

Cosmology with SNe Ia and Gravitational Lensing

Ulrich Feindt

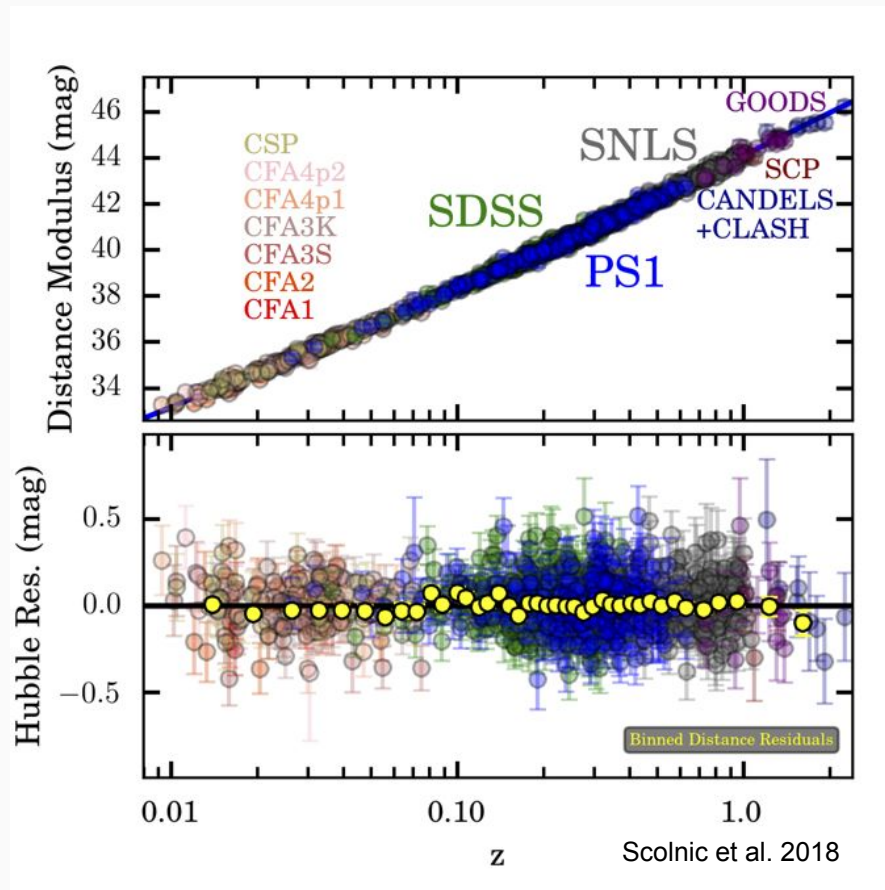
ZTF Team meeting
August 7th, 2018



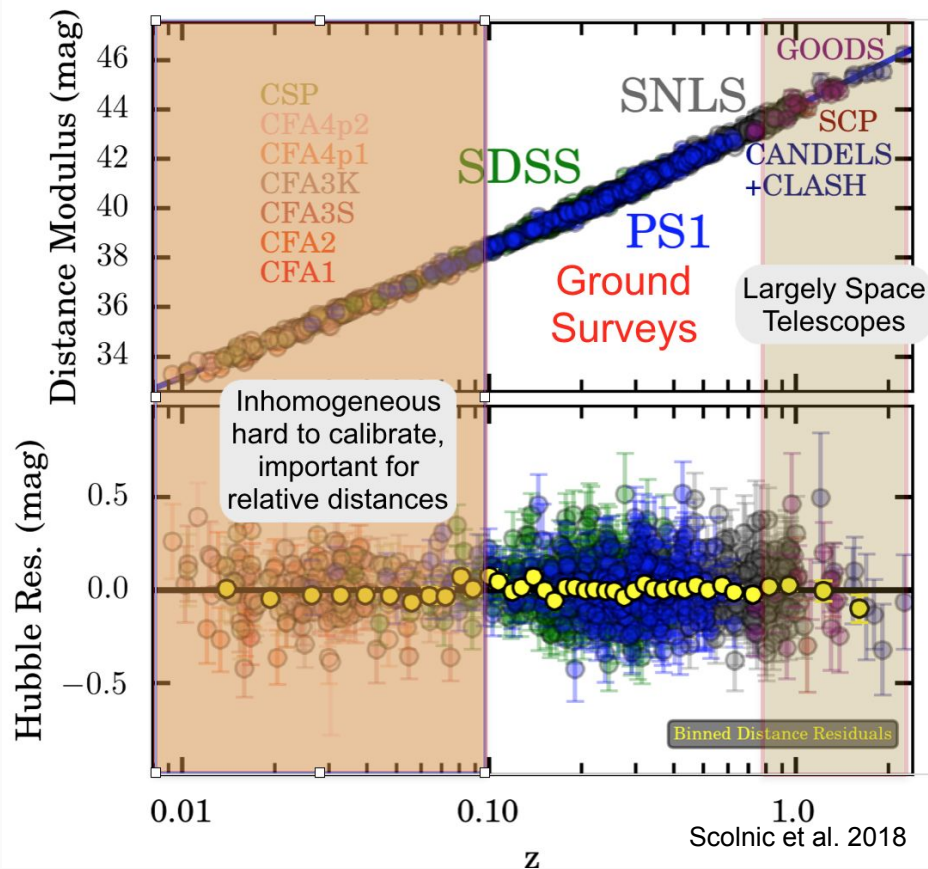
Goals

- ZTF is a perfect survey for low-redshift SN Ia cosmology
- Build data set of multi-color lightcurves to anchor Hubble diagram
 - Expect ~2000 SNe Ia with i-band coverage over 3 years
 - Sample size large enough to measure local structure/peculiar velocities
 - Will find many early SNe and cover second peak of most (overlap with Physics of SNe SWG)
