Transient Astronomy at Deep Springs
Part I - The Plan

A Program of Work Being Performed in Collaboration with:
Geoff Marcy, Sofia Mikulasek, and Luke Suess

Presentation to the Community
December 8, 2022
Brian Hill, Herb Reich Chair of Natural Science

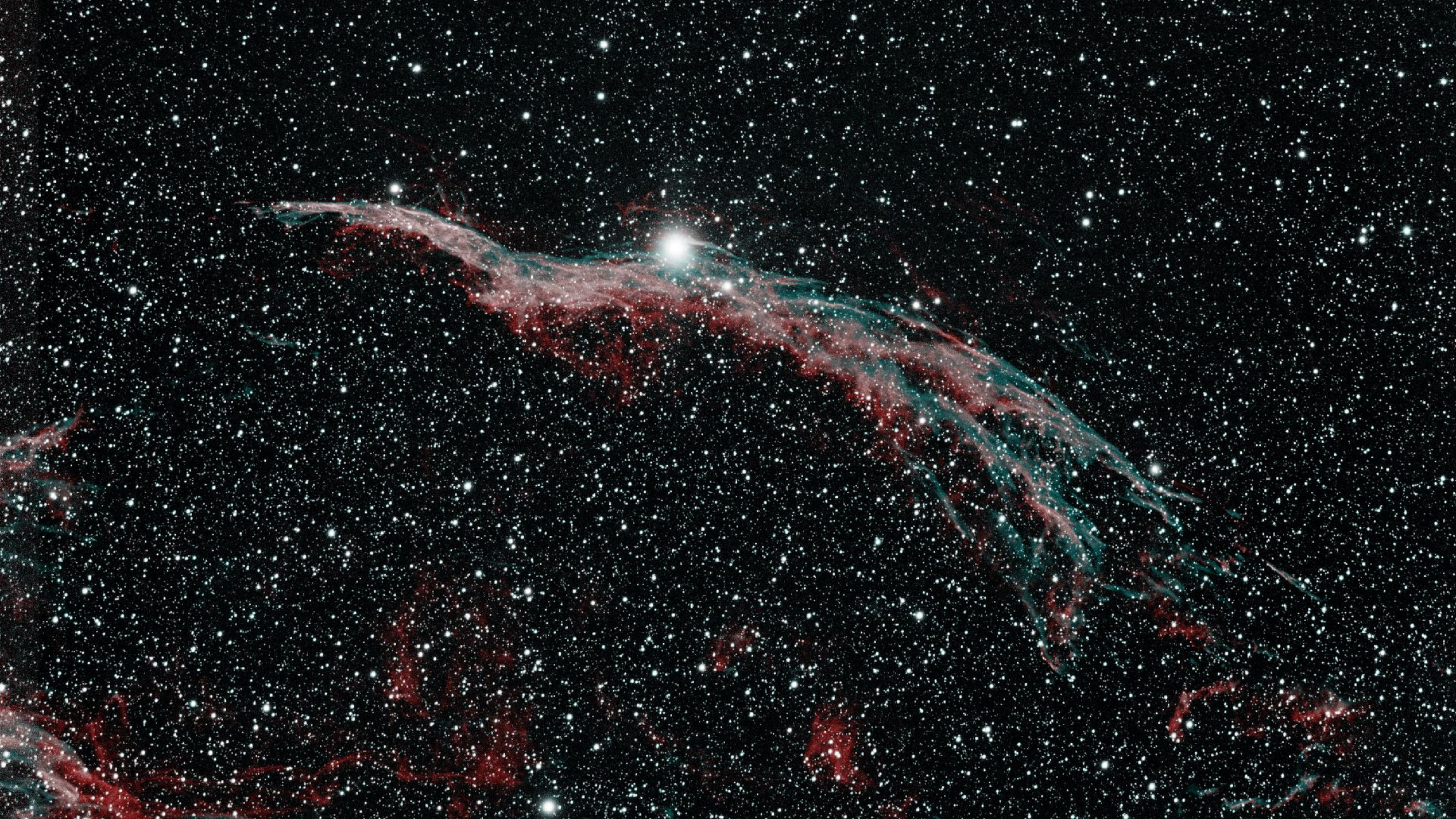
Outline

1. Supernovae
2. The Standard Flashbulb of Cosmology
3. The Importance of Our Dark Skies
4. Deep Springs Observatory and Its Equipment
5. Target Selection and Data-Taking
6. Data-Analysis and First Results

The Western Veil Nebula

Alice Owen and Declan Rexer

June, 2021



The Western Veil Nebula

Alice Owen and Declan Rexer

June, 2021

Image Properties

- Red Channel — Represents Hydrogen Gas
- Blue-Green Channel — Represents Oxygen Gas
- White Channel — Full Spectrum
- Field of View — Approximately 1°

Target Properties

- Full Nebula is 3°
- 2100 Light-Years Away
- Supernova from ~10,000 Years ago
- Light Arrived Here ~6,000 B.C
- Would have been visible in the daytime

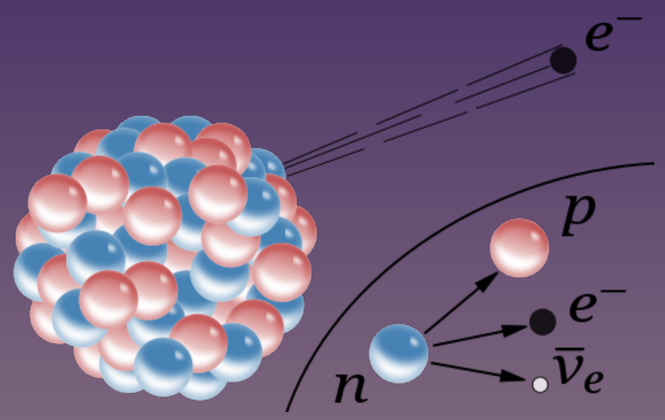
What is a Supernova!?

Type II vs. Ib and Ic

- A star at least 8x the mass of the Sun:
  - Fuses Hydrogen into Helium at a rapid rate
  - As little as 10,000,000 years to use up its Hydrogen
- A Type II Supernova undergoes "core collapse" while unconsumed Hydrogen is still surrounding its core
- Other types *continue consuming all of their Hydrogen* and then start fusing Helium
- A Type Ib Supernova:
  - Undergoes core collapse while unconsumed Helium is still surrounding its core
  - Its core contains Carbon and Oxygen
- The remainder, Type Ic supernovae, *continue consuming all their Helium:*
  - In their core, they produce heavier elements such as Neon and Magnesium
  - Surrounding their core is Carbon and Oxygen

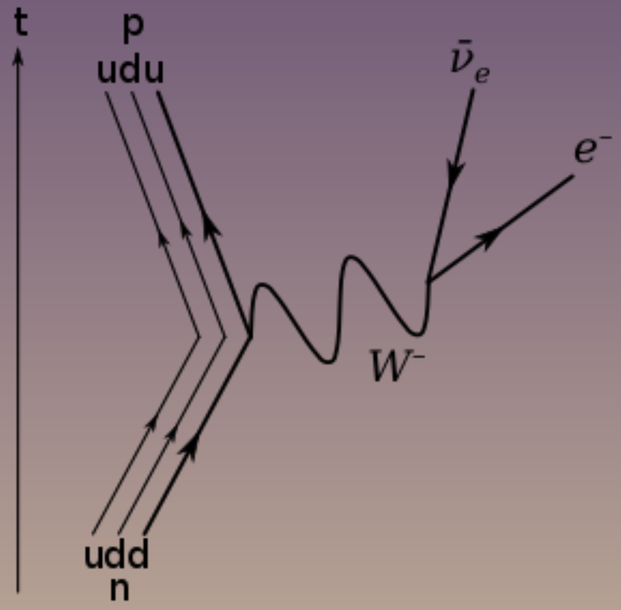
What is "Core Collapse?"

