The Case for Higher Resolution

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Competing High Resolution MOS Facilities

1) VLT FLAMES, in the southern hemisphere, comparable telescope aperture and resolution but smaller field and fewer fibers (125). Higher resolution spectra (R □45, 000) can be acquired with the UVES fiber system, for eight stars at a time.

2) **AAT HERMES**, in the southern hemisphere with smaller telescope aperture, higher resolution, comparable field, and fewer fibers (400).

3) **APOGEE** (near-IR), in the northern hemisphere with much smaller aperture, similar resolution, larger field and fewer fibers.

4) **4MOST** on the VISTA telescope in the southern hemisphere, smaller aperture, larger field, similar resolution (TBD, post-2018)

5) **MOONS** (optical and near-IR) on the VLT in the southern hemisphere, similar aperture, smaller field, similar number of fibers, similar resolution (TBD, future)

Summary: several existing and proposed multi-object systems have R 🖫20, 000. This is relatively easy to achieve and enables a fairly wide range of science.

ngCFHT has the largest collecting area of any of these telescopes and I believe there is a strong case for considering a higher resolution than the proposed R = 20,000.

This case is based on

• the extra science that becomes possible at higher resolution and

• the enhanced legacy value of higher resolution survey data.

For chemical studies in the bulge and disk, R ~20,000 has its limitations. A primary limitation is the fairly severe line blending in spectra at R = 20, 000, particularly for the more metal-rich stars which will be studied in the Galactic bulge and inner disk. This makes it difficult to make accurate measurements of the weak lines of most of the n-capture elements.

For this reason, much of the recent high-quality comprehensive chemical studies have been done with higher-resolution systems like UVES (VLT), HIRES (Keck) and MIKE (Magellan), all offering resolutions ~ 45,000. More elements can be measured, and the precision of the element abundances is significantly better. (Recall M. Asplund’s talk).

These higher-resolution spectra also offer better radial velocity accuracy for dynamics of Galactic substructure, dwarf spheroidal galaxies, preliminary Doppler planet search studies, and (maybe) for RV asteroseismology.

The enhanced legacy value of a spectroscopic survey at R 🖫45, 000.

While stellar surveys at a resolution of 🖫20,000 are valuable, they will be surpassed in the future by surveys at higher resolution, because these ar worth doing.

For most stellar and Galactic goals, largescale stellar spectroscopic surveys at R ~ 45,000 provide the ultimate spectroscopic data. There is limited motivation to do future stellar surveys at yet higher resolution. The legacy value of a survey at R ~ 45, 000 would be unsurpassed.

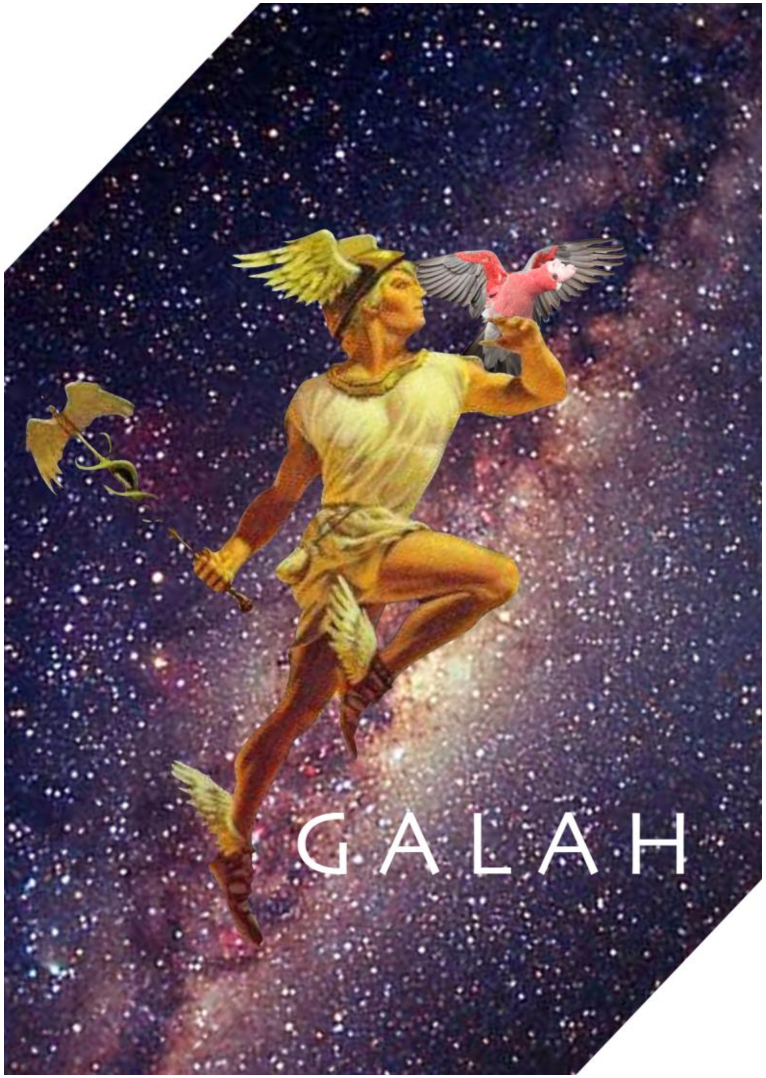
Is such a high resolution feasible for a multi-object spectrometer ?

