MSteSci1 pipeline

Characterising M-dwarfs in the PLATO sample

Nikki Miller

Uppsala University, Sweden

nikki.miller@physics.uu.se | nikkimiller.space

Rymdstyrelsen
Swedish National Space Agency

UPPSALA UNIVERSITET

M-dwarfs in PLATO

Table 3.2: Requirements of the PLATO stellar samples

	Sample 1 (P1)	Sample 2 (P2)[5]	Sample 4 (P4)	Sample 5 (P5)
Stars	≥ 15 000 (goal 20 000)	≥ 1000	≥ 5000	≥ 245 000
Spectral type	Dwarf and subgiants F5-K7	Dwarf and subgiants F5-K7	M dwarfs	Dwarf and subgiants F5-K7
Limit *V*	11	8.2	16	13
Random noise (ppm in 1 hour)	34	34	800	
Observation phase	LOP	LOP	LOP	LOP
Sampling time (s)				
Initial measurement	-	-	-	≤ 600
Centroid measurements	-	-	-	≤ 50 for 5% of targets
Transit oversampling			-	≤ 50 for 10% of targets
Imagettes	25	2.5	25	25 for > 9000 targets
Wavelength	500–1000 nm	500–1000 nm 300 stars with colour information	500–1000 nm	500–1000 nm

PLATO Definition Study Report 2017

Working with M-dwarfs

Pros:

★ Small – easier to detect (Earth-like) exoplanets using transits and RVs

★ Numerous – most stars are M-dwarfs

★ Long lifetimes

Cons:

