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The ING observatory in the 2015-2025 decade

Marc Balcells[1]

[1] Isaac Newton Group of Telescopes, Apartado 321, 38700 Santa Cruz de La Palma, Canary Islands, Spain

Abstract

The Isaac Newton Group, after nearly 30 years of productive operation of the William Herschel, Isaac Newton and Jacobus Kapteyn telescopes, is reviewing its science focus. The central goal is to respond to the changes in the astronomical landscapes in UK, the Netherlands, and especially in Spain, now a mature world-player community with access to 10-m class telescopes on La Palma and Paranal.

The current model, which exploits scientific and instrumentation diversity, will continue to be offered until 2017. In the meantime, an ING-led consortium is building WEAVE, a next-generation spectroscopic facility for the WHT. WEAVE is a multi-fibre system capable of deploying either 1000 single-fibre probes, 25 mini-IFUs or a single large IFU, to feed a two-arm bench spectrograph which delivers resolving powers of either 5000 or 20,000. WEAVE will exploit a new field corrector at the WHT that enlarges the prime-focus FOV diameter from the current 40 arcmin to 2 degrees.

WEAVE will be used to carry out massive surveys that exploit Gaia data in topics of Milky Way astronomy and stellar evolution; surveys that carry out galaxy evolution studies linked to various multi-wavelength surveys, including the LOFAR radio telescope; and redshift surveys of distant galaxies for cosmology. Community fibres will be available. The expectation is that these surveys will use 70% of the WHT time until at least 2022. The rest of the time will be available via normal TAC allocations, for use of facility instrumentation.

Plans for the INT include involving external institutions in the provision of new instrumentation and/or telescope upgrades in exchange for significant fractions of telescope time.

1 Introduction

The year 2014 marks the 25th anniversary of the first light for ISIS, the work-horse two-arm spectrograph of the 4.4-m William Herschel Telescope (WHT). Still the most demanded WHT instrument and used in 25 to 30% of the nights, ISIS is one of several aspects that have made the Isaac Newton Group of Telescopes[1] (ING) particularly useful for the astronomical communities of the UK, the Netherlands and Spain.

[1] www.ing.iac.es

For an observatory to remain competitive, adapting to the realities of the immediate future is a must. In the past two decades, astronomical communities in Europe have gained access to ESO's four 8-m VLT telescopes in Paranal Observatory, and Spain has built its own 10-m GTC at Observatorio Roque de los Muchachos (ORM). Astronomy has grown worldwide, and has become more international. Very large databases with data from the best telescopes are openly available, e.g., SDSS[2], HST[3]; they make it possible for an astronomer to never plan, carry out and process observations; or for astronomers to never have to opportunity to visit an observatory.

Astronomy is also increasingly becoming multi-frequency, benefitting from the combination of optical, infrared, radio, X-ray, Gamma-ray data; fewer and fewer scientific papers are based on data from a single telescope, and astronomical communities need to leverage investments to secure access to a wide variety of observing platforms.

For Spain, the last 25 years have seen an impressive growth from insignificance to full relevance in the international astronomical arena. Spanish astronomers now use facilities and establish their academic careers world-wide. Spanish institutions were users of telescopes, but now they are partners in the operation (ING, CAHA), or operate their own facilities (GTC; Javalambre). Spanish institutes and Spanish industry regularly win important construction contracts in telescopes and instrumentation.

2 The best use for a 4-m telescope

As early as 2008, the ING Director's Advisory Committee highlighted that the WHT could only remain competitive in the era of 10-m telescopes by focusing on what large telescopes cannot deliver, a case in point being wide-field astronomy. Larger apertures always win when the goal is reaching fainter targets. But surveys, where a large number of objects need to be covered to a given S/N, the rate of progress scales as the product $A \times \omega$, where A is the telescope collecting area and ω is the solid angle of the viewing cone of the telescope. By providing a 4-m telescope with a wide field of view, the survey speed can be several times larger than for a typical 10-m telescope (Fig. 1). The DAC thus suggested that a wide-field spectrograph would make the WHT competitive for a period of at least a decade.

