Time Domain Science from a WFIRST Nearby Galaxy GO Program

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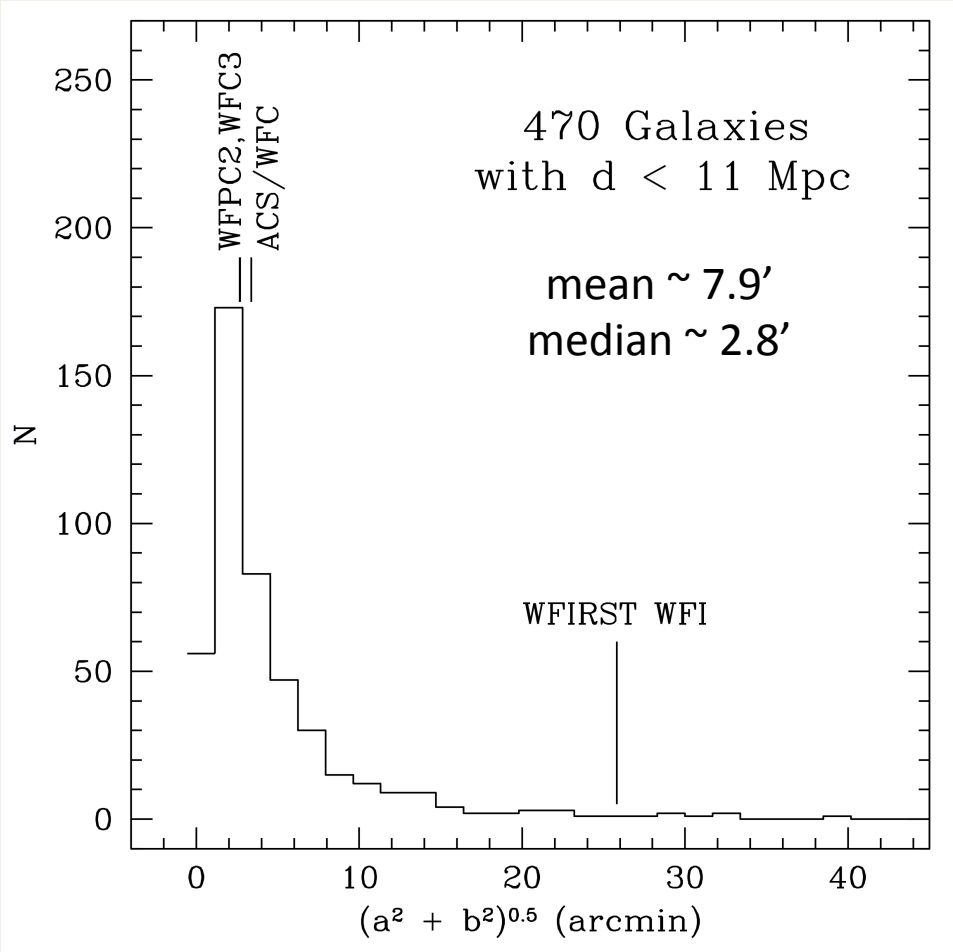
An element of a SIT proposal led by Janice Lee (STScI) and Daniel Dale (UWyoming)

A WFIRST Nearby Galaxy GO program

- A design reference mission for a hypothetical program to image with WFI a complete or representative sample of galaxies, spanning from the Magellanic Clouds out to distances of 10—15 Mpc
- Such a Local Volume Galaxy survey will seed an enormous range of GO science
- *One such aspect is time domain science, or, transient discovery, monitoring, and analysis*

