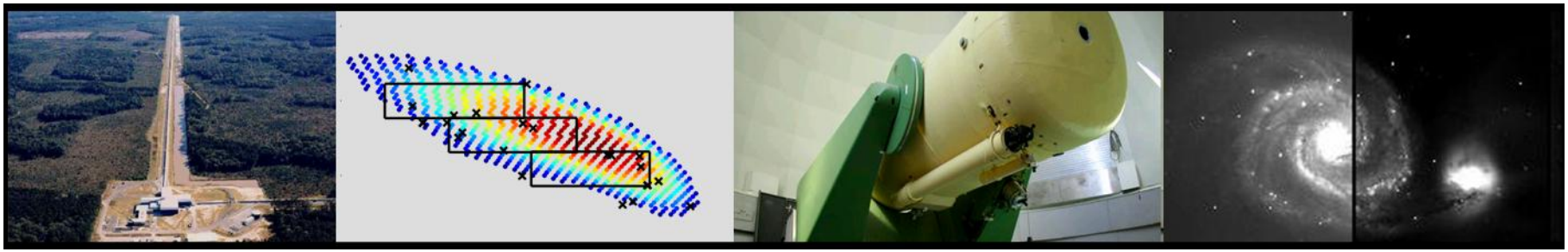


Dawn of GW Astrophysics: Multi-messenger Astronomy Part 2

Neil Gehrels

NASA-GSFC

Dawn Conference

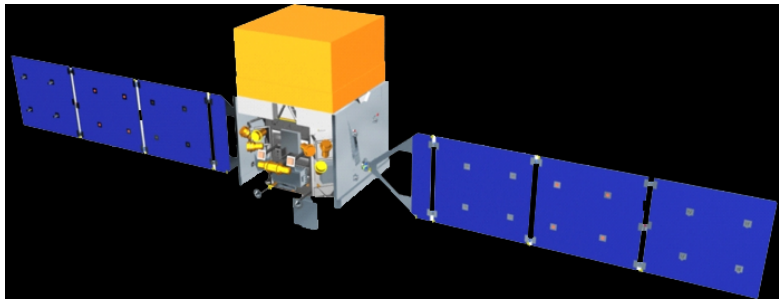
May 7, 2015

Binary NS Mergers – GW and GRB Sources

Two ways of EM observations of GW events

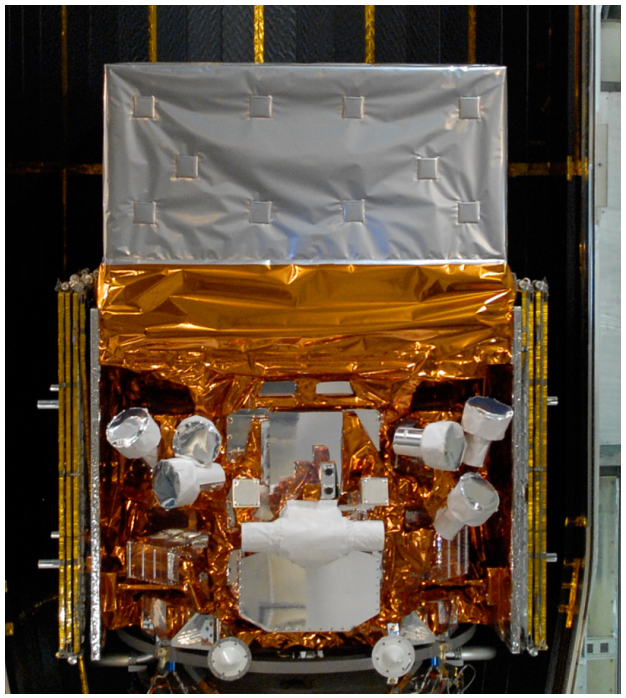
Counterpart identification between GW and EM can go both ways:

1) Detection of prompt GRB signal coincident with GW event



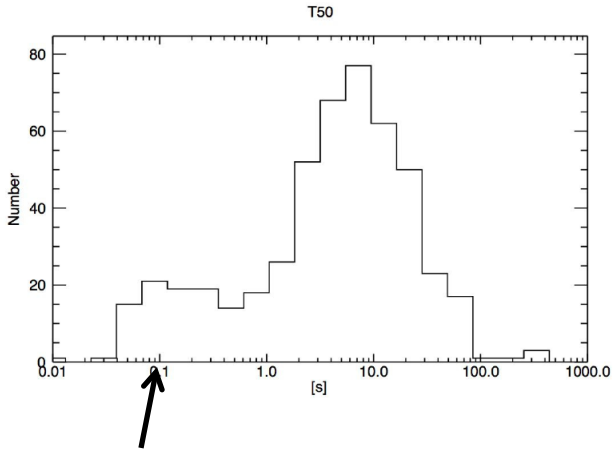
2) Multi-wavelength follow-up observations of GW events

Best instrument for prompt short GRBs is GBM



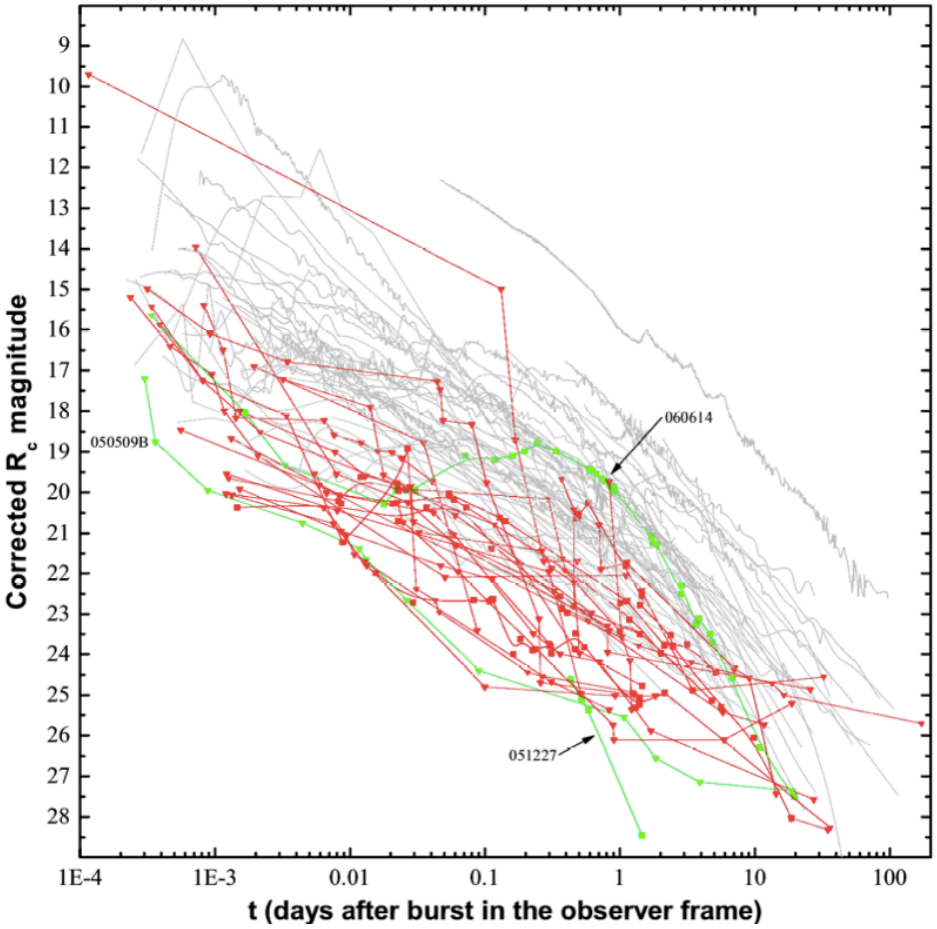
Meegan+ 09

- Views entire unocculted sky
- 350 GRBs per year
- High fraction of short GRBs
- Accurate time stamp