The best use of 4-m class telescopes in the era of 10-m telescopes was a topic of debate in the decade of 2000 for astronomy funding agencies worldwide. In Europe, ASTRONET[4] sponsored the development of a *Infrastructure Roadmap for European Astronomy* [2] and a review of 2-m - 4-m telescopes [3]. Both reports proposed that multi-object spectrographs on 4-m class telescopes were crucial for extracting science from important photometric and astrometric programmes led by Europe, such as the Gaia[5] satellite, the LOFAR[6] low-frequency array, and optical-infrared imaging surveys currently being carried out.

[2] http://www.sdss.org
[3] http://www.stsci.edu
[4] http://www.astronet-eu.org
[5] http://sci.esa.int/gaia/
[6] http://www.lofar.org

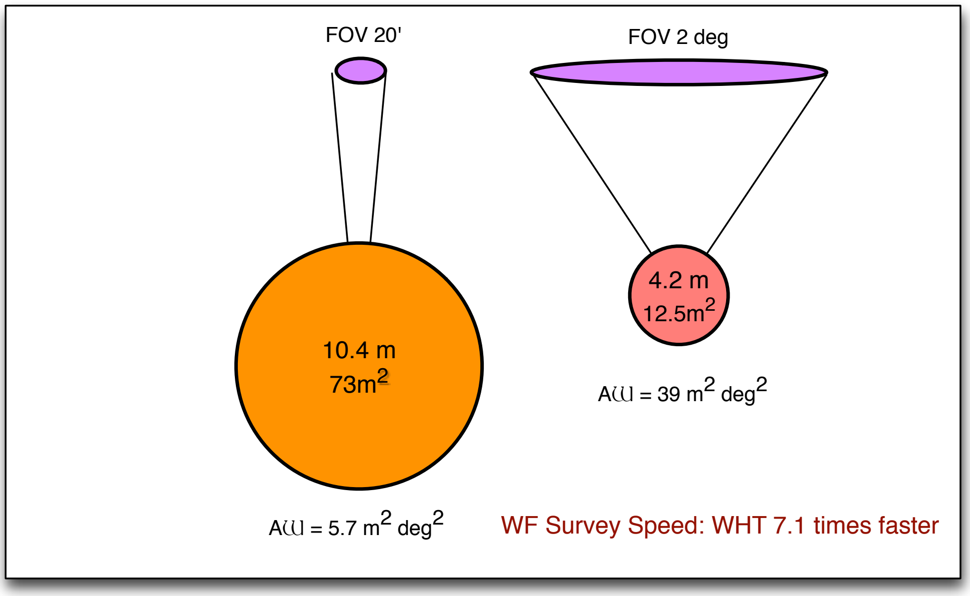

Figure 1: Survey efficiency of 10-m and 4-m telescopes compared. The speed at which one covers a given number of objects to a given S/N scales as the product of telescope collecting area A times viewing solid angle ω. This product is 5.7 $\mathrm{m}^2\,\mathrm{deg}^2$ for a 10-m telescope with a 20-arcmin FOV, and 39 $\mathrm{m}^2\,\mathrm{deg}^2$ for a 4-m telescope with a 2-degree FOV. Survey speed is 7.1 times faster for the smaller telescope.

3 Plan for the WHT

With the arguments above, the ING partners, after a careful analysis involving the funding agencies and advisory committees, and in consultation with our communities, completed in 2010 a decadal strategy for the WHT, which was approved by the funding agencies. Key in this strategy is to turn the WHT into a wide-field telescope, and provide it with a high-multiplex, high-efficiency spectrograph. The WHT, with the KPNO 4-m Mayall Telescope, would become one of the last 4-m to evolve into a largely survey telescope. Other 4-m class telescopes (CFHT; UKIRT; AAT; CANA; TNG; Blanco) had made that transformation earlier.