Yes : the HERMES system at the AAT is an example.

HERMES has four non-contiguous bands between about 470nm and 790nm, covering a total of about 100 nm. Each band has its own VPH grating and detector. Bands are separated by dichroic beam splitters.

The wavelength bands were carefully chosen to maximise the number of measurable chemical elements (25 to 30 from all major nucleosynthesis processes).

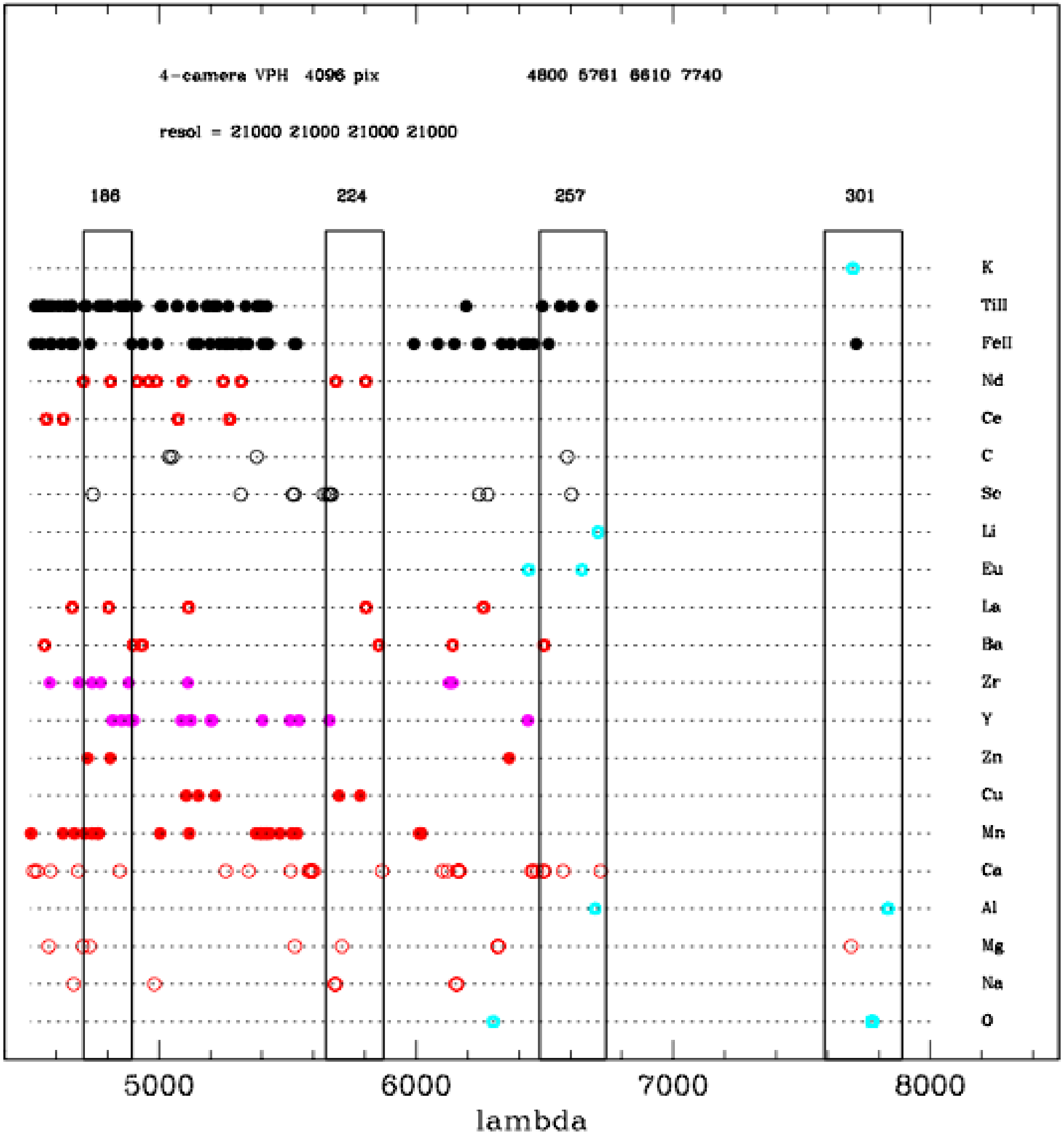
The HERMES spectrometer has two high resolution modes (28,000 and 45,000) and it is relatively easy to change from one mode to the other (Barden et al 2010).



