4MOST – 4m Multi-Object Spectroscopic Telescope

4GP: 4MOST galactic pipeline

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On behalf of IWG7

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www.4MOST.eu

Overview

- What the Galactic pipeline does
- How the Galactic pipeline works
- Who we are
- Pipeline status summary

Reminder of abbreviations

- **4GP**: 4MOST Galactic Pipeline
  - The software and data used to analyse spectra of stellar targets

- **IWG7**: Galactic Pipeline Infrastructure Working Group
  - The group of people working together to build 4GP

- **Level 2**: data product derived from the reduced spectrum

What the galactic pipeline does

- Derives, from the 1D calibrated stellar spectra,
  - a radial velocity
  - stellar parameters (T_{eff}, log g, [Fe/H], ξ, V_{rot}, age)
  - abundances of selected elements
  - a normalised spectrum

- Inputs to the pipeline are
  - the reduced spectra
  - astrometric, photometric and asteroseismic data

From the IWG7 management plan

Pipeline philosophy

- Collaboration between Galactic survey members
  - Avoid duplicated effort (similar targets and requirements)
- Use best techniques to analyse each spectrum
  - Possible to provide multiple results (e.g. with/without Gaia priors)
- Combine codes into a single automatic pipeline
  - Provides infrastructure to manage “firehose” of data
  - Enables quality control and rapid turnaround
  - Does not preclude manual re-analysis of subsamples

Targets

Consortium Survey		Brightness range (magnitudes)	Targets (millions)
S1	Milky Way Halo LR	$15.0 \leq G \leq 20.0$	1.5
S2	Milky Way Halo HR	$12.0 \leq G \leq 17.0$	1.5
S3	Milky Way Disc and Bulge LR (4MIDABLE-LR)	$14.0 \leq G \leq 19.0$	10.0
S4	Milky Way Disc and Bulge HR (4MIDABLE-HR)	$10.0 \leq G \leq 15.5$	2.5
S5	Galaxy Clusters	$18.0 \leq r \leq 22.0$	1.7
S6	AGN	$18.0 \leq r \leq 22.8$	1.0
S7	Galaxy Evolution (WAVES)	$18.0 \leq r \leq 22.5$	1.6
S8	Cosmology Redshift Survey	$20.0 \leq r \leq 23.9$	8.0
S9	Magellanic Clouds (1001MC)	$10.5 \leq G \leq 19.5$	0.5
S10	Transients (TiDES)	$18.0 \leq r \leq 22.5$	0.3
Total			> 28

Table 2. The minimal number and typical magnitude range of targets that each Consortium Survey expects to observe in the first five-year survey of 4MOST.