Ben Williams talk yesterday afternoon

Limitations of Existing Data



~56% of galaxies have diameters < ACS/WFC

~33% have not been imaged with HST

~9% have been imaged in WFC3/IR

All but a few would fit entirely on WFIRST WFI

Transients Detectable with WFIRST in a Nearby Galaxy Program

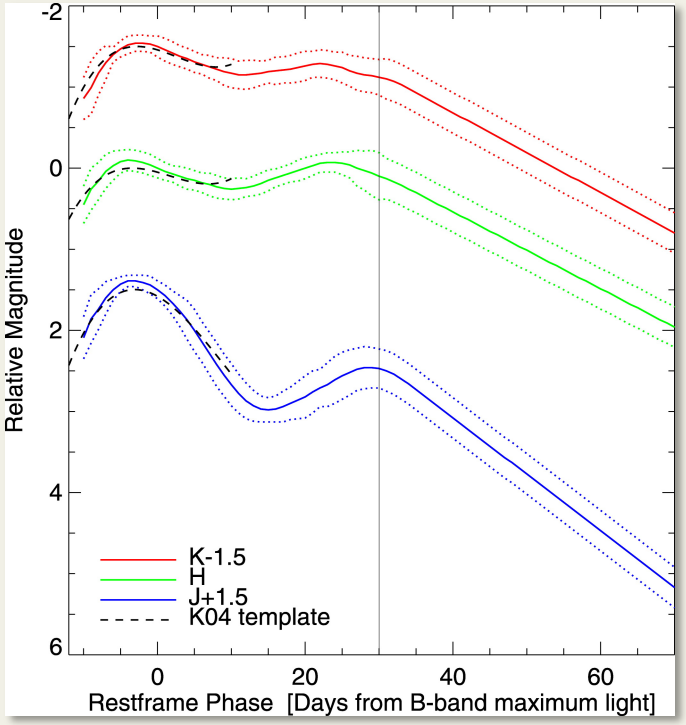
- Cepheids
- Luminous novae
- Luminous blue variables
  - ➢ Outbursts/eruptions ("SN impostors")
- Supernovae*
- ….

Take advantage of the superior spatial resolution and, more importantly, large FoV

*especially at late times

Particularly, Type Ia Supernovae

- The NIR is an important window to examine, and standardize, their behavior

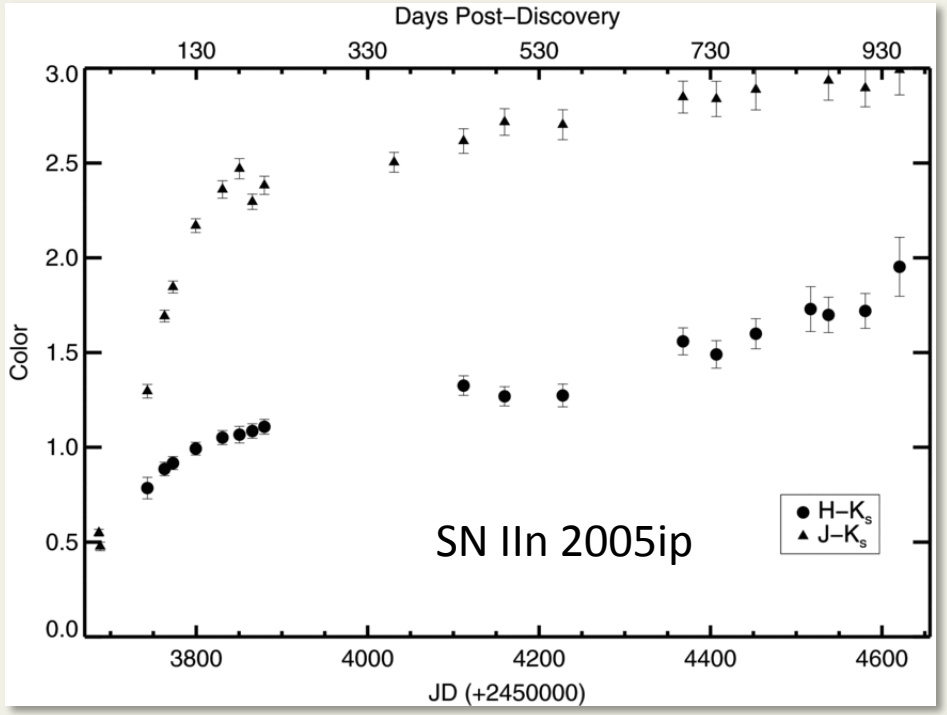


e.g., Kirshner WPS

(e.g., Wood-Vasey et al. 2008; Barone-Nugent et al. 2012; Friedman et al. 2015)

