LSST DESC & COIN

RESSPECT

Recommendation System for Spectroscopic Follow-up

Project update

Emille E. O. Ishida on behalf of the RESSPECT team

LSST France, 4 November 2020

Fundamental truth about supervised learning:

The performance of any supervised learning algorithm is dependent on the degree of **representativeness** between training and target samples.

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Fundamental truth about SN cosmology with LSST:

Machine learning for photometric classification is unavoidable.

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To build a **recommendation system** for the construction of an **optimal training sample** given available spectroscopic resources.

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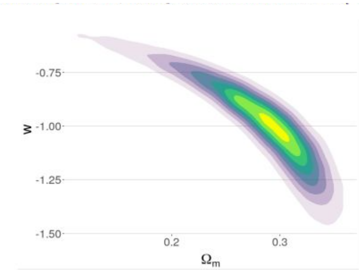
*It is **NOT** the goal of RESSPECT:*

- Build a better classifier
- Maximize the number of spectroscopically confirmed SN Ia
- Test a complete cosmology pipeline
- ...

The SN Ia photometric cosmology pipeline

Cosmology results from photometrically classified SN IA



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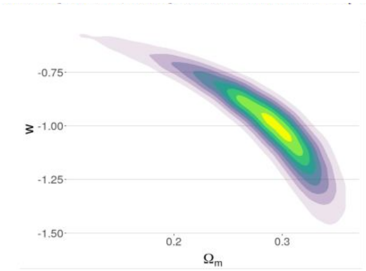

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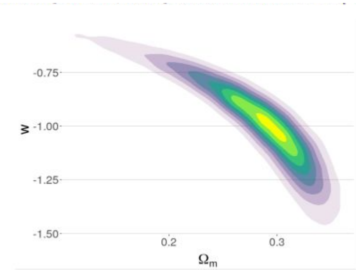

←

Photo-classified SN Ia

←

SN candidates

←

Trained machine learning classifier

Context

The SN Ia photometric cosmology pipeline

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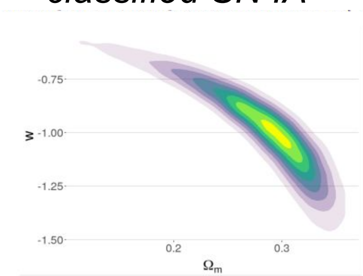

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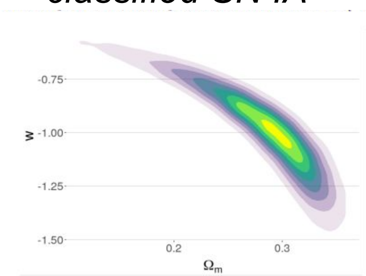

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`Optimize this!`

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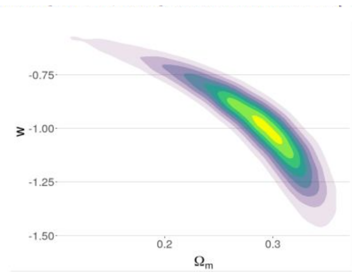

Photo-classified SN Ia

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Trained machine learning classifier

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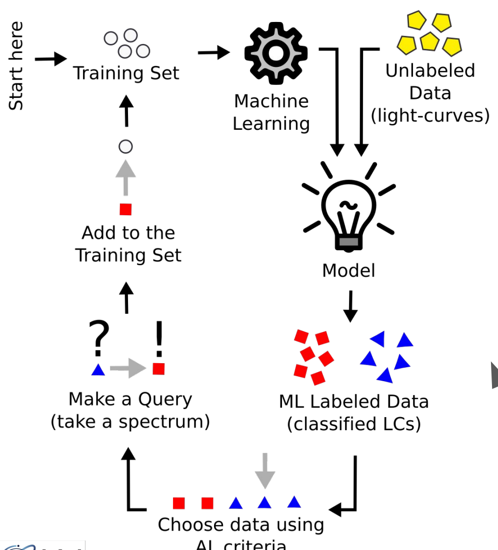
Training sample

Optimize this!

