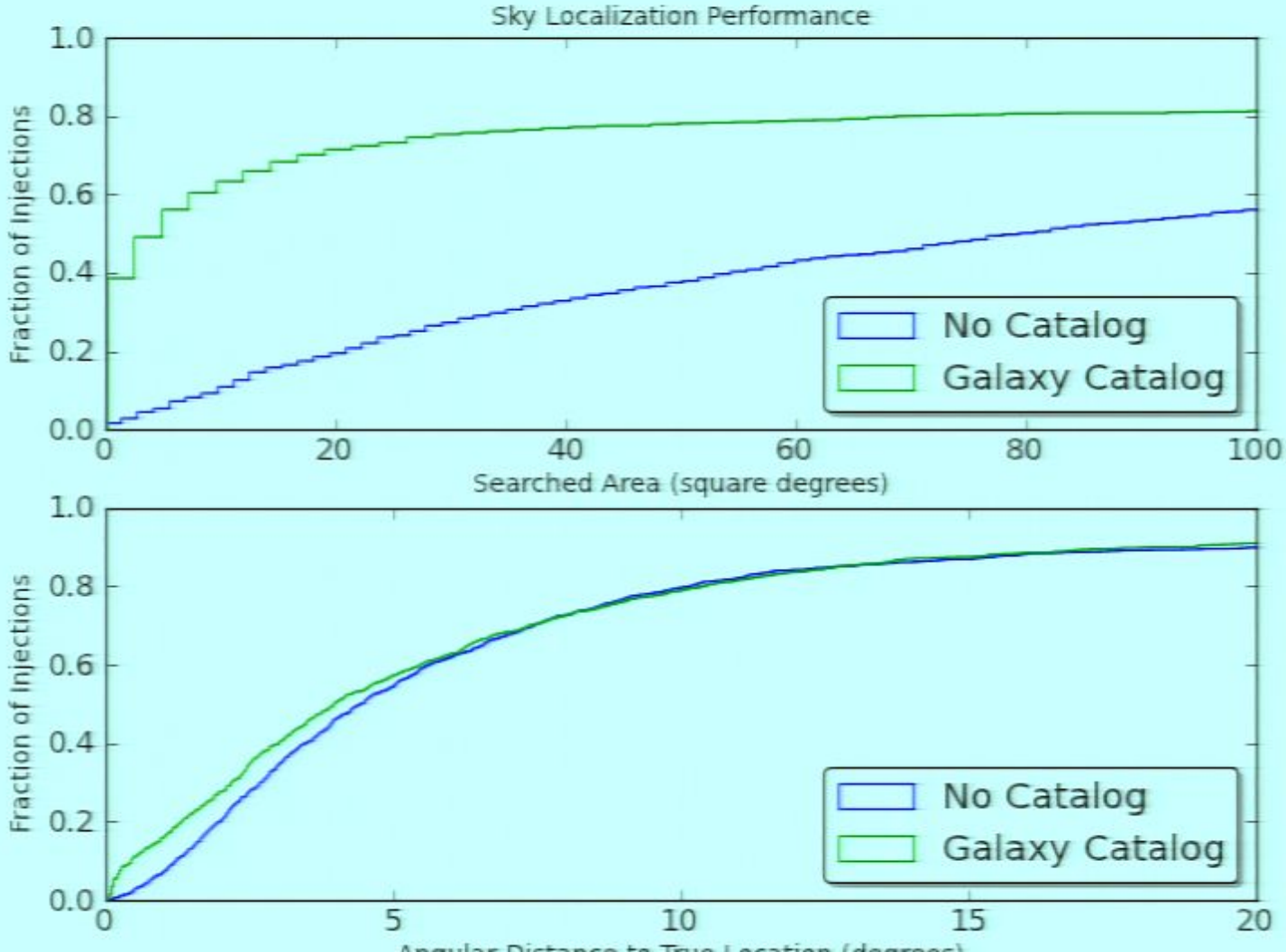
Sky localization performance



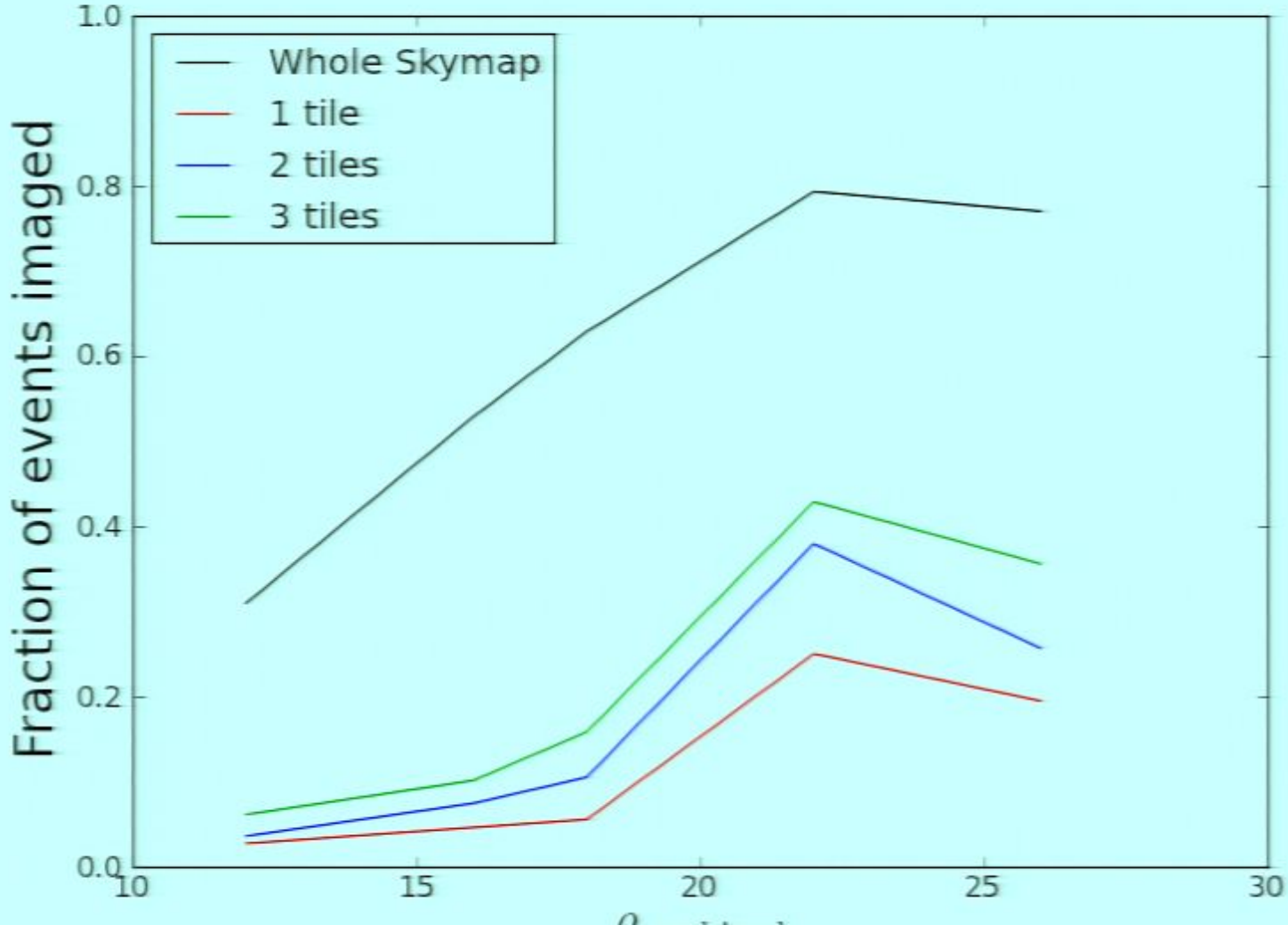
Sky localization performance



