The La Silla Schmidt Southern Survey (LS4)

A shallow, southern, high-cadence, optical survey to compliment the Rubin Observatory.

Here I'll give you the who, what, where, how, when and why...

Peter Nugent (10-23-2022)

Why?

Why consider a shallow, optical survey in the south at a time during which it will not only overlap with the Rubin observatory, but also with the BlackGEM and DECam facilities?

- *The cadence of the LSST is not optimal for many transients.* While the reach of this experiment is impressive, most science cases are focused on high-precision photometry and astrometry over long periods of time for the optically brighter end of the transients (e.g., variable stars, high-proper motion stars, etc.), while on the fainter end the focus is on transients with slower evolution (e.g., high-redshift type Ia supernovae for cosmology). Some transients (NEOs and KBOs) require frequent paving across the entire sky.
- *Not all volumes are created equally.* The follow-up capabilities of most of the world's telescopes can only handle the brighter sources discovered by the Rubin Observatory and there is a large swath of transient science in which a timely spectrum is the only path forward for new science. In addition, much of the local universe is inaccessible to the Rubin Observatory due to saturation.
- *One survey is not the path forward for transient astrophysics.* What has become increasingly apparent in astronomy is the power of two or more overlapping surveys. This now forms the backbone of multi-messenger astronomy as well as the desire to initiate collaborations between such surveys as Euclid and WFIRST with the LSST, or the DES and DECaLS imaging surveys paving the way for a spectroscopic survey like DESI.

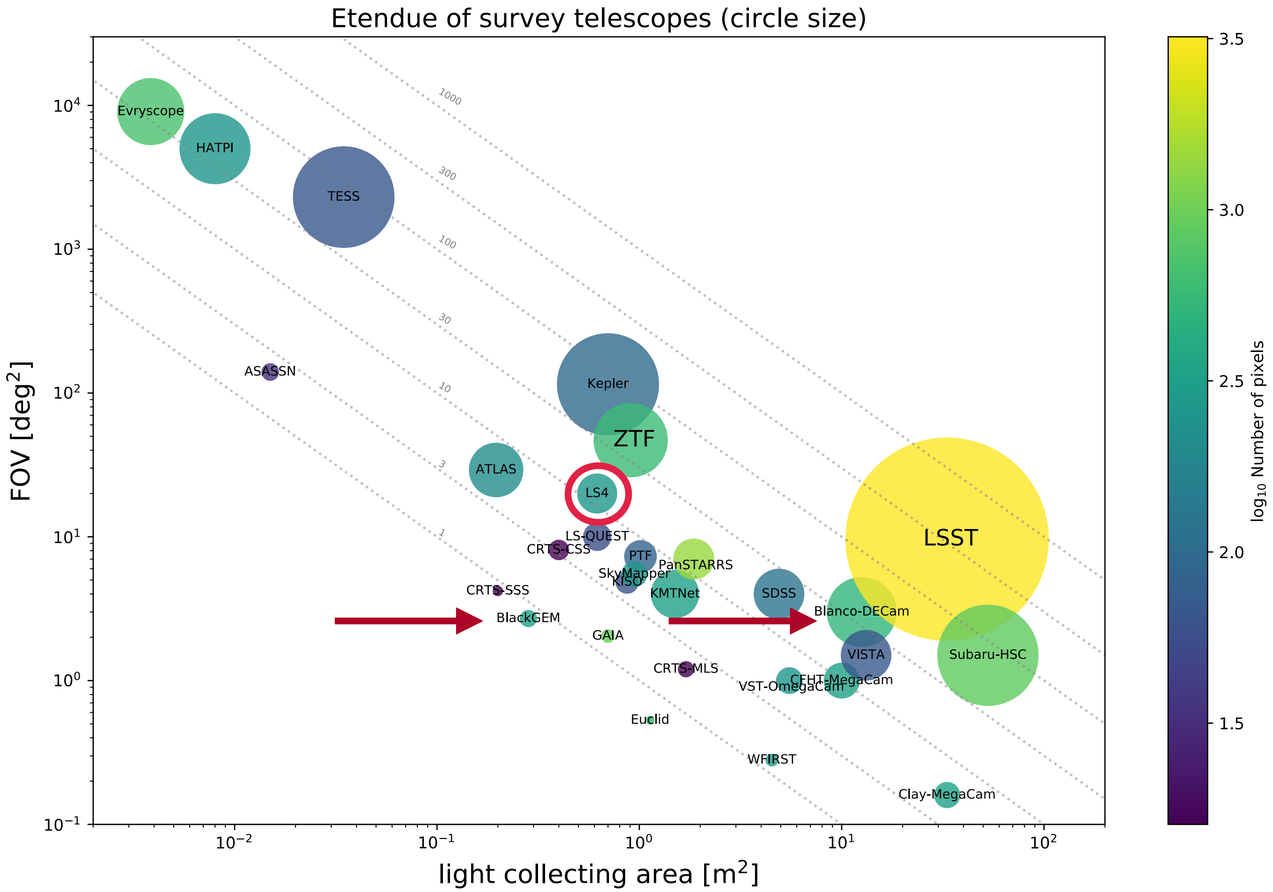
Why?

Why consider a shallow, optical survey in the south at a time during which it will not only overlap with the Rubin observatory, but also with the BlackGEM and DECam facilities?

= *Shallow survey, with higher cadence which maximizes easily obtainable follow-up resources.*

Where & When

Only two options and both are in the south (since who wants to compete with ZTF-II):
CTIO 0.5-m and ESO 1-m Schmidts

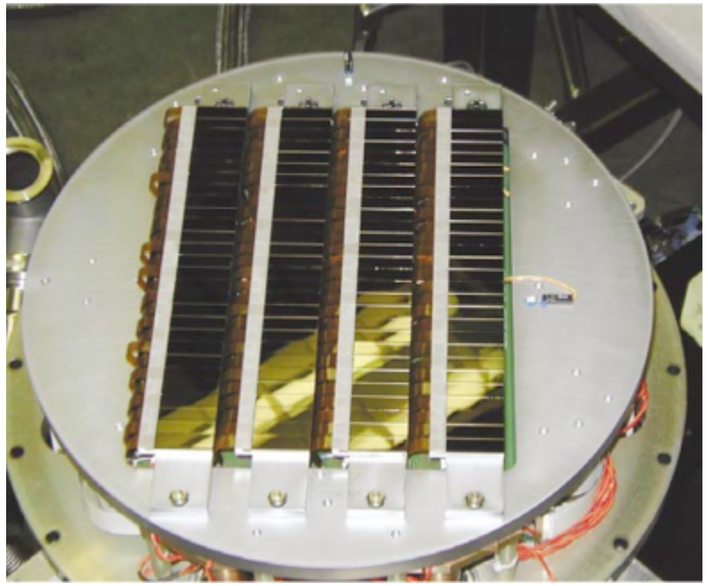


La Silla 1.0-m Schmidt has the biggest and most immediate impact:

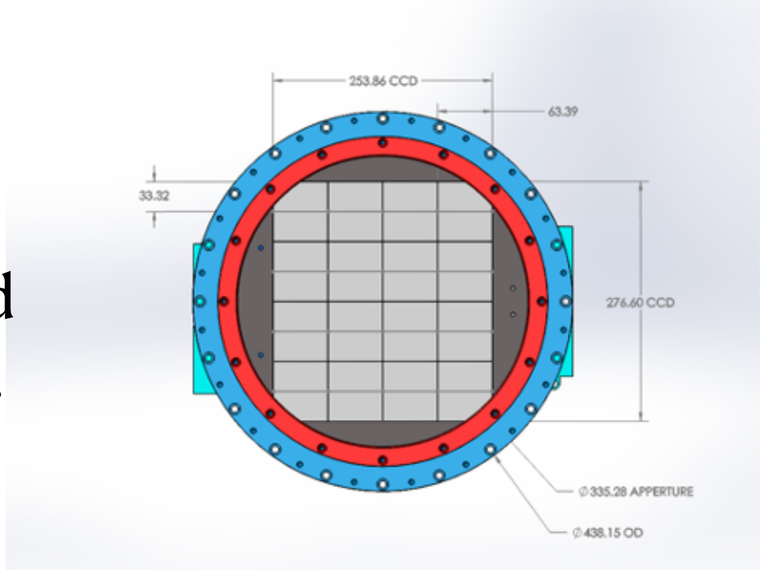
- Easiest to modify and we have done a survey there in the recent past (LSQ).
- About half a ZTF.
- Nicely fills in the gap between HATPI (< 13th mag) and Rubin (16th < r < 24th mag)
- Can be modified to be on-sky by 2024.

