WHALES

Type Ia Supernova Discovery Program

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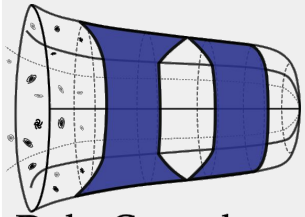
Jun 28,2023



Duke Cosmology

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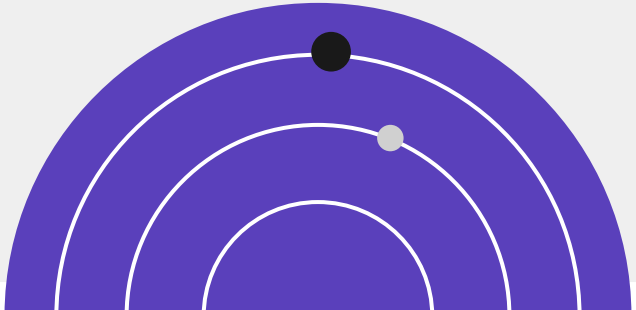
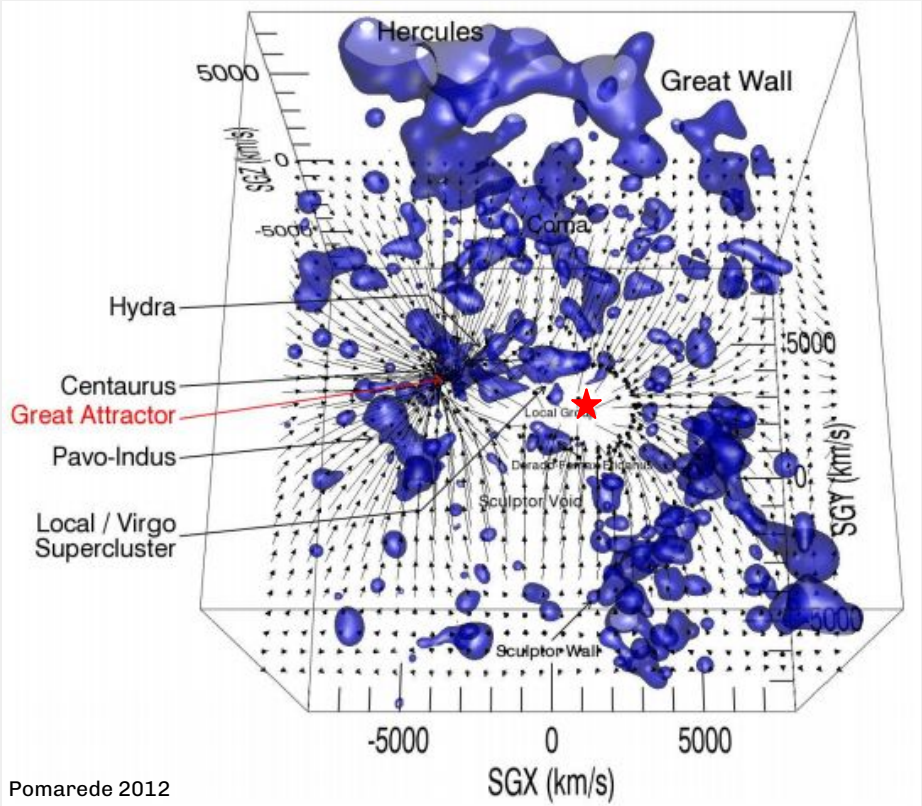
Motivation



Where are we going?

CMB measurements reveal our direction and speed, but lack explanation for the specific location and velocity.

Half of the 600 km/s motion can be explained, due to our local supercluster

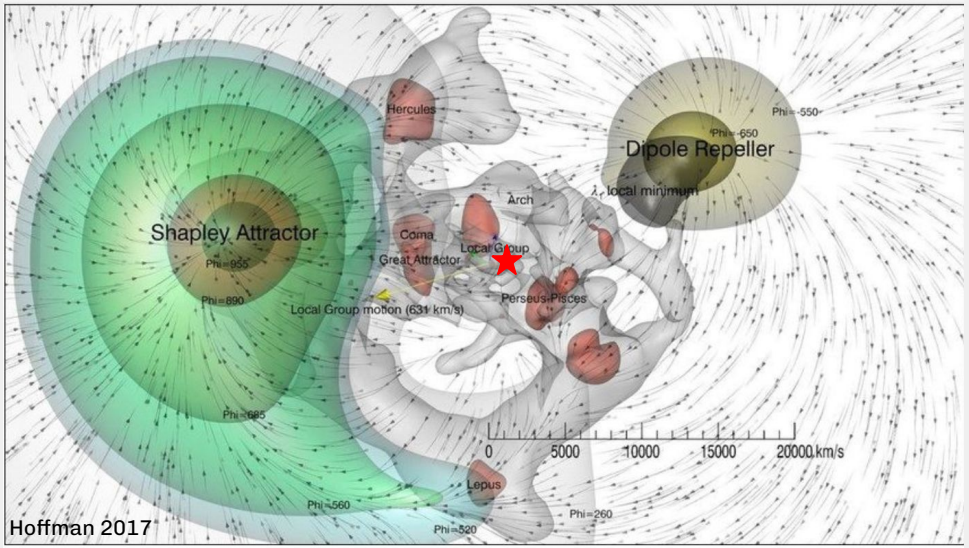


Pomarede 2012

Where are we going?