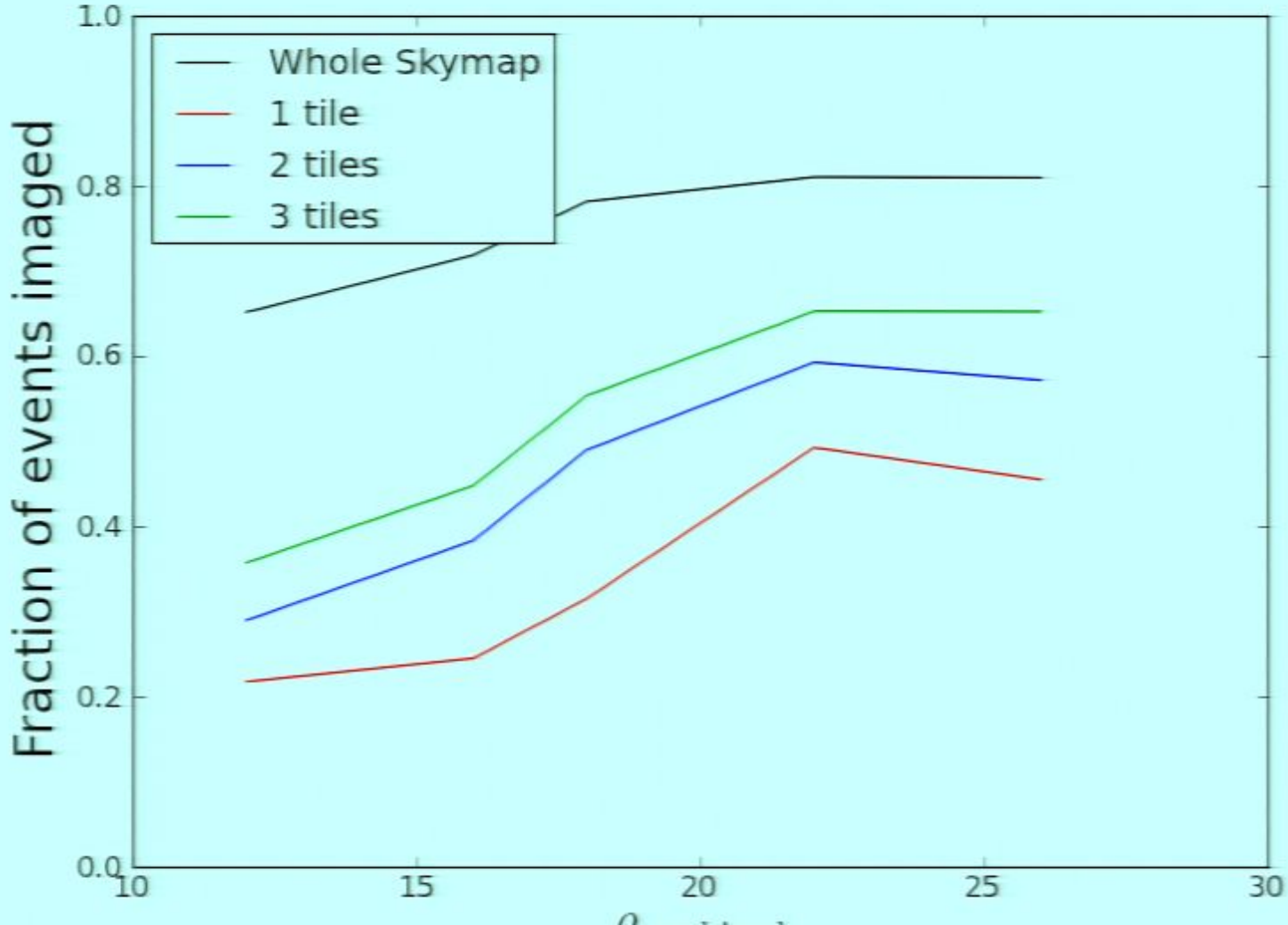
Sky localization performance



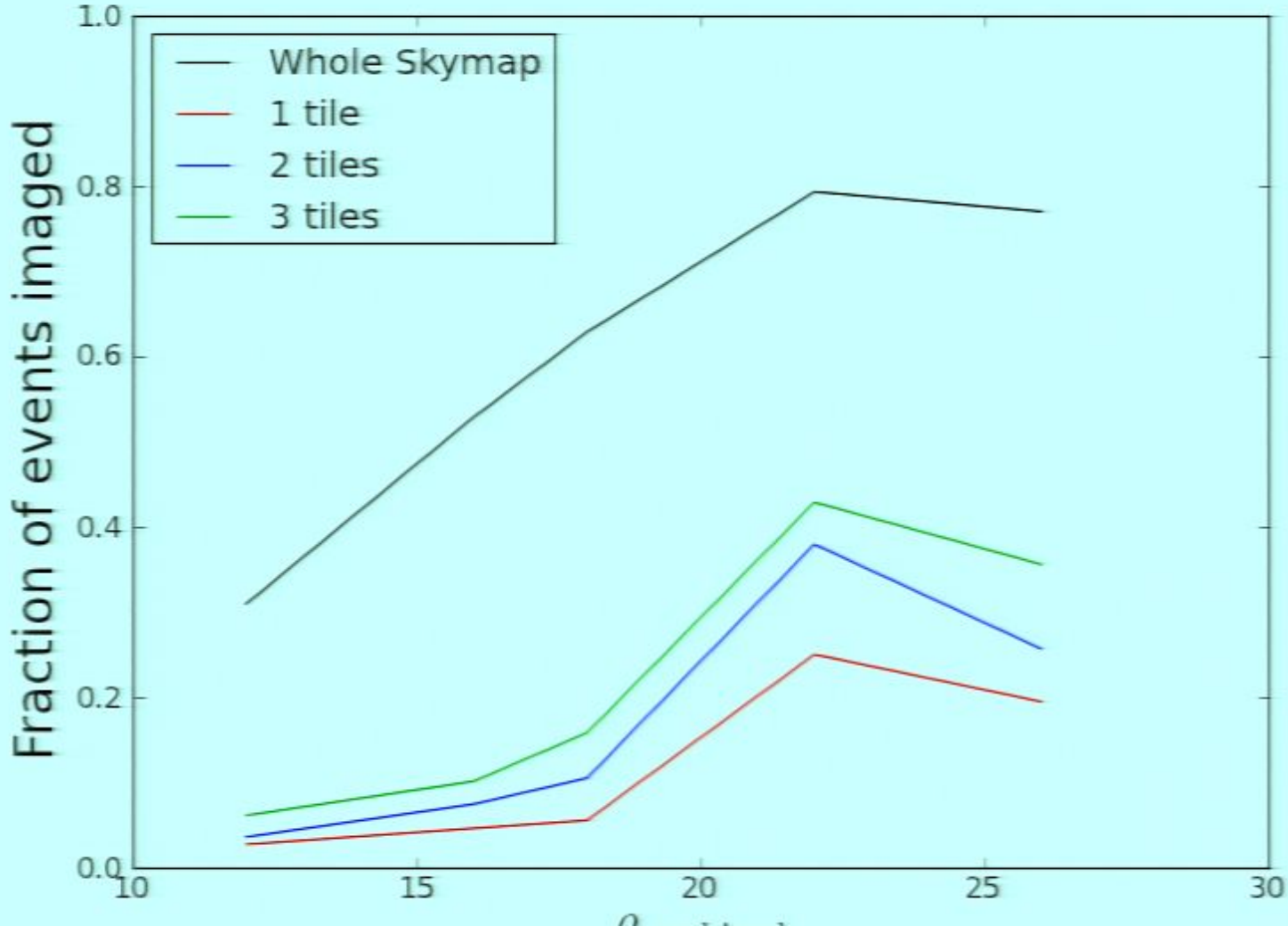
Sky localization performance