How

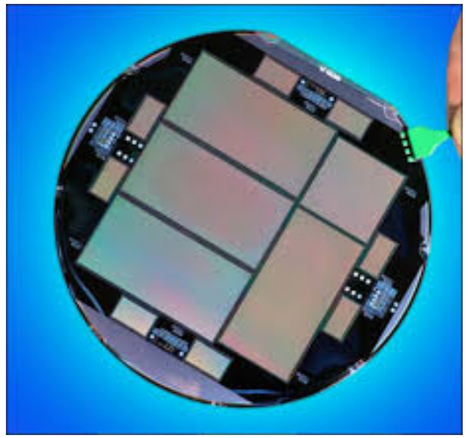
Use (re-use) everything at our disposal.

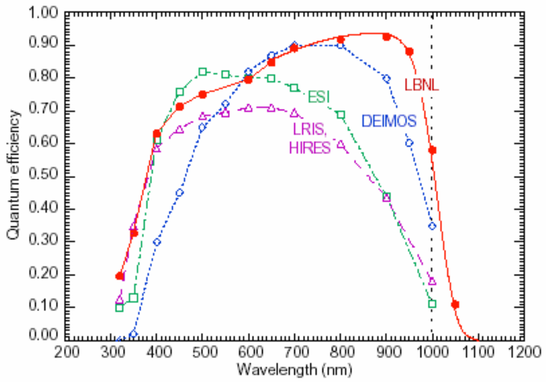


32 2k*4k CCDs cover the un-vignetted field of view with 1” pixels.



Refit the La Silla Schmidt Camera with DES CCD’s to cover the entire focal plane. 20 sq deg.





Many extras available from the DES fabrication runs, high QE in the red.

Survey: *Volume*, Cadence, & Follow-up

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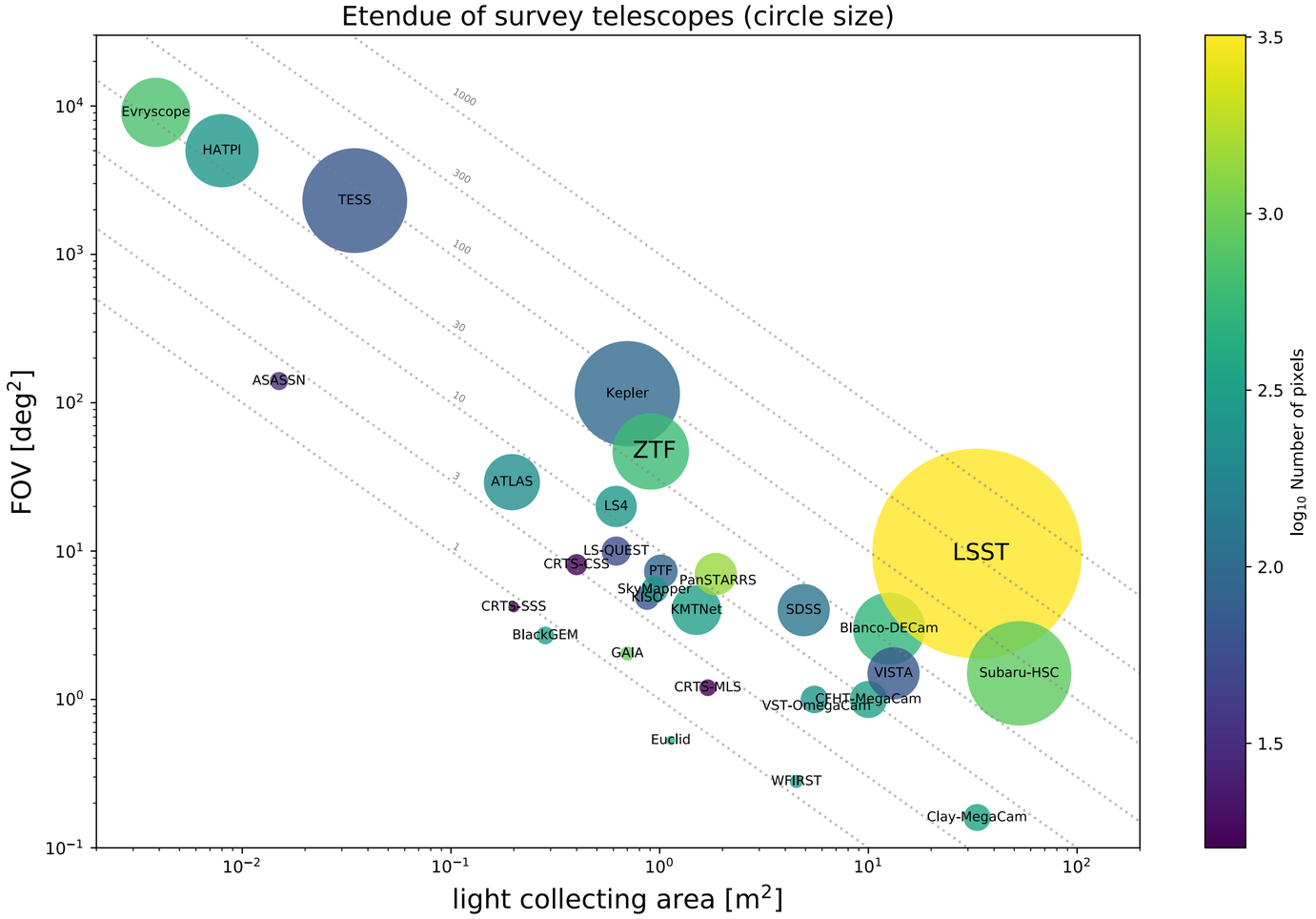

The volume you survey should be large enough to provide nightly discoveries, and with them a large enough number to discover some exotic transients. It should not be so deep as to stretch your follow-up resources.

I.e. we would like to be nearly the opposite of the Rubin transient discoveries and get a spectrum of everything which goes bump-in-the-night.

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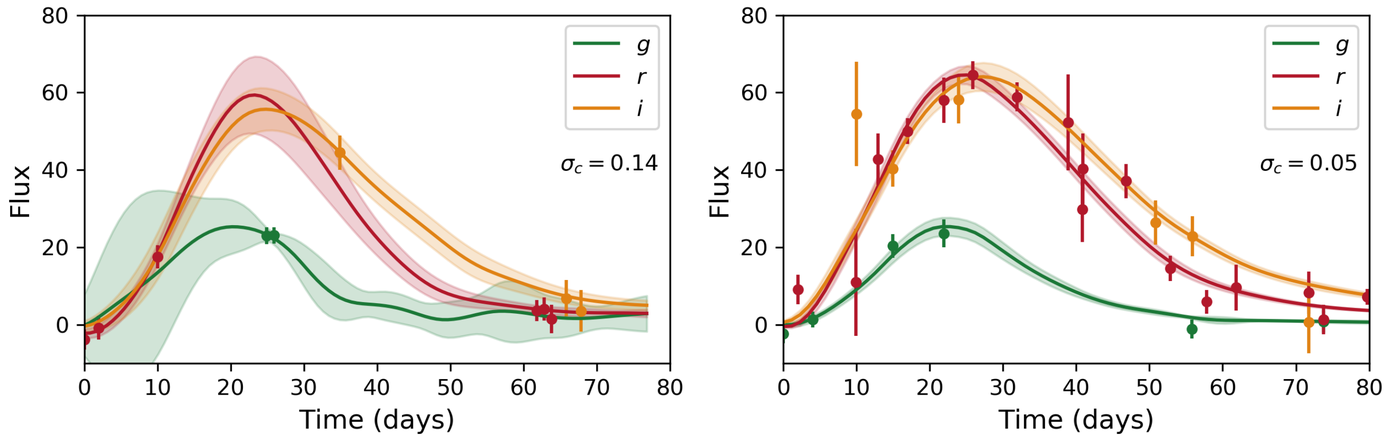

On the left we have the proposed *kraken_2026* cadence for the LSST while on the right we have the cadence proposed by Lochner *et al.* (2018) for an example supernova at intermediate redshift. These are fit with a standard SALT2 model under the assumption that there is no spectroscopic redshift available for the host. Also shown is the error on the color parameter, σ_c, a proxy for light-curve quality.

The cadence for LSST is not ideal for fast evolving transients or for catching things particularly young - especially if you don't know what happened the night before.

Thus look at cadences that can survey a large enough volume nightly, or every other night.

Colors are very important!