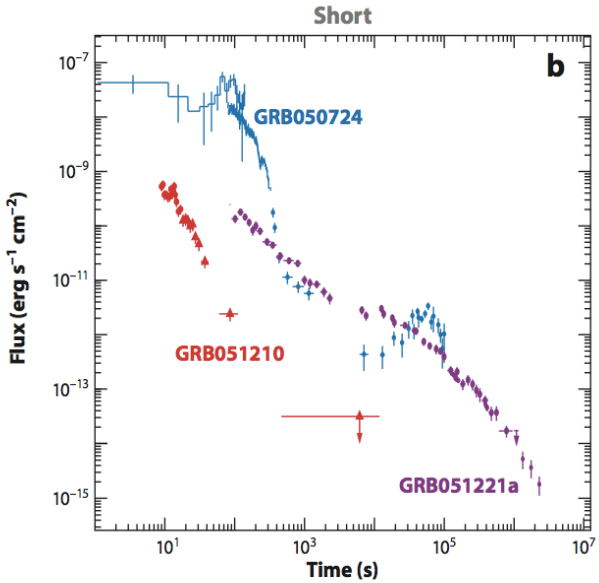


~25% short GRBs

EM afterglows are bright when on-axis

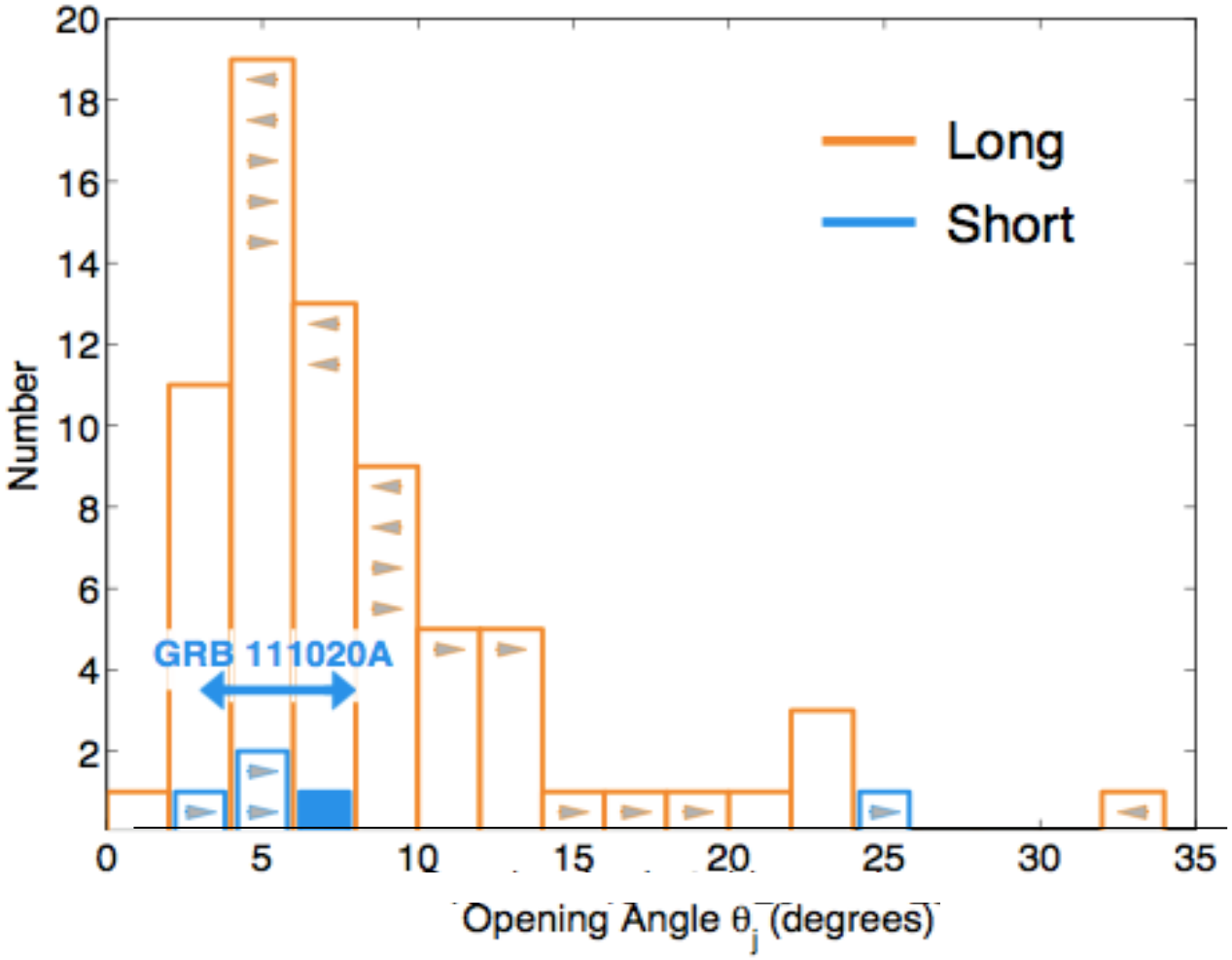


Kann+ '08



Gehrels, Ramirez-Ruiz & Fox '09

But, beaming angle is small

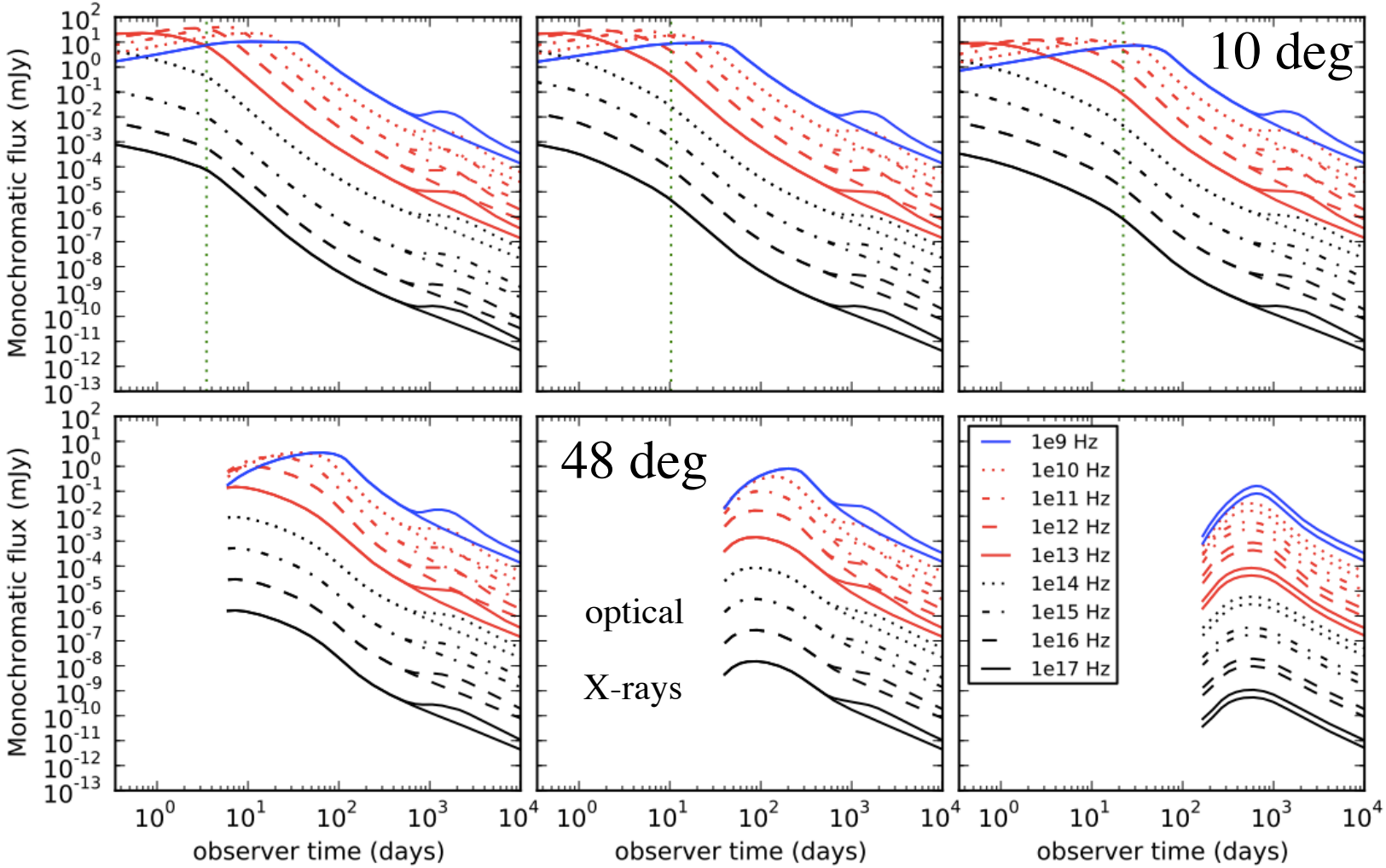


Short GRBs

- $\theta_B \sim 5$ deg
