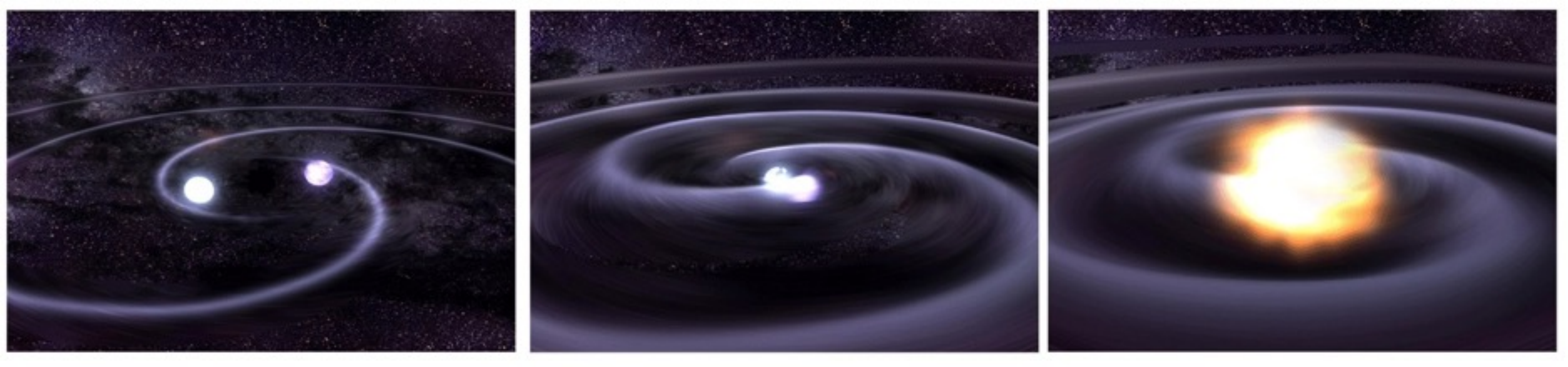

# Time-Domain Astronomy with WFIRST

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NASA GSFC
March 2, 2016

# Time-Domain Astronomy with WFIRST

- Electromagnetic (EM) counterparts of gravitational wave (GW) sources
- Superluminous Supernovae (SLSN)
  - See talks by Lin Yan, Dan Whalen
- Intermediate Luminosity Red Transients (ILRT)
  - See talk by Schuyler van Dyk