HERMES : a new high-resolution fiber-fed multi-object spectrometer on the 4-m AAT

spectral resolution 28,000
(also R = 45,000 mode: slit mask)
390 fibres over π square degrees
4 bands (BGRI) ~ 1000 Å
First light 2013

Main driver: the GALAH survey (a million stars with $V < 14$ for chemical tagging, stellar astrophysics, Galactic chemical evolution)



HERMES wavelength bands

Expect SN ~ 100 per resolution element at R = 28,000, V = 14 in 60 minutes

Limited by the 4-m aperture to distances of about 1 kpc for dwarfs and 5 kpc for giants

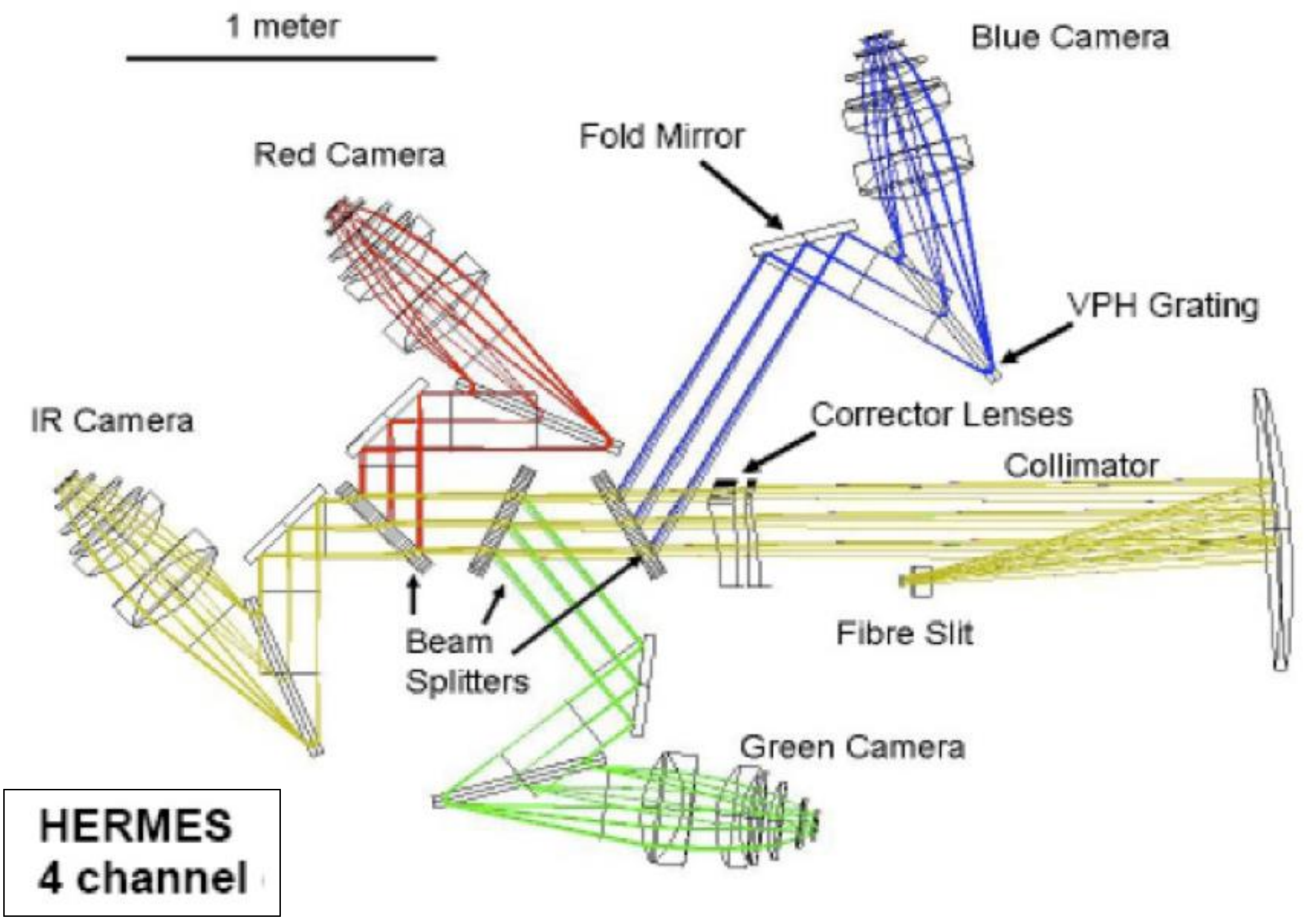
The HERMES bands

Band	λ_{min}	λ_{max}
Blue	471.8	490.3 nm
Green	564.9	587.3 nm
Red	648.1	673.9 nm
IR	759.0	789.0 nm

The HERMES chemical space

The 25 HERMES elements: Li C O Na Al K
Mg Si Ca Ti
Sc V Cr Mn Fe Co N Cu Zn
Y Zr Ba La Nd Eu

The HERMES bands (BGRI) were chosen to ensure measurable lines of these elements from the major nucleosynthesis processes. Also Hα and Hβ. May get a few more elements (~ 30) in some stars.

