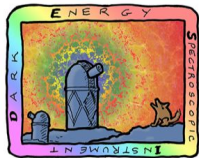


DESI Redshifts and Rubin LSST Transients

Segev BenZvi, University of Rochester
on behalf of the DESI Collaboration

Vera C. Rubin
Project & Community Workshop
Tucson, Arizona
August 11, 2022





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Time Domain Science with DESI + Rubin LSST

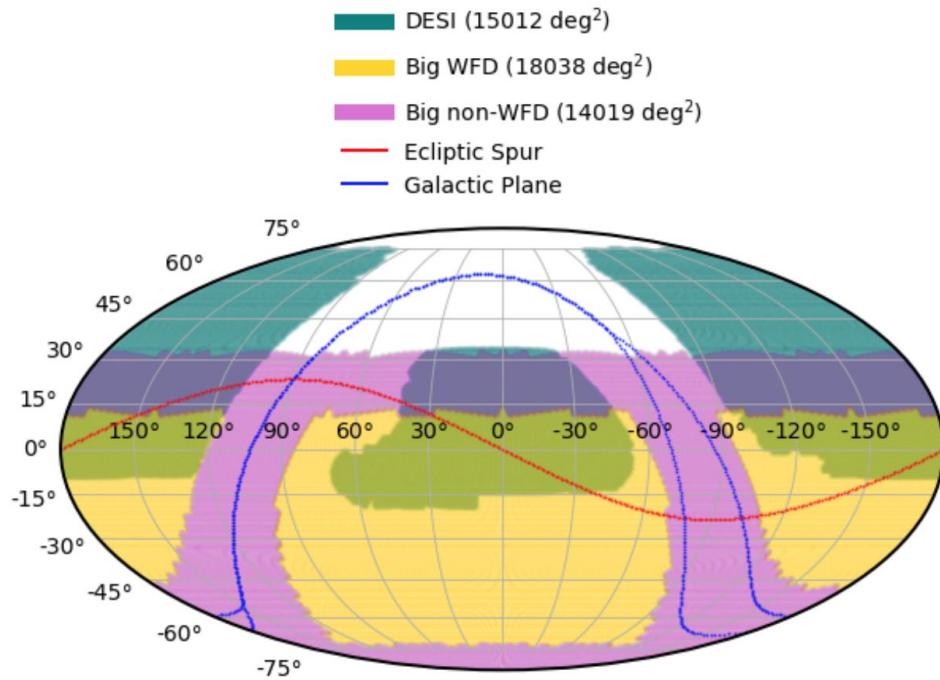
DESI covers $O(4000 \text{ deg}^2)$ of the LSST footprint. While DESI is not optimized for time-domain searches, LSST transients + DESI spectroscopy has many applications.

Wide fields:

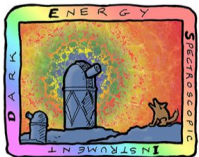
- **Peculiar velocities** with supernovae
- **Host redshifts** for transients
- **Spectroscopic follow-up** for transient typing and outlier searches

Deep drilling fields:

- **Supernova cosmology**
- **AGN reverberation mapping**



Credit: K. Olsen+, arXiv:1812.02204

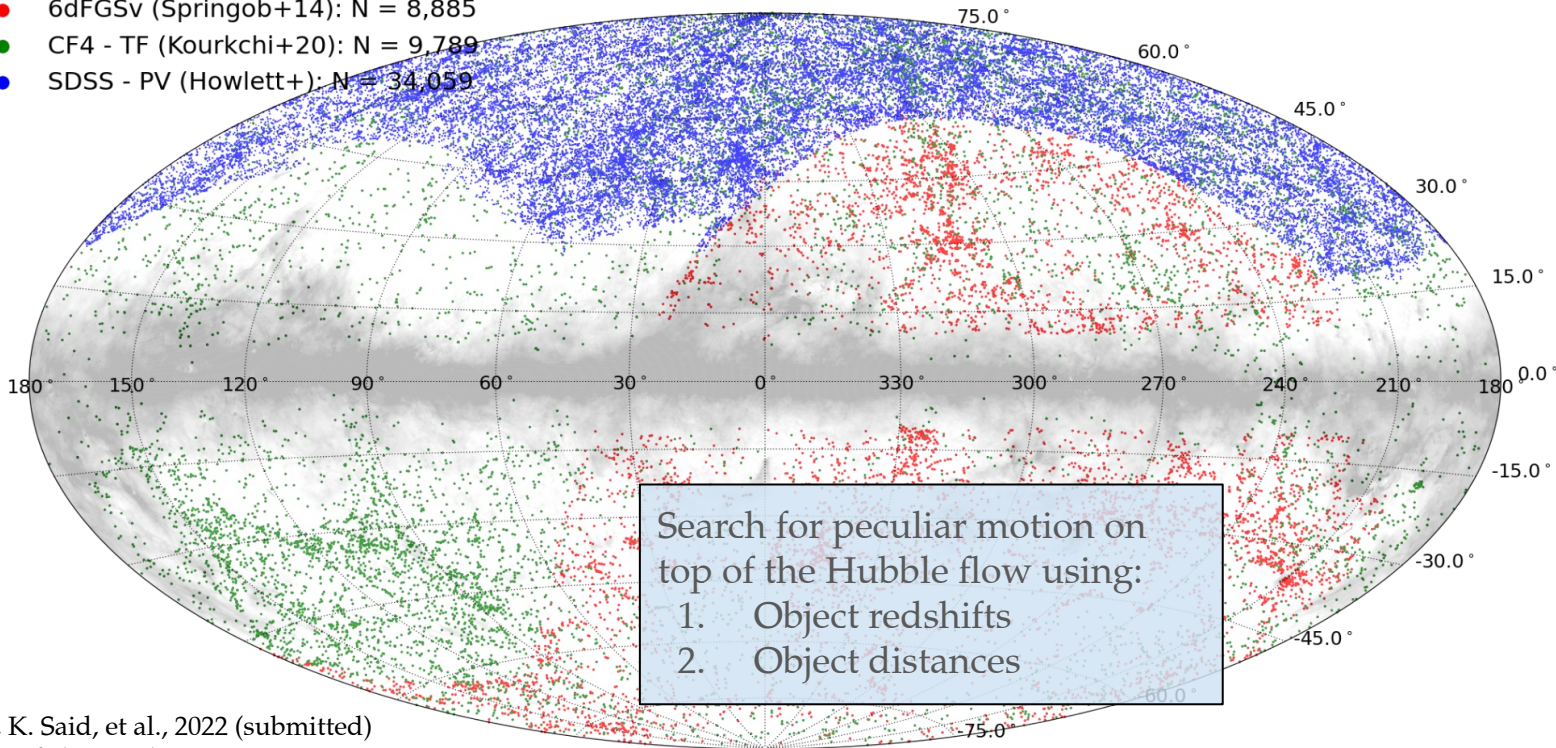


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The DESI Peculiar Velocity Survey

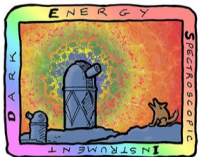
- 6dFGSv (Springob+14): $N = 8,885$
- CF4 - TF (Kourkchi+20): $N = 9,789$
- SDSS - PV (Howlett+): $N = 34,059$



Credits:

C. Howlett, K. Said, et al., 2022 (submitted)

C. Saulder et al. (in prep)

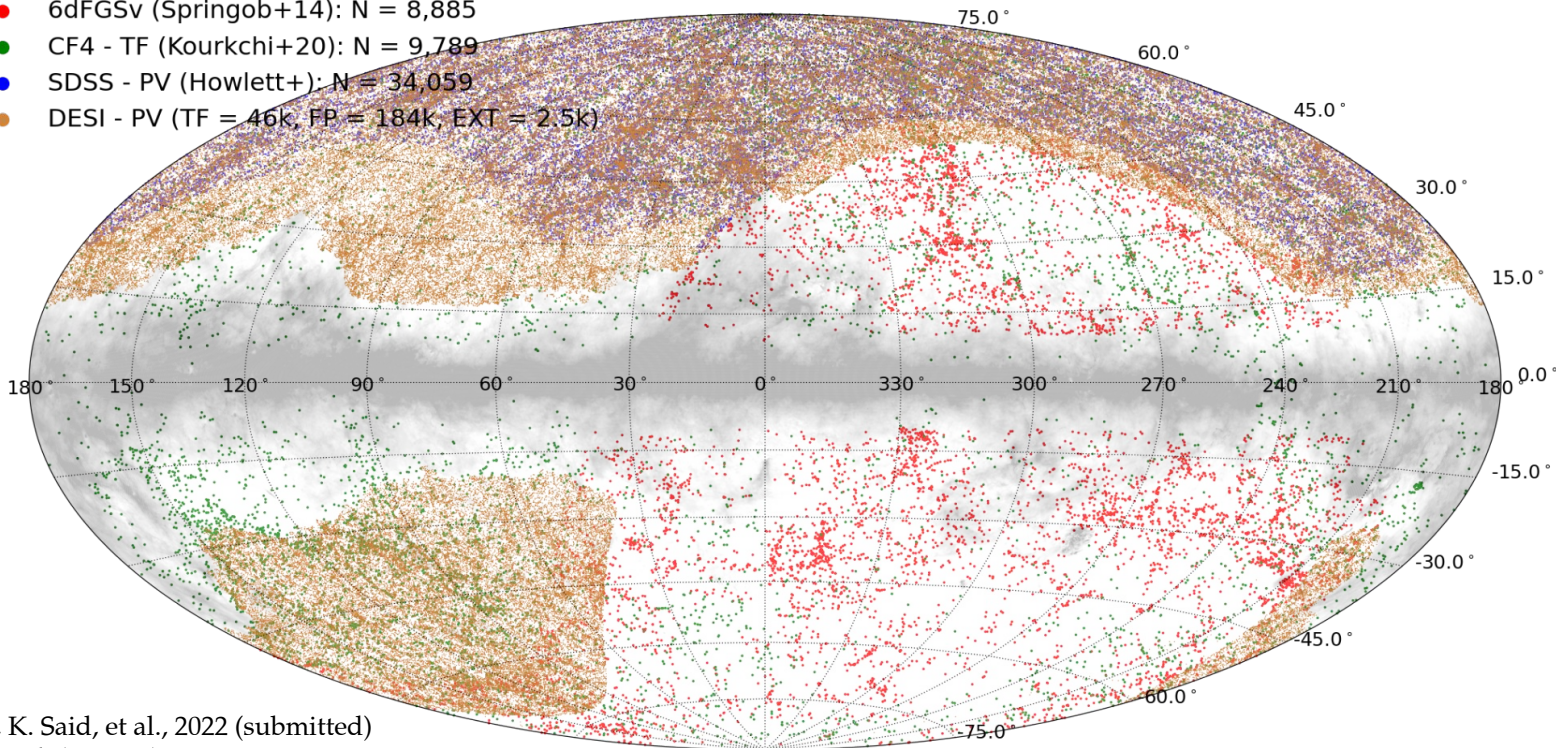


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The DESI Peculiar Velocity Survey

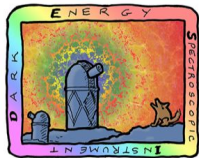
- 6dFGSv (Springob+14): $N = 8,885$
- CF4 - TF (Kourkchi+20): $N = 9,789$
- SDSS - PV (Howlett+): $N = 34,059$
- DESI - PV (TF = 46k, FP = 184k, EXT = 2.5k)



Credits:

C. Howlett, K. Said, et al., 2022 (submitted)

C. Saulder et al. (in prep)

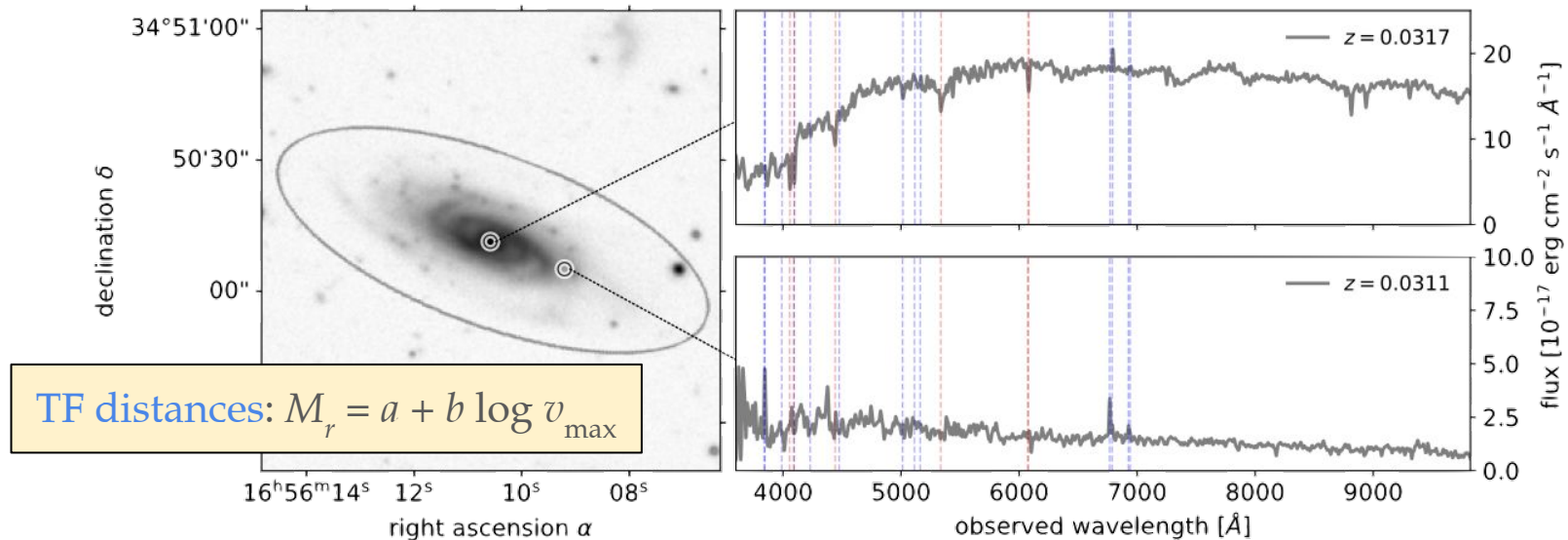


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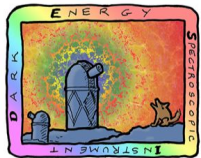
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Redshifts + Independent Distances: Tully-Fisher Sample

Credit: K. Douglass+ (in prep)



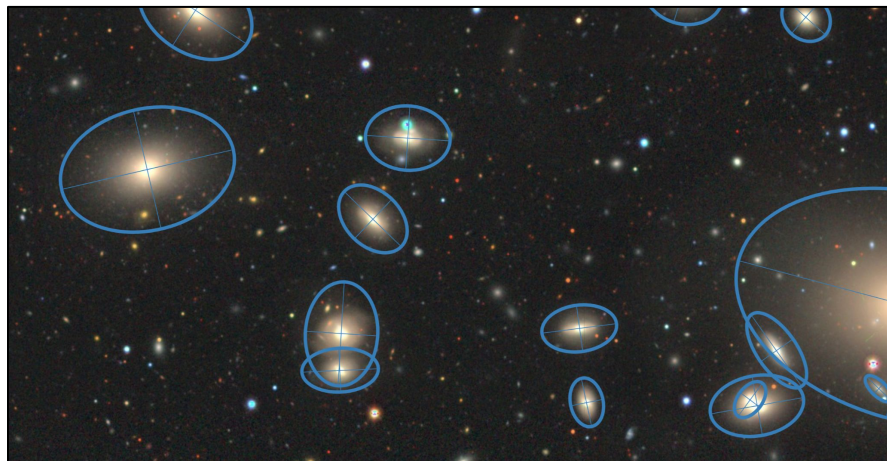
DESI TF secondary targets: large spirals in the **DESI Legacy Survey** [Siena Galaxy Atlas](#). Target nucleus + point(s) on semimajor axis of the R_{26} isophotal ellipse.



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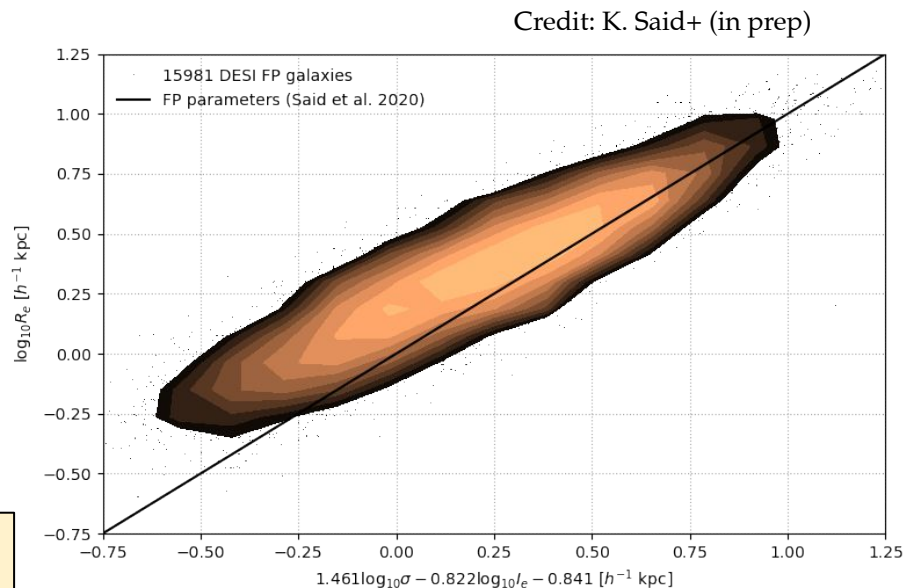
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Redshifts + Independent Distances: Fundamental Plane Sample



FP distances: $\log R_e = a \log \sigma_v + b \log I_e + c$

R_e and I_e from DESI Legacy Survey; σ_v from DESI spectroscopy. Achieving 20% velocity dispersion in DESI SV (compare to > 30% in 6dFGSV).