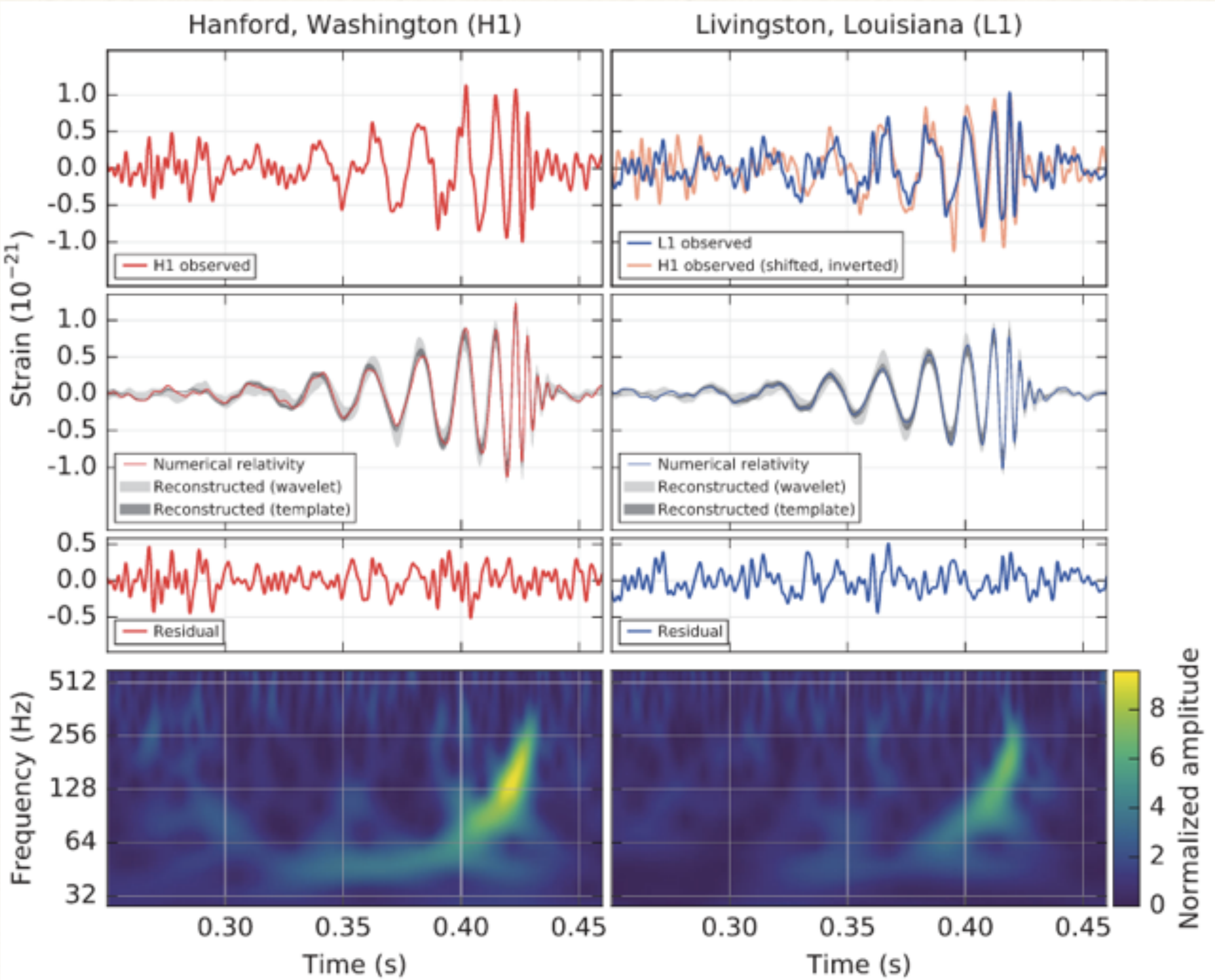
# Take-Home Messages

- Time-domain science requires a robust target-of-opportunity capability
- Cadence, cadence, cadence …
- Prompt data downlink and processing $\Longrightarrow$ prompt transient notification (community follow-up)

# Advanced LIGO/Virgo Network

Hanford + Livingston (aLIGO), Cascina (Virgo), KAGRA (Japan), IndIGO (India?)

