TRANSFER LEARNING IN ASTRONOMY: A NEW MACHINE LEARNING PARADIGM

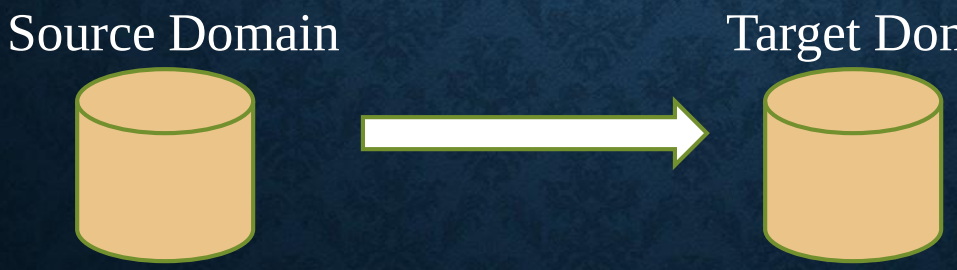
- *What is Transfer Learning?*
- What is Domain Adaptation?
- A Case Study in Supernova Ia Classification

MOTIVATION TRANSFER LEARNING

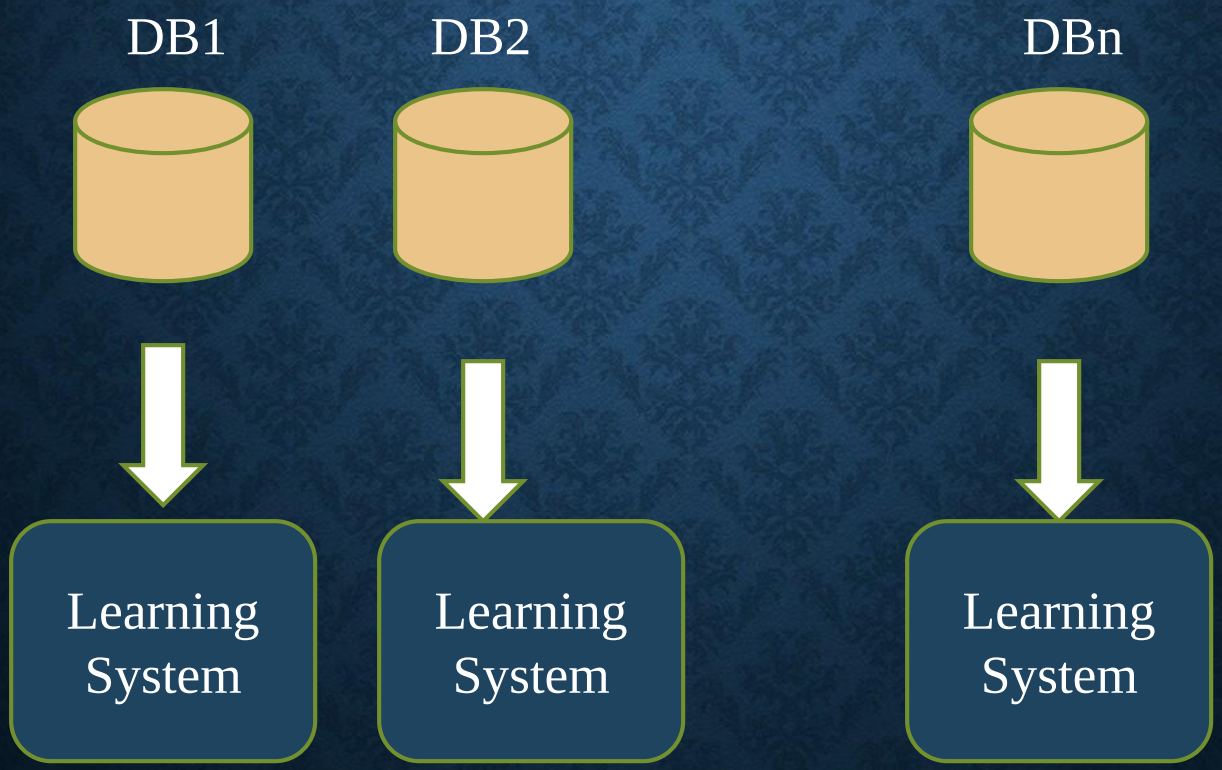
Motivation for transfer learning

- The goal is to transfer knowledge gathered from previous experience.
- Also called Inductive Transfer or Learning to Learn.

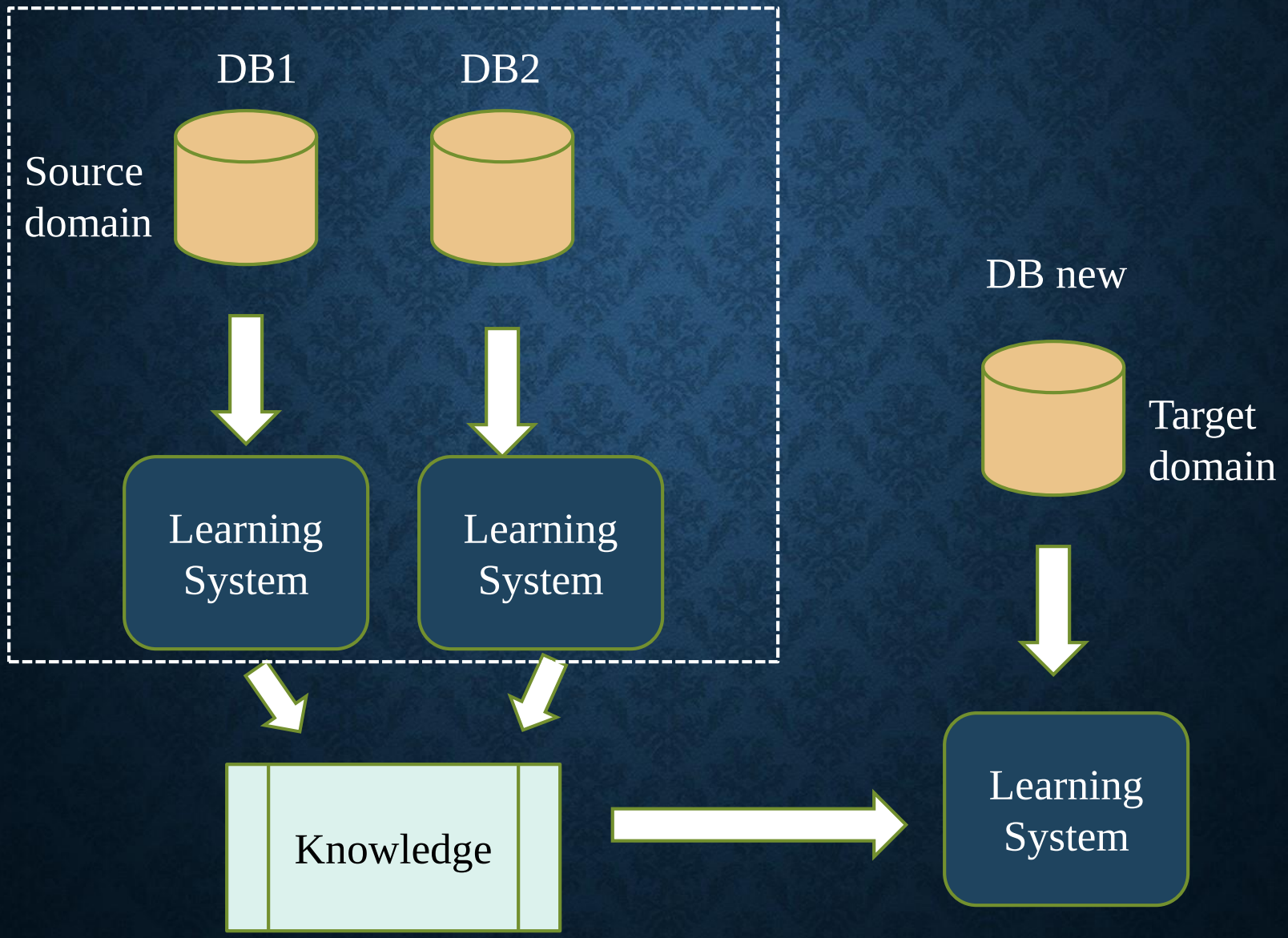
Once a predictive model is built, there are reasons to believe the model will cease to be valid at some point in time.



TRADITIONAL APPROACH TO CLASSIFICATION



TRANSFER LEARNING



TRANSFER LEARNING

Scenarios:

1. Labeling in a new domain is costly.

DB1 (labeled)

Classification of Cepheids

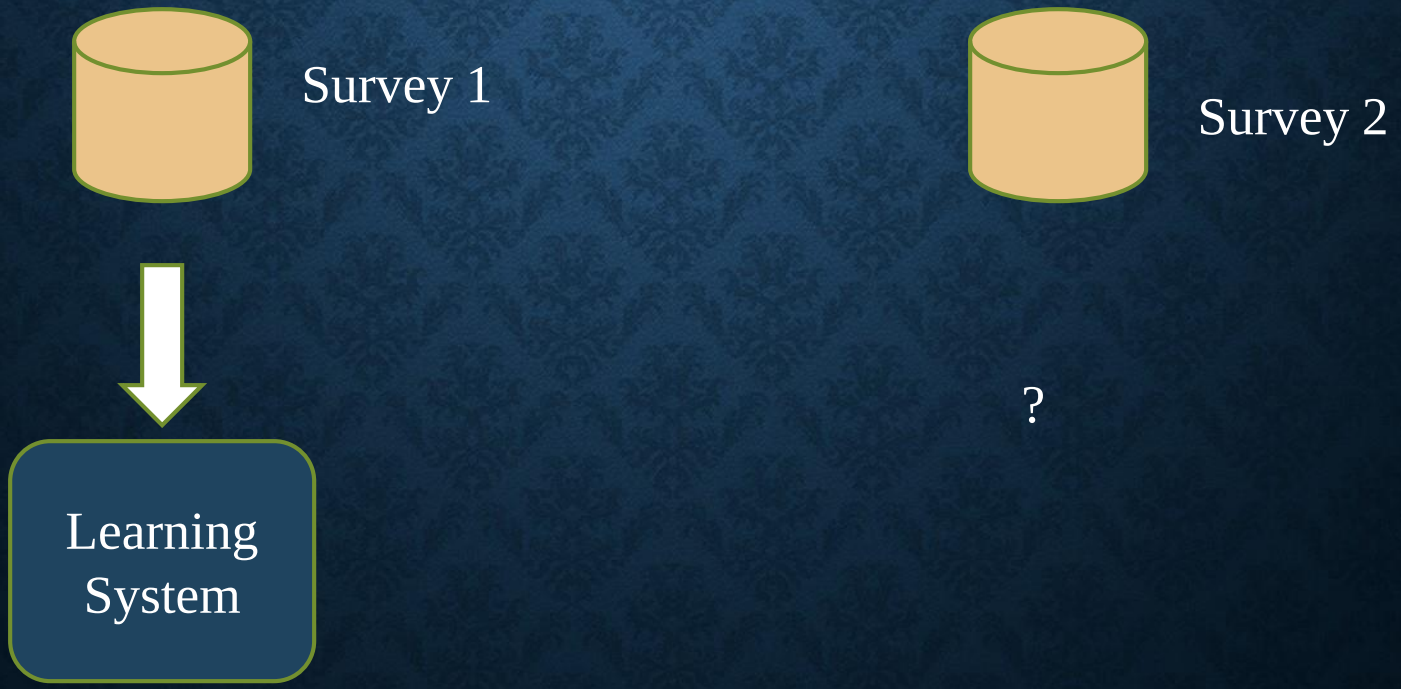
DB2 (unlabeled)