Also, Core-Collapse Supernovae

- The possible presence of dust or dust formation



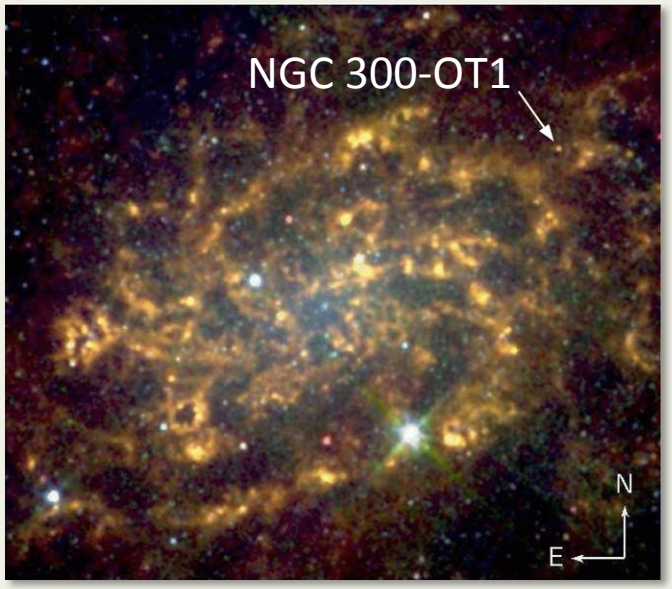
(e.g., Gerardy et al. 2000; Fox et al. 2009; Szalai & Vinko 2013)

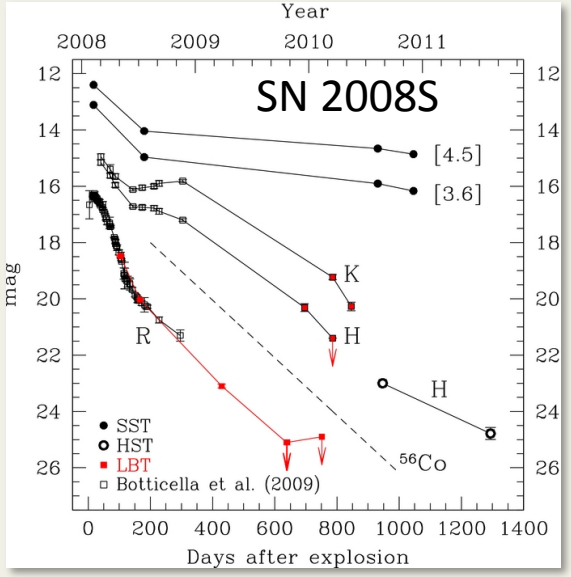
Intermediate-Luminosity Optical Transients (ILOTs)

- Objects similar to SN 2008S and NGC 300-OT1

  (Botticella et al. 2009; Berger et al. 2009)

- Red-to-NIR particularly useful, since ILOTs show IR excesses (e.g., Thompson et al. 2009; Szczygiel et al. 2012)