- 1/250 in beam

Fong+ 12

and off-axis afterglows are weak

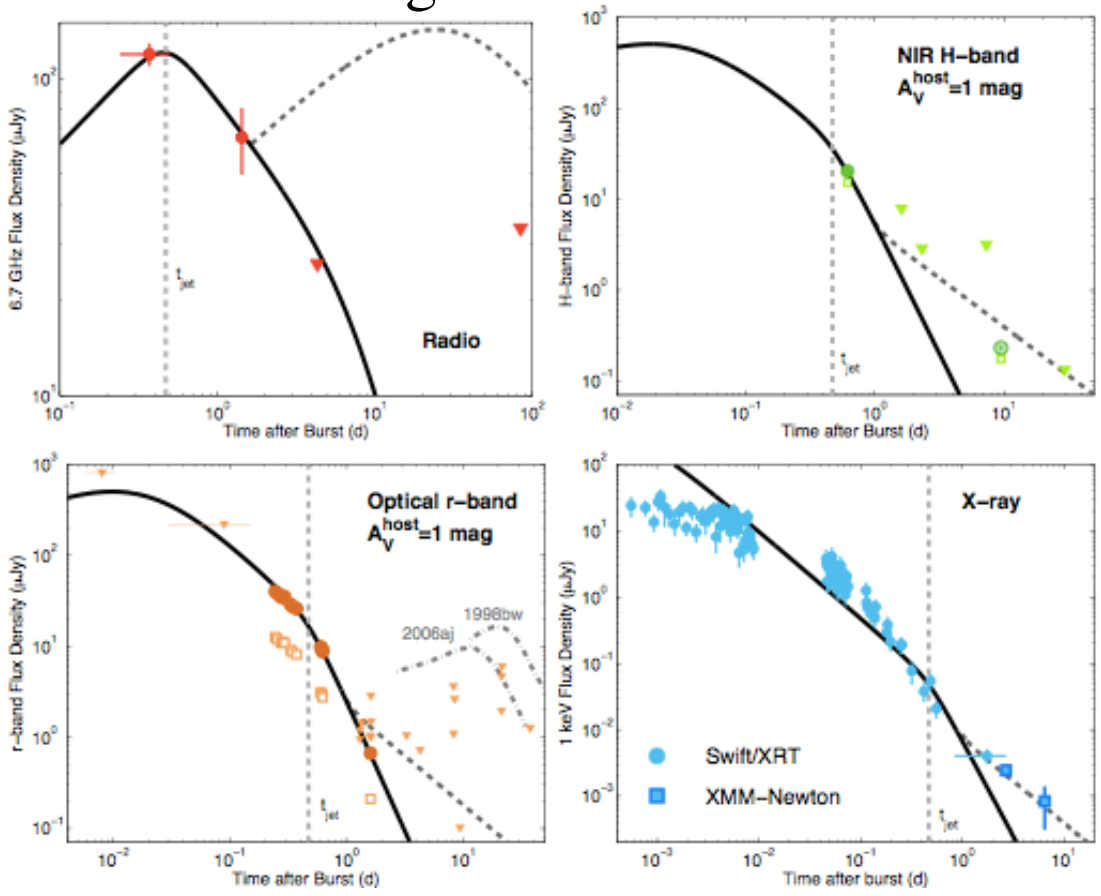


van Eerten, Zhang, MacFadyen '10

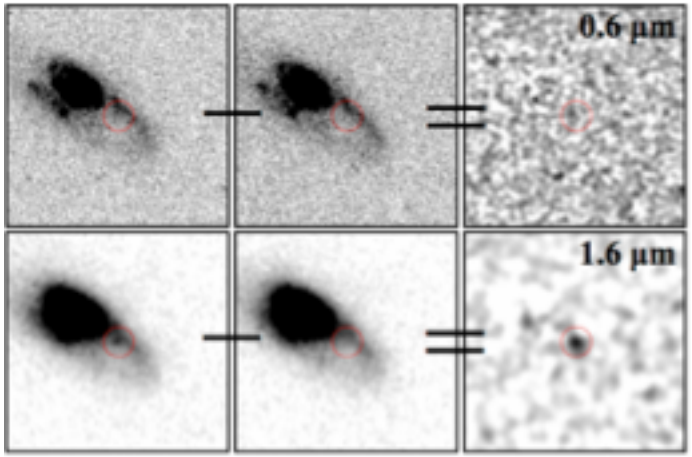
Kilonovas are isotropic, but weak

Swift GRB 130603B

Light Curve Excess



Unusually Red Afterglow
HST