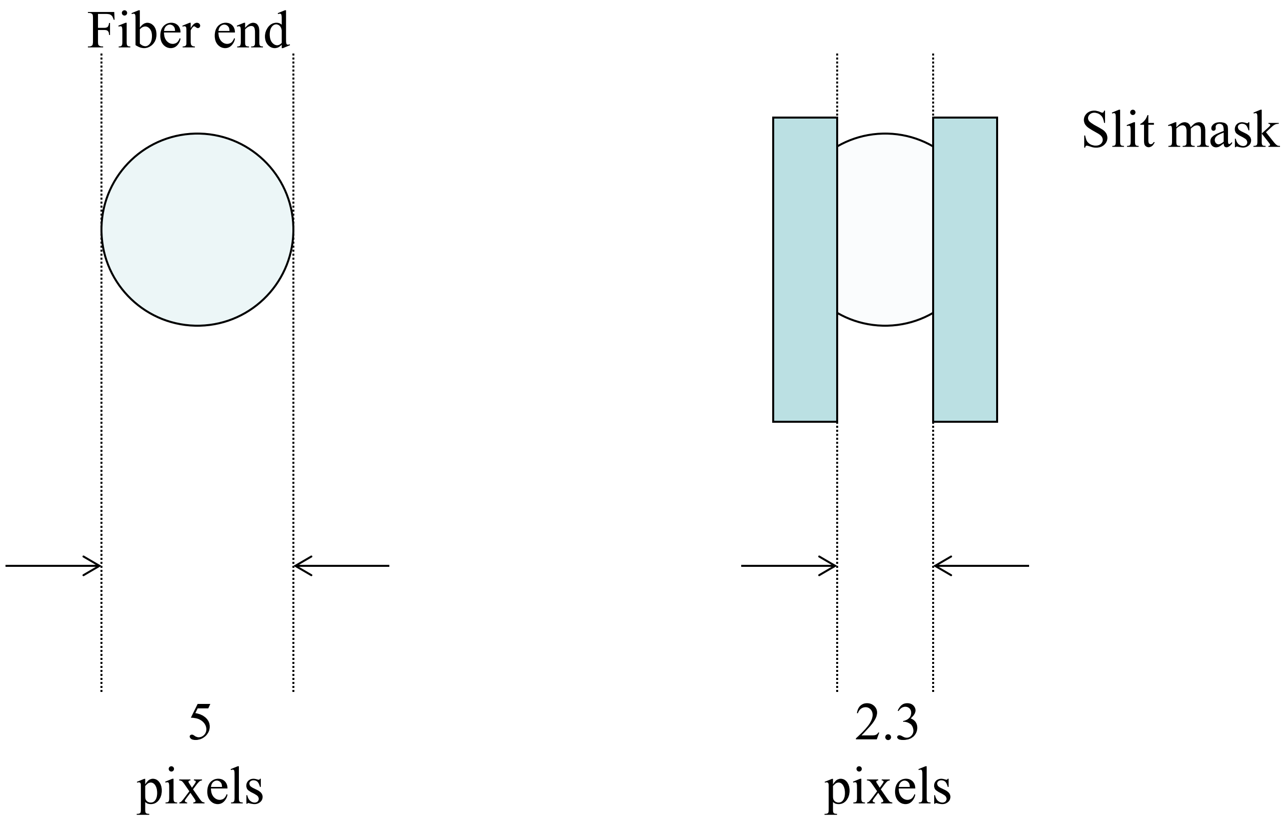

1 meter
Blue Camera
Fold Mirror
Red Camera
VPH Grating
IR Camera
Corrector Lenses
Collimator
Beam
Splitters
Fibre Slit
Green Camera
HERMES
4 channel

At the spectrograph end, the fibers are configured into a curved slit (to correct for field curvature).

In the lower resolution mode (R = 28,000), the slit is unmasked and the whole width of the fiber slit projects to about 5 pixels on the CCDs, so is well oversampled.

In the higher resolution mode (R = 45, 000), a curved slit mask is used to mask off the outer edges of the fiber slit, so that the masked fiber slit projects to about 2.3 pixels on the CCD (these numbers are consistent given the geometry of the fiber and mask). The light lost to the mask is likely to be only about 0.5 mag.

The prime focus focal length of the ngCFHT will be a bit longer than that of the AAT (~ 18 m vs 14 m) but the seeing at the CFHT site is better than at the AAT, so the fiber diameters for the two instruments may be fairly similar.