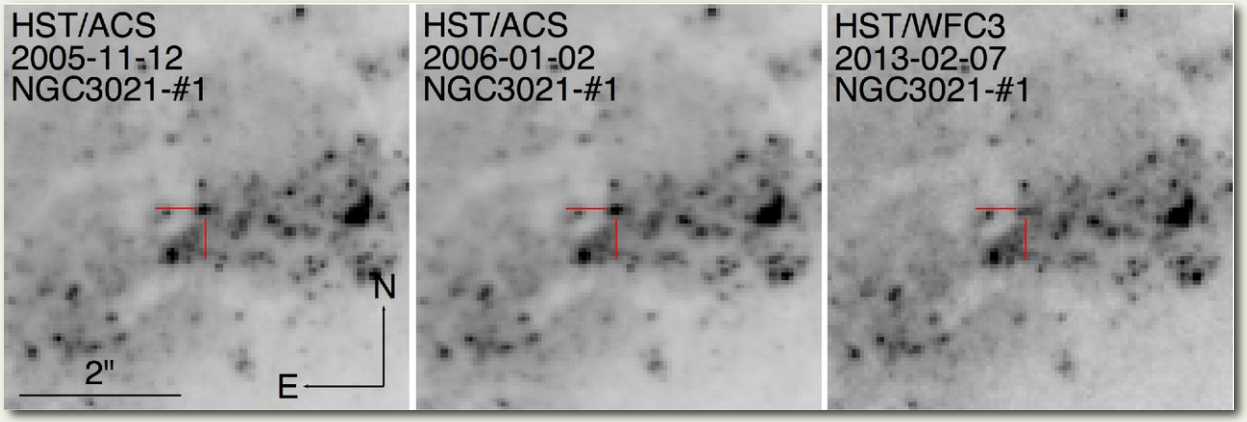




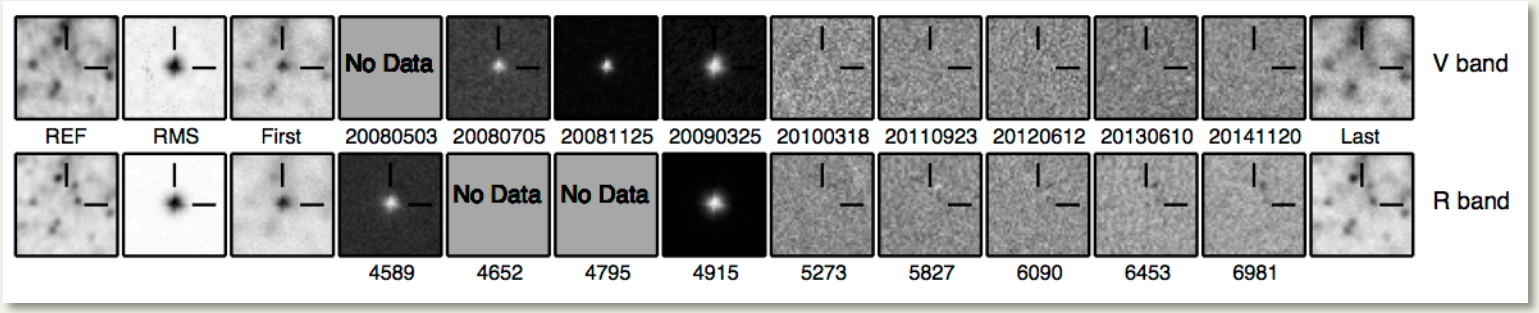
One scenario:
low-mass massive star (superAGB?) experiencing electron-capture supernova

Ideal Platform to look for "failed supernovae"