kilonovae @ 200 Mpc
J ~21

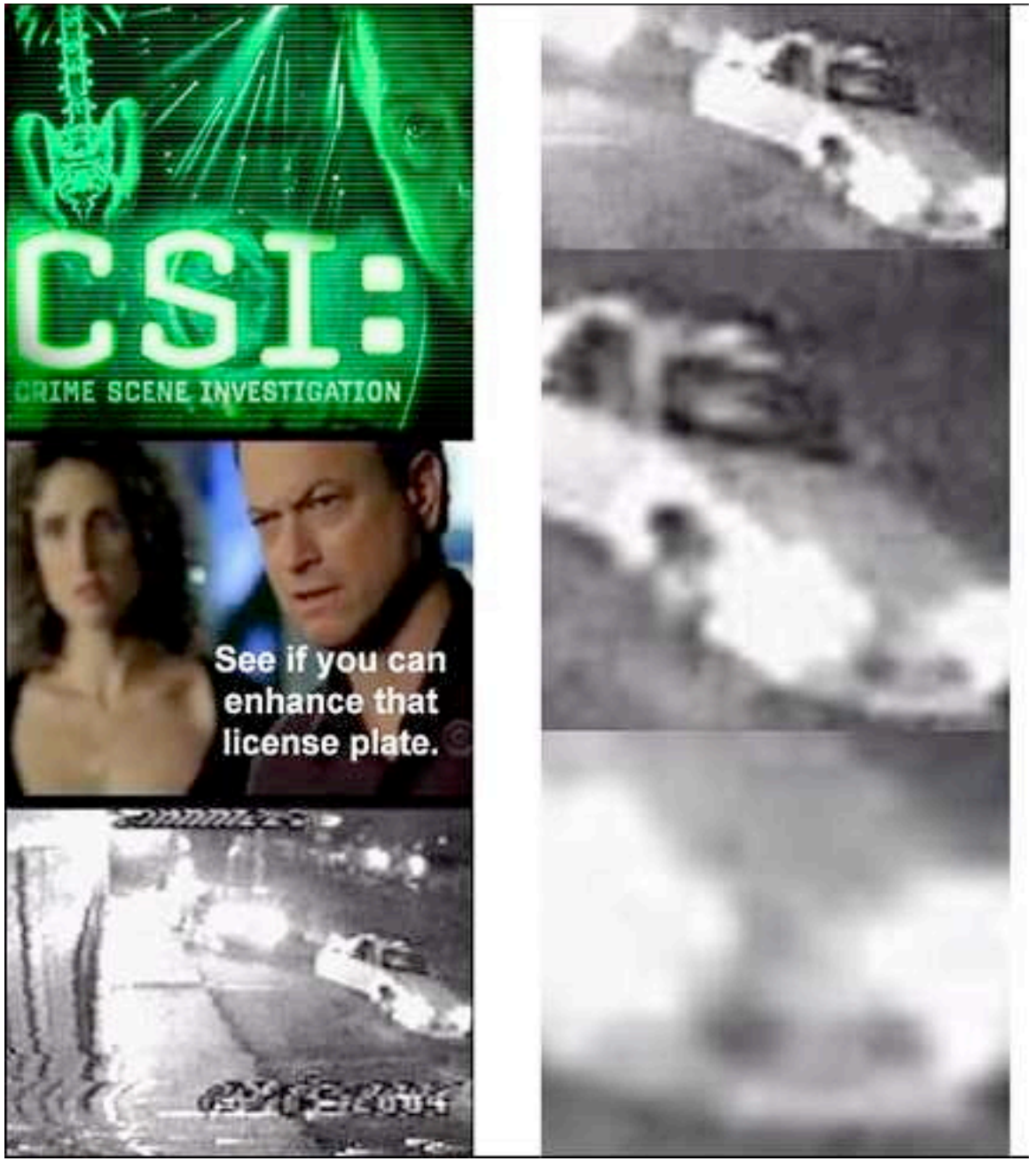
Berger+ '13, Tanvir+ '13, Fong+ '13

What we need are telescopes that are

- sensitive
- red or NIR response
- wide-field
- fast response

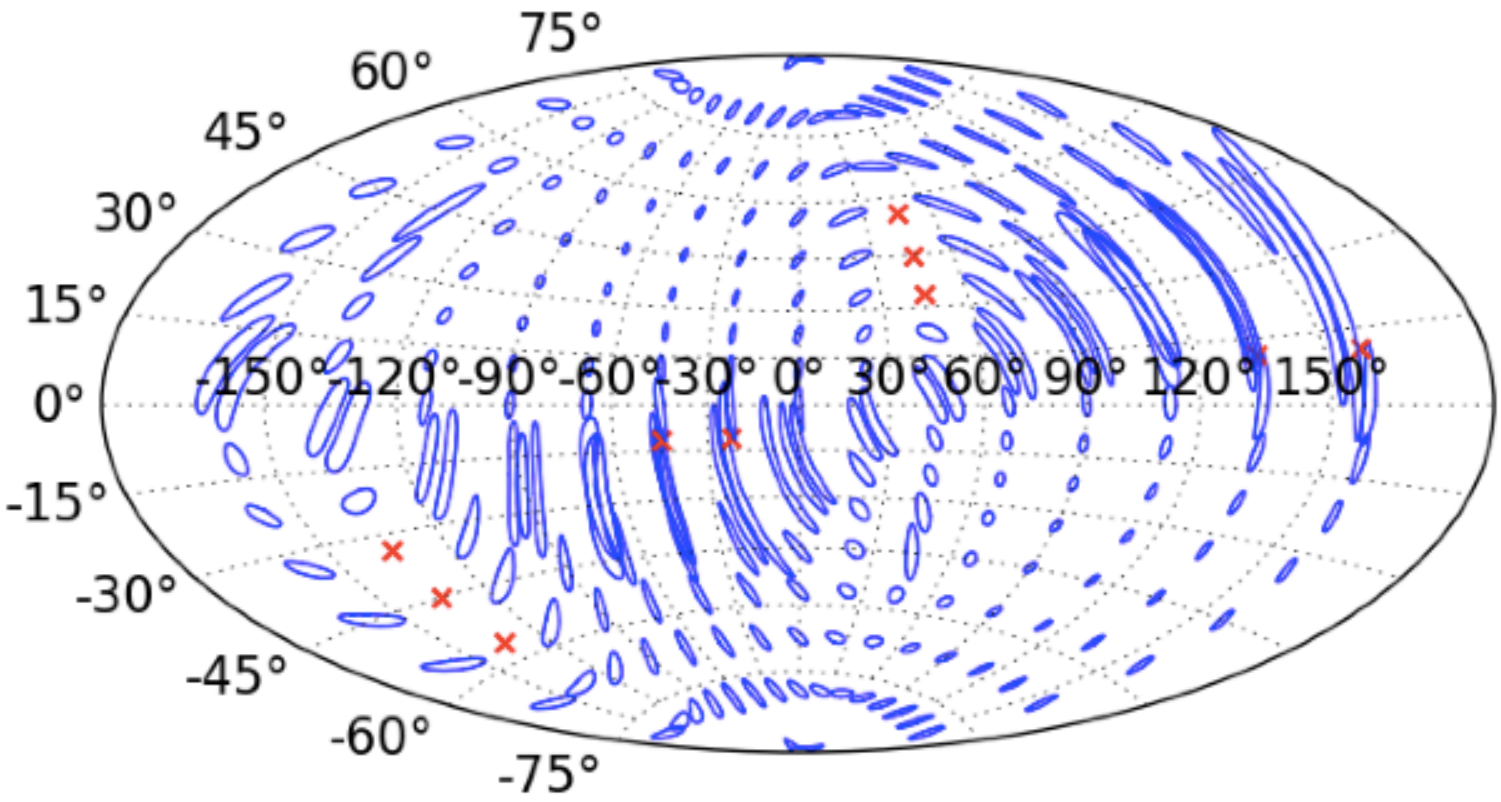
Or …

CSI Enhanced Imaging