CMB measurements reveal our direction and speed, but lack explanation for the specific location and velocity.
Half of the 600 km/s motion can be explained, due to our local supercluster

The other half is theorized to be a result of the pull of the Shapley Supercluster

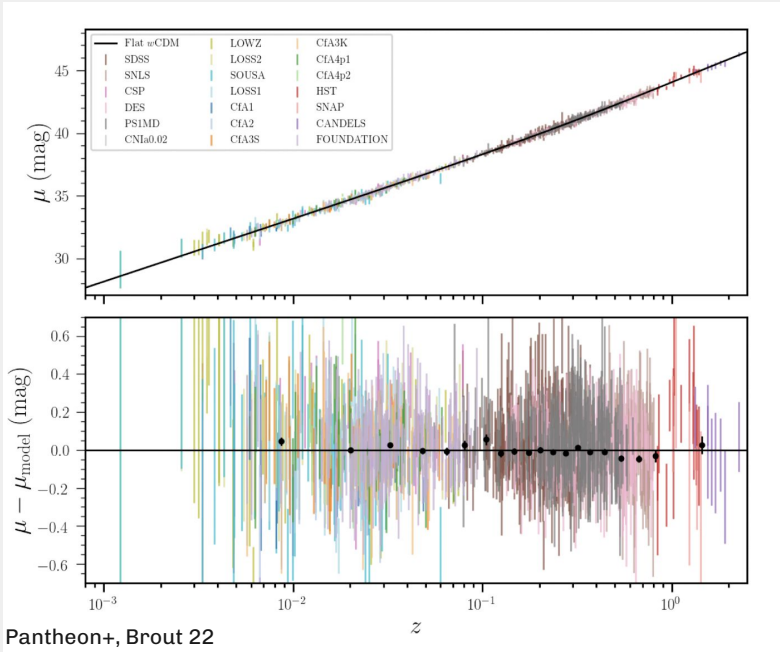


Hoffman 2017

Why is answering this important?

Understanding the H_0 tension:

- To measure H_0, we compare the brightness of Type Ia supernovae to their redshifts
  - In December 2021, SH0ES reported 73.04 ± 1.04 km/s/Mpc

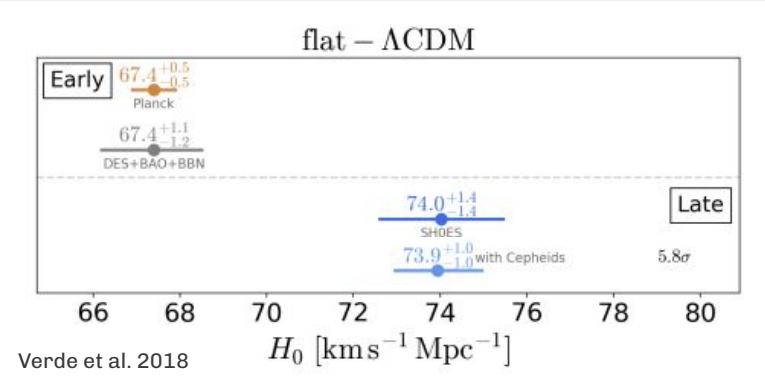


Pantheon+, Brout 22

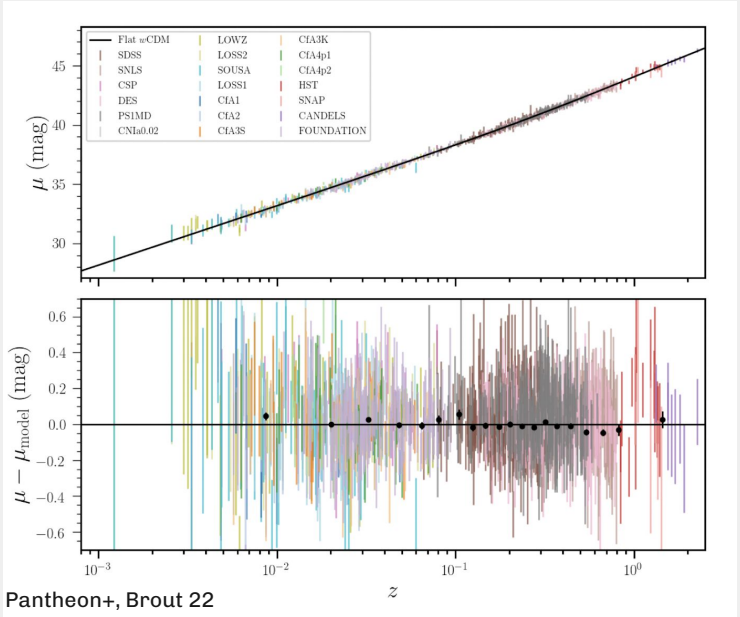
Why is answering this important?