Classification of Long Period Variable Stars LPV

TRANSFER LEARNING

Scenarios:

2. Data is outdated. Model created with one survey but a new survey is now available.



MULTITASK LEARNING:
Train in Parallel with Combined Architecture

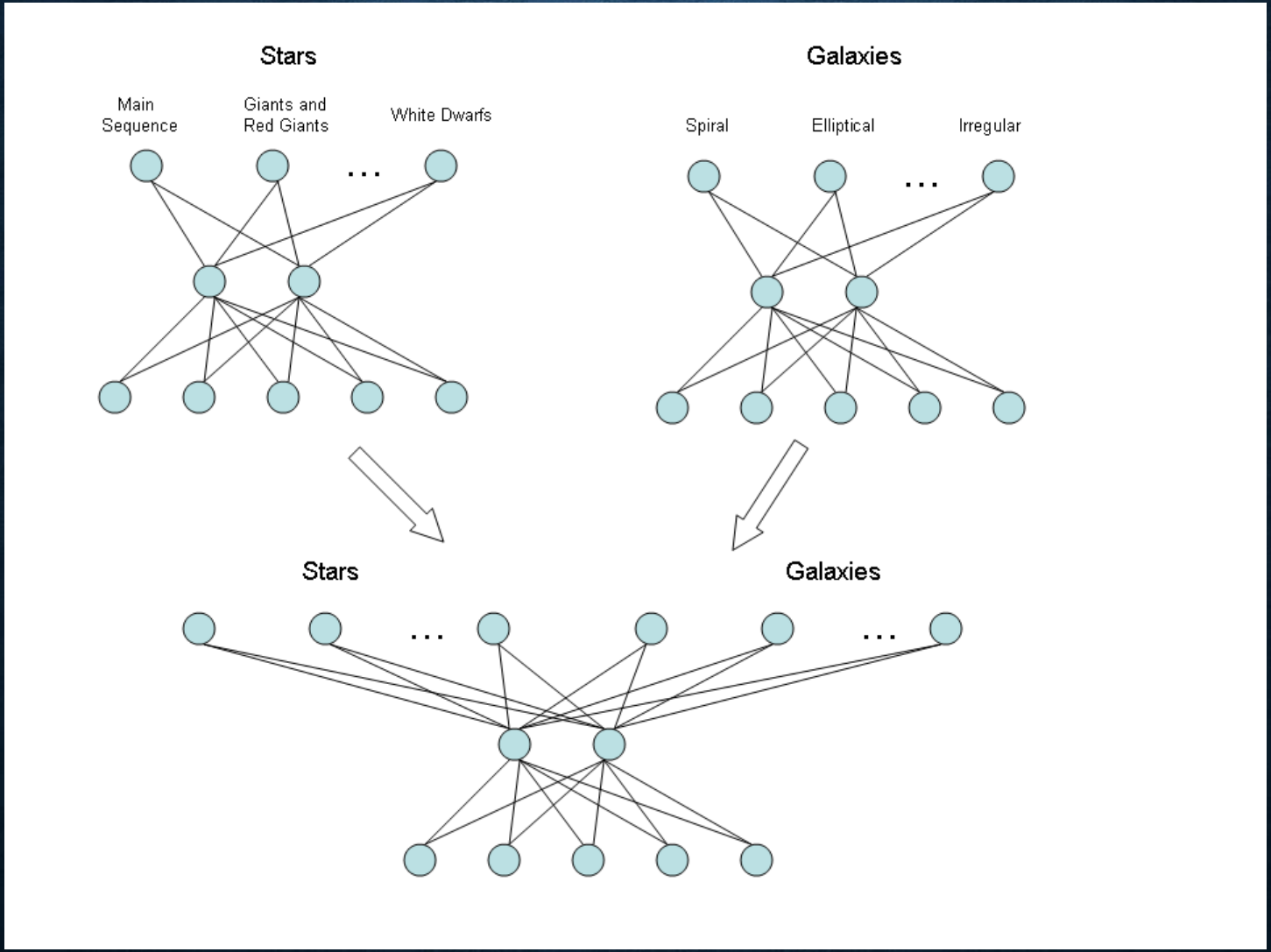


Figure obtained from Brazdil, et. Al. Metalearning: Applications to Data Mining, Chapter 7, Springer, 2009.

KNOWLEDGE OF PARAMETERS

Assume prior distribution of parameters

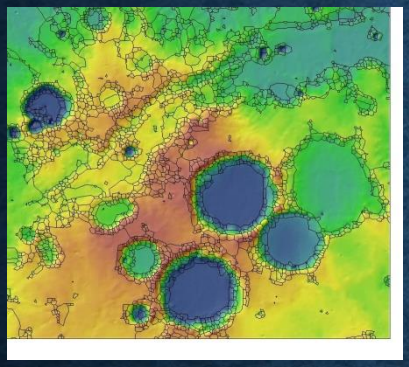
Source domain

Learn parameters and adjust prior distribution

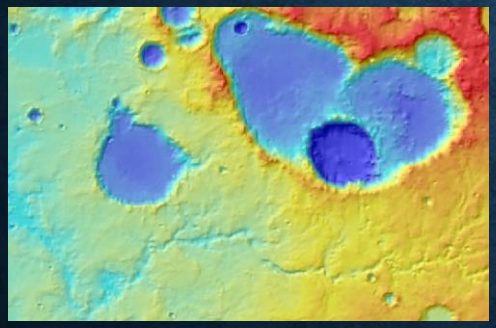
Target domain

Learn parameters using the source prior distribution.