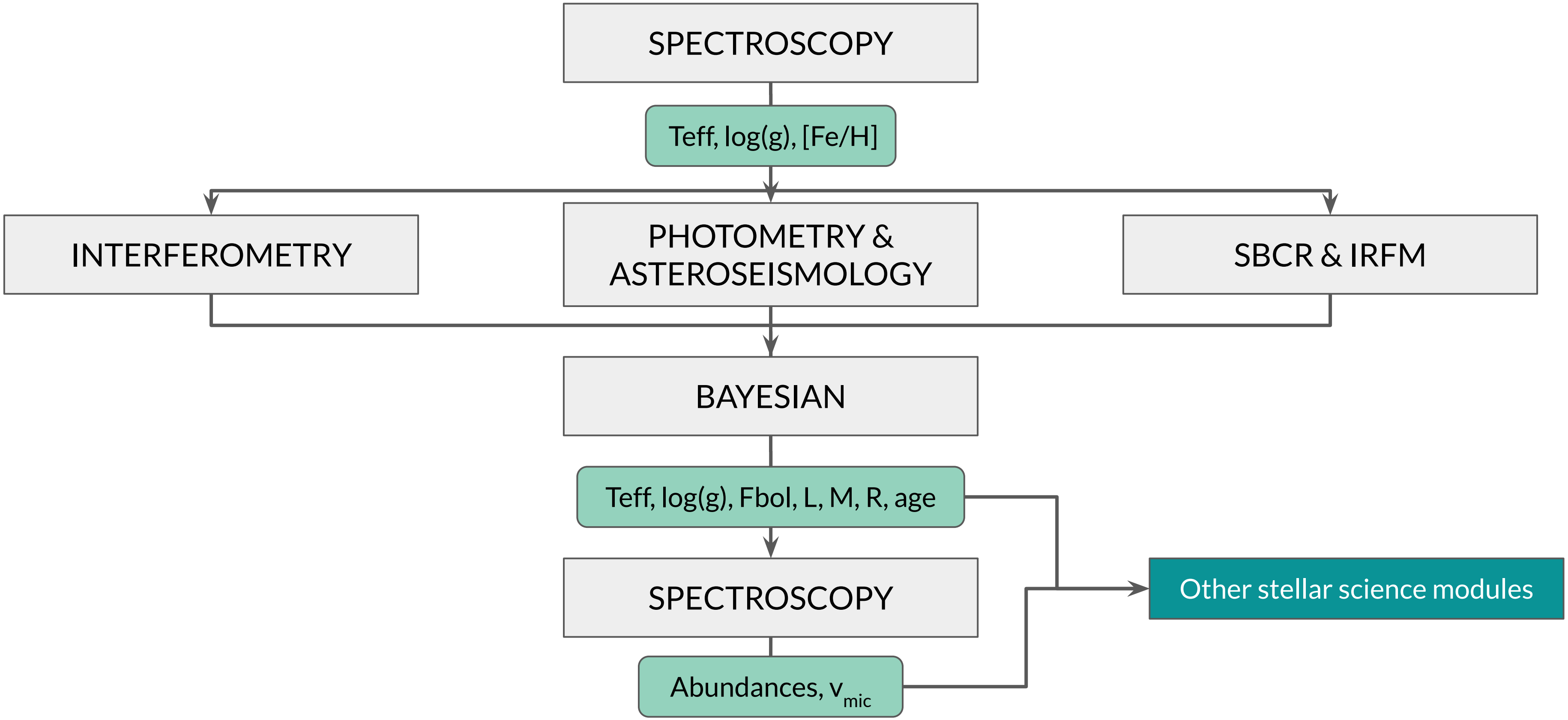
★ Intrinsically faint

★ Complex spectra dominated by molecular features

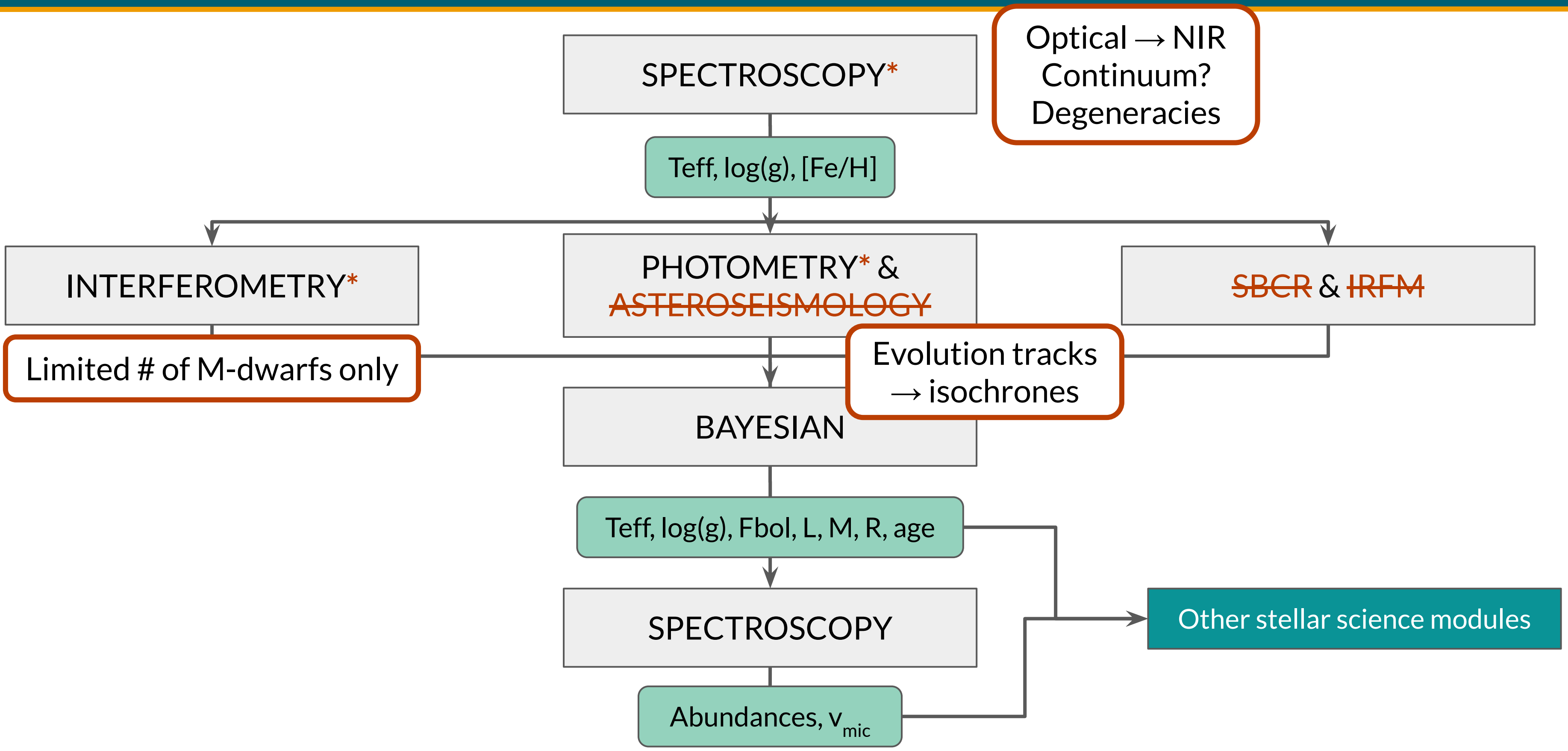
★ Often magnetically active, flares, etc.

★ Is the habitable zone even habitable (?)