Understanding the H_0 tension:

- To measure H_0, we compare the brightness of Type Ia supernovae to their redshifts



Verde et al. 2018

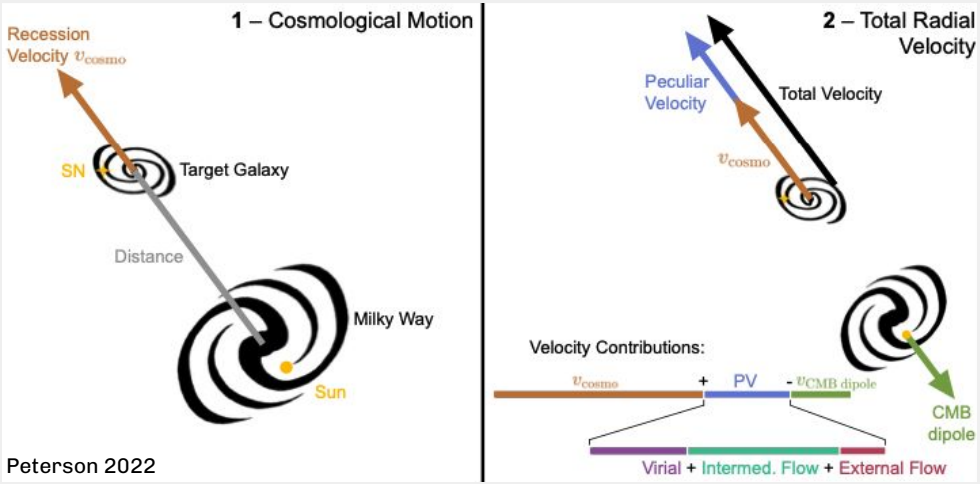


Pantheon+, Brout 22

Why is answering this important?

Understanding the H_0 tension:

- To measure H_0, we compare the brightness of Type Ia supernovae to their redshifts
- The redshifts are affected by peculiar velocities
  - All motions of galaxies that are NOT due to the expansion of the universe
  - Peculiar velocity corrections change H_0 by ~0.5 km/s/Mpc (Peterson et al. 2022)

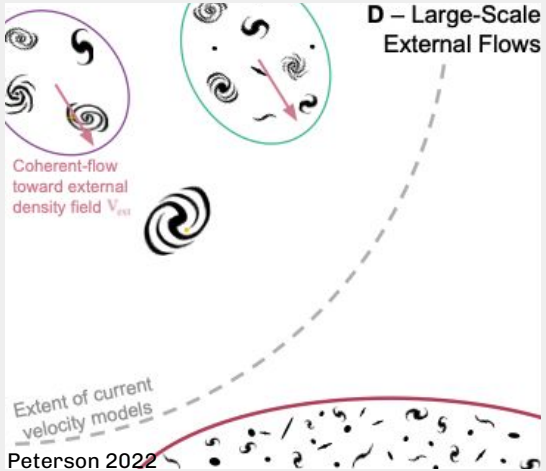


Peterson 2022

Why is answering this important?

Understanding the H_0 tension:

- To measure H_0, we compare the brightness of Type Ia supernovae to their redshifts
- The redshifts are affected by peculiar velocities
- Motions from nearby superclusters must be corrected to measure H_0 accurately



Peterson 2022

Weighing Haloes Accurately, Locally, and Efficiently with Supernovae (WHALES)

Shapley Supercluster

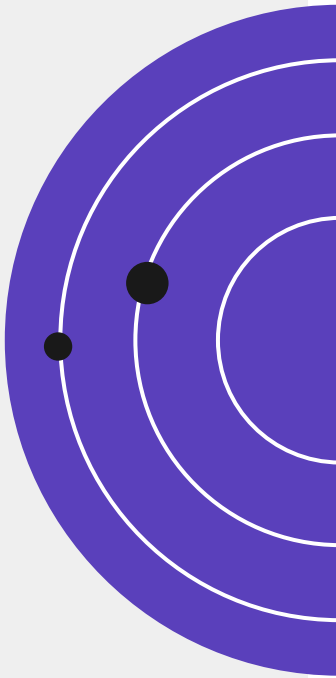
Central to bulk flow models
No SNe Ia discovered/ measured in its direction

SNe Ia

Our goal is to use SNe Ia on both sides of the supercluster $0.02 < z < 0.1$ (mean redshift is around 0.05) to compare the inferred velocities with those expected from the predicted mass from bulk flow models

