The **Rapid Transient Surveyor**

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RTS: Experimental Method

Identify 1,000s of supernovae per year. Obtain peak and slope of light curves.

Near peak luminosity, obtain a wide low-R infrared spectrum to determine extinction.

Combine with known galactic redshifts.

Reconstruct 3-D dark matter map. (a la Tully et al.)

Confirm Type Ia supernovae (SNIa). Derive absolute brightness of SNIa. Determine distance to host galaxy from apparent brightness.
Why is this important to study?

- $\Lambda$CDM predicts our local group should be at rest with respect to Universe.
- Current measurements show 630 km/s.
- Even correcting local sources and to 0.05c, e.g., Shapley concentration, we’re ~200km/s w.r.t. CMB.
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Asteroid Terrestrial-impact Last Alert System

- NASA funded to discover dangerous asteroids.
- Two wide field 0.5-m telescopes:
  - Haleakala: Online; Mauna Loa: in commissioning now.
- Observing half the sky to V=20, 3 times/night in two filters.
- Currently detecting 20,000 asteroids and 500 other transients/night.
ATLAS finds thousands of SNIa/year.

<table>
<thead>
<tr>
<th>(&lt; z)</th>
<th>(&lt; m)</th>
<th>#/yr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.016</td>
<td>15</td>
<td>~30</td>
</tr>
<tr>
<td>0.04</td>
<td>17</td>
<td>300</td>
</tr>
<tr>
<td>0.1</td>
<td>19</td>
<td>5000</td>
</tr>
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ATLAS: peak brightness and decline rate.

SN are really standard candles in the NIR:

Getting NIR light curves is very costly so we’ll combine visible photometry with NIR spectrum.

Kirshner 2015
What can we learn from a NIR SN spectrum?

• Spectral slope = reddening by dust
  – Reduces the apparent visible brightness of SN.
  – Correctable!

• Spectral features:
  – Confirmation that SN is type Ia.
  – Location of features confirms (but does not determine) redshift of host galaxy.
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State/UH: $5M in telescope refurbishment/robotic upgrade.
Permanent installation.
Queue interrupt and scheduling for ToOs.
Integrated NIR IFS.

Upgraded version of Robo-AO for the UH 2.2-m on Maunakea
Residual wavefront error will be reduced with Robo-AO-2.

<table>
<thead>
<tr>
<th>Spectral Band</th>
<th>$\lambda$</th>
<th>$\lambda/D$</th>
<th>Strehl</th>
<th>FWHM</th>
<th>Strehl</th>
<th>FWHM</th>
<th>Strehl</th>
<th>FWHM</th>
<th>Strehl</th>
<th>FWHM</th>
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</thead>
<tbody>
<tr>
<td>$g'$</td>
<td>0.47 $\mu$</td>
<td>0.044&quot;</td>
<td>7%</td>
<td>0.06&quot;</td>
<td>2%</td>
<td>0.07&quot;</td>
<td>1%</td>
<td>0.11&quot;</td>
<td>0%</td>
<td>0.48&quot;</td>
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<tr>
<td>$r'$</td>
<td>0.62 $\mu$</td>
<td>0.058&quot;</td>
<td>19%</td>
<td>0.07&quot;</td>
<td>10%</td>
<td>0.07&quot;</td>
<td>6%</td>
<td>0.08&quot;</td>
<td>1%</td>
<td>0.12&quot;</td>
</tr>
<tr>
<td>$i'$</td>
<td>0.75 $\mu$</td>
<td>0.070&quot;</td>
<td>30%</td>
<td>0.08&quot;</td>
<td>20%</td>
<td>0.08&quot;</td>
<td>14%</td>
<td>0.08&quot;</td>
<td>5%</td>
<td>0.10&quot;</td>
</tr>
<tr>
<td>$J$</td>
<td>1.25 $\mu$</td>
<td>0.117&quot;</td>
<td>64%</td>
<td>0.12&quot;</td>
<td>54%</td>
<td>0.12&quot;</td>
<td>45%</td>
<td>0.13&quot;</td>
<td>33%</td>
<td>0.13&quot;</td>
</tr>
<tr>
<td>$H$</td>
<td>1.64 $\mu$</td>
<td>0.153&quot;</td>
<td>76%</td>
<td>0.16&quot;</td>
<td>69%</td>
<td>0.16&quot;</td>
<td>62%</td>
<td>0.16&quot;</td>
<td>51%</td>
<td>0.16&quot;</td>
</tr>
</tbody>
</table>

Adopting a 150 mas spaxel size on the IR IFS.

Assuming AO sharpened $V=17$ A0 tip-tilt star for the NIR (or MV for the visible).

Ensquared Energy vs. SNIa $m_V$

2x2 spaxels, 30° ZA, median seeing
How to add an IR IFS to Robo-AO.

- Robo-AO is a two OAP relay design
  - R1: DM, UV dichroic
  - R2: TTM, ADC, Vis/IR
- Instrument ports:
  - T~50%-55%, F/40
- IFS Lenslet
  - Requires ~F/140
- Solution:
  - Split to IFS after R1 (F/20). Effective T~75%.
  - Needs own TTM and SW dispersion correction.
How to add an IR IFS to Robo-AO.
Robo-AO-2 IR IFS specifications

- Simultaneous wavelength coverage **0.84 – 1.83 µm**
- Spectral Resolution **R~100**
- Spatial sampling **0.15” per spaxel**
- Field of view defined by lenslet array 58x40 (**8.6” x 6.0”**) 
- **No moving components** (e.g., filter wheels, grating wheels, optics) in the spectrograph for simplicity and stability of spectra.
Gain in integrated SNR and observing time per band.

AO corrected: 0.3”x0.3”, vs. seeing limited: 0.8”x0.8”.
SNR in each NIR band in 20 minutes

But we’re really interested in measuring the extinction…
Measuring Extinction, $A_\lambda$, of thousands of SNIa

$$m_\lambda = m_{\lambda, \text{intrin}} + A_\lambda$$

$$A_\lambda = A_{Ks} \left( \frac{\lambda}{\lambda_{Ks}} \right)^\alpha$$

$\alpha = -1.95$ (Wang, Jiang 2014)

- Roughly x2-3 times faster with AO.
- $\sim 15$ SNIa/night = 5 hours.
- We’ll keep pace with discoveries (inc. weather, other SNs, transients).
- In one year we’ll have, $>4,000$ SNIa distances, sufficient coverage of the $z<0.1$ universe.
What will RTS do?

With 1 full year of observations, we will characterize >4,000 SNIa and map local Dark Matter to 30 times larger than Laniakea!

Test many cosmological theories, possibly challenging the current standard model.

Other science: quickly characterize NEOs.

Pathfinder for similar LSST followup techniques and instrumentation.

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M. Salama: Robo-AO Kitt Peak + IR APD [9909-48] Tr 10:30