# Direct Detection of Gravitational Waves!

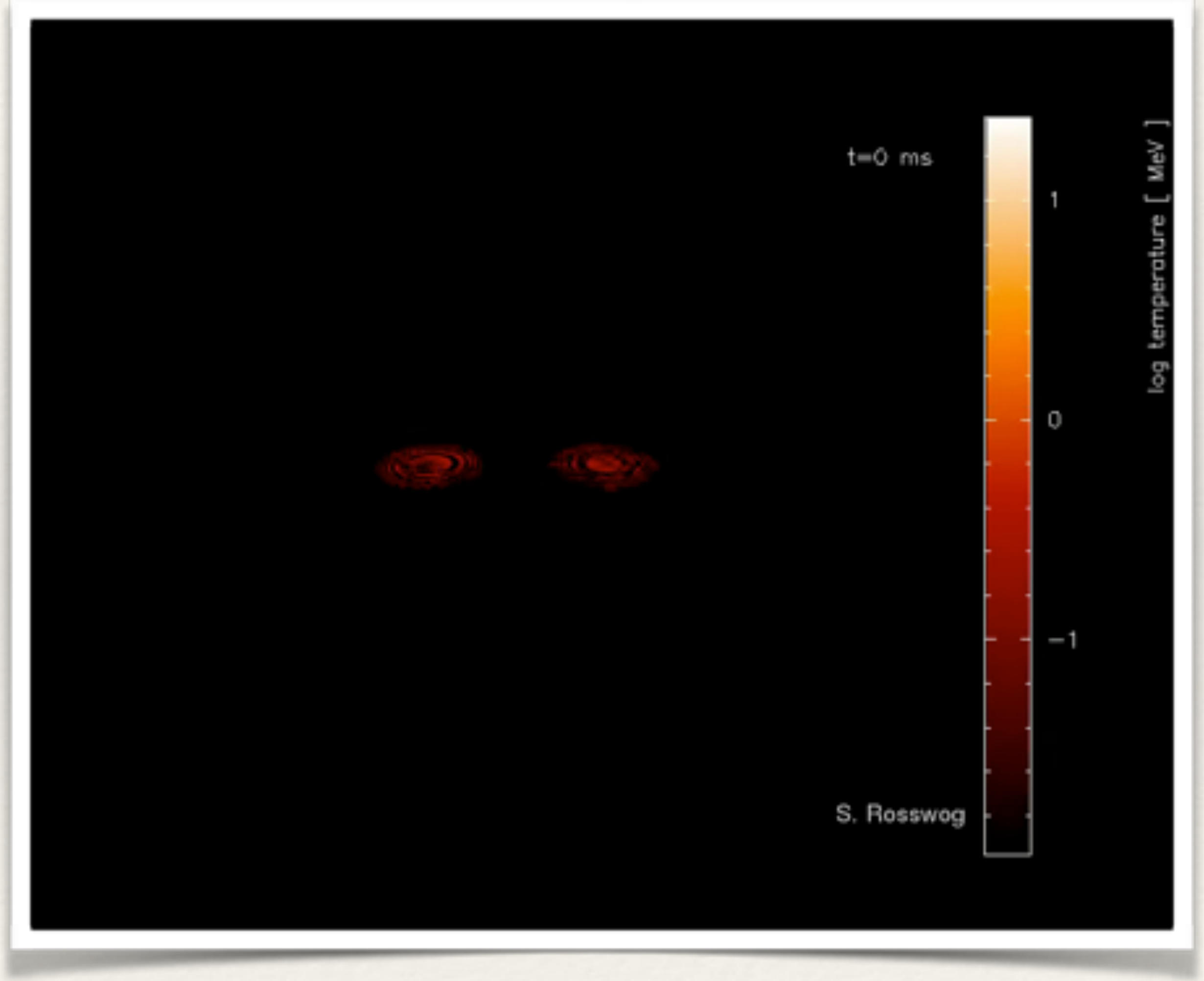



LVC 2016

Merger of two ~ 30 $M_{sun}$ black holes!!!

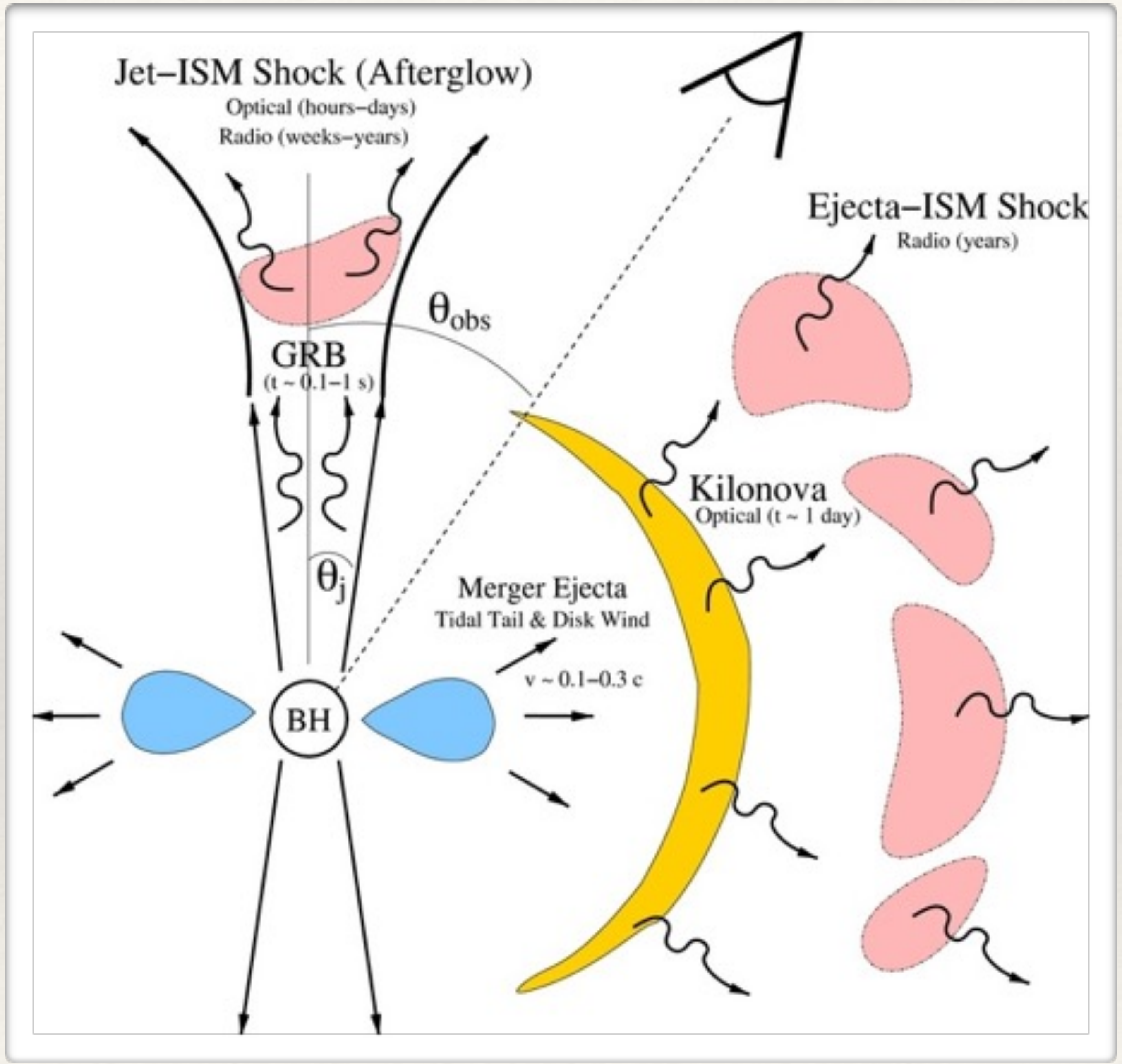
# Why Electromagnetic Counterparts?