- Also expect to find more strongly lensed supernovae and could measure H_0
- Large samples will also allow studies of rates and populations (both Ia and CC)

Current state of SN cosmology



Current state of SN cosmology (cont.)

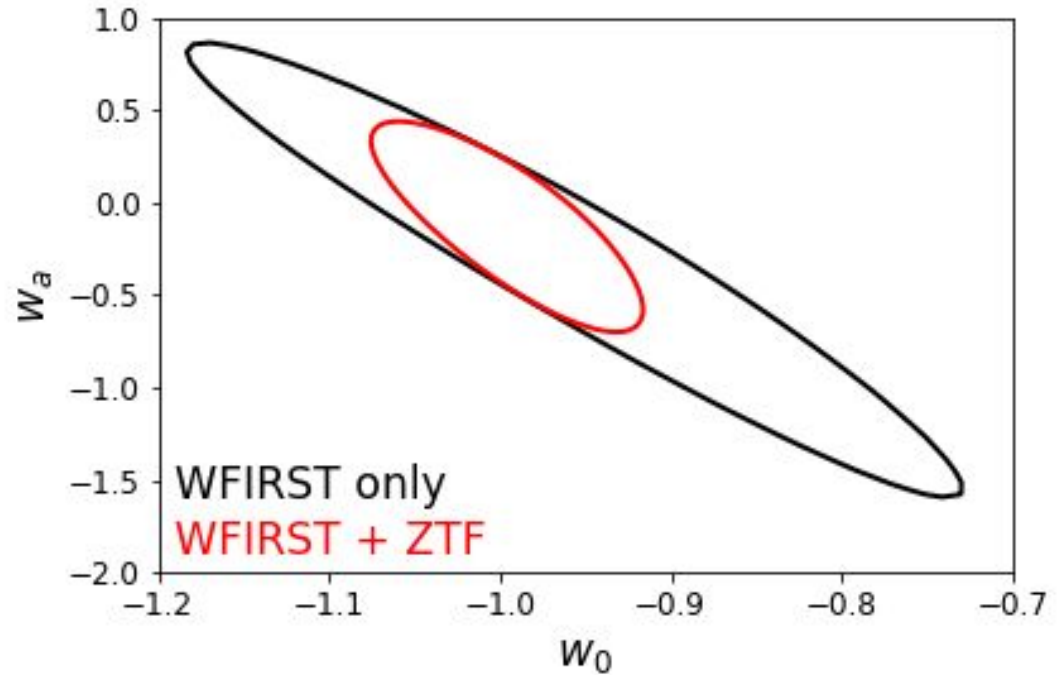


Anchoring the Hubble diagram

Future surveys (e.g. LSST) will mostly provide a high-redshift sample of SNe Ia.

A large low-redshift sample will be essential for precise measurement of dark energy.

