NIR Observations of Gravitational Wave Sources

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C: NASA

NIR Observations of Gravitational Wave Sources

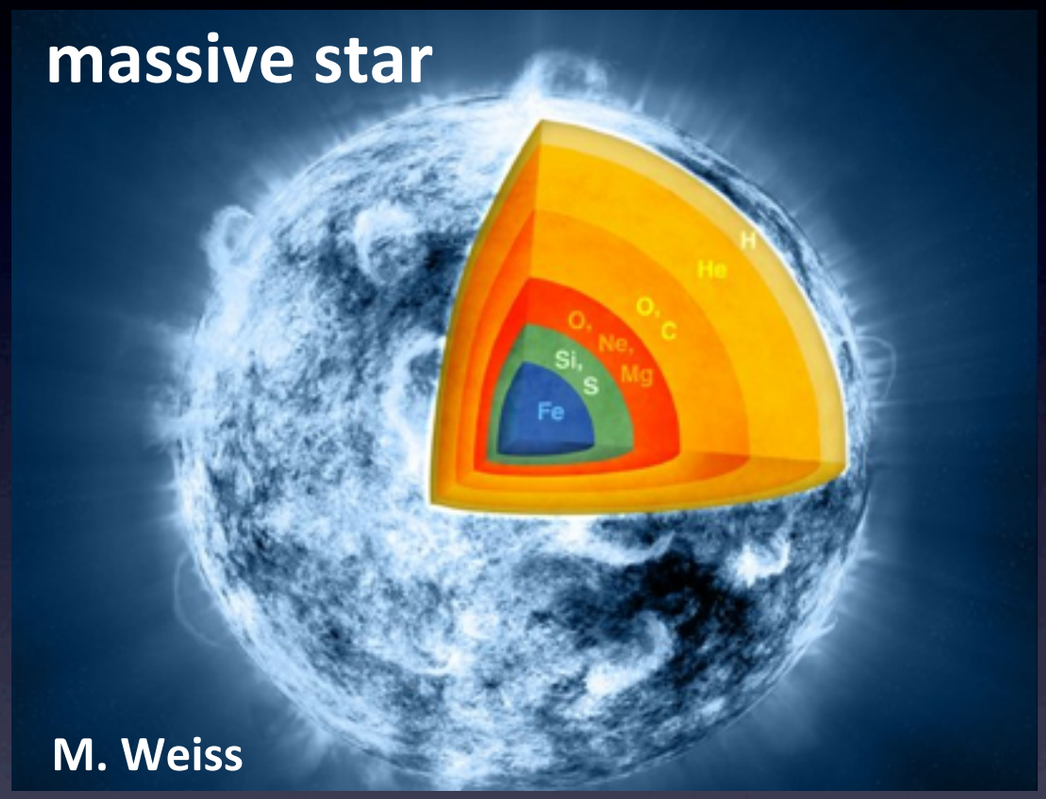
- Why NS merger?
- EM emission and NIR observations

New astronomy with Gravitational waves

Sensitivity increase
by a factor of 10 (in amplitude)
=> volume increase
by a factor of 1000!

Gravitational wave sources

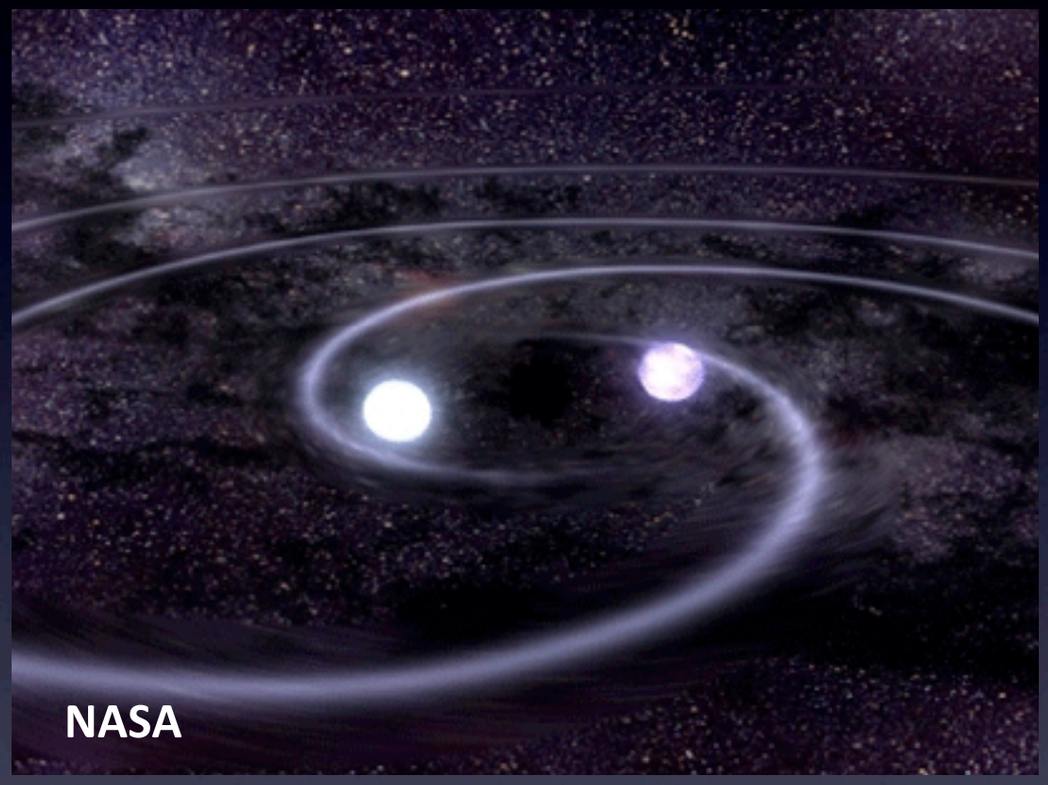
Supernova



d ~ 10 kpc (Galactic)