- GW detectors provide chirp mass, luminosity distance, (crude) inclination angle
- EM counterpart provides:
  - redshift ($H_0$?)
  - Astrophysical context (host, offset)
  - Composition (r-process nucleosynthesis)
  - Inclination




Rosswog *et al.*, 2012

# What will an EM counterpart look like?

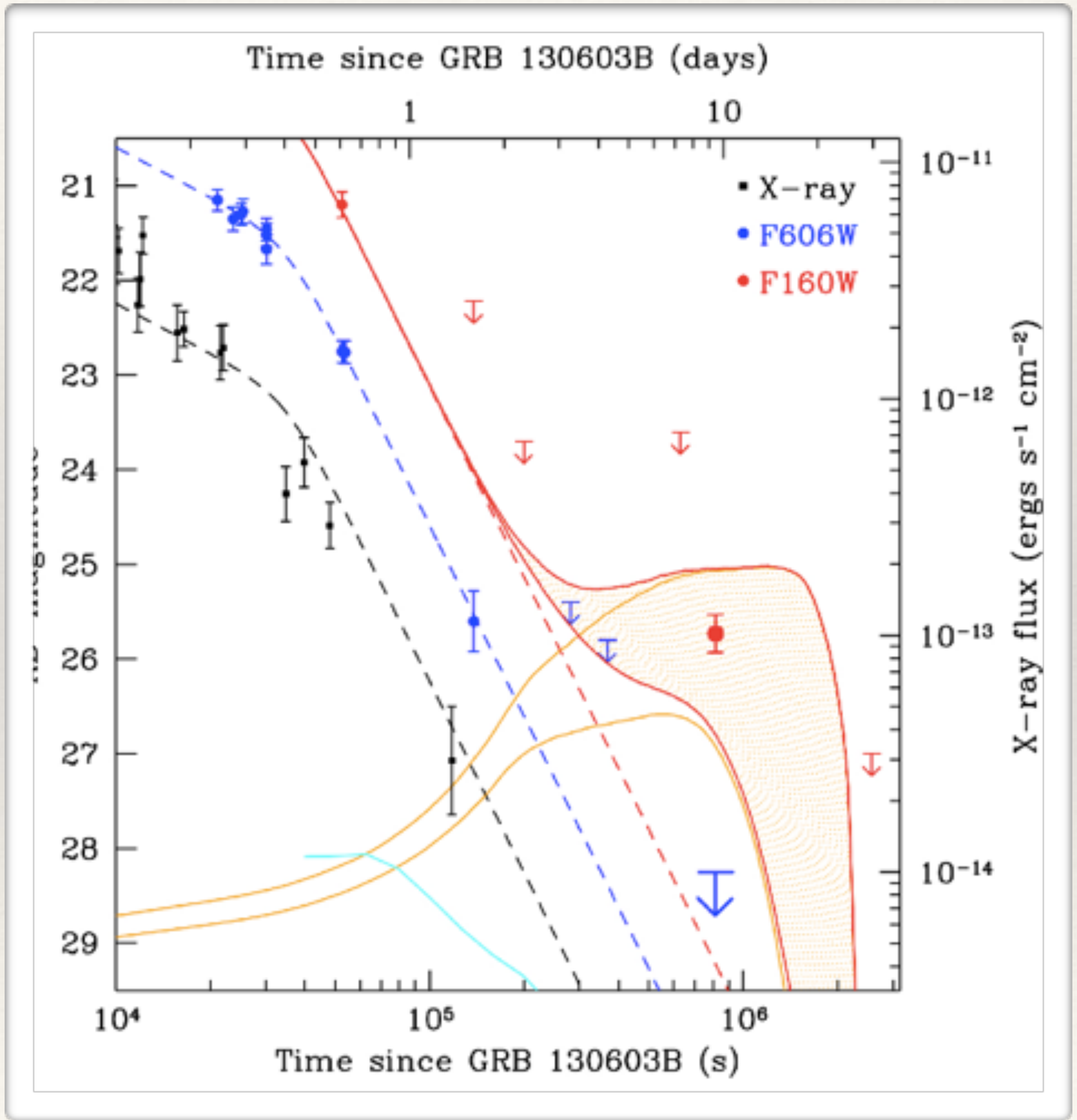



Metzger & Berger, 2012

On-axis: Short Gamma-ray Burst; Off-axis: Kilonova

# “Kilonova” Light Curves

- Due to r-process nucleosynthesis (lanthanides), very large opacity - much redder than supernovae
- Timescale - ~ days to weeks
- Late-time (~ 1 week) “bump” in NIR light curve of short GRB 130603B , with no corresponding optical signal
- Still waiting for confirmation from additional nearby short-hard GRBs



