Assassinating ASASSN:
Supernovae Identification Using ATLAS Data

Corey Mutnik[1, *]

[1] *Department of Physics & Astronomy,*
University of Hawaii at Manoa,
2505 Correa Rd, Honolulu, HI, 96822, USA[†]

Using current data collection and reduction techniques, we plan to identify supernovae (SNe) faster and fainter than the All-Sky Automated Survey for Supernovae (ASASSN) team is able to. We expect to identify all SNe, with $m > 17.5$ and declinations above $-30°$, before ASASSN is able to.
m>17.5 –OR– $m > 17.5$
17.5 (0.5mag) –OR– 18 (1mag) fainter...which is it?
not emphasis on Type Ia supernovae?

1. INTRODUCTION

Supernova (SN)
check plurality throughout paper: SN or SNe
Supernovae (SNe) identification using data collected by ATLAS.

good ref paper `http://iopscience.iop.org/article/10.1088/0004-637X/745/1/42/pdf`
fix biblio style / numbering
Look at previous JT paper to see if:
numbers inside mathmode: -30°, $-30°$
abbreviations in abstract: ... (ASASSN), or is just ASASSN good
figure with smaller cbar? rotated xtick labels?
histogram w/o vertical bar at dec=-30°
remake histogram with peak date not discovery mjd
Check figure width look okay: [width eq 3.35in] –OR– [width eq 1 linewidth]

change out figure of histo with line at dec=-30
add other figures (starrat and the like)

Fix citations: ASASSN data[1] or use diff cite method
Shappee et al.[1]
Shappee et al.[1]
...Should be "Shappee et al. (2014)"

2. COLLECTED DATA

2.1. ASASSN Data

- **ASASSN or ASAS–SN**

The All-Sky Automated Survey for Supernovae (ASASSN) group collects data using eight 14 *cm* telescopes. Each night, these telescopes are able to cover roughly $20,000\ deg^2$, reaching down to ∼17th magnitude. These eight telescopes are split evenly between two sites. The first telescope array is located on Haleakala and began collecting data in December 2013. In July 2015, the second array became operational at the LCOGT Cerro Tololo station. This allows ASASSN to detect SNe in both hemispheres. **Cite using footnote.–OR–**[1]

Using 400mm f/2.8G Nikon lenses allows for a large field of view. ProLine PL230 CCD cameras are used as detectors. Detection of transients is made possible using image subtraction. With images having 7.8″pixels, ASASSN relies on volunteers collecting confirmation images with larger telescopes. **Cite using footnote.**

2.2. ATLAS

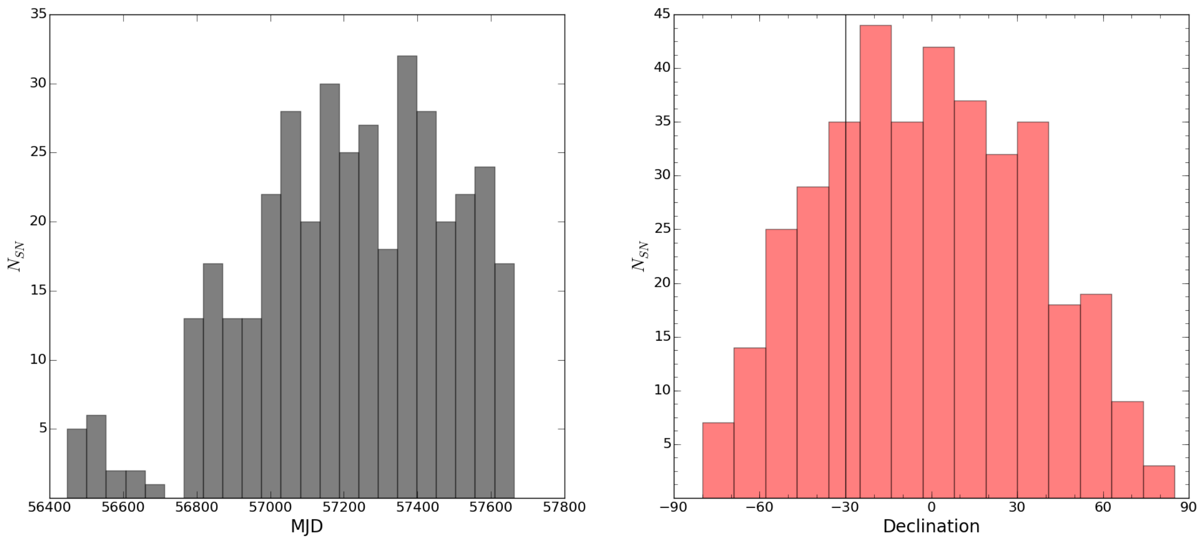
ATLAS PathFinder 2 Observations

- ATLAS specs
- how data was collected
- how *.diff.fz is made - subtract wallpaper from reduced data
- how *.ddt is made
- what is starrat
- [2]