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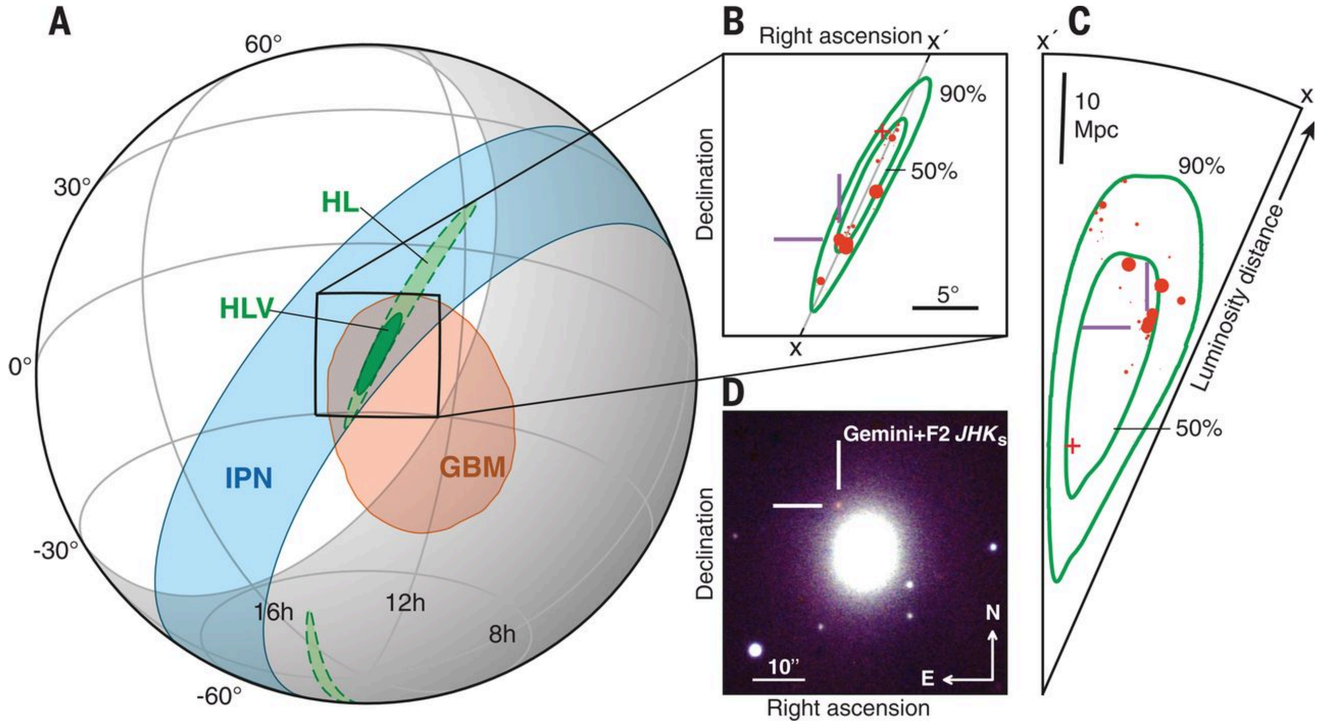

M. M. Kasliwal et al. Science 2017;358:1559-1565

GW follow-up is benefitted greatly by not only your ability to rapidly pave over the sky in ~100 sq. deg. swaths, but your ability to determine which are the best candidates to trigger follow-up on w/ spectroscopy, UV from space, IR follow-up, etc. (the big glass). Knowledge of what happened there the previous night and color evolution is key.

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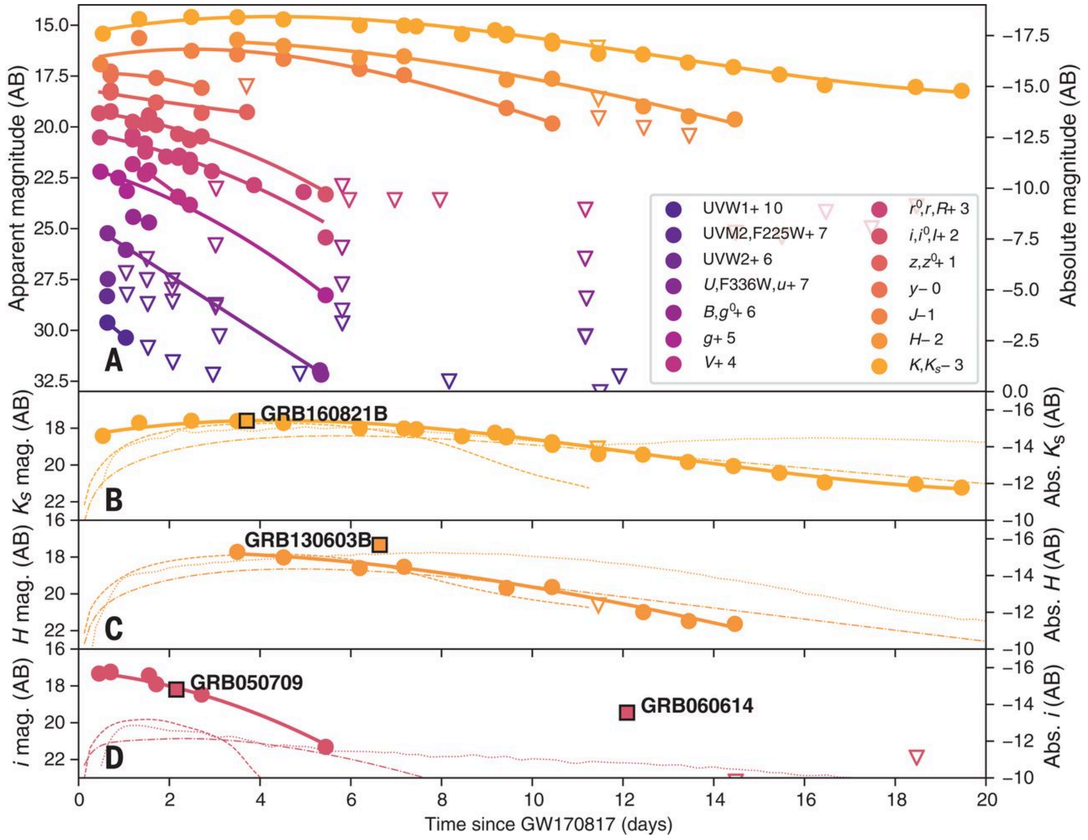

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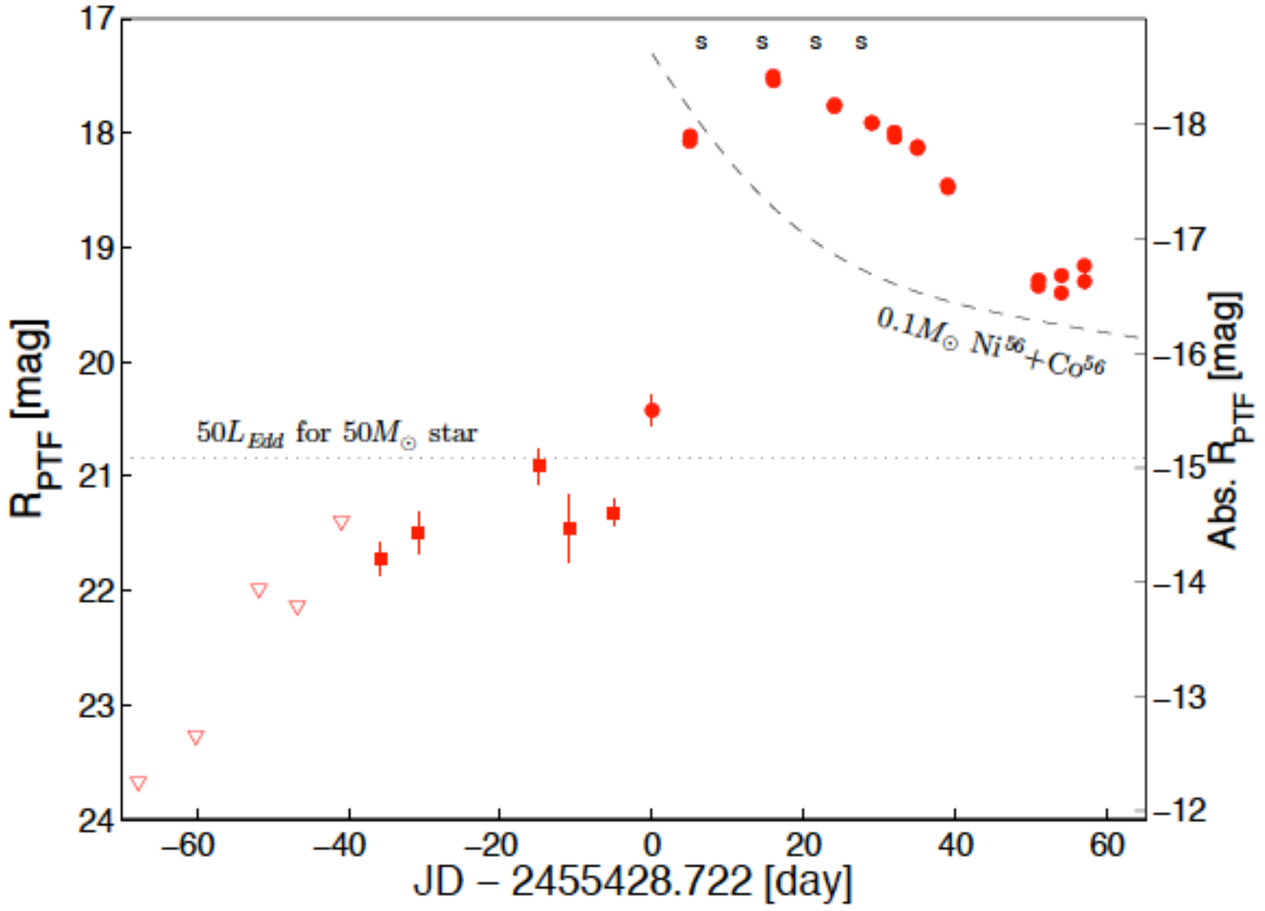