KNOWLEDGE OF PARAMETERS

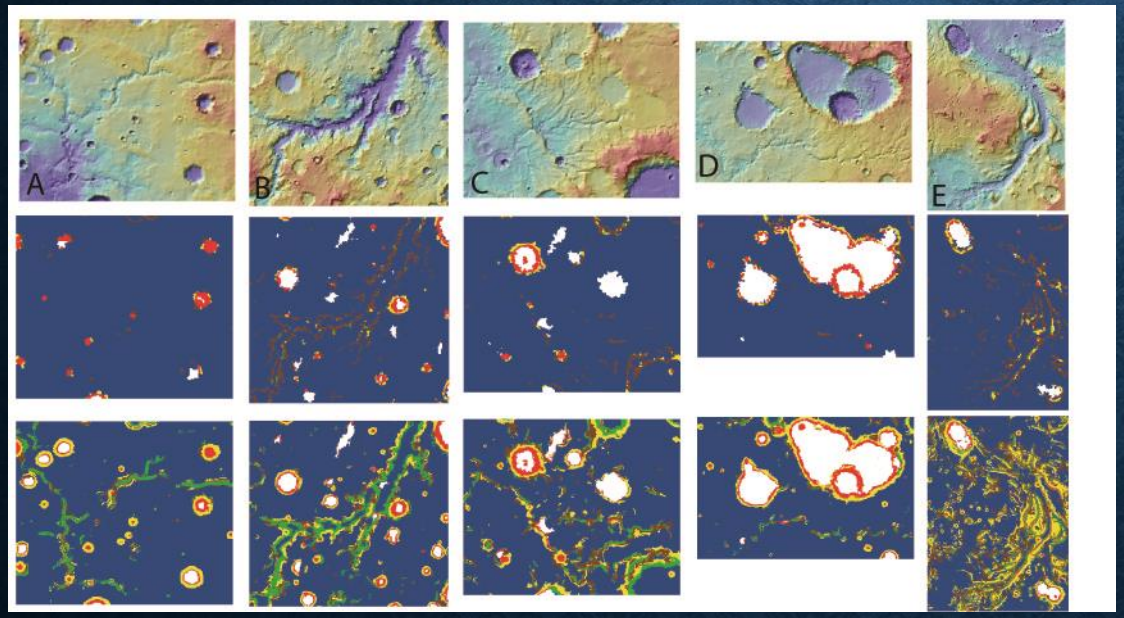


Find coefficients w_s using SVMs



Find coefficients w_T using SVMs initializing the search with w_s

FEATURE TRANSFER



Identify common
Features to all tasks

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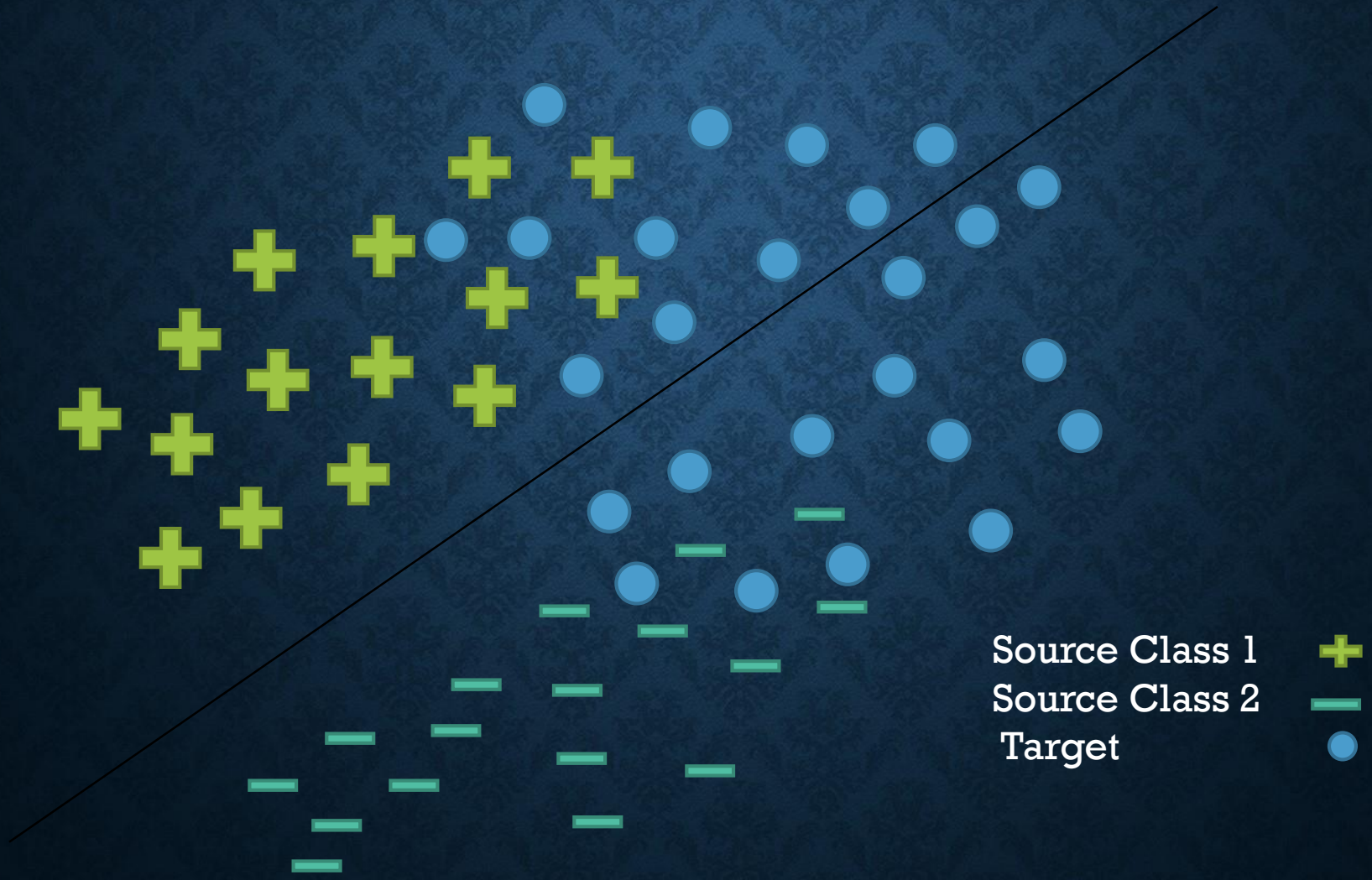
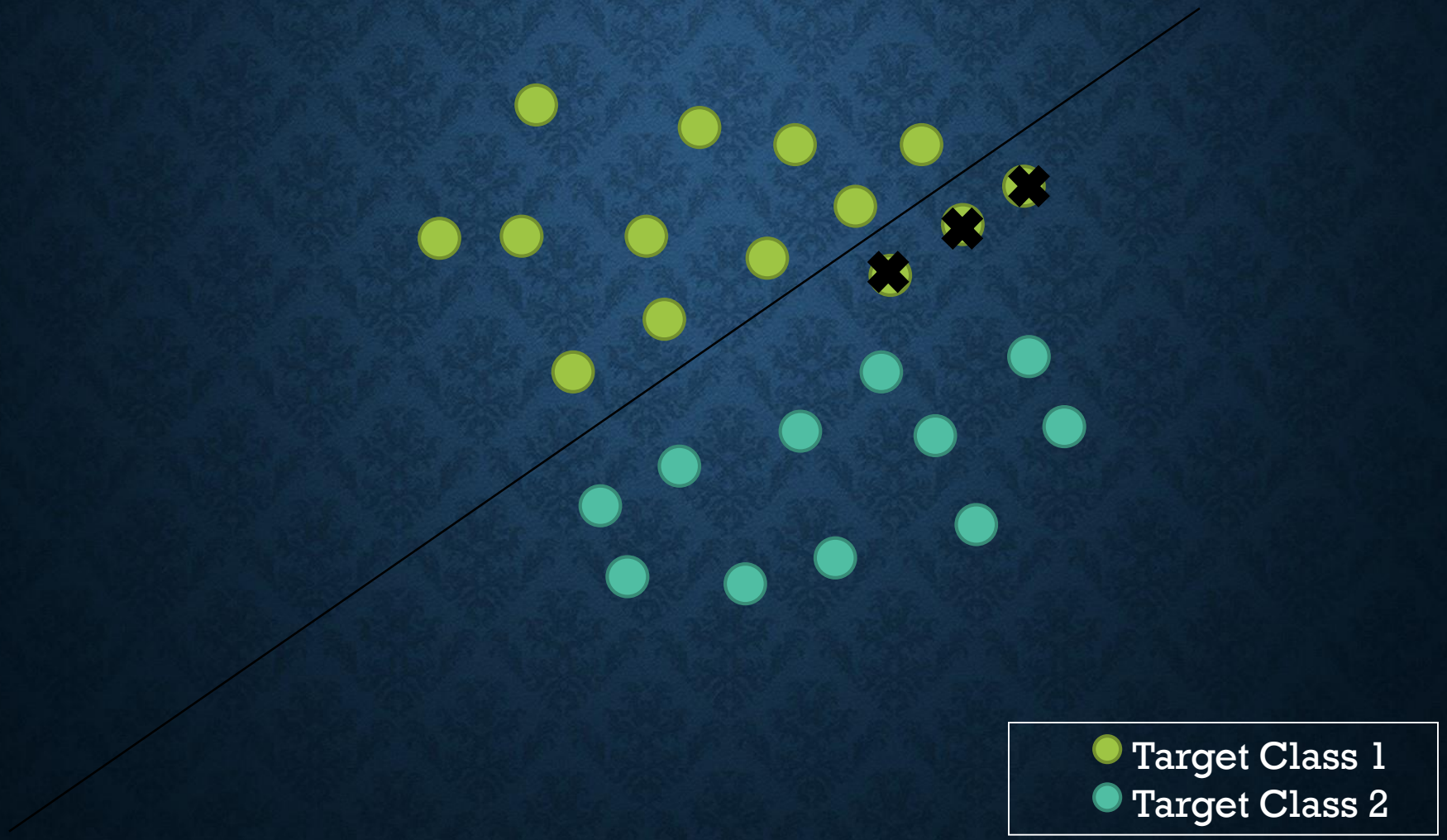
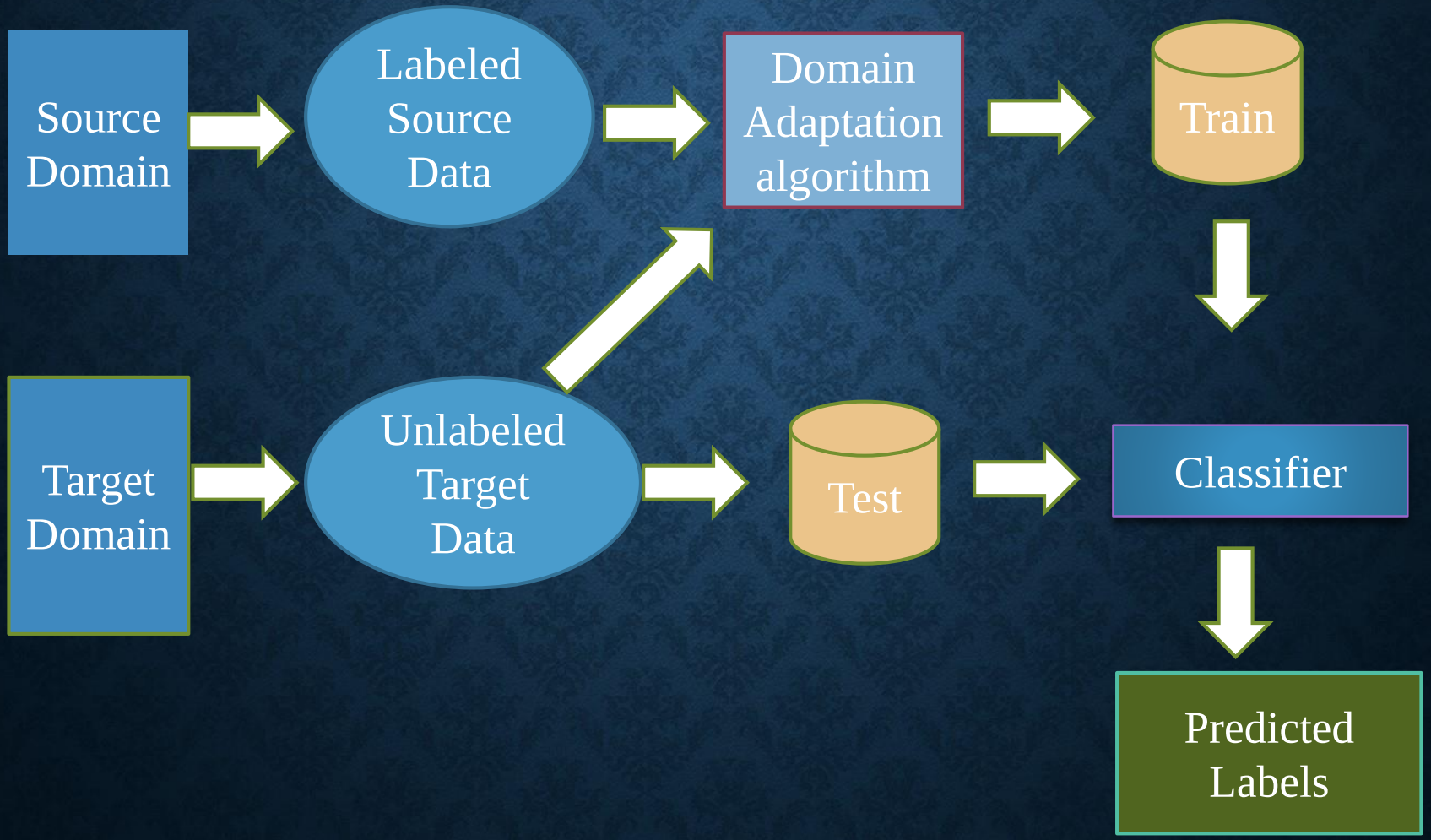
DOMAIN ADAPTATION



