Development of the single fibres and IFUs of WEAVE

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ABSTRACT

WEAVE is a new wide-field spectroscopy facility proposed for the prime focus of the 4.2m William Herschel telescope. The facility comprises a new 2 degree field of view prime focus corrector with a 1000-multiplex fibre positioner, a small number of individually deployable IFUs, and a large single IFU. The IFUs and the MOS fibres can be used to feed a dual-beam spectrograph that will provide full coverage of the majority of the visible spectrum in a single exposure at a resolution ~5000 or two 50nm-wide regions at a resolution of ~20000.

This paper sums up the design of these two modes and describes the specific developments required to optimise the performances of the fibre system.

Keywords: WEAVE, WHT, IFU, Optical fibre

1 INTRODUCTION

The WEAVE project is described in a separate paper: WEAVE the next generation wide-field spectroscopy facility for the William Herschel Telescope (Dalton & al.) [1].

Wide-field multi-object spectroscopy will be in particular demand in the coming decade, given the many ambitious imaging surveys on the way, including Gaia, optical and NIR surveys with VISTA and VST, Pan-STARRS, UKIDSS, and radio surveys such as LOFAR. The science goals of these surveys range over stellar and sub-stellar astronomy, galactic astronomy, galaxy evolution and cosmology. In all cases, extracting physics from the spectroscopic observations are crucial for full scientific exploitation.

The instrument should have three front ends: a massively multiplex MOS mode for point sources, with fibres that project to about 1.3 arcsec on the sky, a large integral field unit with a FOV above 1 arcmin in diameter, with wide (2-3 arcsec) fibres; a third front end featuring multiple deployable mini-IFUs.

In this paper, we describe the preliminary design of the MOS and the mini-IFUs, designed by the GEPI at Observatoire de Paris, and an illustration of the use of a multi-fibre spectrograph with the exoplanet searches.

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2 DESCRIPTION

A schematic view of the instrument is shown in Figure 1.

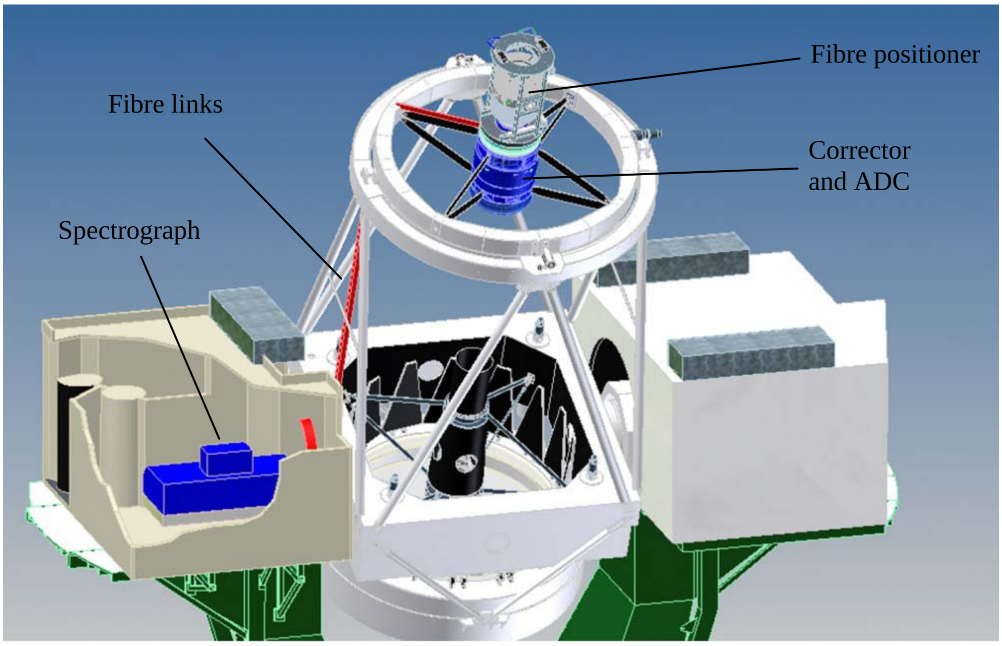

Figure 1 WEAVE installed at the WHT

The WEAVE fibres ensure the link between the positioner and the spectrograph. WEAVE will be installed at the prime focus. There are 1000 single fibres on each focal plate and about twenty IFUs on one of these plates.

3 PRELIMINARY DESIGN

3.1 Fibre injection principle

At the entrance, the sky aperture of 1.3'' is defined by a microlens. For the injection, the principal issue is the aperture of the telescope F/2.7 (Figure 2). A field lens is necessary to slow down the beam. The microlens will also allow an aperture to match the input focal of F/3 of the spectrograph.