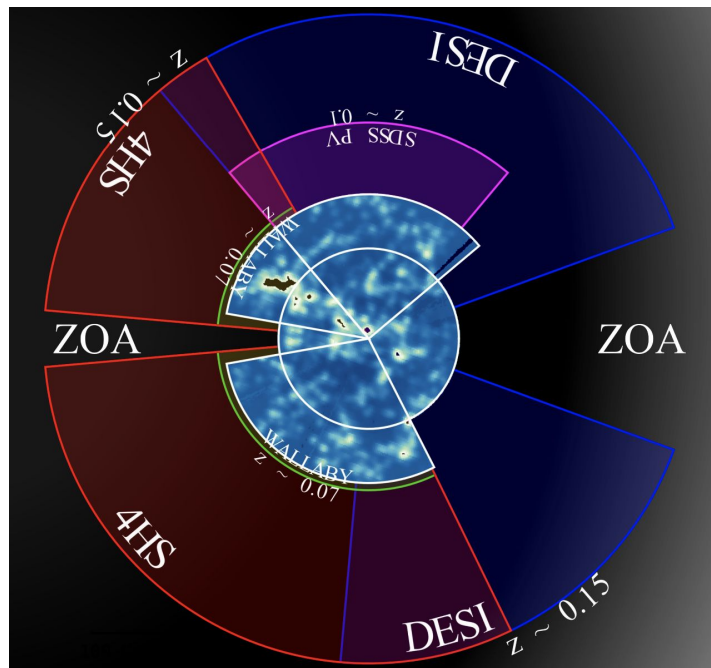




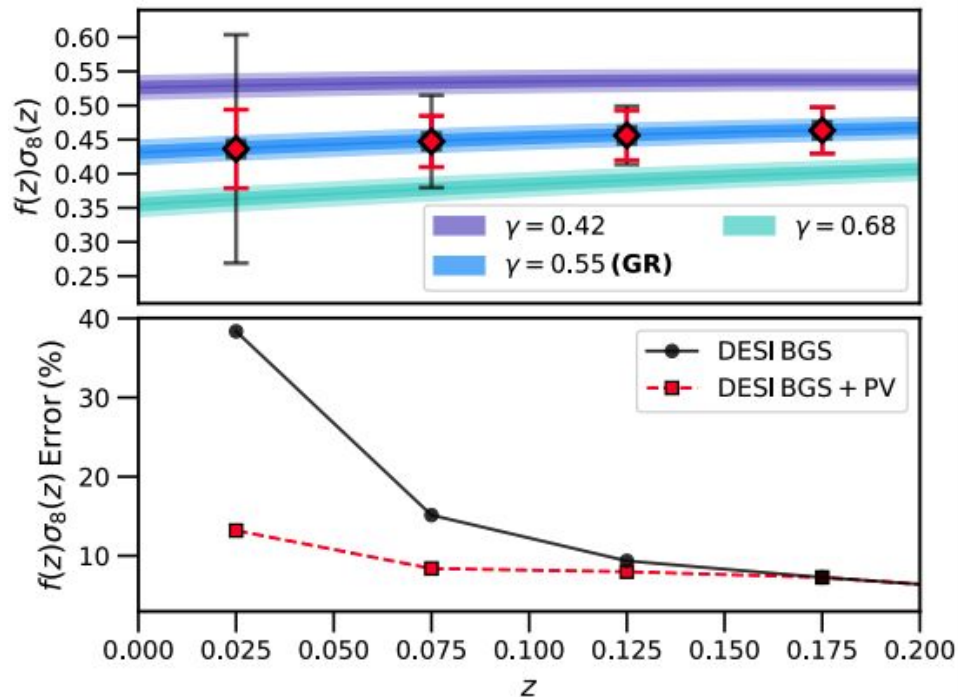
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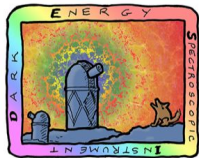
Sensitivity to $f\sigma_8$ at $z \leq 0.2$: RSD vs RSD+PV



