What Should Spectroscopic Followup of Transients Look Like in the LSST Era?

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Background

- LSST will find ~10^6 SNe and extragalactic transients (~300/night for 10 years)
- One of the primary science goals for LSST is to be a transient ***discovery*** machine
- Most other transient science cases require spectroscopy for classification and characterization
- Many past attempts to define wish lists for capabilities (e.g., Najita et al. arXiv:1610.01661)
  - But LSST will happen soon (2022?), so we have to start with current facilities
  - To advance the field, we need to do something ***new***, but the required scale needs coordination within the transient community and probably new ways of allocating time

Two Strawman Fallacies

- We just have to take a bunch of spectra of LSST transients to make discoveries

Past and Current Surveys

- Local Universe:
  - LOSS (~1000 spectroscopic classifications); ASASSN (~1000)
- Distant universe
  - SNLS (~500), DES, ESSENCE, SDSS II, Hi-z, SCP, etc. (several hundred total)
  - PS1 MDS (~500)
  - i/PTF (~1000 classifications); ZTF (~1500)
  - e/PESSTO (??)

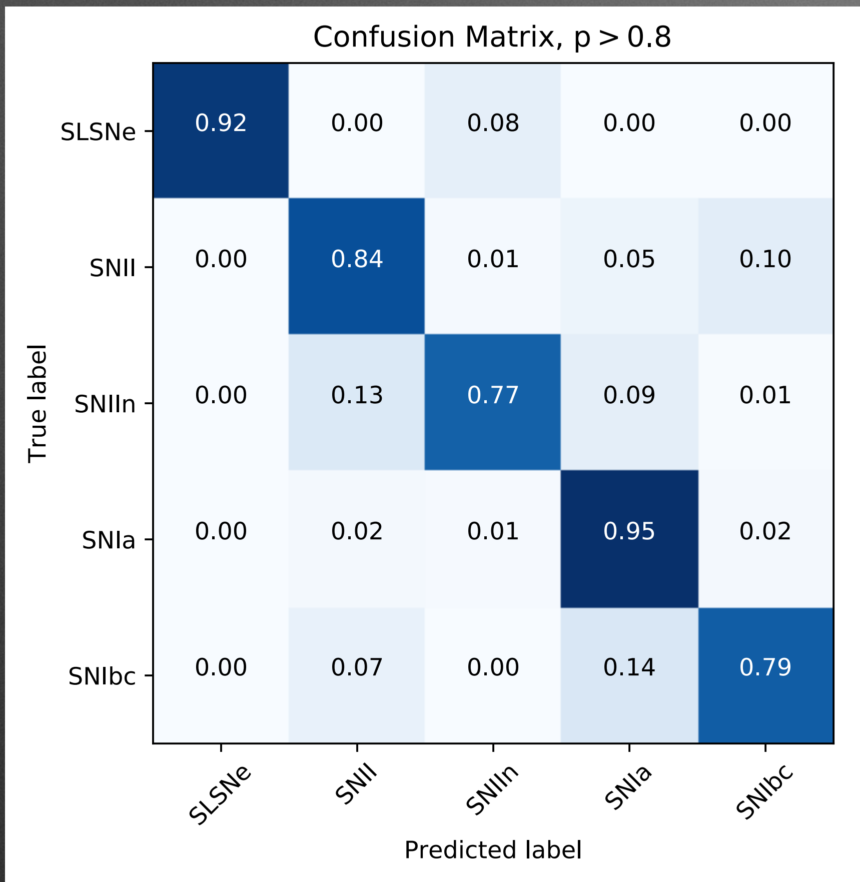
A Scary Calculation

- A 22nd mag transient can be classified in ~1 hour with Gemini (2x20m with GMOS, plus 20m of overheads), so imagine if you take over half the telescope time:
  - 5 spectra/night * 365d * 70% efficiency (weather losses, useless spectra) is ~1300 spectra a year. For 10 years of LSST, this is 13,000 spectra. So call it 10^4 spectra.
- These are intentionally over-optimistic numbers! But… the result is not much more than the previous surveys
- Spectra need to be taken more *efficiently* if we are to do something *new* and make discoveries

Two Strawman Fallacies

- We just have to take a bunch of spectra of LSST transients to make discoveries
- We can just wait for the ML algorithm to go “beep”