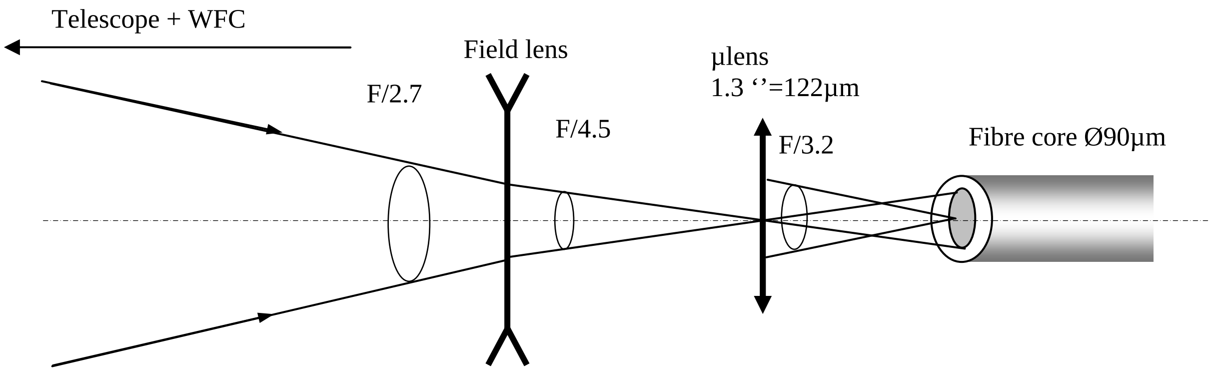

Figure 2 Fibre injection principle

For the IFUs, the filling factor needs to be optimized. For a hexagonal arrangement, the size of the buffer of the fibre had to be the same as the size of the microlens.

3.2 Fibre transmission

At this stage, only Polymicro fibres are investigated. Polymicro fibres are well known and are used in various astronomical instruments. The goal for the wavelength coverage is 370-1000nm. The choice of the fibre is oriented toward the FBP (see figure below).