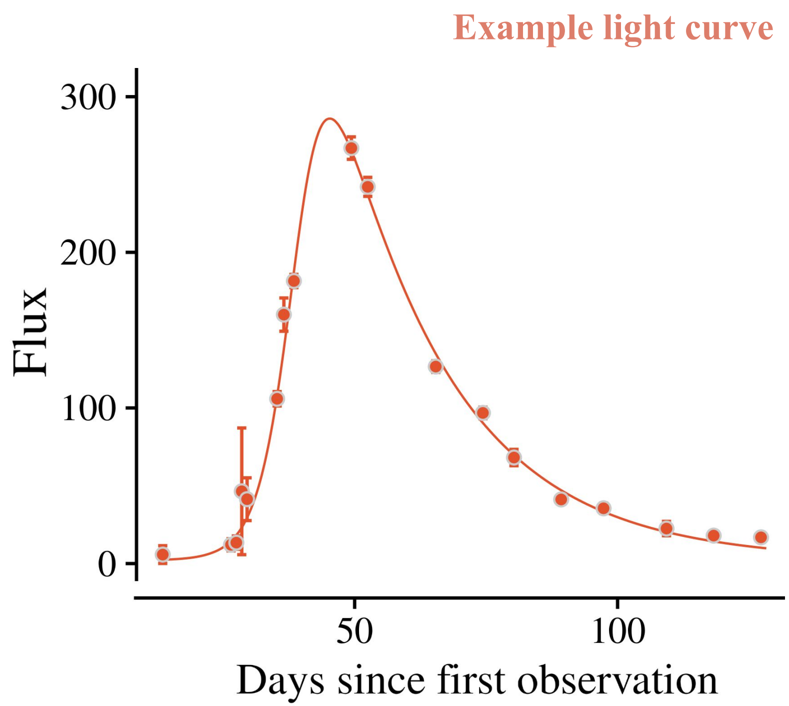
Using this!



Ishida et al., 2019, MNRAS from CRP #4

Take into account observational caveats

- Window of Opportunity for Labelling
- Evolving Samples
    - We must make query decisions before we can observe the full LC
- Multiple Instruments
- Evolving Costs
    - Observing costs for a given object changes as it evolves.



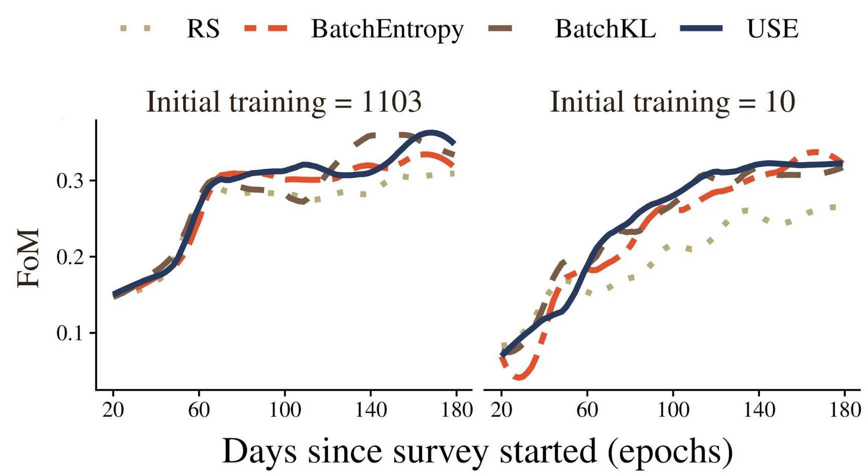
[Kennamer et al., 2020 - arXiv:astro-ph/2010.05941](https://arxiv.org/abs/2010.05941)

Conclusion of phase 1

It is advisable to start from scratch

- Supernova Photometric Classification Challenge data (SNPCC)
- Data separated into four groups
  - Original training set - 1,103
  - 18,216 in pool set
  - 1,000 objects each in validation and test sets
- Assumed access to an 8m and 4m telescope for labeling
  - 6 hours per telescope on each night

- Pre-processed data with parametric fits (Bazin *et al.* 2009)
- Observing Costs calculated from brightness estimates of each objects and telescope properties



Kennamer et al., 2020 - arXiv:astro-ph/2010.05941

Active Learning details

- Ensemble of Random Forest Classifiers for query decisions
- **Four** Active Learning Strategies under **knapsack constraints**:
  - Random Sampling
  - Uncertainty Sampling
    - Entropy used to measure uncertainty
  - Batch Entropy
    - Measures a joint entropy over batches
    - Takes advantage of submodular properties of entropy
  - Batch KL-Divergence
    - Measures a Joint KL-Divergence/Mutual Information, equivalent to BatchBALD
    - Takes advantage of submodular properties of the KL-Divergence/Mutual Information

Proved equivalence between KL-Divergence and Bayesian Active Learning by Disagreement (BALD) - check the Appendix!