02

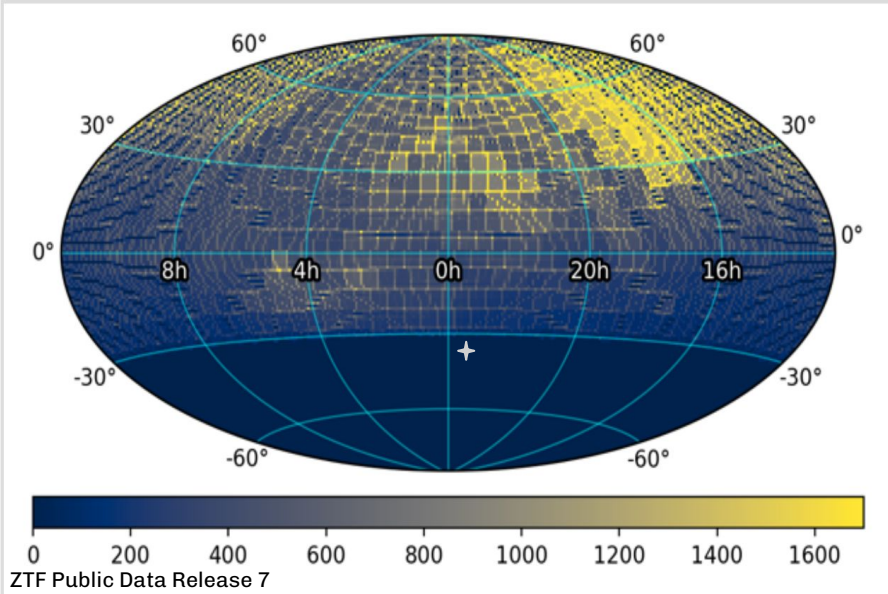
Creating a Survey



Picking a Telescope

Location

Shapley is in the south (Dec~ -31 deg) in declination so we want a telescope in the Southern Hemisphere



ZTF Public Data Release 7

Picking a Telescope

Location

Shapley is in the south (Dec~ -31 deg) in declination so we want a telescope in the Southern Hemisphere

Size

We want a large field of view and decent aperture so that we can cover a wide area

SkyMapper

Only one telescope fit the bill and allowed for a prompt start of the survey

SkyMapper

Location

Siding Spring Observatory, Coonabarabran, NSW, Australia

Field of View

2.34° x 2.40° field of view = 5.6 square degrees

Seeing

68% of the time the seeing is less than 1.75 arcsecs

Filters

u v **g r i** z

Information from Keller 2007 and image from ANU

SkyMapper

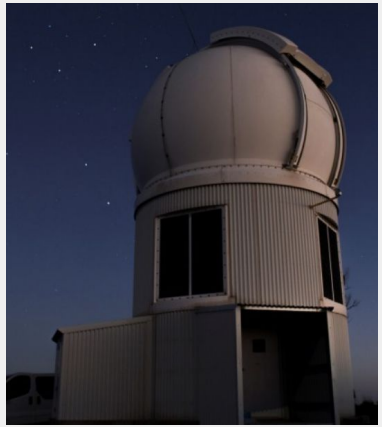
Location

Siding Spring Observatory, Coonabarabran, NSW, Australia

field of view = 5.6 square degrees

the seeing is less than 1.75 arcsecs

SkyMapper has previously been used for a SN survey but the results weren't particularly good and people gave up on it.
Our use case is much simpler as our SN are quite nearby, and Skymapper already has calibration.



Information from Keller 2007 and image from ANU

2.3m Wide-Field Spectrograph (WiFeS)

Location

Siding Spring Observatory, Coonabarabran, NSW, Australia

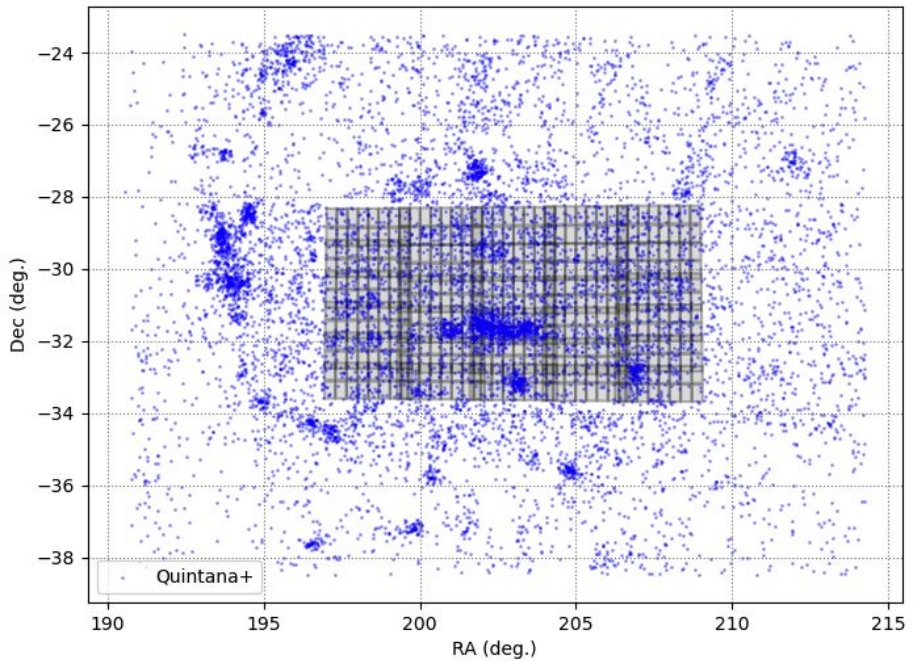
Field of View

38 x 25 arcsec (25 slitlets that are 1 arcsec wide and 38 arcsec long)

No Fiber-Optics

Concentric image-slicer with “long-slit”slitlets

Survey Strategy



We want to focus on the densest regions

At z~0.06, typically it is needed to cover a huge area to find a lot of SNe.