ATLAS began collecting data in June 2015. Reduction methods are always being refined and improved. Data reduced before December 2015 is not trusted, when ATLAS became truly operational. **REWORD**

3. PROCEDURE

want to make input sections subsections under this section? quantify: how many objects



(a)

(b)

Figure 1: *SN discovered by the ASASSN project. Panel '(a)' shows ASASSN SN discovery dates. Panel '(b)' is ASASSN data, binned by dec. The vertical line at -30° indicates the lower limit on ATLAS observations.*

are potentially SNe before class.var. restriction, how many after
$0.9 < starrat < 1.2$
possibly include starrat figure
use DS9 image?
remake it
identify exact dates shown by tiles

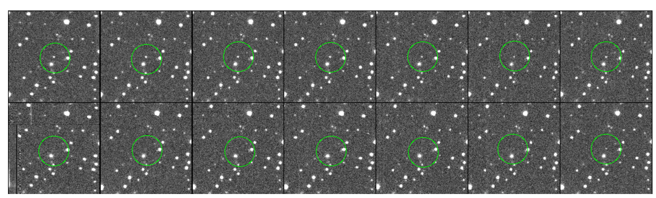


Figure 2: *Each tile shows a different ATLAS observation of the SN "ASASSN-16ke". The SN is enclosed by a green circle, to show its exact location.*

In order to assassinate ASASSN, it was necessary to show that ATLAS had the potential to find all of ASASSN discovered SNe. To do this, a list of all ASASSN discovered SNe was obtained[1]. [–**OR**–**cite website using footnote**] By October 11, 2016 ASASSN has reported discovering 385 SNe. Many of these objects were reported before ATLAS was operation. Object cuts are discussed in § 4. Once the data was properly culled, the remaining SNe were found in observations made by ATLAS. One such SN is shown in Figure 2. Finding these SNe in the ATLAS data allowed restrictions to be placed on classification variables, drastically reducing the number of potential SNe candidates. With such a restricted object list, visually examination is able to be used in identifying SNe.

comment on lower panel showing ATLAS obs before SN appeared in fig 2?

4. EXPECTED OBSERVATIONS

Rename section
Necessary to define MJD?

With a declination (dec) limit of approximately -30°, 100 SN were not expected to be present in the ATLAS data. ASASSN reported the discovery of another 165 SN before ATLAS began collecting data. These two sets do not exist independent of one another. After applying dec and MJD based restrictions and accounting for overlaps between these groups, 161 SN remained from the initial 385 reported by ASASSN. Another 65 SN peaked before ATLAS was truly operational, leaving 96 as potential candidates. All 96 of these objects were found in the ATLAS data, resulting in a 100% completion rate. **CHECK VALIDITY OF THIS**

The 65 SN that peaked before ATLAS was truly operational can be further broken down as follows. Reported peak brightnesses occurring on or before 57364 accounts for 14 SN. During this time the ATLAS reduction process was still being refined, making any reduced data unreliable. Another 50 SN fell in regions that had no overlap with ATLAS observations due to the pattern in which data was collected. The final case was a Type II supernova (SNII). SNII are notoriously short lived; making it likely that ATLAS observed this region of the sky in the time surrounding the explosion, but not during the event.

5. FAILED MATCHES

Remove subsection headings?

We expect to see 96 of the ASASSN SN in ATLAS observations. This presents us with 850 overlap opportunities, using a ± 10 *day* window. Of these, 694 observations were recorded and properly reduced. **Why these matches failed can be broken up into four categories – no match, no difference image, no ddt file, or no match within an existing ddt file. These cases are discussed in sections 5.1–5.4.**
§ 5.1–§ 5.4
Why these matches failed can be broken up into four categories, each of which is discussed in the subsections below.

5.1. No match

A total of 25 expected observations lack any matches with ATLAS data. These failed matches do not fall within the ± 10 *day* window used.

5.2. No diff file

Missing difference images account for 49 of the expected 850 observations. Matches that were missing difference images can be attributed to an error in the ATLAS pipeline. An error during differencing caused a break in the pipeline and no further images to be generated for that night. Such an error will be corrected once the data is re–reduced.