12 million LR and 4 million HR targets

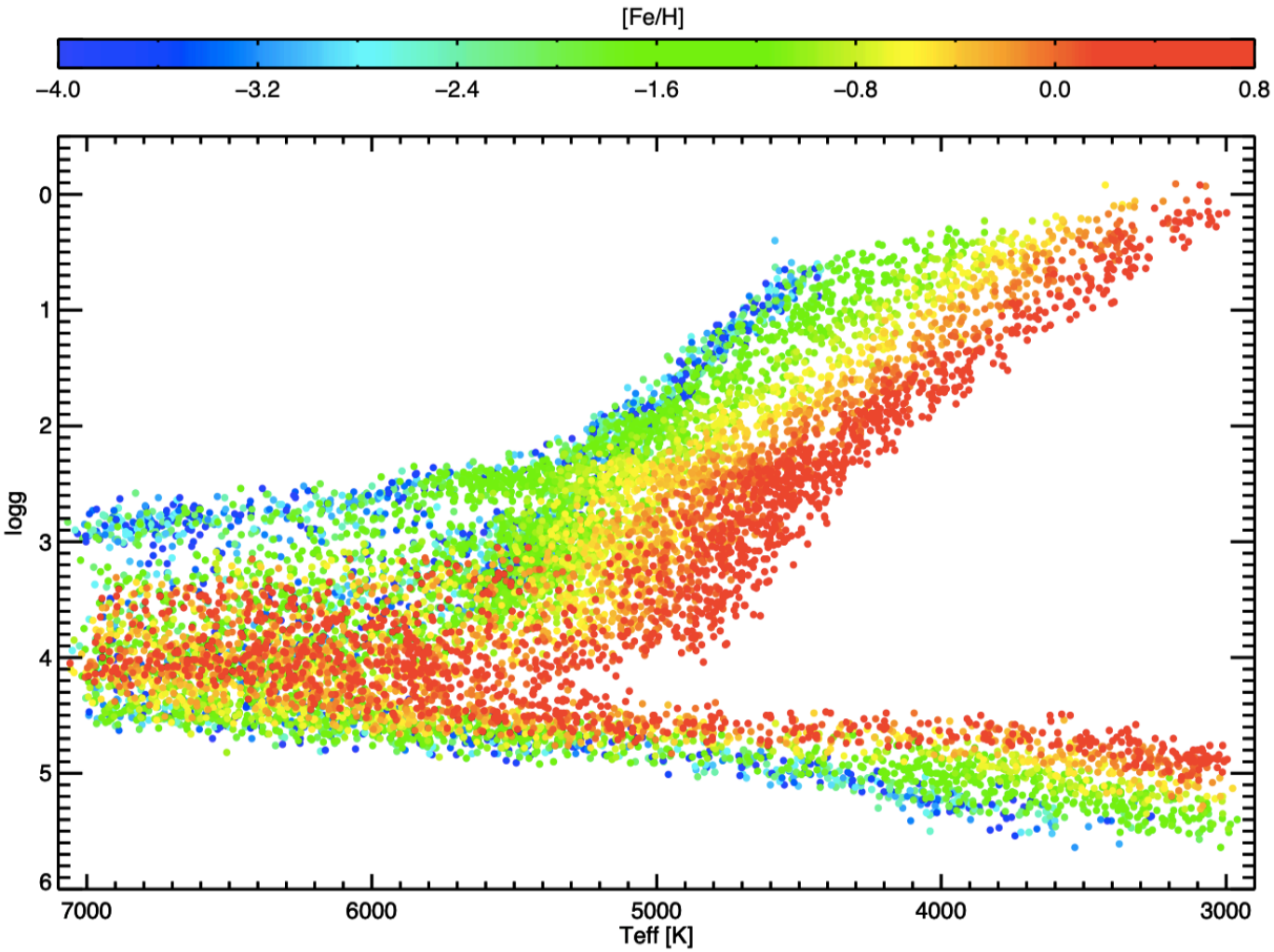
Mostly FGK dwarfs and giants

FGK star performance requirements

Survey	SNR / Å	RV [km/s]	[Fe/H] (dex)	[X/Fe] (N,dex)
S1 (LR halo)	10-25	1-2	0.2 dex	alpha, <0.1 dex (@SNR/Å=25)
S2 (HR halo)	40-140	2	~0.1 dex	<20, 0.2-0.3 dex
S3 (LR disk/ bulge)	10-50	1-2	~0.1 dex	~10, 0.1-0.2 dex
S4 (HR disk/ bulge)	100	1	0.05 dex	~20, 0.05 dex
S9 (Magellanic clouds)	20-100	2	0.2 dex	Few, 0.2 dex

