Supernovae and Active Galactic Nuclei in the Rubin LSST era

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Abstract

I present two test cases in preparation of variability science with Rubin LSST exploiting simulated and archival data.

- Preliminary results from a DESC project on the measurement of the SNIa rate from the DC2 simulated data [3], in order to retrieve information on the statistical and systematic uncertainties which may affect the interpretation of Rubin data.
- My contribution to the AGN SC Data Challenge 2021 [1,6], to develop data driven methods for addressing the problem of AGN selection and characterization in large surveys.

Recovered SN Ia rate from DC2 data

Our **dataset** is composed of SNIa detected on difference images in a DC2 subset of $15\,deg^2$ of the Wide-Fast-Deep (WFD) area [5].

There are $\sim$**5400** simulated SNIa, but only **2549** are on the DiaObject table (i.e., at least one detection with $S/N > 5$ on difference images).

We selected only SNe with at least 5 detections, obtaining a final sample of **779 objects**. An example of light curve is shown in Fig. 1.

We used the Directional Light Radius method (DLR, [2]) to rank **host galaxy candidates** of each transient by considering the size and the morphology of the galaxy and the angular separation from the SN (Fig. 2).

By comparing our associations with the truth table, we found **667 SNe correctly associated** (86%).

If the best candidate has a $DLR > 5$, the SN is considered **host-less**. We identify **22 host-less SNe**, half of them is host-less also in the truth table.

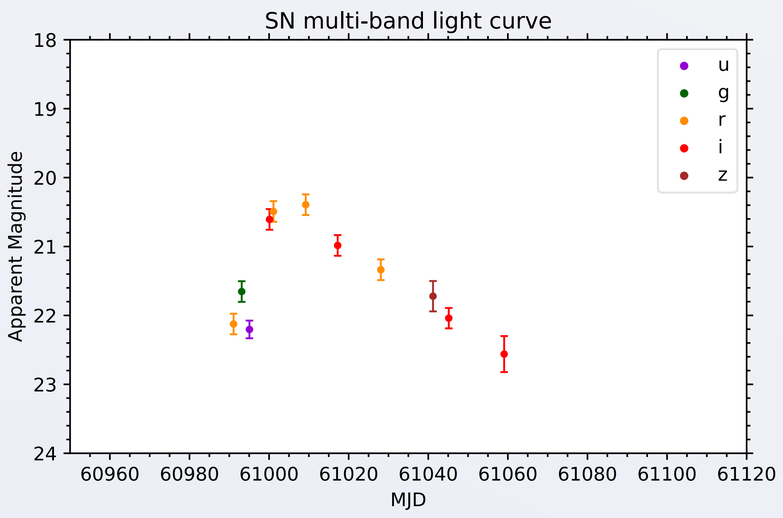

Figure 1: Example of light curve for a DC2 Supernova

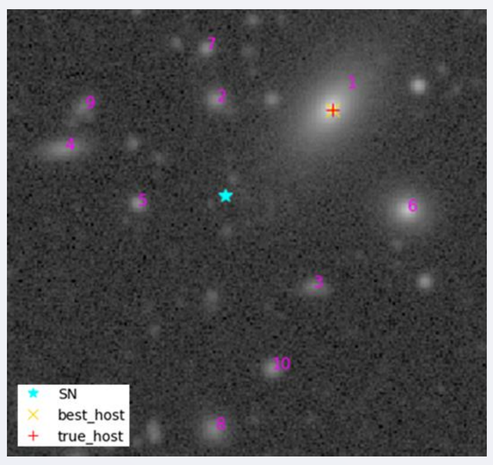

Figure 2: Cutout image around a SN showing the results of the host-galaxy association. The orange ‘x’ identifies the best host candidate, the red ‘+’ is the true host galaxy and the magenta numbers are the other candidates.

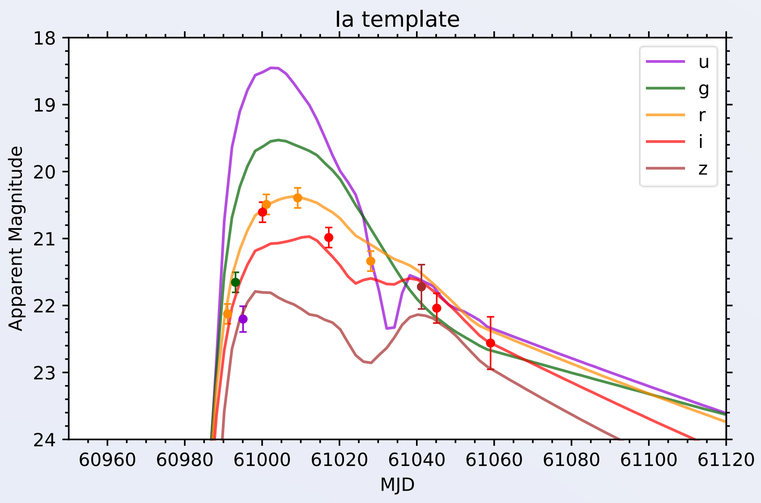

Figure 3: Example of light curve template fitting with *pSNid* using the same object shown in Fig. 1 and with SN Ia templates.