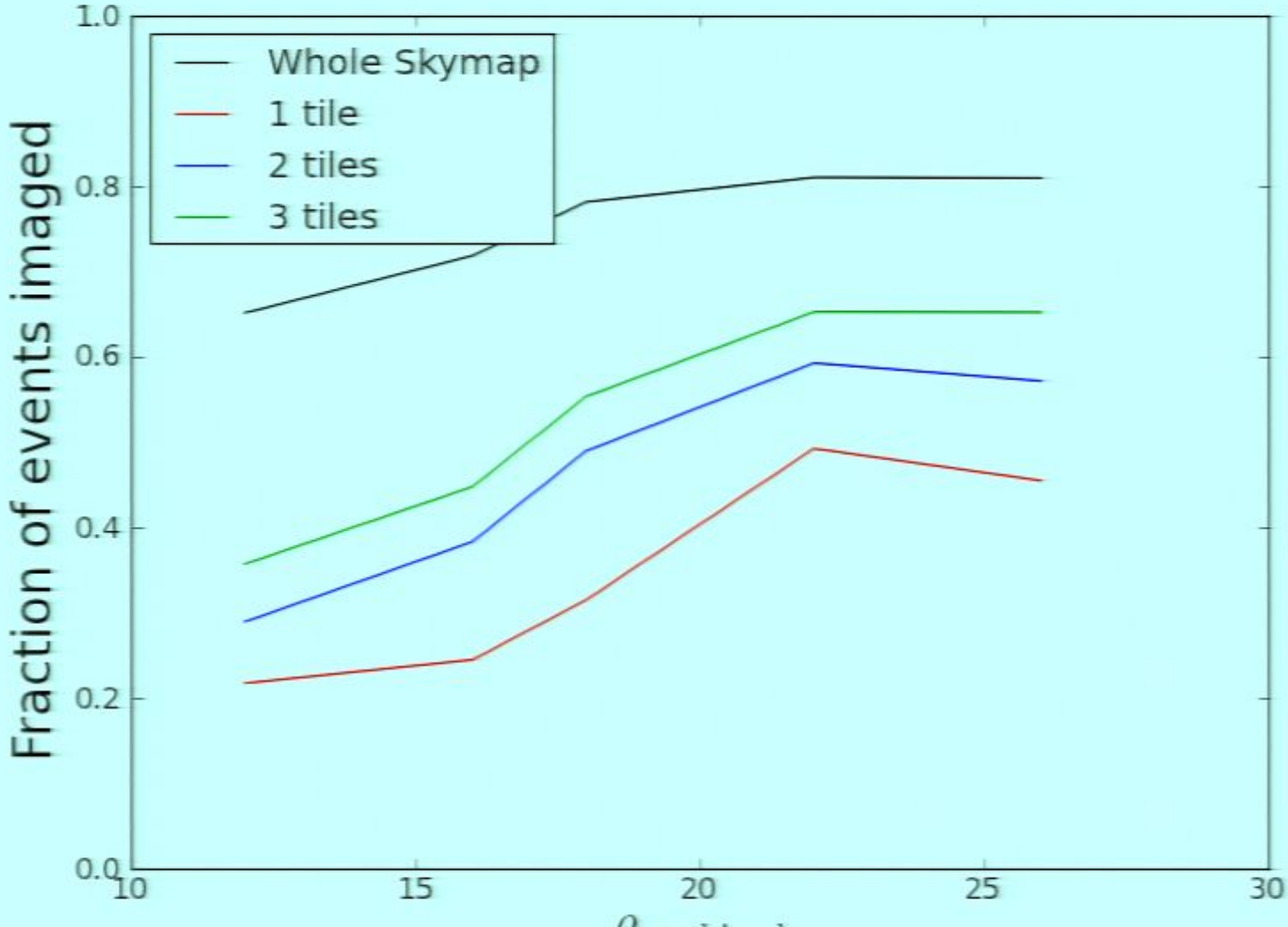
Sky localization performance



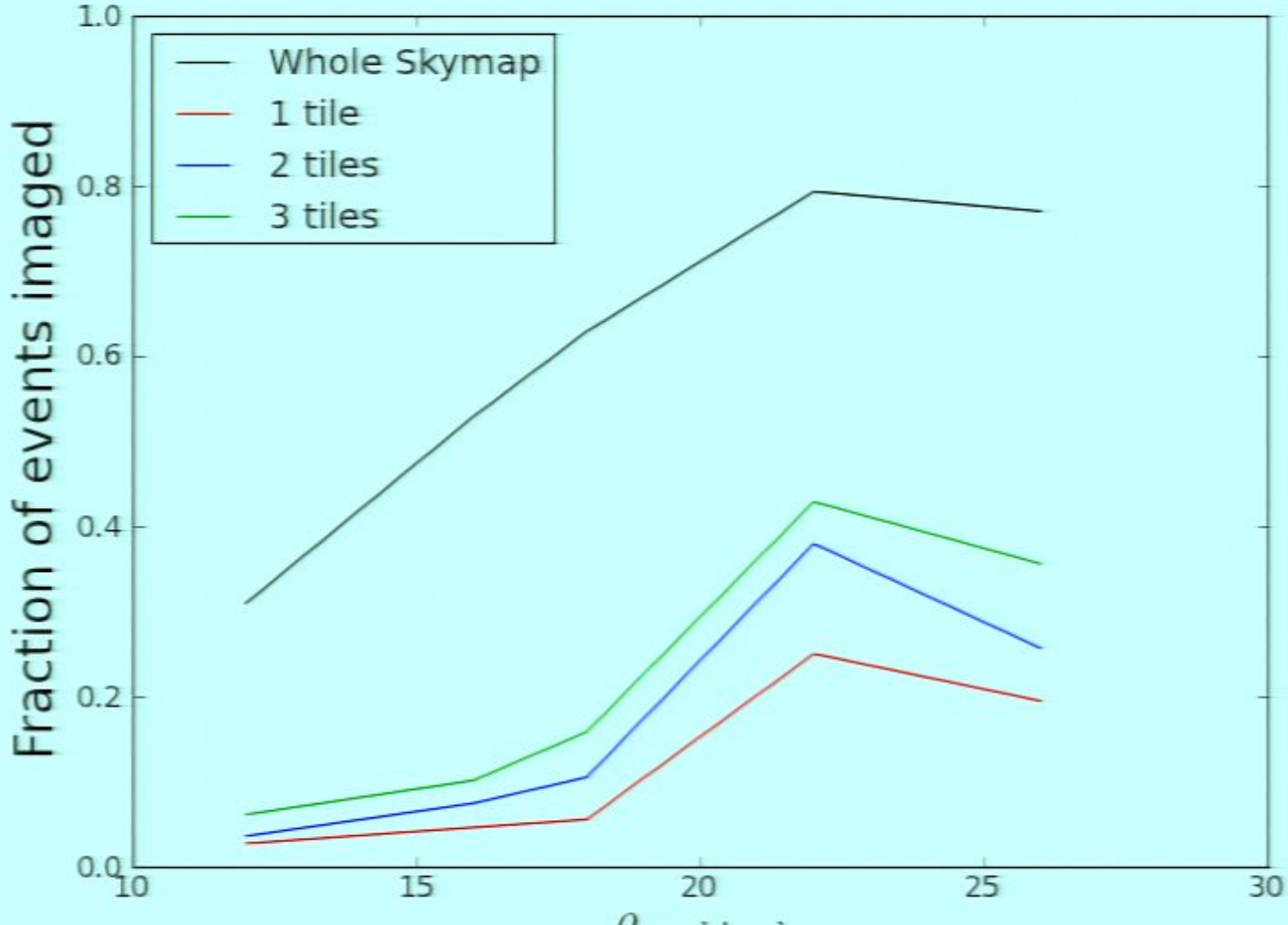
Sky localization performance