DOMAIN ADAPTATION



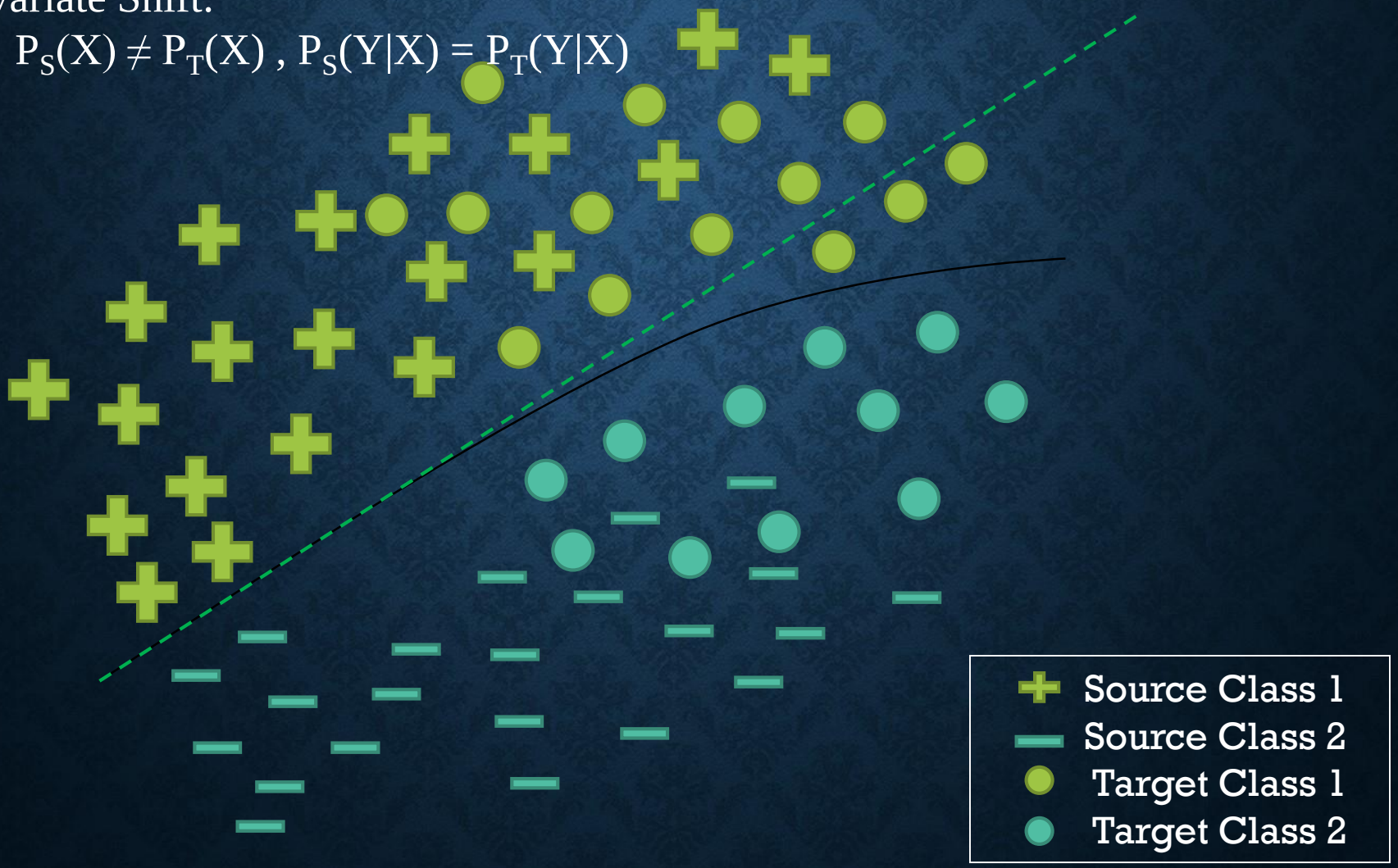
DOMAIN ADAPTATION



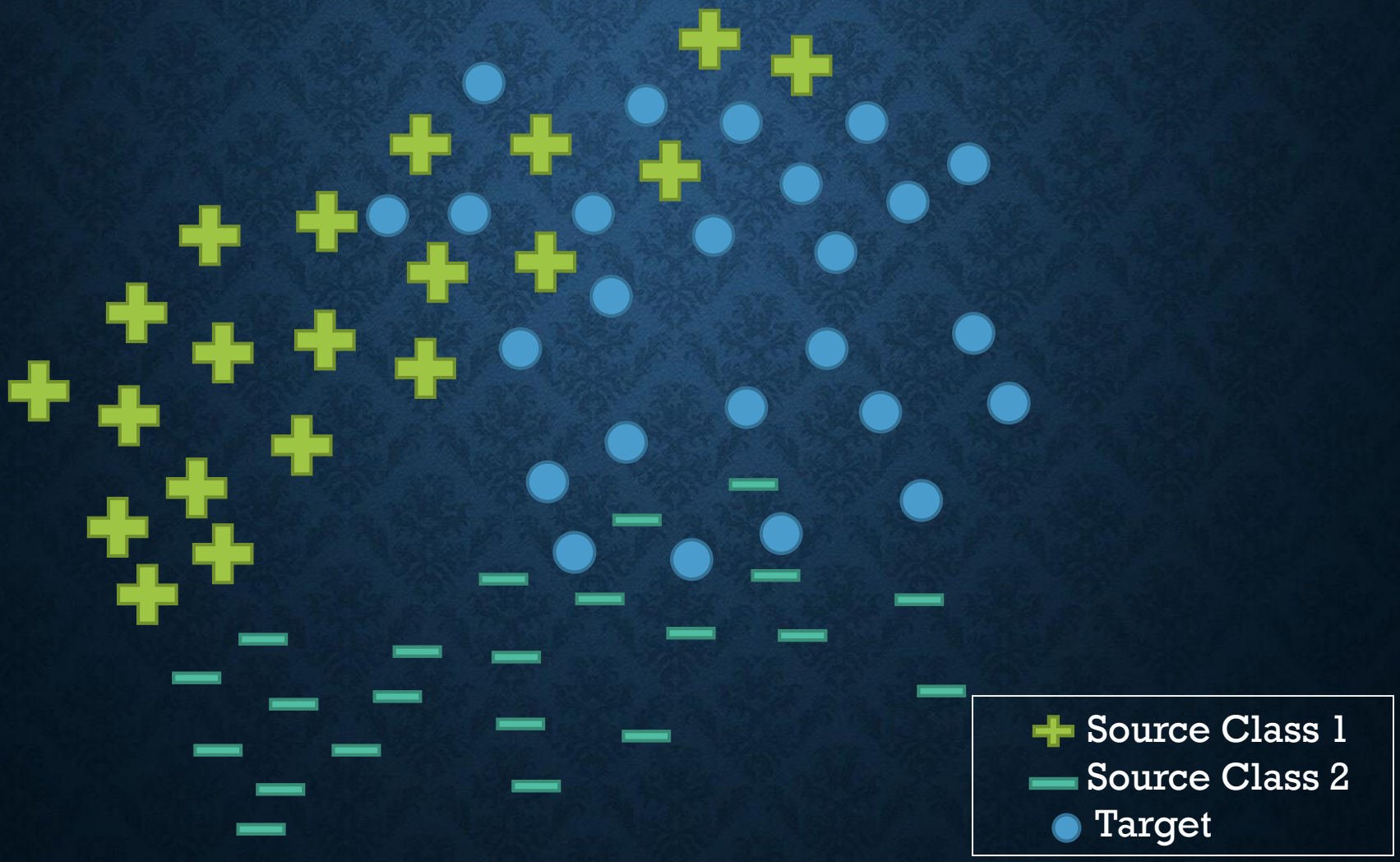
COVARIATE SHIFT

Covariate Shift:

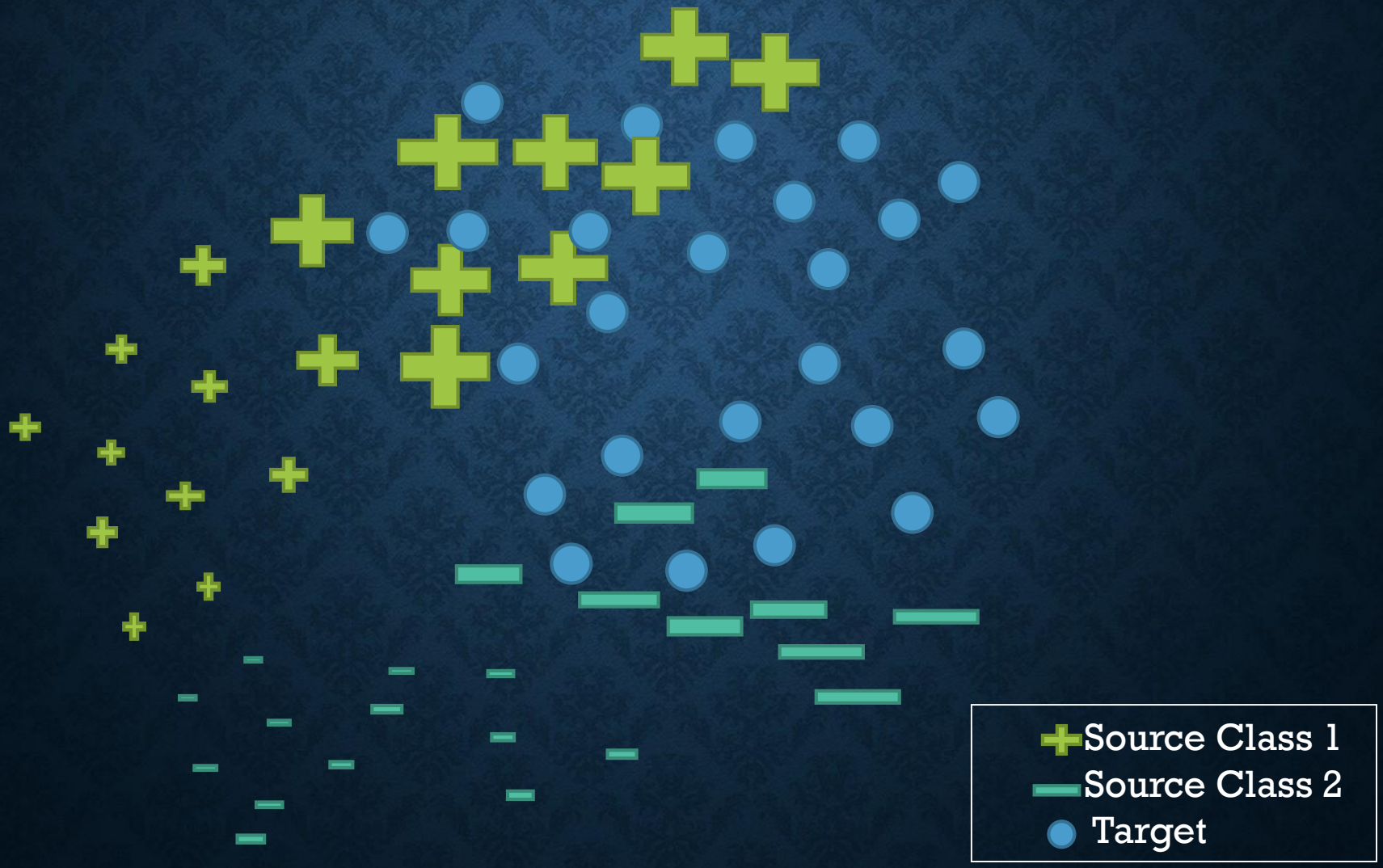
$P_S(X) \neq P_T(X)$, $P_S(Y|X) = P_T(Y|X)$