- Red supergiants that simply vanish

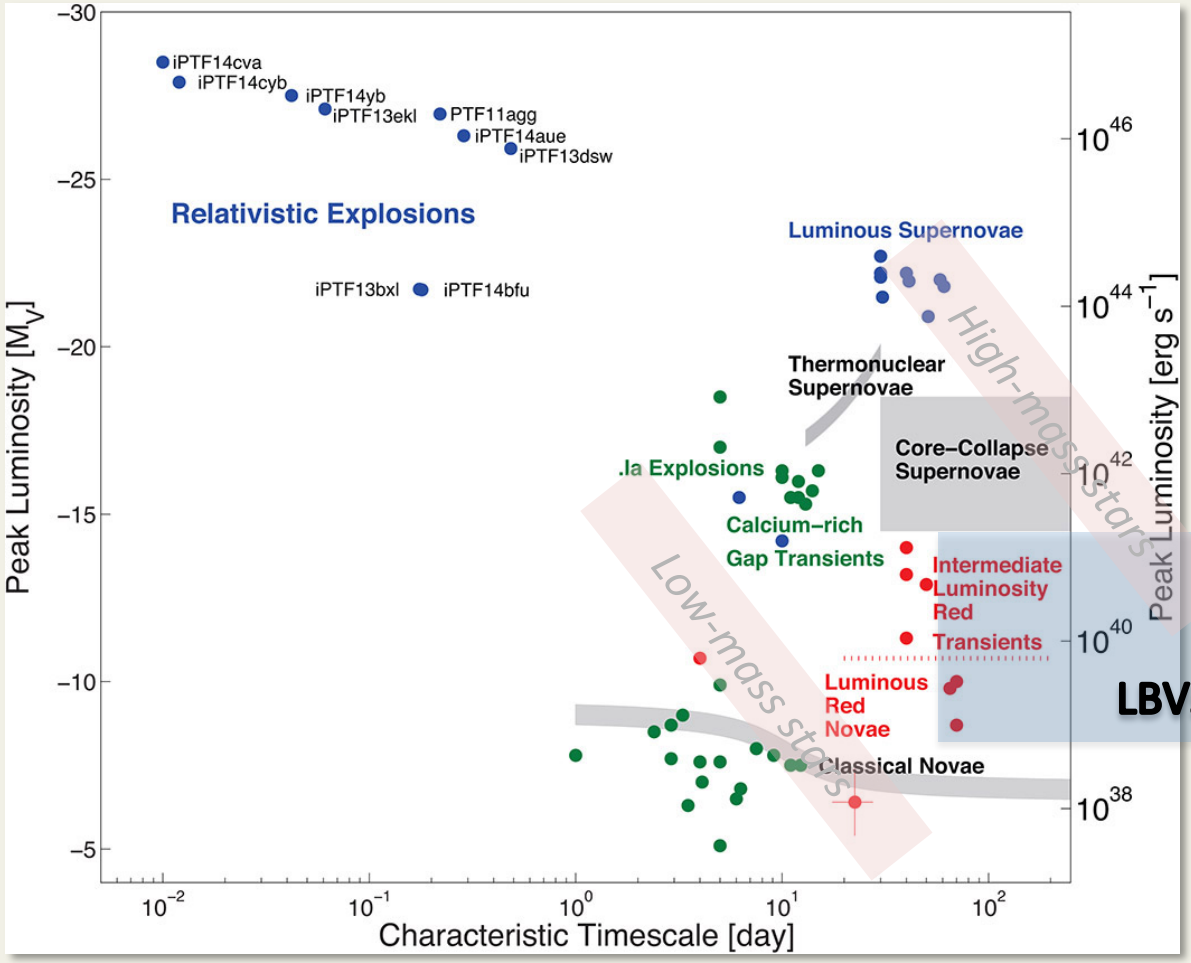


Fraction of failed CC-Sne
$0.09 < f < 0.39$
(Kochanek 2015)



(Kochanek et al. 2008; Gerke et al. 2015; Reynolds et al. 2015)

Transients Phase Space



DEPTH

LBVs

CADENCE

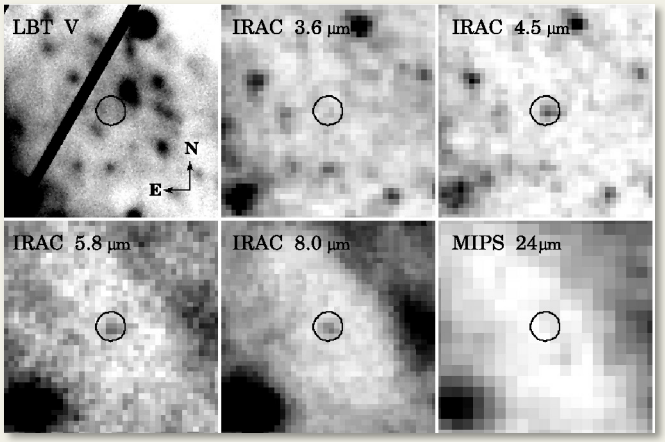
(e.g., Kulkarni & Kasliwal 2009; Nugent 2015)

How to execute the program

- **Build deeper, coadded stacks through a series of shorter, dithered exposures**
- Exposures should be obtained over an extended timeframe and be of a non-uniform cadence
- Optimizing the cadence: a mixed sequence of rapid, hour- to day-long intervals and longer, days- to weeks-long intervals
- Faster cadence ideal for, e.g., fast-evolving luminous novae (e.g., Czekala et al. 2013)
- Longer cadence better for, e.g., Cepheid periods (e.g., Freedman et al. 2001)
- Optimize bands for color and luminosity characterization

