Classification Spectroscopy

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What is the US plan for spectroscopic classification in era of LSST?

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“We’d all like more spectrographs, but I don’t think we’re going to get them.”

Is Single-object Spectroscopy Necessary?

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Science themes that require rapid classification

- Distribution of Matter at low redshift via velocity flows (Ia SNe) catalogs
  - => Are light curves sufficient for classifying?
- Local Death of Stars rate (Luminosity function of core-collapse SNe)
  - => Light curves sufficient?
- Clues to progenitors of supernovae (by routine, robotic and rapid spectroscopy)
  - => Gut indicates that MOS is required
- TDE/AGN studies with TDA+MMS+SRG ("leave no nucleus behind”)
  - => Rapid response spectroscopy?
- Flux-limited SNe sample: explore phase space, redshift completeness of galaxy
  - => Rapid response spectroscopy required
- A dedicated TDA+MMS facility? perhaps a TDA+MMS facility along with a stable of SEDM equipped telescopes?

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Peter Nugent

- Provide some history of early days of classification and how that weaves into the future

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	Rapid response spectroscopy	MMS spectroscopy	Photometry
Velocity flows	Key science case?		
Galactic black holes		Seems required	AO?
CCSN Lum function			
Progenitor stars	Likely too inefficient	Seems required	
TDE/AGN studies			
Flux limited SNe	Key science case		
Flux limited galaxy sample		Seems required	Narrow band filters?

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So how do we do better? What’s special now?

- SED Machine is highly sought after and successful. Remember, before SED Machine existed the notion that a 1.5-m telescope would be a relevant rapid classification facility was suspect.
- There is a key technological improvement
- New business models
- Machine learning

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Spectral Resolution

- When SED Machine started we picked spectral resolution by convolving various templates and running through various automatic classifiers.
- Robert Quimby (SDSU) showed that R~50 was probably OK but we picked R~100 to be safe.
- Anna Ho is an expert on the problem of “label transfer” and so I asked her to comment on how more modern techniques might be used.