From *ESO Messenger* Vol. 175

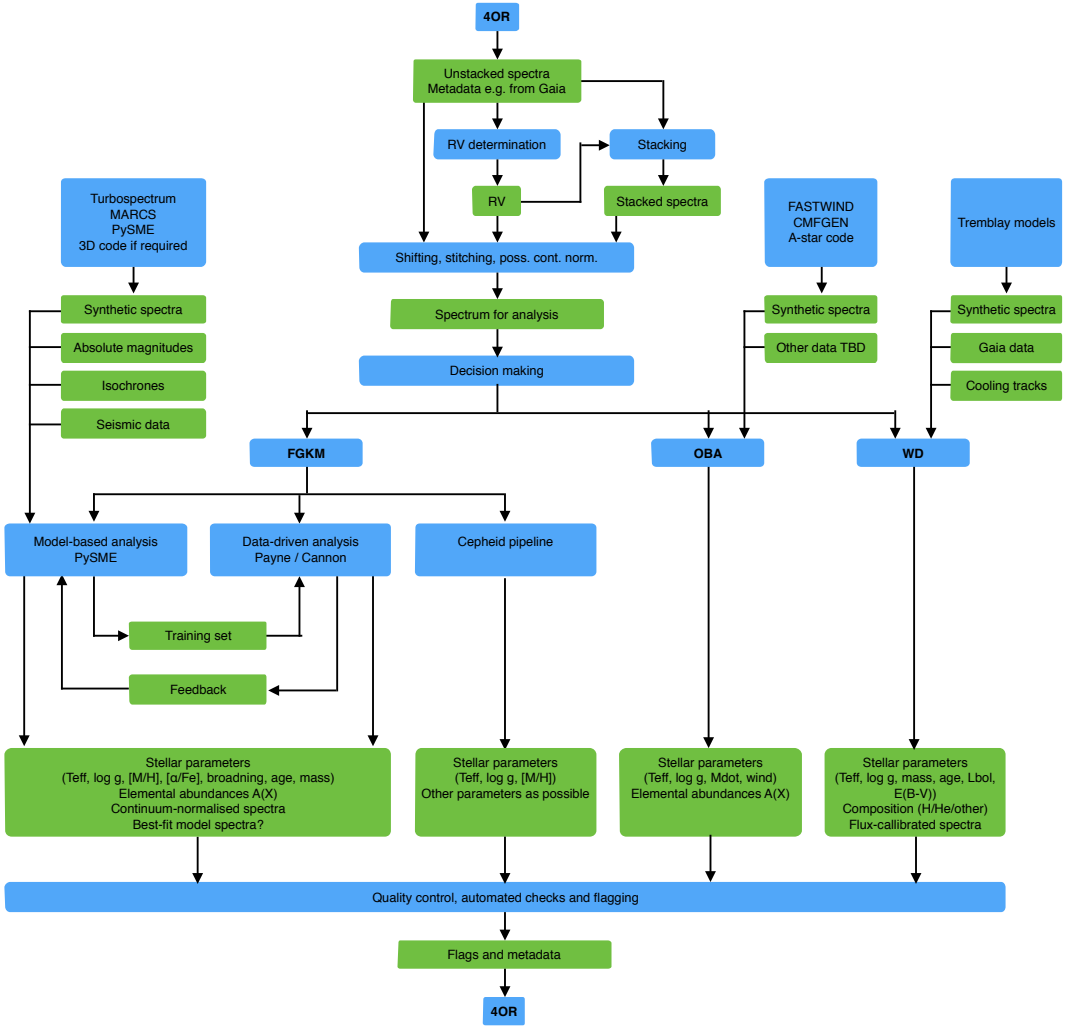
FGK star targets



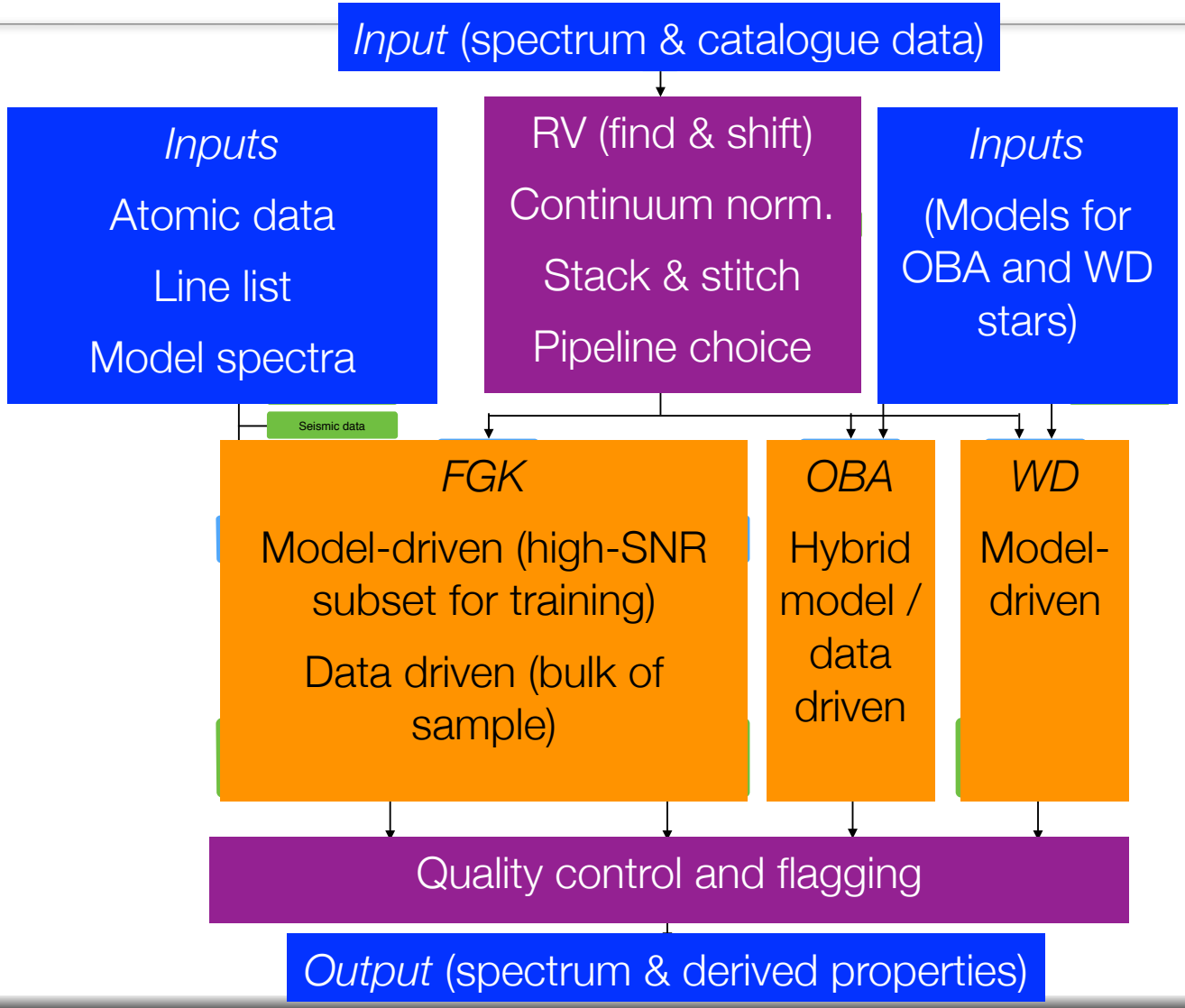
Other stellar types

- WDs from S3 (LR Disk & bulge)
  - RVs (few km/s), atmospheric parameters, chemistry
- OBA stars from S9 (Magellanic clouds)
  - RVs (1-2 km/s), stellar parameters, chemistry
- Cepheids
  - Epoch RVs plus stellar parameters
- Additional modules can be added, given provided effort

How will it work