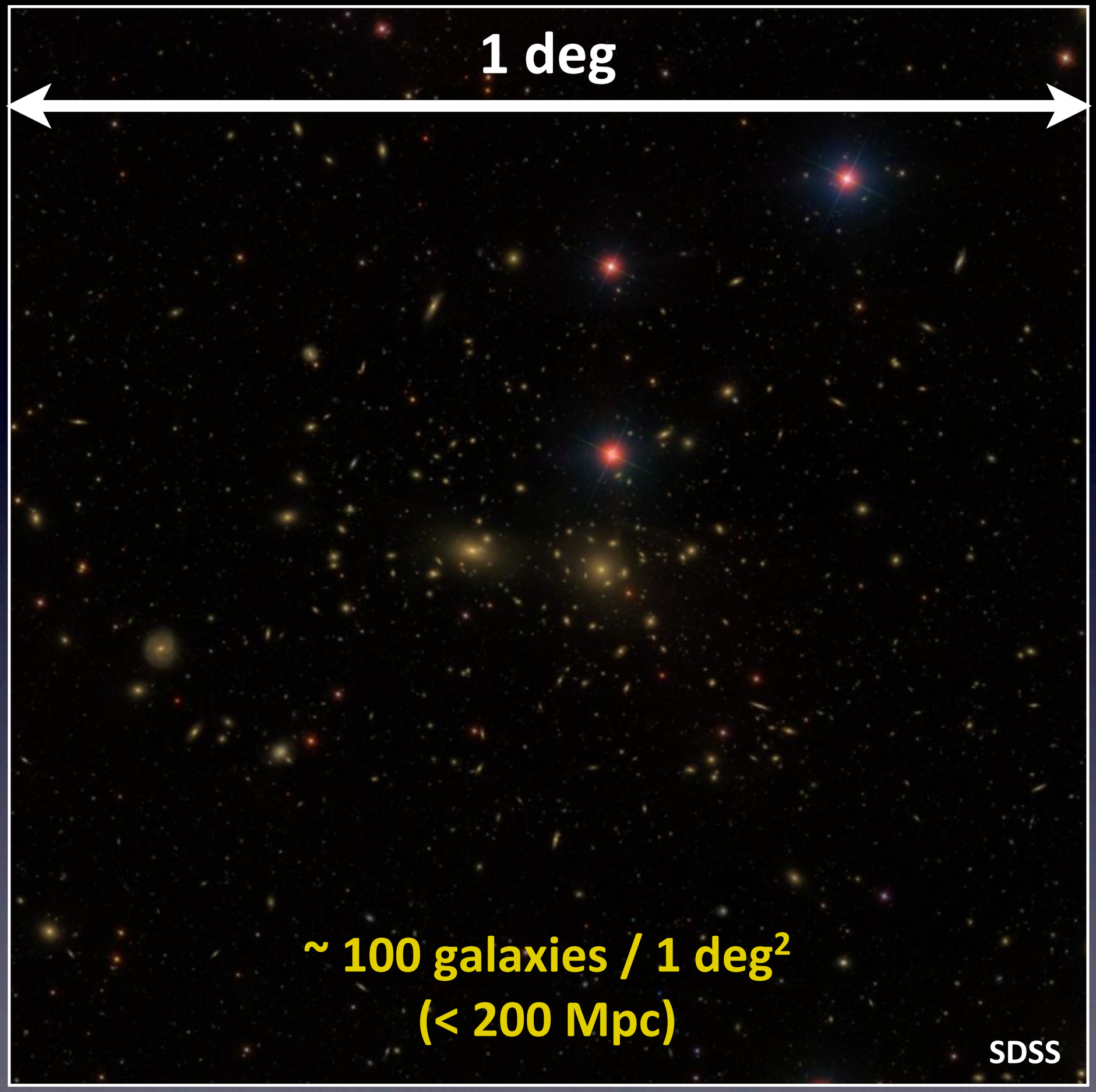
~ 0.01 events/yr

NS merger



d ~ 200 Mpc (Extragalactic)

~ 0.1-100 events/yr


1 deg
~ 100 galaxies / 1 deg^2
(< 200 Mpc)
SDSS

GW alert error

e.g. 6 deg x 6 deg

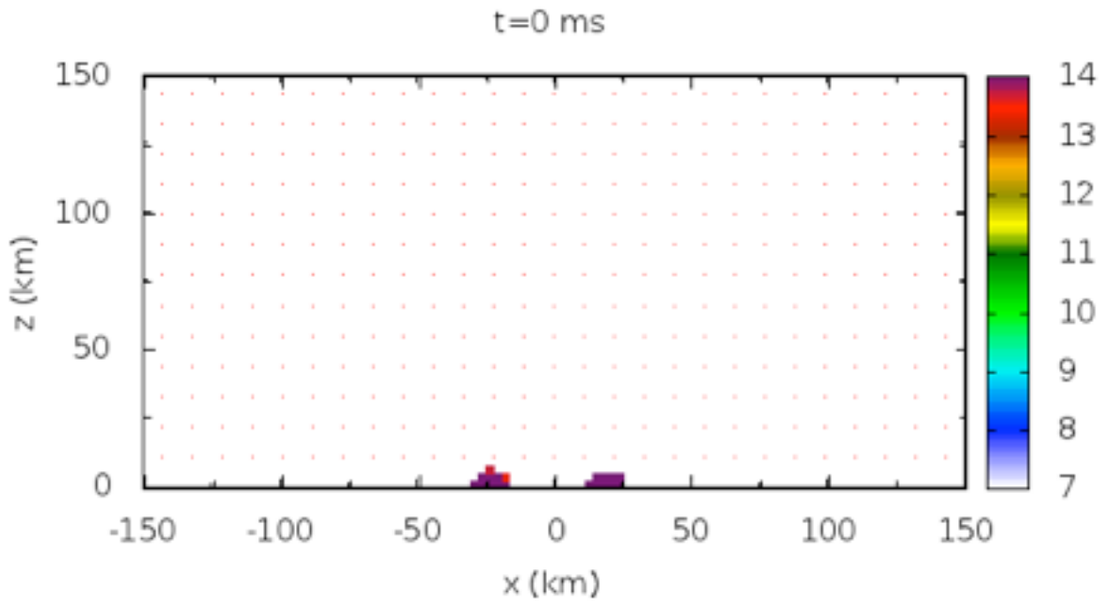
(not box shape in reality)