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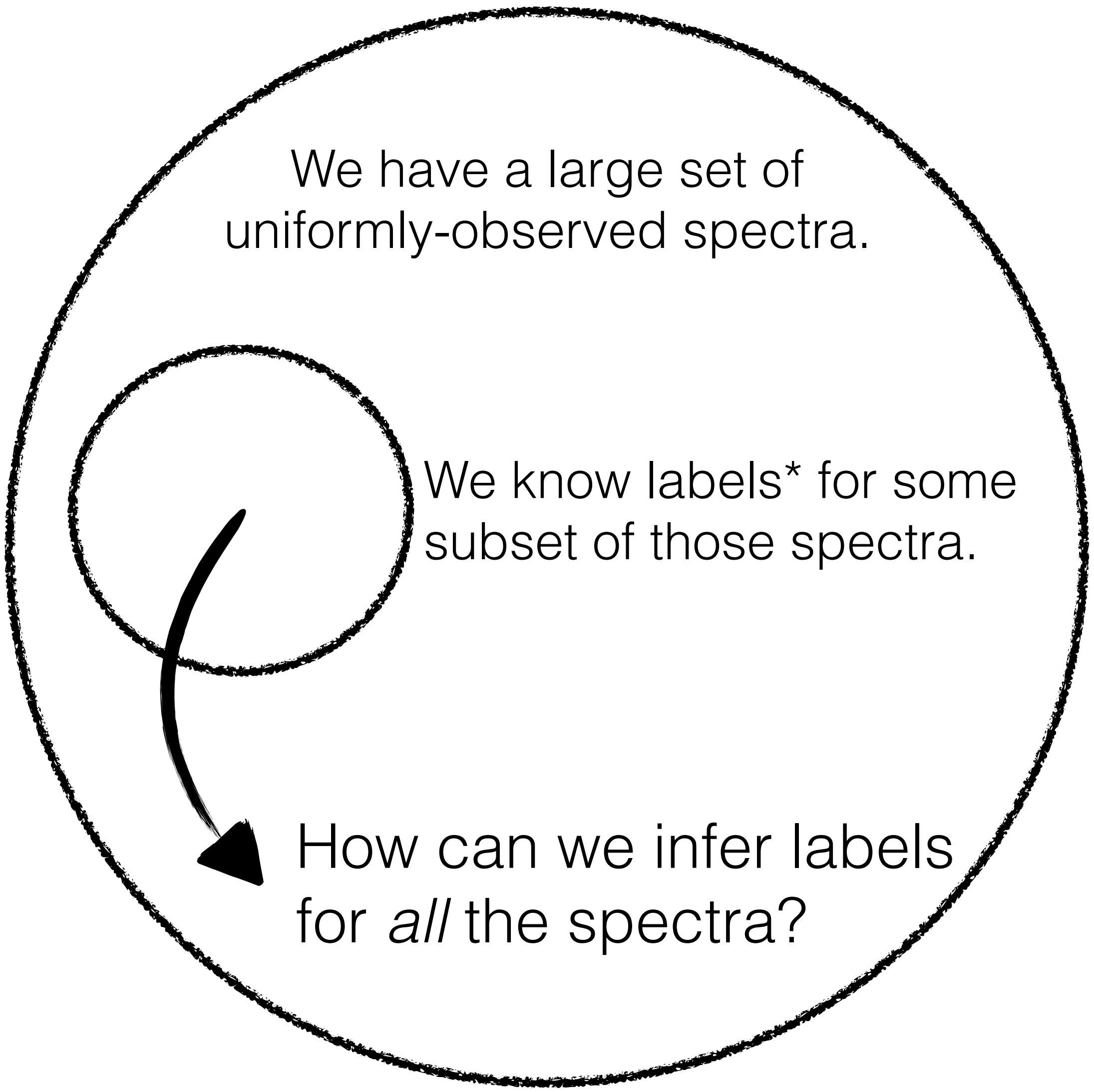
Data-driven modeling in the era of large spectroscopic surveys

Ho et al. (2017a), Ho et al. (2017b)

with *The Cannon* team: Hans-Walter Rix, David Hogg, Melissa Ness, and Andy Casey