Precursor Database

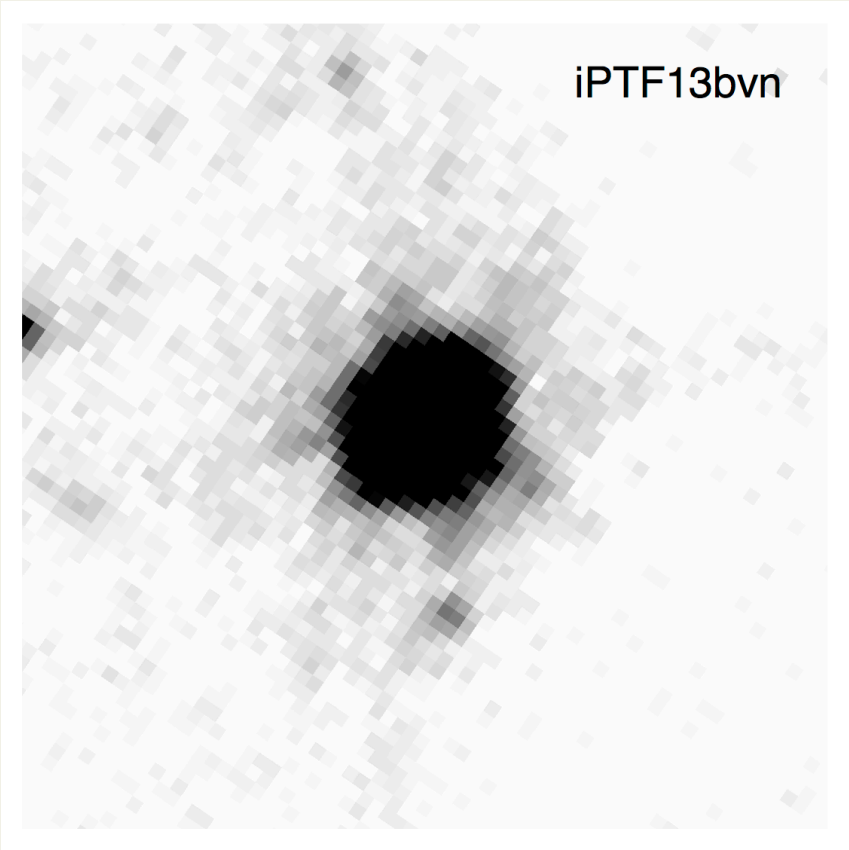
- **Deep stacks will be a wonderful archival database for transient precursor identification**
- Most core-collapse SN progenitors are red or yellow supergiants
- Precursors of ILOTs may be intrinsically dust-obscured, so NIR is particularly valuable

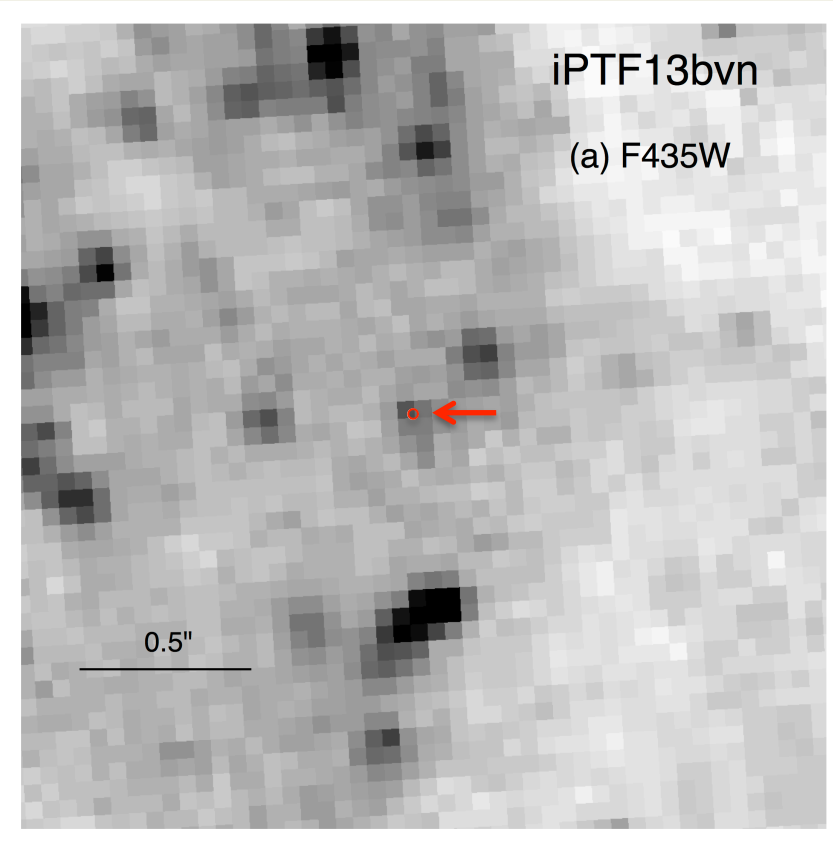


(e.g., Prieto et al. 2008;
Berger et al. 2009; Kochanek 2011)