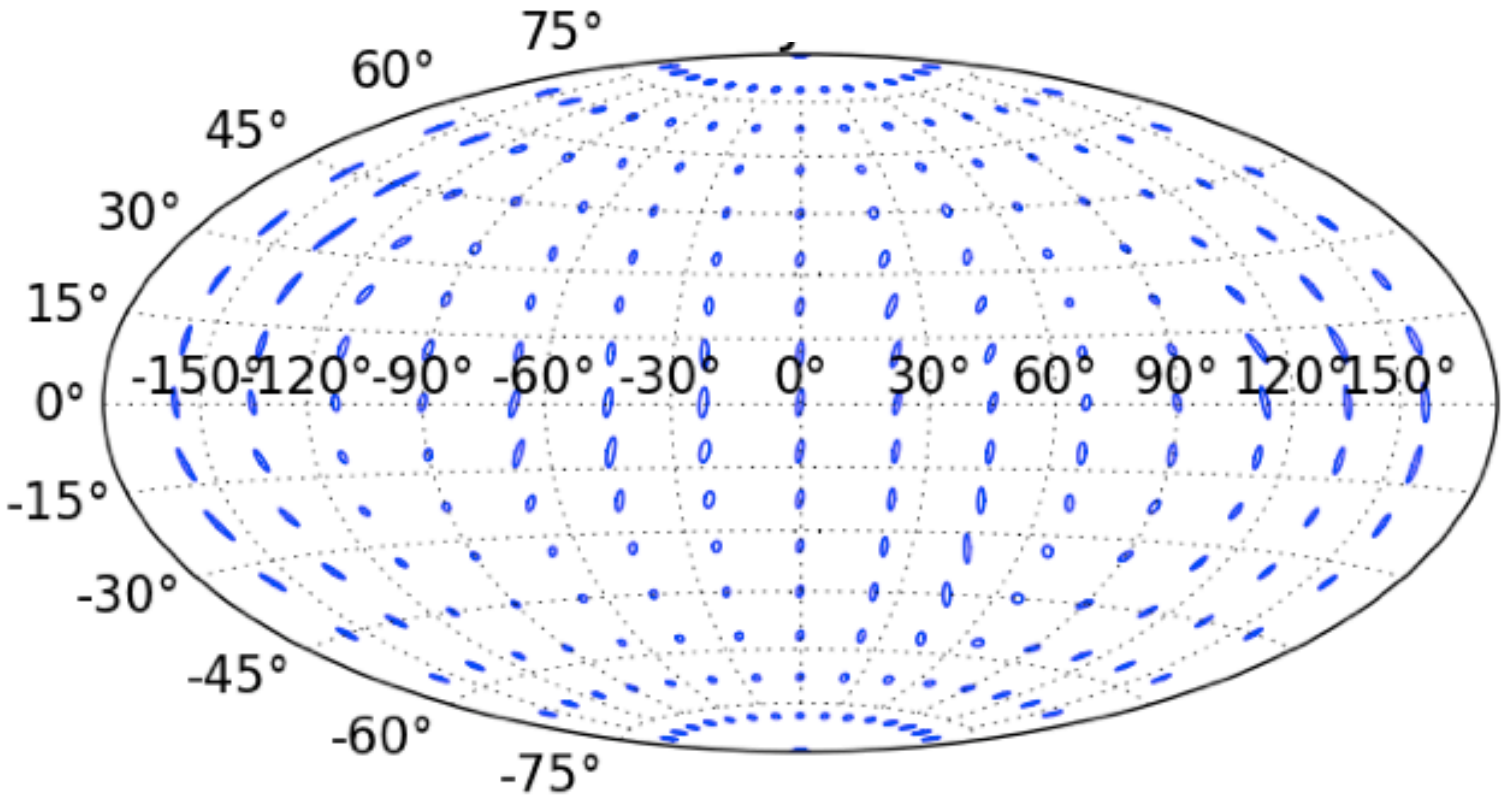


CSI Enhanced Imaging

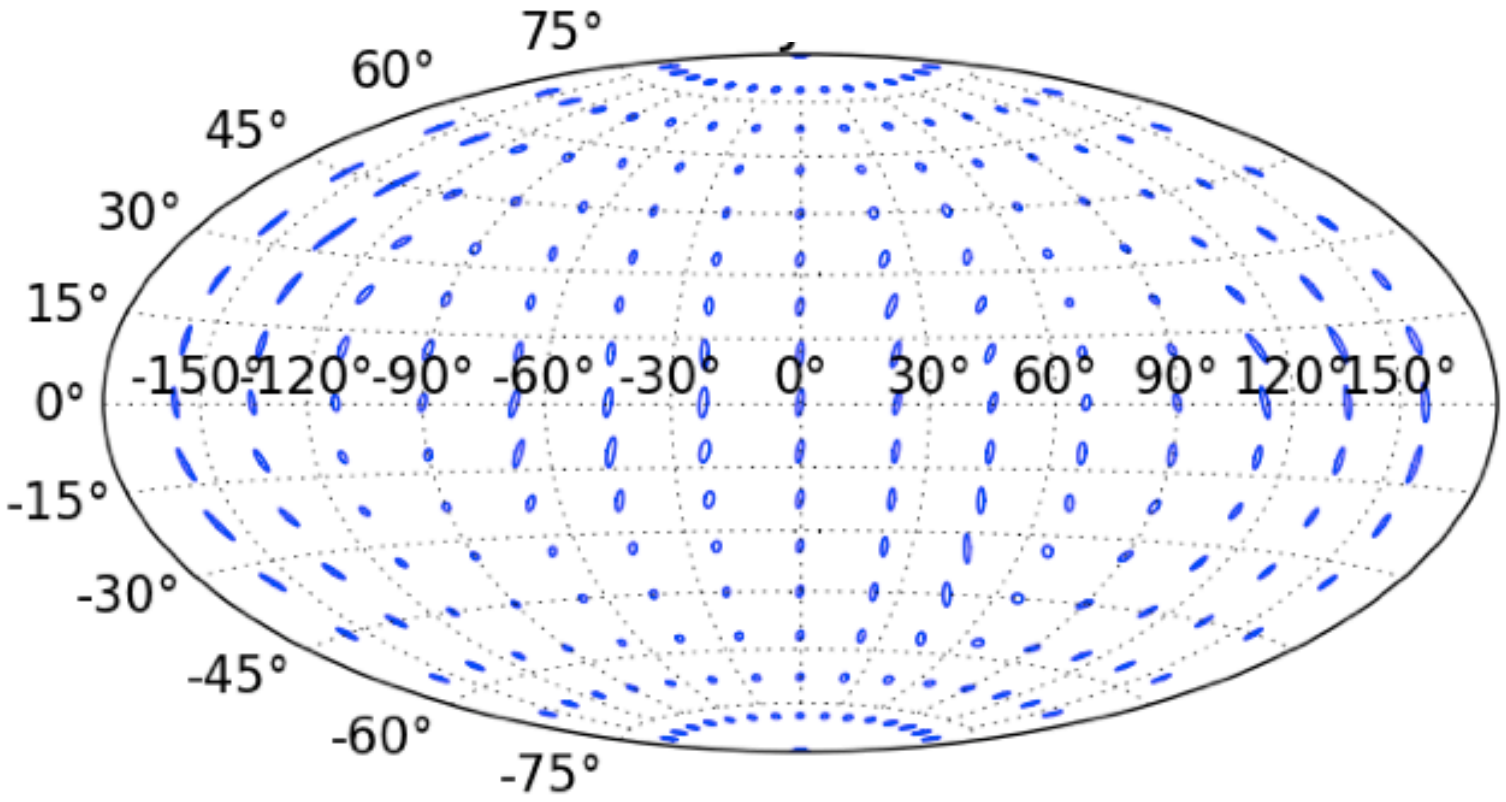
GW event large error boxes



GW event large error boxes

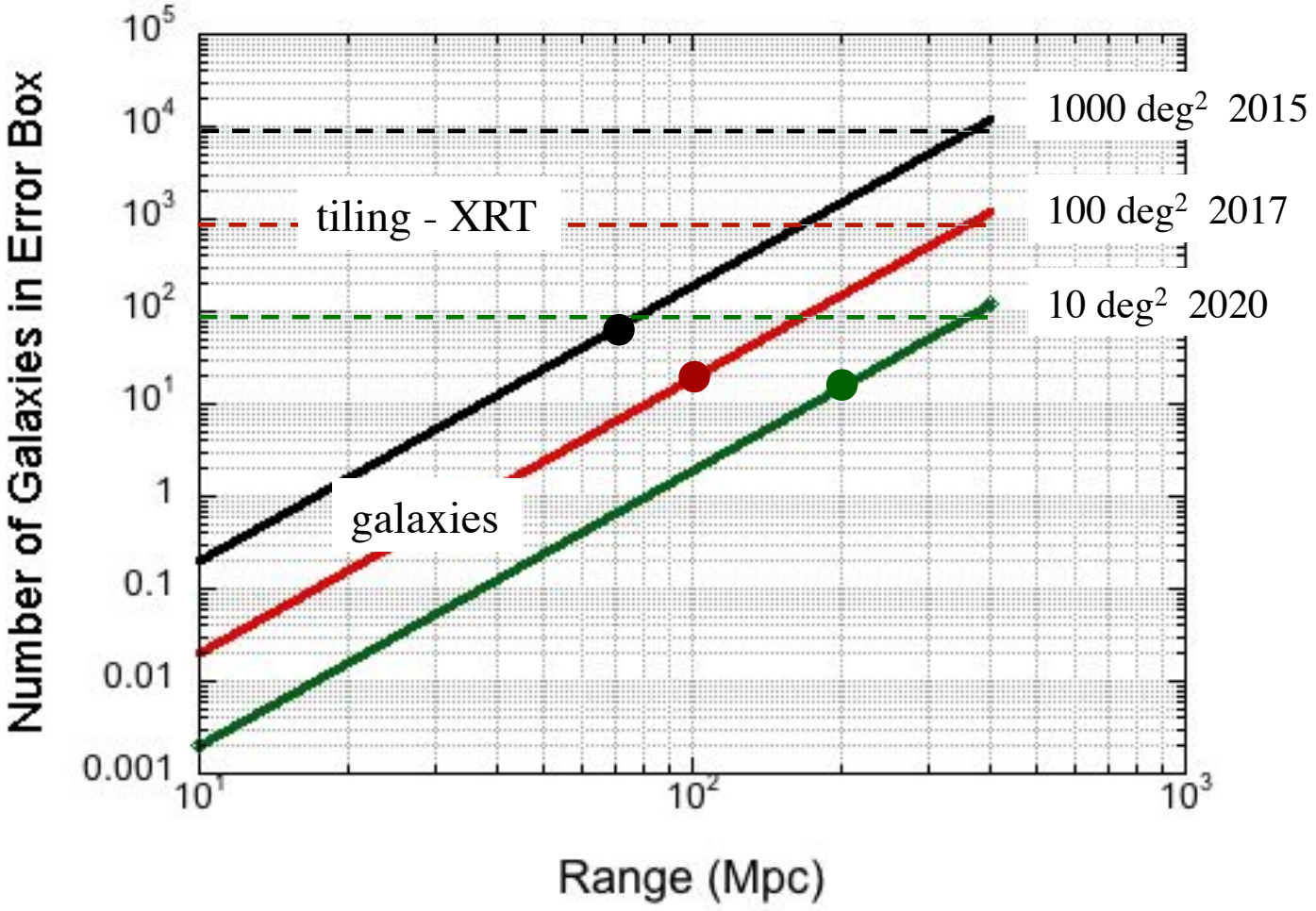


GW event large error boxes



What we need is LIGO-India and Kagra.

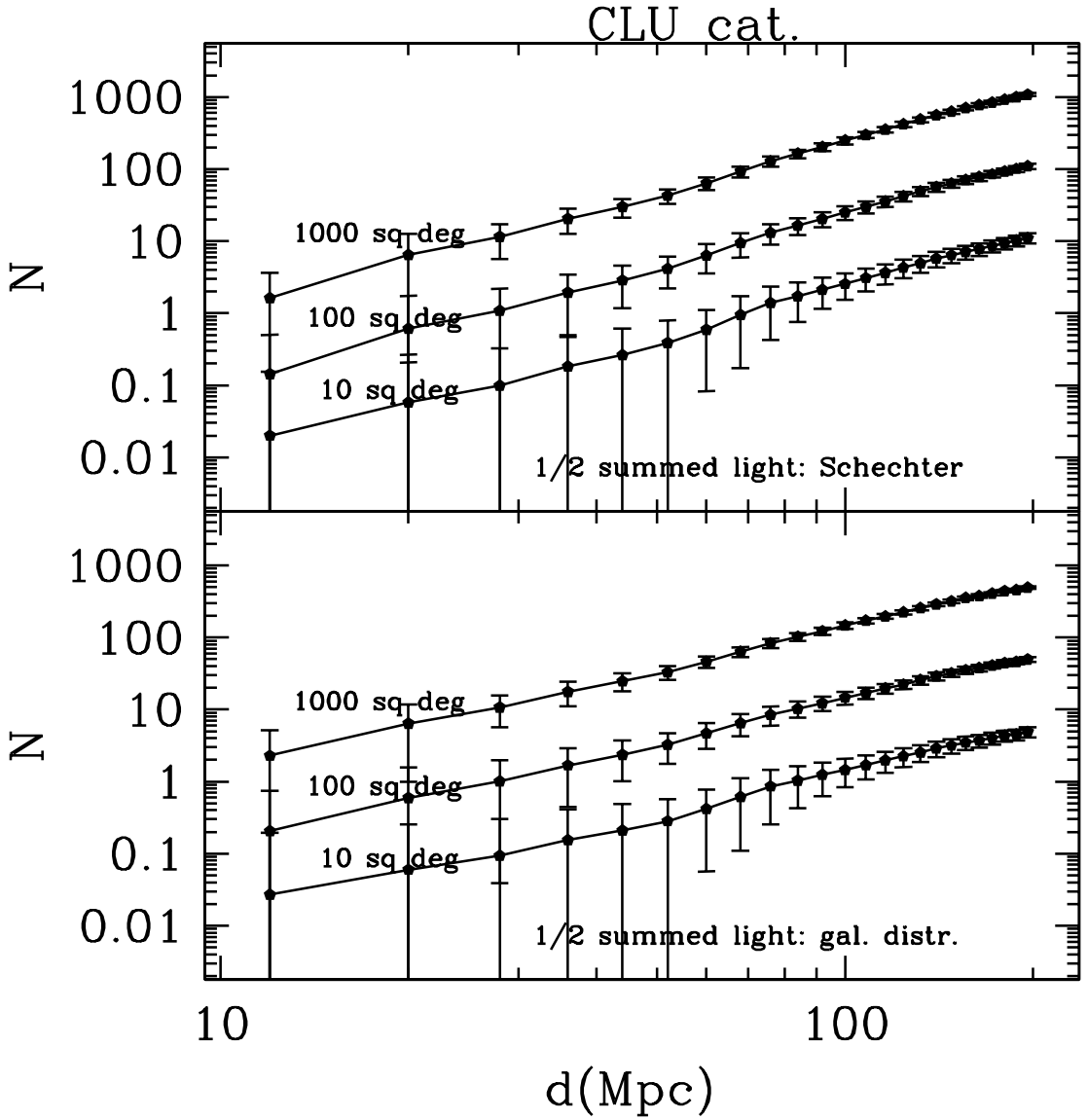