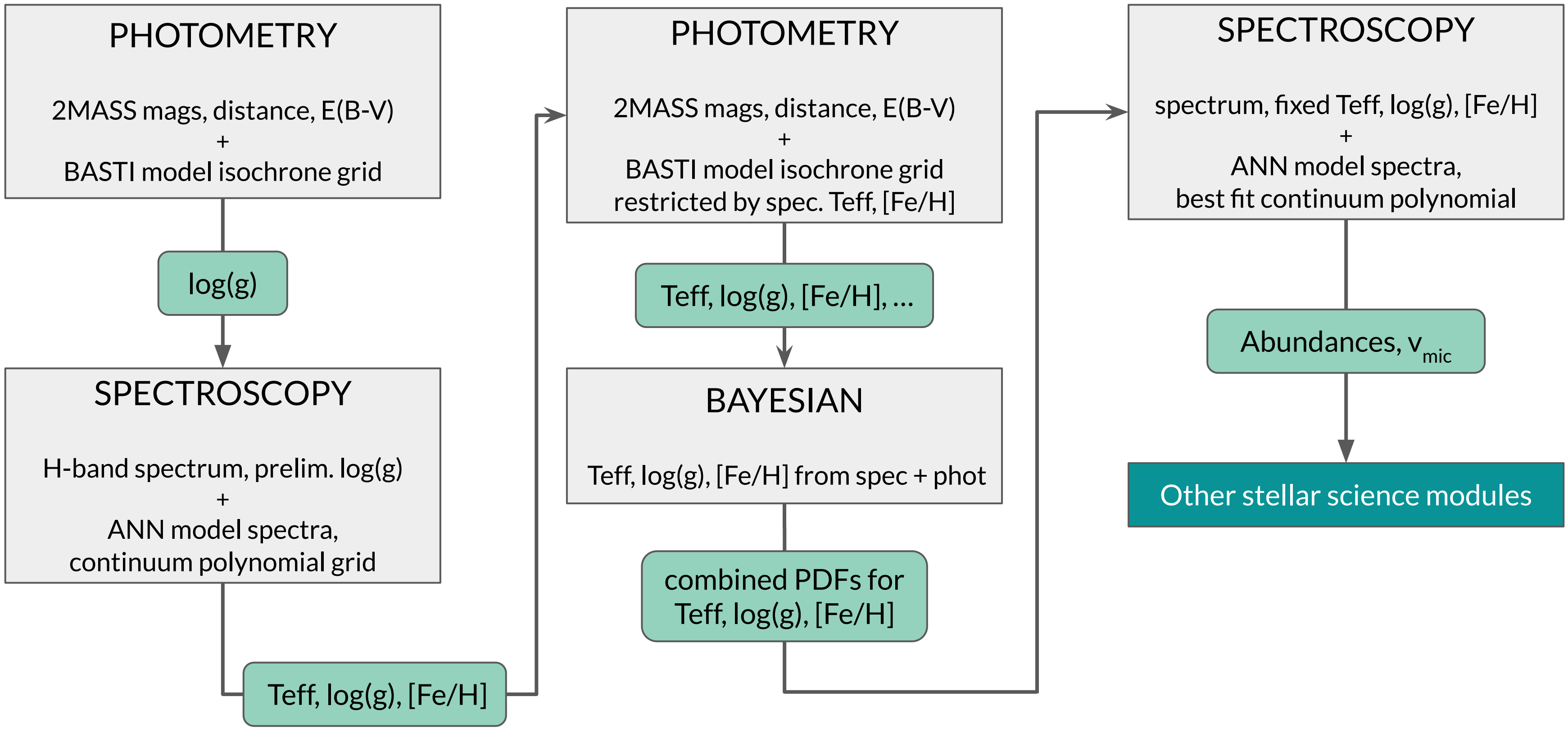
PLATO stellar science module MSteSci1 for FGK stars



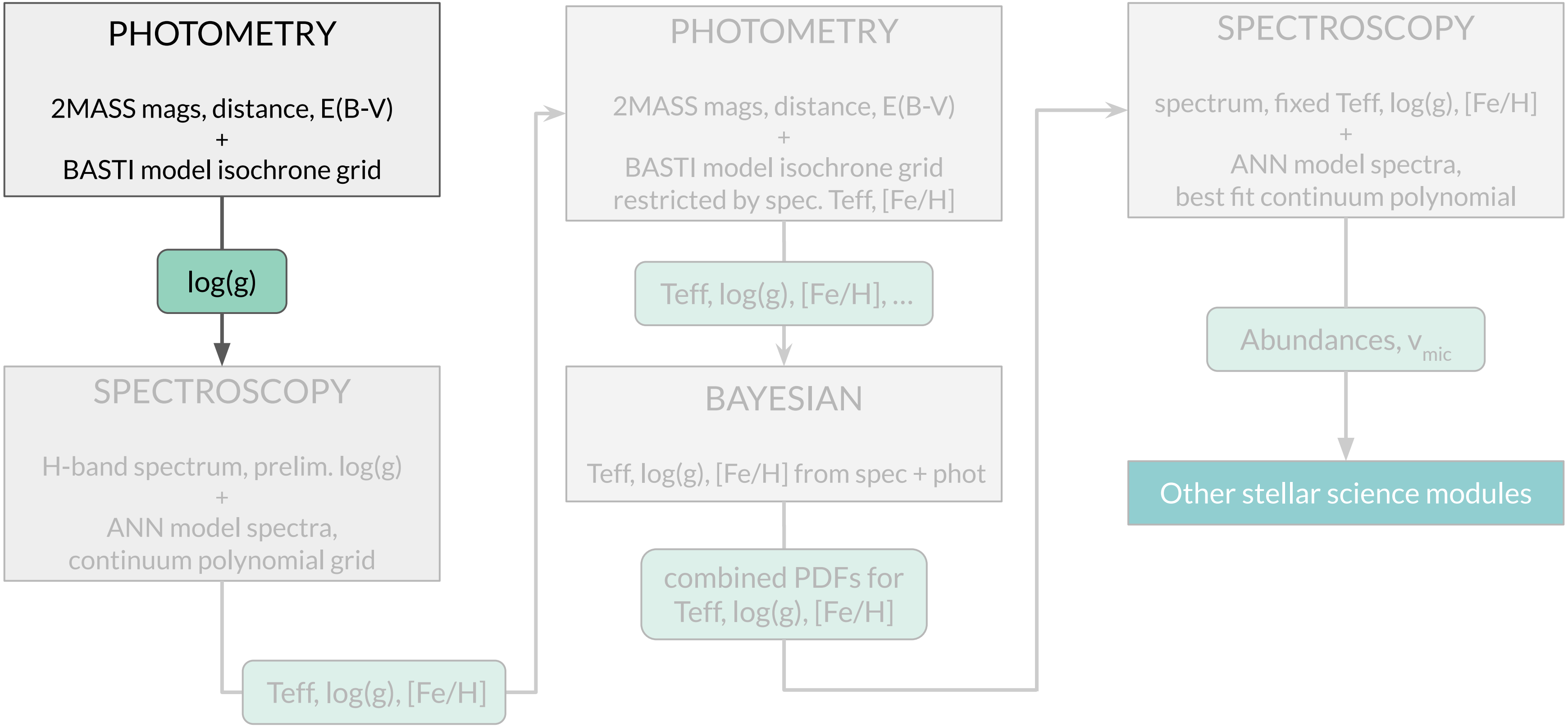
PLATO stellar science module MSteSci1 for FGK stars