*physical parameters:
temperature, logg, mass, individual element abundances…

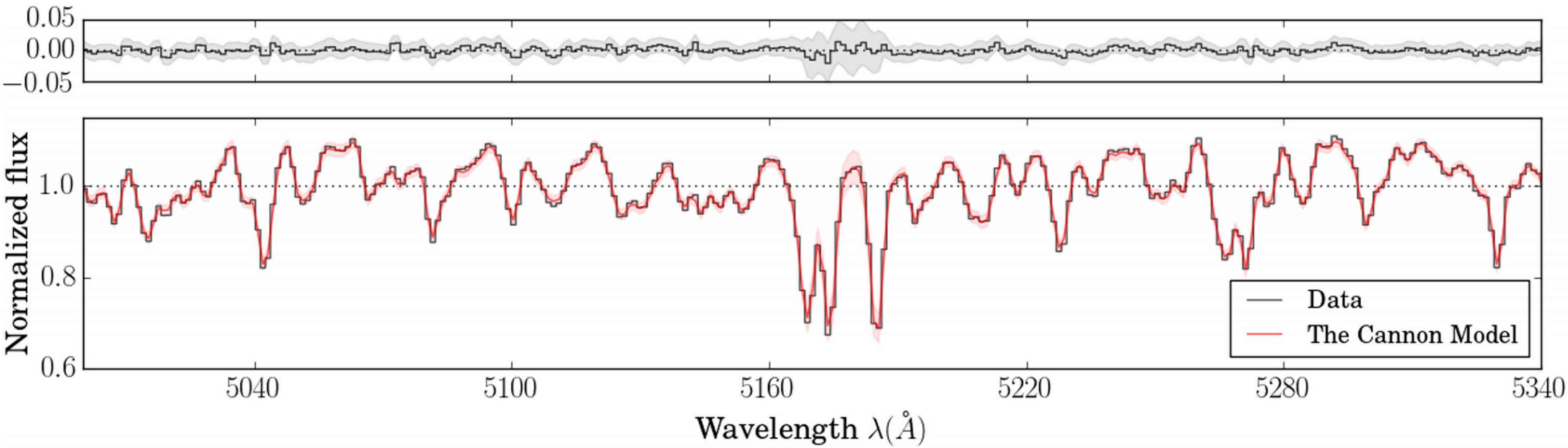
Motivation

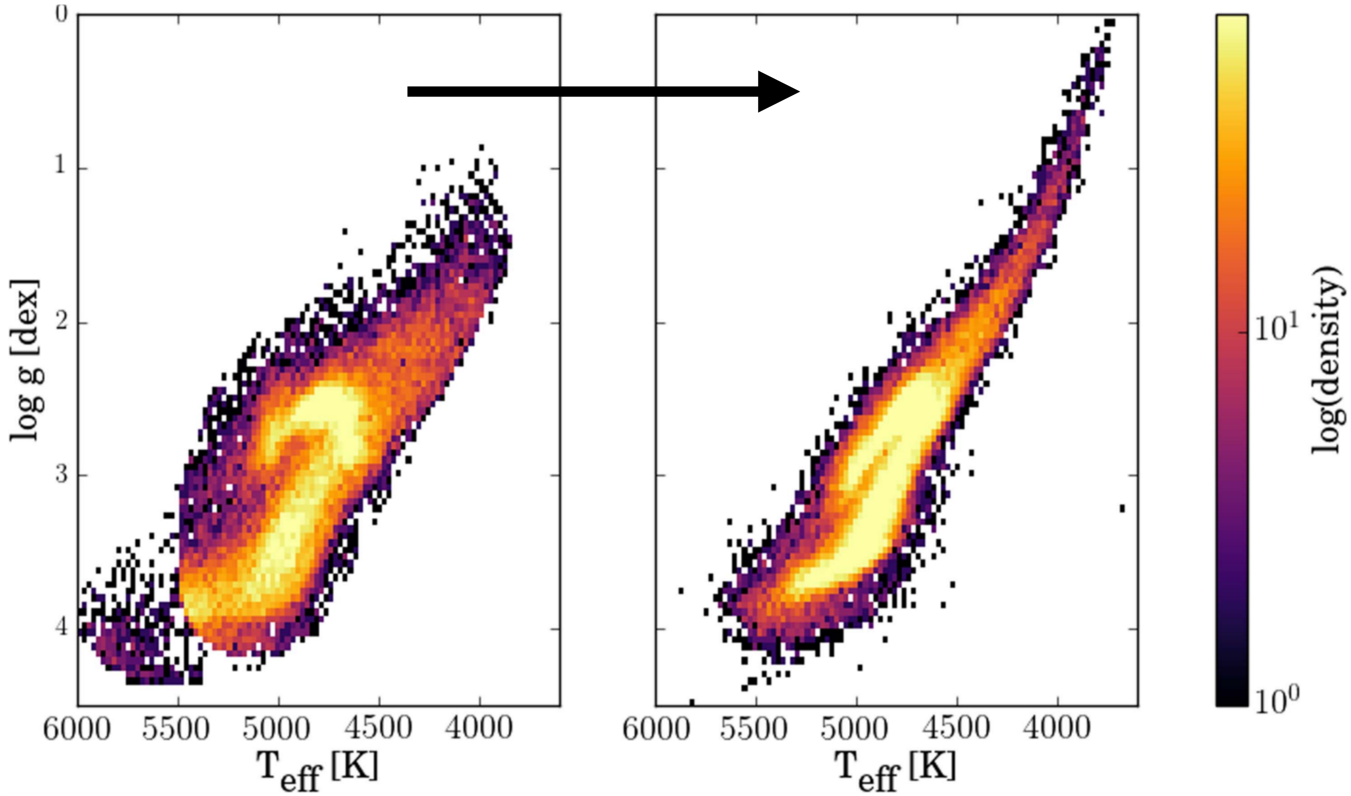
- massively multiplexed stellar surveys are delivering spectra for millions of stars (LAMOST, APOGEE, GALAH, RAVE, Gaia, …)
- quality of spectra cannot be captured by physical models
- labels should be a property of the object, not the spectrograph
- need to be fast
- high-resolution & high SNR —> demands on instrumentation & exposure time

