The Survey Strategies of WFST for Type Ia Supernovae

M. Hu, L. Hu, J. Jiang, L. Xiao, L. Fan, J. Wei, X. Wu
Purple Mountain Observatory, Chinese Academy of Sciences, Nanjing 210023, China
kaihukaihu123@pmo.ac.cn

中国科学院紫金山天文台
PURPLE MOUNTAIN OBSERVATORY, CAS

1. Introduction

Type Ia supernovae (SNe Ia) are of great importance both as an established cosmological probe and as the end point of a carbon-oxygen (CO) white dwarf (WD). However, it is still unclear how WDs increase their mass near the Chandrasekhar limit and how the thermonuclear explosion occurs. Optimizing survey strategies to discover SNe Ia is crucial to these opening questions. 2.5-meter Wide-Field Survey Telescope (WFST) is an upcoming time-domain facility in western China. We construct a framework to simulate the process of WFST discovering SNe Ia. Our simulation shows that WFST can find more than 10^5 SNe Ia during the phase earlier than their peak brightness with one-year running. In particular, the high-cadence deep survey can discover more than 200 infant SNe Ia per year, much more than the discovered infant SNe Ia so far. In the future, the survey with WFST will incredibly enlarge the research on SNe Ia.

2. Methods

Our simulations include three aspects of modules. The first one is generating spectral templates based on the explosion rate and the parameter distribution of SNe Ia. The second one is calculating the 'real' magnitude from the earth by considering the redshift effect, the extinction of the host galaxy and the Milk Way. The last one is acquiring the 'observed' magnitude from WFST through introducing the effects of air extinction, point spread function, zero-point calibration and background noise.

We considered five types of survey strategies, naming as baseline, wide, high-cadence, deep, and high-cadence deep surveys with the abbreviations of 'BaSur', 'WiSur', 'HiSur', 'DeSur', and 'HeSur', respectively. A summary of these five survey strategies is shown in Table 1. WFST will continuously monitor the pre-set sky area with two optical filters of r and x bands, where x could be u, g, i, or z band depending on the moon phase.

Strategy	Filter	Cadence	Pointing	Exp
BaSur	$r+x$	1 day	$1r$+$1x$	30s
WiSur	$r+x$	3 days	$1r$+$1x$	30s
HiSur	$r+x$	1 day	$2r$+$1x$	30s
DeSur	$r+x$	1 day	$1r$+$1x$	60s
HeSur	$r+x$	1 day	$2r$+$1x$	60s

5. Conclusions

We construct a framework to simulate the process of WFST discovering SNe Ia. This framework includes simulations of spectroscopic normal SNe Ia, dust extinction along the line of sight, and observing conditions of WFST site. We then investigate the ability to discover SNe Ia with five survey strategies: baseline, wide, high-cadence, deep, and high-cadence deep surveys. Our simulations show that WFST can discover more SNe Ia candidates than the ones submitted to TNS in the year 2021, and the high-cadence deep survey is preferred because it is the most efficient one to capture infant SNe Ia. These accumulated infant SNe Ia will be crucial in revealing their progenitor systems and explosion mechanisms.