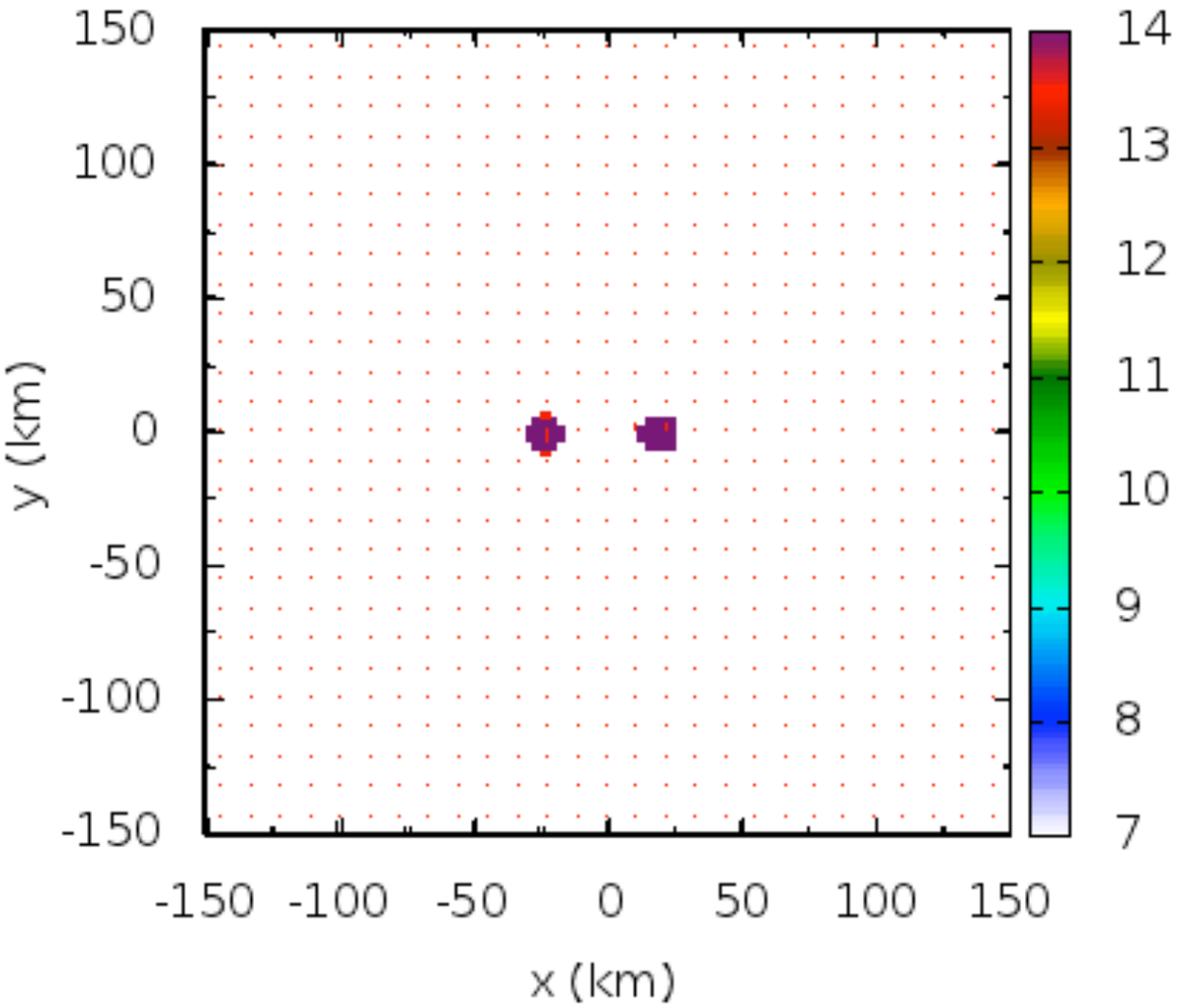
GW detection

Electromagnetic transient search

Source identification

1 deg



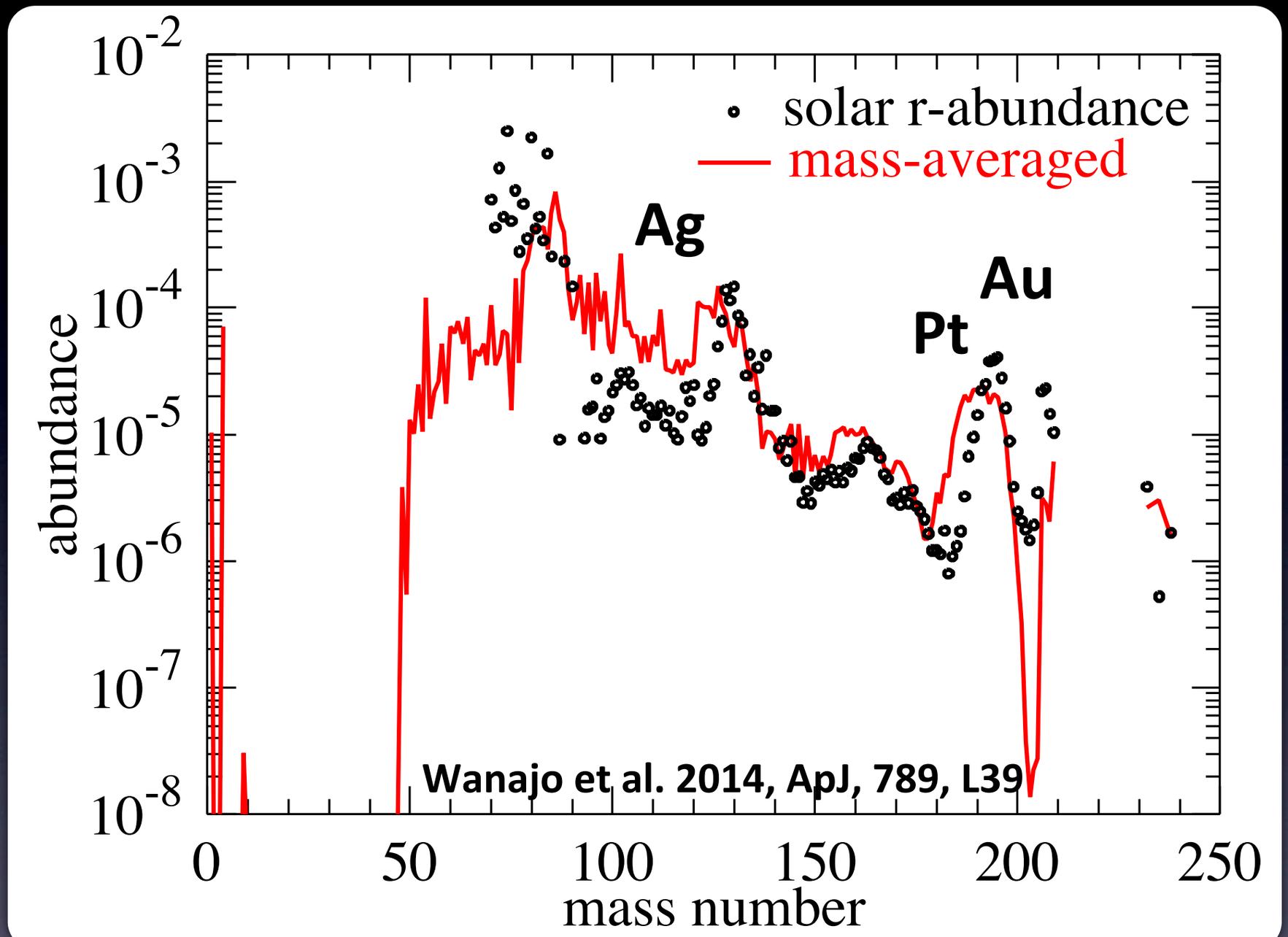


Mass ejection from NS mergers

M ~ 10^{-3} - 10^{-2} Msun
v ~ 0.1 - 0.2 c

Hotokezaka+13, PRD, 87, 4001
Rosswog+13, MNRAS, 430, 2580

r-process nucleosynthesis



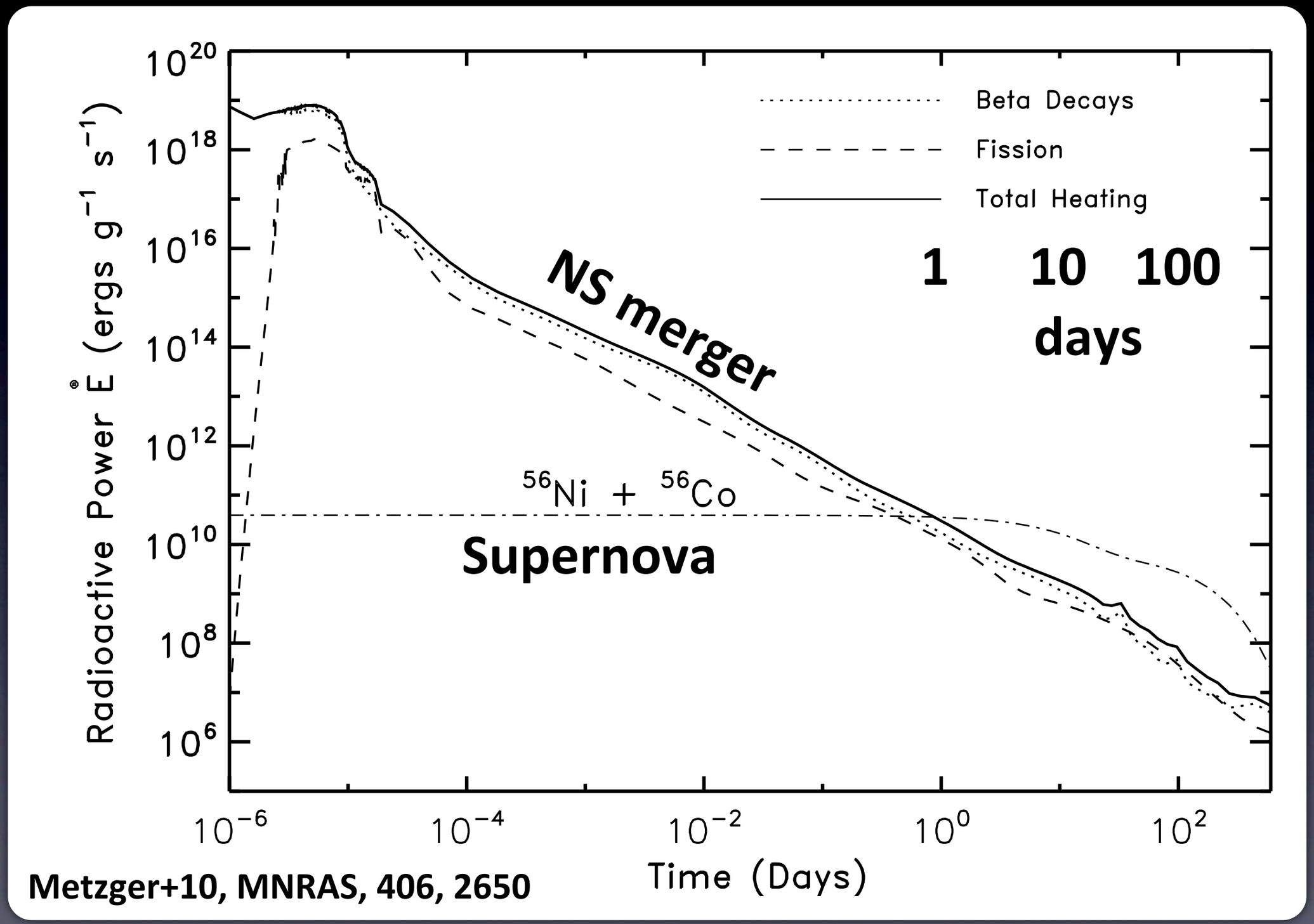
NS merger can be the origin of r-process elements