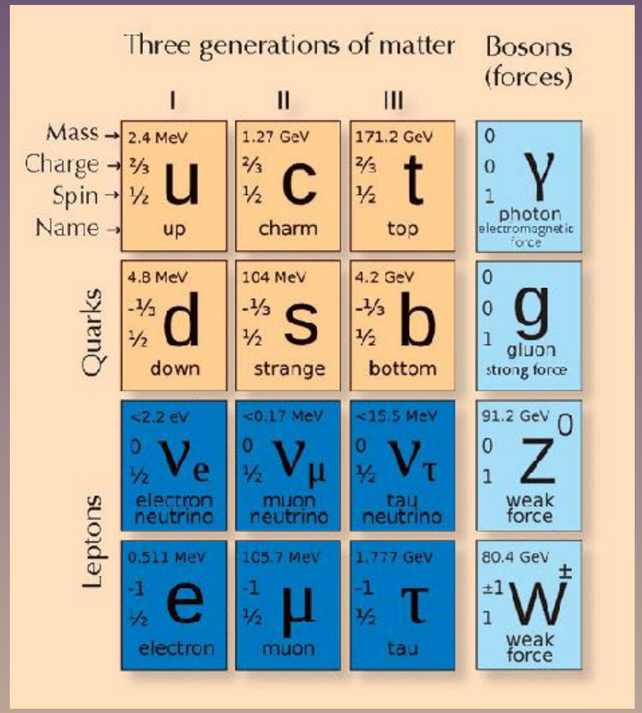
Beta Decay



Example, Tritium
beta decays into Helium-3

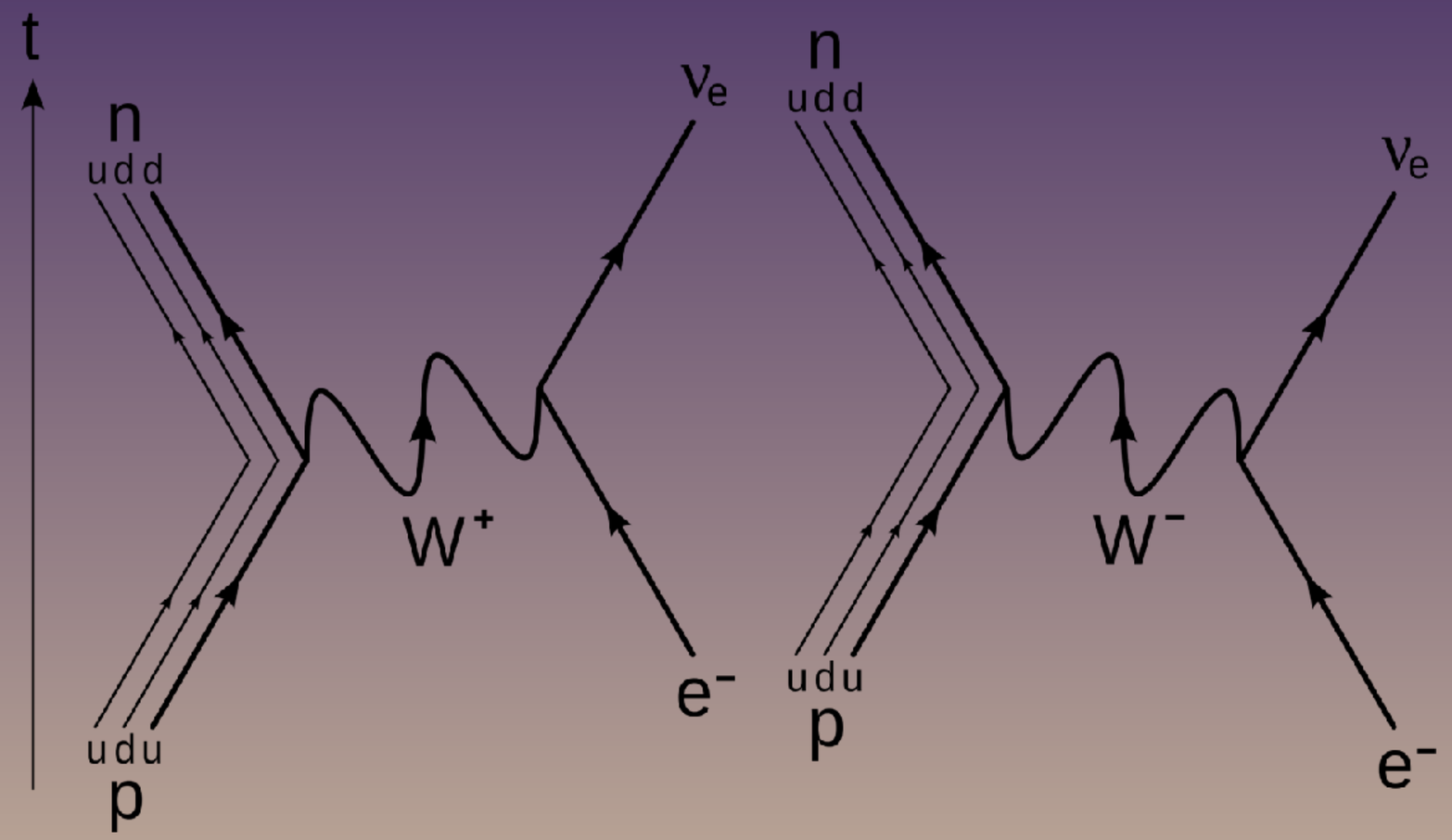
Standard Model Explanation





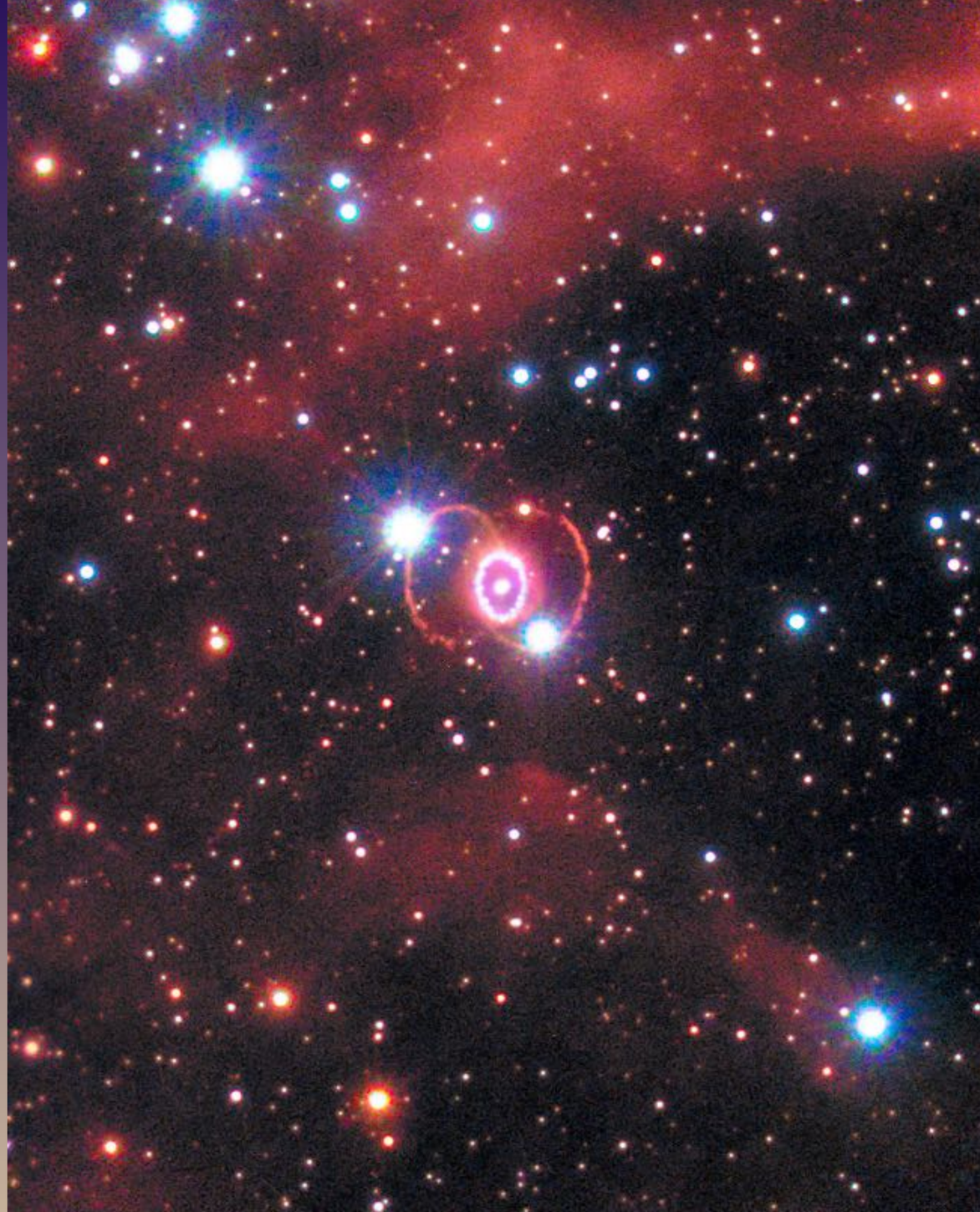
What is "Core Collapse?"

Two Interpretations of the Feynman diagram for Electron Capture



What is "Core Collapse?"

- In a fraction of a second, all the electrons and protons in the star's core combine to become neutrons
- Temperatures reach 100,000,000,000 Kelvin
- Hours for the shock wave to reach the surface of the star
- Months to brighten
- Years to fade away
- Supernova 1987A, Large Magellanic Cloud, 158,000 Light-Years Away