Credit: K. Said



Credit: C. Howlett

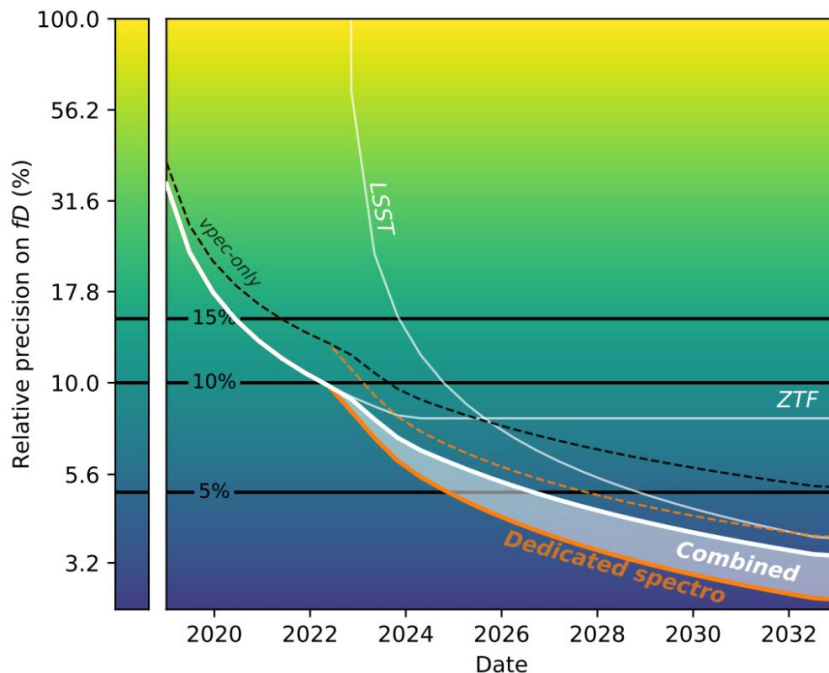
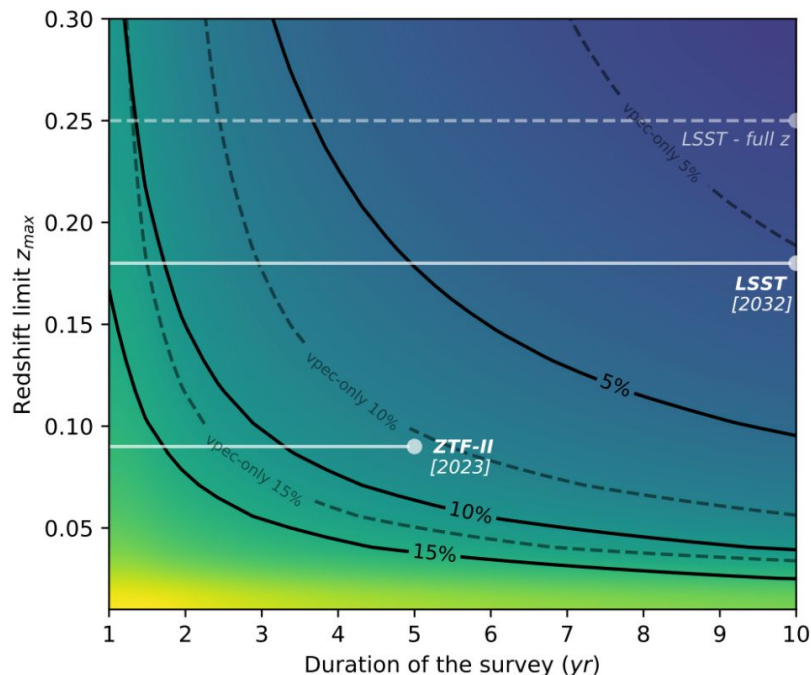


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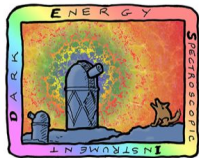
LSST PV Survey using SN Ia Distances

With $O(5000)$ SNe Ia at $z \leq 0.1 \Rightarrow \sim 5\%$ uncertainty on $f\sigma_8$ in 5 years!



Credit: R. Graziani+ (2020)

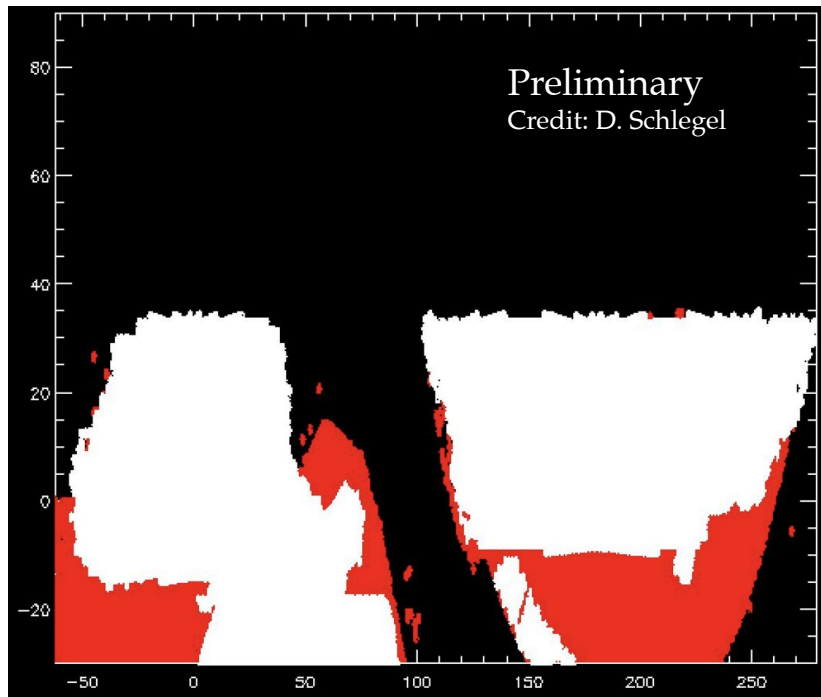
Rubin Project & Community Workshop - Aug. 2022



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PV with LSST + DESI (& DESI-II)

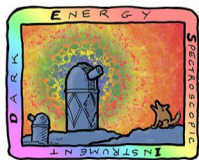


Recipe for a DESI+LSST SN PV Survey:

- Host galaxy redshifts
- LSST SNe with $\sigma_M \sim 0.1$ mag.

Extending the DESI footprint:

- $f\sigma_8$ uncertainty $\sim (\Omega_{\text{survey}} n_{\text{SN}})^{-1/2}$
- **~15% reduction** just by improved overlap with LSST.
- Obtain additional hosts in low- z survey fainter than DESI BGS limit.



