Characterizing the Population of SNIa with RCF

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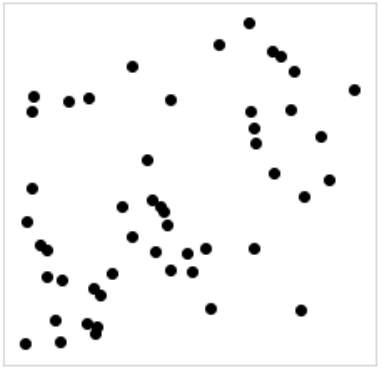
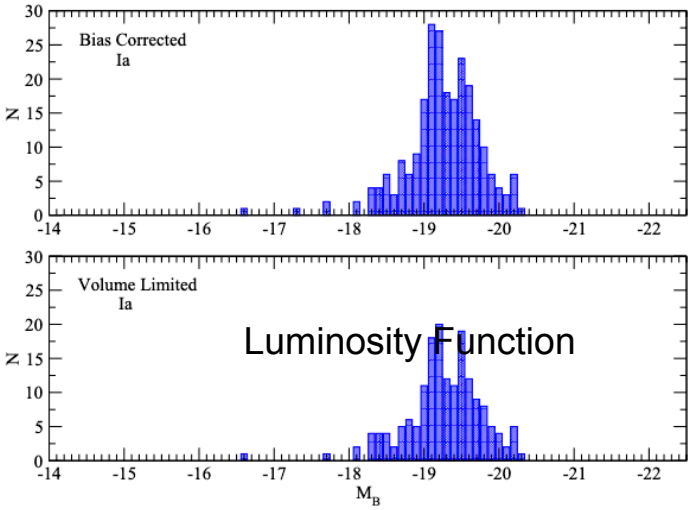
ZTF should characterize Stochastic Populations of Transients



Rate : comoving number density per rest frame time

	RCF	mag < 18.5
SNIa	1352	875
Classified	1865	1206

Perley et al., 2020



Richardson et al., 2014

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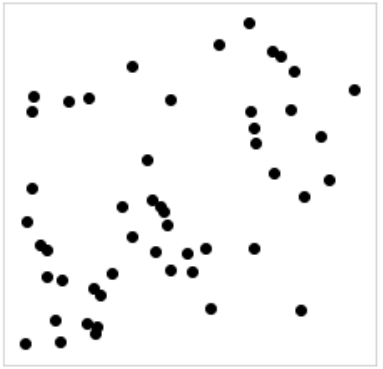

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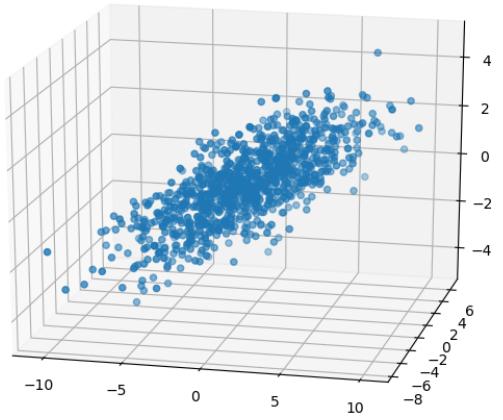


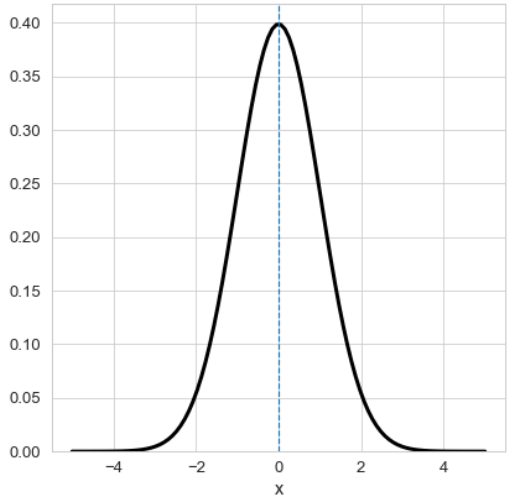
Complete Set of Properties

Populations for Transients

- Rate : r_v
- Properties : $\{\phi_i\}$:
- Distribution Function : $P_u(\{\phi_i\};\Psi)$
- Characterizing the population implies finding both r_v and Ψ