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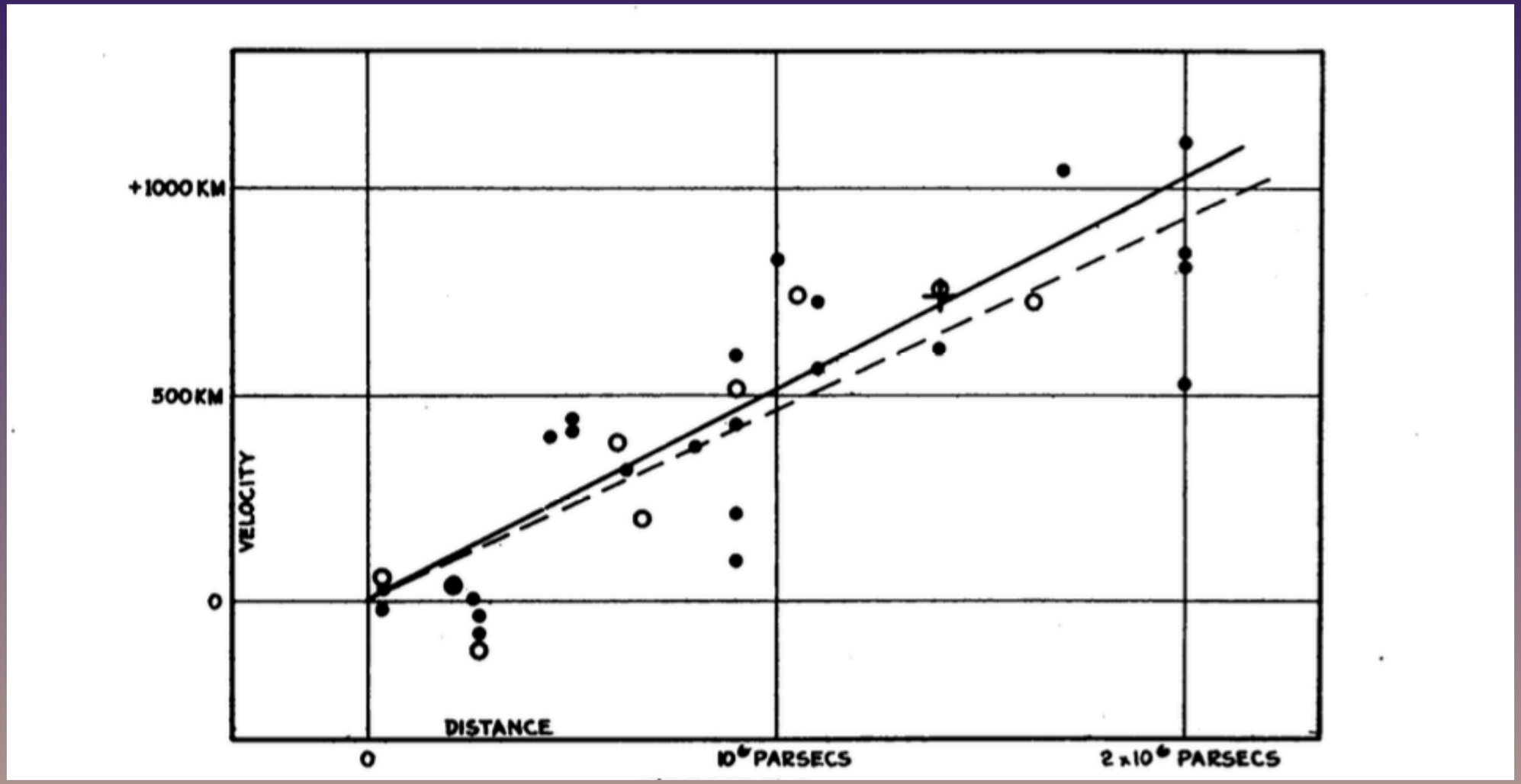
Type II, Type Ib, Type Ic — Notice Something Missing?

Type 1a Supernovae Properties:

- A white dwarf accreting matter from a companion star
- Negligible Hydrogen (hence Type I, not Type II)
- Always the same intrinsic luminosity!
- Absolute magnitude -19.5 (the brightness it would be at 10 parsecs which is 32.6 light-years)
- By comparison, the "absolute magnitude" of our sun is 4.8
- Difference is almost 25 magnitudes
- 25 magnitudes is 10,000,000,000 times as bright (if at the same distance)
- Always the same intrinsic luminosity!! Worth repeating ;)
- The standard flashbulb of modern cosmology
- As bright as a moderately-sized galaxy!!