PLATO stellar science module MSteSci1 for M-dwarfs



PLATO stellar science module MSteSci1 for M-dwarfs



Photometry module – likelihood calculation

For each band *b*, compare de-reddened observed magnitudes m_0

with a grid of *i* absolute model magnitudes *M*

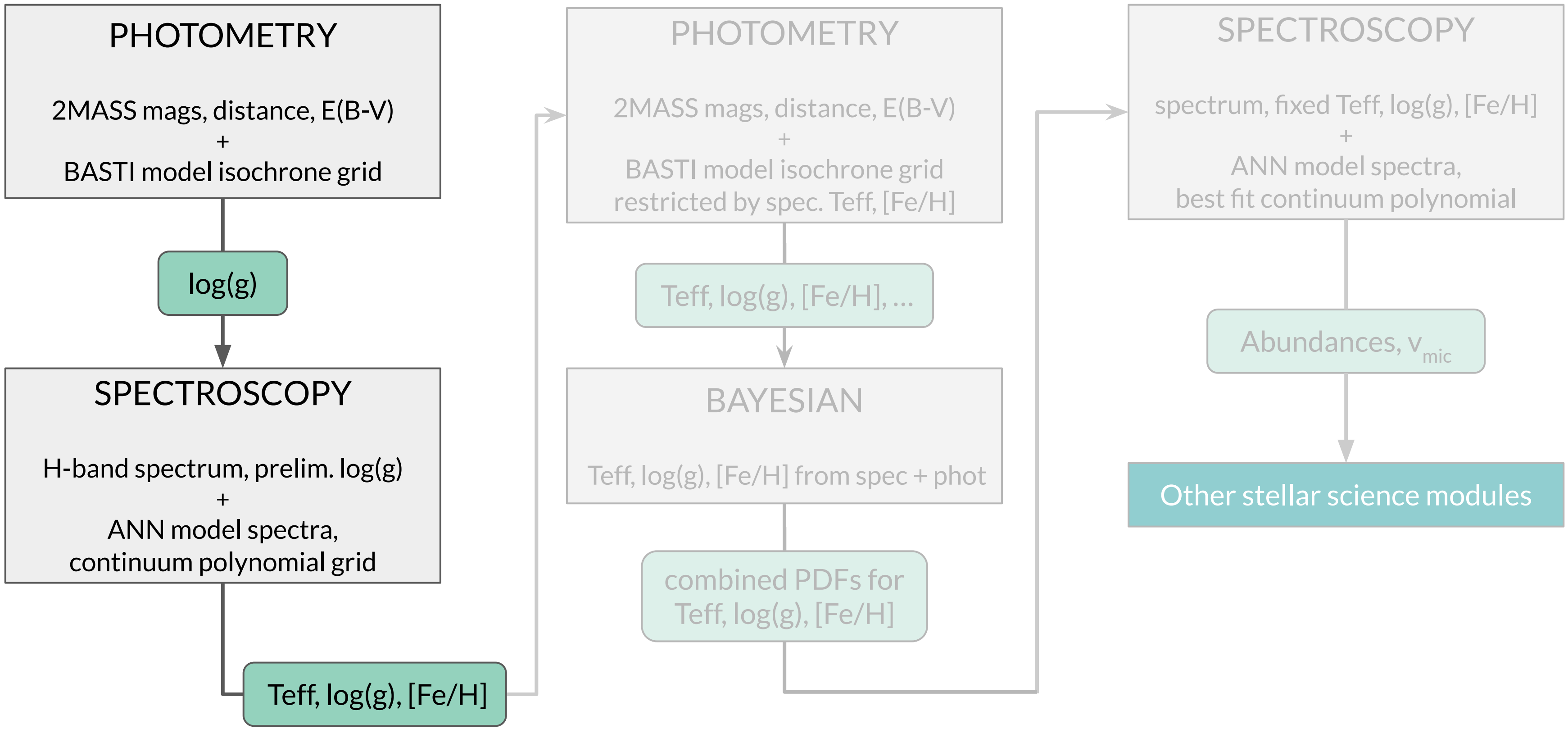
distributed over a grid of *j* distance moduli μ,