How will it work (simplified)



How will it work (common core)

- Continuum normalisation: fit to envelope of continuum
- Radial velocity: cross-correlation with template spectra
- Stack and stitch: code provided by L1 pipeline / 4XP
- Decision making: From photometry & astrometry / ML (tbd)
- QC: Checks that parameters are in range, flags from sub-pipelines, etc.

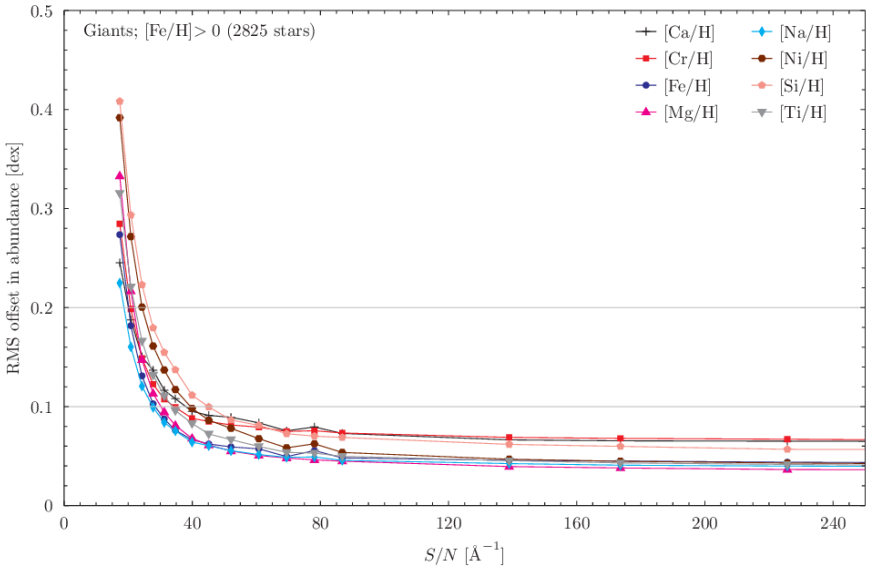
How it will work (FGK stars)