The Big Bang and The Original Hubble Plot

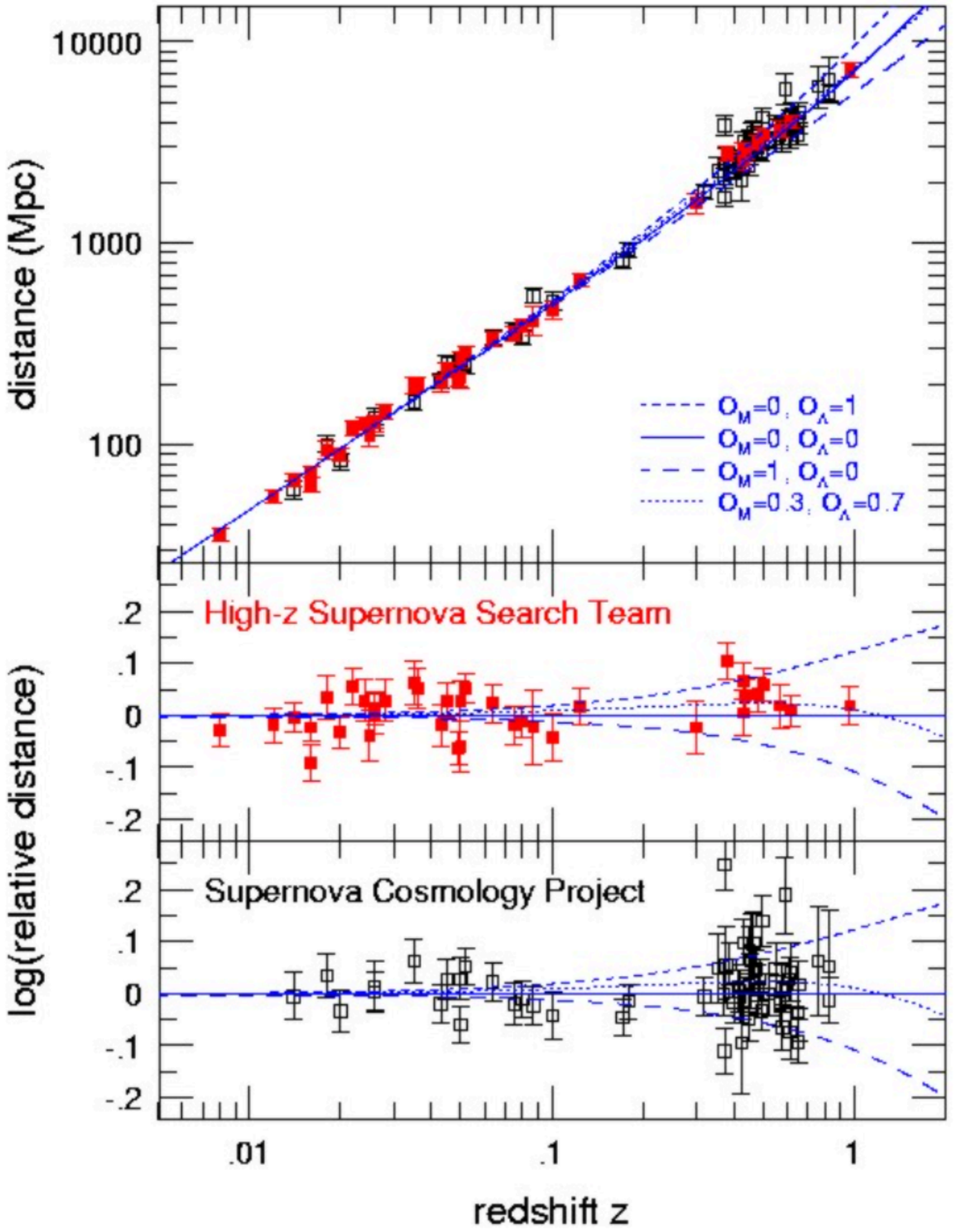


E. Hubble, Proceedings of the N.A.S, 1929

Standard Candle Used was Cepheid Variable Stars

Modern Hubble Plot

- Standard Flashbulb used is the Type 1a supernova
- Each data point is a supernova!
- Strong Evidence for both dark matter and dark energy
- 2011 Nobel Prize in Physics
    - Saul Perlmutter for the Supernova Cosmology Project
    - Adam Riess and Brian P. Schmidt for the High-z Supernova Search Team
- Systematic and statistical uncertainties are challenging
- Calibrating Type 1a supernova (the standard flashbulb) is ongoing



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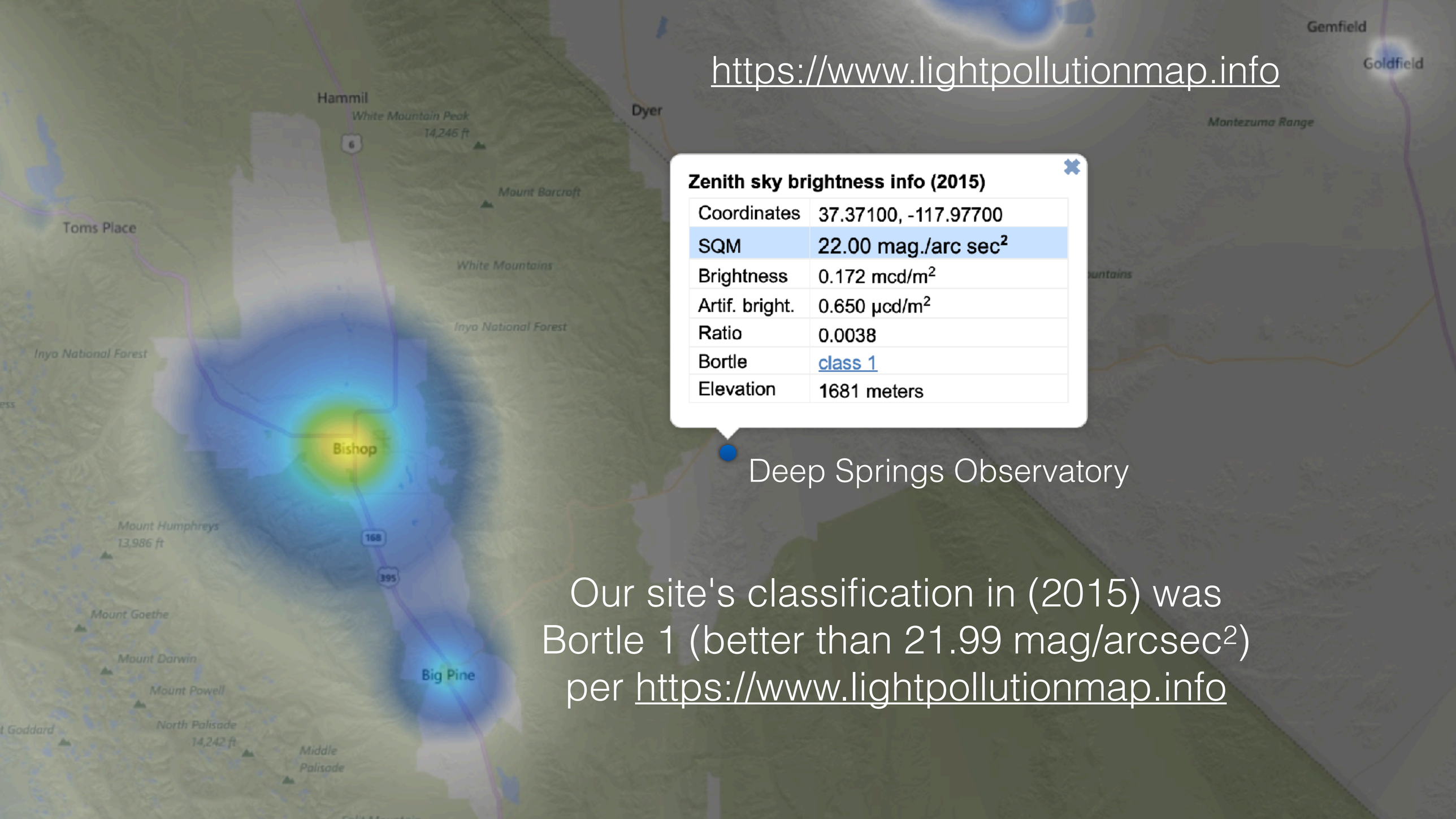
https://www.lightpollutionmap.info
Zenith sky brightness info (2015)
Coordinates 37.37100, -117.97700
SQM 22.00 mag./arc sec²
Brightness 0.172 mcd/m²
Artif. bright. 0.650 µcd/m²
Ratio 0.0038
Bortle class 1
Elevation 1681 meters
Deep Springs Observatory
Our site's classification in (2015) was
Bortle 1 (better than 21.99 mag/arcsec²)
per https://www.lightpollutionmap.info
Hammil
White Mountain Peak
14,246 ft
Dyer
Gemfield
Goldfield
Montezuma Range
Mount Barcroft
Toms Place
White Mountains
Inyo National Forest
Inyo National Forest
Bishop
Mount Humphreys
13,986 ft
168
395
Mount Goethe
Mount Darwin
Big Pine
Mount Powell
North Palisade
14,242 ft
Middle
Palisade