Pre-outbursts prior to going SN:

SN 2010mc - Ofek *et al.* (2013) Nature & SN 2011ht – Fraser *et al.* (2013) ApJ

Possible Explanation: Super-Eddington fusion luminosities, shortly prior to core collapse, drive convective motions that in turn excite gravity waves that propagate toward the stellar surface and eject substantial mass.

Enabled by near nightly cadence on a large fraction of the sky. Rubin would expand the reach!

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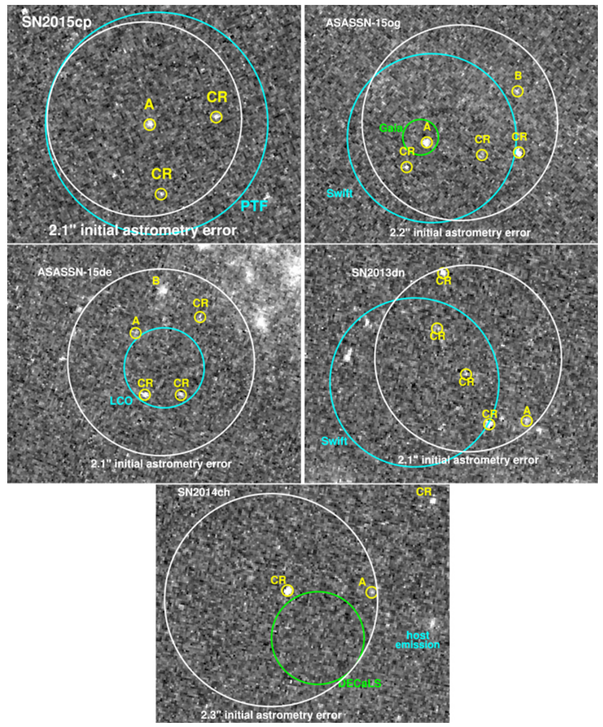

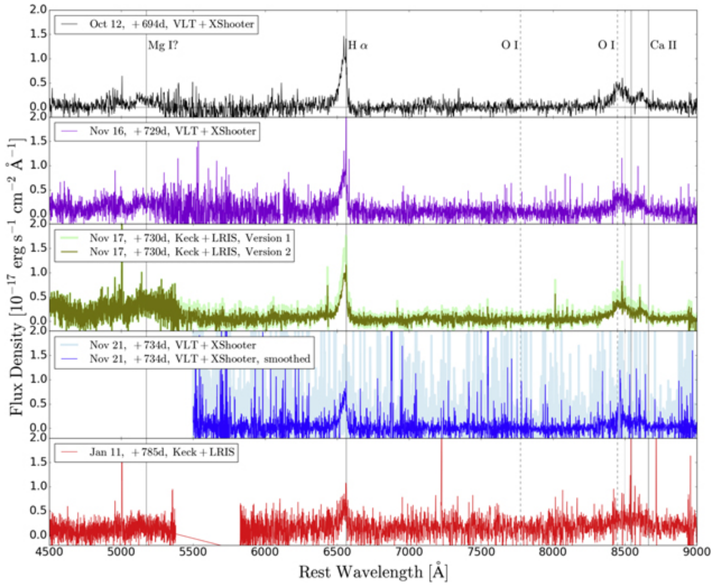

Post-outbursts after going SN:

SN 2015cp - Graham *et al.* (2019) ApJ

Possible Explanation: Running into the CSM created by a nova-like system which swept out the local area and delayed interaction.

SNIa —> SN II-n

Rubin would expand the reach!

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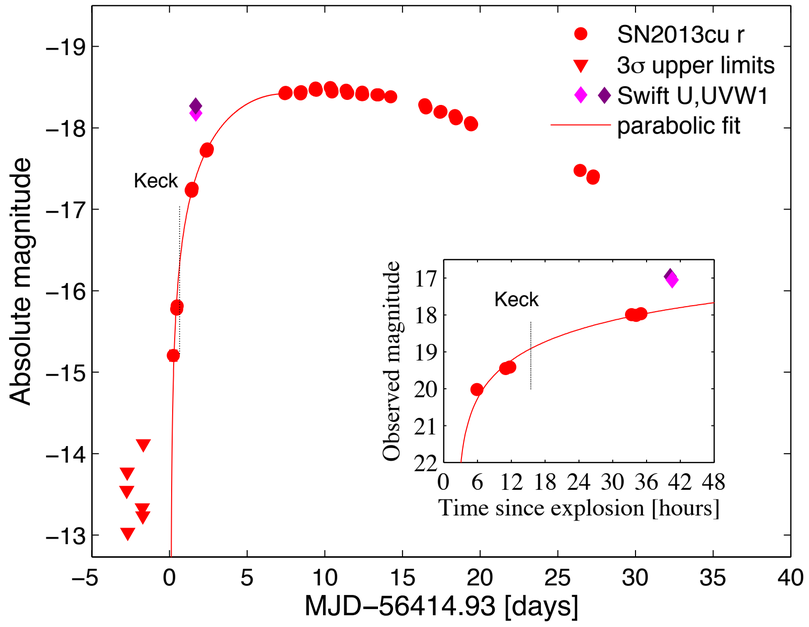
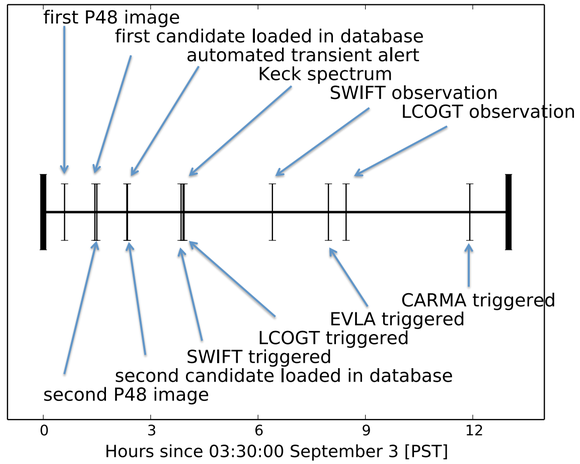
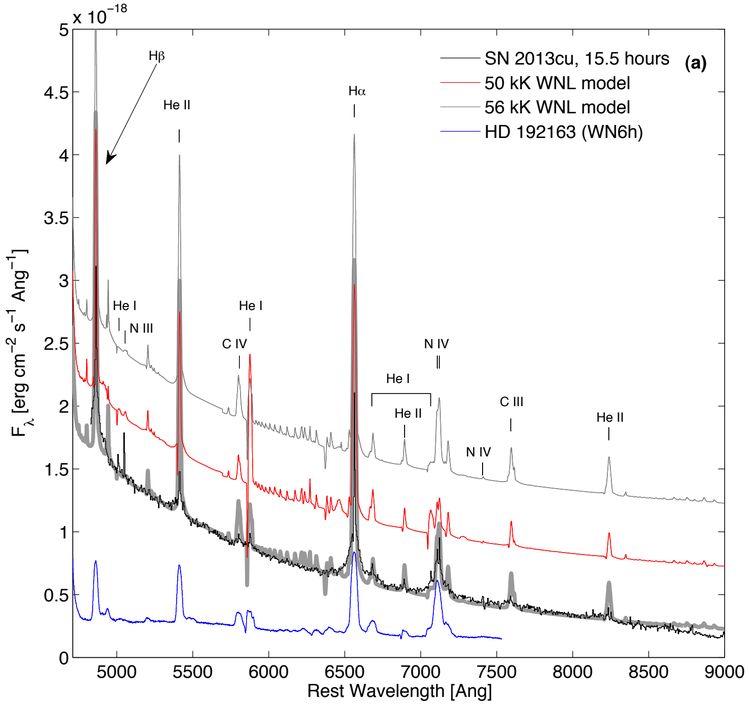


Flash spectroscopy. For several core-collapse SNe, one can light up the surrounding CSM to glimpse the progenitor system and then trigger radio, space, etc..