Concrete Hypothetical Example

- Rate : r_v



- Properties : $\{\phi_i\}$: x

- Distribution Function : $P_u(\{\phi_i\};\Psi)$: Normal Distribution

$$\Psi = \{\mu, \sigma^2\}$$

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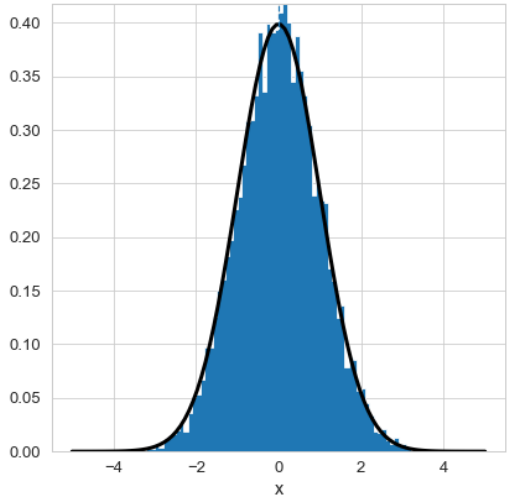

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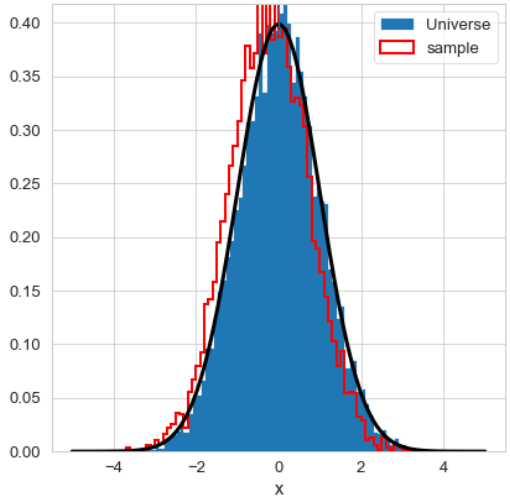


- Properties : $\{\phi_i\}$: x

- Distribution Function : $P_u(\{\phi_i\};\Psi)$: Normal Distribution

$$\Psi = \{\mu, \sigma^2\}$$

- Characterizing the population implies finding both r_v and Ψ : $P(\Psi, r_v|\text{sample})$

Rate Calculation : Fixed Ψ

- log-likelihood in terms of expected number & detected numbers

$$\mathcal{L} = -\bar{N}(\Psi, r_v) + N_{\rm sample} \log(r_v) + ...$$

neglecting uncertainties in transient properties

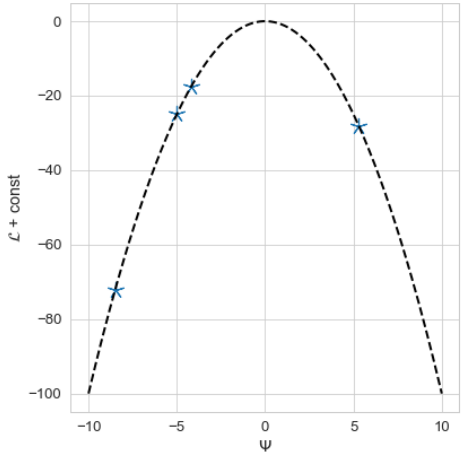
- $\bar{N}(\Psi, r_v)$: expected number accounting for survey efficiency, linear in r_v
- Differentiation shows expected answers for estimate and uncertainty
- Evaluated using several realizations needed to suppress Poisson noise in simulations which are systematic errors in $\bar{N}(\Psi, r_V)$

Very important to evaluate the selection used in ZTF, through observation and sample selection : RCF/ BTS like program crucial!

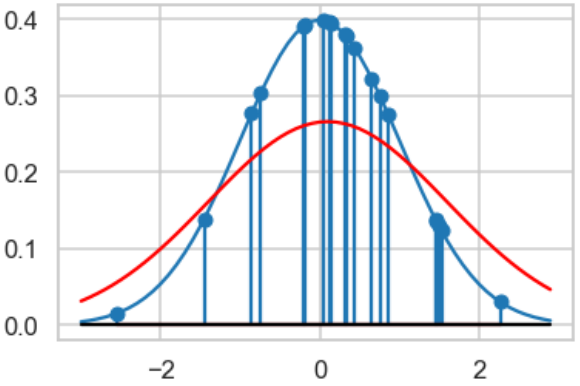
Rate & Properties Simultaneously

$$\mathcal{L} = -\bar{N}(\Psi, r_v) + N_{\text{sample}} \log(r_v) + P_u(\{\phi_i\}|\Psi)$$