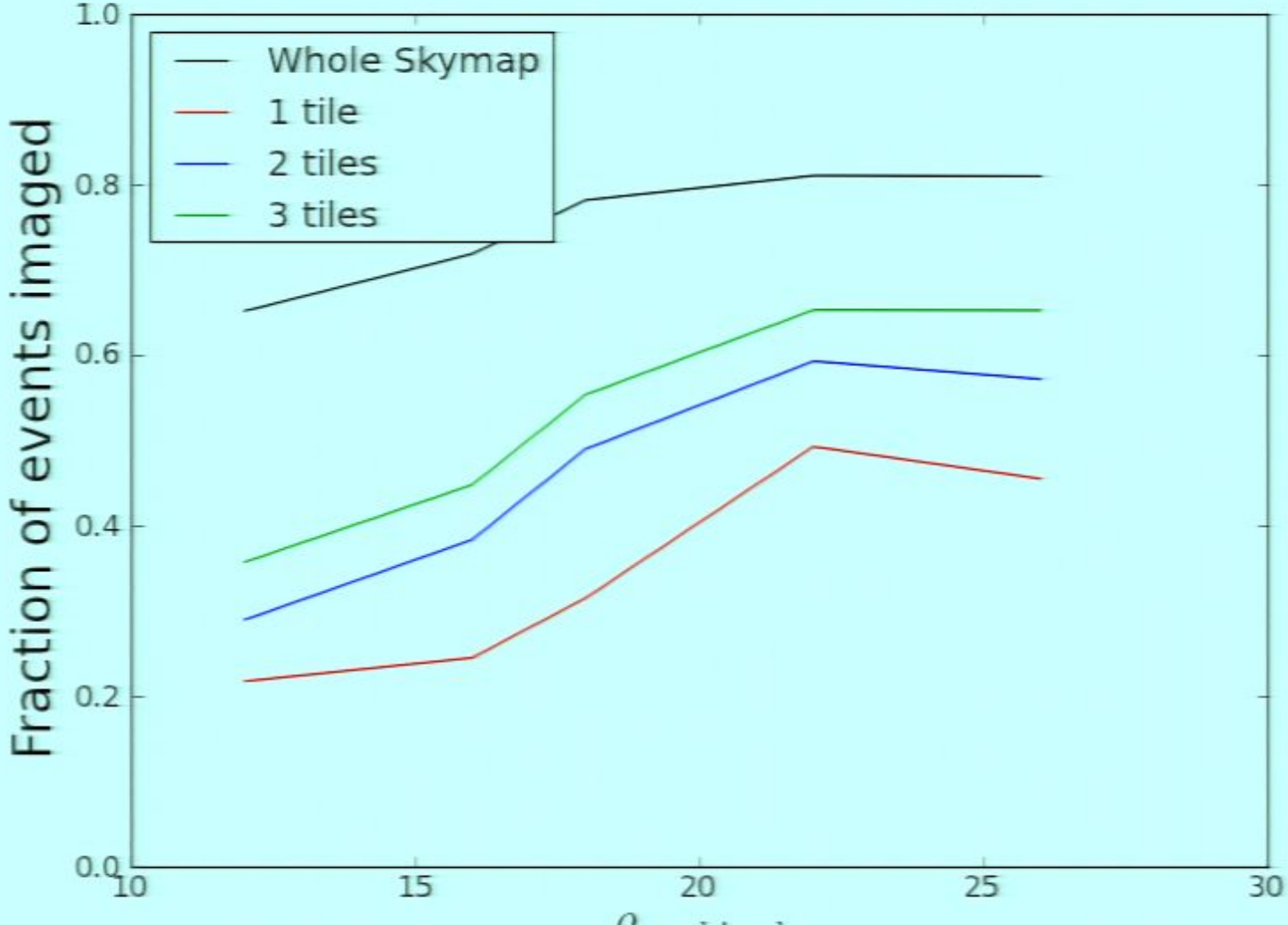
Sky localization performance



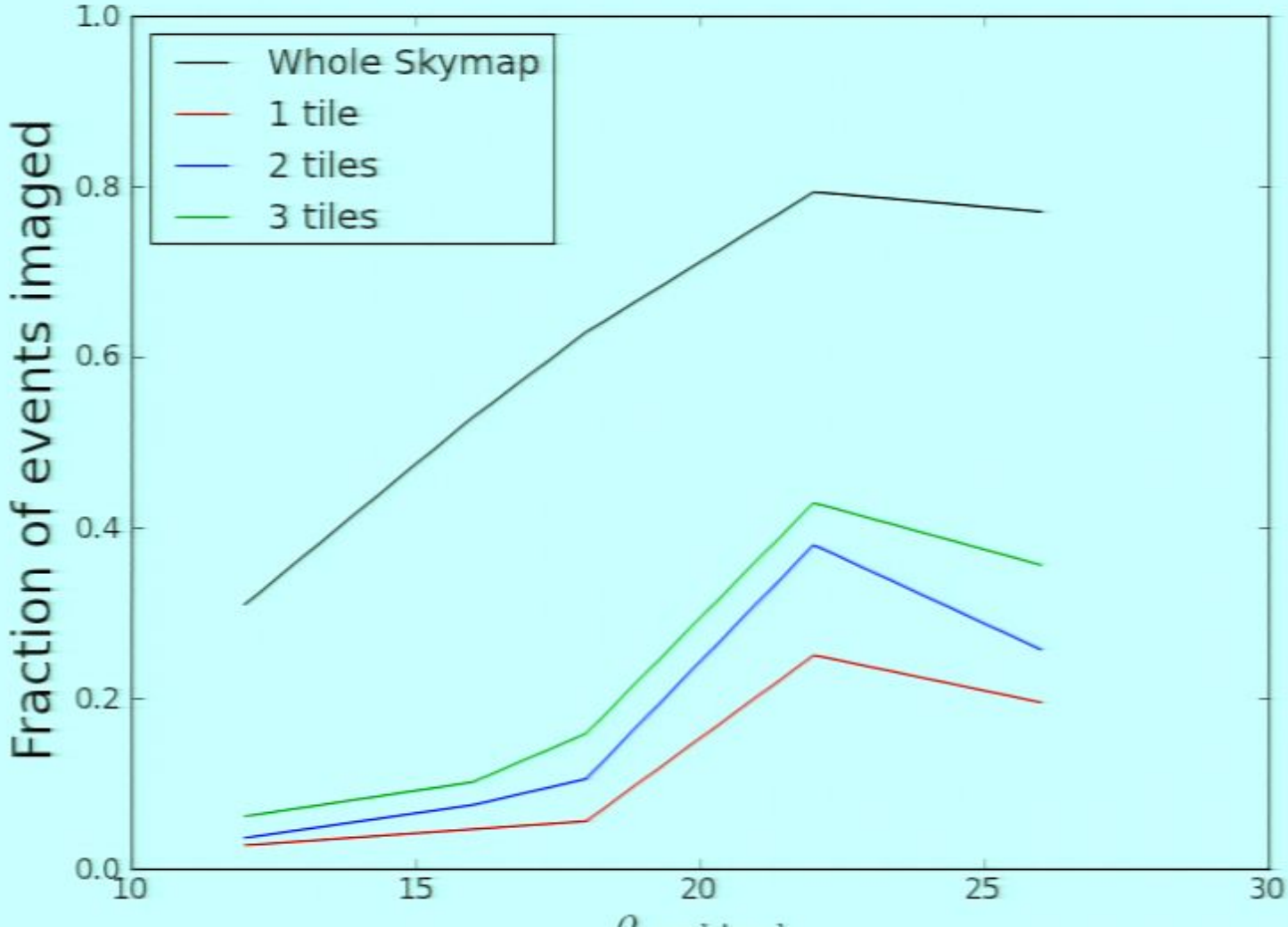
Sky localization performance