INSTANCE BASED METHODS



INSTANCE BASED METHODS



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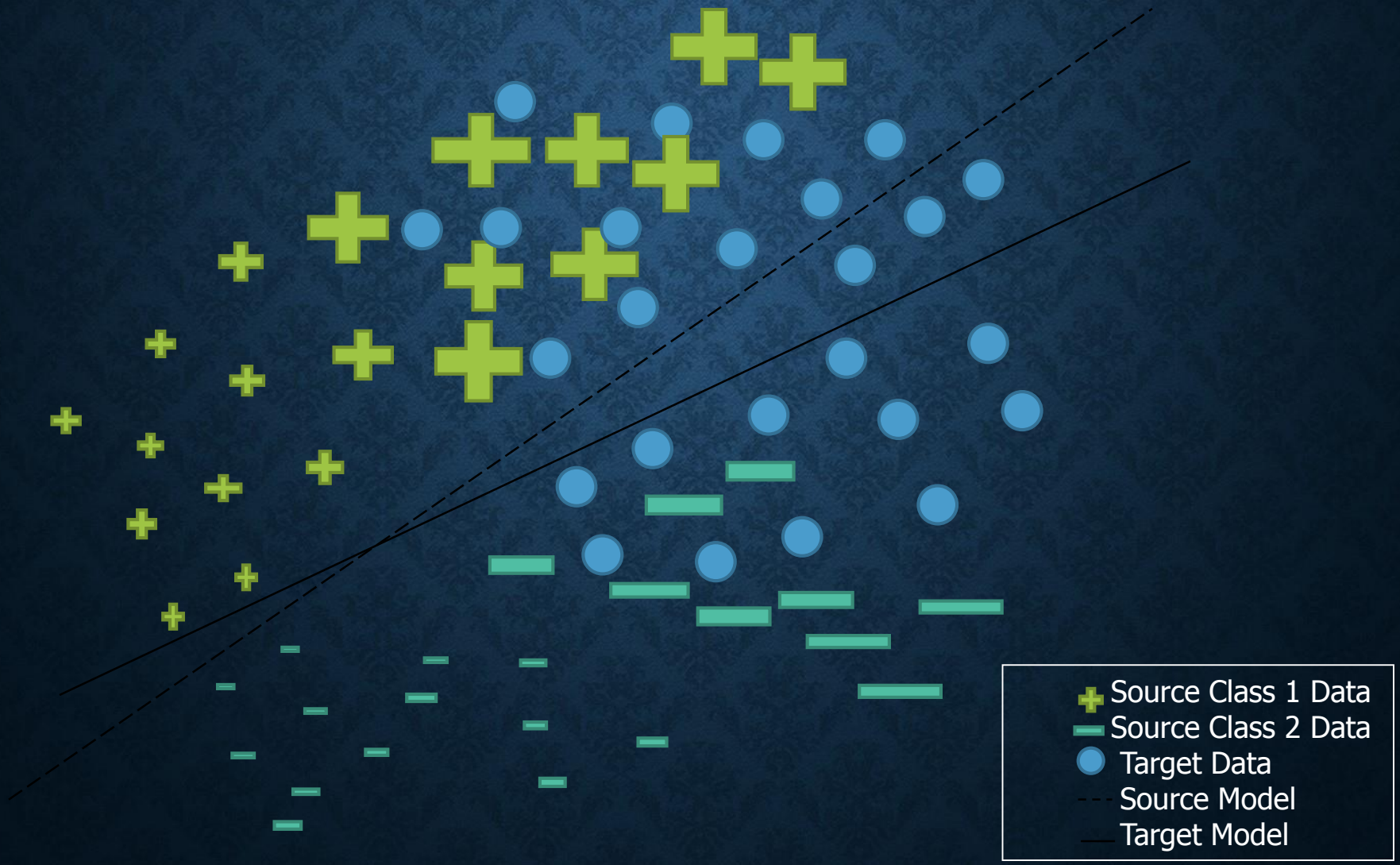
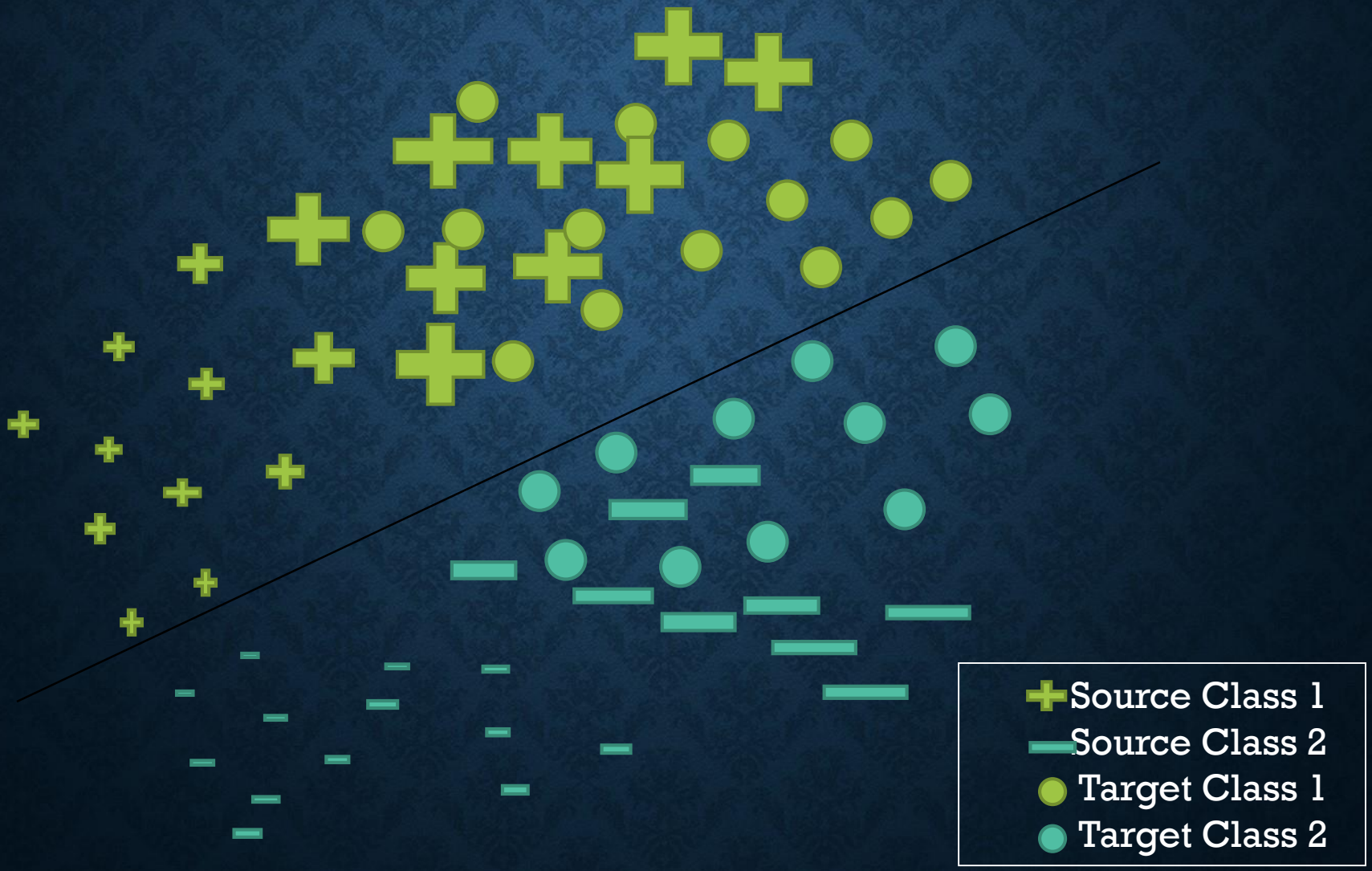


INSTANCE BASED METHODS



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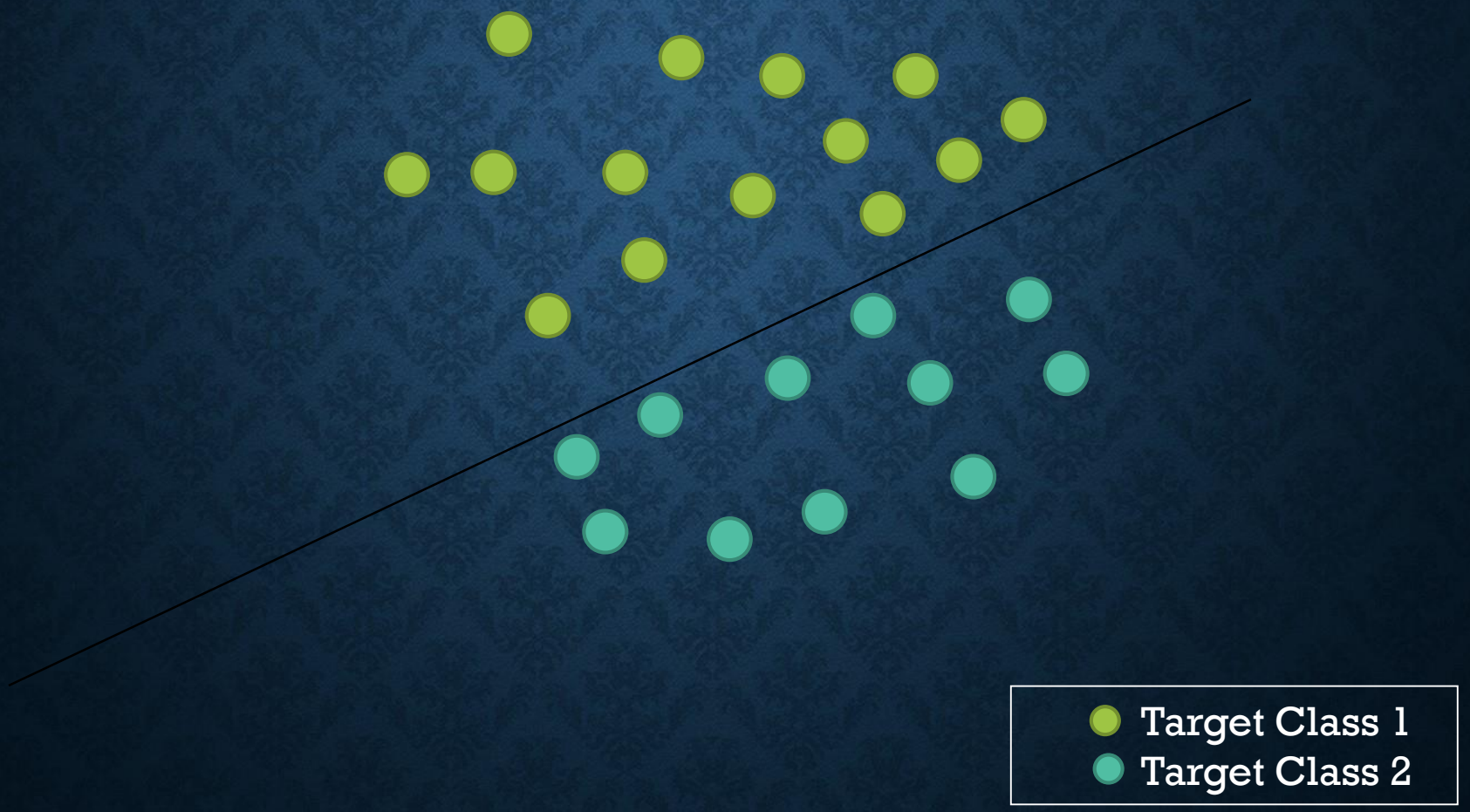
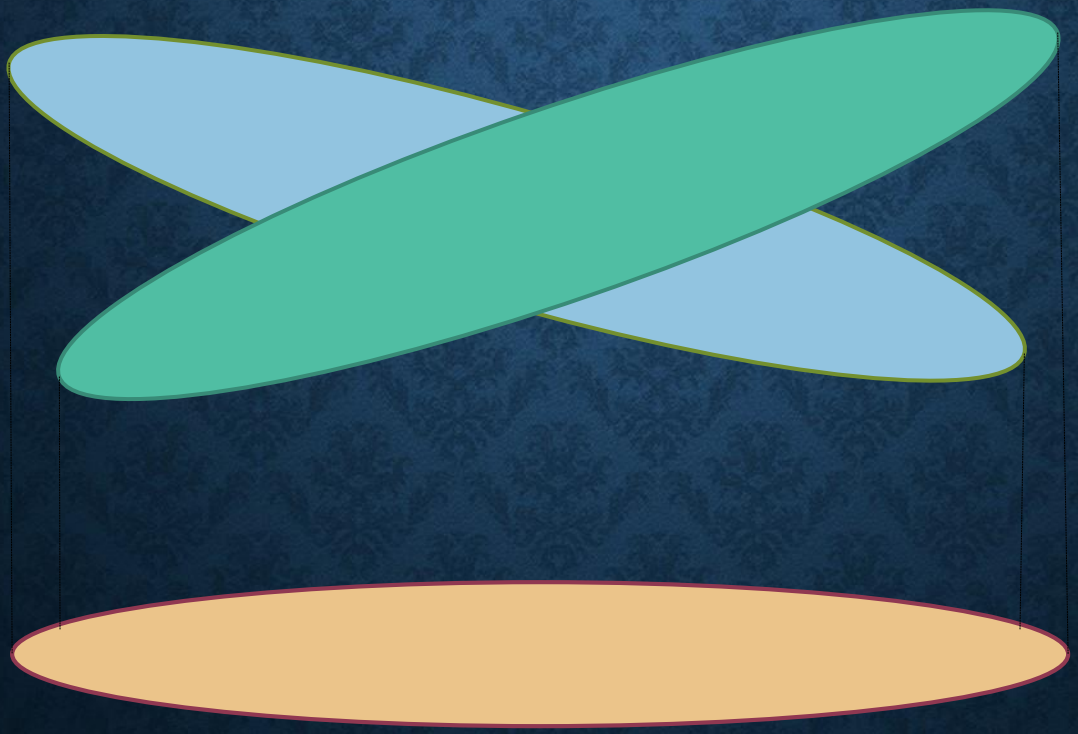
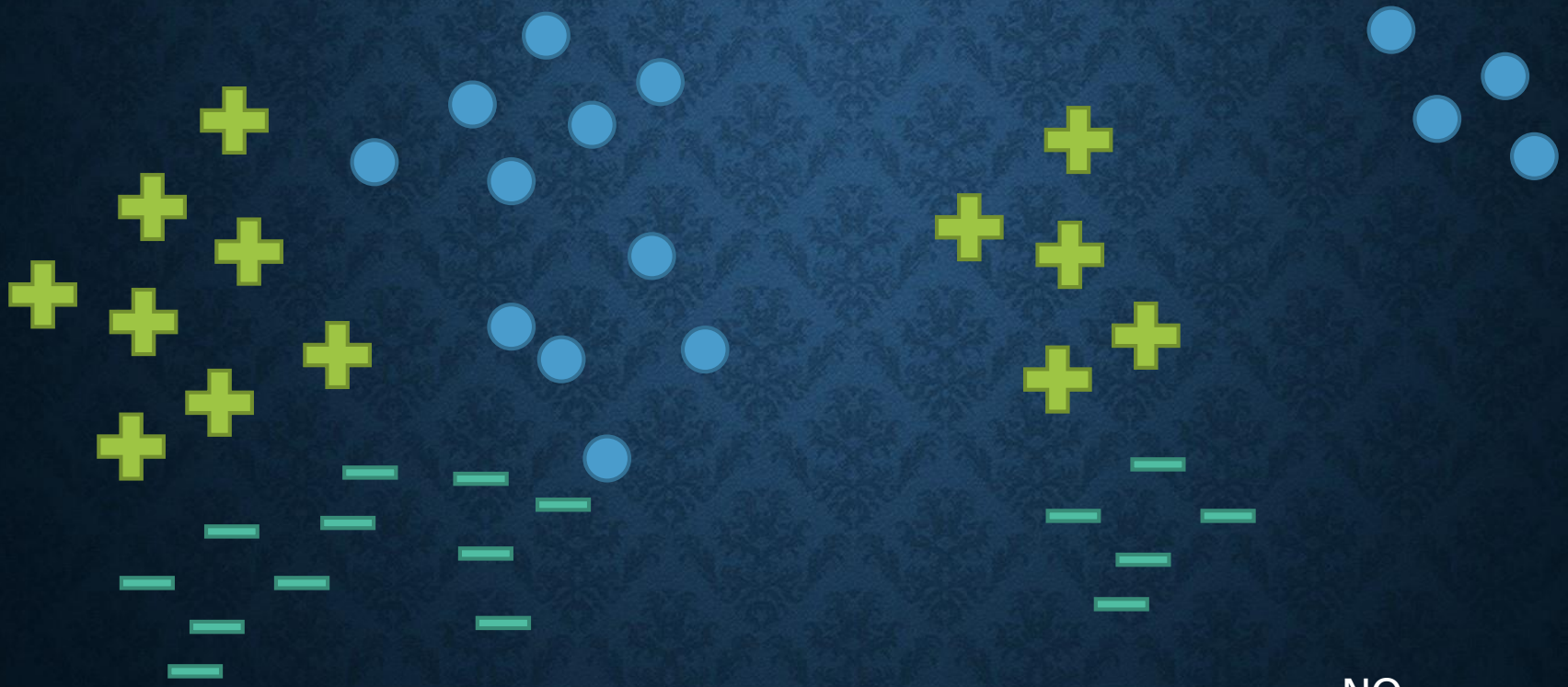