5.3. No ddt file

For matches that were completely missing a ddt file, ddt files were missing for the entire night. This accounts for 15 failed matches and will be corrected by the next round of differencing.

5.4. No ddt Match

Of the total 850 expected matches, 67 do not show up in existing ddt files.

Nature constantly plays a role in collecting astronomical data. When observations are made at the beginning or end of a night, ambient light levels rise and sky background fluctuations. 3 of the 67 missing ddt lines can be attributed to poor observation conditions, brought on by clouds and increased levels of sky background.

Errors during the image differencing process led to the loss of 8 expected overlaps. Older differencing techniques caused entire portions of images to be lost, accounting for 3 failed matches.

There were 6 cases where bright host galaxies caused the SN to become extremely faint in the difference image. Outdated differencing procedures lead to less uniform backgrounds, making it harder to identify faint objects. **reword?** While preforming photometric calculations, the ATLAS pipeline failed to trigger on these 6 faint objects.

There are various reason why the PSF across an image may vary. Here, the major contributers are high levels of sky background and optical issues inherent to the ATLAS system. If not properly corrected for, such issues cause observed objects to become distorted. Distortion can cause sharp edges to become fuzzy, resulting in the ATLAS pipeline failing to trigger on such objects. This accounts for 3 of the missing matches. Objects that were only in reduced images, but not in differenced images account for 26 of the matches missing from the ddt files. Such instances arise when the object is fully subtracted during differencing, due to it existing in the wallpaper. As the wallpaper is an ongoing project, corrected future versions will not cause this issue. **[WORDING]**

There were 17 cases in which the SN was not detecting in either the reduced or differenced image, indicating poor astrometry. Another possible explanation is bad photometry. If photometry is the issue, the SN explosions must have occurred outside the nominal ± 10 *day* window.

The final group of matches missing from the ddt files comes from an issue with the array dimensionality. Each image is saved as a matrix. The software that determines the correspondence between pixel coordinates and each objects RA, dec assumes the captured image fully extended to the edges of the matrix. In practice, the edges of some collected data are not completely filled. **When these unfilled**

frames overlap with consecutive images, the objects lie where they are expected. Not every image fully extends to the intended edges. For this isolated case, the image data ends above the bottom edge of the array. Although the object is expected to be there, it does not exist on this particular image.

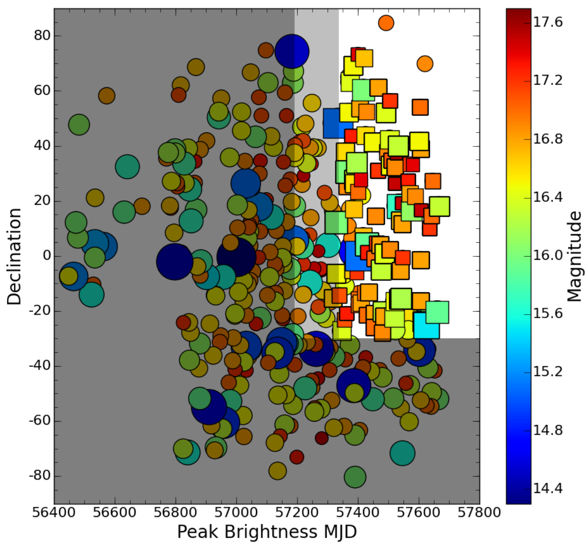


Figure 3: *ASASSN SN that do not have matches in ATLAS data are represented by circles. Squares show SN that were found in ATLAS observations. Regions that have a lower chance of containing SN have been covered in gray. Dark gray regions eliminate objects below the ATLAS observation limit of* $-30°$ *and those discovered before ATLAS was operational. The light gray region extends from ATLAS first night of collecting data up until 57364, when the reduction method was refined enough to produce usable data. Like the color, point-size represents magnitude.*

6. RESULTS AND DISCUSSION

It has been shown that all ASASSN discovered SNe overlapping ATLAS observations in sky and time are detectable in ATLAS data. Restricting classification variables drastically reduces the false alarm rate, requiring visually inspection of fewer objects. This shows the ability for ATLAS to identify all SNe faster and fainter than ASASSN is able to.

As seen in Figure 3, SNe that were not observed ATLAS fall on the edges of observation limits.
Summary of data matched between ASASSN and ATLAS.
reference sections that explain particular cases that matching failed How ASASSN SN help identify those in ATLAS data.