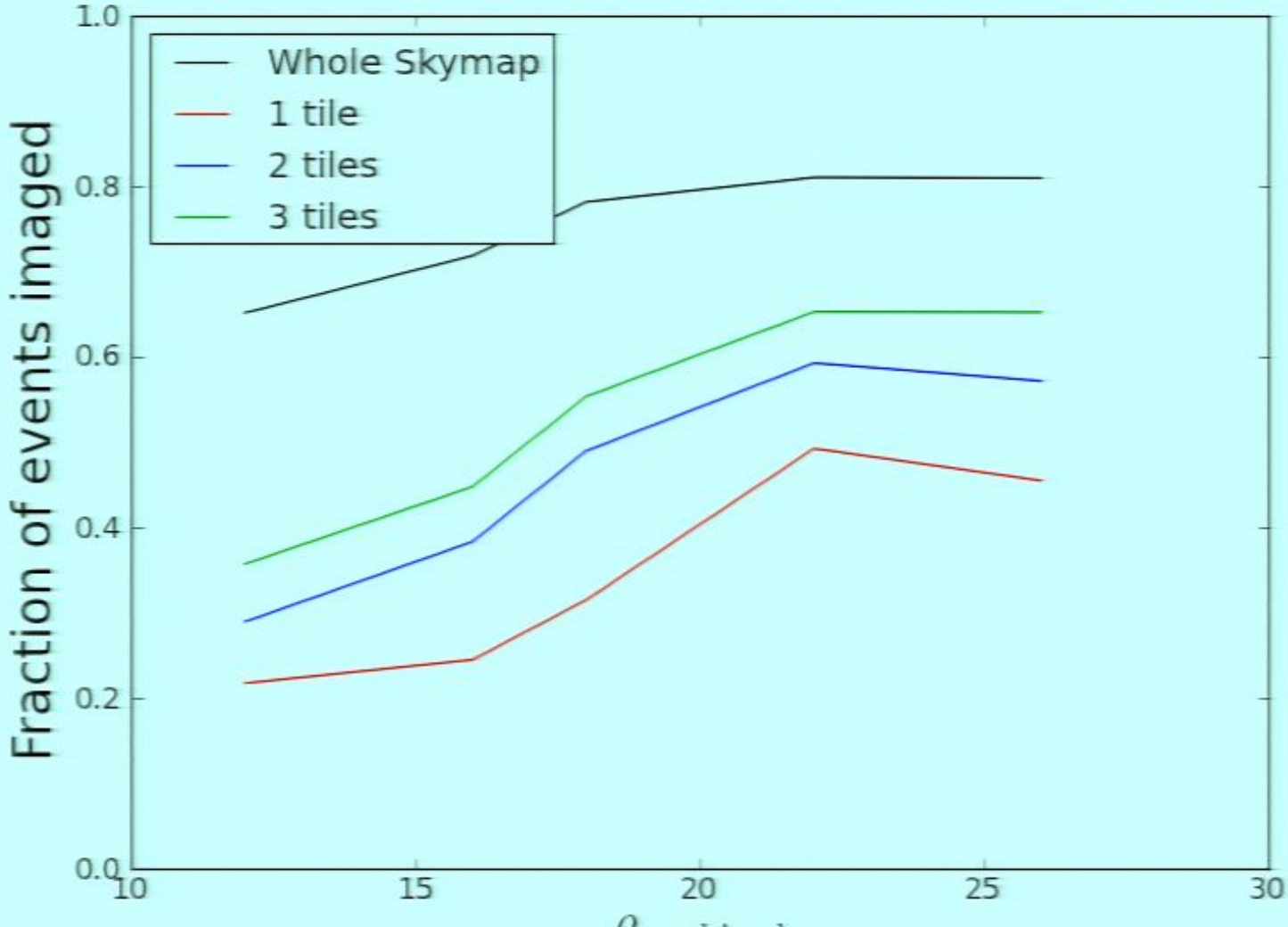
Sky localization performance



Sky localization performance



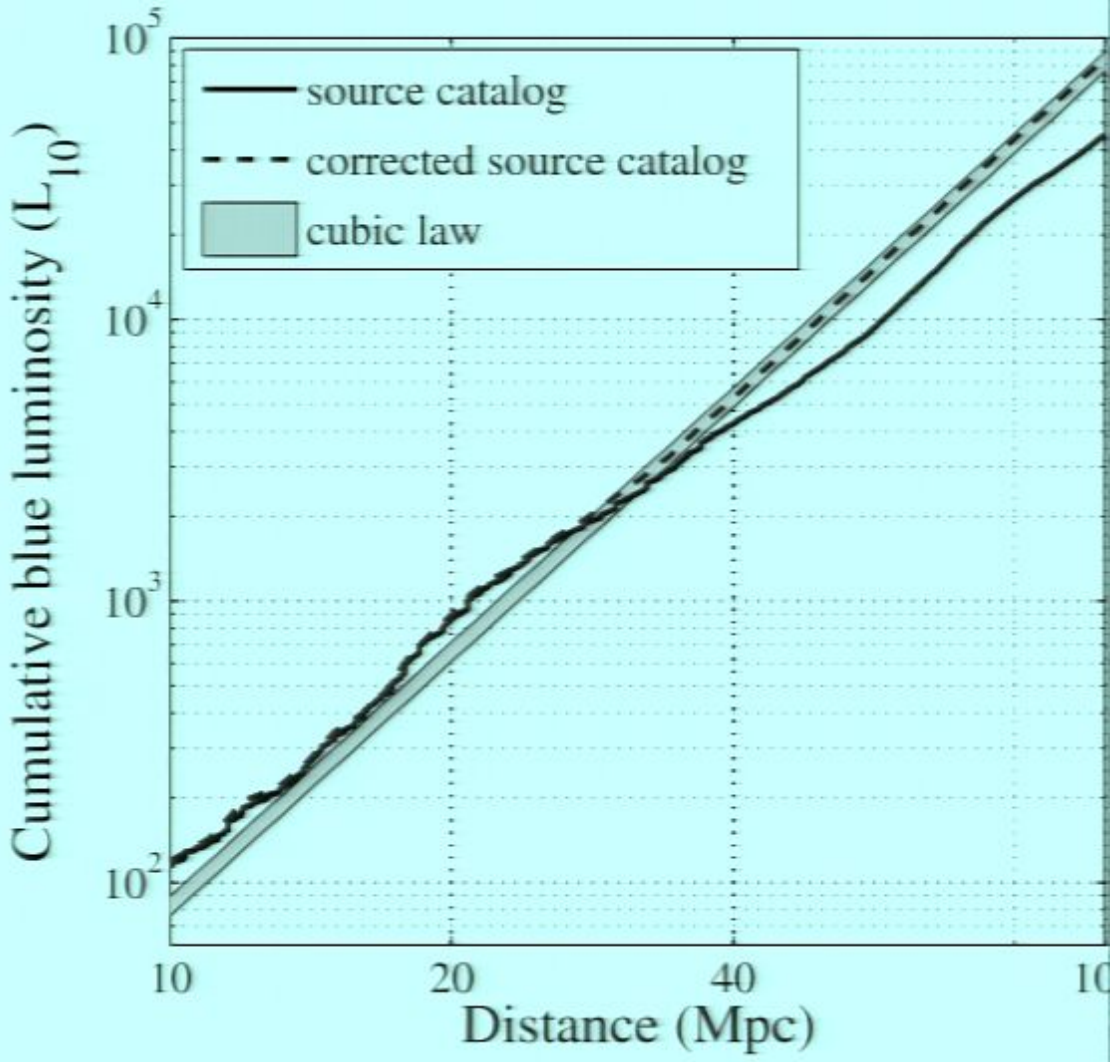
Sky localization performance



The Completeness Problem

Catalog is roughly 80% complete to 40Mpc and only about 50% complete at 100Mpc.