FEATURE-BASED METHODS

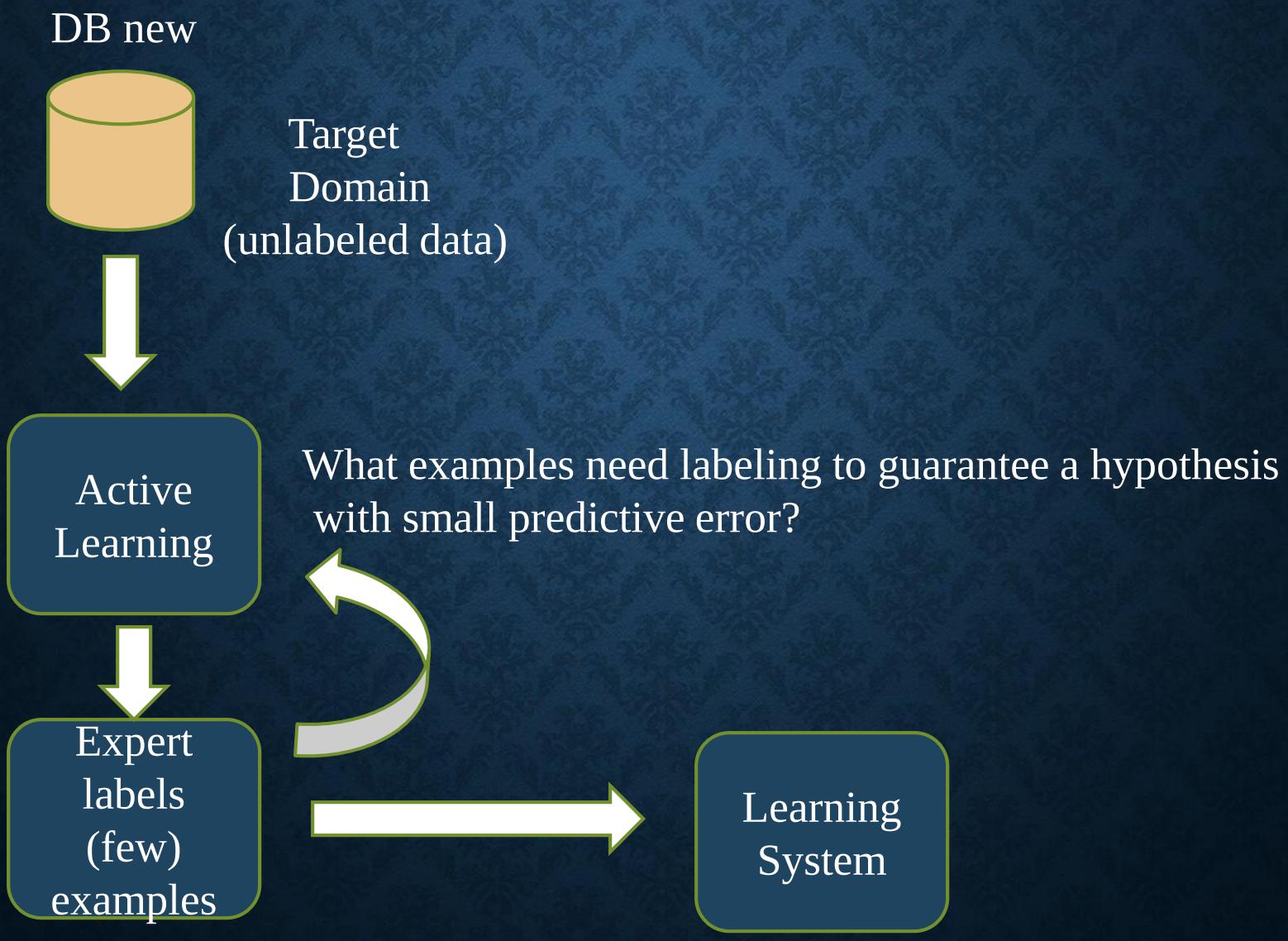
When source instances cannot represent the target distribution at all in the parameter space, we can project source and target datasets to common feature space (i.e., we can align both datasets).