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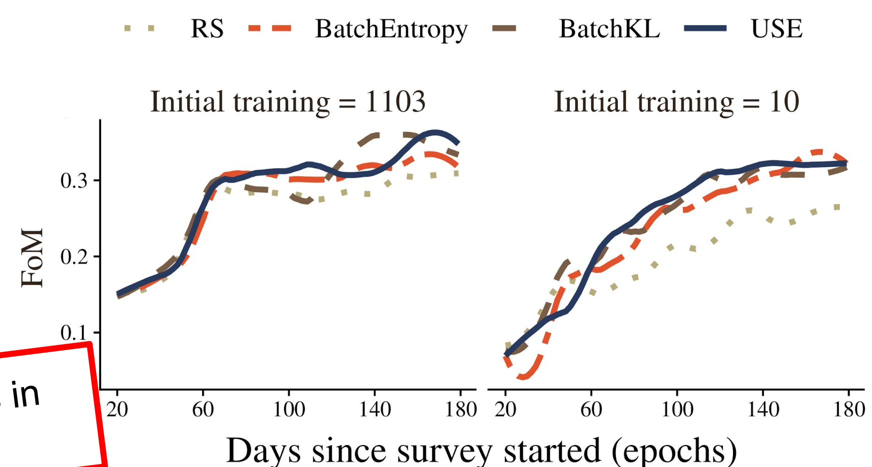


Accepted for oral presentation at IEEE Symposium Series in Computational Intelligence, 2020

arXiv:astro-ph/2010.05941

Active Learning part is closed

- Start from scratch
- Simple AL strategies are the best we can do
- Further improvements will require theoretical development

This is only half of the story ...

The cosmology part ...

Cosmology results from photometrically classified SN IA

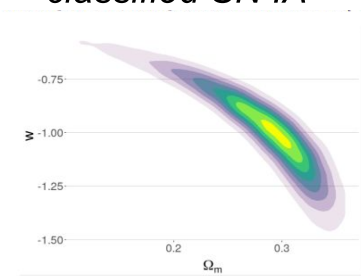


Photo-classified SN Ia

SN candidates

Trained machine learning classifier

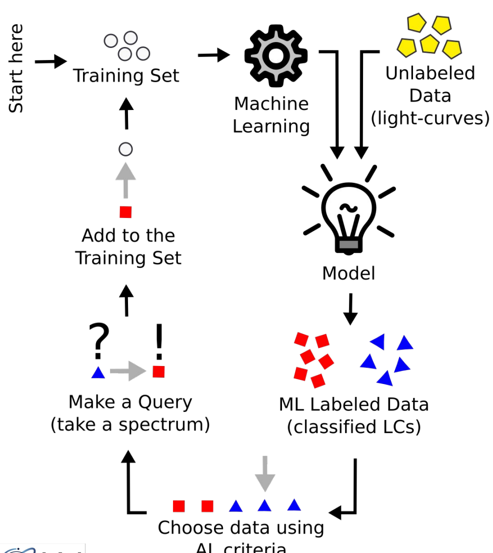
learning algorithm

+

Training sample

This also changes!

Every time this changes ...



COIN Cosmostatistics Initiative

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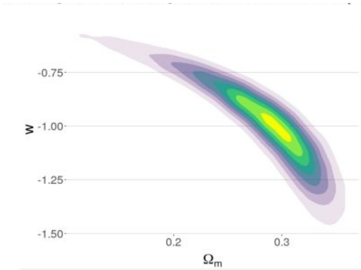