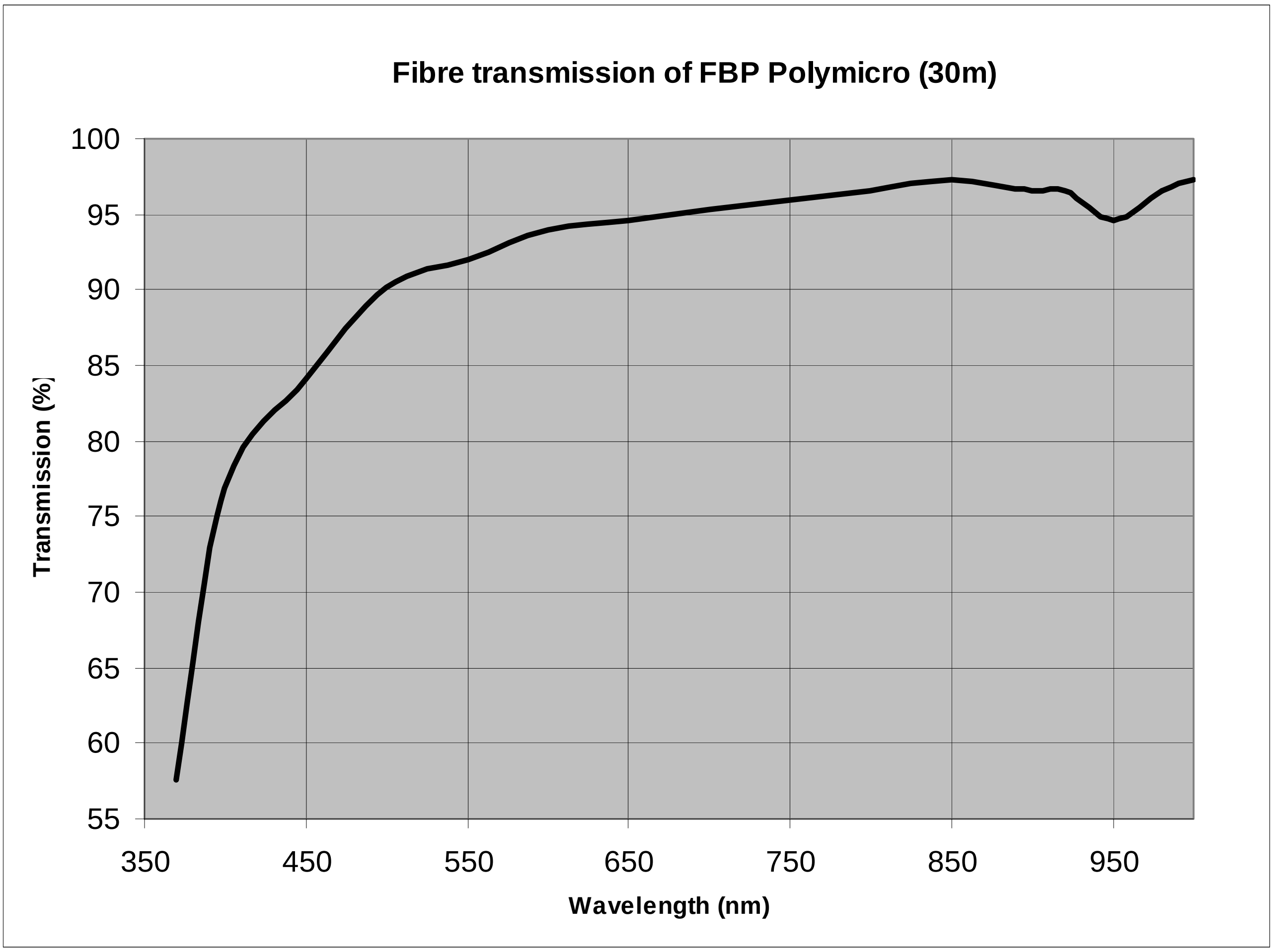

Figure 3 Fibre intrinsec transmission

A first estimaton of the length is thirty meters, distance between the prime focus at the top of the telescope and the spectrograph.

3.3 Focal Ratio degradation

Focal Ratio Degradation (FRD) is the decrease in focal ratio (decrease in effective F-number) in an optical fibre. The ability of a fibre to preserve the angular distribution of the input beam from the telescope to the spectrograph is very important.

The major causes of FRD are mechanical variations in the fibre dimensions with length (under the manufacturer’s control) and the mechanical set-up of the instrumentation (under the control of the user). Small variations in the fibre core diameter or core-clad interface can cause mode stripping, resulting in FRD. Both macrobending and microbending will cause FRD.

In WEAVE, we inject at a fast F ratio of F/3.2, which limits the FRD. At the output, the F ratio is slightly degraded and is at F/3, aperture of the collimator of the spectrograph.

3.4 Conceptual design of a bundle

A bundle is composed of 24 fibres that enter into four retractors, each of which holds six fibres. The situation is illustrated in the following figure.