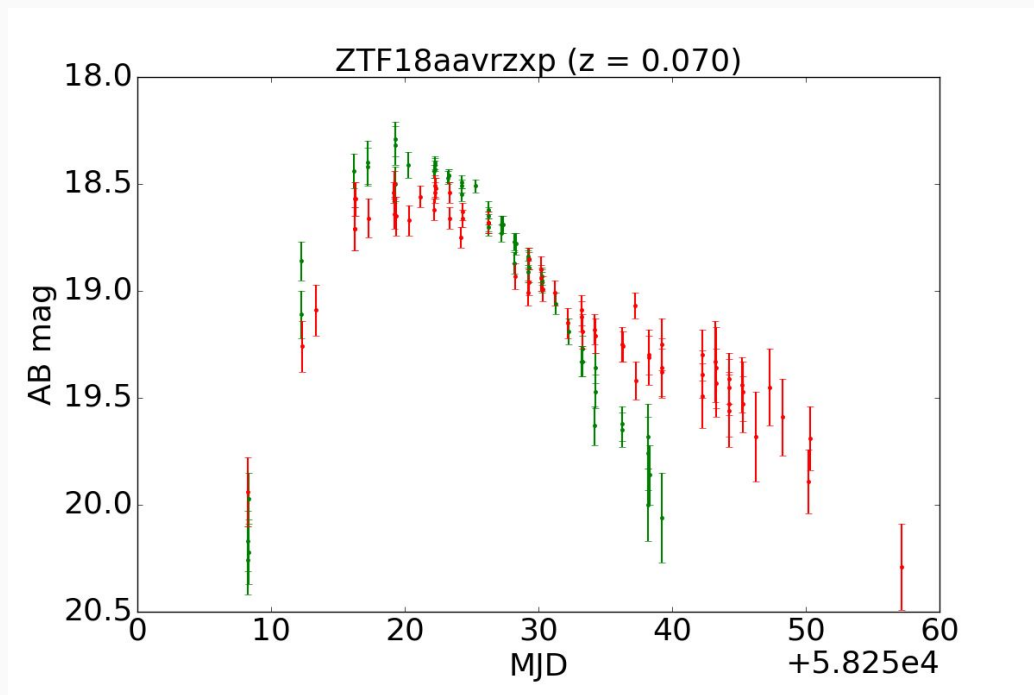
Additionally having a single well-calibrated data set will remove statistics from measurements of H_0 .



Lightcurve selection

Light curve requirements:

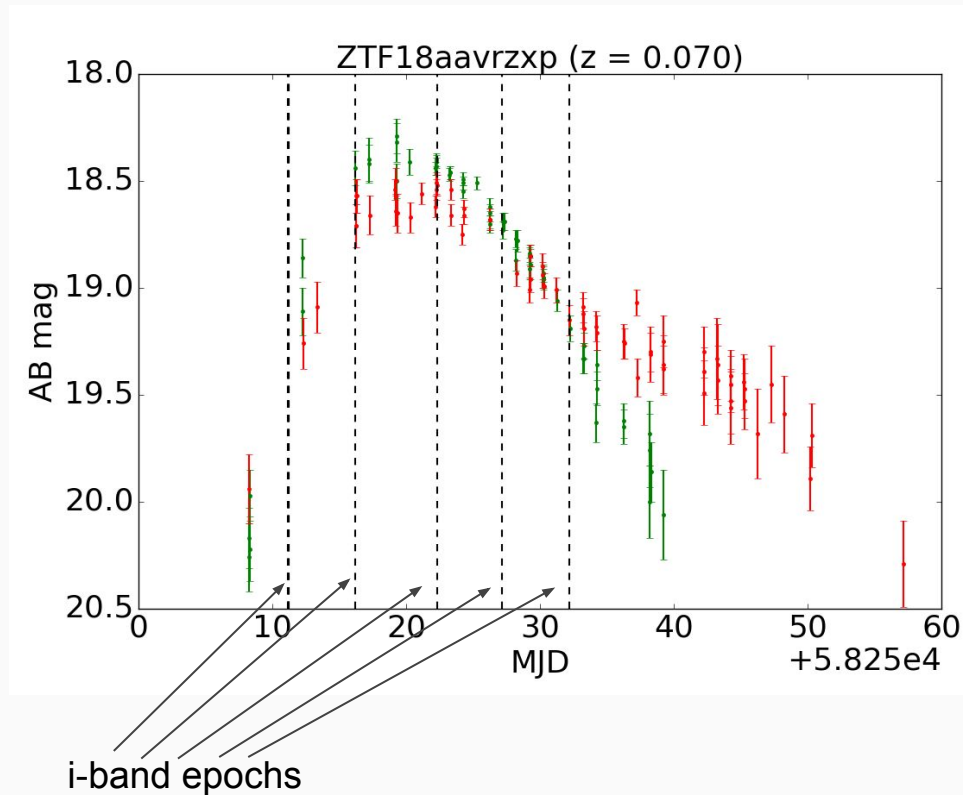
- Spectroscopically confirmed Ia
- Good SALT2 fit with normal lightcurve width for SN Ia
- g/r coverage before peak
- At least 3 observations in g/r/i