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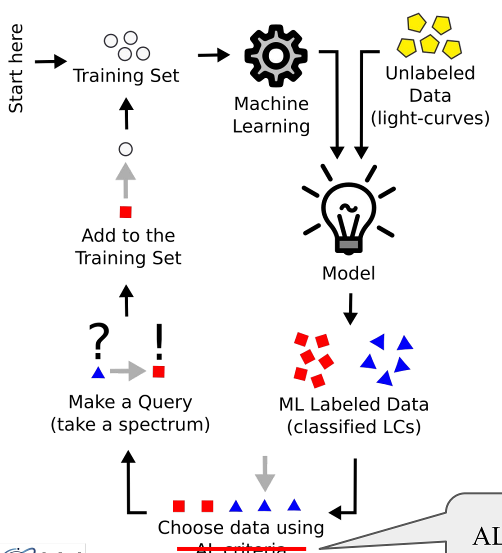
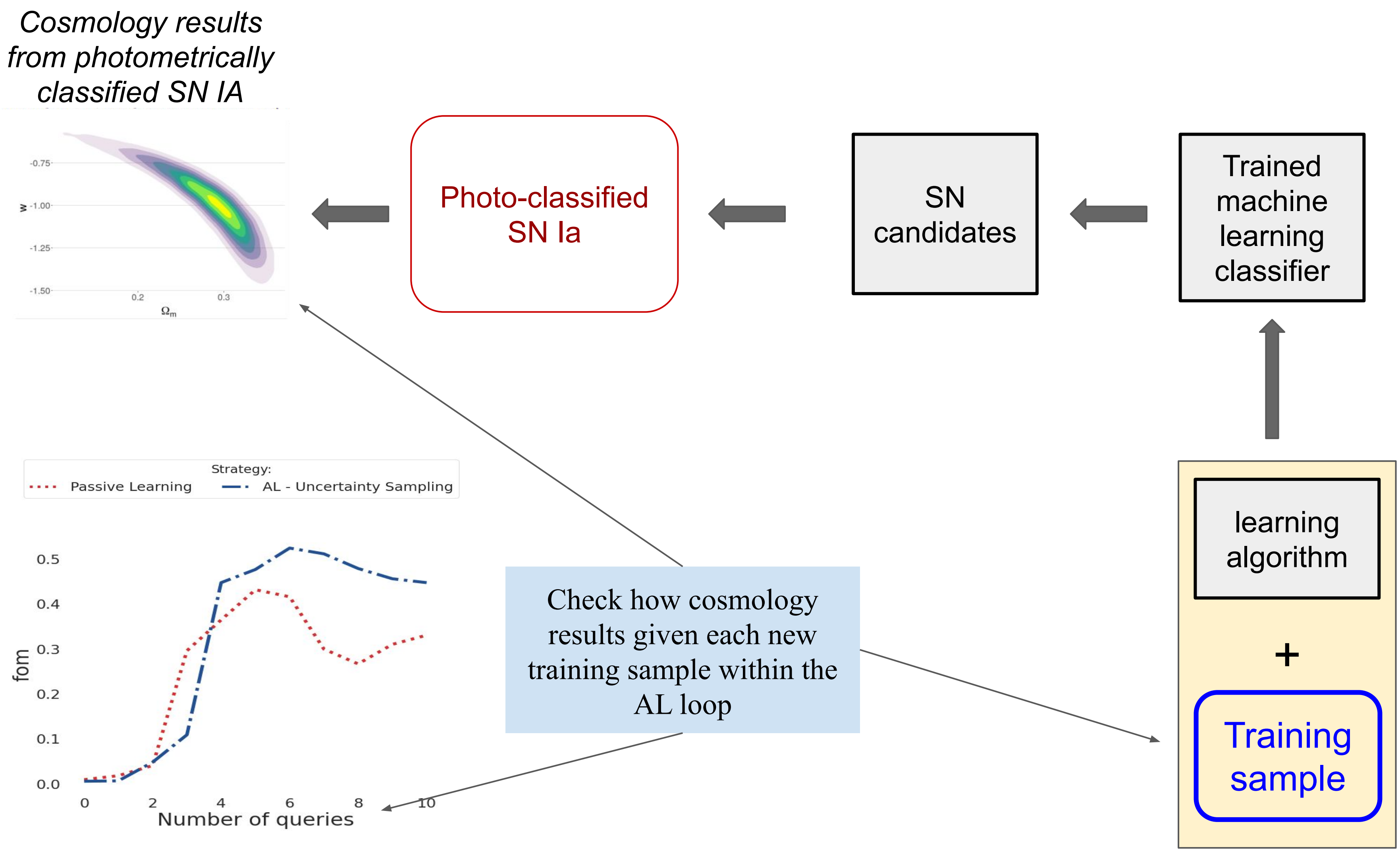


AL + cosmo criteria

Ishida et al., 2019, MNRAS from CRP #4

Hypothesis

Better classifier leads to a better cosmology



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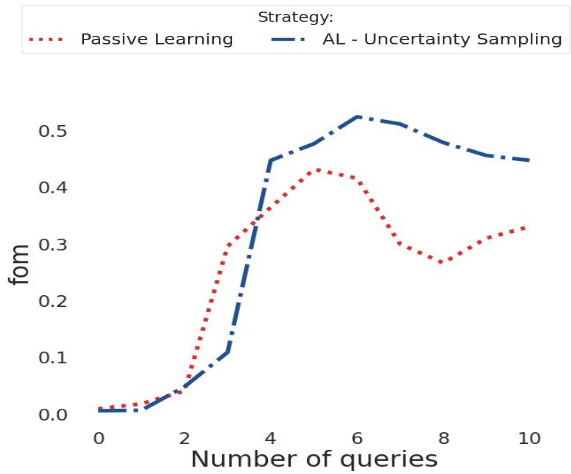