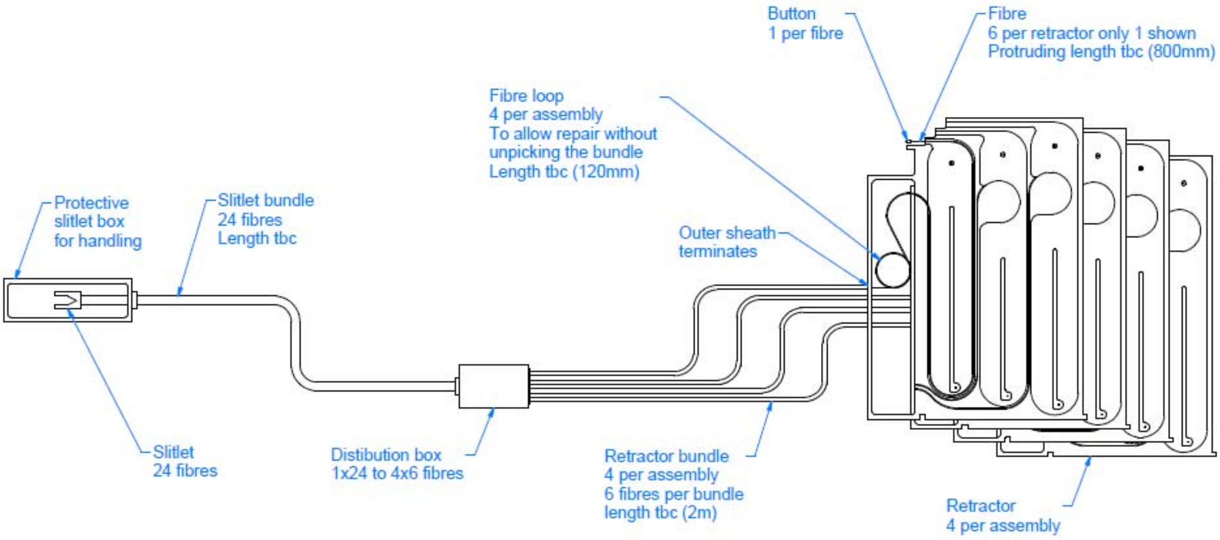

Figure 4 Schematic drawing of a bundle

4 EXOPLANET SEARCHES WITH A MULTI-FIBRE SPECTROGRAPH

The understanding of planet formation and its relation to the environment is one of the frontiers of modern astrophysics. Over 600 exoplanets are currently known [2], mostly in the solar neighbourhood. There is the well-known observational fact that planets are more frequently found around dwarf stars of higher metallicity [3, 4]. This could arise either because a higher metallicity environment favours the formation of planets or because planet formation entails the formation of chemically enriched debris that pollutes the stellar surface. It is intriguing that among giant stars, no such preference for high metallicity host stars is observed [5]. A possible explanation of this dicotomy has been suggested [6], in terms of the original sites of formation of the planet-host stars.

Another thing that we would like to understand is the relationship between planet formation and mass of the planet-host star, if any. There is a mild indication that more massive stars are more likely to form giant planets, yet the picture is complicated by the fact that currently available samples comprise stars of different ages and metallicities.

All these issues could be conveniently tackled by studying the planet population in several groups of stars with the same age and chemical composition. Such groups of stars are indeed available as stellar custers, both Open and Globular clusters provide interesting samples of stars for which we would like to know the frequency of planets, and the characteristics of these planets. This topic is largely unexplored, transit searches of planets in clusters have been unsuccessful, as a search of planets in the Hyades [7, 8, 9, 10], although one planet detection has been claimed around a giant star in this cluster [1]. Recently Pasquini et al. [1] claimed 9 candidate planet-host stars in the Open Cluster M 67. A cursory glance at the latter paper gives an immediate idea of what is the main difficulty of the programs searching for stars in clusters with the radial velocity technique. The group set out to monitor a sample of about 90 stars in M 67 using single object sepctrographs, HARPS at the ESO 3.6m telescope, SOPHIE at the OHP 1.93m telescope, CORALIE at the Swiss 1.2m Euler telescope and HRS at the Hoberly-Eberly 10m telescope. After four years of painstaking observations they assemble over 600 radial velocity points and find 9 stars with definite radial velocity variations compatible with the presence of a planet. Yet for none of these stars they have enough radial velocity points to compute an orbit. It will probably take four more years before they can collect sufficient data to confirm or reject the presence of planets around these nine candidates.

The slowness of the process is determined by the fact that each radial velocity has to be measured with a dedicated exposure on one telescope. If one could use a multi-object spectrograph to monitor the radial velocities of the stars the observation time would be reduced by a factor one hundred.

Could WEAVE carry out such observations? The multiplex of WEAVE is clearly more than enough for this purpose and it would be necessary to use only a small fraction, about 1/10 of the available fibres. The real issue is whether WEAVE will be able to attain the required radial velocity accuracy. In order to search for giant planets around F and G stars one should be able to achieve a precision in radial velocity of the order of 10 to 30 m/s. While this is well above the specifications of WEAVE we argue here that it is likely that WEAVE will achieve such precision.

The main argument in favour of this is by analogy to what has been achieved by Giraffe. A precision of 30 m/s has been claimed by [1]. Like WEAVE, Giraffe was designed to achieve a radial velocity precision of the order of 1 km/s. The high resolution mode of WEAVE will have more or less the same resolution as the high resolution mode of Giraffe, but a wavelength coverage that is four times larger. Using the scaling relation provided by [14]

$$\sigma_{\rm RV} = {\rm const} \times (S/N)^{-1} R^{-\frac{3}{2}} (\Delta\lambda)^{-\frac{1}{2}}$$

where R is the resolution, S/N is the signal-to-noise ratio and λ is the spectral coverage, we conclude that at a given S/N ratio WEAVE should achieve a factor of 2 smaller resolution than Giraffe, i.e. of the order of 15 ms.

One of the keys of the high radial velocity precision achieved by Giraffe is the fact that it can make use of a simultaneous Th-Ar calibration. This allows control of any variation in temperature and pressure of the spectrograph, with respect to the moment when the calibration arc was observed. WEAVE will not have such a facility, however and arc exposure can be obtained during the night, very quickly (a thing that cannot be done with Giraffe). This suggests that an observation scheme like ARC–SCIENCE–ARC is possible and is likely even more effective than a simultaneous calibration.

The role of the fibers in this context is very important, since all fiber systems provide a certain amount of scrambling, thus making the radial velocity measurement little dependent on the precise positioning of the star on the fibre, and of photo-centre motion. The good result of Giraffe[13] shows that this can be achieved without particular arrangements. Nevertheless a laboratory study on the scrambling properties of different fibers would be desirable and could allow a selection of the best-performing fibers.