1. what restrictions we intend to place on classification variables like starrat
2. possibly describe what starrat is, how it will help id SN
3. such restrictions cut the number of objects down from xx to ∼1000/2000

ACKNOWLEDGMENTS

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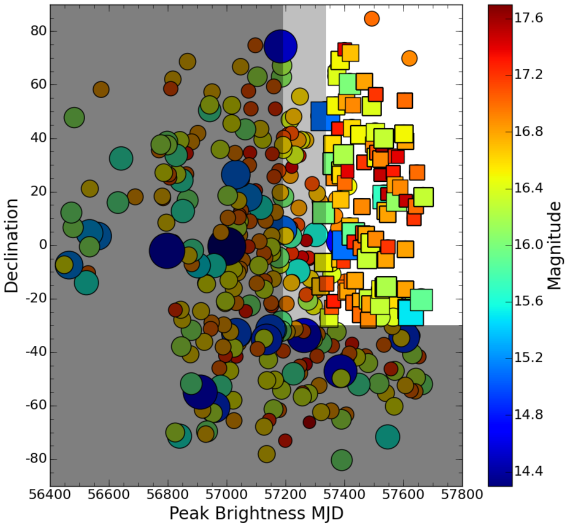
* cmutnik@hawaii.edu

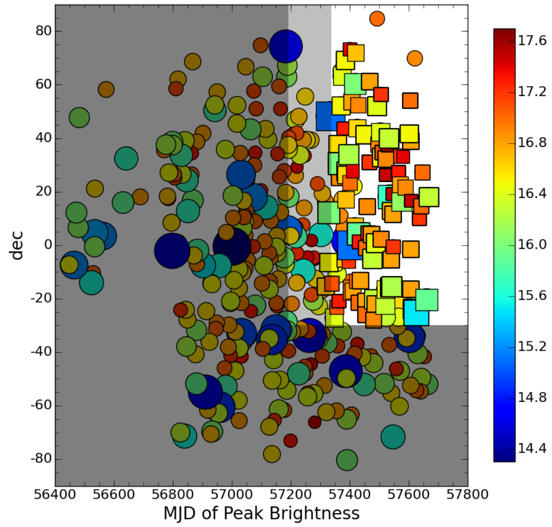
† ASTR 399

[1] B. J. Shappee, J. L. Prieto, D. Grupe, C. S. Kochanek, K. Z. Stanek, G. De Rosa, S. Mathur, Y. Zu, B. M. Peterson, R. W. Pogge, et al., Astrophys. J. **788**, 48 (2014), 1310.2241.

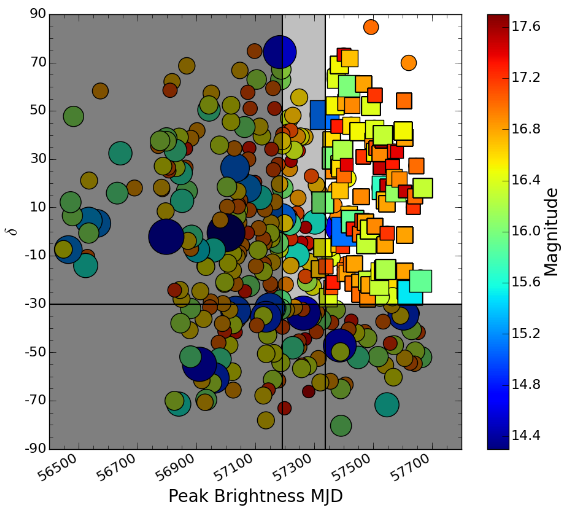
[2] J. L. Tonry, PASP **123**, 58 (2011), 1011.1028.



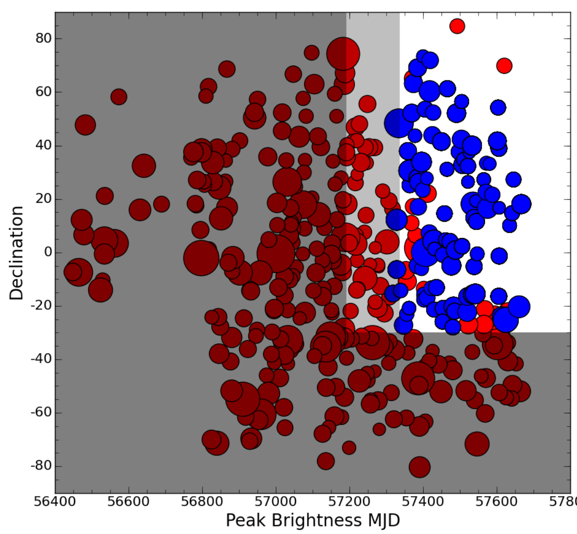
(a)