- **Rate ~ 10^{-4} events/yr/Galaxy (<= GW)**
- **Mej ~ 10^{-2} Msun/event (<= Opt/IR)**

NIR Observations of Gravitational Wave Sources

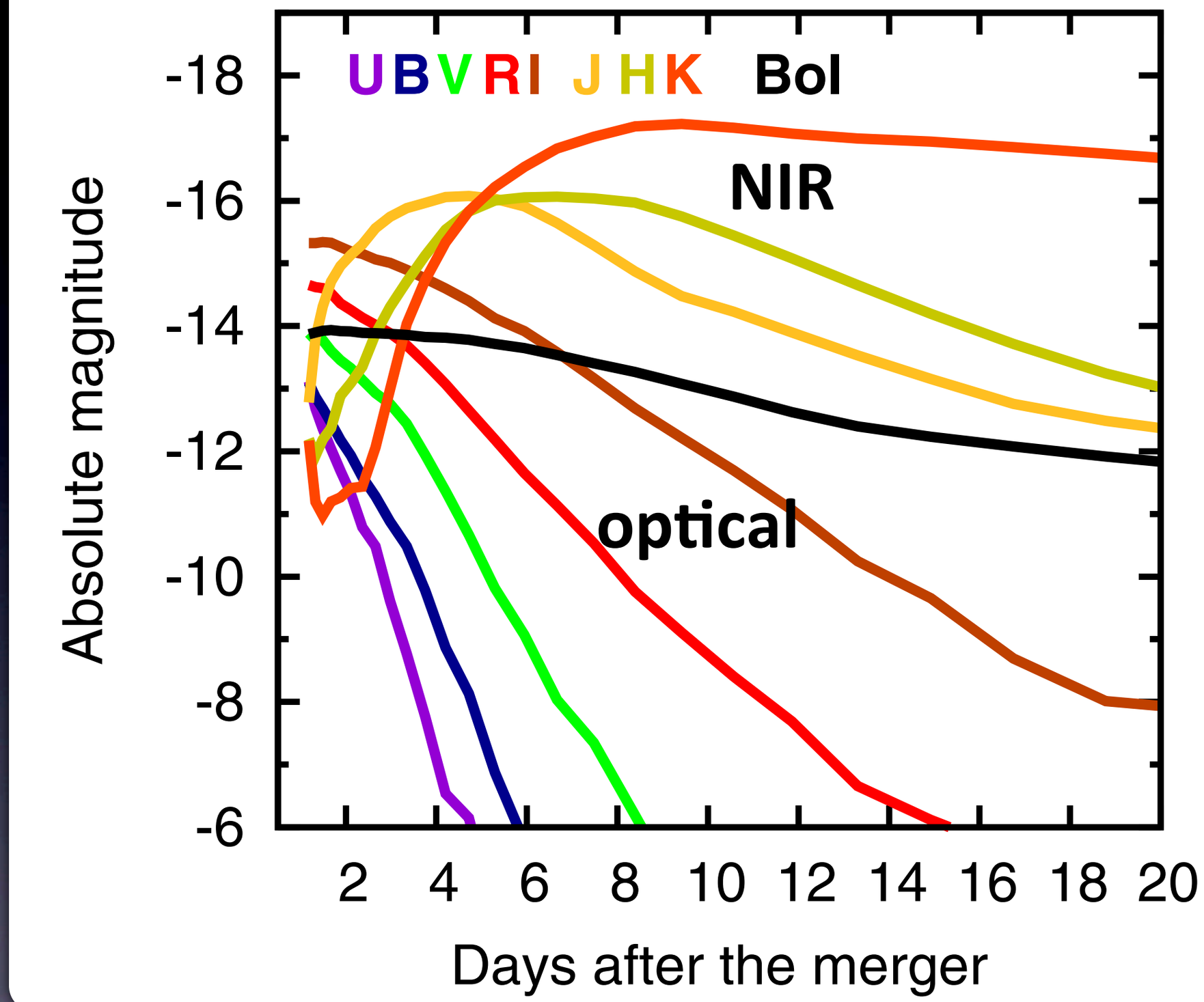
- Why NS merger?
- EM emission and NIR observations