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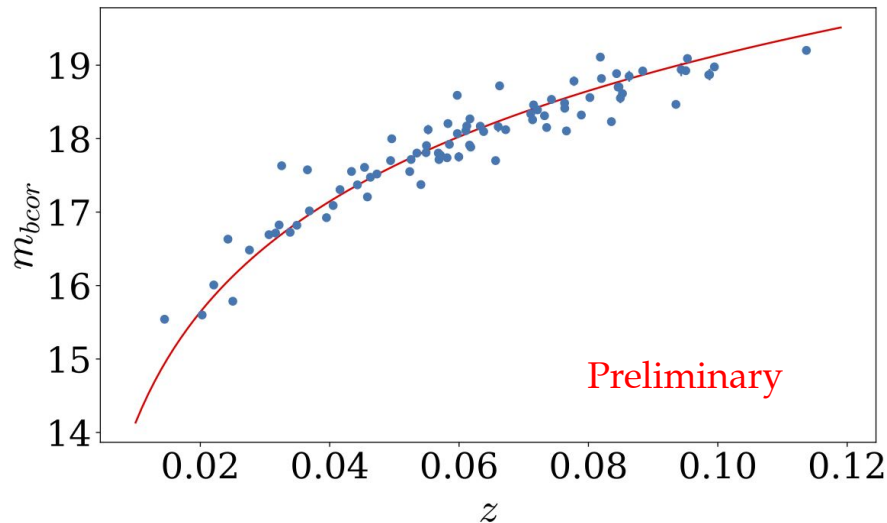
Host Redshifts for Supernovae

DESI Multi-Object Spectroscopic Transients (MOST) Hosts secondary targeting program is obtaining spec- z for **all historical supernovae** in the DESI footprint.

Currently focused on DESI redshifts + the ZTF Bright Transients Survey:

- SN types \leftrightarrow host properties
- Observations of nuclear transients
- SN Ia (and non-Ia?) cosmology

Note: **this program does not depend on ToO follow-ups or any serendipitous observations of transients.**



Credit: M. Soumagnac+ (in prep)



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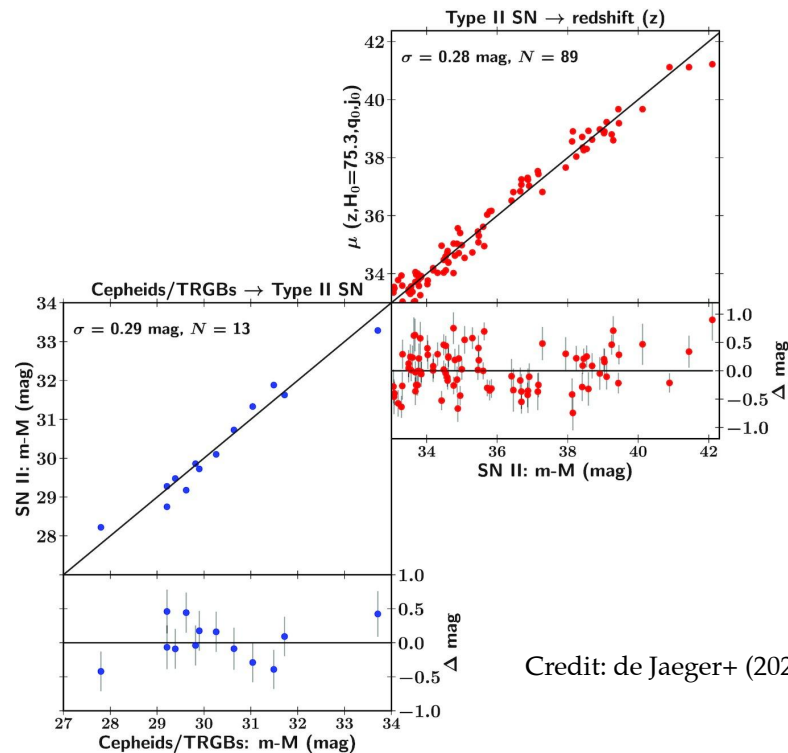
A MOST Hosts Program for LSST

LSST + DESI (& 4MOST); a MOST
Hosts program “for free.”

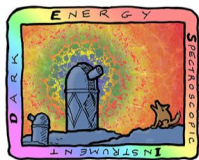
Spec- z 's for:

- **Standardizable SNe** (right)
- GWs: **bright standard sirens**
- AGN **reverberation mapping**

Environmental studies of transients:
host type, host environment in
large-scale structure, etc.



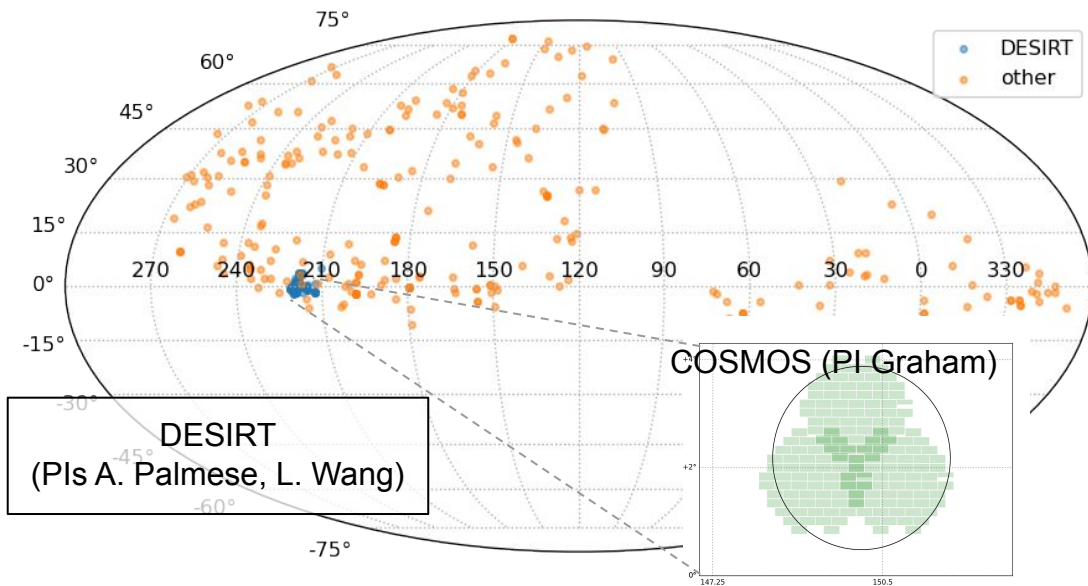
Credit: de Jaeger+ (2022)



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ToO Follow Ups: DESI + LSST

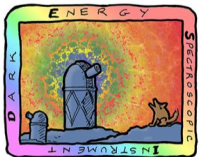


DESI can provide systematic spectroscopic follow-ups of **active LSST transients**.