Principles

- by simultaneously fitting all labels, can achieve comparably high precision at low resolution (Ho et al. 2017a&b, Ting et al. 2017, 2018, …)
- by modeling noise, can achieve high precision at low SNR (Ness et al. 2015, Casey et al. 2016, Ho et al. 2017a, …)
- at some lower bound (R ~ 100) estimates for labels become more correlated and estimates become less precise (Ting et al. 2017)
- can let the data improve our physical models (Ness et al. 2016, Casey et al. 2016)

Applications to R ~ 1800 LAMOST spectra

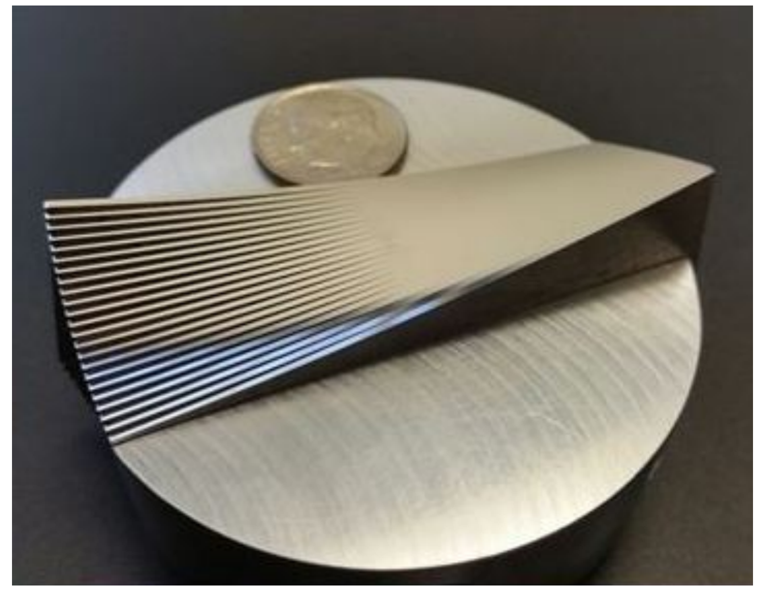




- improved precision for Teff, logg, [Fe/H]
- first measurement of [a/Fe], [C/H], [N/H]
- largest catalog of stellar masses & ages to-date

New Technology

- Despite SED Machine’s success throughput is terrible. Many problems likely have to do with lenslet array.
- Carnegie Postdoc Rosalie McGurk is developing low cost slicer.