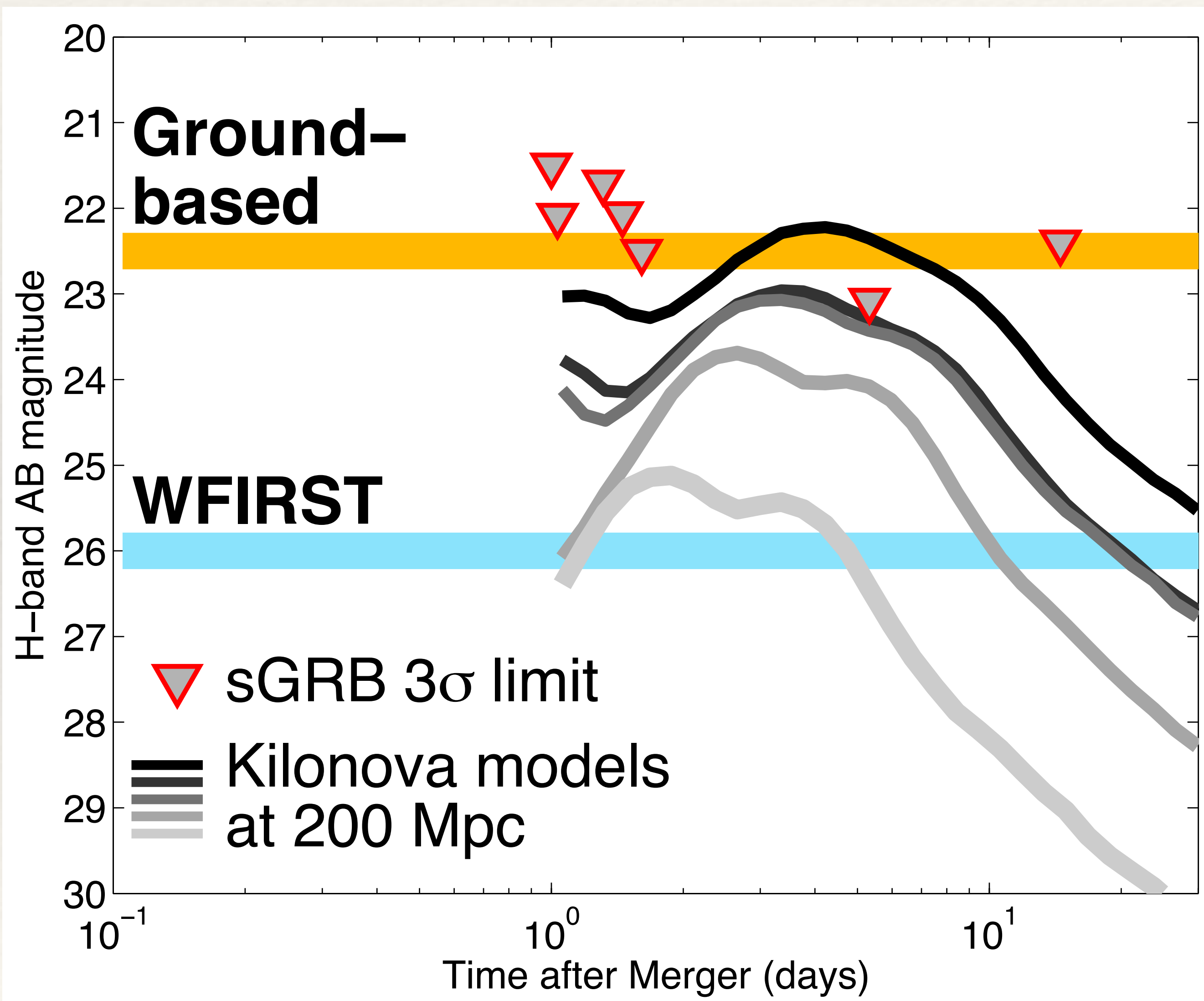

Tanvir *et al.*, 2013

# aLIGO in WFIRST Era

| Epoch | Estimated Run Duration | $E_{GW} = 10^{-2} M_\odot c^2$ Burst Range (Mpc) LIGO | Virgo | BNS Range (Mpc) LIGO | Virgo | Number of BNS Detections | % BNS Localized within 5 deg$^2$ | 20 deg$^2$ |
|---|---|---|---|---|---|---|---|---|
| 2015 | 3 months | 40 – 60 | – | 40 – 80 | – | 0.0004 – 3 | – | – |
| 2016–17 | 6 months | 60 – 75 | 20 – 40 | 80 – 120 | 20 – 60 | 0.006 – 20 | 2 | 5 – 12 |
| 2017–18 | 9 months | 75 – 90 | 40 – 50 | 120 – 170 | 60 – 85 | 0.04 – 100 | 1 – 2 | 10 – 12 |
| 2019+ | (per year) | 105 | 40 – 80 | 200 | 65 – 130 | 0.2 – 200 | 3 – 8 | 8 – 28 |
| 2022+ (India) | (per year) | 105 | 80 | 200 | 130 | 0.4 – 400 | 17 | 48 |

Expect tens of binary neutron star (BNS) detections per year in WFIRST era (but large uncertainties)!