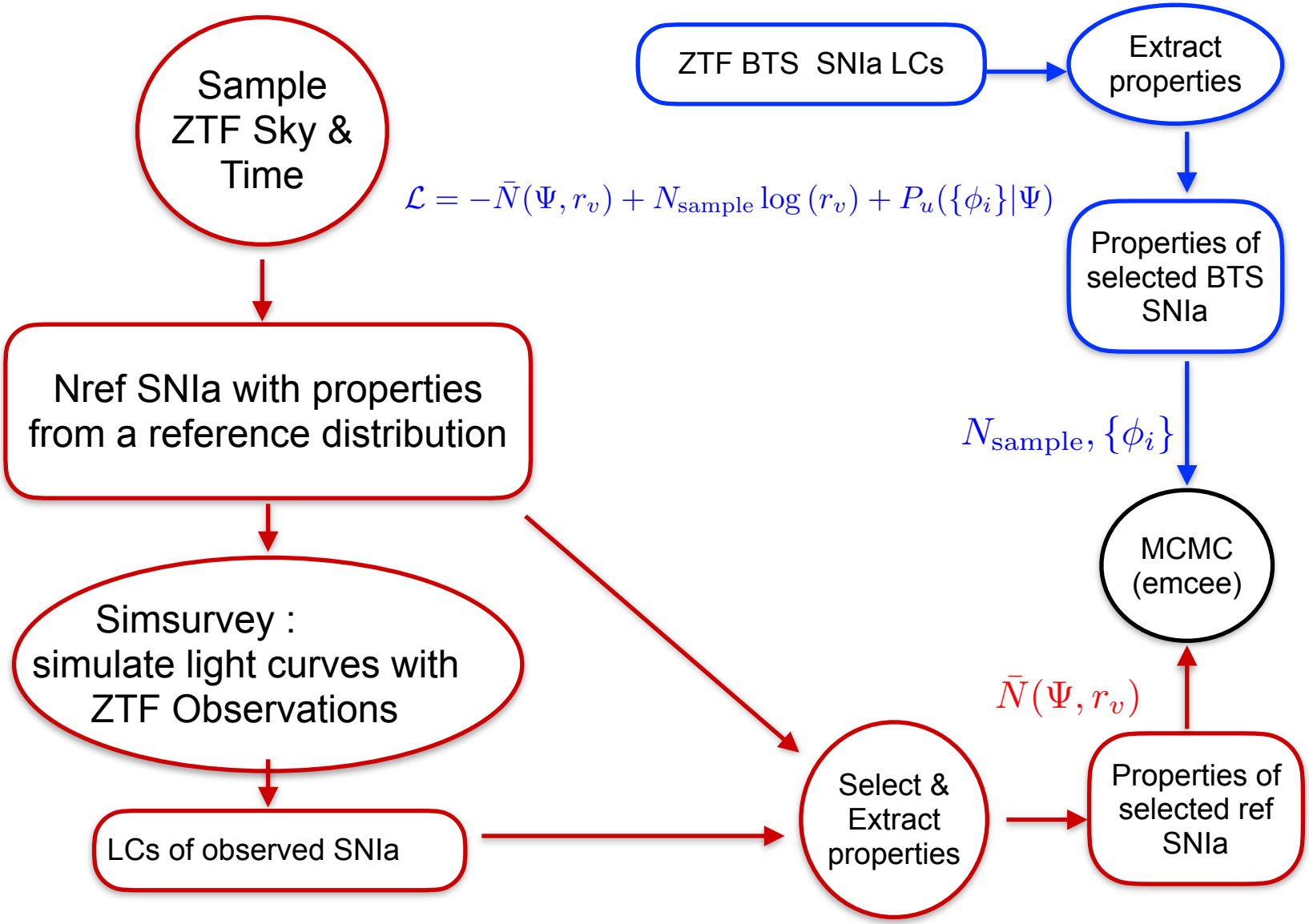
- Need to evaluate likelihood and expected number of objects in a sequence required by MCMC