centered around the observed distance modulus μ_0

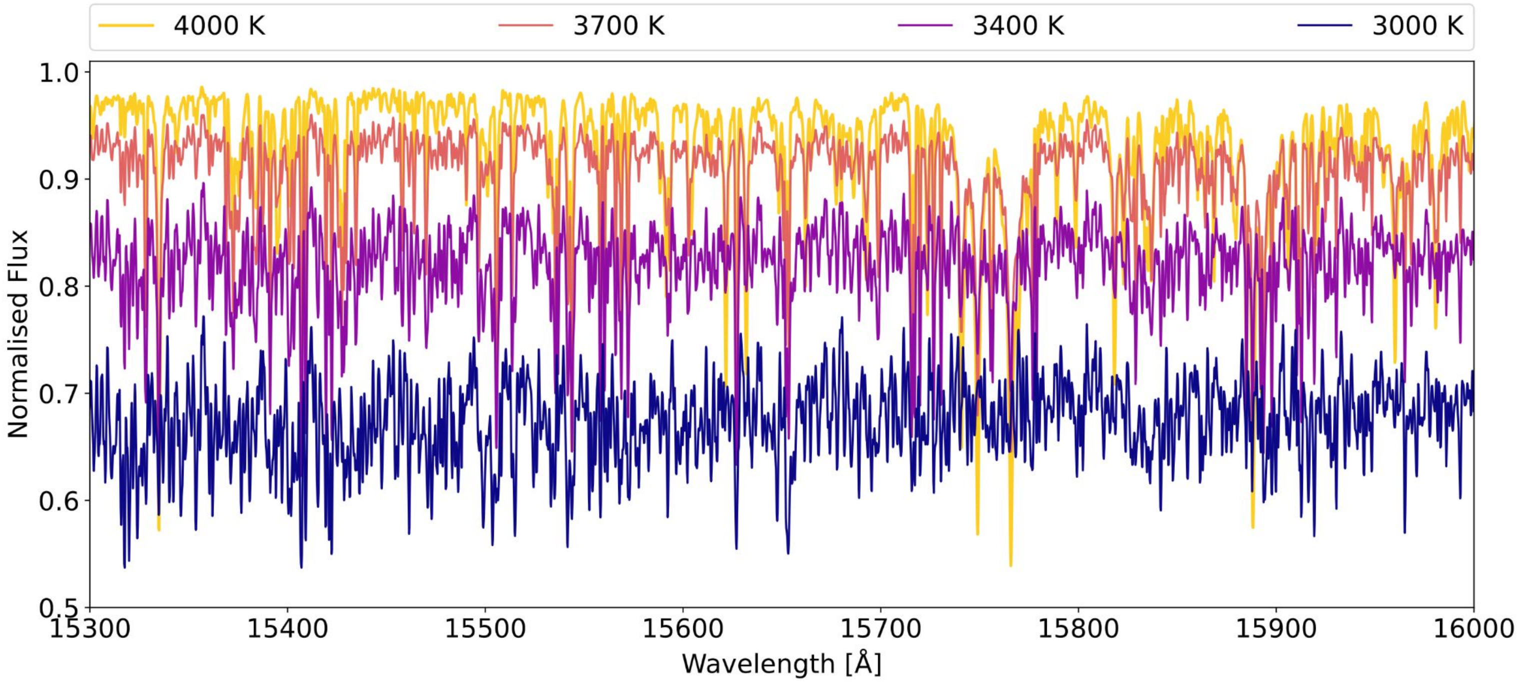
$$\log \mathcal{L}_i \propto \sum_{b=1,N_b} \left[\sum_j -\frac{(m_{b,0} - \mu_j - M_{b,\mathrm{mod},i})^2}{2\delta m_{b,0}^2} \right] + \log \sum_j \exp\left[-\frac{(\mu_j - \mu_0)^2}{2\delta\mu_0^2} \right]$$

$$\mathcal{L}_i \propto \exp\left(\log \mathcal{L}_i - \max(\log \mathcal{L}_i)\right)$$

PLATO stellar science module MSteSci1 for M-dwarfs



M-dwarfs in the H-band



Olander et al. (2025)