# Unique role for WFIRST in GW Follow-Up

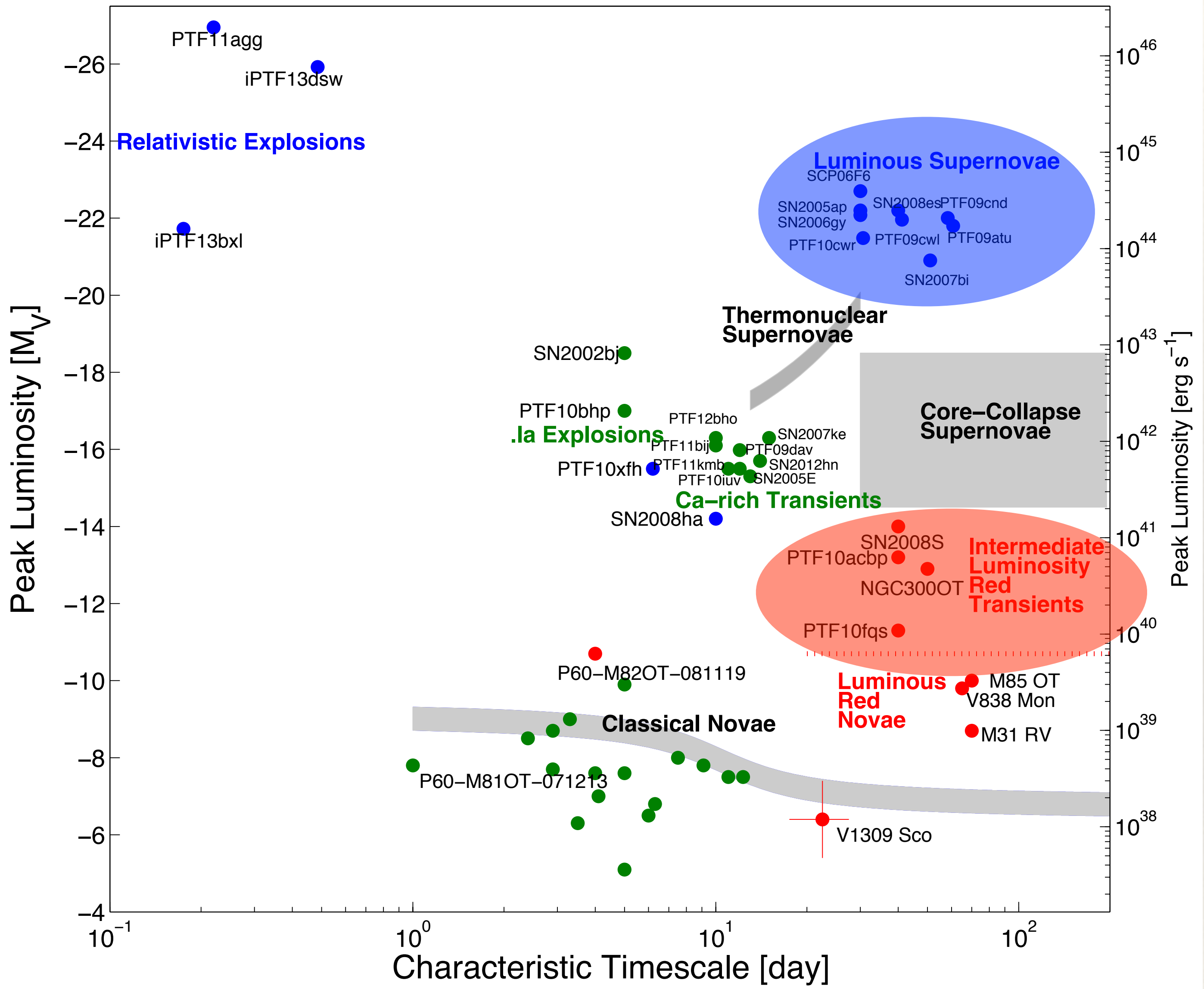



- WFI field-of-view reasonable for expected GW localizations
- Required sensitivity cannot be achieved from ground
- Real-time identification ⟹ spectroscopic follow-up with JWST and/or GSMTs (TMT, GMT, E-ELT)

# GW Follow-Up: Further Work

- GW follow-up **requires** ToO response time of ~ 1 day (as well as prompt downlink, processing, and subtractions)
- Can the observatory support this capability? Yes (at least right now).
- Can other observing programs support ToOs (e.g. interrupt SNe and microlensing cadences)? TBD.