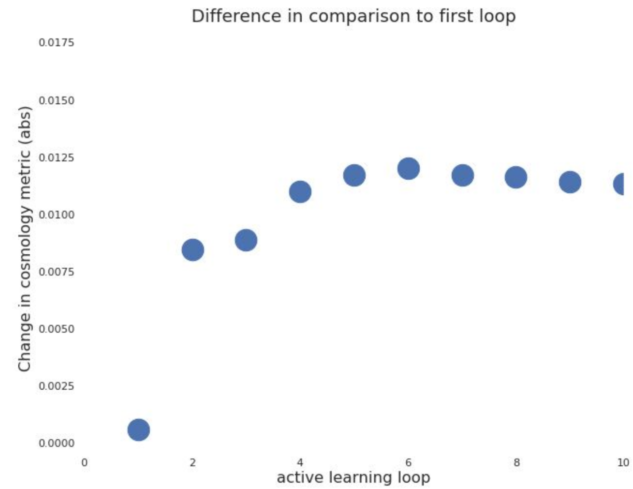

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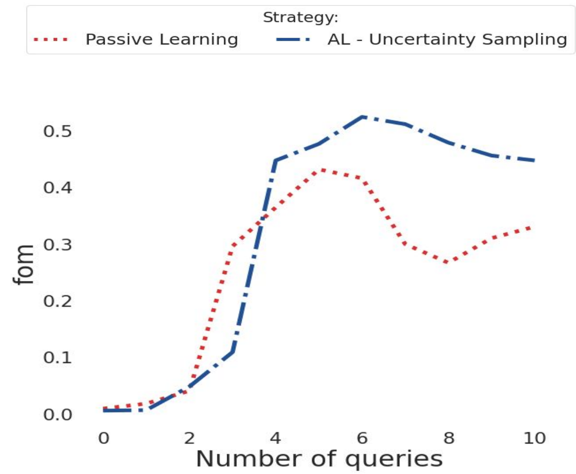

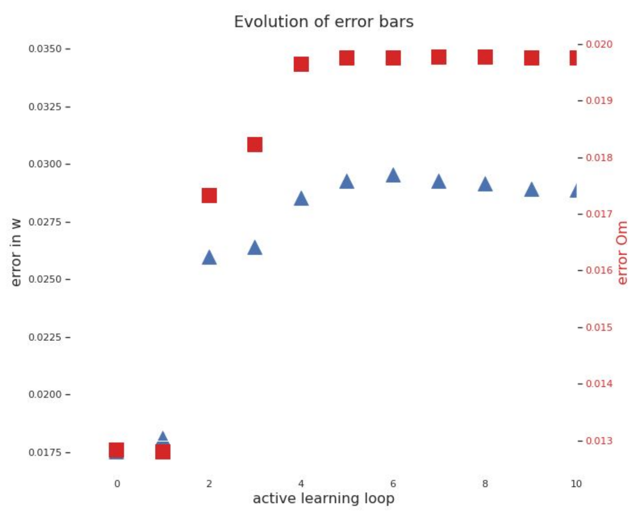

`Goal:` use the cosmology metric to choose between different **possible batches** per night, which would have the **same effect** from the classifier point of view

Summary and next steps

- Active learning stage is well developed with important theoretical contribution for computer science community
- Currently running the pipeline on PLAsTiCC data for astronomy paper
- Implement the choices between multiple batches in the same run

- Cosmology metric is under development
- Develop a mathematically coherent procedure to combine active learning and cosmology metric

Negotiating extension of ICA until DESC 2021 Summer meeting...

Summary and next steps

- Active learning stage is well developed with important demonstration for computer science community
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Interdisciplinarity at its best!

