Time Domain Science from a WFIRST Nearby Galaxy GO Program

Schuyler D. Van Dyk
(IPAC/Caltech)

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., 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

\[ 0.09 < f < 0.39 \] (Kochanek 2015)

(Kochanek et al. 2008; Gerke et al. 2015; Reynolds et al. 2015)
Transients Phase Space

(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

Position of SN II-P 2016X

M83 overlay courtesy Janice Lee & David Thilker

Pasadena, 2016 Mar 2

Community Astrophysics with WFIRST:  
Guest Observer and Archival Science
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