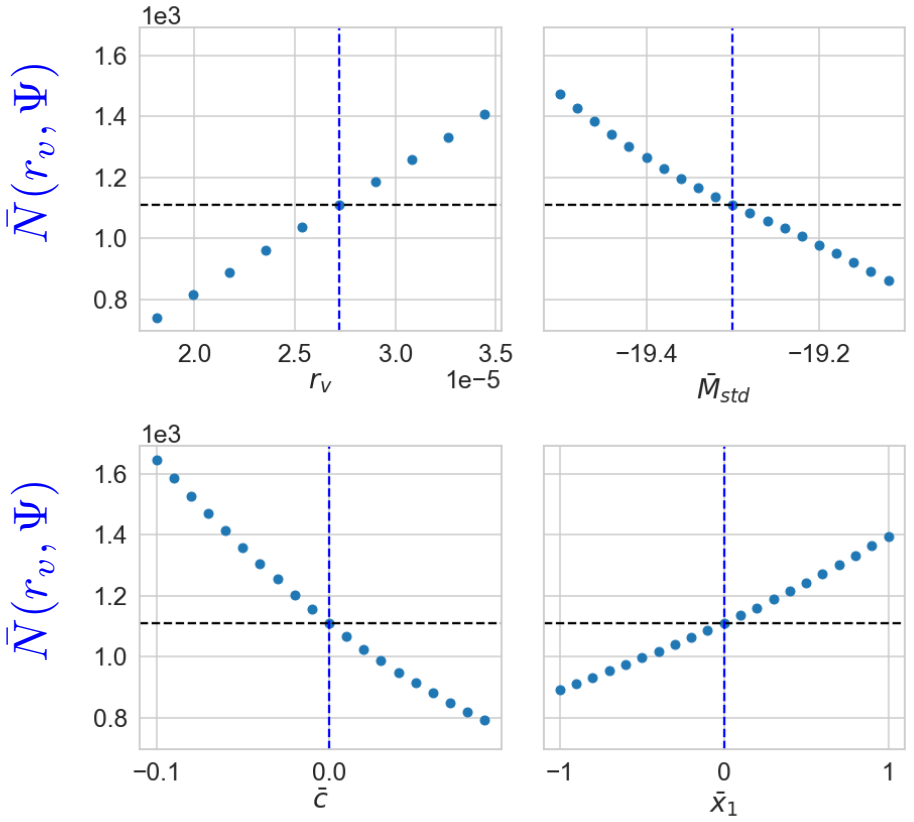
- Use importance sampling to evaluate $\bar{N}(\Psi, r_V)$