What classifiers can do

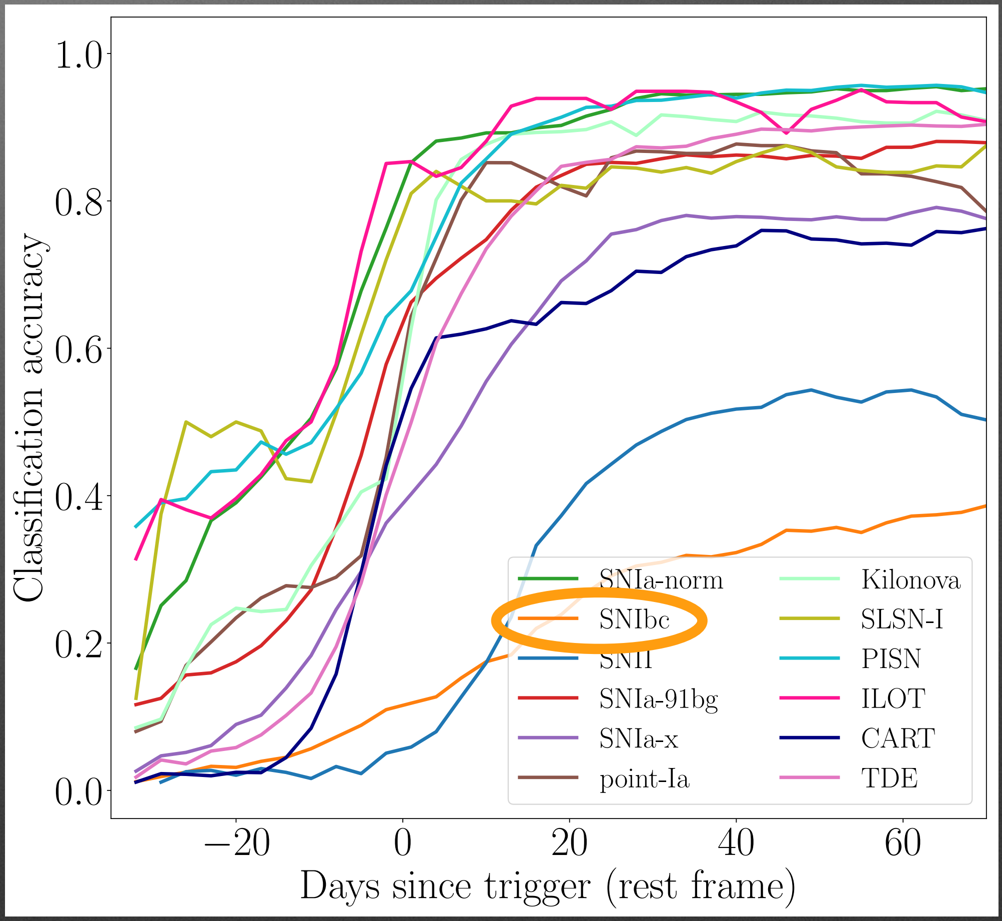


Villar et al. 2019: full PS1 lightcurves but assuming spectroscopic redshifts

- ML is excellent at real/bogus
- ML is very good at separating variable stars, AGN, transients, moving objects, etc.
- Classifiers are quite good with SNe Ia
- Classifiers are not, and will not be, sufficiently good with rarer classes of transients on fast time scales
- Classifications will become better as more data come in, but what is the use if you need to wait for the transient to fade away to ID it as interesting? What about novel classes of objects?

SNe Ia are easy

- Homogeneity
- Base rates
    - In a magnitude-limited blank field survey, ~70% of extragalactic transients are SNe Ia
    - With a limited number of data points, it will always be harder for a classifier to have high confidence that a transient belongs to a rare class of objects as opposed to being a common object in the tails of the distribution or outskirts of feature space



RAPID: Muthukrishna et al. 2019 assuming spec. redshifts

Approach #1: Do nothing and wait

- The best transients for detailed studies are the nearest and brightest.
- Save the real-time resources for studying these (from local universe surveys)
- Use photo-z's and host galaxy redshifts for LSST (piggyback on future large spectroscopic surveys)
- Use the LSST transients primarily for population studies, rates, etc.

Approach #2: Colors/Lo-res followup

- Use the LSST WFD survey for the discoveries, but obtain additional info elsewhere:
  - Detections in other surveys (esp. at the bright end)?
  - Simultaneous multiband images (GROND-lite: *griz?)* to generate at least one epoch with real colors
  - SEDMachine-like approach?
- Both require >4 m telescopes (which one? which instrument? which timescale?) for sufficiently short exposure times to allow you to observe a significant number of objects

Approach #3: Coordinated spectral campaign

- The current way of obtaining followup is everybody writes separate ~10 hr Gemini/SOAR/etc. proposals with specific trigger criteria and focused science goals
  - For less-common classes, the photometric classifications will not be sufficiently accurate on the relevant timescales, and rare or unknown things will fall through the cracks.
  - Fragmented followup will be suboptimal in several ways (Do you wait for high-confidence photo classifications? If so, how do you find actual new things?)
  - With a significant false-positive rate, we need to make all classifications public

Approach #3: Coordinated spectral campaign

- A baseline spectroscopic survey that acquires classifications for some objects before light curve classifiers know they are unusual or novel is required
- A truly random spectroscopic survey would spend 70% of its time on SNe Ia and 20% on SNe II — we've already done that
- Classification targets chosen with a bias against high-confidence SNe Ia?
  - How to allow for a diversity of targeting approaches?
  - Management concerns: Increase ToO time on SOAR/Gemini, TAC process

Final thoughts

- The worry: if we arrive in 2022 with no change in our time allocation and proposal processes for followup, LSST will have limited scientific impact for transient science over current surveys

- The required scale of efforts is above the level of individual small proposals

- But the transient community needs to decide as a community what we actually want while allowing for individual initiative…