r-process nucleosynthesis powers EM emission



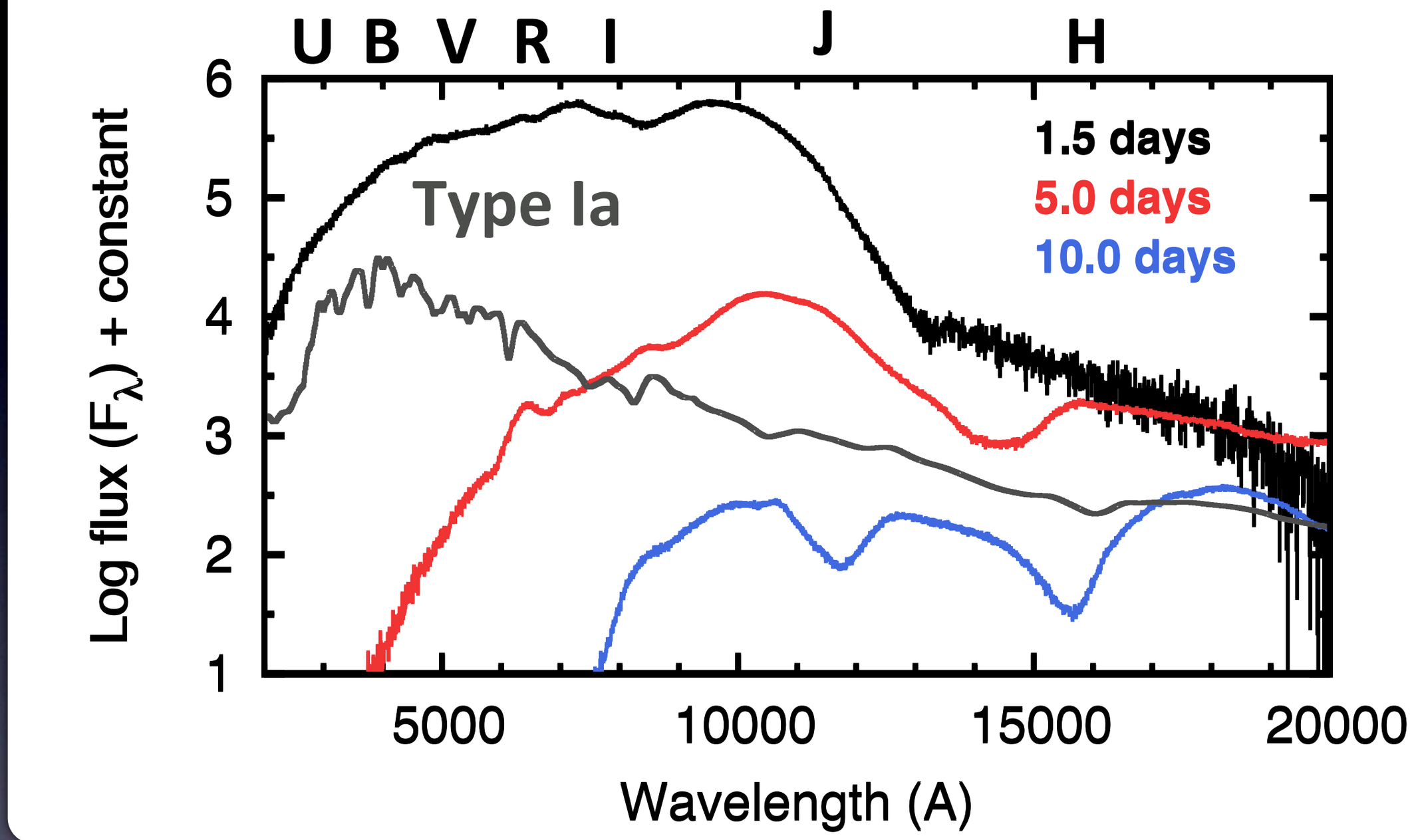
Metzger+10, MNRAS, 406, 2650

Thick against gamma-rays => Opt/NIR emission



MT & Hotokezaka 2013

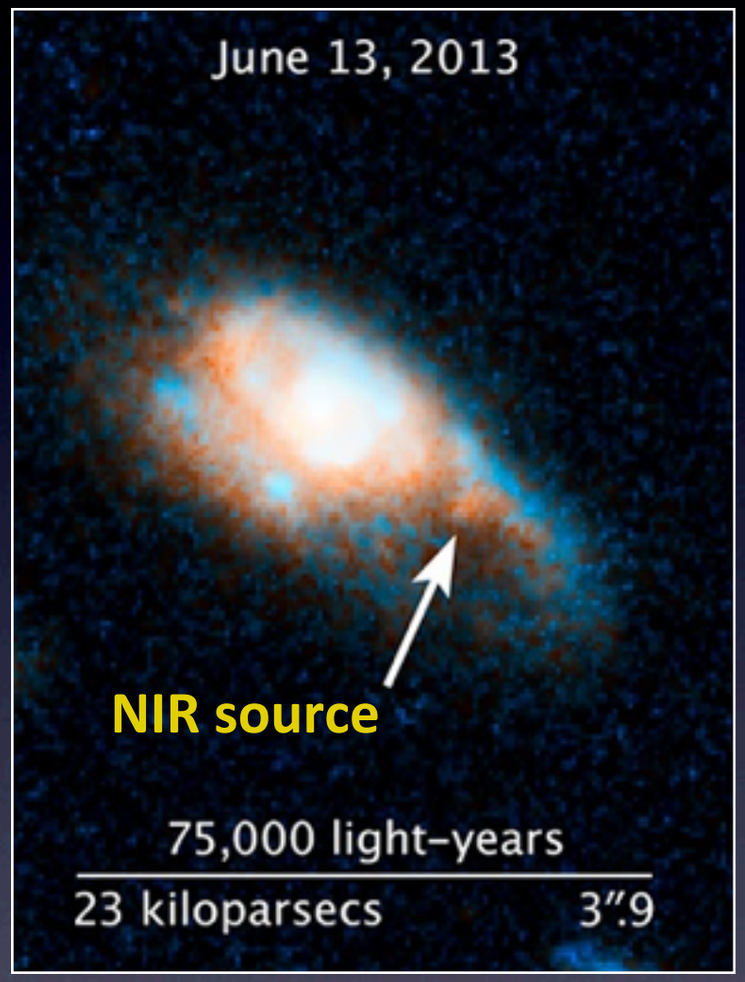
- Very red SED (peak at NIR) R-H ~ 7 mag
- NIR emission lasts longer