Shapley has 12,000 galaxies in 200 square degree and we expect 120 SNe in one year.

We are currently tilling 30% of the supercluster every three days during the observable season (we expect ~20 SNe).

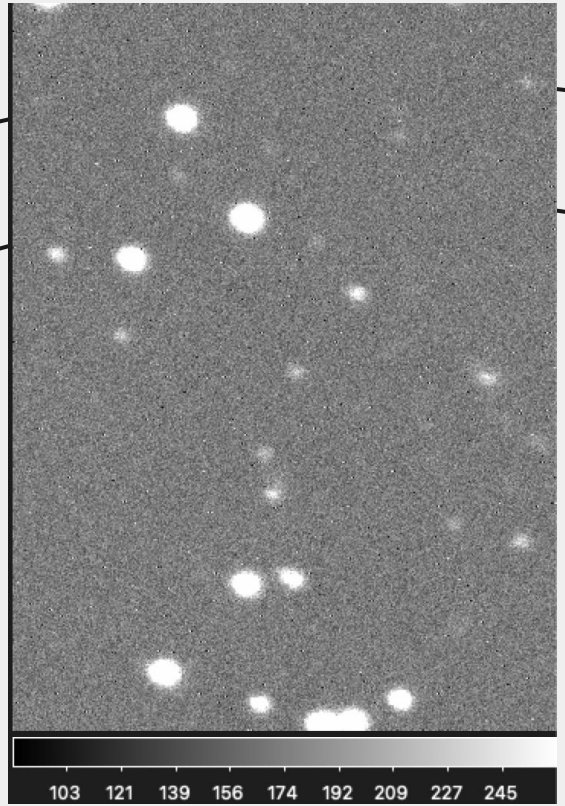
03

Data Processing Pipeline

Current Processing Pipeline

1st

Get images from the telescope



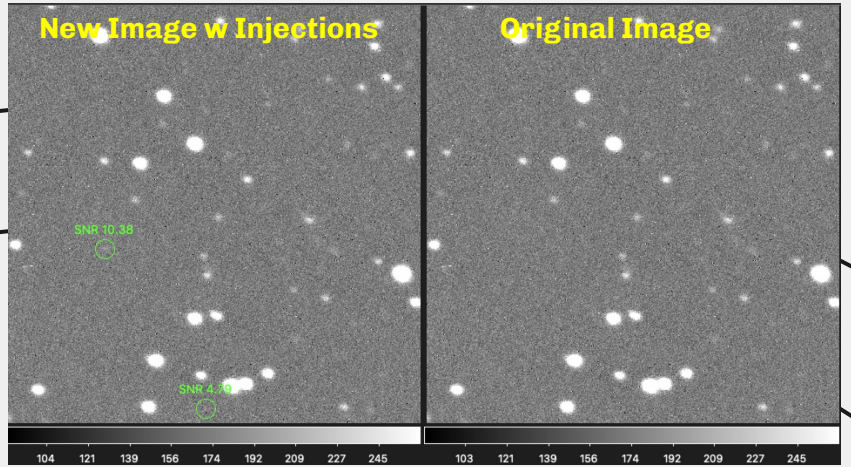