(b) **Same as (a) with cbar=0.9**

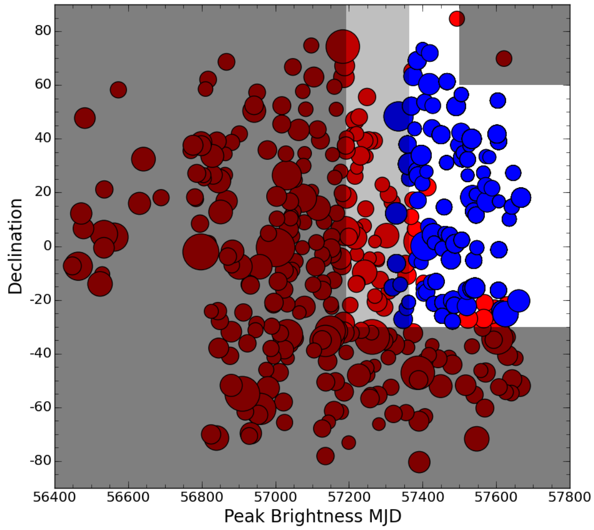


(c) **cbar the same size as (a) but xtick labels are formatted differently. Differentiation between Grey regions has been made easier.**

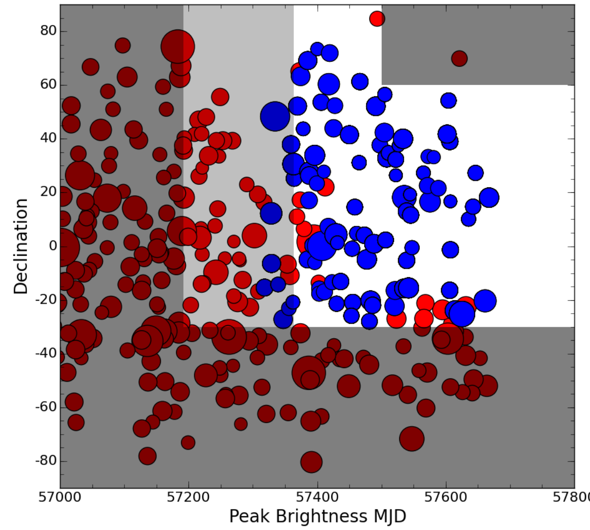


(d) **Here color is used to distinguish between SN that matched and those that didn't. Magnitude is still represented by point–size, with lower values having larger areas.**

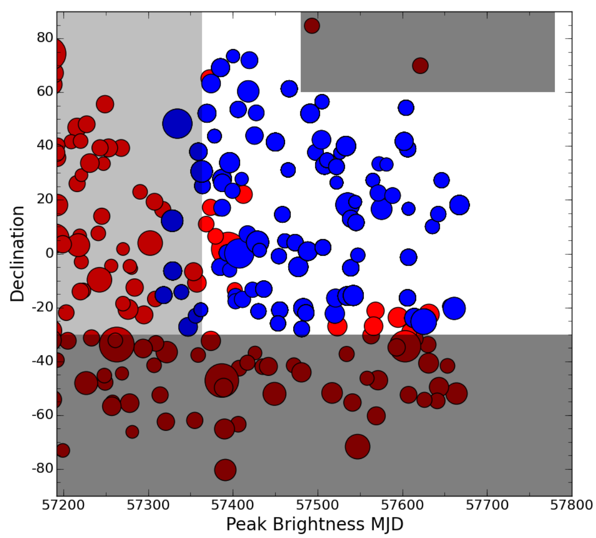
Figure 4: **Panels (a), (b), (c), and (d) are all variations of the same plot. Slight variations in way labels; doesn't change content.**



(a) **Here, a gray region starting at 57500, has been added for when ATLAS went from 4 to 5 observations a night, giving and effective limit at dec=+60°.**



(b) **Here, the figure is restricted, to better show where ATLAS was truly operational.**



(c) **Here, the figure is restricted further, to better show where ATLAS was truly operational. 57480 was used as the time when ATLAS went form 4 to 5 obs, lowering dec limit.**

Figure 5: **Panels (a), (b), and (c) are all variations of the same plot shown in Figure 4. Slight variations in way labels; doesn't change content.**