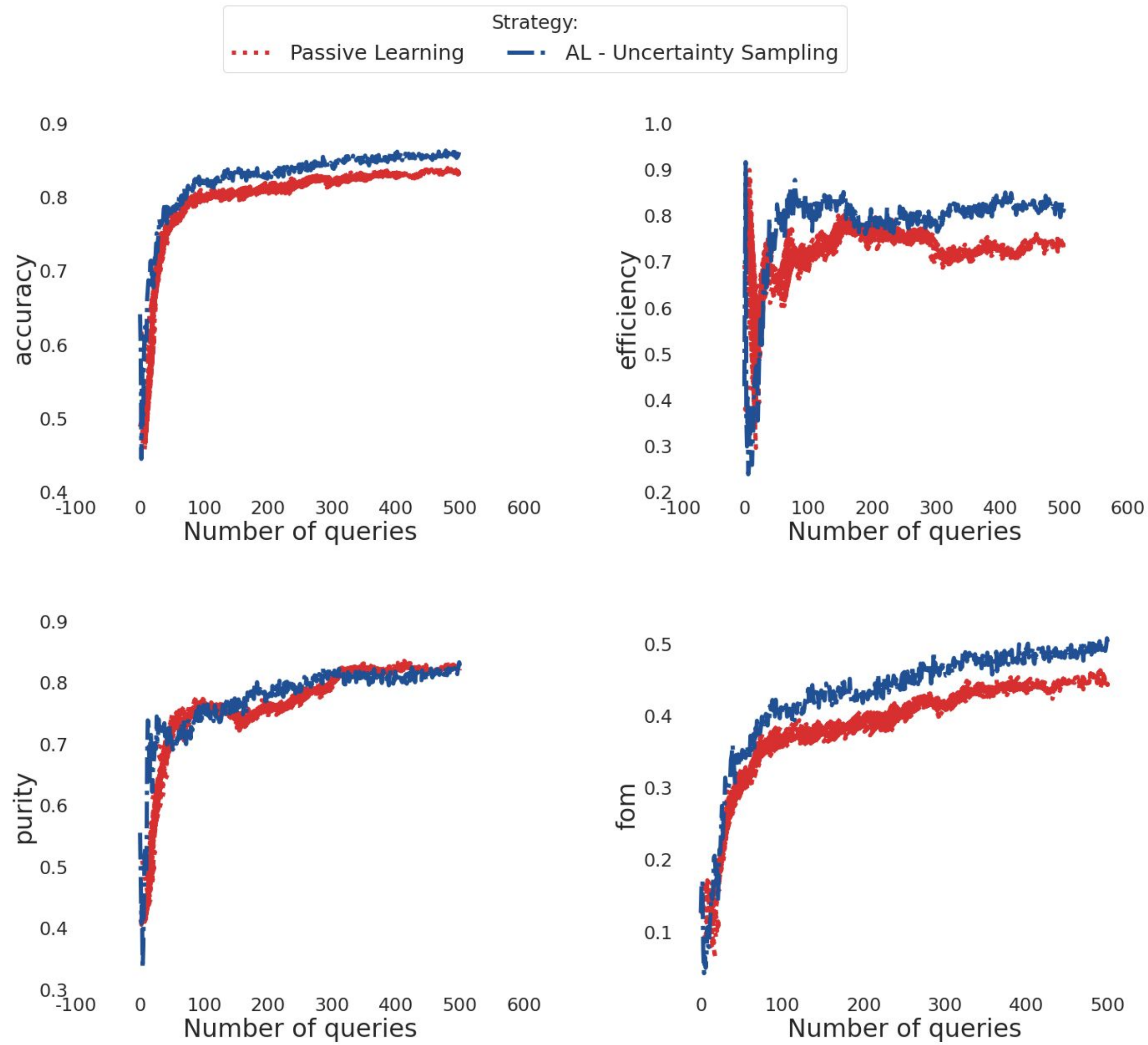
COIN Cosmostatistics Initiative

LSST DESC & COIN RESSPECT Recommendation System for Spectroscopic Follow-up

LSST DESC Dark Energy Science Collaboration

Extra slides