Lightcurve selection

Light curve requirements:

- Spectroscopically confirmed Ia
- Good SALT2 fit with normal lightcurve width for SN Ia
- g/r coverage before peak
- At least 3 observations in g/r/i
- Currently no i-band data due missing reference images but we checked that observations were taken

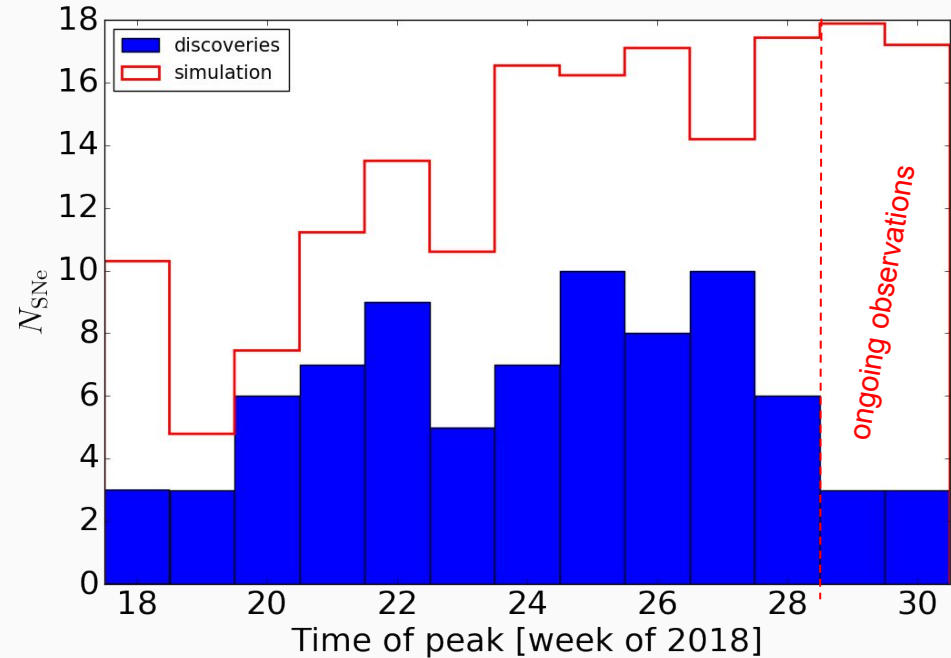


Current state of SN Ia sample

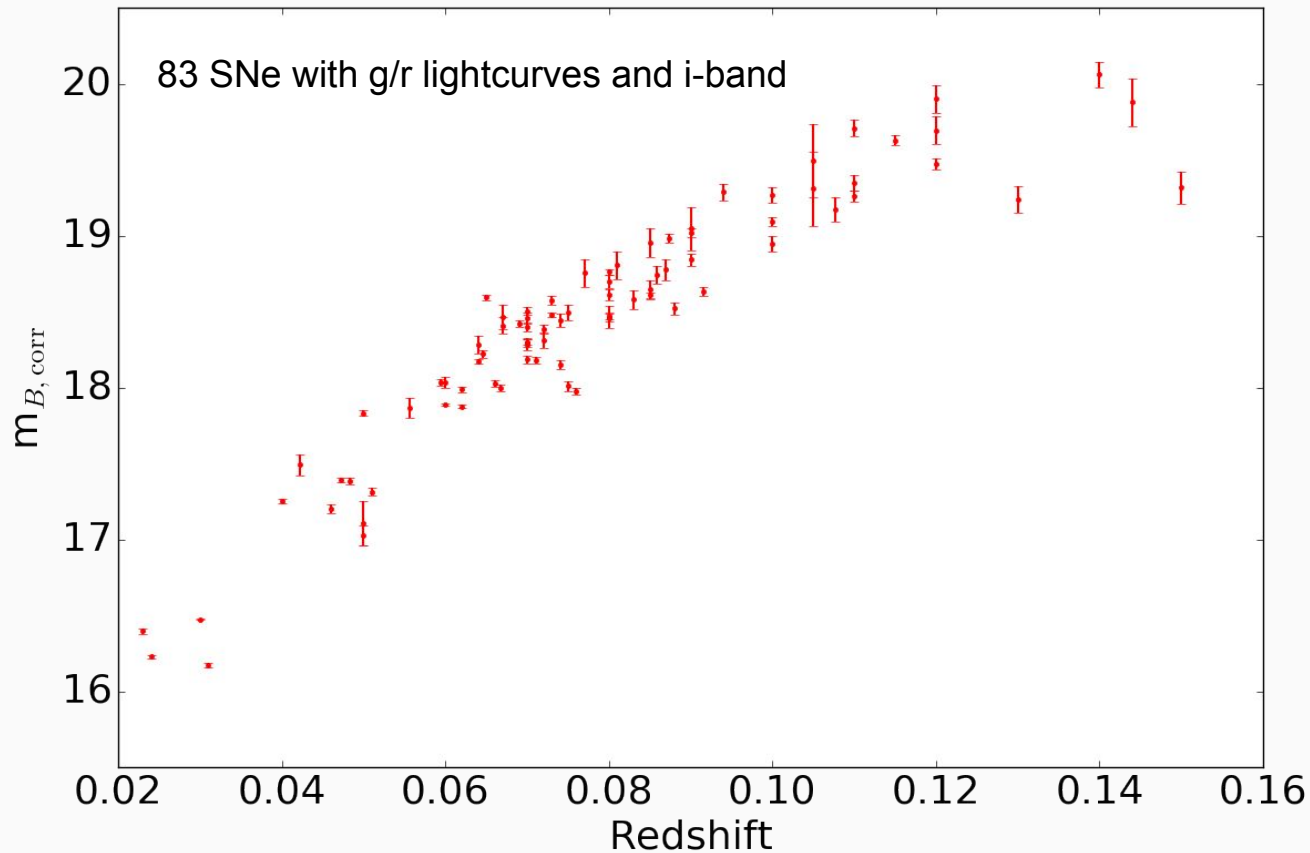
By now ZTF has found almost 300 SNe Ia:

- 99 SNe that fit criteria
- 37 additional SNe without i-band observation

In comparison to the simulations we have not found as many as expected (but did not yet account for fields without references).