Precursor Database (2)

SN Progenitor Identification: What we can do today with HST



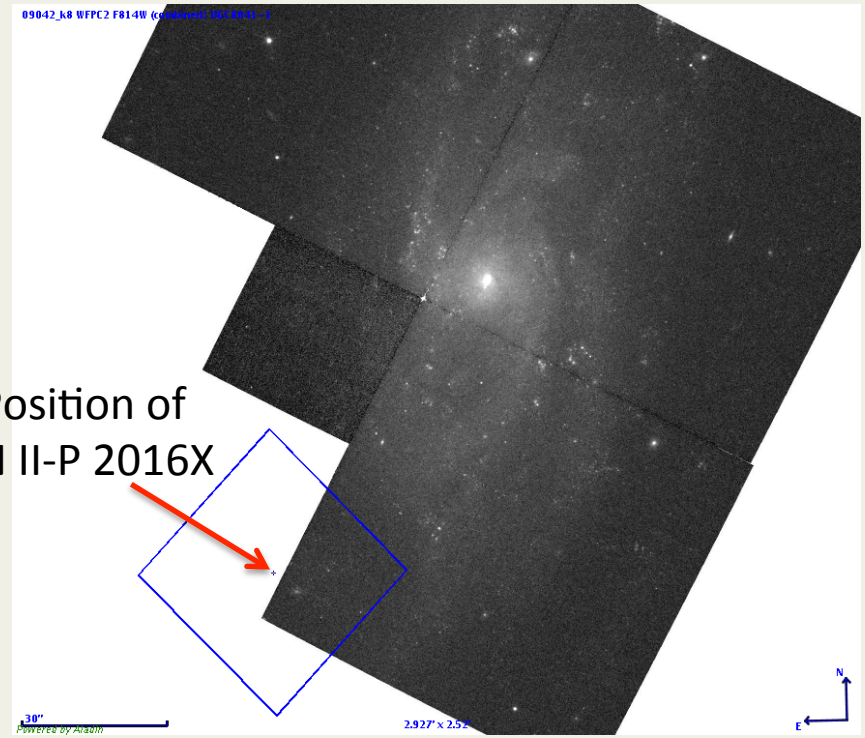


(although, this is not a RSG or YSG….)

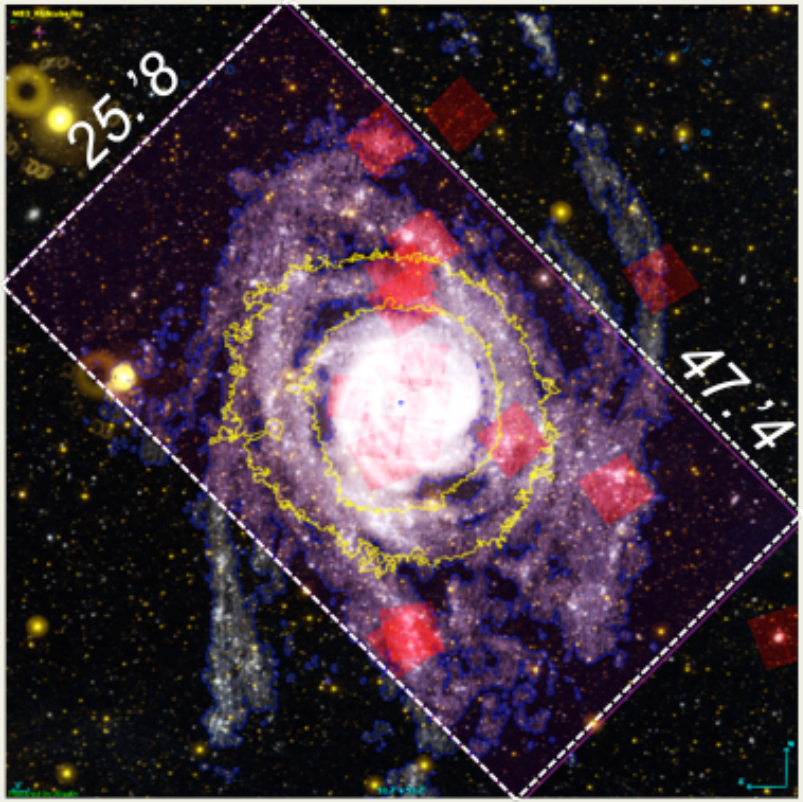
Precursor Database (3)