6. References

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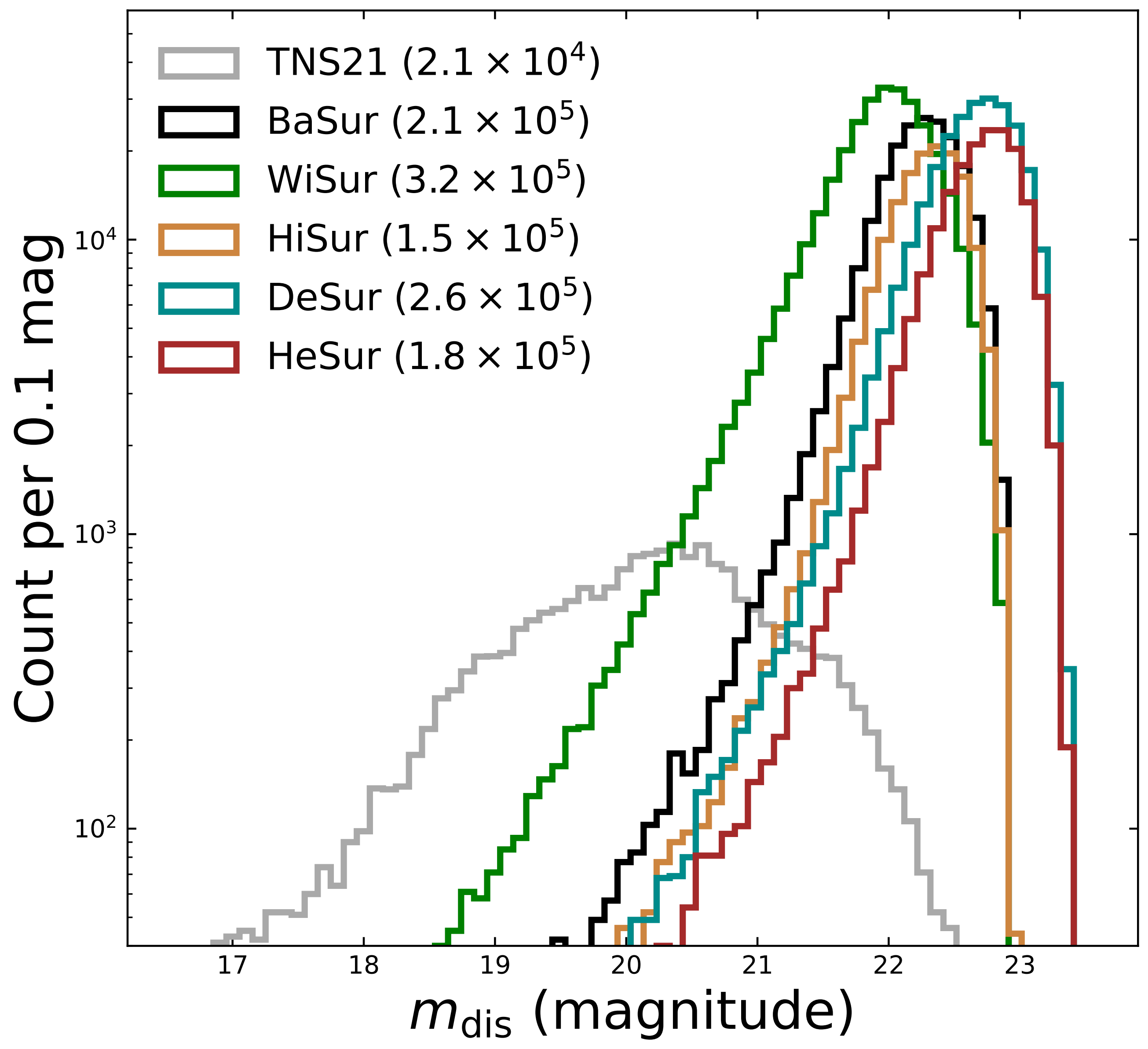
3. Discovering SNe Ia Earlier than the Peak Brightness



The rising time of SNe Ia is usually less than 20 days, making discovering SNe Ia earlier than the peak light difficult. Transient Name Server (TNS) is a network platform to publish discovered transients by the running survey programs. We statistic all the 'possible supernovae' submitted to TNS in the year 2021, which provides an upper limit of the number of discovered supernovae by all the survey programs. As comparison, Figure 1 displays the m_{dis} distributions of the discovered SNe Ia with the five survey strategies by WFST. The total number of the discovered SNe Ia candidates within any survey strategy is higher than the total number of the 'possible supernovae' submitted to TNS in the year 2021. Particularly, WFST can discover much more SNe Ia candidates with larger m_{dis}, indicating WFST can discover relatively distant SNe Ia and early-phase ones.

4. Discovering Infant SNe Ia

In the right figure, the upper panel displays the distribution of discovery magnitude (m_{dis}) versus redshift z for the discovered infant SNe Ia with high-cadence deep survey. The infant SNe Ia is defined as the discovery time (t_{dis}) less than 2 days since the explosion. The gray symbols are SNe Ia discovered by ZTF with early-phase observations in the year 2018, and the cyan symbols are SNe Ia with early-phase observations from other literature. The solid red line in the lower panel is the corresponding accumulated count of the discovered infant SNe Ia with high-cadence deep survey. As comparison, the black, yellow, and cyan lines are the count relating to baseline, high-cadence, and deep surveys, respectively. It is clearly shown that high-cadence deep survey is the best one for catching the infant SNe Ia, which are scarce and valuable. Multi-band observations within a few days after the explosion provide a powerful probe to investigate the physical origins of SNe Ia.