DESIRT (DECam+DESI program); see [AstroNote 2022-107](#).

XMM-LSS and **COSMOS** DDFs to be used as **DESI calibration fields** every lunation. Many free fibers for ToOs!

Test recommendation engines like [RESSPECT](#) using DECam. Present focus: SNe. Future: **unusual transients and outliers**. **Identify new classes** and measure their number density.

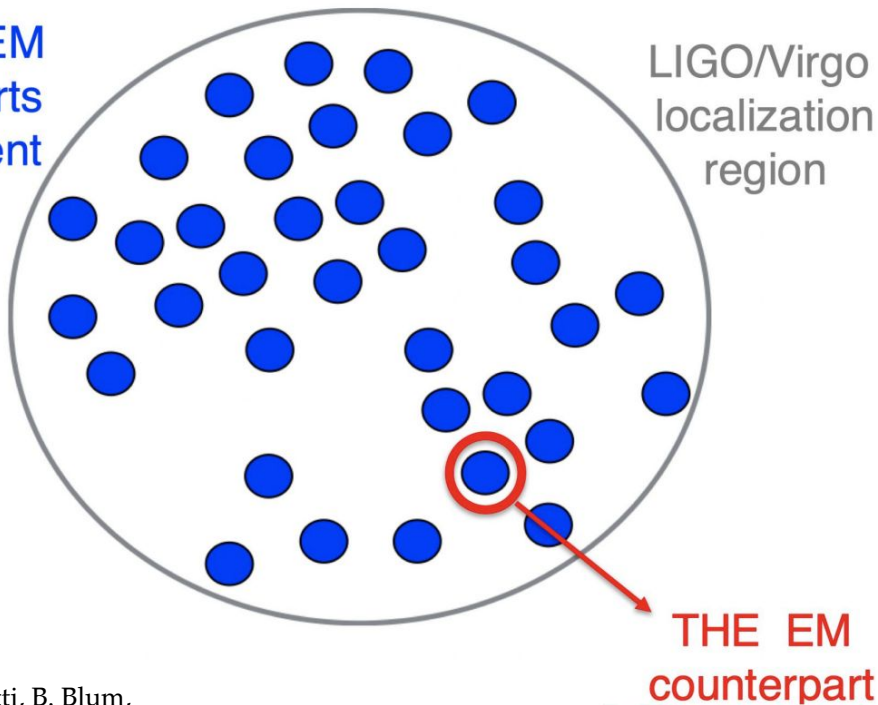


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Follow-Ups of Extraordinary ToOs

Potential EM
counterparts
to GW event



LIGO/Virgo
localization
region

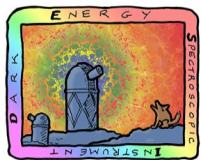
THE EM
counterpart

DESI is capable of targeting transients in **multi-messenger alerts'** regions of interest.

Not possible for every alert.
Focus on **well-localized BNS candidates with many optical counterparts from LSST?**

Procedure tested on [IceCube-210922A](#). Humans in the loop create a ToO ledger and run DESI fiber assignment.

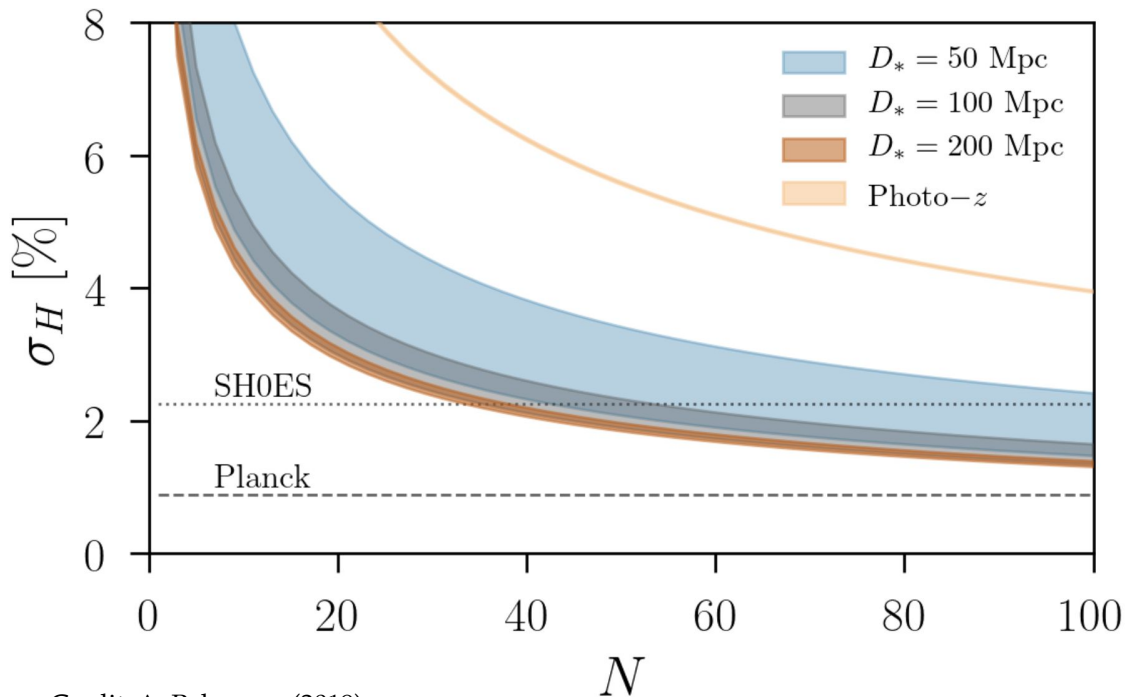
Credit: R. Margutti, B. Blum,
PCW Multi-messenger session (Aug. 9)



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LIGO-Virgo-KAGRA + LSST + DESI: Bright Standard Sirens



Credit: A. Palmese+ (2019)

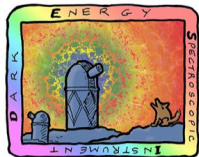
H_0 : standardized GW distance +
host localization from LSST +
DESI redshifts.