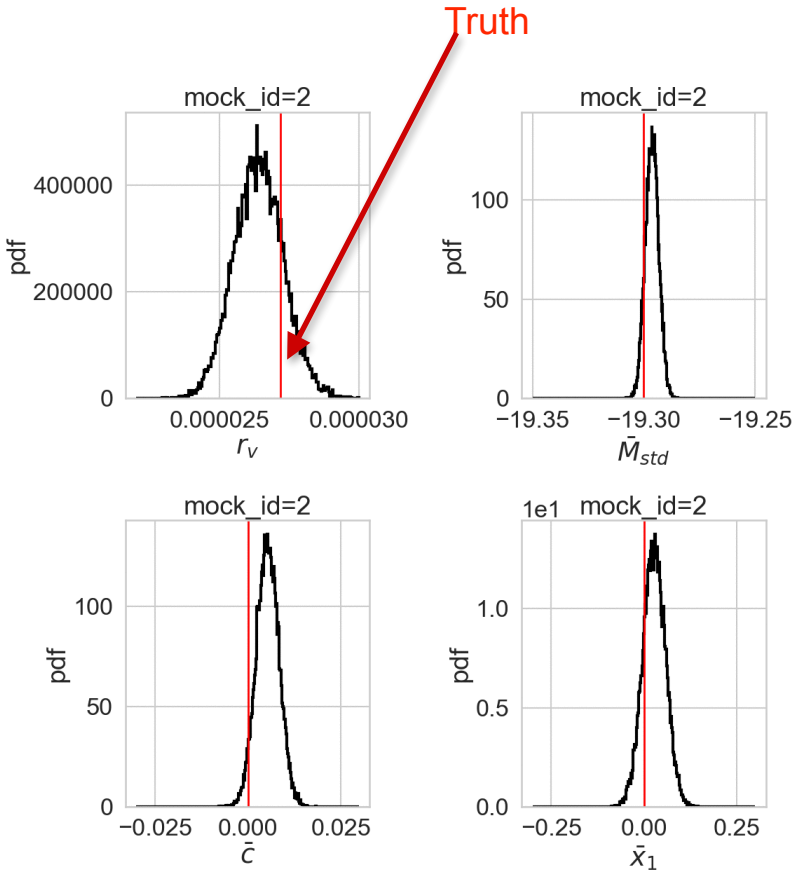


Flow Chart : SN Ia



Simulation Results



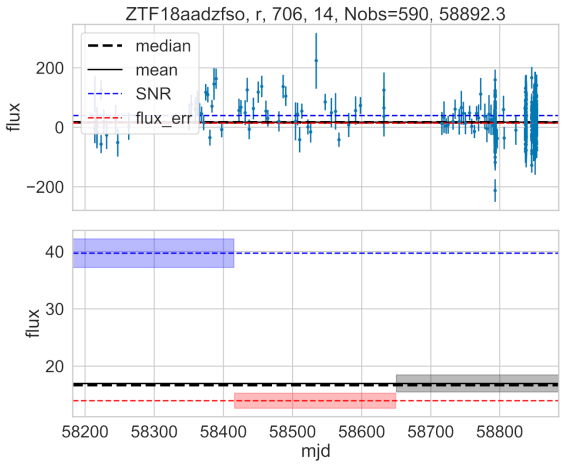


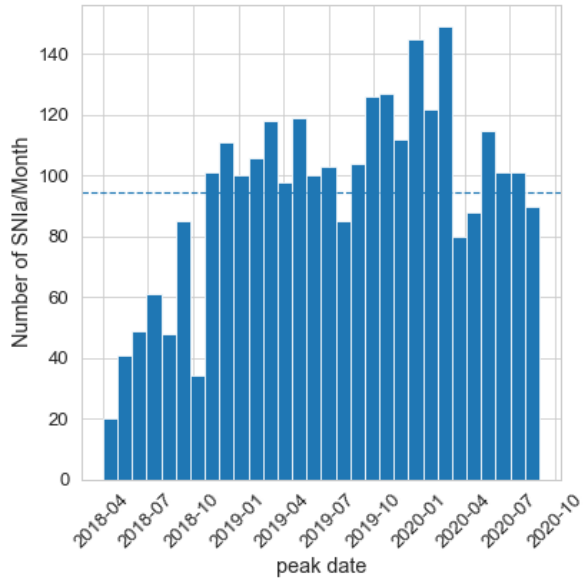
$\bar{N}$ changes with rate, or brighter populations

Posteriors for different realizations

ZTF Data

- Use forced photometry light curves from the ZTF Bright Transient Sample (mag < 18.5) sample
    - IPAC FPS : originally setup ZTF_IPAC to use FPS more easily. For the Perley et al. sample, light curves from Caltech.
    - ZTF_IPAC also does baseline corrections to the fluxes based on pre-transient observations (Early ZTF data : pre-transient can be few, maybe we should use post-transient epochs)
- Extract SNIa parameters using SNCosmo
- Number of samples greatly increase from the Fremling et al. 2019 sample to Perley et al. 2020 sample.

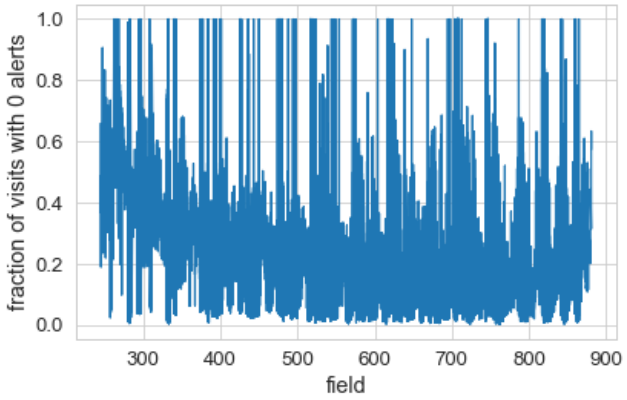


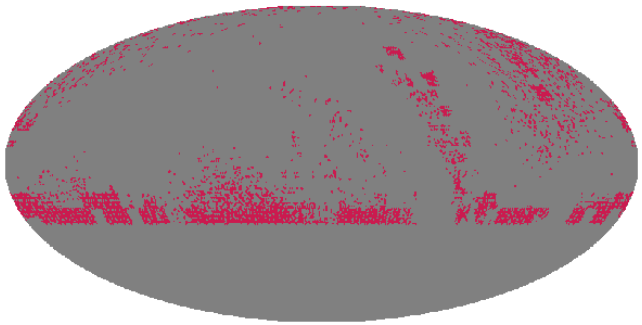


Simulations (to get expected numbers)

- Need large number of realizations of ZTF to suppress scatter in expected number
    - Simulation tools needed modification with 3 yr sample.

- Applying the same selection in simulations, by using lightcurve/ position filters from BTS
- Accurately implement ZTF observing & selection: still hard!
    - Where has ZTF observed & obtained alerts correctly ?
        - observing logs w/ annotations (Caltech)





Summary

- Simultaneously infer the rate and distribution of population properties from data
- Warm-up with SNIa, but can be applied to to other transients with models
- Key survey input : objective selection criteria and implemented in simulations
- Significantly involved in terms of computation, but more in terms of book keeping