Another approach – galaxy strategy



galaxies to cover 50% of light
XRT FoV = 0.11 deg²

Kanner, Gehrels+ 2012

Another approach – galaxy strategy



CLU catalog
Kasliwal

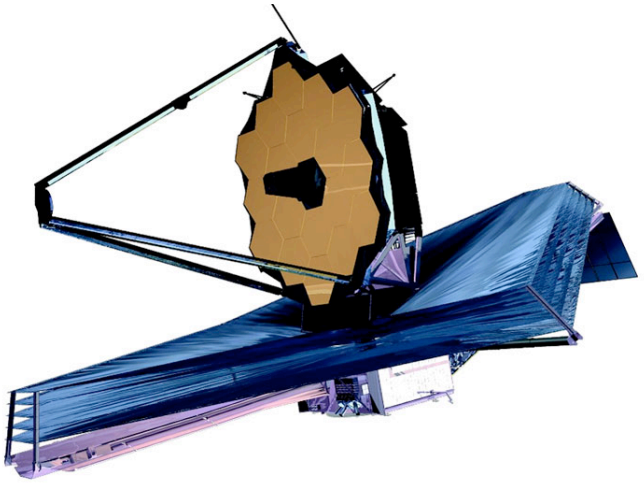
Gehrels, Kasliwal, Singer, Kanner, Nissanke, Cannizzo 2015