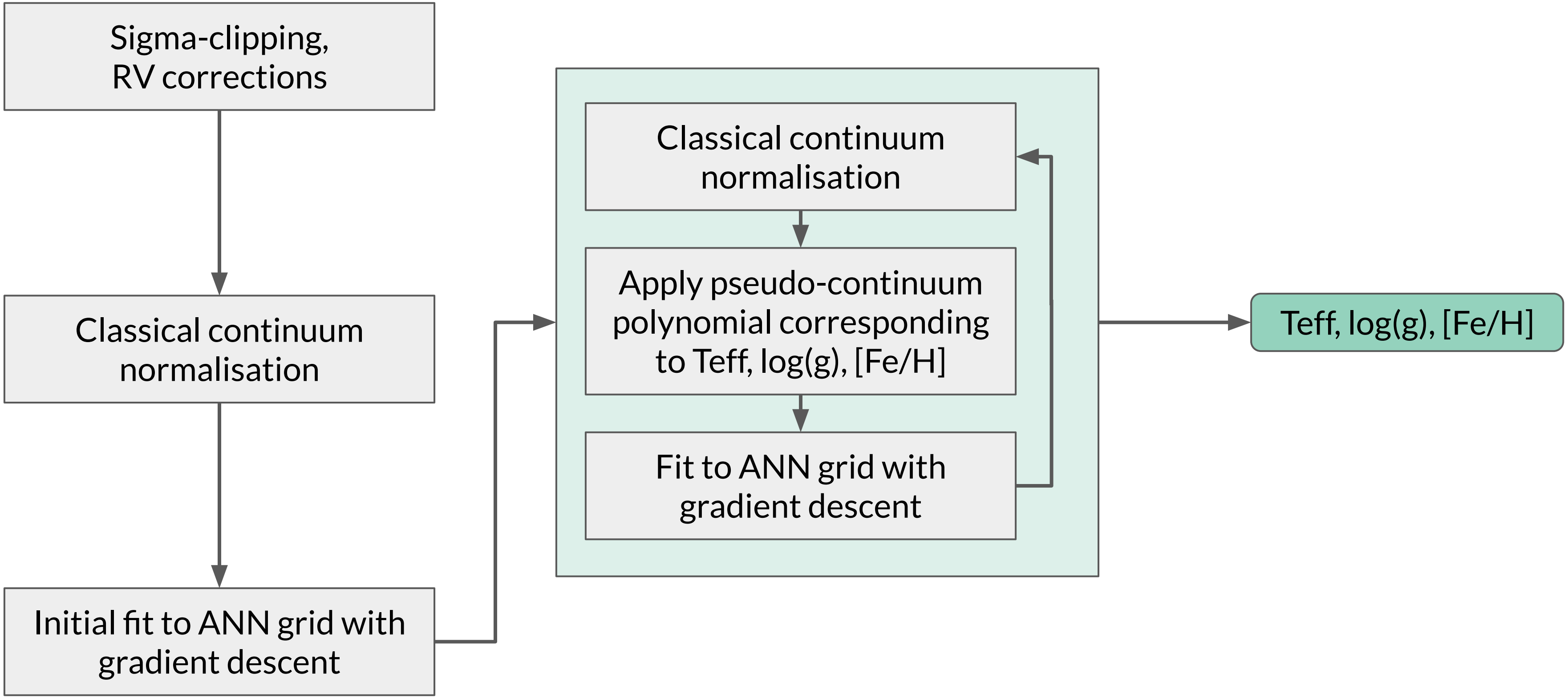
Spectroscopy module – components

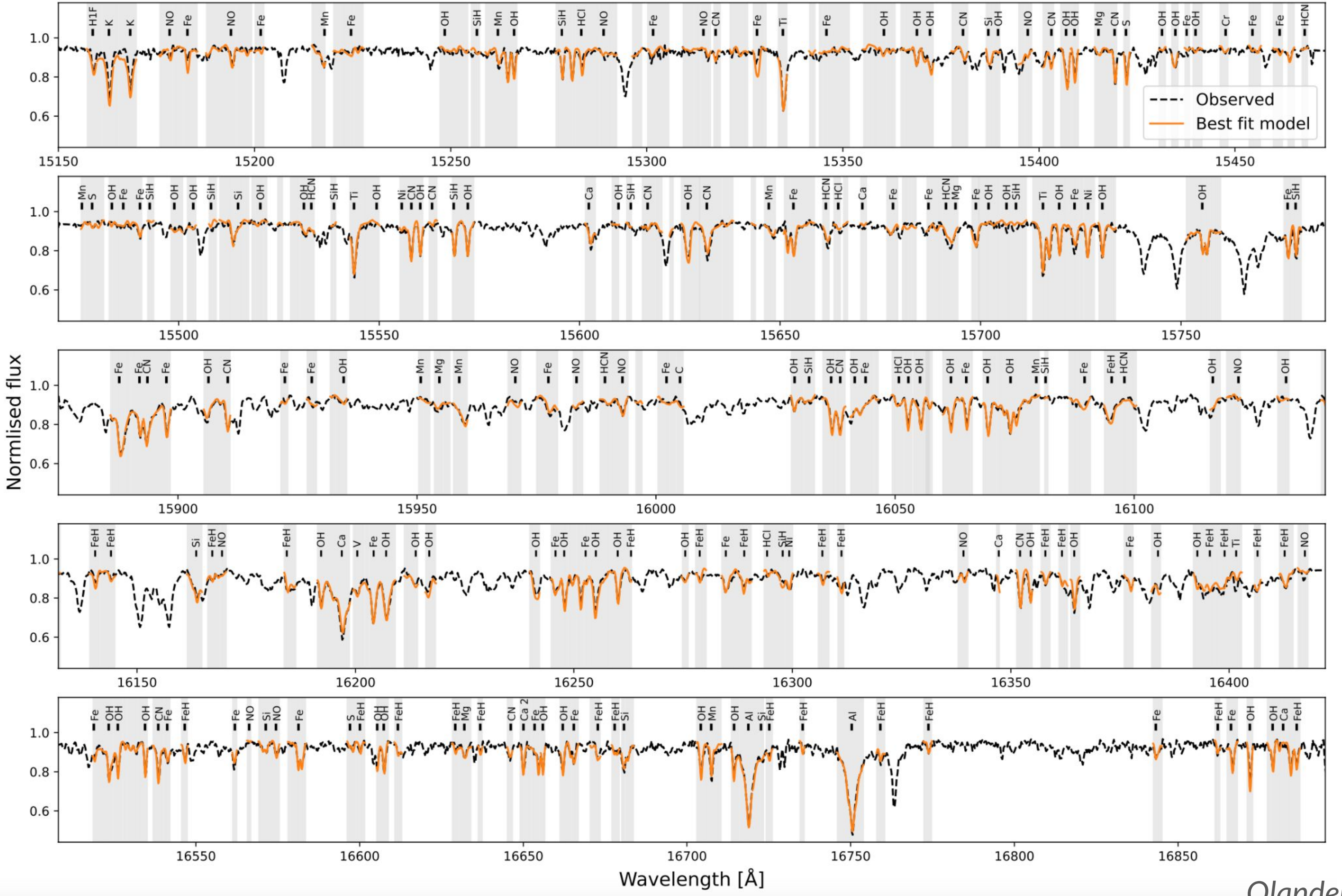
- Procedures from FGK pipeline
  - Sigma-clipping
  - Radial velocity corrections
  - Classical continuum normalisation