Important in the plan was to continue to provide observation services to as wide a community as possible. This would be accomplished, in the first place, by ensuring that the new survey instrument would have a truly broad science case in fields central to the research traditions of the three partner countries. Secondly, by retaining a fraction of the nights for activities for which users cherish the WHT: observing with other facility instruments,

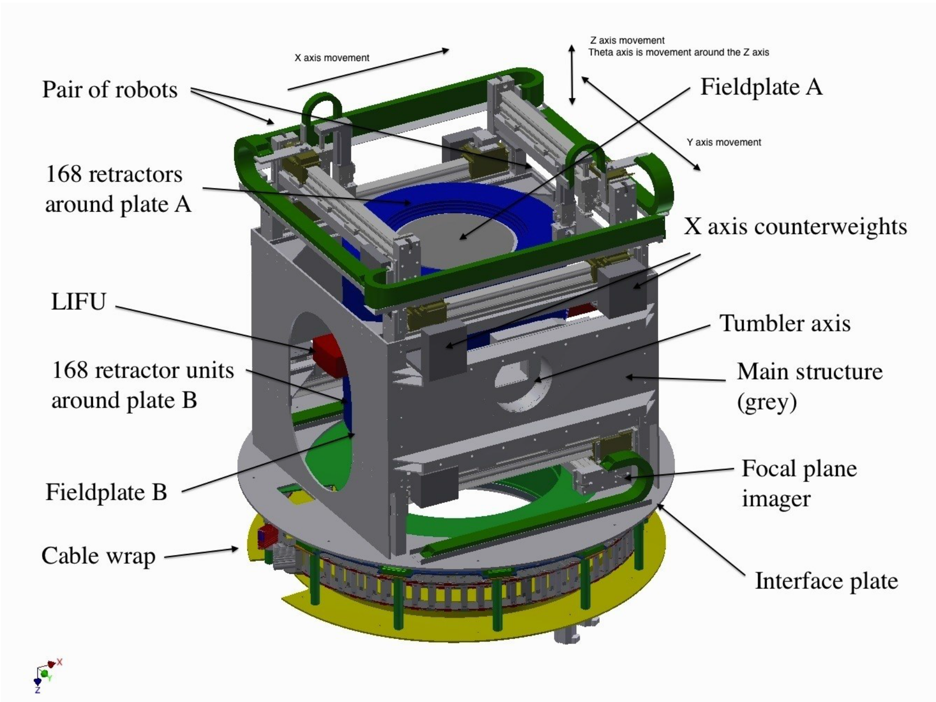

Figure 2: The final design of the WEAVE fibre positioner. Light from the primary mirror enters from below. Of the two field plates, plate A is shown in the configuration position and plate B (below) is in the observing position. A 180-degree rotation around the tumbler axis reverses their positions, while a 90-degree rotation places the large IFU (LIFU, red in the image) in the observing position. The two x-y robots are at the top. The blue drums are the fibre retractors.

observing with visiting instruments, and technology development.

Until approximately 2017, during construction of the WEAVE instrument, the WHT will continue to be used as a multi-purpose, multi-instrument telescope offering time through the various programmes of the national TACs.

4 The WEAVE spectroscopic facility

The WEAVE instrument is fully described elsewhere in this volume [1]. In short, WEAVE comprises the following:

Telescope top-end and two-degree corrector. A new top-end holding the prime focus unit of the WHT. The unit includes a new field corrector delivering a field of view of 2 degree diameter. Featuring lenses as large as 120 cm diameter and an atmospheric dispersion corrector, the six-lens corrector will deliver an image quality better than

0.45" EE80 (polychromatic 380nm to 1000nm; 0.8" including mechanical tolerances), with a flat throughput better than 70% in that range.

Fibres. WEAVE will be equipped with 4000 fibres. Two sets of 1000 fibres are for single-fibre MOS. A third set of 1000 fibres is organised into 20 mini-IFUs covering 11×9 arcsec^2. The final set of 1000 fibres is organised into a single IFU covering 90×78 arcsec^2.