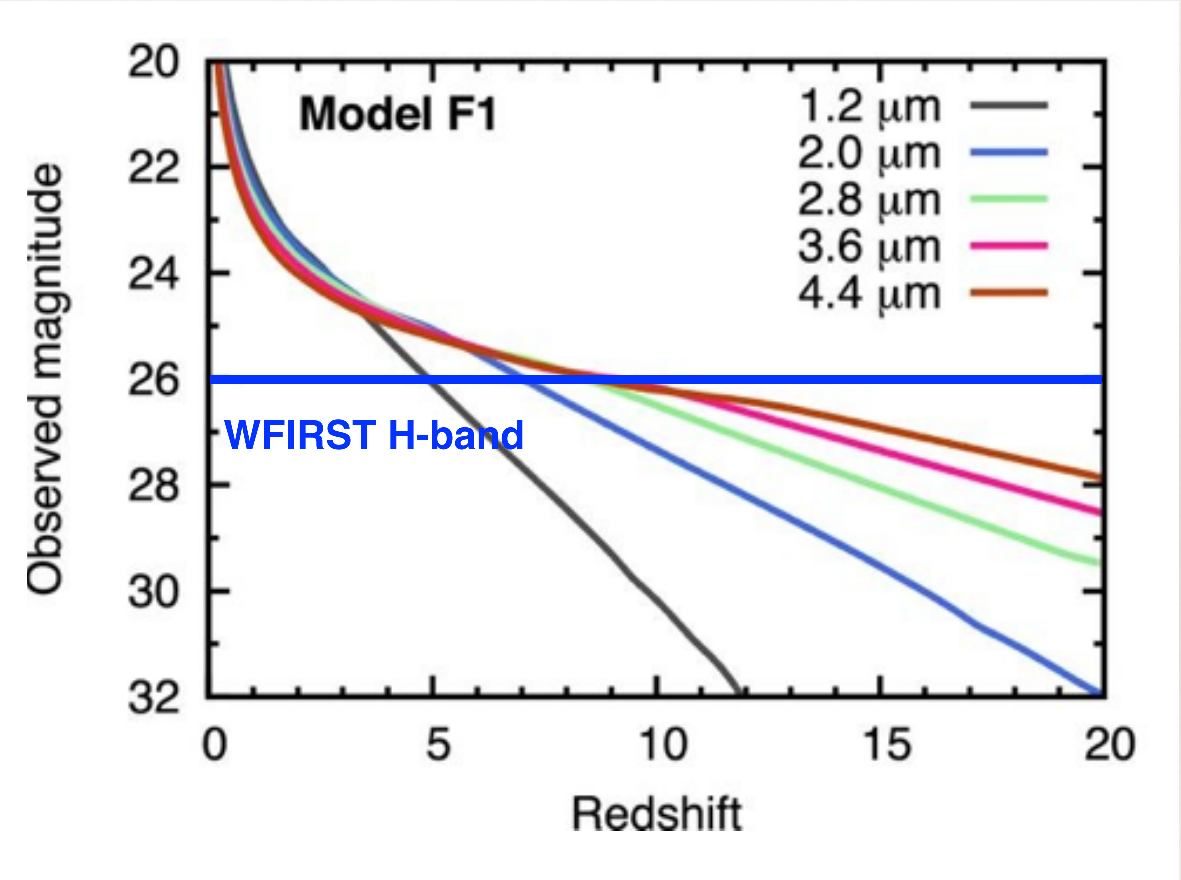
# Transient Phase Space Diagram




Wide-field transient surveys have uncovered a number of new transient classes in the last decade. Here I will focus on SLSN and ILRTs.

# Superluminous Supernovae

- SLSN: Peak absolute magnitude < -21; (rest-frame) time scales months to years
- Diverse power sources: circumstellar interaction, central engine (magnetar?), large Ni mass (pair instability)
- Rates serve as probes of star formation across cosmic history
- Pair instability events detectable out to epoch of reionization