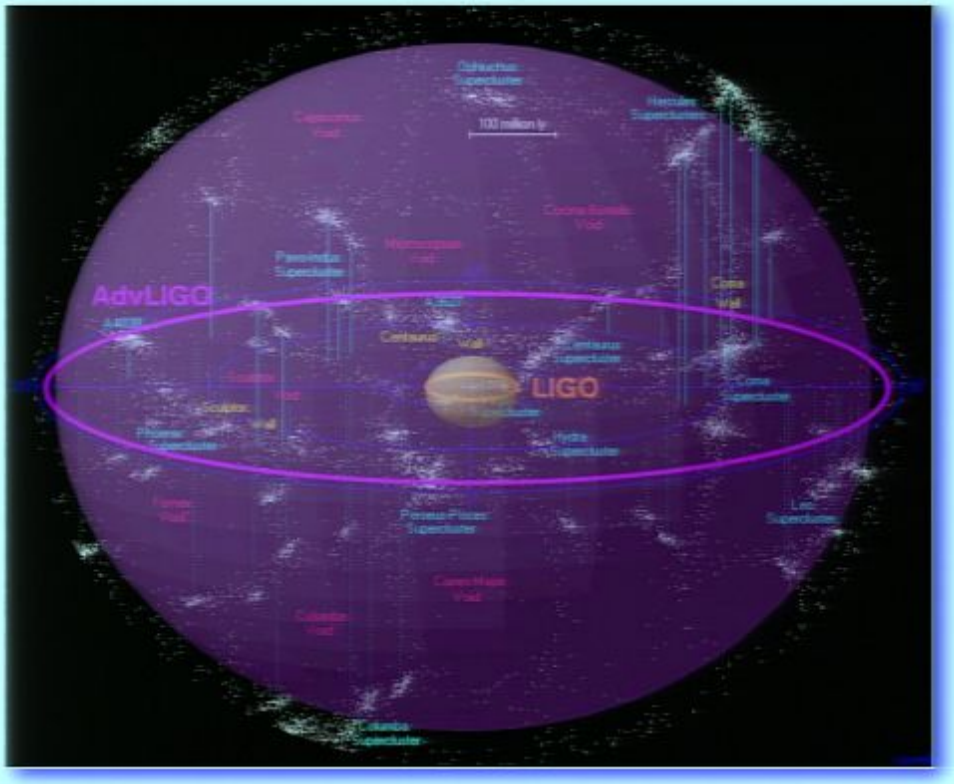
Advanced LIGO can see BNSs to ~400Mpc



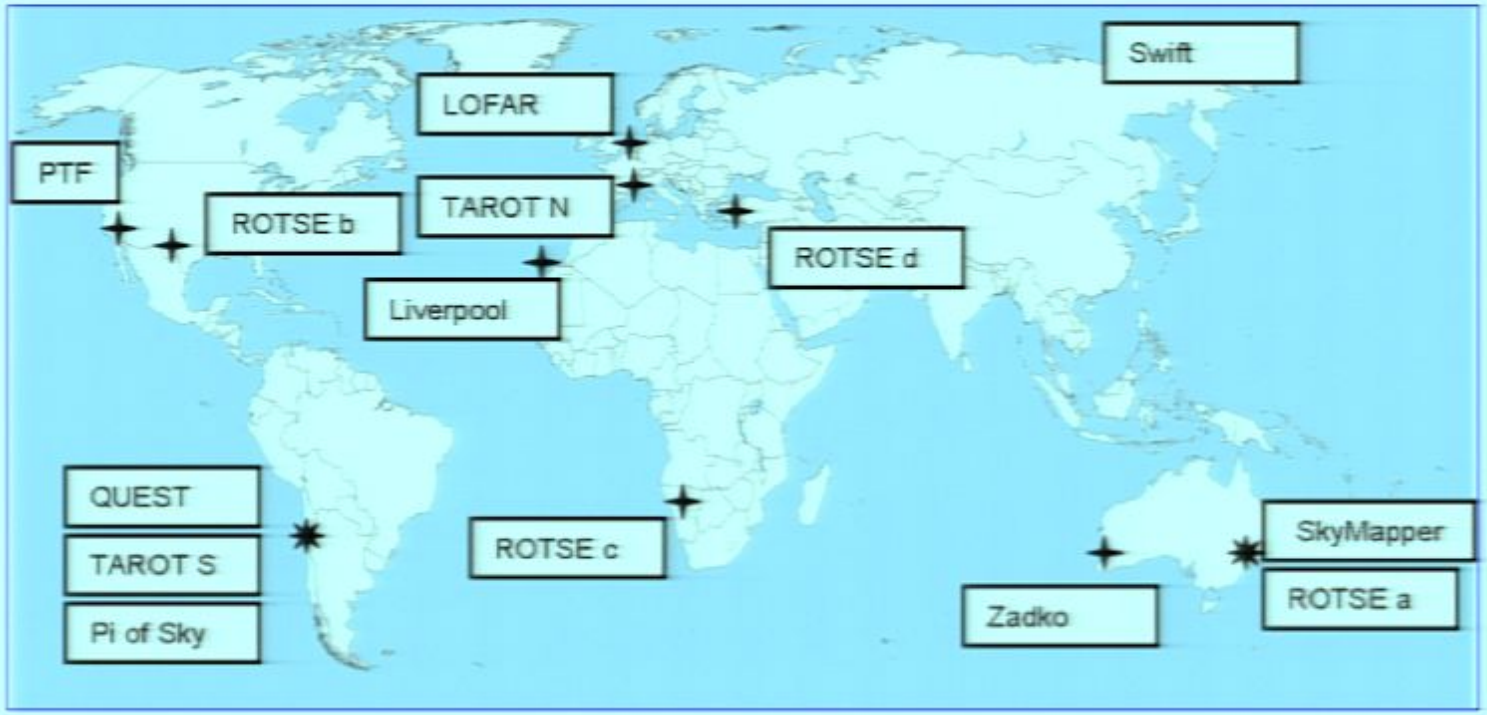
Kopparapu et al (20

Looking towards Advanced LIGO

- Better galaxy catalogs?
  Kulkarni & Kasliwal (2009)
- Improved astrophysical priors, e.g. to account for kicks
- EM expectations?
  Metzger et al (2010)
  Nakar & Piran(2011)
- Better coordination with EM astronomers, e.g. observing and analysis strategies
- GW latency expectations
- Better EM coverage/More EM partners



The telescope network

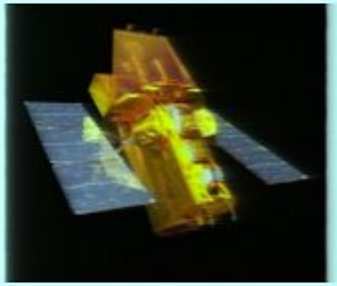


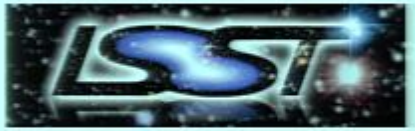
Possibilities for the advanced detector era