Current Processing Pipeline

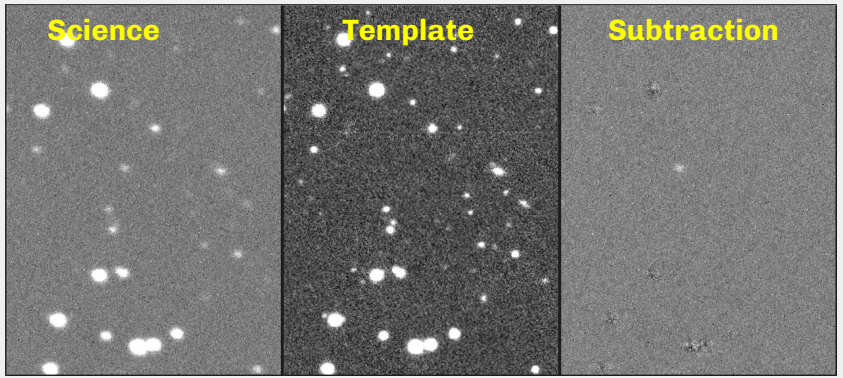
1st

Get images from the telescope

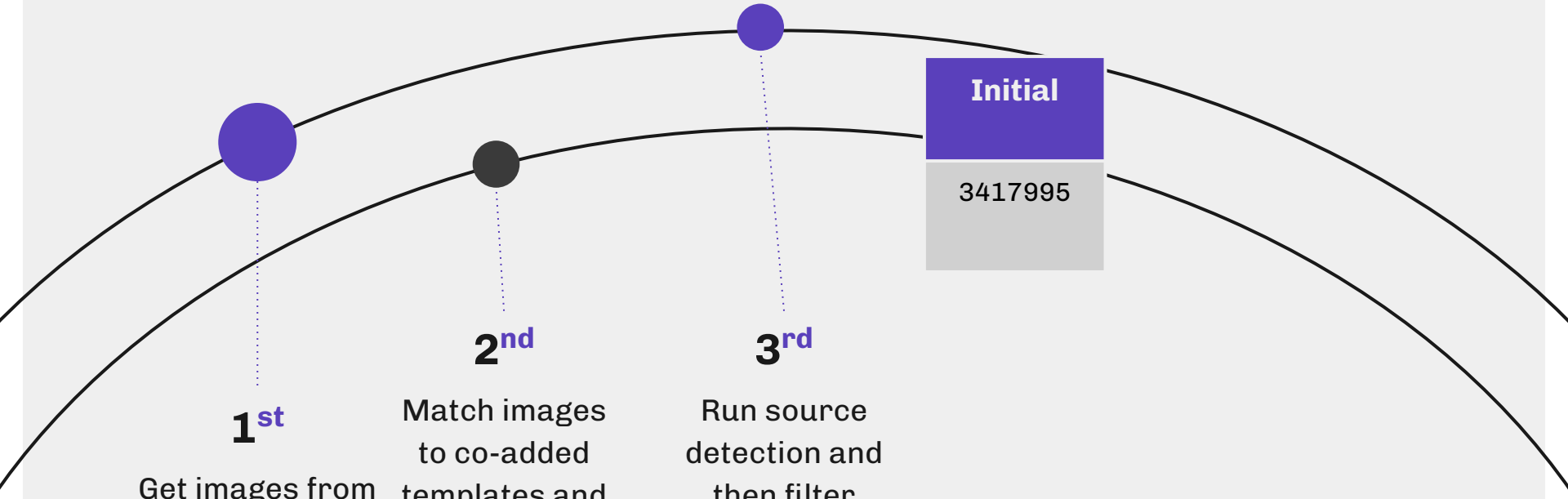
2nd

Match images to co-added templates and prep and perform subtraction





Current Processing Pipeline



1st

Get images from the telescope

2nd

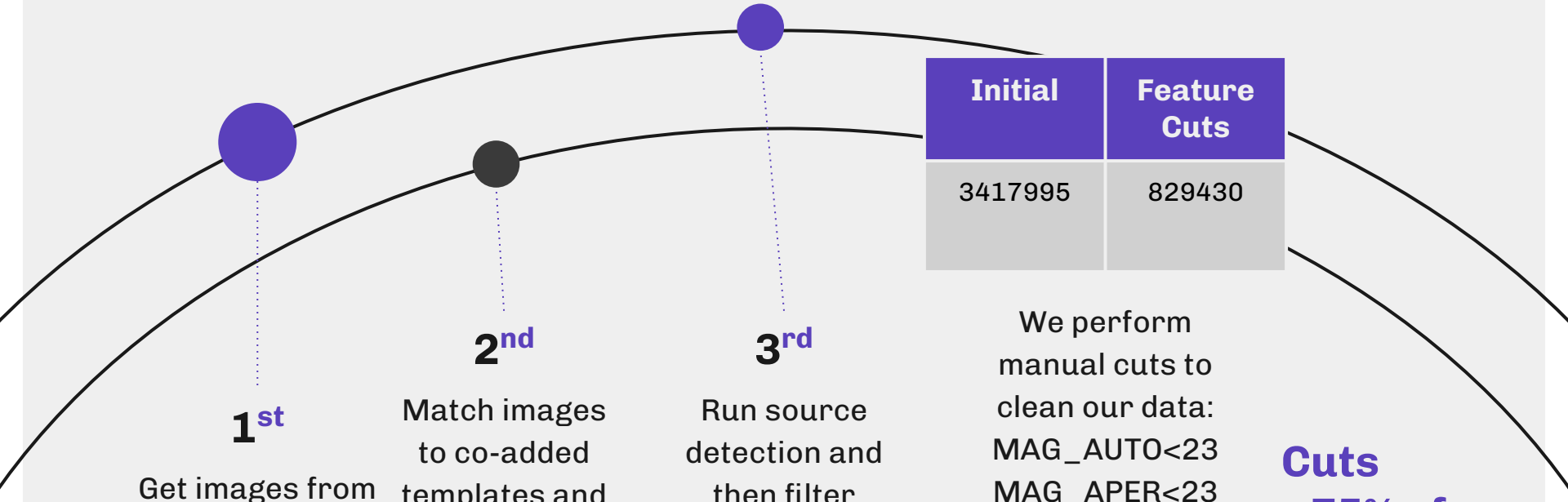
Match images to co-added templates and prep and perform subtraction