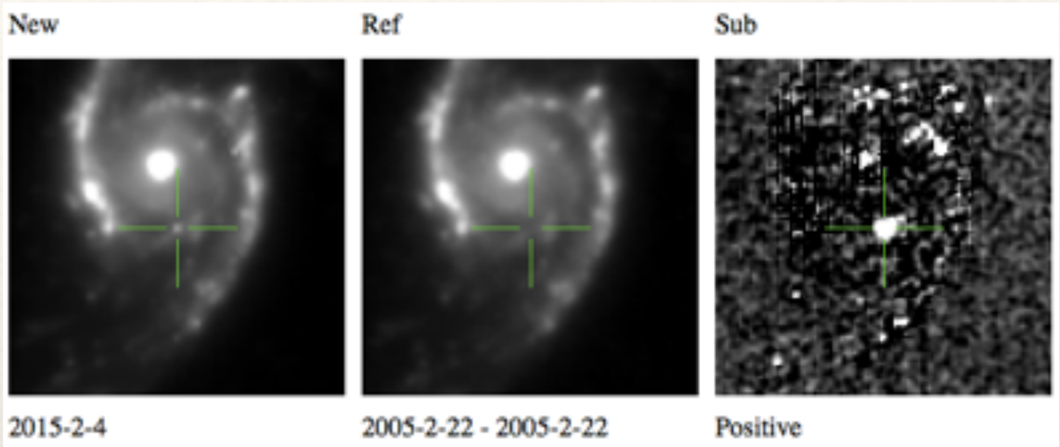

Tanaka *et al.*, 2013

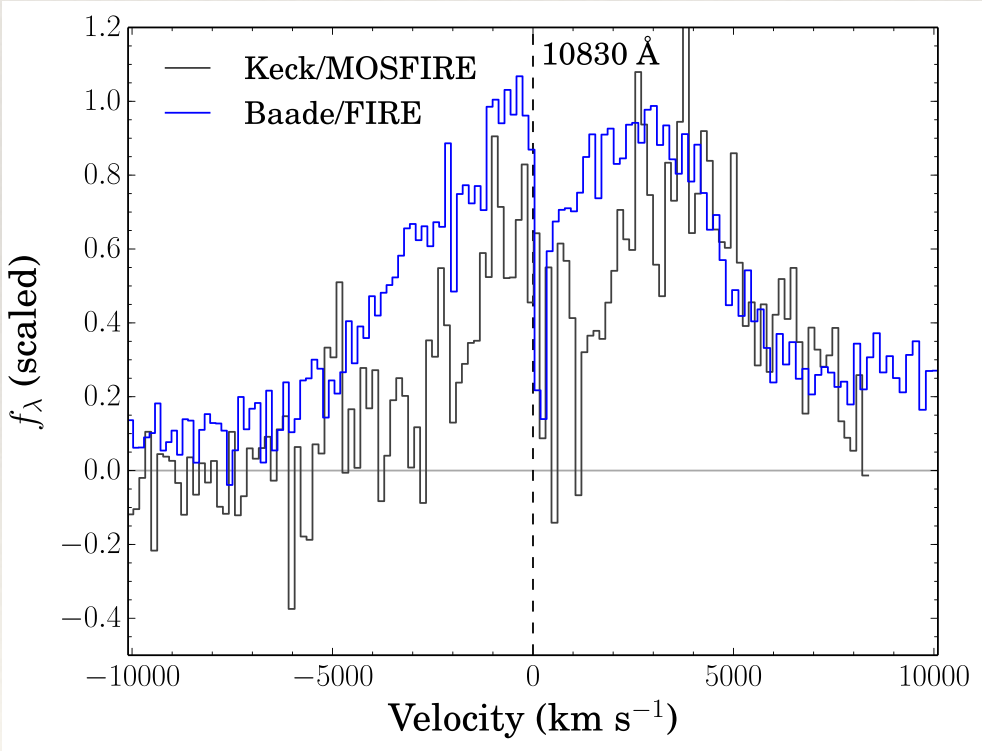
# SLSN: Further Work

- Even using low-redshift rates, thousands of SLSN in the HLS survey out to $z \sim 7$
- **But: identifying them requires an intelligent cadence for HLS (regular observations with temporal separation of months to years)**
- SLSN also of great interest for GO programs

# Intermediate Luminosity Red Transients

- ILRT: "Gap" transients with luminosity between novae and supernovae ($-10 < M_V < -14$)
- Spitzer Infrared Intensive Transients Survey (SPIRITS: PI Kasliwal) - new IR gap transients with *no optical counterpart*
- Likely multiple source populations, possibly including stellar mergers, massive star eruption, failed supernovae



# ILRT: Further Work

- Sensitivity of WFIRST implies ILRTs can be found in unbiased surveys
- But timescales probably too short for HLS $\Longrightarrow$ GI programs probably required
- Could be folded into nearby galaxy survey programs if cadence appropriately matched
- **Regardless requires prompt data processing (image subtraction!) and transient notification**

# Take-Home Messages

- Time-domain science requires a robust target-of-opportunity capability
- Cadence, cadence, cadence …
- Prompt data downlink and processing $\Longrightarrow$ prompt transient notification (community follow-up)