We used ***pSNid*** [4,7] to classify the light curves in three different conditions:

- without prior on redshift;
- using the redshift prior from the truth table (as a spectroscopic redshift);
- Using the photometric redshift of the associated galaxy, if available.

SNe correctly classified as type Ia:

- no prior, 403 SNe (51%);
- z-spec prior, 563 SNe (72%);
- z-phot prior, 513 SNe (66%).

We are analyzing the redshift distributions of SNe as obtained by the different *pSNid* runs (Fig. 4) and the number of correctly classified SNe as a function of redshift (Fig. 5).

There is a strong bias towards low-redshift in absence of a redshift prior, while the use of the photometric one reflects both the error of the galaxy association and the photometric redshift estimation.

Fine tuning of the pSNid parameters, as well as the measurement of the observed SN Ia rate and the comparison with the simulation inputs are on-going. **Stay tuned for further updates!**

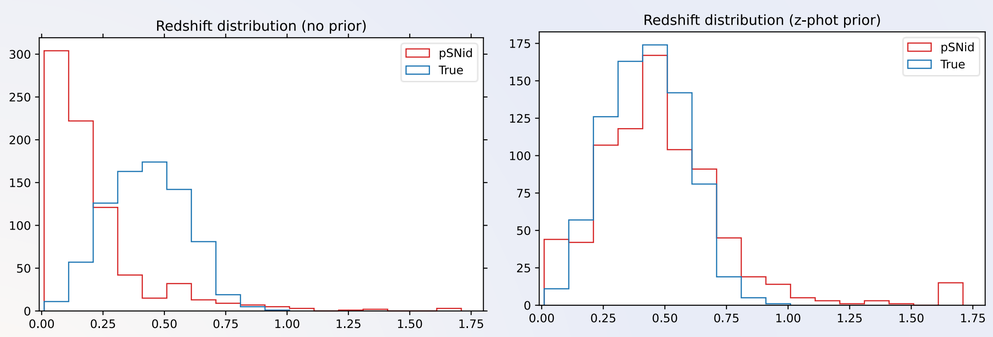

Figure 4: Comparison between *pSNid* (red) and true (blue) redshift distributions. Left panel shows a *pSNid* run without a prior on redshift, right panel shows a *pSNid* run with the photometric redshift of the associated galaxy

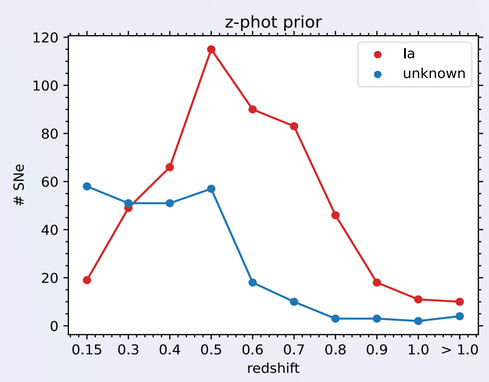

Figure 5: Number of SNe classified as Ia (red) or unknown (blue) as a function of redshift

AGN SC Data Challenge 2021

The **dataset** is composed of SDSS Stripe-82 images.

We prove that light curve variance and **correlation** among bands alone, allow us to produce samples of QSOs (and AGNs) with a completeness of $\sim 90\%$, albeit with low purity ($\sim 50\%$) (Fig. 6,7).

By adding the **extendedness** and **color**, it is possible to remove most of the contaminants reaching a purity of 95% and decreasing the completeness by less than 10% (Fig. 8).

Correlation analysis among different bands thus enables a very fast and cheap first order selection of candidate QSOs (and possibly less luminous AGNs)

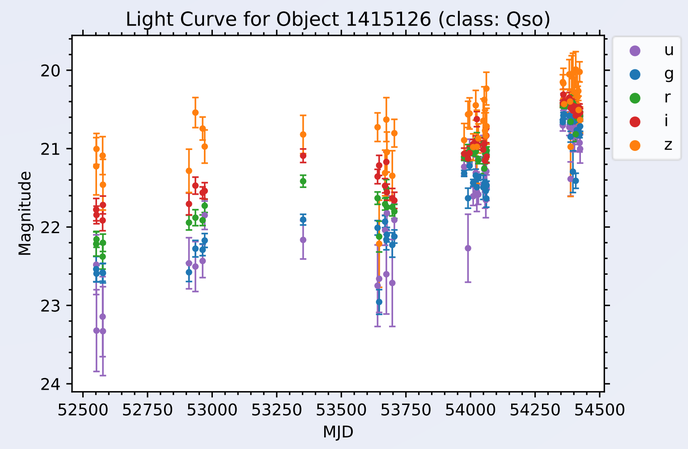

Figure 6: Example of light-curve in different bands for a quasar in the SDSS Stripe-82