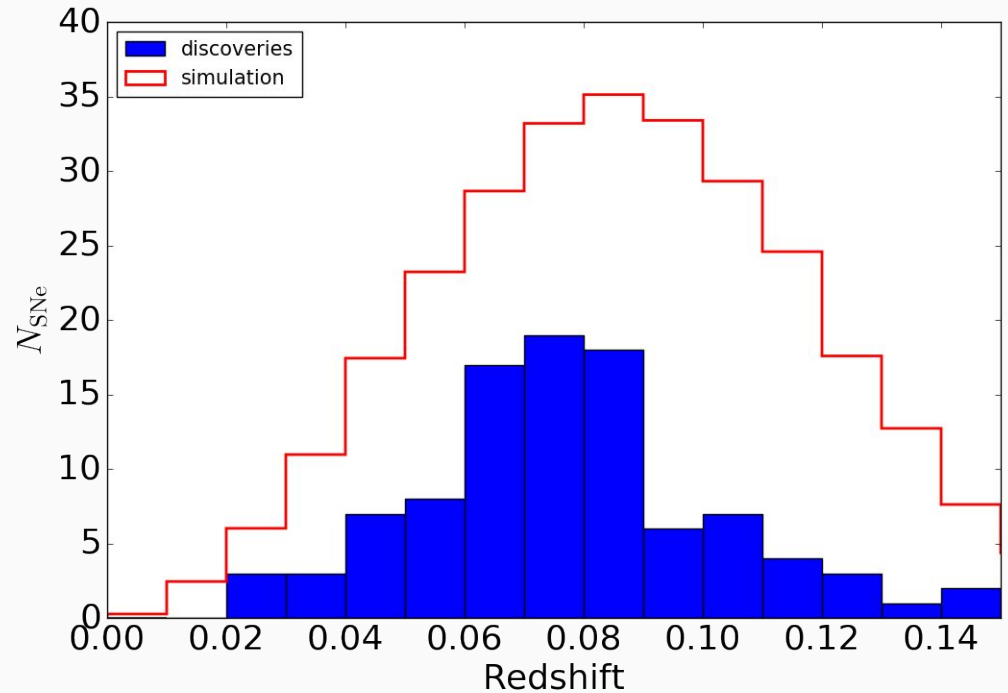


The first ZTF SN Ia Hubble diagram



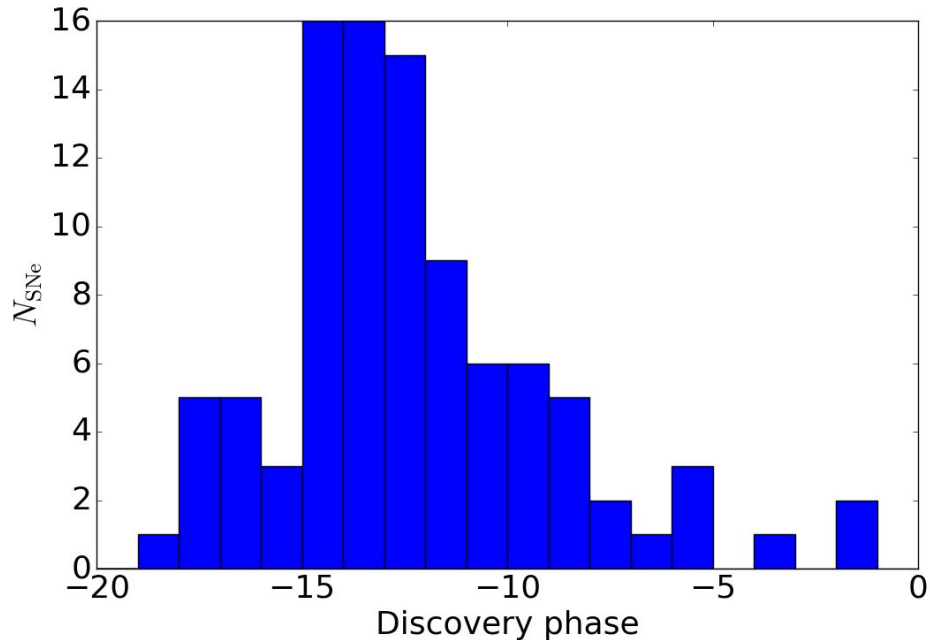
Redshifts distribution

- Most SNe are around redshift $z = 0.07$ (as expected from simulation)
- Simulations of the same time span predict about twice as many SNe