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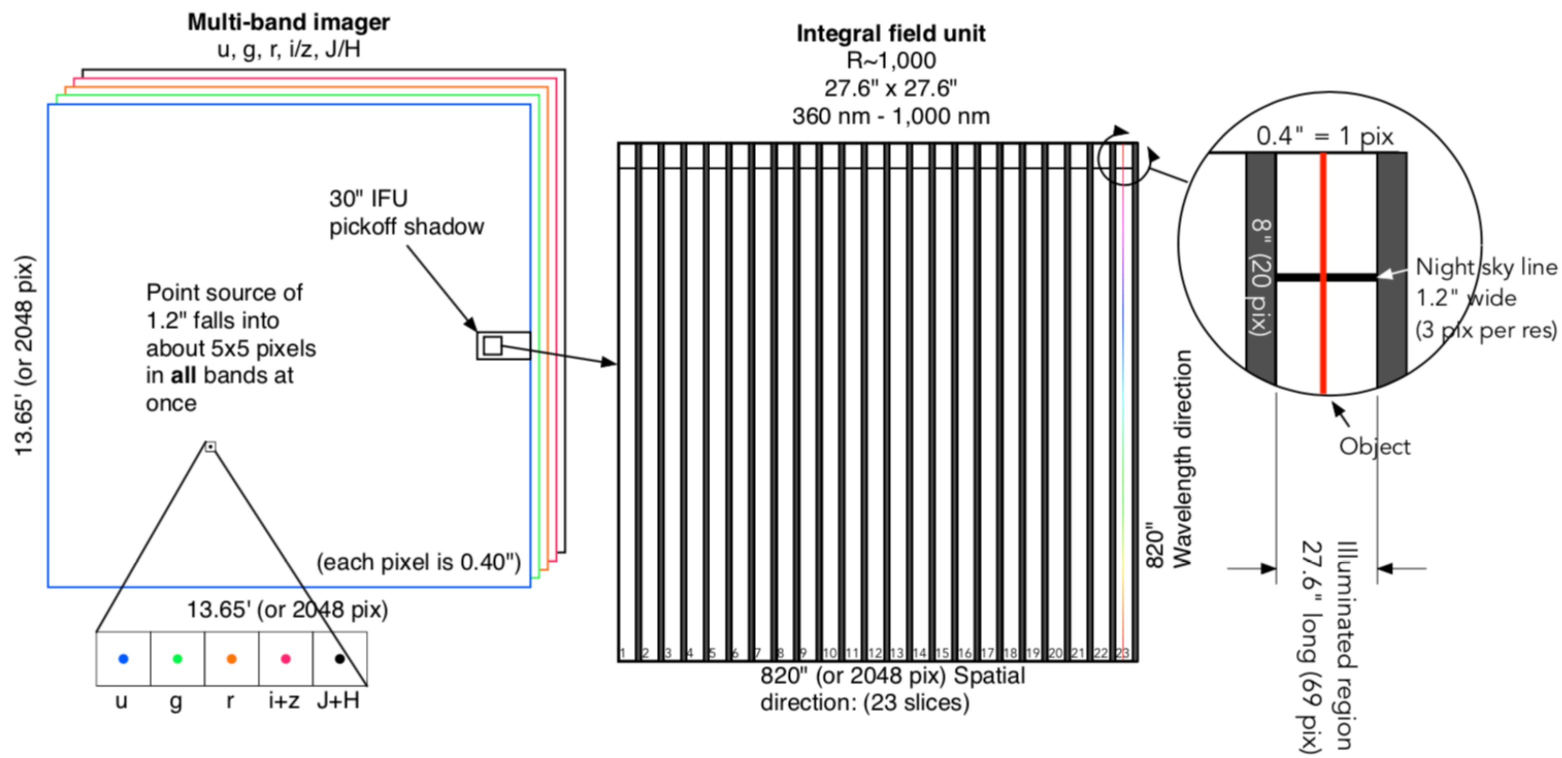
R²S²I



- Swope Telescope Rapid Response Spectrograph and Imager
- R~1,000 SED Machine + u through H imager

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New Technology 2 — Low cost telescopes

- The cost of a telescope scales at least as D^2
- The cost of N telescopes scales as N
- A 1-meter Planewave and SED Machine cost about $1.3 M in parts + labor (but no AIT or commissioning).
- If you buy enough Planewaves to have the same aperture aperture as a Magellan (6.5 m) the total cost is $45 M USD.
- This is less than **half the cost** of a Magellan!
- This argument is old, likely as old as the photographic plate, but I think the science case is different today.

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Business model

- Fund NRE through a single investment (partially funded via SED Machine NSF ATI and R^2S^2I).
- Institutions buy a telescope and instrument at $1.5 M.

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