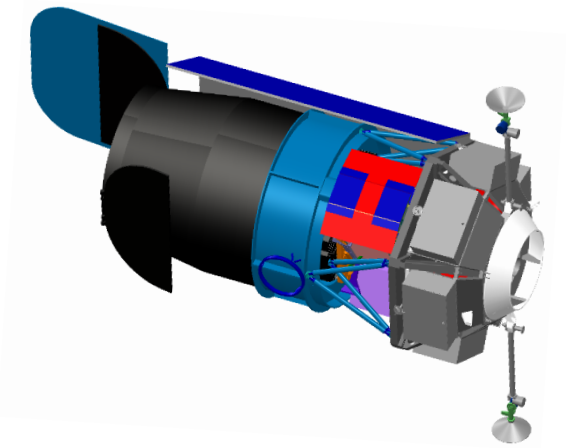
What we need: JWST & WFIRST

JWST
- 3" FoV
- 0.6 – 27 μm
- 2 day TOOs
- 29 mag
- high res spectroscopy

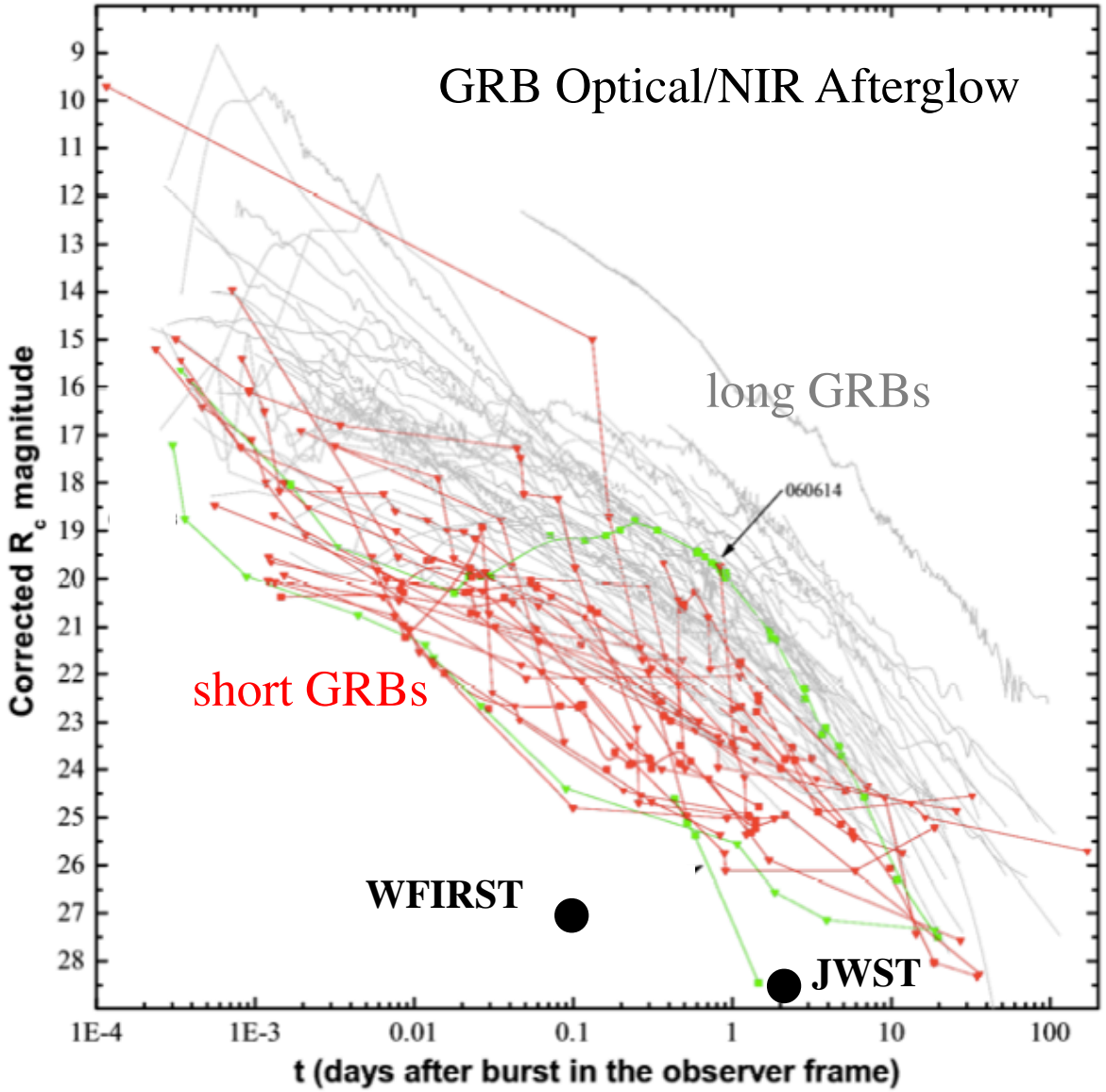
WFIRST
- 30" FoV
- 0.6 – 2 μm
- 2 hour TOOs (TBD)
- 27 mag
- R=100 spectroscopy