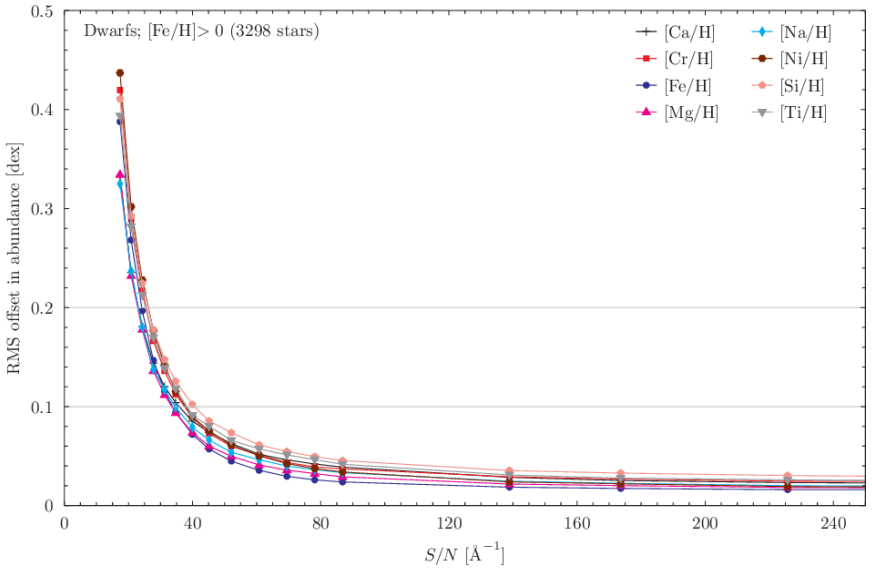
- High SNR subset of stars analysed using PySME (Valenti & Piskunov 1996; Piskunov & Valenti 2017)
  - Analysis will include custom line list, NLTE corrections, <3D> if necessary
  - Verified against benchmark stars with well-known parameters to test accuracy

- Bulk of stars to be analysed using rapid machine learning technique
  - Implemented Cannon (Ness et al. 2015) and Payne (Ting et al. 2018) but final pipeline choice still open

How (well) it will work (FGK stars)

- Tests with the Payne (Ting et al. 2018) on synthetic spectra (LRS, metal-rich stars)





Training and verification data

- Need:
  - Spectra of ~10^4 stars observed early at high SNR in LRS & HRS to provide training data
  - Spectra of bright benchmarks / clusters / asteroseismic fields for verification
  - IWG7 "mini-survey" in planning

Other sub-pipelines

- WDs
  - Classification, grid-search, fit with interpolation
  - Developers: Pier-Emmanual Tremblay, Nicola Gentile Fusillo

- Hot stars (OBA)
  - Grid search with synthetic models
  - Automatically learns difference from synthetic spectra
  - Developer: Joachim Bestenlehner

Pipeline design

- Modular design
  - Some modules shared (RV, continuum, QC, etc.)
  - Some modules form sub-pipelines (e.g. Cannon code)
  - Easy to slot in an additional code for testing / production

- Framework splits input FITS files into spectra, defines pipeline tasks, marshals results, etc.
  - Manager / worker architecture allows use of multiple computers using Kubernetes

Who we are (IWG7)

- Working group leads:
  - Karin Lind (Stockholm)
  - Georges Kordopatis (Nice)
  - Ross Church (Lund)

- Members drawn from the galactic surveys
  - Complete list on www.4most.eu

Pipeline status

- Operational but not final:
  - Overall framework
  - Major sub-pipelines (FGK/WD/OBA)
  - RV / continuum / stitching

- Still to come
  - Sub-pipeline choice
  - Stacking across multiple OBs
  - QC pipeline
  - Testing on more realistic spectra (coming this autumn!)

Questions?