Bortle I

- 22 mag / (arc sec)^2 ?!?
- Unpack that!!
- 1 arc-second = 1/60 of an arc-minute
- 1 arc-minute = 1/60 of a degree
- 1 degree = 1/360 of a full circle
- ==> 1 arc-second is 1,296,000 of a circle
- Due to air turbulence it is common for stars to be spread out into 2-3 arcseconds (let's say 2.5 arcseconds to make it definite and easy)
- 2.5 arc-seconds wide by 2.5 arc-seconds high is 6.25 square arc-seconds of sky
- 22 mag / arc sec ==> 20th magnitude practical limit
- At our site, we should be able to push our gear to see 20th magnitude objects

Zenith sky brightness info (2015)

Coordinates	37.37100, -117.97700
SQM	22.00 mag./arc sec^2
Brightness	0.172 mcd/m^2
Artif. bright.	0.650 µcd/m^2
Ratio	0.0038
Bortle	class 1
Elevation	1681 meters

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Deep Springs Observatory and Its Equipment

- Gift of Deep Springs Class of '77
- Sited for:
  - Minimal visual impact
  - Minimal light pollution
- Designed to extend observing season to 10 months (or more if you are hardy)
- Two years of construction
- State-of-the-art *small* telescope (250mm =10")
- State-of-the-art mount, electronics, software


WERNER


LAKE TAH
MAN'S


RYOBI

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First Target

Deep Springs Observatory

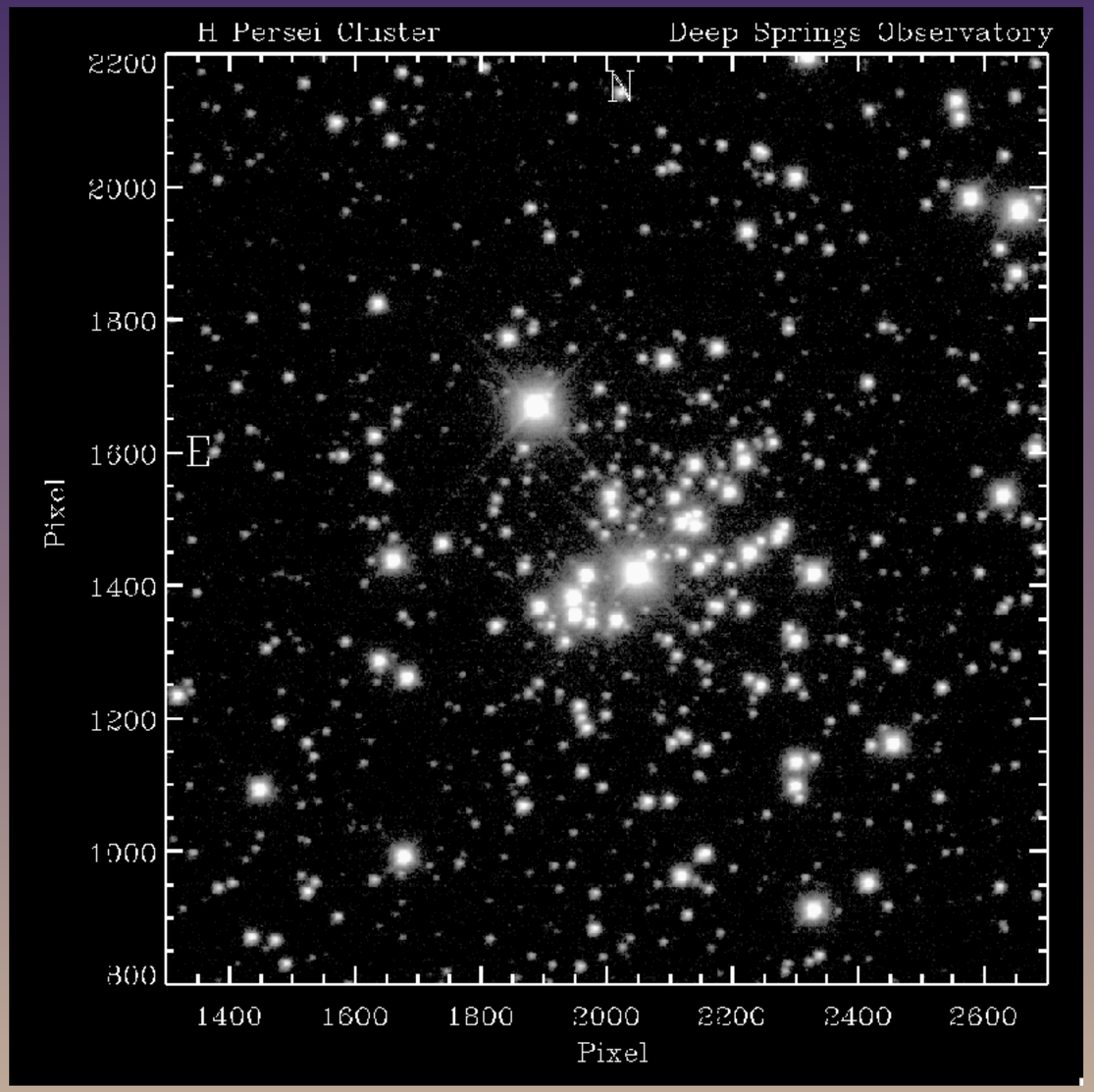
Oct. 18, 2022

CFF Telescopes — 10" Ritchey-Chrétein

H Persei cluster

CBB filter

30-second exposure



First Target

https://skyview.gsfc.nasa.gov/current/cgi/runquery.pl with query parameters DSS2 Red, Coordinates = 02 18 51.89, +57 08 59.2, Image Size (degrees) = 0.25