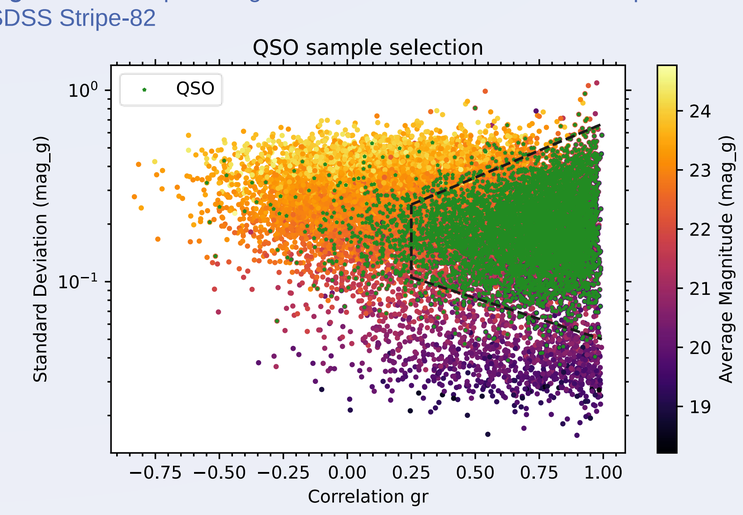

Figure 7: Standard deviation of the light curves vs. g-r band correlation for a random sample of sources. Points are color-coded according to the g-band magnitude. The black dashed lines define the *Wedge* where QSOs (green points) tend to group.

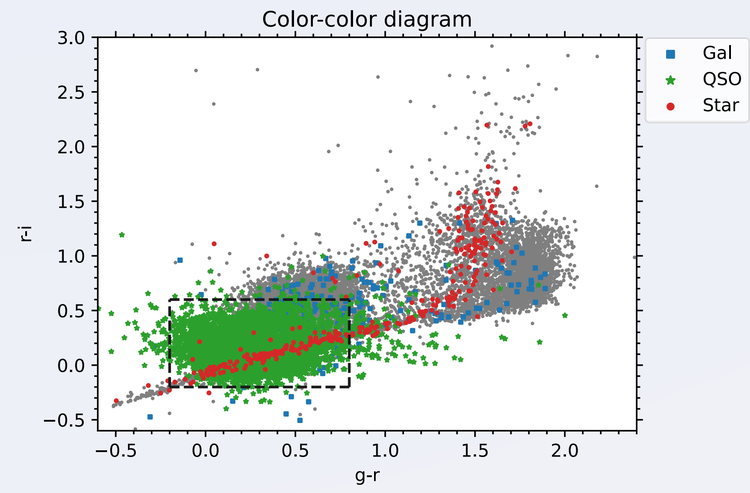

Figure 8: *Color-color* diagram showing the distribution of Galaxies, QSOs and Stars selected by the Wedge, with a cut in LSST *extendedness* > 0.95. Grey dots represent the total sample, while the black dashed lines highlight the Box where QSOs tend to group

	Galaxy	QSO	Star	Total	Completeness (QSO)	Purity (QSO)
Sample	13066	6177	1995	21238		
Wedge	4767	5614	404	10789	90.9 %	52.0 %
Extendedness	1385	6029	1796	9211	97.6 %	65.4 %
Color	2763	5538	956	9257	90.3 %	59.8 %
Wedge+Ext.	325	5492	331	6148	89.5 %	89.3 %
Col.+Ext.	612	5492	950	7054	89.5 %	77.8 %
Wedge+Col.	716	5093	130	5939	83.0 %	85.7 %
Wedge+Ext.+Col.	138	5055	125	5318	82.4 %	95.0%

Table 1: Results of the selection of QSOs using combination of different criteria.

References

[1] AGN Data Challenge, https://github.com/RichardsGroup/AGN_Data Challenge.git

[2] Gupta et al. 2016, AJ, 152, 154

[3] LSST DESC et al. 2021, ApJS, 253, 31

[4] Sako et al. 2011, ApJ, 738, 162

[5] Sánchez et al. 2021, arXiv:2111.06858

[6] Savić et al. 2022 (in prep.)

[7] SNANA, https://github.com/RickKessler/SNANA

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