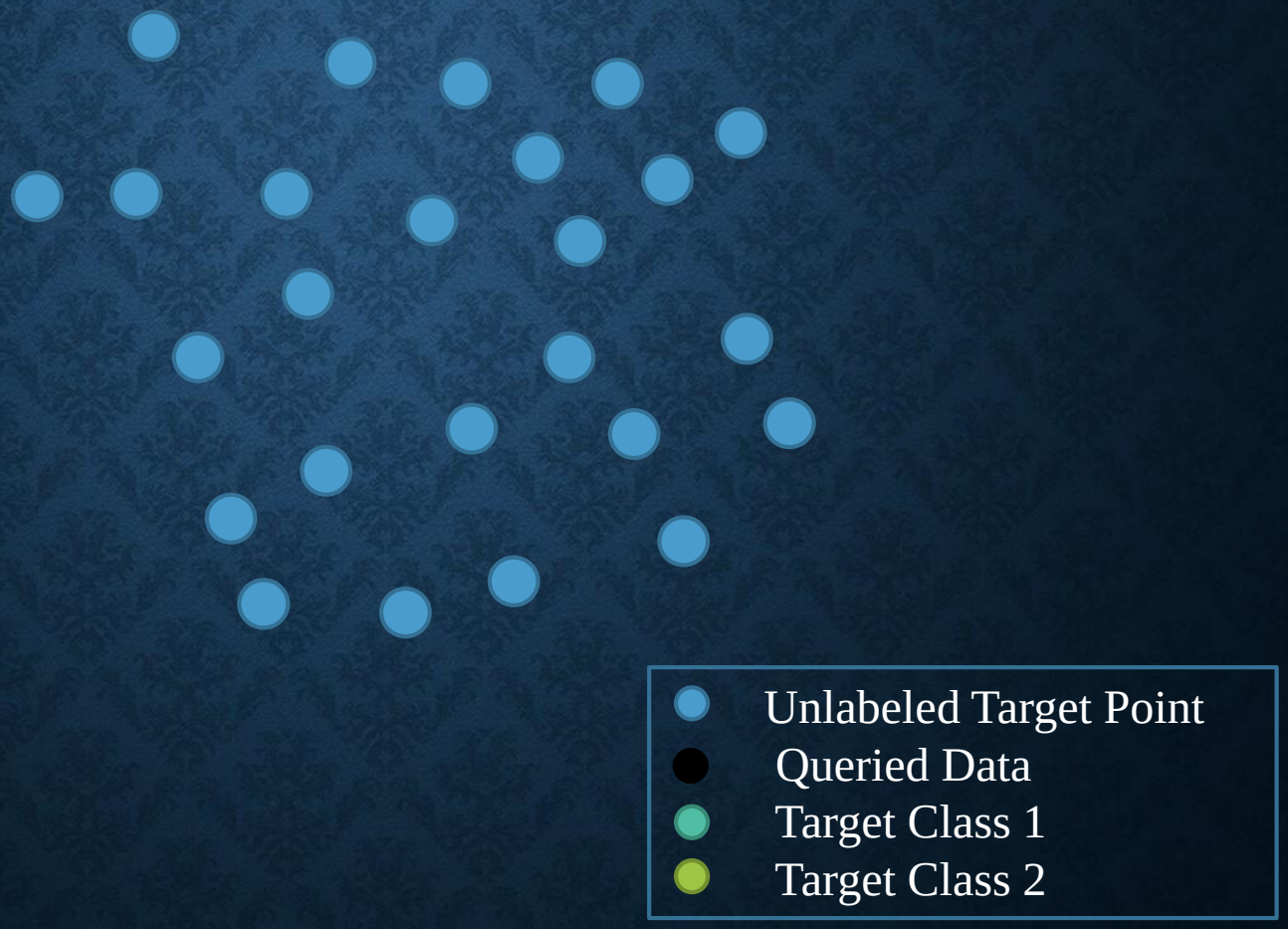
ASSUMPTIONS DOMAIN ADAPTATION



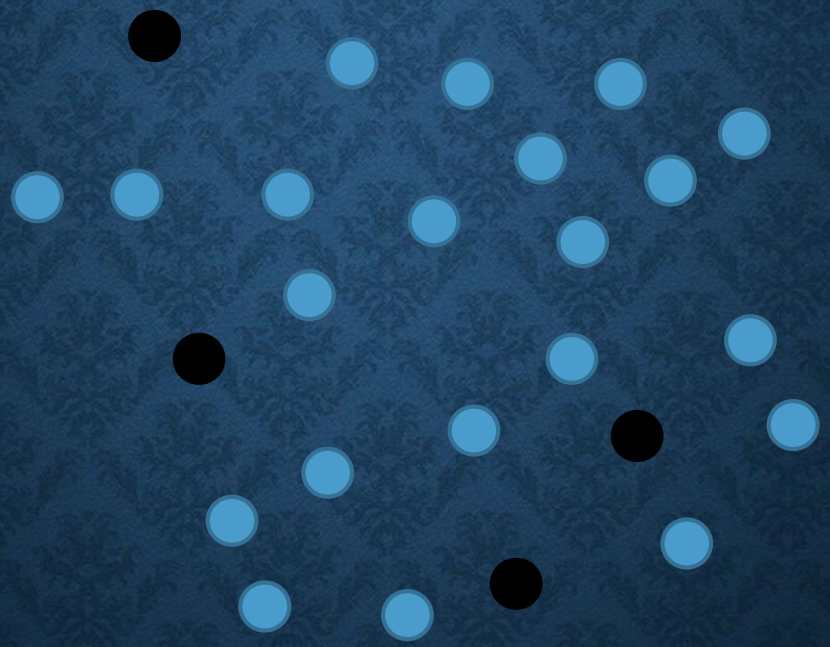
ACTIVE LEARNING



ACTIVE LEARNING

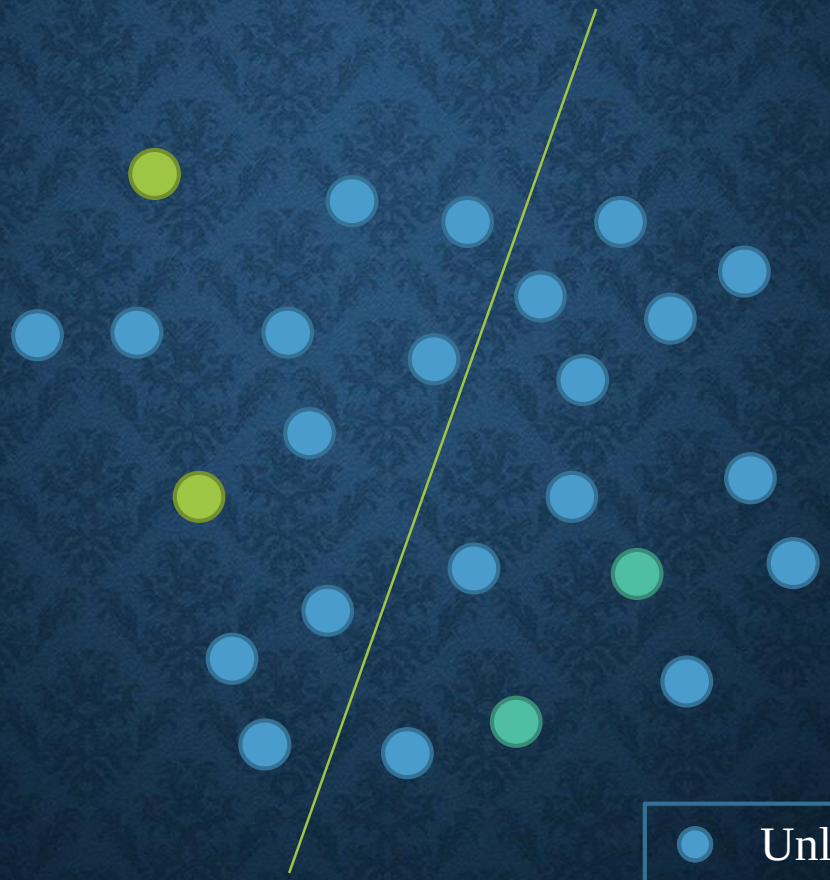


ACTIVE LEARNING

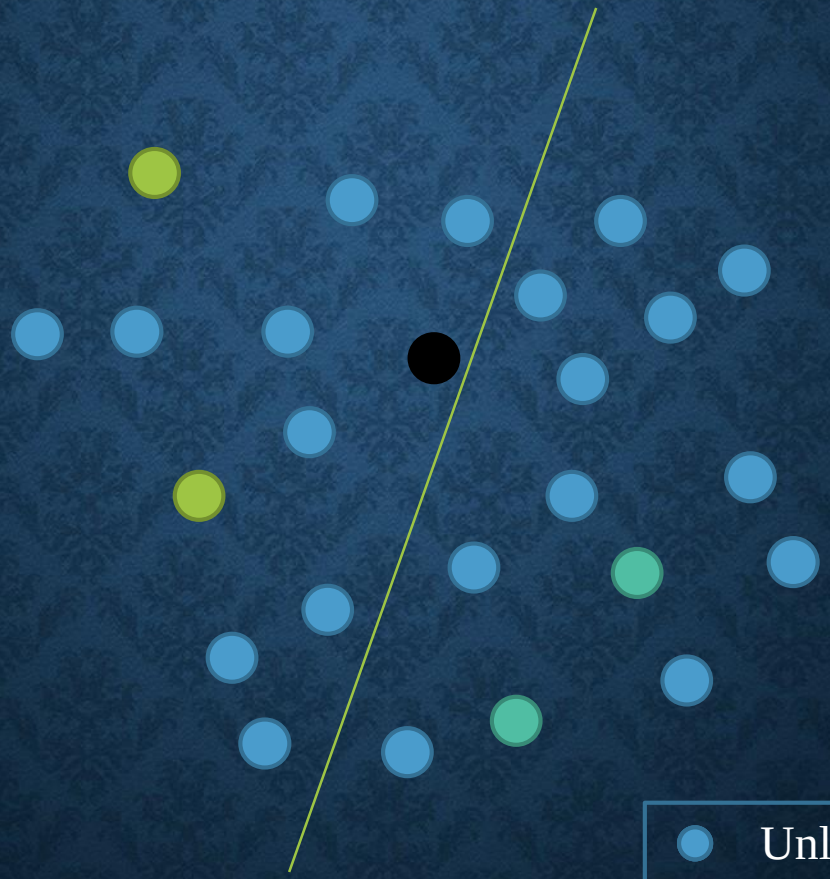


Unlabeled Target Point
Queried Data
Target Class 1
Target Class 2

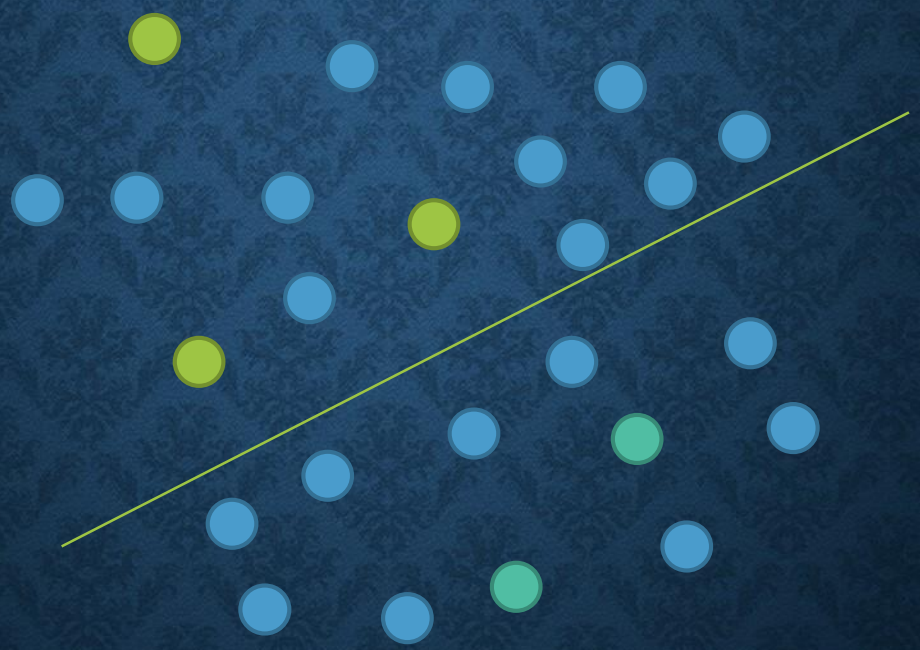
ACTIVE LEARNING



ACTIVE LEARNING

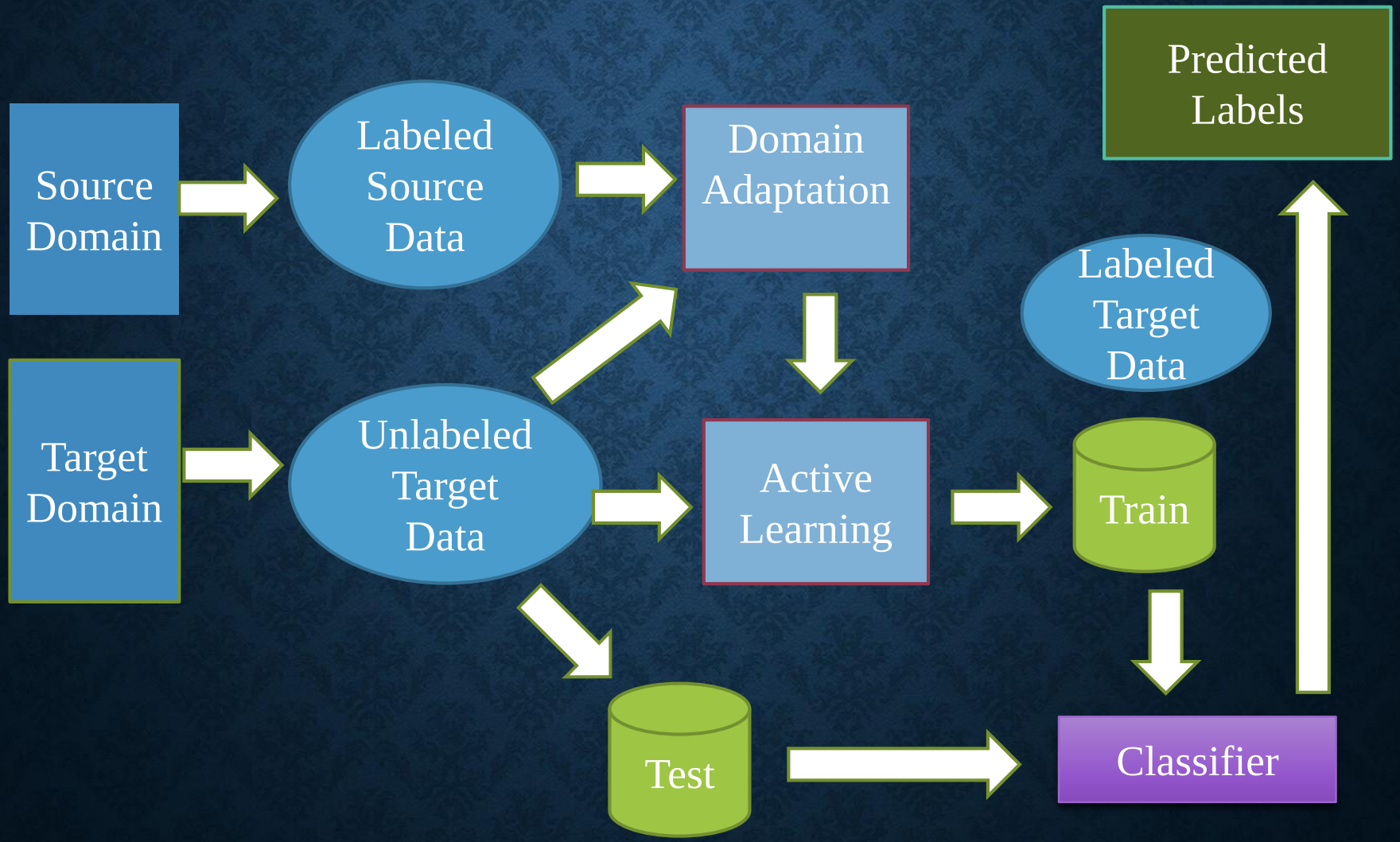


ACTIVE LEARNING



Unlabeled Target Point
Queried Data
Target Class 1
Target Class 2

DOMAIN ADAPTATION + ACTIVE LEARNING



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SOURCE AND TARGET USING SUPERNOVA DATASETS

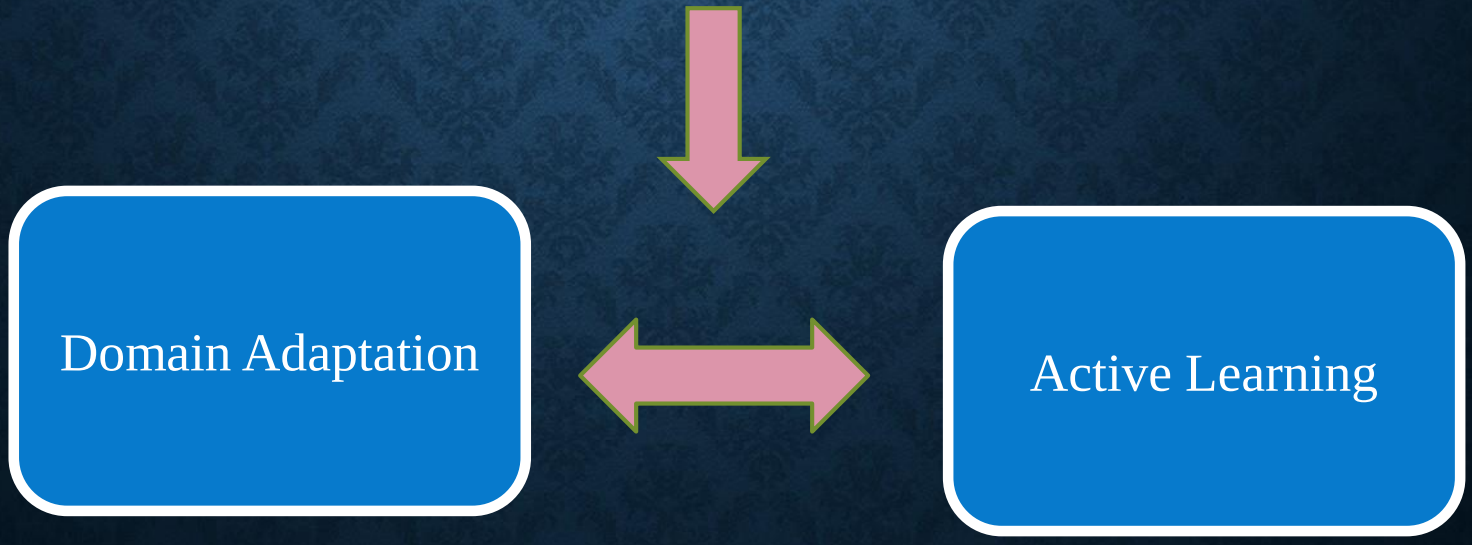
- Spectroscopy
  - Enable parameter inference from astronomical data
    - determine the presence of individual chemical elements (spectral lines)
    - infer the distance (redshift) to extragalactic sources
  - Expensive and time-consuming process
  - Unfeasible to obtain measurements for all cataloged objects

- Photometry:
  - Low resolution counterpart
  - Summarize the intensity of electromagnetic radiation in a handful of broad wavelength windows (filters).
  - Information on individual spectral lines is not accessible.

OVERVIEW

Automatic SN Classification Using Machine Learning

Training data labeled through spectroscopy
Test data obtained through photometry



SAMPLE SELECTION BIAS

Training Set