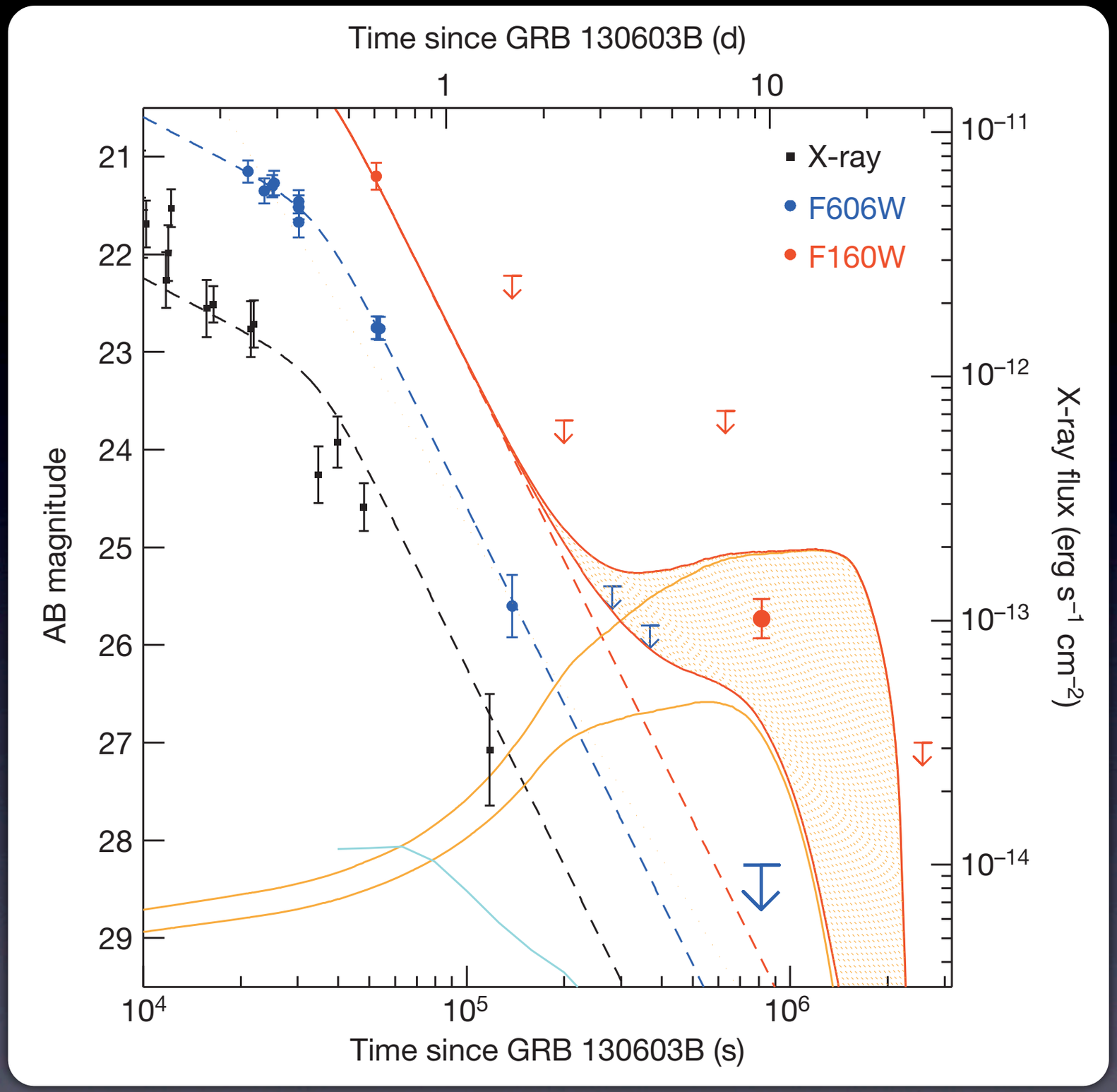


MT & Hotokezaka 2013

- Extremely broad-line (feature-less) spectra

GRB 130603B



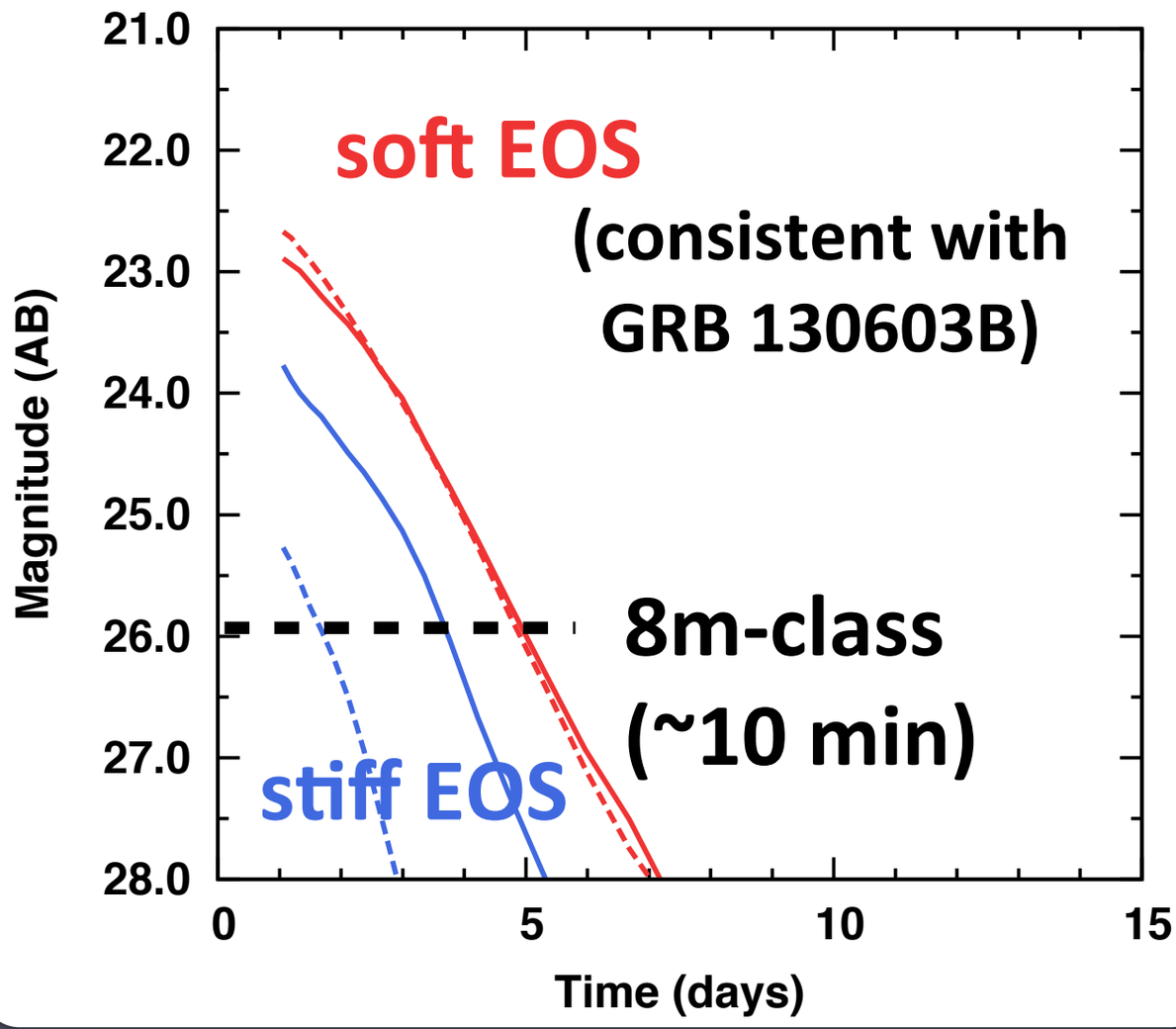


Tanvir+2013, Nature, 500, 547
Berger+2013, ApJ, 774, L23

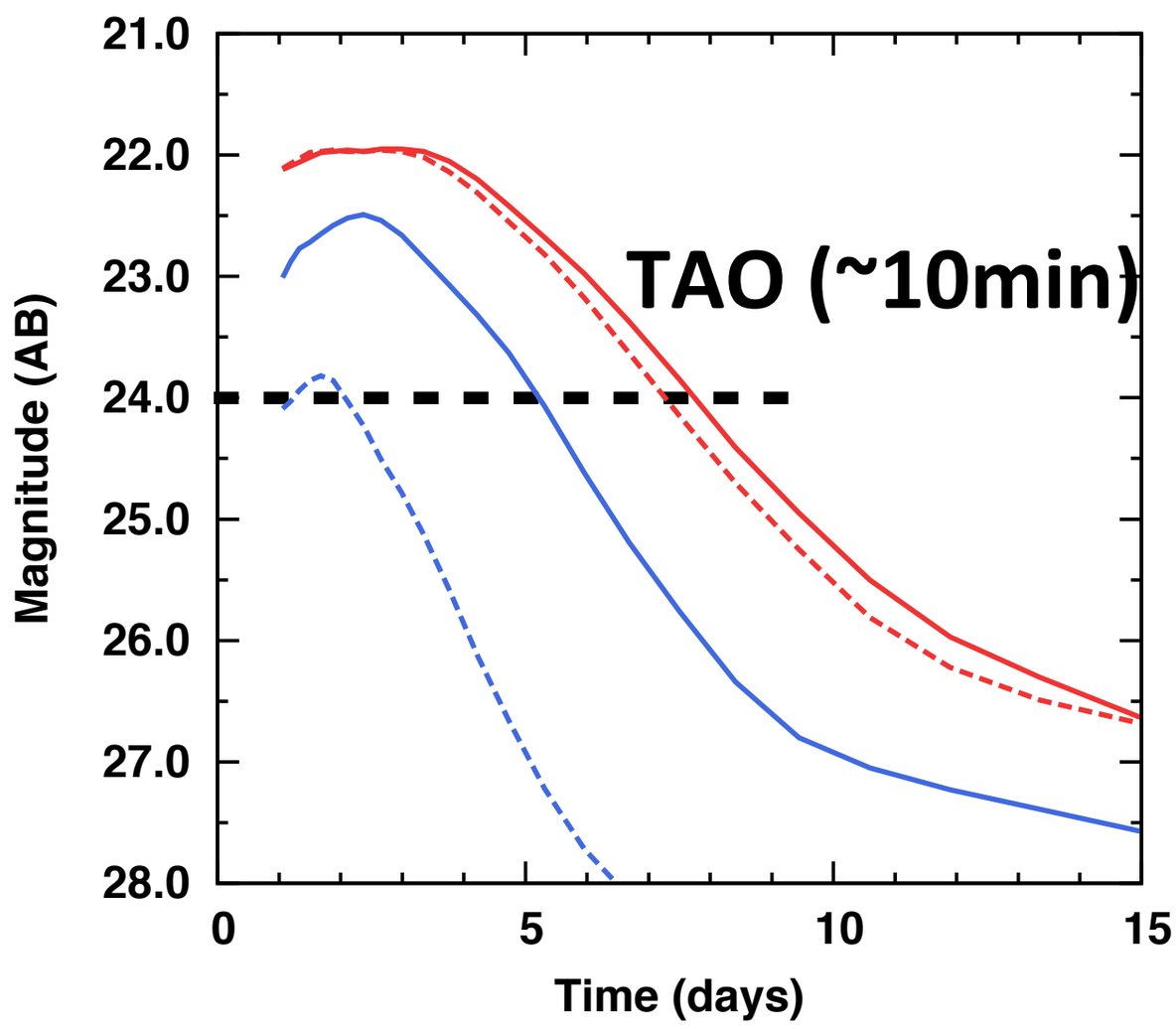
