The Roman High Latitude Time Domain Survey & Kilonova Science

Igor Andreoni
Neil Gehrels Fellow

Rubin PCW 2023

Image credit: NASA/JPL
Nancy Grace Roman Space Telescope

THE NANCY GRACE ROMAN SPACE TELESCOPE
Field of View
Roman White Papers 2023

66 White Papers of which 20 for the High Latitude Time Domain survey

Methods: Rose+ (a, b, c), Deustua+

Subaru/CASTOR and Roman synergy: Harikane+ (a), Koyama+ Thilker+

Spectroscopy and galaxies: Rhoads+, Harikane+ (b), Fox+, Aldering+

Massive black hole binaries and AGN: Haiman+, Yamada+

Stars in the halo: Holwerda +

Distance Ladder: Kraemer+

Tidal Disruption Events: Karmen+

Supernovae: Macias+, Fox+, Moriya+, Fraser+

Kilonovae: Andreoni+, Macias+
High Latitude Time Domain Survey

~Tens of sq. deg.

It will be defined by a Community process

Baseline survey for SN Ia (Rose+2021): 6 months of aggregate telescope time, spread over a 2 year period, with 25% duty cycle during that period, 20 deg$^2$ footprint (wide), 5-day cadence
Supernova detection (Ia + core-collapse)

See also, e.g., Spergel+2015, Foley+2018, Hounsell+2018

$N = 12471$ (recovered)
Transient detection (not Type Ia)

Igor Andreoni

August 10, 2023

Macias+ WP 2023

...will we be able to classify these transients?
Rare supernovae at high $z$
Rare supernovae at high $z$

Moriya+ WP 2023
Roman Field of Regard

**Observing Zone:**
- 54°-126° Pitch off Sun line
- 360° Yaw about Sun Line
- ±15° Roll about Line of Sight off max power roll angle

Earth/Moon Line of Site avoidance angles are a minor sporadic constraint
High Latitude Time Domain Survey: Where to observe?

Foley+ WP 2018

Igor Andreoni
August 10, 2023
Kilonovae

Ascenzi+21

(KN = kilonova)
Heavy “r-process” elements

Element Origins

Merging Neutron Stars
Dying Low Mass Stars
Exploding Massive Stars
Exploding White Dwarfs
Big Bang
Cosmic Ray Fission

See e.g. Lattimer & Schramm (1974)

Credit: Jennifer Johnson

August 10, 2023
Kilonovae - GW170817

Villar+17
(see references therein)
Rubin & Roman kilonova observations

Rubin & Roman kilonova observations

GW170817 best fit at 1Gpc, \( \theta = 26 \) deg

Rubin & Roman kilonova observations

Kilonova low $Y_e, M_{ej}$ at 1Gpc, $\theta=45$ deg

Kilonova detection in the HLTD survey

55s, z=0.2 \( (D_{\text{comoving}} = 850 \, \text{Mpc}) \)

Igor Andreoni

Kilonova detection in the HLTD survey

1hr, $z=0.2$ ($D_{\text{comoving}} = 850$ Mpc)

<table>
<thead>
<tr>
<th></th>
<th>F062</th>
<th>F087</th>
<th>F106</th>
<th>F129</th>
<th>F158</th>
<th>F184</th>
<th>F213</th>
<th>F146</th>
</tr>
</thead>
<tbody>
<tr>
<td>GW170817$_{pol}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GW170817$_{eq}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>low $Y_e$, $M_{ej}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>low $Y_e$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>low $M_{ej}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>high $M_{ej}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Time from merger (days)

Kilonova detection in the HLTD survey

1hr, $z \sim 0.9$ ($D_{\text{comoving}} = 3 \text{ Gpc}$)

Beyond the HLTD survey: Target of Opportunity

Roman

50% area = 1.38 deg²
90% area = 5.06 deg²
17 fields

Rubin

85 deg²

pos.eq.dec

pos.eq.ra

I.A.+2023, figure by Leo Singer

I.A.+2022, ApJS, 260, 1, 18
Beyond the HLTD survey: Target of Opportunity

LIGO-Virgo-KAGRA detection prospects

I.A.+2023, based on the analysis by Petrov+2022
Some key findings…

With a 19 deg$^2$ footprint and 1hr exposures, $\sim 1$–8 kilonovae similar to GW170817 can be found yearly.

1–6 ToO observations of well localized ($A < 10$ deg$^2$) mergers during 1.5 years of LVK O5, or $\sim 4$–21 during 1.5 years of O6.

We need a cadence better than $< 8$ days in at least 2 filters (preferably F158 & F213).

See also Scolnic+18, Chase+22, Macias+23 WP
...and my wish list for further exploration

**Synergies** between Roman and Rubin in Deep Drilling Fields

**Photometric classification** of kilonovae and other transients in the nIR or joint optical + nIR

**Deep & Wide survey** with the F158 & F213 Roman filters

Possibility of **faster ToOs** with Roman (~ 1 week instead of 2 weeks)

**Tools** for survey strategy exploration (similar to MAF)