Need to be able to trigger spectroscopy during the night, and at least <=24 hours, in order to do this effectively.

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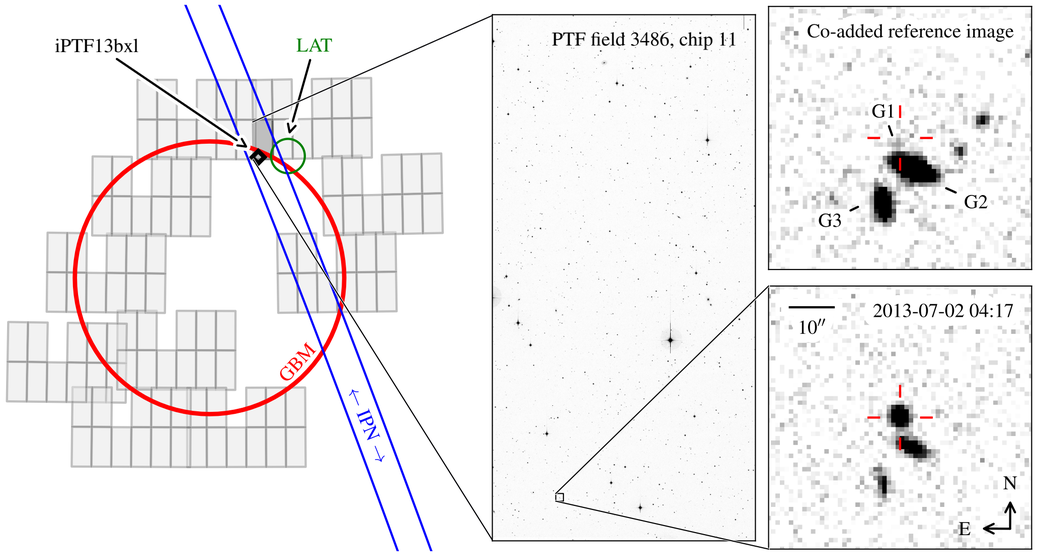
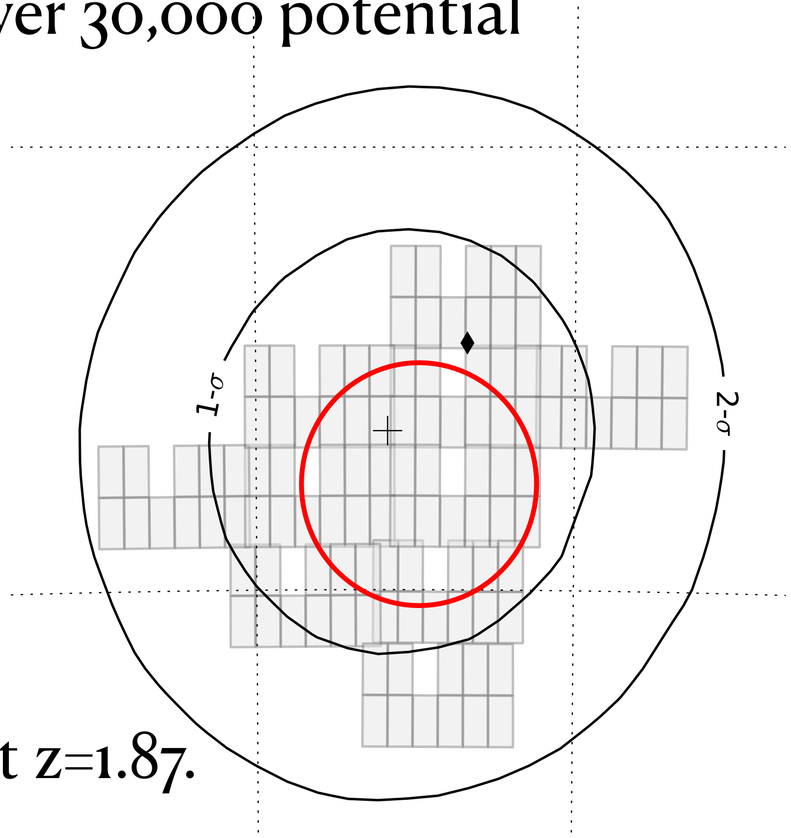


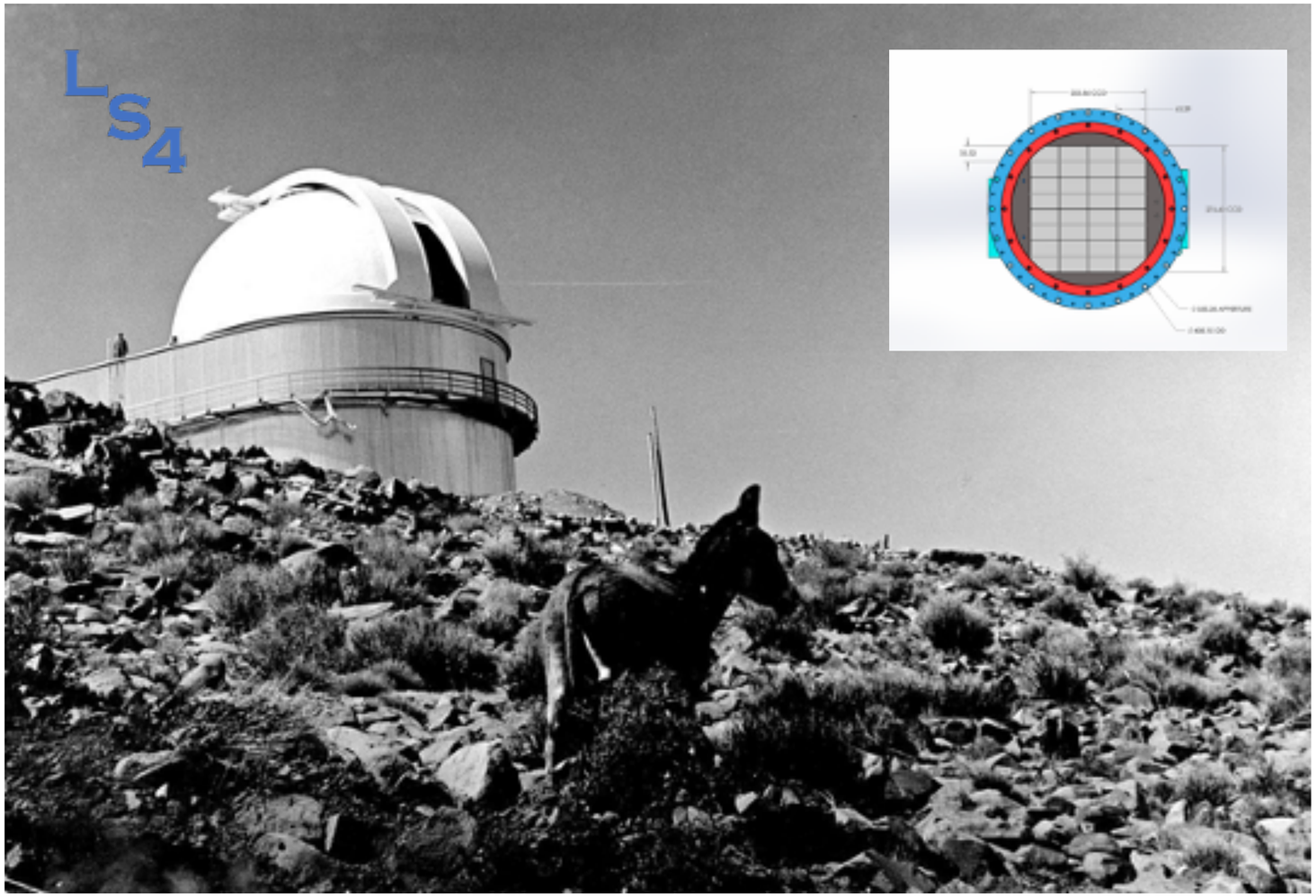
Singer *et al.* (2013) iPTF13bxl found in 71 sq. deg.