3rd

Run source detection and then filter candidates into probable SN transients

Initial
3417995

Current Processing Pipeline



1st

Get images from the telescope

2nd

Match images to co-added templates and prep and perform subtraction

3rd

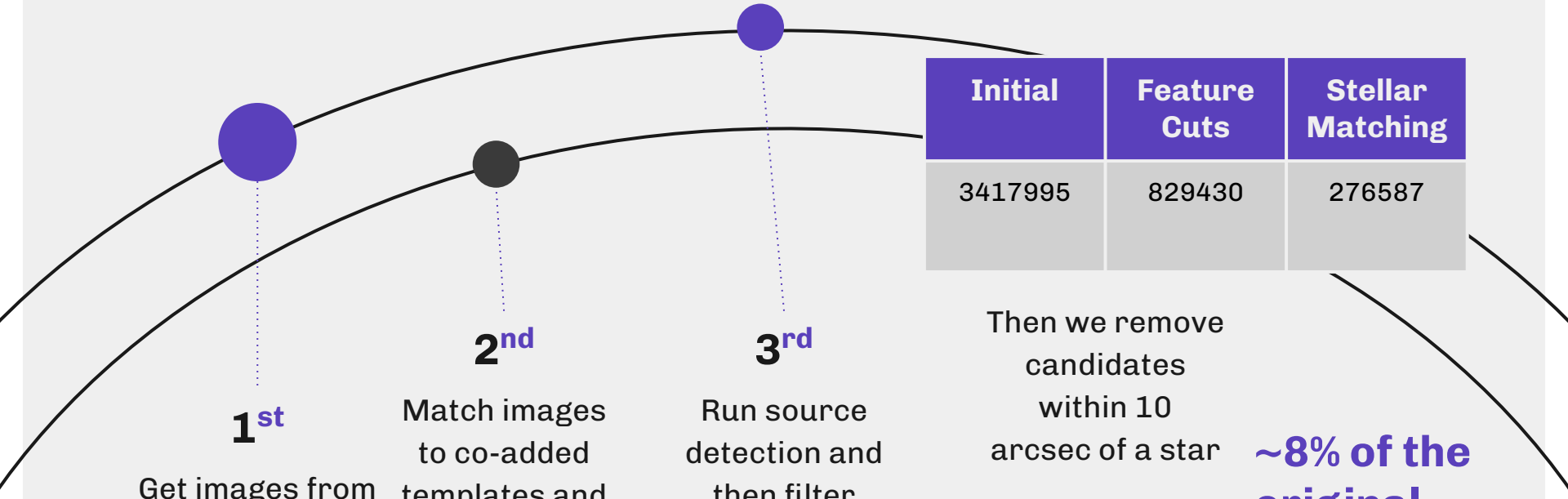
Run source detection and then filter candidates into probable SN transients

Initial	Feature Cuts
3417995	829430

We perform manual cuts to clean our data:
MAG_AUTO<23
MAG_APER<23
SNR>5
ELONGATION<2

Cuts ~75% of the sample

Current Processing Pipeline



1st

Get images from the telescope

2nd

Match images to co-added templates and prep and perform subtraction

3rd

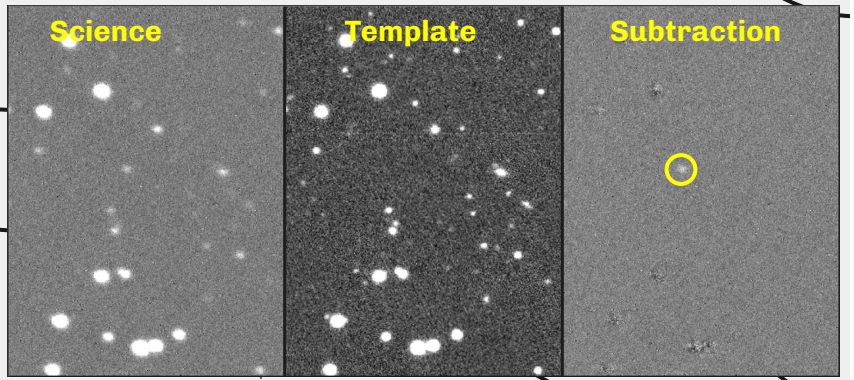
Run source detection and then filter candidates into probable SN transients