What often is the case with HST…

… shouldn't be an issue with WFIRST



archival WFPC2 image of UGC 8041



M83 overlay
courtesy Janice Lee & David Thilker

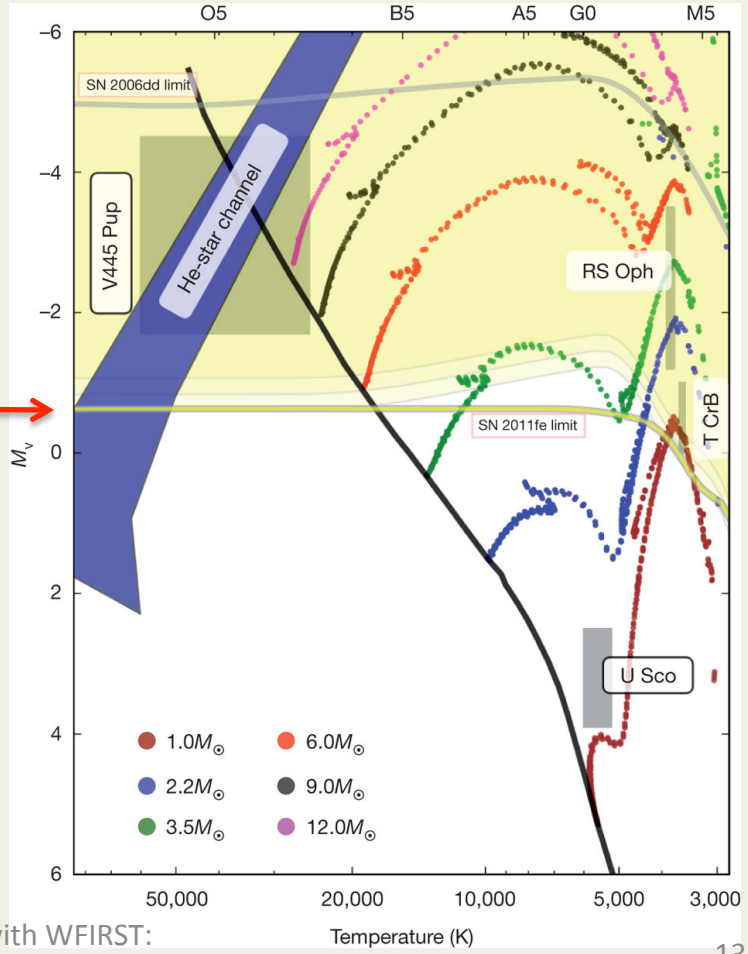
Precursor Database (4)

- Particularly useful for SN Ia progenitor characterization

Progenitor system constraints
in a Hertzsprung–Russell (HR) diagram

SN 2011fe in M101
Deep **non-detection** in
pre-SN HST images
(Li et al. 2011)

(also, Kelly et al. 2014
for SN 2014J in M82)



Summary

- Time domain should be an integral part of any GO Nearby Galaxies program
- Optimization of cadence, depth, and wavelength coverage
- May need to include GO program(s) dedicated to follow-up of SNe and other transients in nearby galaxies
- Deep stacks will be of incredible value for GI science
- WFIRST is complementary to LSST for transient science
  - WFIRST will provide stability, superior angular resolution, access to dec > +10°, and coverage to 2 μm
  - LSST will provide the vital optical component
  - Will only be able to detect transient precursors with LSST to ~3—4 Mpc