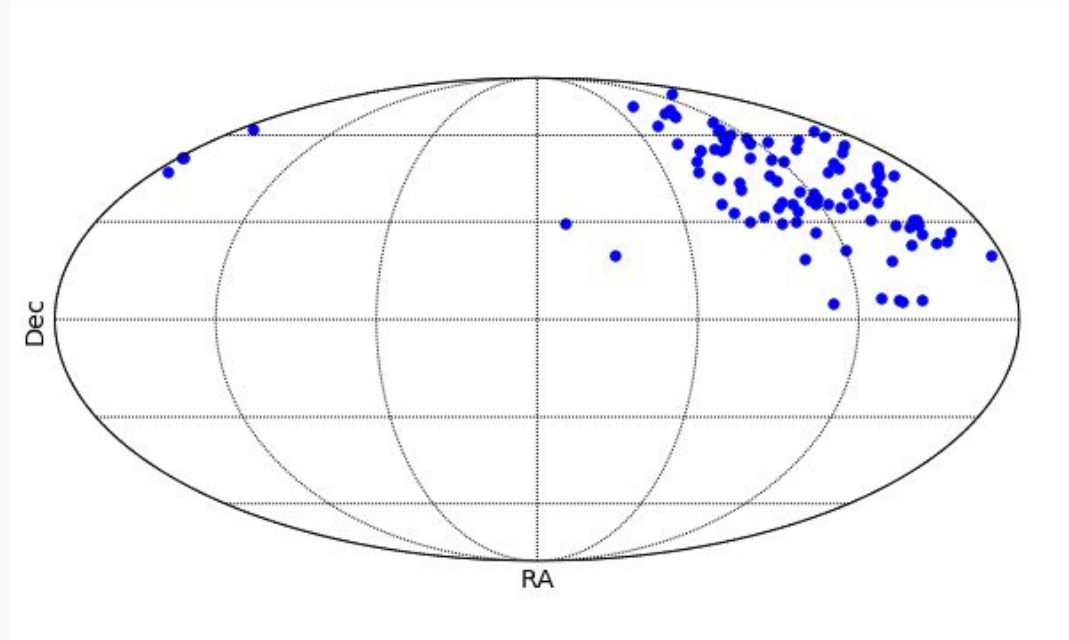
Discovery Phases

- Almost all SNe in cosmology sample discovered more than a week before peak
- Already a unique sample of early discoveries of SNe in the Hubble Flow
- Could be compared to various explosion models (M. Bulla)



Sky coverage