Fibre positioner. The fibre positioner is based on the pick-and-place principle of 2dF and Autofib-2: each fibre terminates with a magnetic button and a prism; two x-y robots grab fibres one by one and position them at the requested position on the focal plane. Replicating the successful 2dF design, a tumbler allows MOS observations with one set of 1000 fibres while the other set is being positioned. The 20 mini-IFUs occupy 20 fibre slots on one of the two sides of the tumbler. The large IFU is placed at a 90-degree position. See Fig. 2.

Spectrograph. A new two-arm spectrograph, placed on the GHRIL Nasmyth platform, will be fed by one of the four 1000-fibre sets and deliver spectra with resolving power 5000 covering from 370nm to 1000nm, or resolving power 20,000 over one-quarter the wavelength coverage. The overall system throughput is higher than VLT/FLAMES *per fibre*, for a multiplex 10 times higher.

Data system. The WEAVE facility comes with an integrated data system that comprises survey management tools; core processing system, advanced data products, and archive system.

WEAVE is being built by a partnership involving STFC, NOVA, NWO, IAC, ING, GEPI, INAF, Konkoly and INAOE. The project plan calls for delivery at the WHT in 2017, and start of science surveys in 2018.

5 WEAVE science

The WEAVE science case was written by a science team of over 100 astronomers in the partner countries. It has three broad topics:

Gaia follow-up: to provide radial velocities with errors $\sim$2 km s^{-1} for $\sim 10^7$ stars with parallaxes and proper motions from Gaia ($16 < V < 20$). To provide abundances for $\sim 10^5$ stars with $V < 17$. Target selection will be made to allow a wide range of scientific explorations, from Milky Way archaeology to stellar evolution.

Galaxy evolution: to provide redshifts, velocity dispersions, metallicities and alpha enhancement for galaxies up to $z \sim 0.5$ in the field and in the infall regions of clusters. To use the mIFUs, to provide velocities, dispersions and abundances for cluster dwarfs as dynamical probes of galaxy cluster potential. To provide redshifts for large numbers of sources detected by LOFAR. To study dark matter in disk galaxies by mapping the vertical velocity dispersion of galaxy disks using the LIFU.

Cosmology: to obtain large-scale structure maps using LOFAR sources as probes. To examine the Lyman-α forest in quasars to extend LSS mapping to redshifts above $z = 2$.

Community fibres: a fraction of the WEAVE fibres will be available every night for programmes outside the main surveys, similar to the practice with the SDSS surveys.

6 The INT

The 2.5-m INT will continue to be used with its current instrumentation, the prime-focus Wide Field Camera (WFC) and the Cassegrain Intermediate Dispersion Spectrograph (IDS). The INT remains important for ING not only because it continues to deliver an impressively high level of publications, but also because it is central to ING's student programme: four to six MSc or PhD students spend a year at ING supporting visiting observers.

Funding restrictions have prevented us from upgrading the telescope and instruments. We plan to reverse this situation through a programme involving institutions who may be able to contribute competitive instrumentation or telescope upgrades in exchange for significant amounts of telescope time.

7 Concluding remarks

We expect that the plans for the future will overall lead to better and more fundamental science coming out of the ING telescopes. These plans also imply an opportunity for the communities served by ING to gain access to a powerful new facility and to contribute to the design of the science surveys.

It is to be expected that some of the science now delivered by the WHT will progressively move to the GTC. Interestingly too, through our instrumentation plans for the INT we may open the way for some of the science now done on the WHT, for instance time-domain astronomy of moderately bright targets, to be carried out on the INT.

References

[1] Aguerri, J. A. L. 2015, this volume

[2] ASTRONET infrastructure roadmap, 2009, http://www.astronet-eu.org/IMG/pdf/Astronet-Book_light.pdf

[3] Report of the European Telescope Strategy Review Committee, 2010, http://www.astronet-eu.org/IMG/pdf/PlaquetteT2_4m-final-2.pdf