kilonovae @ 200 Mpc
J ~23





Afterglows



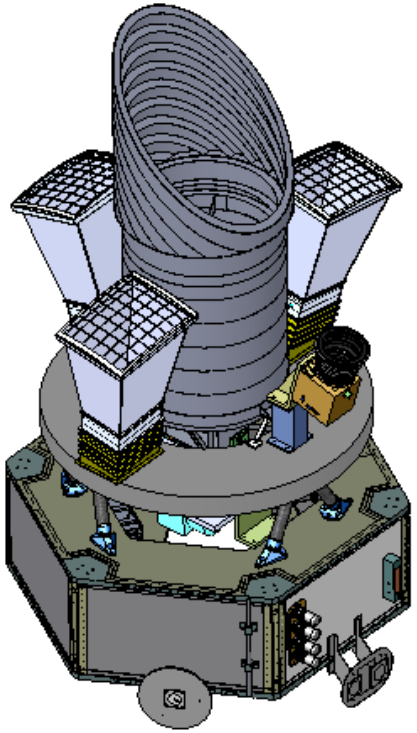
Kann+ '08

WFI F_{lim}
- point sources
- S/N=5
- 2ks

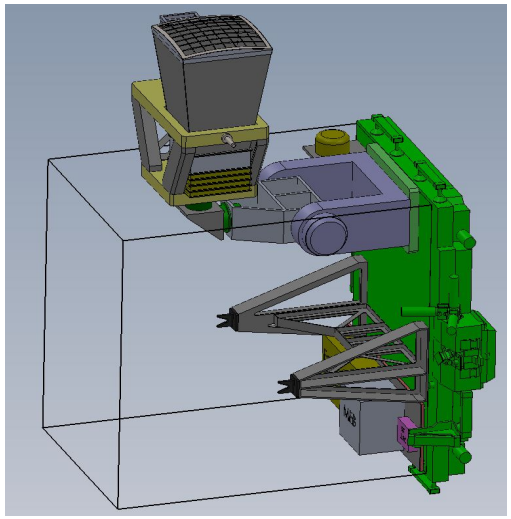
AB=27 in J band

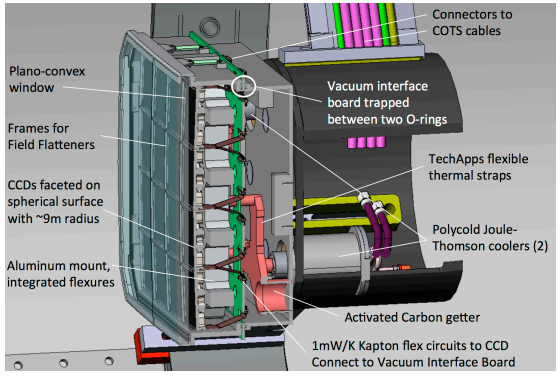
What we need going wide: ZTF & Lobster

Explorer EX 2011



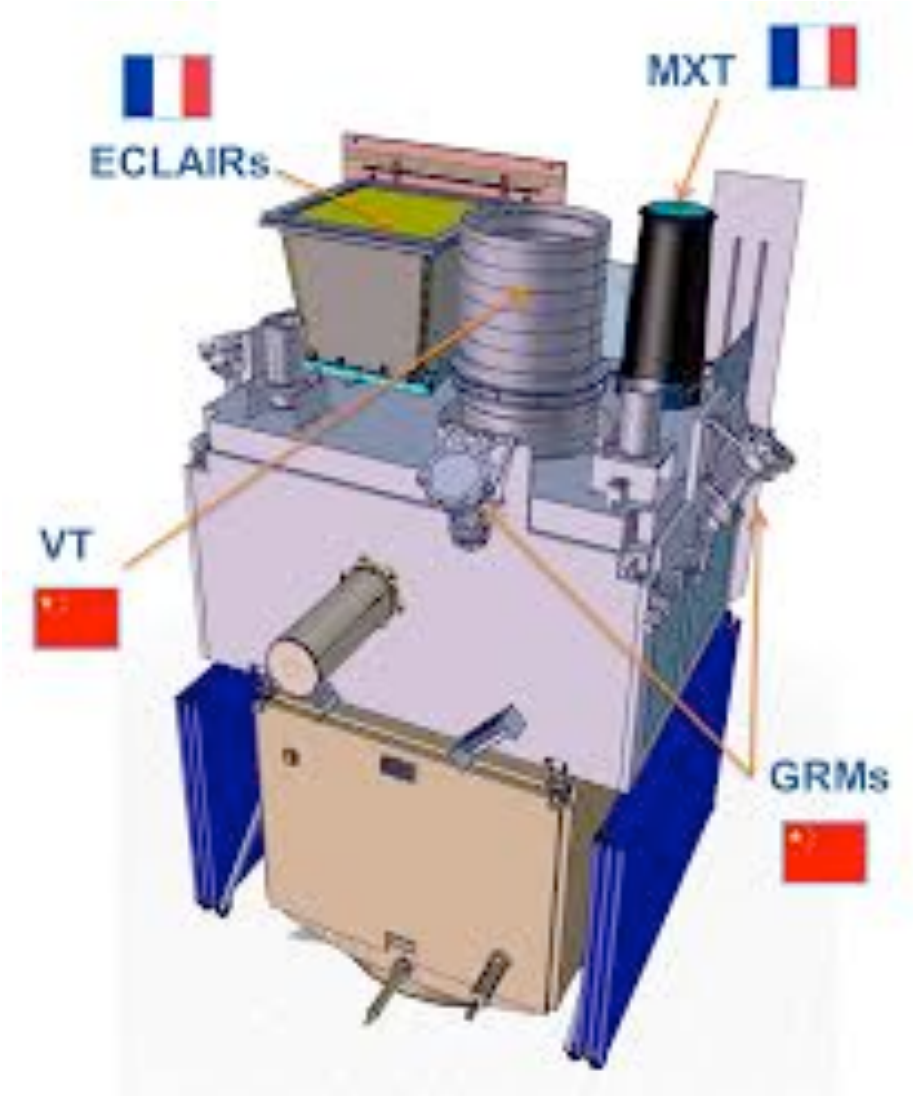
Explorer MOO ISS 2012





ZTF CCD Array

What we need: GRB trigger like SVOM



What we need: data & community

Rapid distribution of 3-D error regions

Galaxy catalog in the optical where wide-field imaging is available to eliminate false positives for prompt follow-up and working with localization volumes

Expanded open archive of GW and EM data. Possible new or existing facility to serve as the science data center to support the community.

Conclusions

- Bright EM counterparts are expected in rare GW events where merger axis is aimed toward us
- For off-axis mergers, the EM emission will be weak
- A galaxy strategy will allow sensitive narrow-field telescopes to participate
- The EM emission parameters (beaming, kilonova) are poorly known. Coincident detection with a GW event will great improve our knowledge of the explosion.

GW Rates from GRB Rates

Short GRB rate is ~10 Gpc^{-3} yr^{-1}
(300 short GRBs/yr to z=0.5)

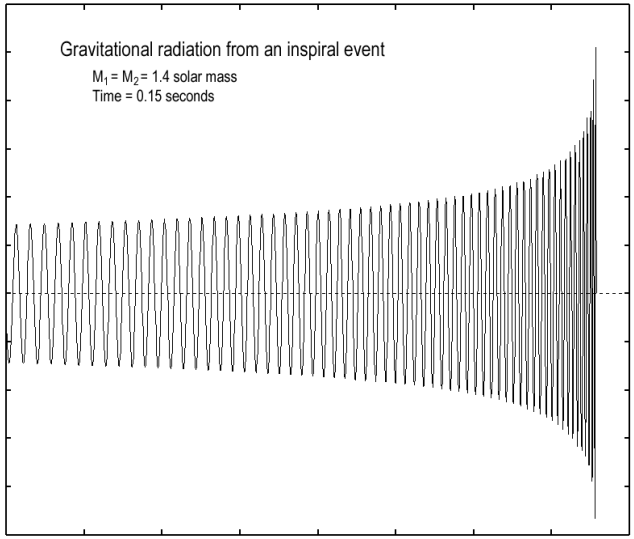
If all short GRBs due to NS-NS mergers
& beaming angle is 5 – 20 deg
$\Rightarrow$ NS-NS merger rate is 150 - 2500 Gpc^{-3} yr^{-1}

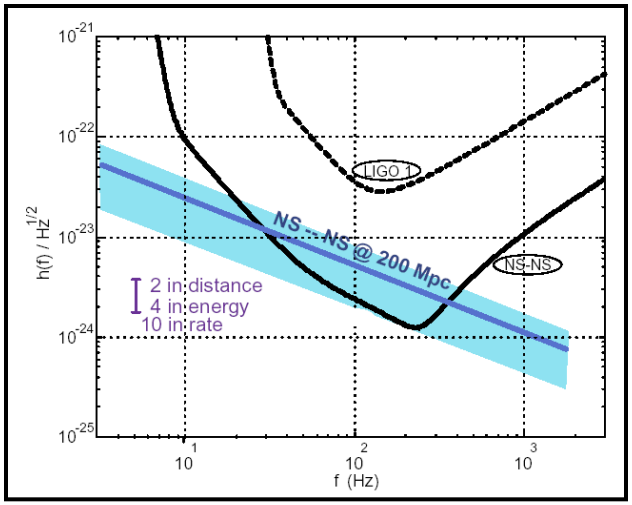
[Consistent with NS-NS population synthesis modeling by O'Shaughnessy, Kalogera, …]

For ALIGO/Virgo NS-NS merger sensitivity distance is ~200 Mpc:

aLIGO detection rate is 3 - 50 yr^{-1}

(plus BH-BH and gamma-ray quiet mergers)





K. Thorne