As expected by theoretical models!!
==> ejection of ~0.02 Msun

Advantage of NIR

Optical (i)

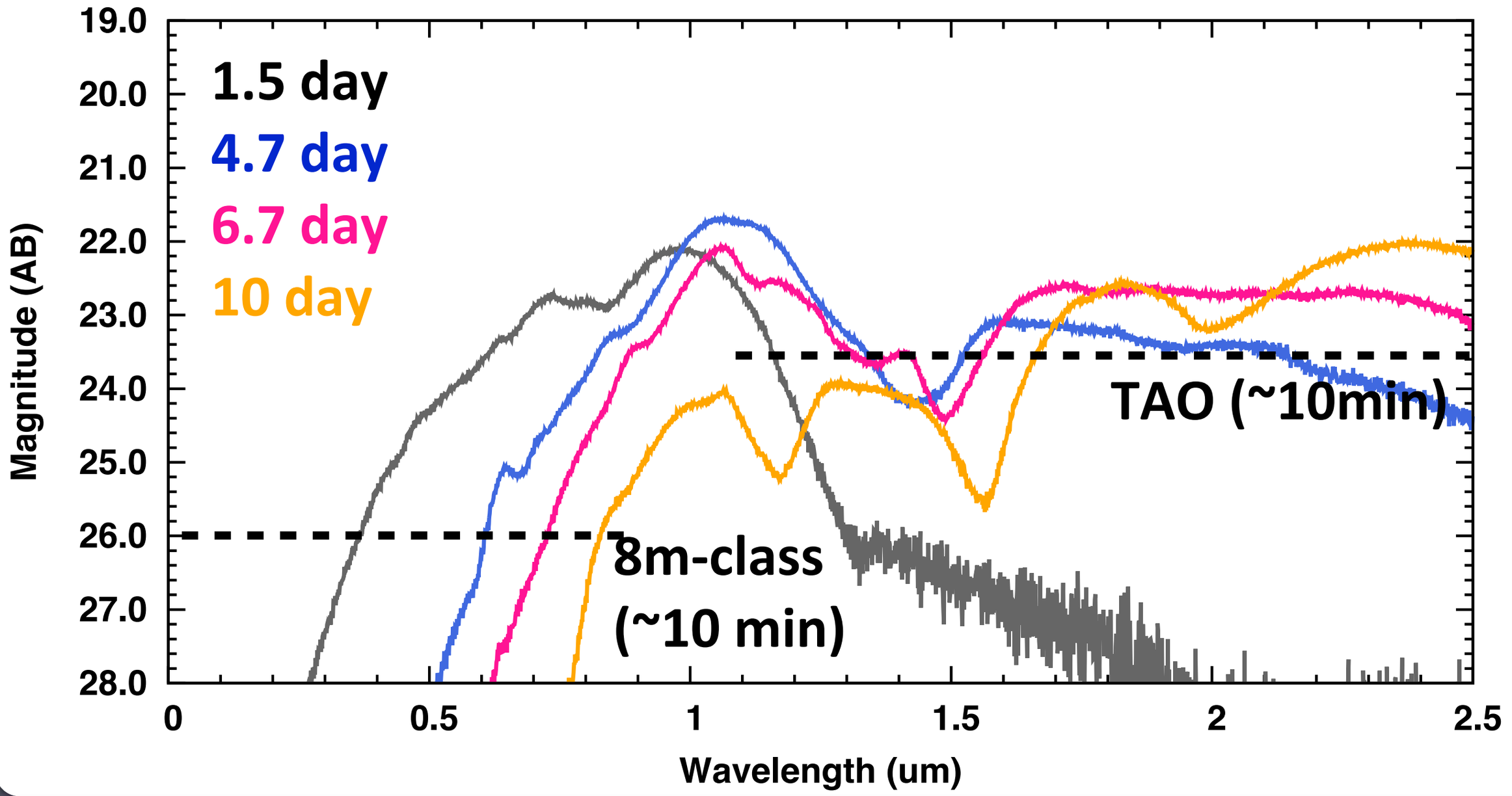


NIR (J)



MT+14

Advantage of NIR



MT+14

GW alert error
e.g. 6 deg x 6 deg
(not box shape in reality)

TAO/SWIMS
3.7’ x 8.6’
(0.06 x 0.14 deg)