- Pseudo-continuum suppression
  - Grid of polynomials fitted to synthetic spectra over a range of Teff, log(g), [Fe/H]

- ANN trained on a random grid of synthetic spectra with 9 labels
  - “The Payne” algorithm (Ting+2019)
  - T_{eff}, log(g), [Fe/H], v_{mic}, [O/Fe], [Mg/Fe], [Ca/Fe], [Si/Fe], [Ti/Fe]

Spectroscopy module – procedure

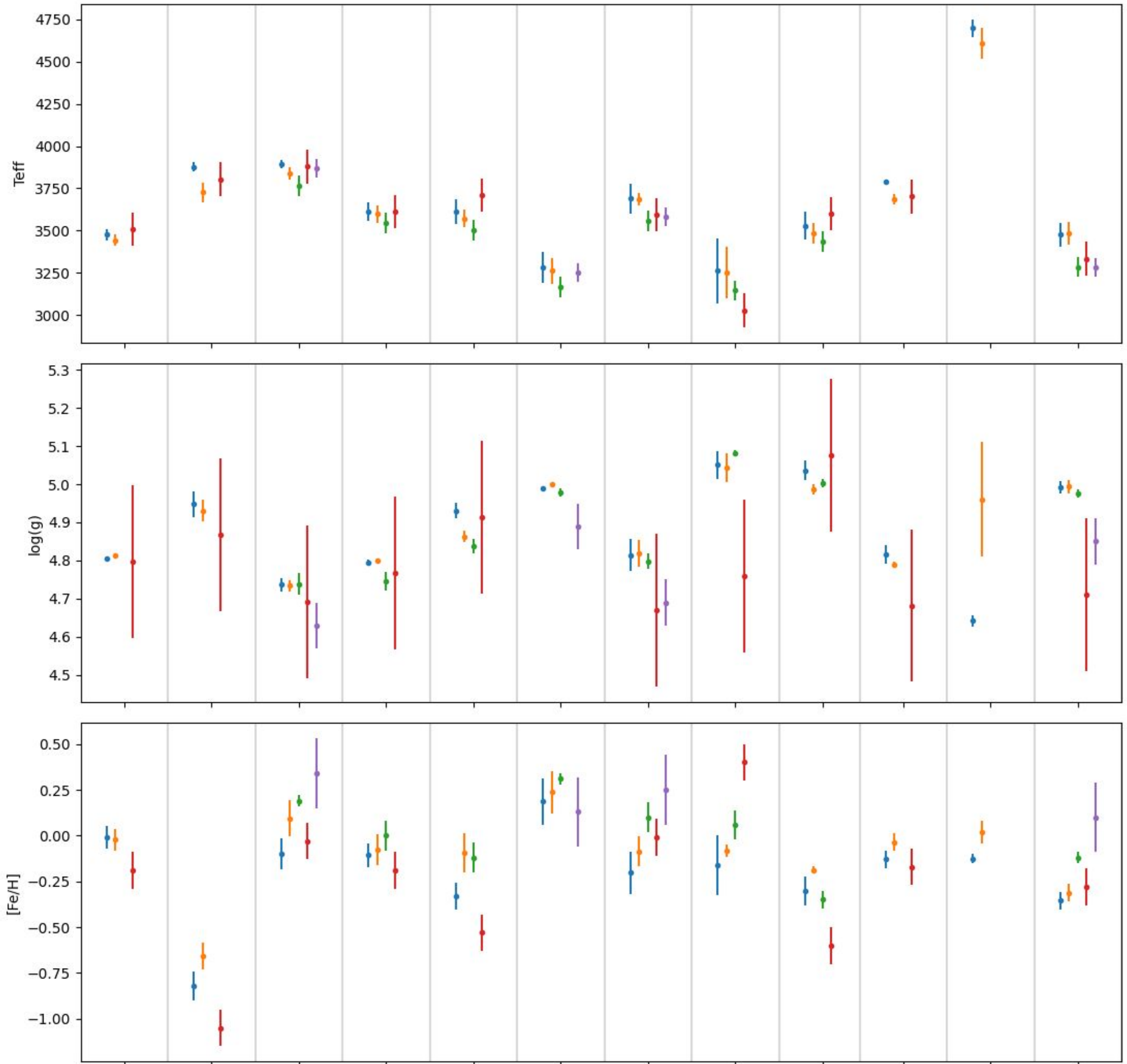




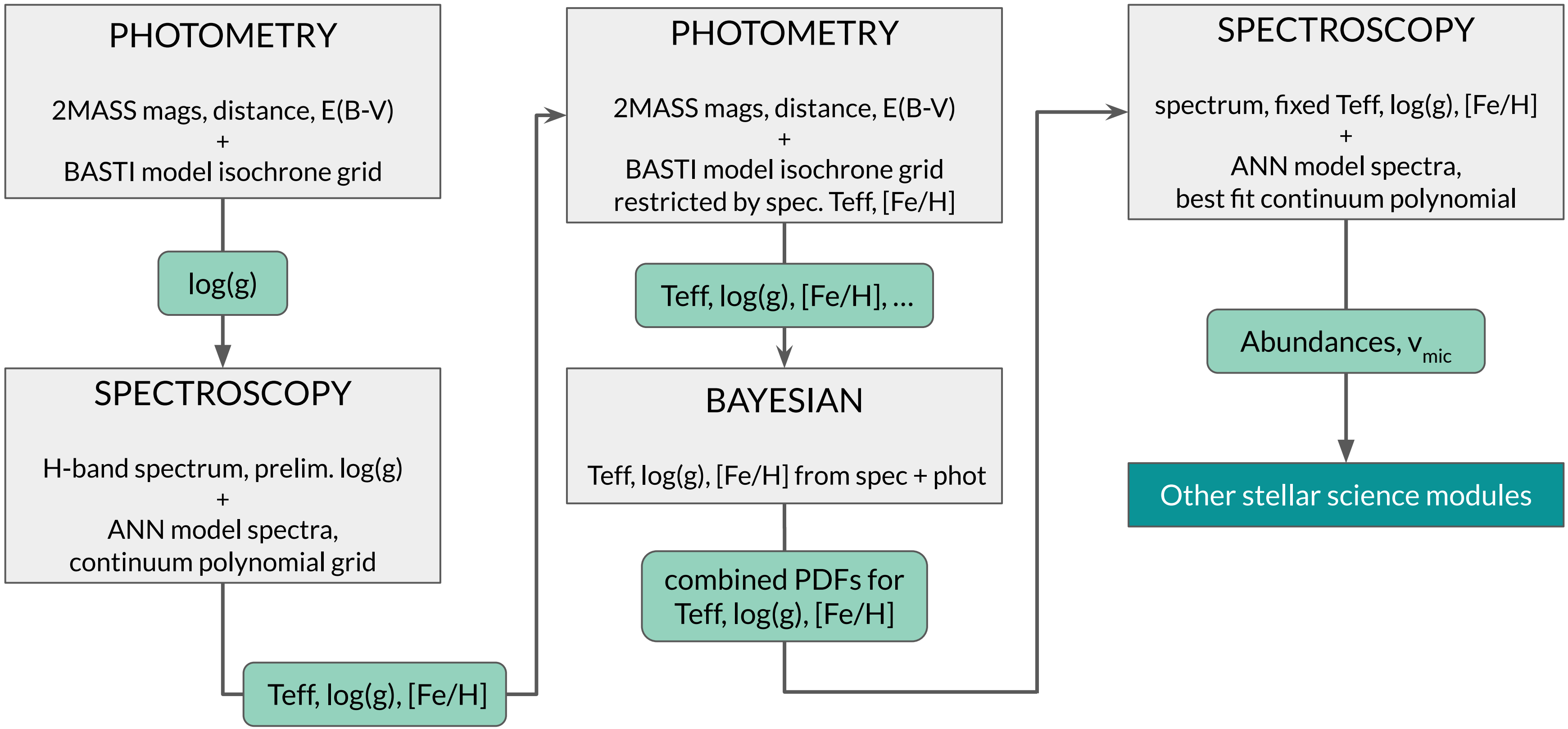
Olander et al. (2025)

Comparison to other studies of M-dwarfs

- Current version
- Olander et al. (2025)
- Mann et al. (2015)
- Sarmento et al. (2021)
- Passegger et al. (2019)



PLATO stellar science module MSteSci1 for M-dwarfs



Under construction…

- ❏ ***Full integration*** into PLATO infrastructure
  - ✓ Major restructure and improvements
  - ✓ Bug fixes and unit tests
  - ✓ Fast, class-based code

C, O, (Mg?), Al, Si, K, Ca, Ti, (Mn?), (Fe?), (Ni?)

- ❏ New ANN with ***more abundances***, vsini(?)
  - ✓ Random training grid generated with Turbospectrum from MARCS atmospheres
  - … Adaptation of Payne scripts, and training the ANN

- ❏ Photometry upgrade to include ***WISE photometry*** and more metallicities

- ❏ End-to-end ***validation*** of whole pipeline and output parameters

Summary

- M-dwarfs present different challenges to FGK-type stars, so require different treatment

- Homogeneous pipeline for characterising ***M-dwarfs*** for PLATO is in active development

- Plenty to do before launch!

Thank you!
Questions?

nikki.miller@physics.uu.se
nikkimiller.space

Rymdstyrelsen
Swedish National Space Agency

UPPSALA
UNIVERSITET