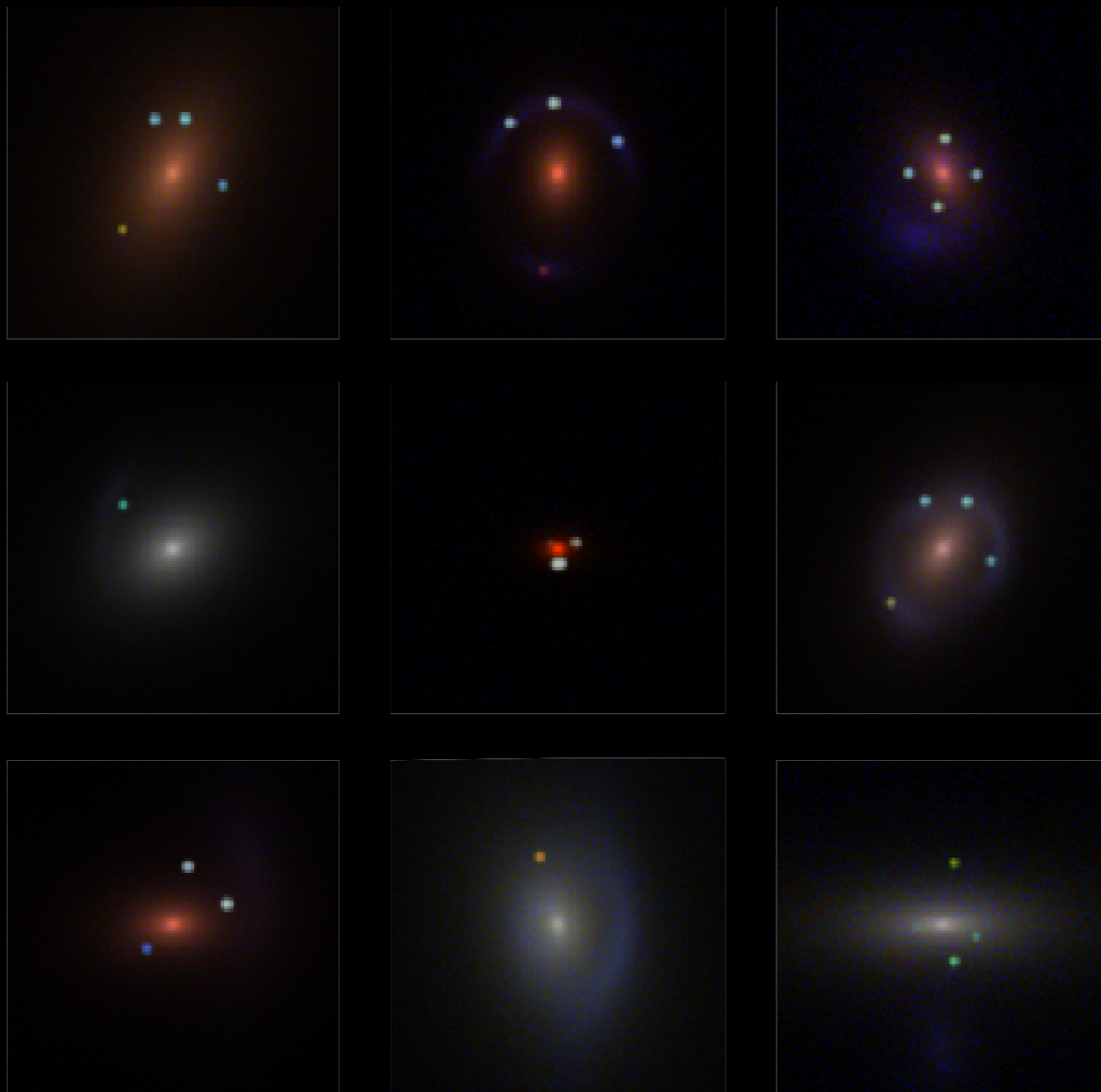
- ZTF will provide a unique SN Ia sample (untargeted and covering the whole northern sky)
- Even a few hundred SNe can contribute significantly to studies of the nearby structure
- Calibration need not be at the same level as for anchoring the Hubble diagram