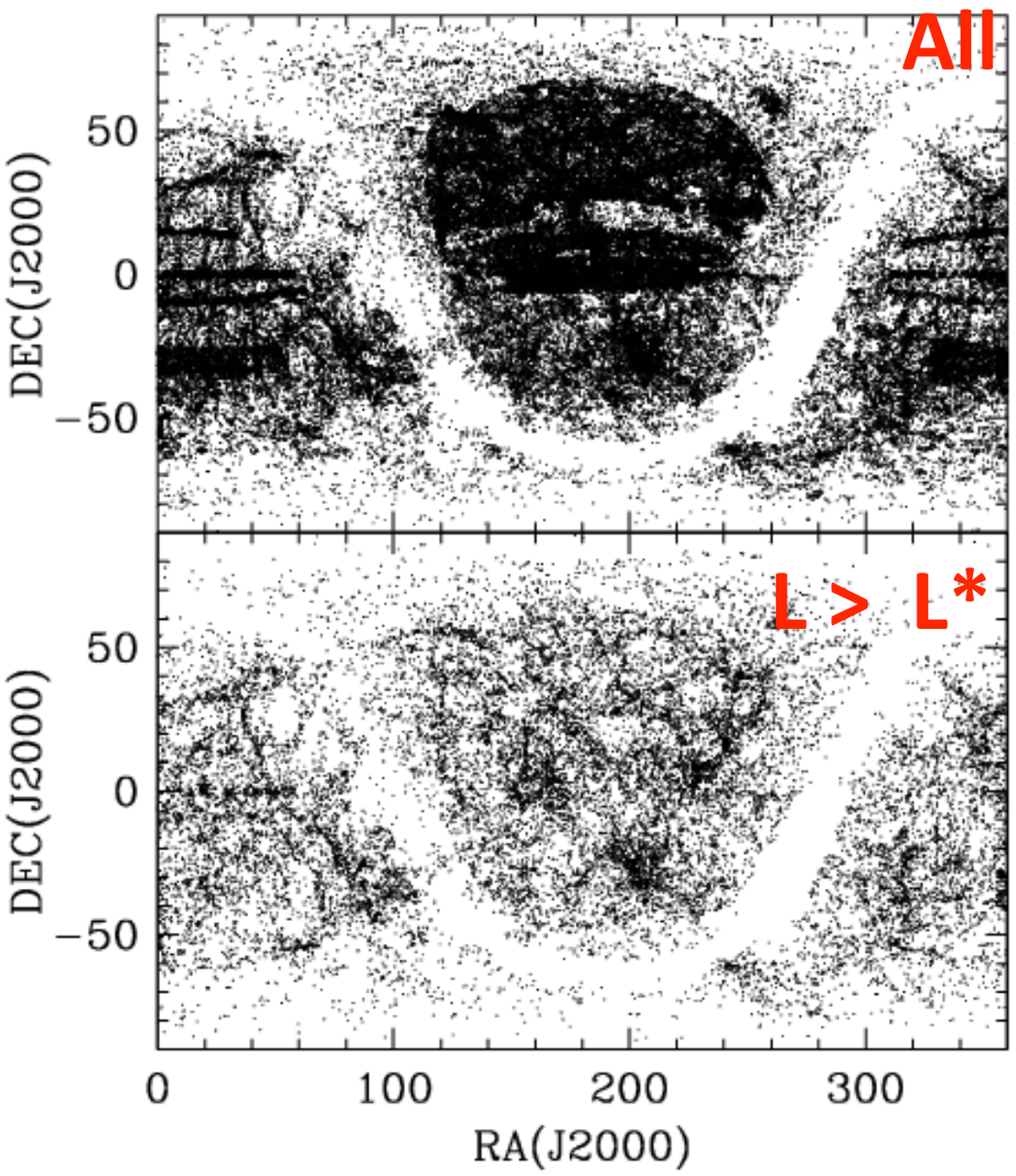
8m Subaru
Hyper Suprime-Cam
1.5 deg

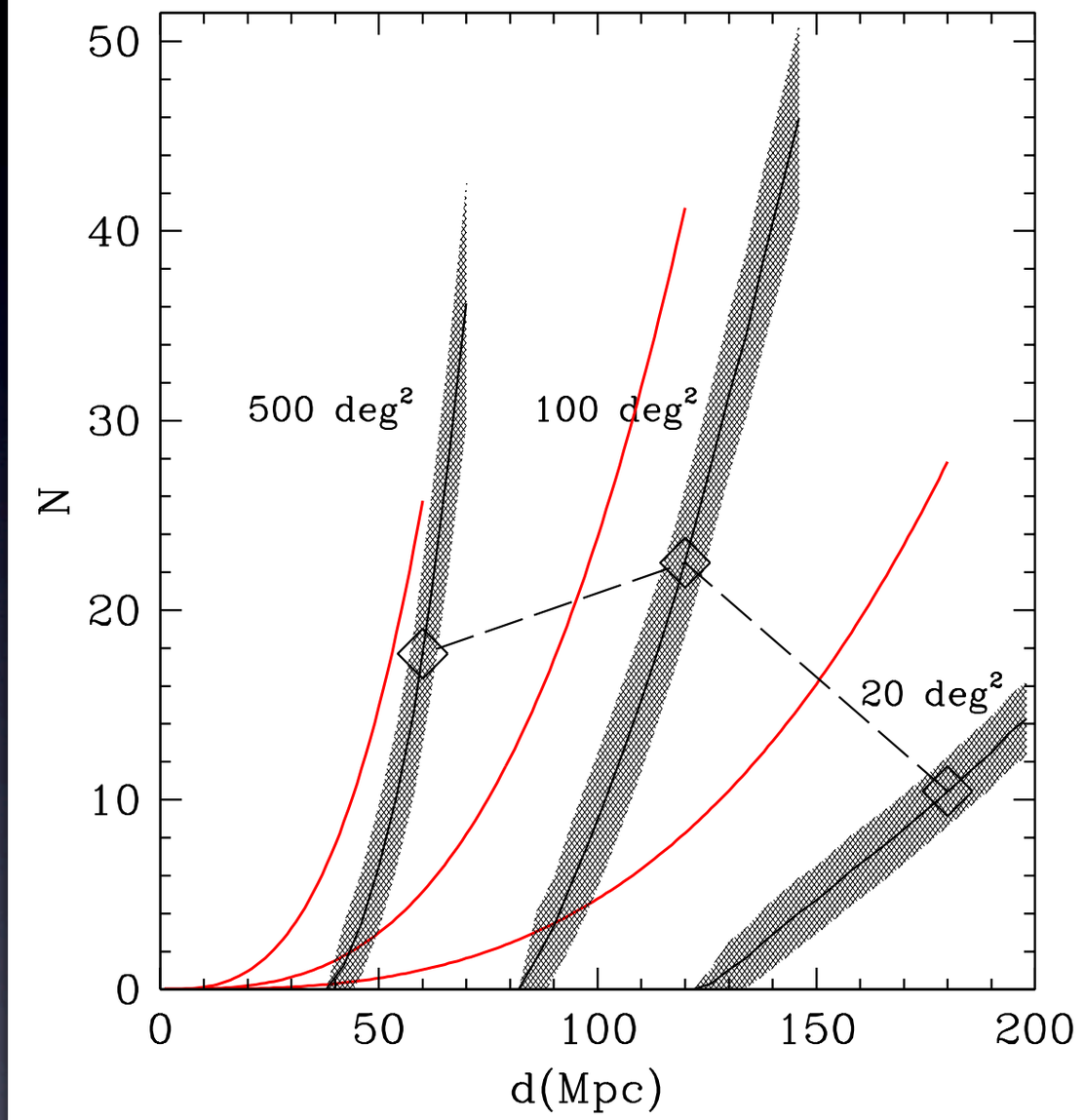
8m LSST
(2020-)
3.5 deg

4m Blanco
DECam
2.2 deg

3.6m CFHT
MegaCam (1 deg)

Galaxy search





Gehleres+15

10-50 galaxies in the localization area

(Caveat: ~50% of light, incompleteness of the catalog)

Summary

- EM follow-up is critical for GW astronomy
- EM emission from NS merger
  - radioactively powered emission
  - NS merger as potential origin of r-process elements
- NIR observations
  - Pros: Peaks at NIR wavelengths
  - Pros: NIR emission lasts longer
  - Cons: narrow field of view
    but can be overcome by galaxy search
  - Flexible operation of TAO
  - Spectroscopy for nearby events ... Smoking gun!