Palomar Observatory

DSS2 Survey

48" Oschin Schmidt Telescope

H Persei cluster

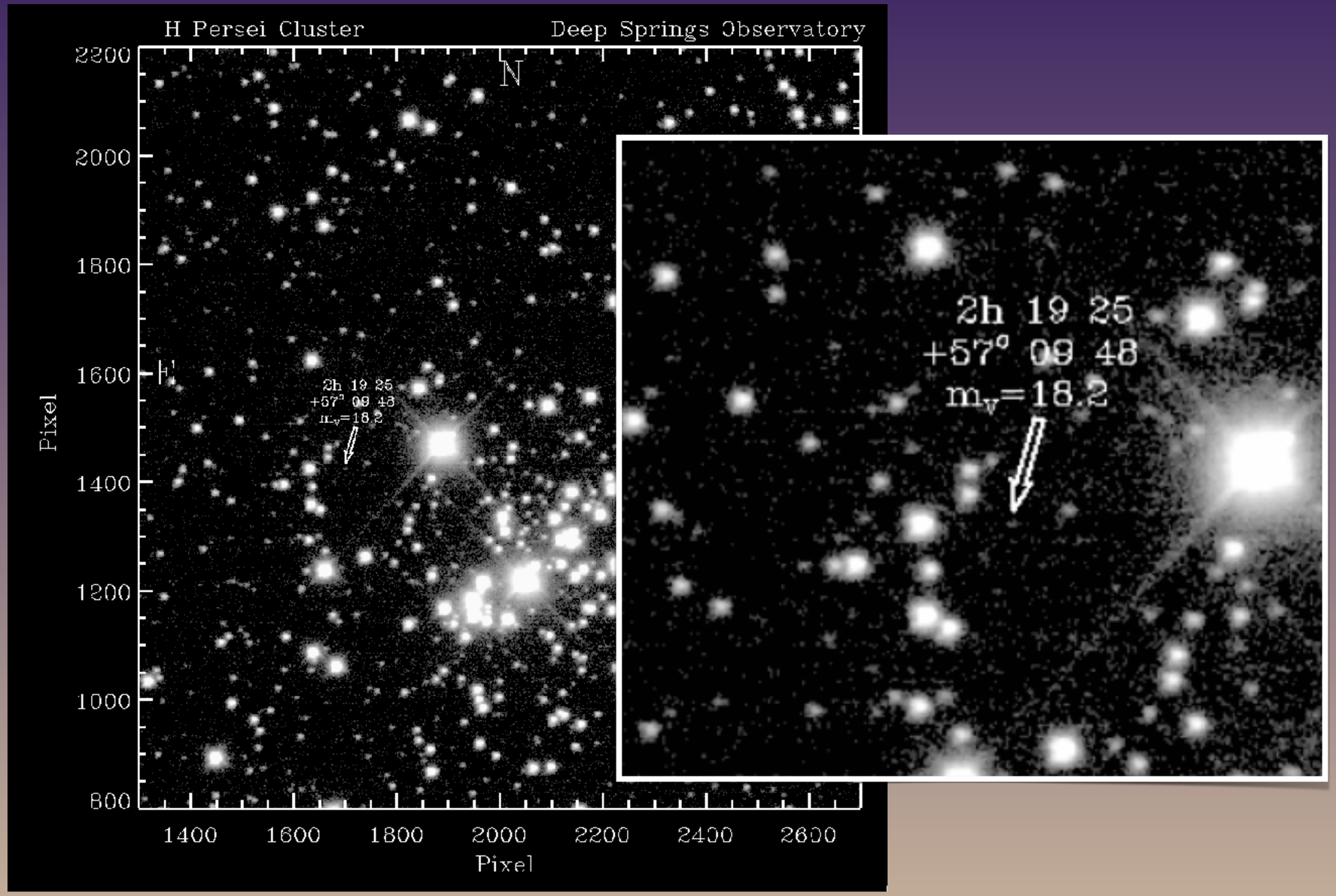
Red filter

40-minute exposure

Title: The second Palomar Sky Survey
Authors: Reid, I. N., Brewer, C., Brucato, R. J., McKinley, W. R., Maury, A., Mendenhall, D., ,
Journal: Astronomical Society of the Pacific, Publications (ISSN 0004-6280), vol. 103, July 1991, p. 661-674. Research supported by California Institute of Technology, NSF, National Geographic Society, et al.
Bibliographic Code: 1991PASP..103..661R

First Target

Magnitude 18 stars are present in our images with 3-σ confidence



Target Selection

https://www.physics.purdue.edu/brightsupernovae/

All active supernova over mag 17.0

Name	Mag	Type	Host
2022zut	13.5	Ia	NGC 3810
AT2022zfb	14.1	unk	none
ASASSN-22jp	14.2	Ia	NGC 4415
AT2022zxb	14.7	unk	none
2022xkq	15.0	Ia-91bg	NGC 1784
2022xxf	15.2	Ic-BL	NGC 3705
2022wsp	15.4	II	NGC 7448
AT2022aagp	15.8	unk	NGC 2777
2022yqv	15.9	Ia-91T	UGC 10984
AT2022znu	16.0	unk	none
2022yvv	16.0	Ia	anonymous
2022wwt	16.0	Ia	anonymous
AT2022zyr	16.1	EGN	M31
AT2022zjo	16.1	unk	NGC 2152
2022yvw	16.1	IIb	NGC 1359
2022ypd	16.1	Ia	MCG +0-52-30
2022rnt	16.1*	Ia	IC 4790
2022aaad	16.1	II	none
AT2022xyq	16.2*	unk	ESO 271-G26
AT2022xxs	16.2*	unk	none
AT2022wic	16.2*	unk	none
2022ypb	16.2	Ia-91T	LEDA 918265
AT2022zks	16.3	unk	none
AT2022ynz	16.3*	unk	none
ASASSN-22my	16.3	Ia	NGC 946
AT2022zue	16.4	unk	LEDA 1021768
AT2022ztk	16.4	unk	LEDA 924001
2022xzm	16.5	Ic-BL	CGCG 478-048

A long time ago, in a galaxy far far away, a star exploded. This star exploded so violently that for a few weeks the star outshone its parent galaxy. This type of explosion is called a Supernova. The last one in our galaxy was 400 years ago, making us about 300 years overdue for the next one. On this web page you will find a list of the currently observable supernovae, along with information on their location, reference images, and their last reported brightness. The data on this page comes from TNS and ATEL circulars. These web pages have brought you the latest in supernovae data and images since April 1997. 25 years and counting.

Web page last modified on 11/14/2022 13:59:41 . For yesterday's updates, go to the updates page.

- Created entries for 19 ZTF supernovae, 12 PS1 supernovae 2 PS1 supernovae, 11 Gaia supernovae, 2 ZTF supernovae
- Updated the entries for 2022wqo (Type IIn), 2022wqs (Type II), 2022wtm (Type II), 2022xae (Type IIb), 2022xzc (Type Ic-BL), 2022yoz (Type II), 2022yzg (Type Ia), 2022zmb (Type II), 2022yll (Type Ia), 2022yus (Type Ia), 2022zdn (Type Ia)
- Added images of 2022wpy, 2022wsp (Mag 15.4), 2022xkq (Mag 15.0), 2022zut (Mag 14.0), 2022zzz (Mag 17.9

News: Robert Evans, discoverer of several supernovae (visually) has died. 2022zut just popped up at Mag 14.6 in NGC 3810 . 2022xlp in NGC 3938 is rising rapidly. 2022pul is out of solar conjunction. I now have a program which finds the names of galaxies. You will notice that the magnitudes of the brighter objects (< 17.0) are now updated more often. We now have an image of 2021afdx taken by the JWST. For the year 2022, 16883 supernovae (1772 CBAT, 15111 unconfirmed, and 0 other sources) have been reported. (21098 last year). The brightest SN of the year 2022 are 2022hrs (Mag 12.3) followed by 2022ffv (Mag 13.3) and 2022fw (Mag 13.5)

TNS has moved to a new URL: https://www.wis-tns.org/. To post your discoveries, go to the TNS getting started page. The Open supernova Catalog has died, links will be removed eventually. Latest Supernovae is now supported by Purdue University and maintains a new mirror hosted in the Department of Physics and Astronomy that is overseen by Dan Milisavljevic. Purdue mirror page: http://www.physics.purdue.edu/brightsupernovae/.
New features: Modifed the sorted by name list to include removed objects and mark "non public" objects. All galactic objects (CV novae, etc) will be banished on a weekly basis to the boneyard. Thanks for all of the images, I have been posting them on flickr. Join the discussion! Facebook Supernova Enthusiasts Group. The Active supernovae page is a version of this page which is designed to be easier to read. I've done extensive work recently in the Archives. If anybody knows who some of the "unknown" discoverers are, please let me know. *Does anybody know of a grant that I could apply to for supporting this page?* I probably spend about 2 hours a night working on it. Please note my backup e-mail address: dbishopx at gmail.com . To turn off the icons, use this link. With the demise of of Yahoo Groups, I am moving isn_chat to Google groups. Please sign up if interested. LOSS ask people who discover supernovae to provide an offset from a nearby star to make spectroscopy easier.