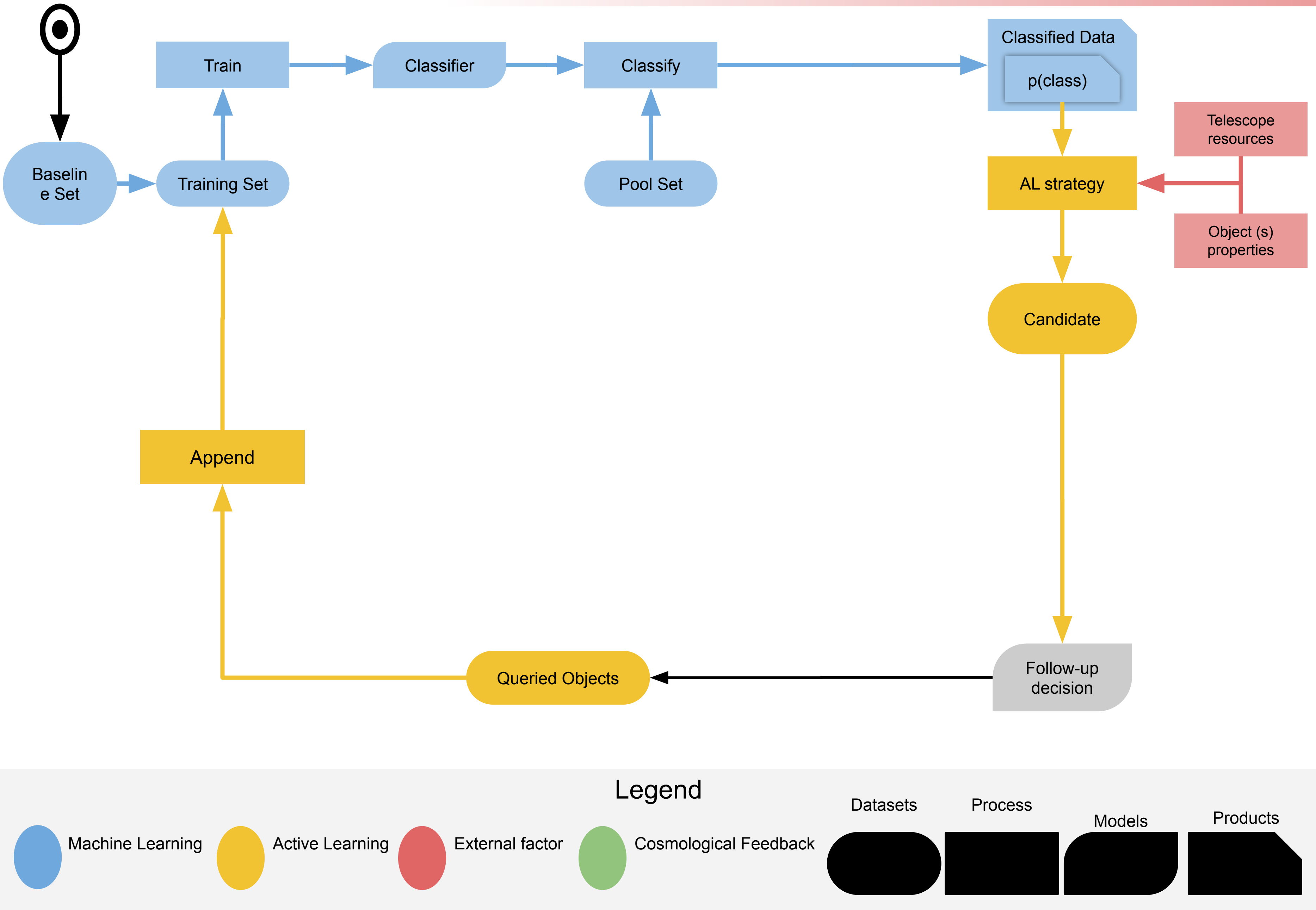
PLAsTiCC results are virtually the same as SNPCC



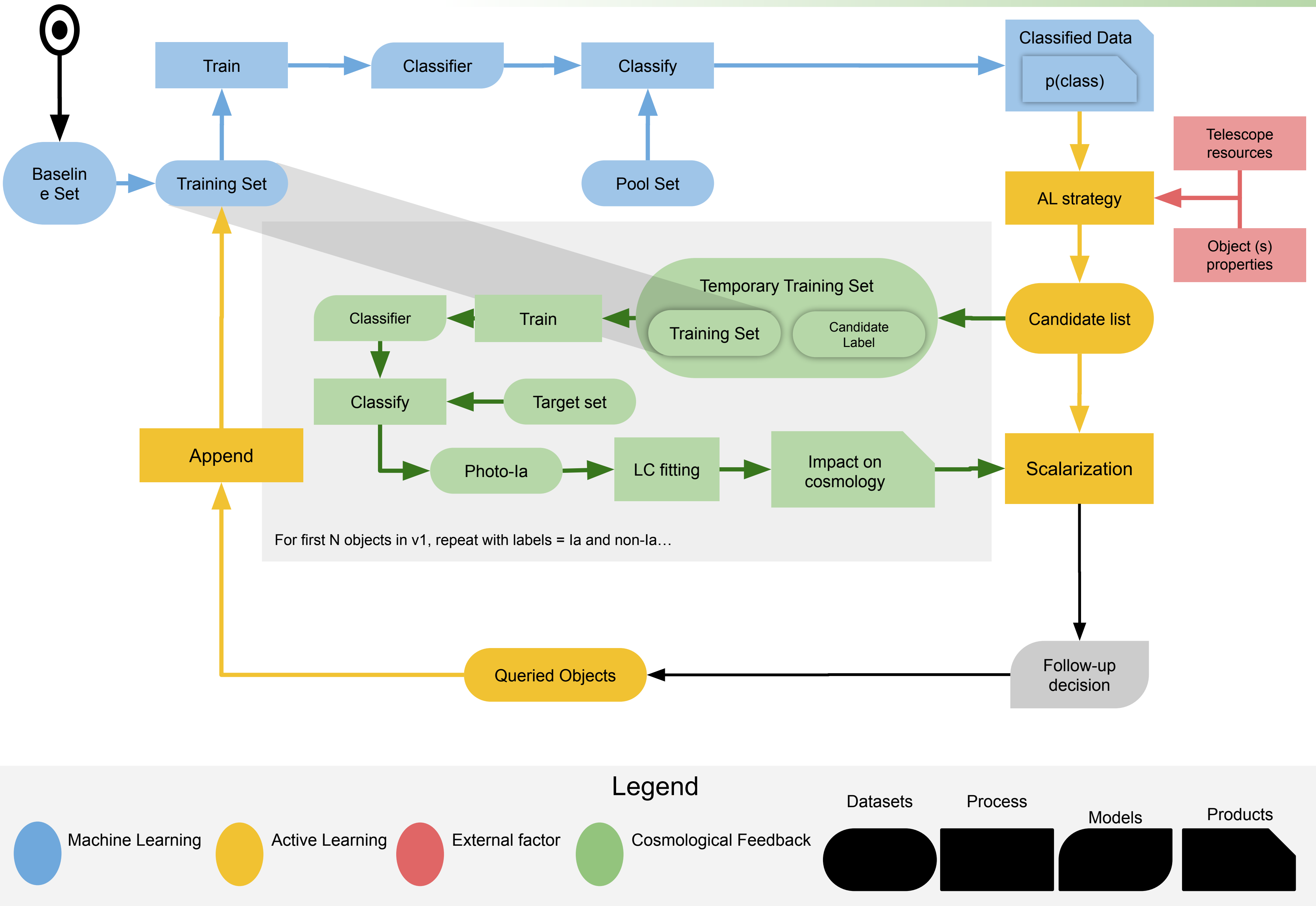
- Initial training of 10 objs
- Validation of 8k objs
- Full LC
- No obs effects considered