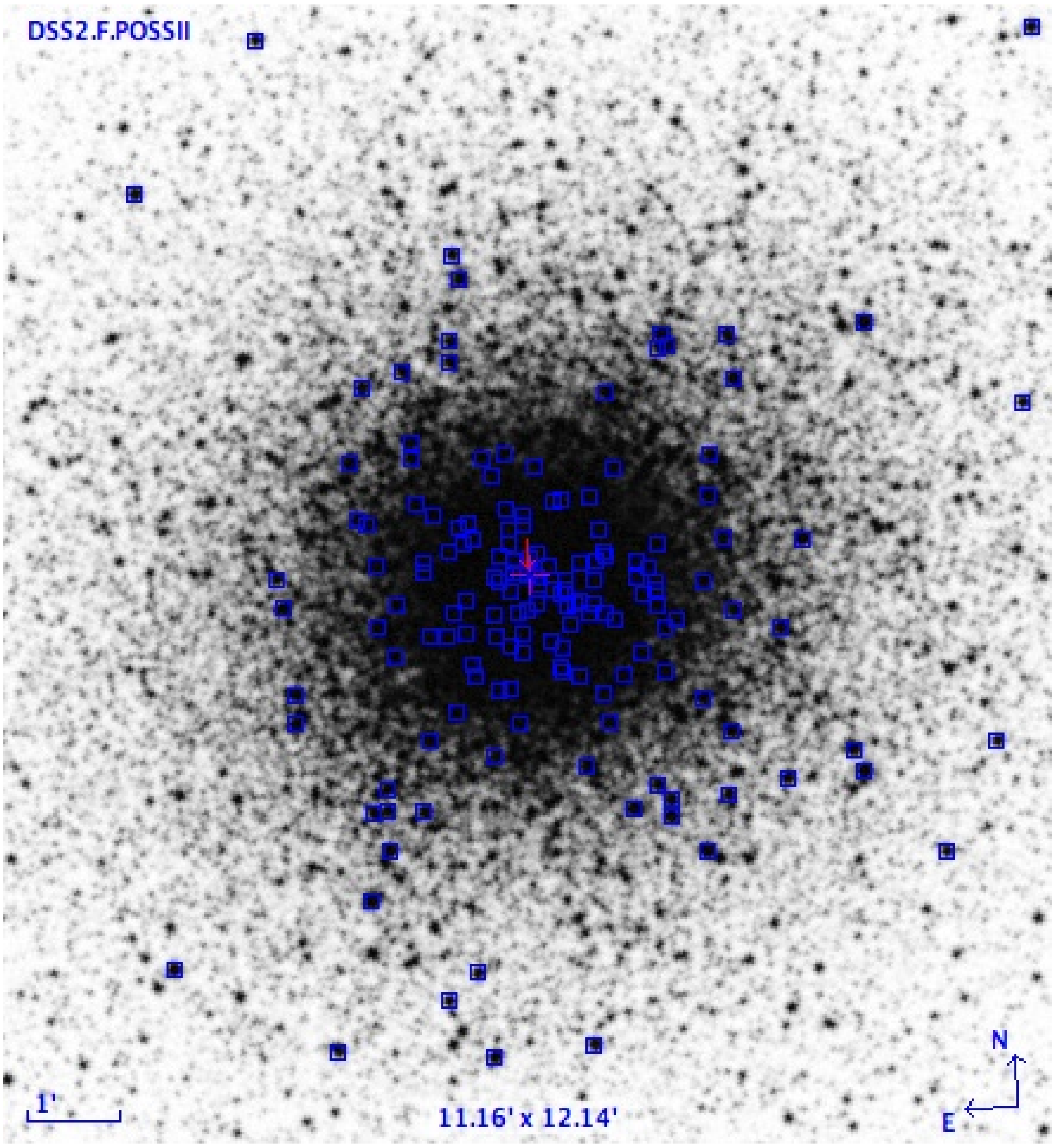

Figure 5 The Globular Cluster M13 (NGC 6205), with a metallicity of $[\mathrm{Fe/H}]\sim-1.5$ *and a declination of +3°27' is an ideal target for planet searches with WEAVE. The stars brighter than J=12 from the 2MASS catalog[15] are overlayed as blue squares. These giant stars are bright enough to be used by WEAVE for planet-hunting.*

5 CONCLUSION

During the following phase, the designs of the MOS and mini-IFUs need to be consolidated with detailed analysis and prototypes. The challenge is also to anticipate the manufacturing of nearly 4000 fibres with collaboration with companies to optimize the different phases of assembly of the fibres.

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