Poorly localized GRBs can be searched for over large chunks of the sky and monitored for their quick evolution. Over 30,000 potential candidates!



Kasliwal *et al.* (2013) iPTF13dsw at z=1.87.

LS4 Quick Facts Summary



Quick facts:

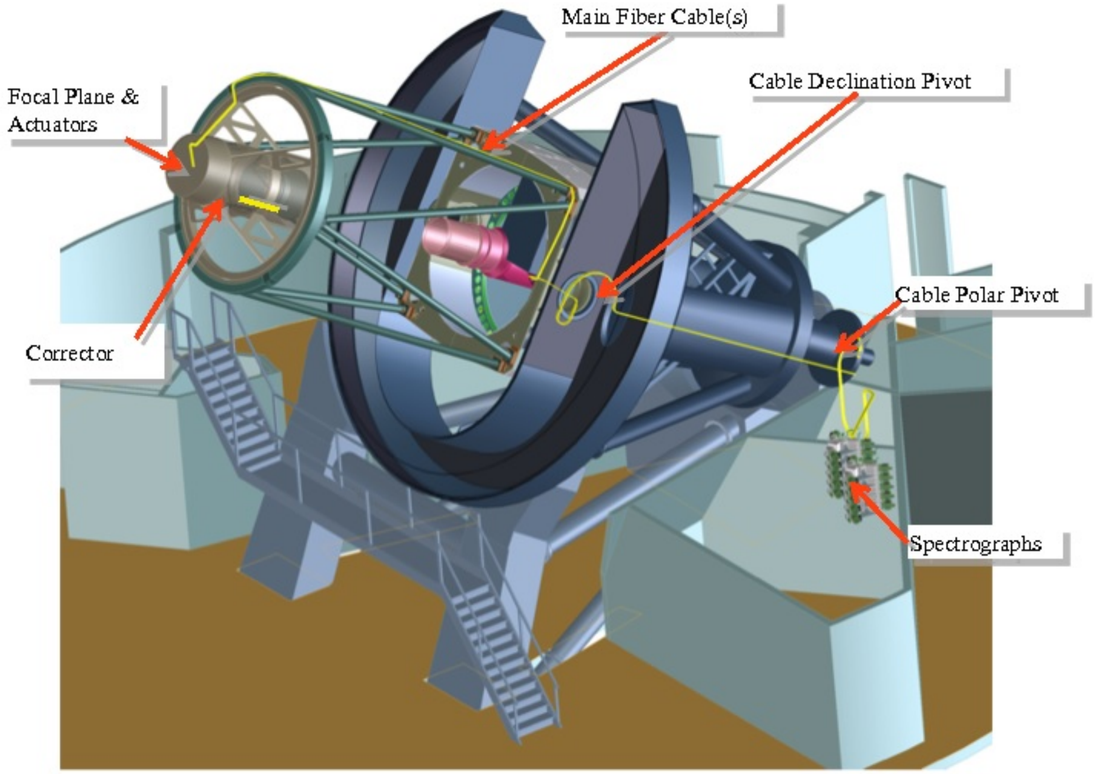
- 20 sq. deg. fov
- 2 fixed filters (g+z)
- 45s exp; 15s read+slew
- g-band: 21.0+/- 0.5
- z-band: 20.0
- 2k-4k sq.deg./night
- 90% Survey mode
- 10% MMA ToO's
- Real-time public data

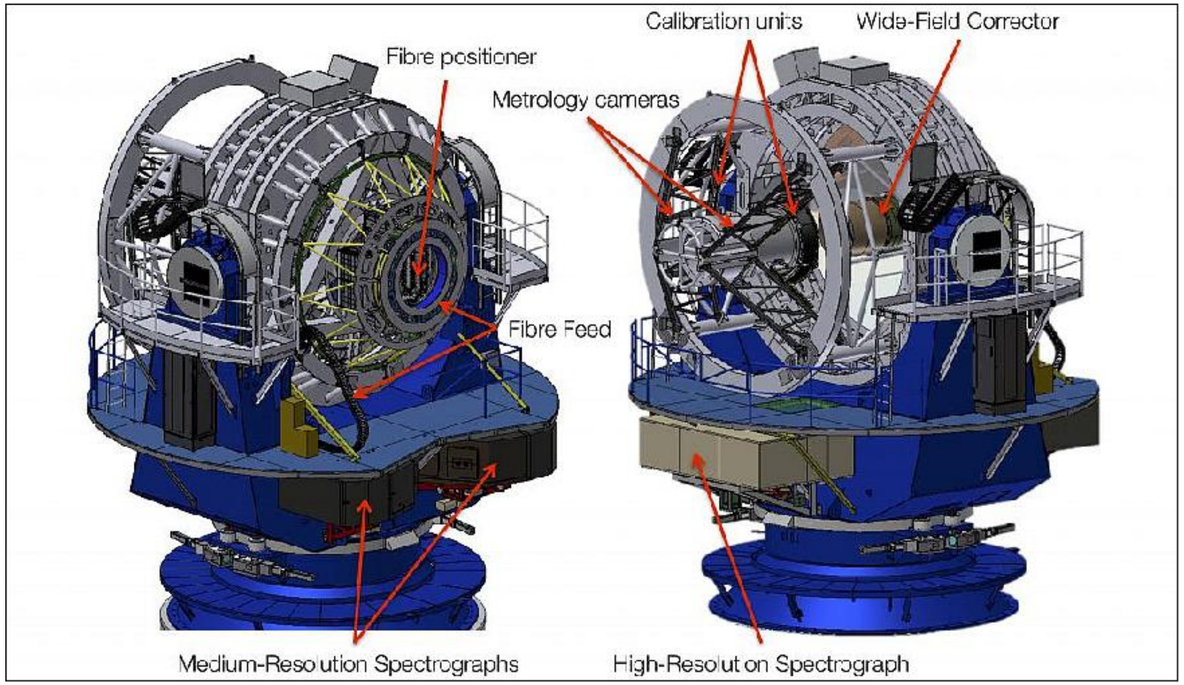
Survey: Volume, Cadence, & *Follow-up*

- The best follow-up is from the public. 90% of the survey will be streamed to the three major brokers: ANTARES, Lasair, ALeRCE.
- Fold in with Rubin data stream to maximize science.
- Work hard to also provide added-value stacks of data.