Initial	Feature Cuts	Stellar Matching
3417995	829430	276587

Then we remove candidates within 10 arcsec of a star

~8% of the original sample

Current Processing Pipeline



1st

Get images from the telescope

2nd

Match images to co-added templates and prep and perform subtraction

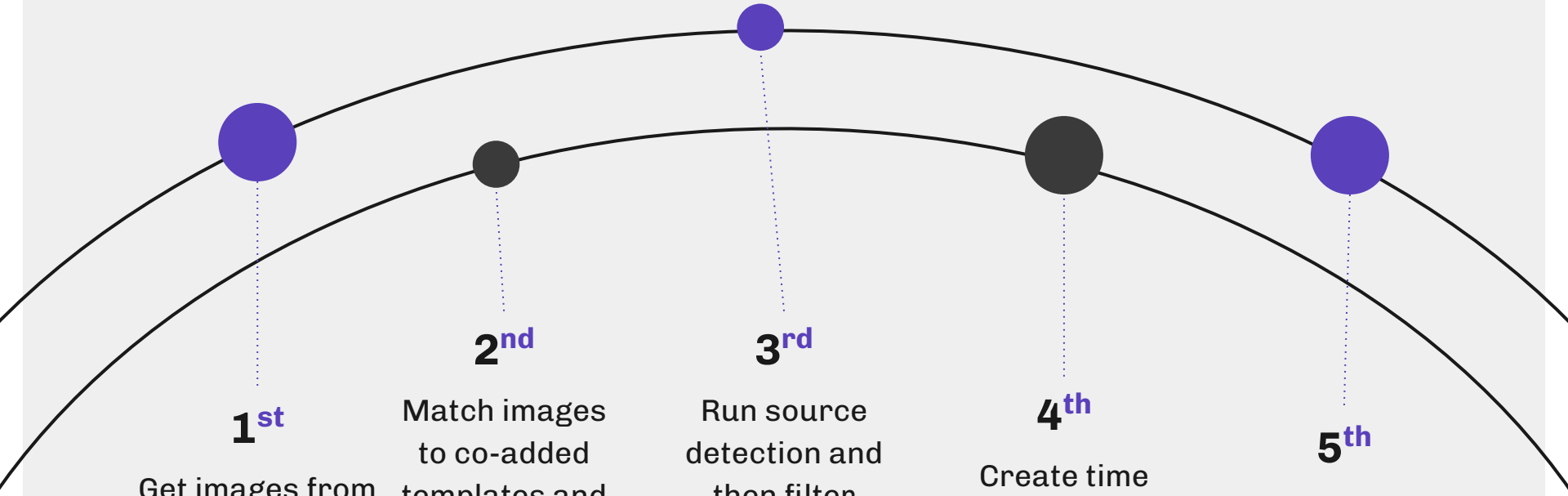
3rd

Run source detection and then filter candidates into probable SN transients

4th

Create time lapse images and pick out the most likely SNIa

Current Processing Pipeline



1st

Get images from the telescope

2nd

Match images to co-added templates and prep and perform subtraction

3rd

Run source detection and then filter candidates into probable SN transients

4th

Create time lapse images and pick out the most likely SNIa

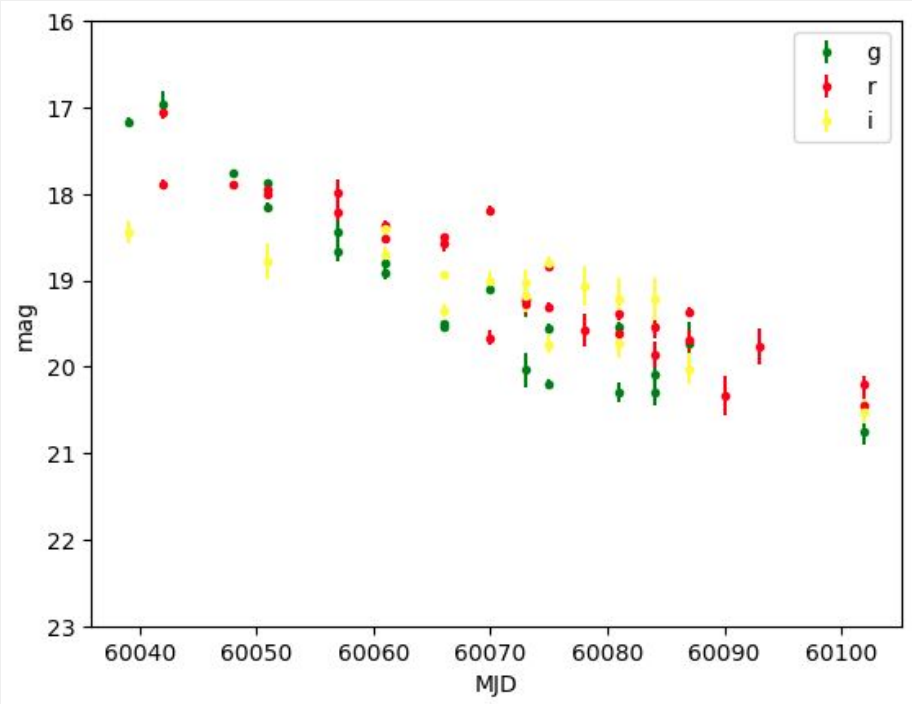
5th

Use spec follow-up to get confirmed typing

PSF Photometry Light Curves

Calculated zeropoints and then magnitudes to get a light curve

This is a preliminary light curve for a confirmed Ia



Survey Changes for YR2

- We are not yet able to process images in real time
  - This means we have been slow in spectroscopic confirmation so a YR1 analysis will rely on a photometric sample

- Tile all of Shapley every 3 days

Thanks

Do you have any questions?

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