Spectroscopic classification

- Most SNe in the sample have been typed by SEDM. If we do reach 19 mag with it, this would cover ~85% of the target SN sample
- We are designing programs using SNIFS, LCO and ePESSTO to cover the remaining part of the sample
- **Current challenges:** Target selection for additional spectroscopy still manual, needs to be switched to using the HU clean channel on AMPEL

Strongly Lensed Supernovae



- New suite of detailed strongly lensed supernova population simulations recently completed by Danny Goldstein (paper forthcoming)
- Simulations include effects of observing strategy, conditions, dust, host galaxies, SN subtypes, and discovery strategy
- Simulations forecast that ZTF should discover up to 20 strongly lensed SNe, ~80% of which will be IIP's or IIn's.

Lensed supernovae "discovered" in ZTF simulation

Lensed SN Program: Status

Search

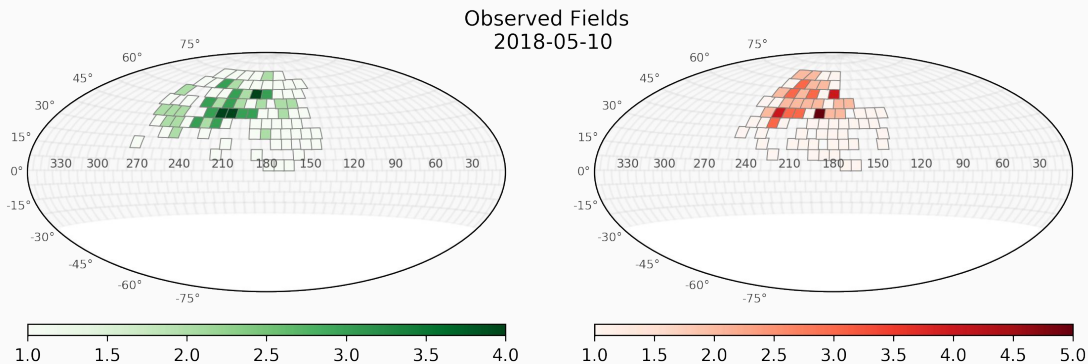
- Filters and broker infrastructure in active development
- We expect to have a regular stream of candidates by the end of Aug 2018
- Planning to develop a co-add pipeline to increase sensitivity to faint objects.
- If interested in getting involved, please contact Danny Goldstein, Peter Nugent, or Ariel Goobar

Follow-up

- MUSE pilot program accepted to get time delays, redshifts, classifications, and lens model for 1 ZTF lensed SN
- SEDm time allocated to screen candidates in elliptical galaxies
- *HST* and Keck proposals in the works

ztfquery

- <https://github.com/MickaelRigault/ztfquery> (private; ask Mickael for access)
- API for accessing ZTF data on IRSA (built on queryIRSA by M. Giomi)
- Tools to download and plot ZTF pointing history



marshaltools

- <https://github.com/ufoindt/marshaltools>
- API for downloading lightcurves and spectra from GROWTH marshal
- Lightcurves can be converted to `sncosmo` format for lightcurve fitting

Summary

- We have found 99 SNe so far that match the requirements for cosmological analyses
- We are doing very well down to SEDM depth already. Next challenge: Going deeper to get all SNe Ia to $z = 0.1$.
- Early lightcurves and uniform coverage will generate cosmology paper within the first year before the full sample has been collected