Feature extraction takes a while ...

External Factors



Cosmological Feedback



Measuring Disagreement / Query by Committee

Train an ensemble of models on available labeled data

Vote Entropy

$$x^*_{VE} = \underset{x}{\operatorname{argmax}} - \sum_y \frac{\text{vote}_{\mathcal{C}}(y,x)}{|\mathcal{C}|} \log \frac{\text{vote}_{\mathcal{C}}(y,x)}{|\mathcal{C}|}$$

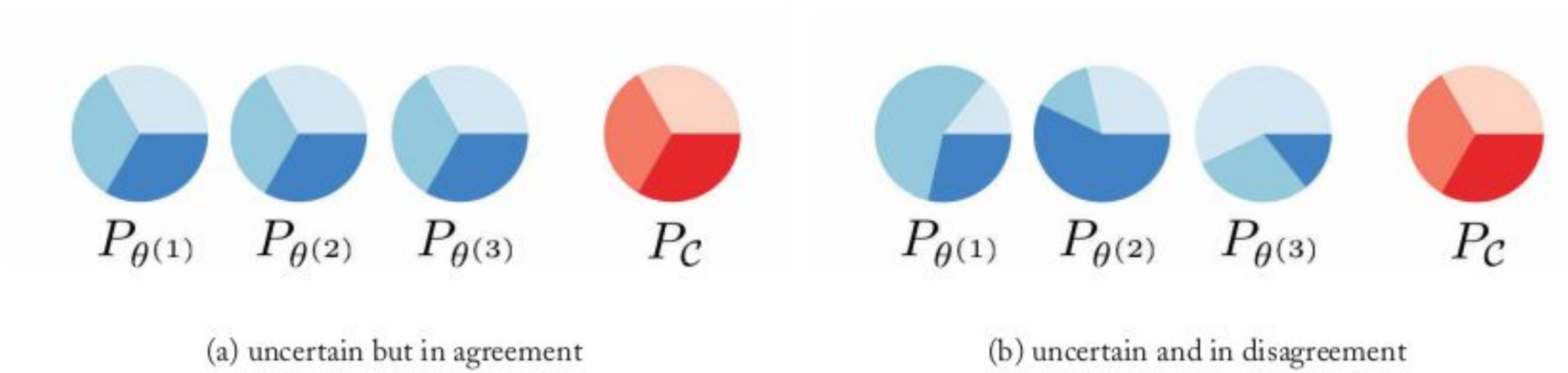
Soft Vote Entropy

$$x^*_{SVE} = \underset{x}{\operatorname{argmax}} - \sum_y P_{\mathcal{C}}(y|x) \log P_{\mathcal{C}}(y|x),$$

Kullback-Leibler divergence

$$x^*_{KL} = \underset{x}{\operatorname{argmax}} \frac{1}{|\mathcal{C}|} \sum_{\theta \in \mathcal{C}} KL\big(P_\theta(Y|x) \parallel P_{\mathcal{C}}(Y|x) \big)$$

Entropy vs KL Divergence



- Equal Entropy
- Low KL

- Equal Entropy
- High KL

Image Source: Settles 2012 Claypool Publishers