Brighter nearby objects (spectroscopy)

Test Set

Extensive Deeper Surveys (photometry)

Main assumption in **supervised** learning is not warranted

AUTOMATED CLASSIFICATION OF SUPERNOVA IA

How can we take advantage of existing supernova datasets already classified using spectroscopy to develop an automated classification method using new photometric surveys?

EXPERIMENTAL SETUP

- Data Acquisition:
  - Simulated data stemming from the Supernova Photometric Classification Challenge, traditionally called post-SNPCC
  - Mimic the characteristics of Dark Energy Survey (DES) data
  - Select only objects having at least 3 observed epochs per filter, with at least 1 of them being before -3 days and at least 1 after +24 days since maximum brightness.
  - In each filter, light curve fitting is performed using Gaussian process regression, and the resulting function is sampled with a window of 1 day. No quality cuts are imposed (SNR>0).

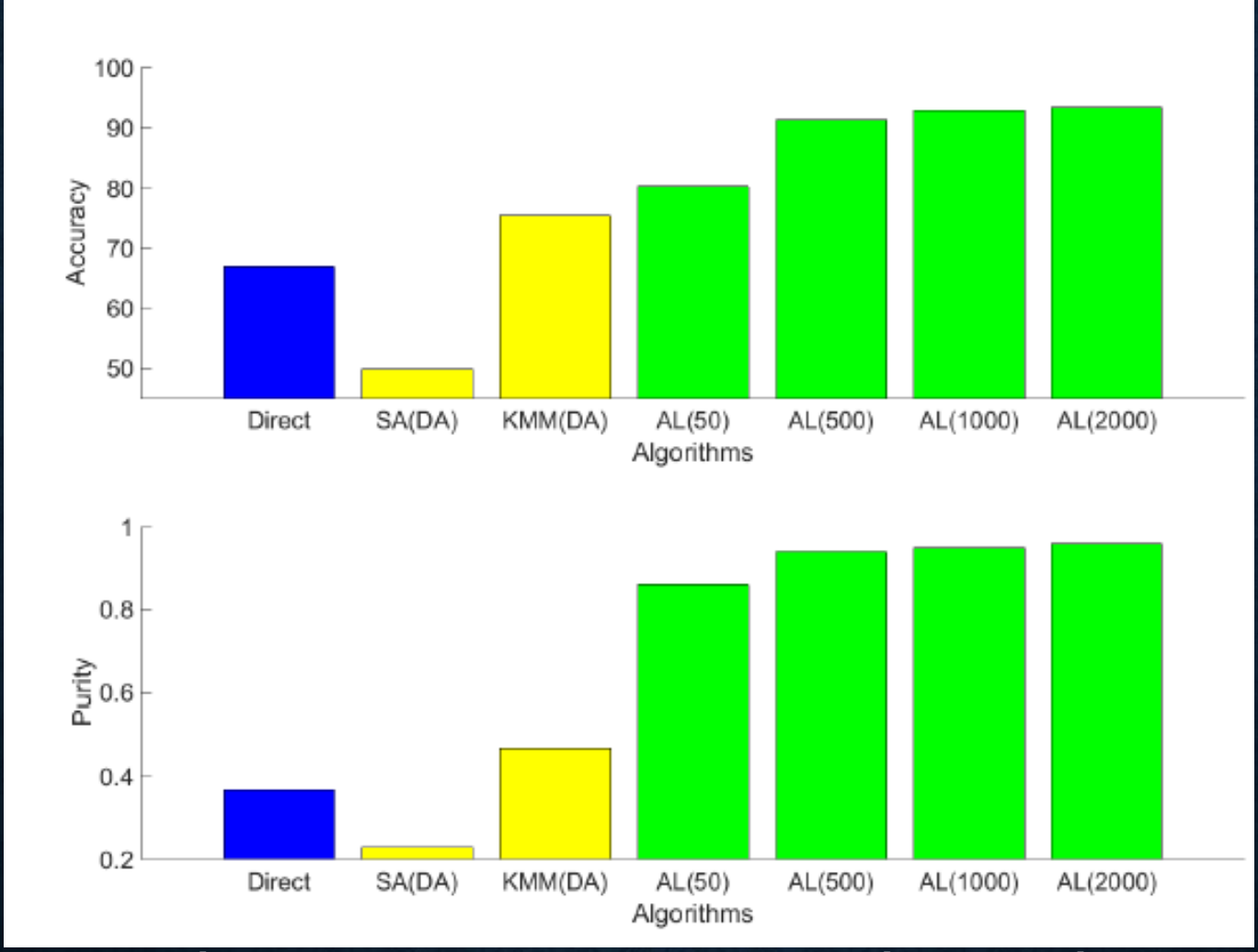
- Datasets:
  - Source Dataset - Labeled (Photometric)
  - Test Dataset – Unlabeled (Spectroscopic)

EXPERIMENTAL SETUP

- Dimensionality Reduction :
  - Original : 108 Features
  - For this research : 20 Features, reduced by KPCA

- Active Learning :
  - 50% Pool, 50% Test
  - 10 Pairs
  - 10 Runs

RESULTS: ACCURACY AND PURITY



Accuracy and Precision on Target Data using Domain Adaptation and Active Learning.

THANK YOU!