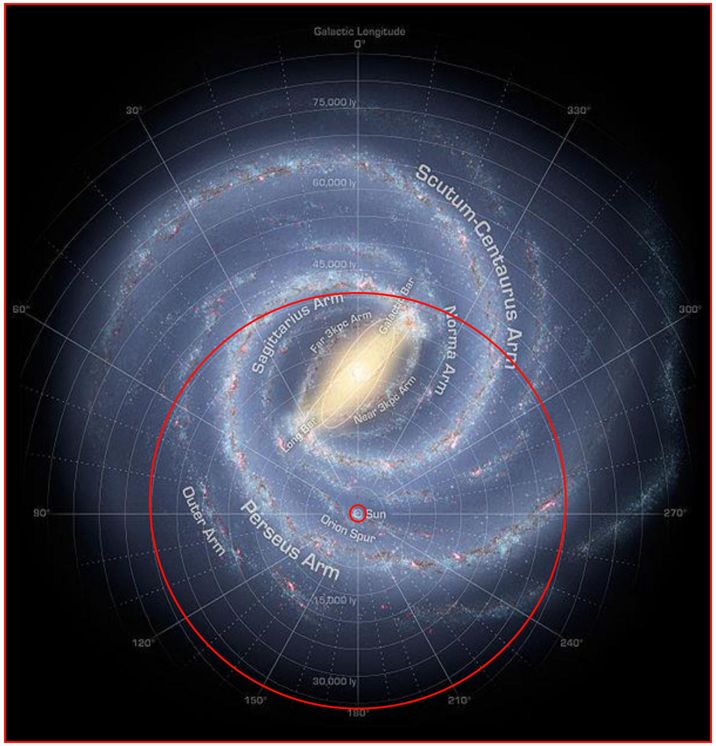


R = 28,000

R = 45,000

With the 10-m ngCFHT aperture, stars with V = 15.5 to 16 (e.g. clump giants at distances up to 10 kpc) could be observed with SN = 100 per resolution element in 60 minutes at R ~ 45,000 in survey mode.

The ngCFHT horizon would reach out to the far side of the Galactic bulge, and into the outer disk (R ~ 20 kpc)



Summary

A higher resolution mode (~ 45,000) is feasible
for the ngCFHT

A high resolution survey would enable chemical tagging of Galactic stars and investigation of the main nucleosynthetic processes over a wide range of Galactocentric radius,
dynamics and abundances in dwarf spheroidal galaxies
and Galactic substructure,
with more accurate element abundances and stellar radial velocities,

ngCFHT has the opportunity to build a truly unique and powerful high resolution MOS facility

The legacy value of a large stellar survey at this resolution would be unsurpassed