Credit: Lucia Santamaria

The era of multi-messenger astronomy

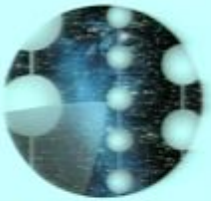
The era of multi-messenger astronomy





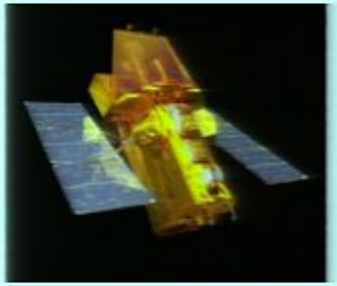
LSC LIGO Scientific Collaboration

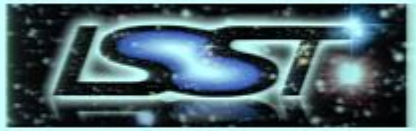
VIRGO

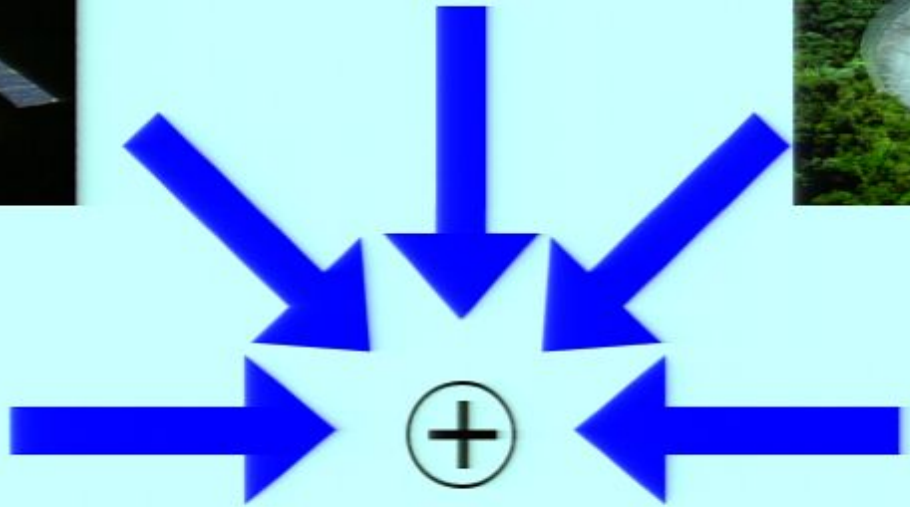


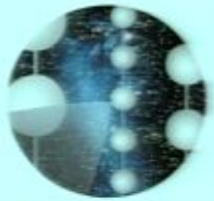
IceCube

The era of multi-messenger astronomy

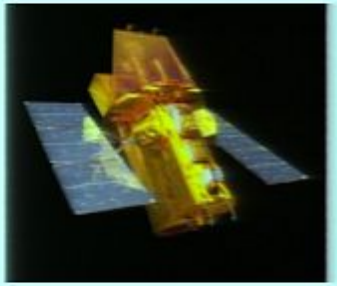








The era of multi-messenger astronomy



LSST

LSC LIGO Scientific Collaboration

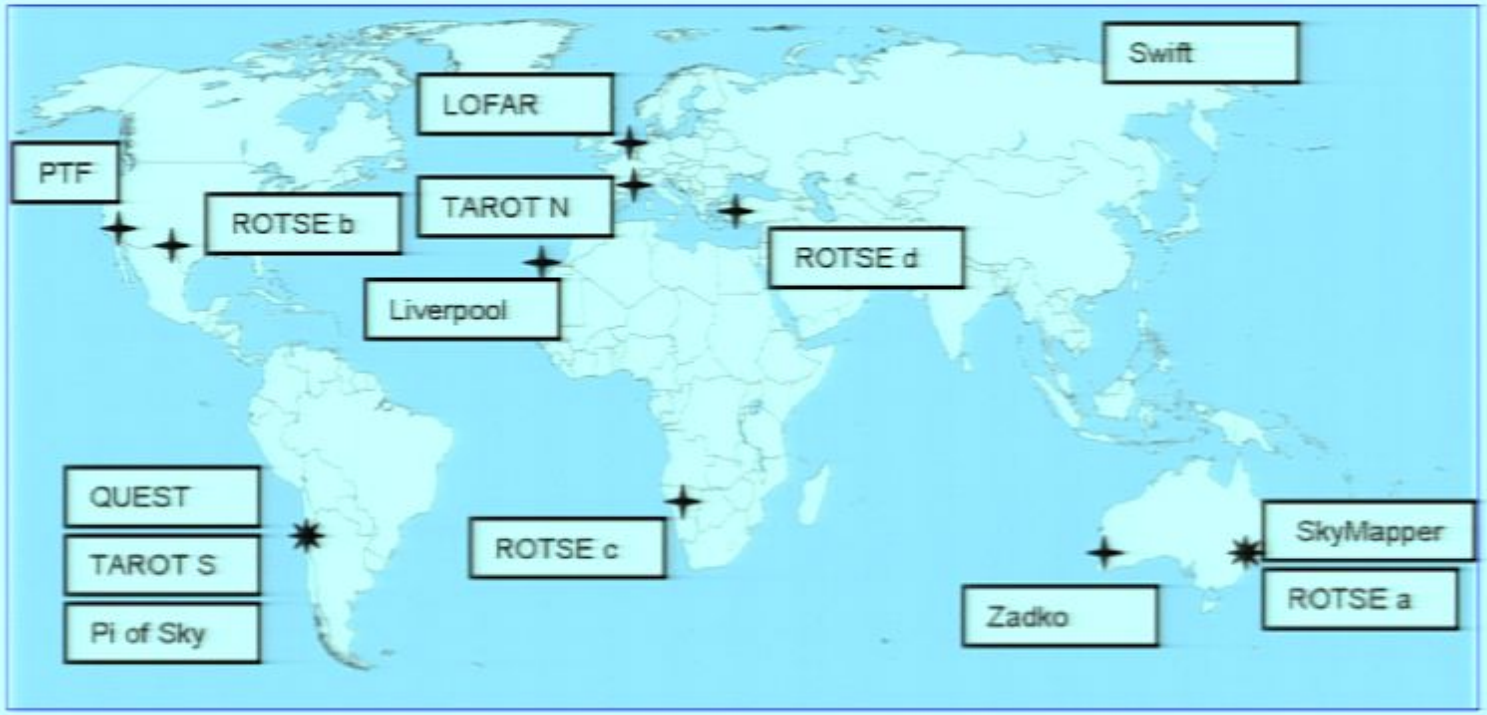
VIRGO

IceCube

- understanding GRBs
- precision cosmology

The era of multi-messenger astronomy

The telescope network



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