Spectra of all transients in GW
localization region.

14% σ_H from GW170817.

More physics than just H_0 ...

- **Evolving dark energy** (Di Valentino+ 2019)
- **EM vs GW distance** (Belgacem+ 2018)



Conclusions

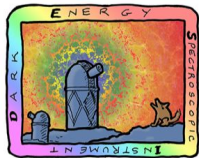
LSST transients + DESI spectra, **requiring no special follow-up**:

- **SN Ia peculiar velocity survey** \Rightarrow new frontier, very tight constraints on $f\sigma_8$.
- Host redshifts for SNe Ia, SNe II, GWs, AGN, ...

ToO follow-up of LSST observations with DESI:

- Multi-messenger **counterparts**: multi-object spectra for many candidates.
- Spectroscopic redshifts to **support photometric SN Ia cosmology** in DDFs.
- Apply **recommendation engines** to prioritize cosmologically important transients, and/or also search for **new categories** of objects.

Plans to increase DESI+LSST overlap in DESI-II improves all these science cases at little cost.



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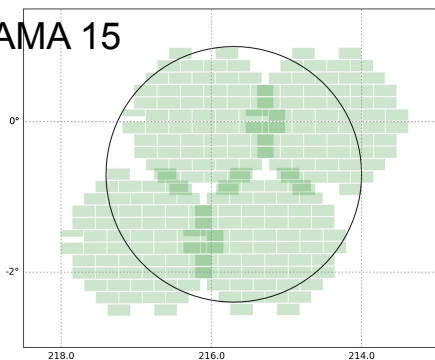
ToO Follow-ups with DESI + DECam

DESIRT: DECam observations of Intermediate Redshift Transients: A. Palmese, L. Wang, ++, [Astronote 2022-107](#).

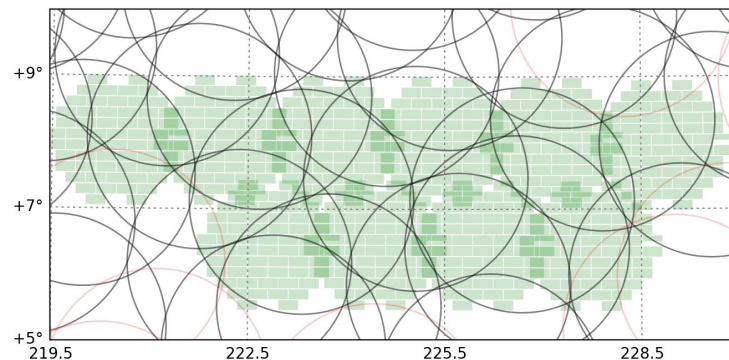
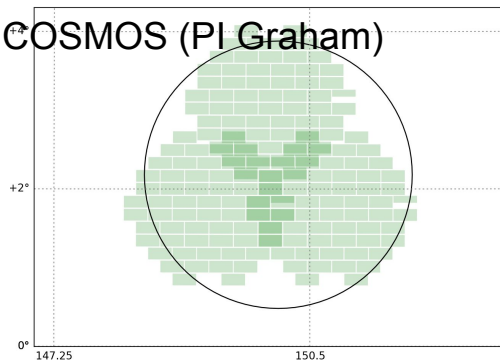
$\sim 80\text{-}100 \text{ deg}^2$ every 3-4 nights, DECam grz+g ($\sim 23.6, 23.6, 22.8, 5\sigma$ depth).

Filling gap between deep fields (e.g., DESSN) and shallower wide-field surveys (e.g., ZTF).

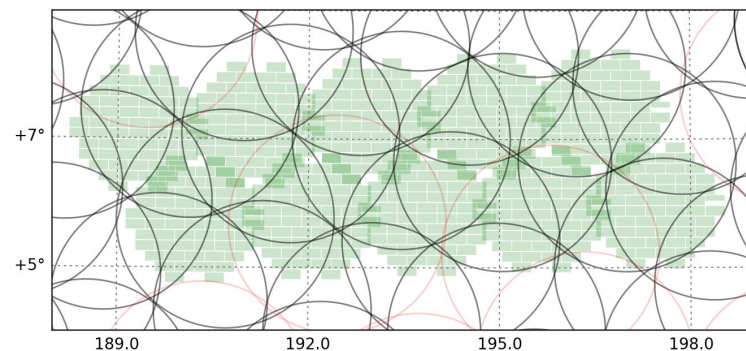
GAMA 15

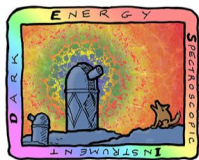


COSMOS (PI Graham)



DESI BRIGHT Main survey fields





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Observations of AGN & MBHBs

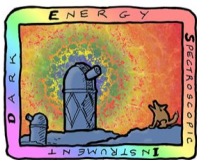
AGN variability: probe of accretion physics, including accretion rates, disk instabilities, jet evolution, absorption along LOS, etc.

Cosmology with **reverberation mapping**:

- Obtain size of AGN BL regions: time lag \leftrightarrow variability in continuum.
- BH masses from time lag and BLR velocity dispersions.
- Scatter radius-luminosity relation: luminosity distance at $z \sim 0.6 - 1$.

Searches for massive black hole binaries in an **M-BHB DESI calibration field**: repeat observations, observe doppler shifts in spectral lines.

LSST could help by identifying targets with high photometric variability.



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Serendipitous Spectroscopy of Transients