Some groups are not reporting all of their discoveries to CBAT.

- ASAS-SN: Supernovae
- ATLAS (no published list)
- Catalina Real-Time Transient Survey:
  - MLS search page (Supernovae only, Possible supernovae)
  - Supernova hunt page
- Dark Energy Survey
- Gaia Photometric Science Alerts programme Alert index
- La Silla-QUEST (no published list)
- MASTER robotic Net List of optical transients, Supernovae
- OGLE-IV wide field survey Discovery images Rapid Transient Detection system
- Intermediate Palomar Transient Factory (no published list)
- PS1 Science Consortium Discoveries
- ROTSE collaboration: Discoveries page
- SkyMapper Supernovae search Zooniverse supernova sighting Results from Supernova Sighting
- SNAD Catalog
- Zwicky Transient Facility (ZTF) Alert archive ZTF Bright Transient Explorer

Other versions of this list, going back 18 months (see the archives)

- Active objects (Machine readable version of main page)
- Sorted by Location (R.A.)
- Sorted by Location (Decl)
- Sorted by Date
- Sorted by Magnitude
- Sorted by Red Shift
- Sorted by Host name
- Sorted by Name
- Statistics

Watch list (list of dimmer objects that may turn into something interesting)

- 2022vxf in UGC 11693 at Mag 17.6 Type Ia-91bg
- AT2022ydu in NGC 3383 at Mag 17.9 Type unk
- 2022ydv in IC 4885 at Mag 18.0 Type Ic-BL
- AT2022xhg in UGC 10216 at Mag 18.2 Type unk
- 2022zic in NGC 7620 at Mag 18.2 Type Ib
- AT2022zia in NGC 3859 at Mag 18.3 Type unk
- 2022ybd in UGC 10717 at Mag 18.4 Type Ia
- AT2022zhz in IC 2023 at Mag 18.5 Type unk
- 2022ydr in UGC 10949 at Mag 18.7 Type Ia-91bg
- AT2022yms in NGC 7038A at Mag 18.8 Type unk
- 2022vyc in UGC 3057 at Mag 18.9 Type IIP
- AT2022xuw in UGC 3104 at Mag 19.0 Type unk
- AT2022xkw in IC 632 at Mag 19.0 Type unk
- AT2022yyz in UGC 11404 at Mag 19.3 Type unk
- AT2022yma in MCG -1-9-6 at Mag 19.5 Type unk
- AT2022xod in UGC 4958 at Mag 19.7 Type unk
- AT2022zea in IC 260 at Mag 19.9 Type unk
- AT2022yvg in anonymous at Mag 19.9 Type unk
- 2022ywf in NGC 493 at Mag 20.0 Type Ia-02cx
- AT2022ymh in NGC 673 at Mag 20.5 Type unk

Other versions of this list, For the year 2022 (see the archives)

- Sorted by Location (R.A.)
- Sorted by Location (Decl)
- Sorted by Date
- Sorted by Magnitude
- Sorted by Red Shift
- Sorted by Host name
- Sorted by Name
- Statistics

Spectra targets (updated 11/5)

- AT2022mtr in ESO 44-G22 at Mag 19.3* (zhost=0.010193)
- AT2022qwl in NGC 3250 at Mag 18.3* (zhost=0.009420)
- AT2022qqo in NGC 3078 at Mag 18.5* (zhost=0.008606)
- AT2022zjo in NGC 2152 at Mag 16.5 (zhost=0.028430)
- AT2022ylu in ESO 351-G28 at Mag 17.5 (zhost=0.011628)
- AT2022zij in ESO 89-G19 at Mag 17.8*
- AT2022wvj in IC 62 at Mag 17.8* (zhost=0.038643)
- AT2022ydu in NGC 3383 at Mag 17.9 (zhost=0.012172)
- AT2022zcj in NGC 2650 at Mag 18.2 (zhost=0.012762)
- AT2022zlz in LEDA 90023 at Mag 18.3 (zhost=0.014417)
- AT2022zia in NGC 3859 at Mag 18.3 (zhost=0.018240)
- AT2022xav in NGC 2944 at Mag 18.7 (zhost=0.022749)
- AT2022znt in ESO 314-G4 at Mag 18.5 (zhost=0.005159)
- AT2022zhz in IC 2023 at Mag 18.5 (zhost=0.032676)

Other versions of this list, For the year 2021 (see the archives)

- Sorted by Location (R.A.)
- Sorted by Location (Decl)
- Sorted by Date
- Sorted by Magnitude
- Sorted by Red Shift
- Sorted by Host name
- Sorted by Name
- Statistics

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In [98]:
```
import os
import numpy as np
from astropy import units as u
from astropy.nddata import CCDData
from astropy.io import fits
from ccdproc import ImageFileCollection, Combiner, combine, subtract_dark, flat_correct
from astropy.visualization import imshow_norm, PercentileInterval, MinMaxInterval, SqrtStretch, LogStretch
import matplotlib.pyplot as plt
%matplotlib inline
import astroalign as aa
from photutils.detection import DAOStarFinder
from astropy.stats import mad_std
from photutils.aperture import RectangularAperture, RectangularAnnulus
from photutils.aperture import ApertureStats, aperture_photometry
```

In [2]:
```
# for an analyses of an observation run done with only a single filter,
# only the observation_date and the exposure times
# will need to be changed

observation_date = '2022-10-2425'
light_exposure = 30 * u.second
dark_exposure = light_exposure  # our method presumes this equality
flat_exposure = 1 * u.second
bias_exposure = flat_exposure  # our method presumes this equality
```

In [3]:
```
# directory where the data being analyzed is kept

data_directory = os.path.join(os.path.expanduser('~'), 'Transients', observation_date)
```

In [4]:
```
# subdirectories -- all relative to data_directory

light_directory = os.path.join(data_directory, 'light')
dark_directory = os.path.join(data_directory, 'dark')
flat_directory = os.path.join(data_directory, 'flat')
bias_directory = os.path.join(data_directory, 'bias')

# the aligned directory is *written to* not read from

aligned_directory = os.path.join(data_directory, 'aligned')
if not os.path.exists(aligned_directory):
    os.makedirs(aligned_directory)
```

In [5]:
```
light_files = ImageFileCollection(light_directory).files_filtered(include_path='True')
dark_files = ImageFileCollection(dark_directory).files_filtered(include_path='True')
flat_files = ImageFileCollection(flat_directory).files_filtered(include_path='True')
bias_files = ImageFileCollection(bias_directory).files_filtered(include_path='True')
```

In [6]:
```
lights = [CCDData.read(file, unit=u.adu) for file in light_files]
darks = [CCDData.read(file, unit=u.adu) for file in dark_files]
flats = [CCDData.read(file, unit=u.adu) for file in flat_files]
biases = [CCDData.read(file, unit=u.adu) for file in bias_files]
```