Survey: Volume, Cadence, & *Follow-up*

Multi-Object Spectroscopy

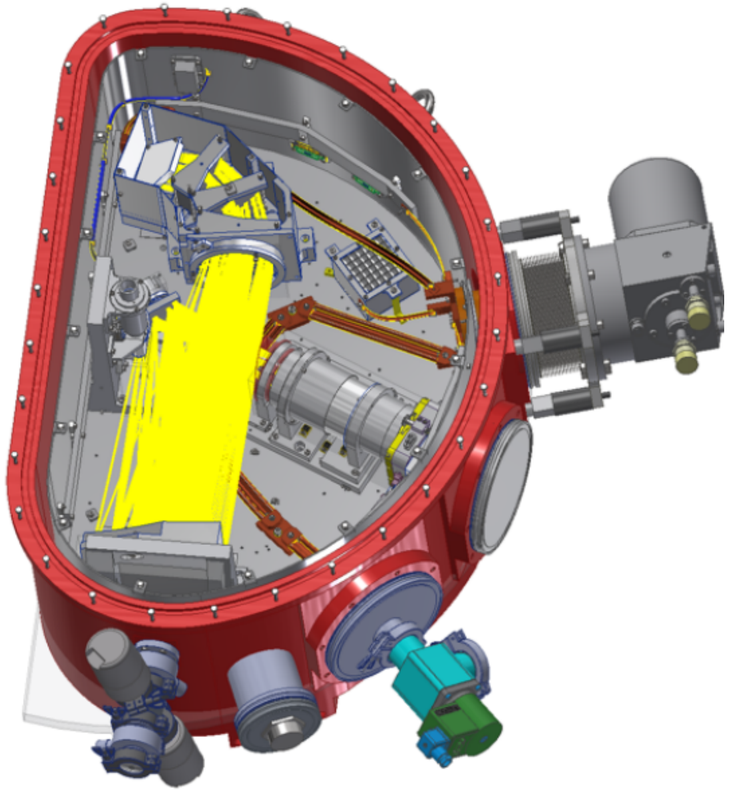




DESI and TiDES/4MOST

Survey: Volume, Cadence, & *Follow-up*

Spectroscopic Transient Follow-up



SoXS

Survey: Volume, Cadence, & *Follow-up*

Photometric (Optical & IR) and Optical Spectroscopic Transient Follow-up

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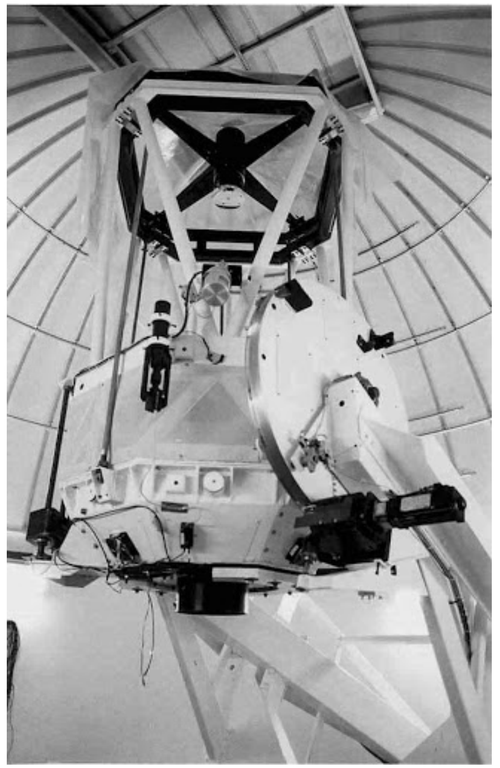

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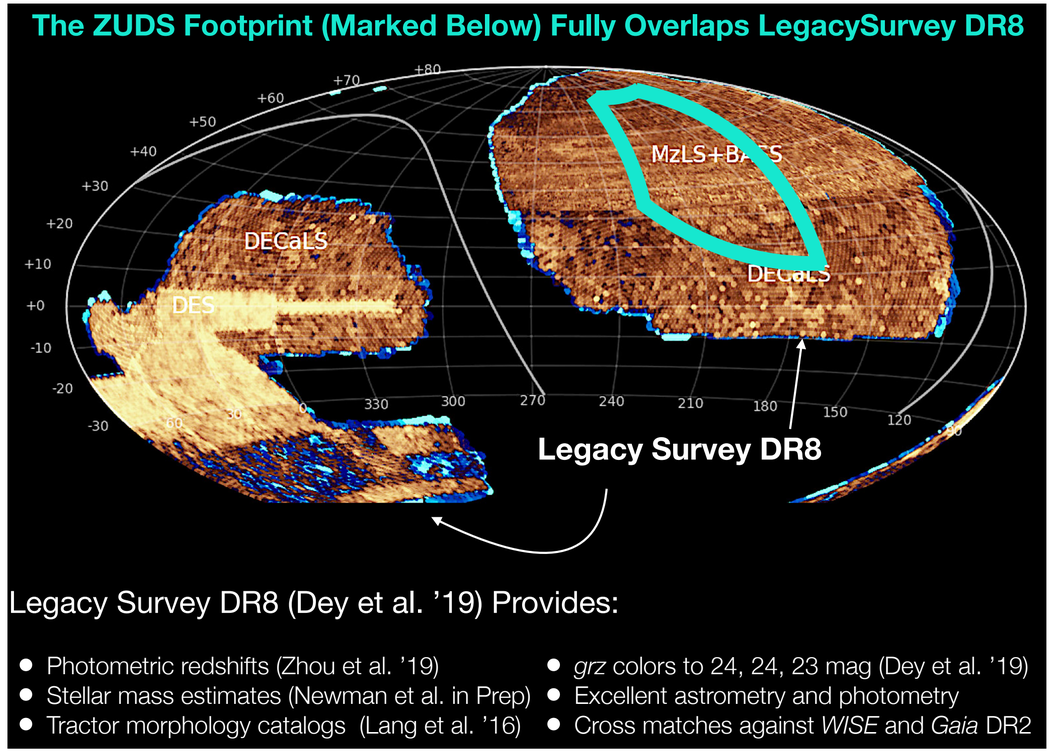
Still TBD: CTIO 1.5 (+ COSMOS spectrograph) and 1.3-m telescopes + ANDICAM upgrade.

Survey Design

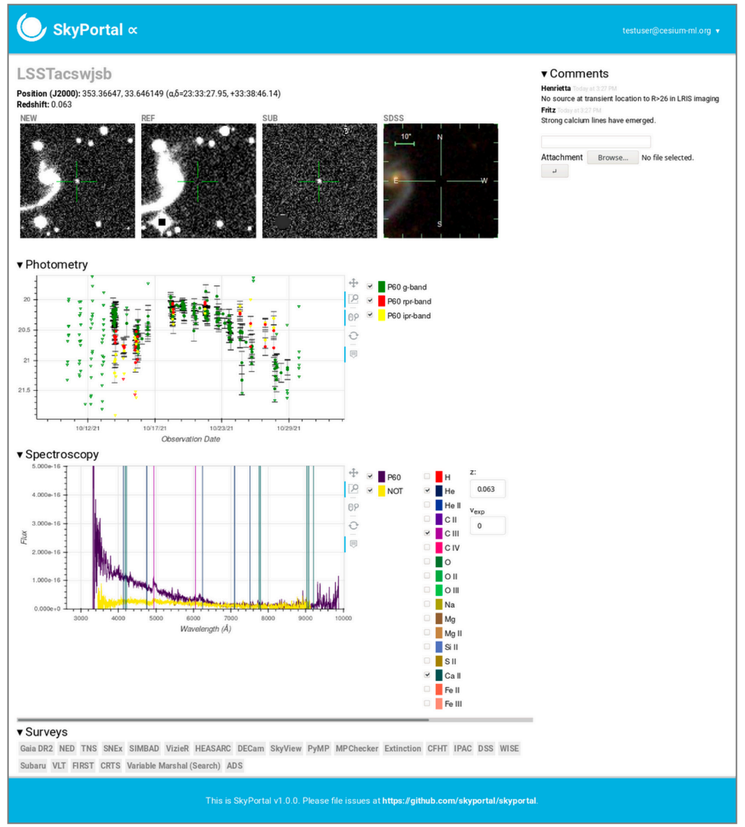
- Beware: You will find what you are searching for.... Thus you need to search for everything!
- The CS folks have to be interested in the astronomy and the Astronomers need to be interested in, and respect, the CS personnel. All major discoveries from here on out will be enabled by computing in one way or another.
- You should be flexible and work constantly to improve your pipelines and your science: drop old/bad science/CS and add new/improved science/CS.
- Speed is very important. Optimizing turn-around opens up new sections of discovery-space, It allows you to quickly recover from inevitable pipeline issues, and is critical in rate determinations.
- Keeping track of *everything* you do: decisions on triggering follow-up, why you set a cadence a certain way, how you characterize an object. It is absolutely key for understanding your science.

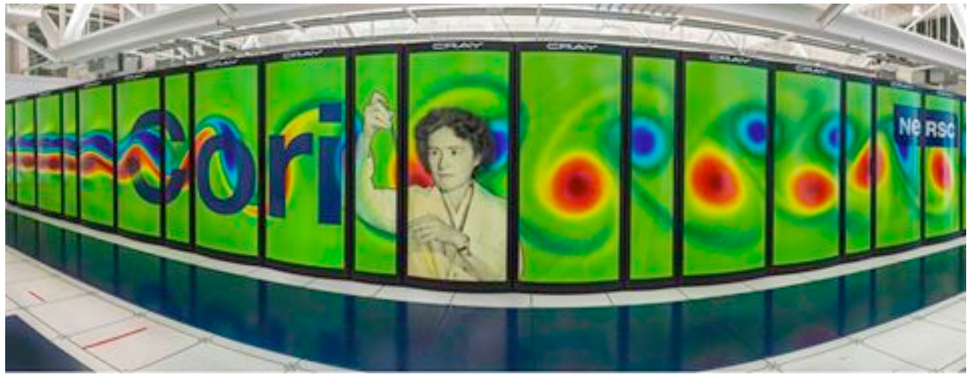
Survey Design



Legacy Survey DR8 (Dey et al. ’19) Provides:

- Photometric redshifts (Zhou et al. ’19)
- Stellar mass estimates (Newman et al. in Prep)
- Tractor morphology catalogs (Lang et al. ’16)
- *grz* colors to 24, 24, 23 mag (Dey et al. ’19)
- Excellent astrometry and photometry
- Cross matches against *WISE* and *Gaia* DR2

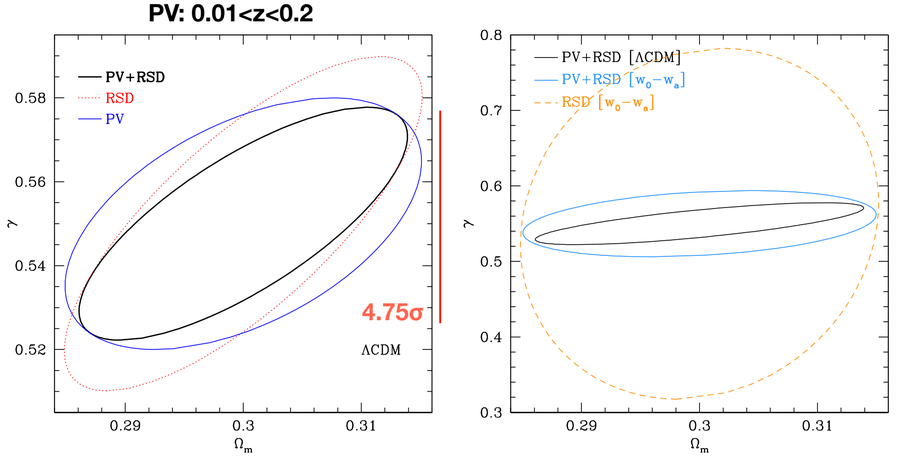




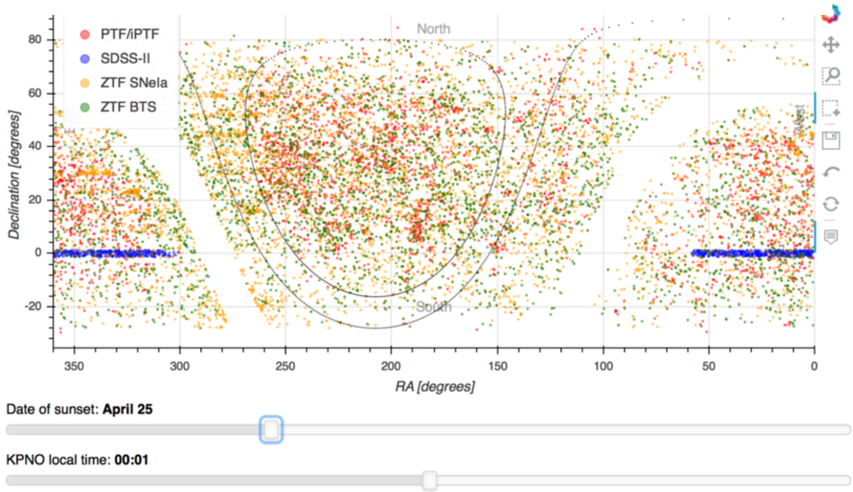
Similar to the ZUDS Survey in ZTF-I, will leverage our compute at NERSC (Cori with 1PB disk space for the project and >6ook cores available), previous survey data and SkyPortal to keep track of discoveries, other brokers, and follow-up.

Cosmology: Peculiar Velocities & Standard Sirens

PV + RSD Synergy



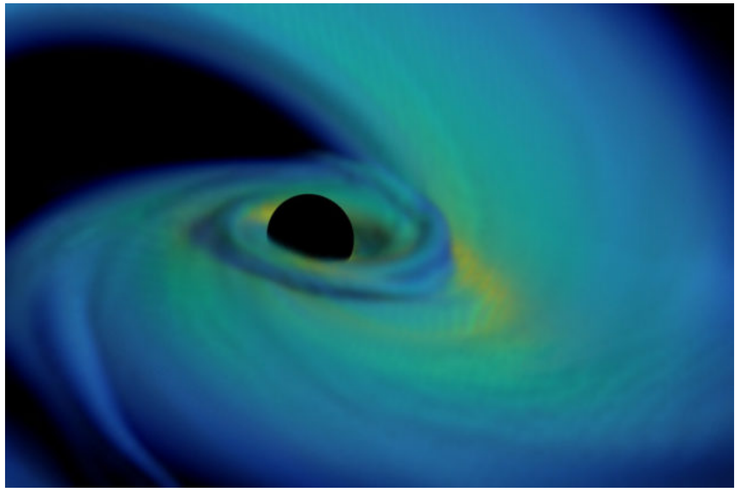
Kim & Linder (2020)

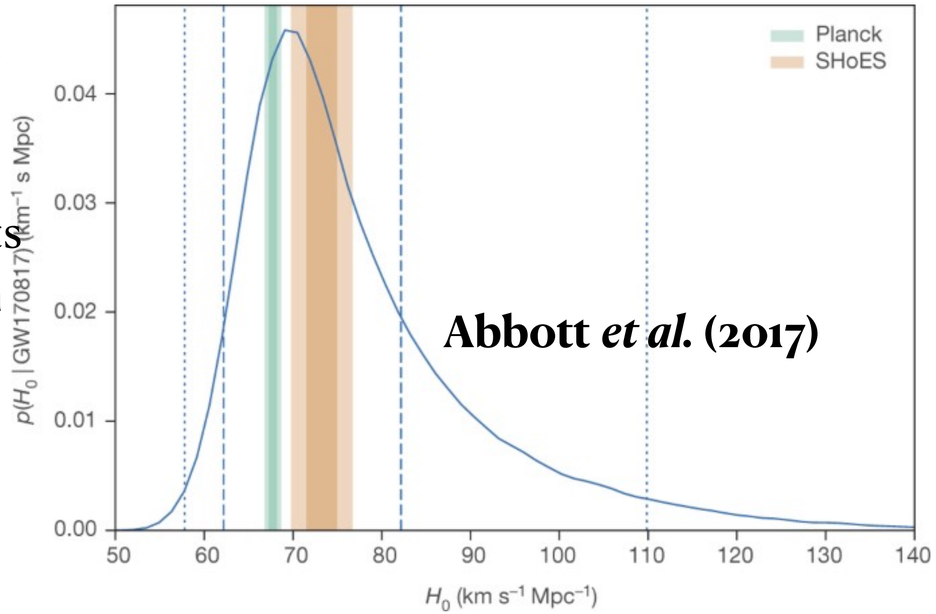


$f = \Omega_m(a)^\gamma$ provides a highly accurate description of the growth of structure, where a wide range of gravity models can be described by single values of the growth index γ (0.55 = GR).

Peculiar velocity SN measurements, over $0.01 < z < 0.2$, constrain $f\sigma_8$ (the ratio of the growth rate). We can compare or combine these with measurements of redshift space distortions from DESI and put constraints on γ.

Kim & Linder (Phys. Rev. D 101, 023516, 2020)





Abbott *et al.* (2017)

Who

The Group We Brought Together

- By and large it is comprised of people I know from the field who were not playing a role in ZTF-II but were interested in extragalactic astronomy. We did, eventually, let in a few folks interested in MW science. Primary focus was on nearby supernova and Multi Messenger Astrophysics.
- Executive Committee comprises institutions who have the funding, camera, CCD's, and compute to make the project work at the 0th level: *LBNL, Fermilab, Northwestern, Tel Aviv University, Yale, Millennium Institute, Berkeley, Portsmouth University & Bar-Ilan University.*
- Partners are a collection transient scientists from European institutions who would directly benefit from such a survey and would be focused on collectively maximizing the science: Cardiff University, DESY, IN2P3, Lancaster University, Ruhr-Universität Bochum, University of Southampton, Stockholm University, Trinity College Dublin, Universidad de Granada, University of Birmingham and CTIO for follow-up.

LS4 Summary & Status

Status: Have received approval from ESO; testing CCD's is completed at Fermilab (Kenneth Lin UCB GSRA) - 32 science grade CCD's + 5 spares; restarted the telescope at ESO and no surprises. Electronics are complete. Targeting first light, January 2024.

R&D plan: Some engineering (similar to MzLS) for camera - Yale and Fermilab have completed this; construction of the camera has started after the QUEST camera came back from La Silla; the rest is pipeline work based on PTF/iPTF/ZTF real-time pipelines and *SkyPortal*.

Overall science goal: Fill in the Rubin Observatory's LSST cadence to increase the scientific potential of nearby/fast evolving transients with a particular focus on SN Ia / SN II-P cosmology & peculiar velocities, and standard sirens with NS - NS/BH mergers.

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