In [10]:
```
light = lights[0]
```

In [11]:
```
calibrated_light = lights_calibrated[0]
```

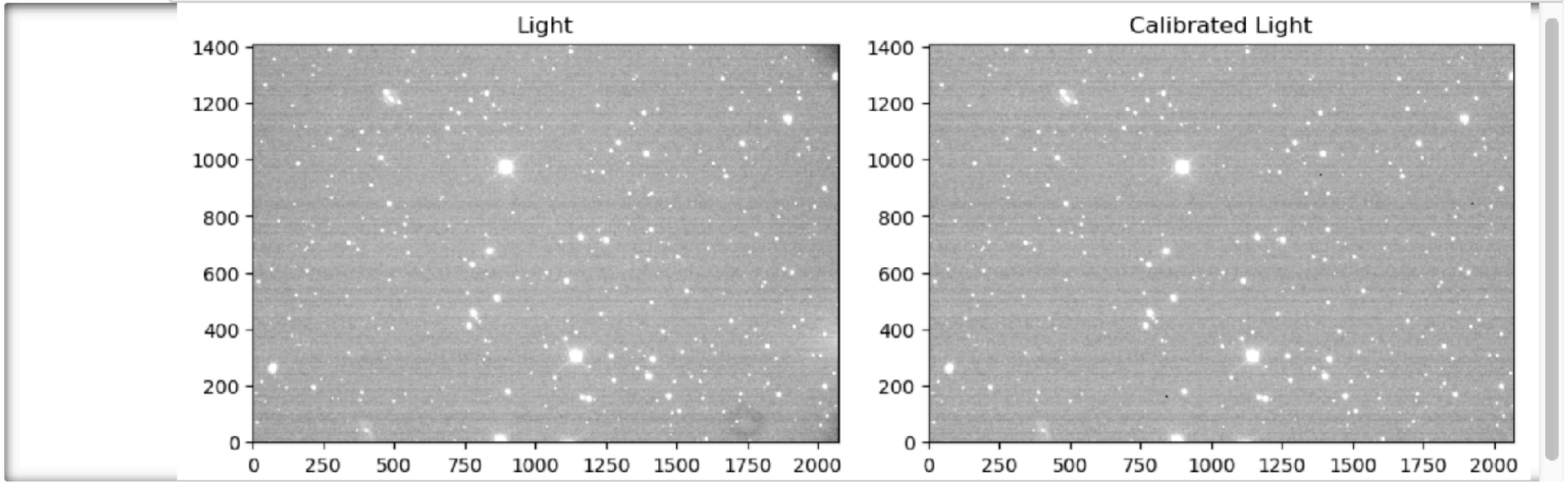
In [12]:
```
interval_95 = PercentileInterval(95)
sqrt_stretch = SqrtStretch()
log_stretch = LogStretch()

fig, axes = plt.subplots(1, 2, figsize=(10, 10))

im_l, norm_l = imshow_norm(light, axes[0], cmap='gray', origin='lower',
                           interval=interval_95, stretch=sqrt_stretch)
axes[0].set_title("Light")

im_c_l, norm_c_l = imshow_norm(calibrated_light, axes[1], cmap='gray', origin='lower',
                           interval=interval_95, stretch=sqrt_stretch)
axes[1].set_title("Calibrated Light")

plt.tight_layout()
plt.show()
```



Our calibrated images appear to have both vignetting and the shadows of dust motes well-removed.

First Supernova Target

Deep Springs Observatory

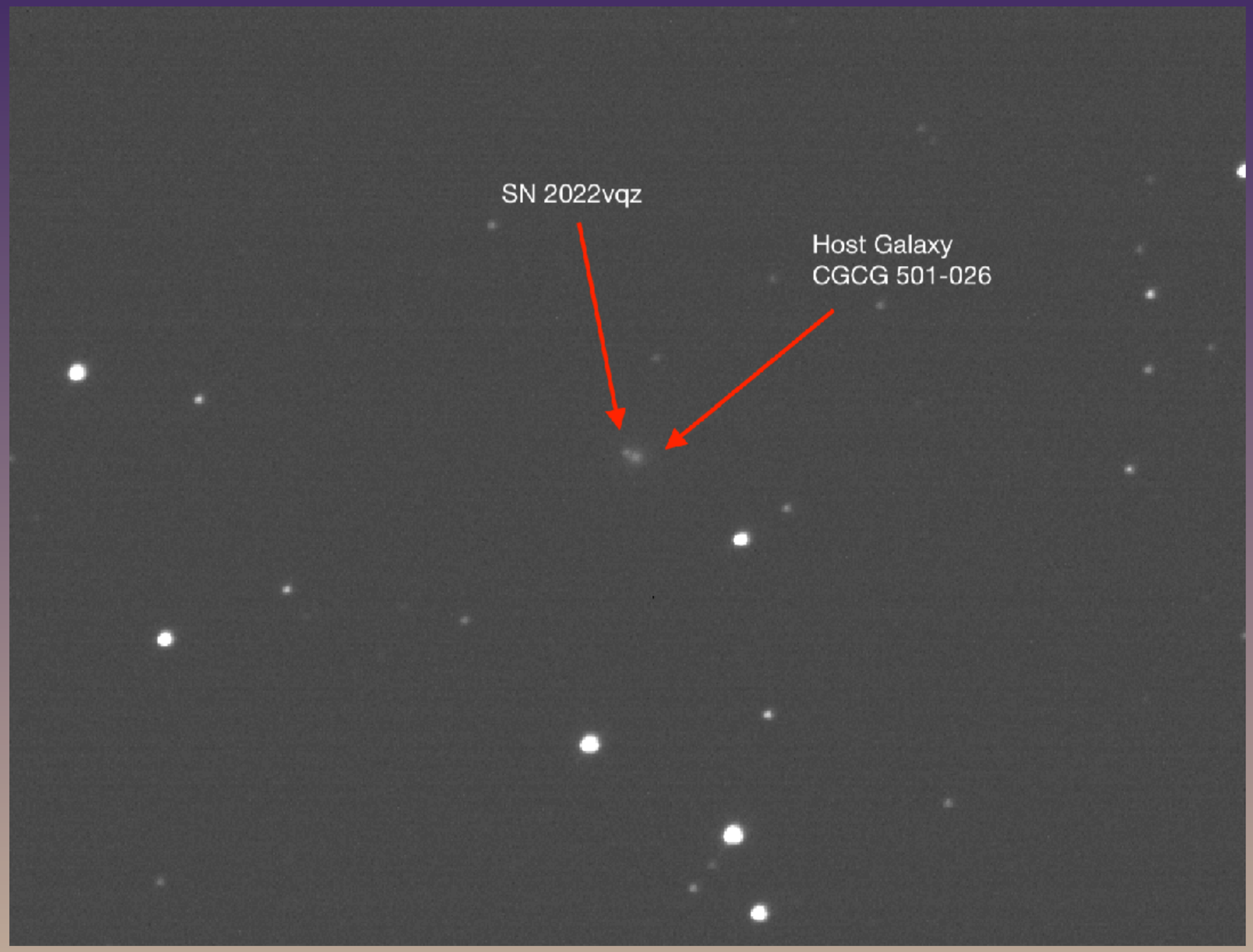
Oct. 24, 2022

10" CFF Telescopes Ritchey-Chretein

SN 2022vqz

CBB filter

30-second exposure



This has been

Transient Astronomy at Deep Springs
Part I - The Plan

Please share my gratitude to:

- The work parties that hauled and poured the concrete
- All the volunteers that framed walls
- installed windows and hung the door,
- put in insulation and put on corrugation
- worked in the wood shop and welding area to create the custom shelves and desk
- the Deep Springs class of '77
- my collaborators, Geoff Marcy, Sofia Mikulasek, and Luke Suess
- and anyone who has or wants to keep us company while we look for tiny dots on a laptop screen

Stay tuned for:

Transient Astronomy at Deep Springs Part II - Results

I hope to be standing here with Sofia and Luke with our first supernova light curves in Spring of 2023.