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Antarctica – a case for 3D-spectroscopy

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1. Advantages of 3D-spectroscopy

DS or Integral-Field Spectroscopy (IFS) provides multiple spectra for each point of a 2-D field, rather than along a narrow, 1-D spectrograph slit only. Therefore, IFS does not require very accurate telescope pointing, nor do pre-assumptions about slit or aperture sizes have to be made. It avoids any 'slit-losses' due to seeing or atmospheric dispersion, which eliminates the need for any parallactic alignment or a dispersion compensator (see Fig. 1).

Integral-field units (IFUs) with 100 % fill factor (e.g., PMAS, Roth *et al.* 2005) can be used for accurate spectrophotometry (Kelz & Roth 2006). As all the information is gathered at the same time, 3D-spectroscopy is more efficient than any scanning technique and insensitive to variable instrumental and atmospheric conditions. The resulting data-cube (with coordinates in RA, Dec, and lambda) allows both a PSF-optimized extraction of single and combined spectra, as well as the re-construction of narrow- and broad-band images, without the need for filters. As the sky background around the target is recorded with better coverage than with slits, an improved background subtraction, in particular in crowded fields, is possible (Becker *et al.* 2004). Additional results from post-processing, such as differential images, abundance ratio maps, or velocity fields can be extracted with little effort from the data cube. Obviously, spectroscopy of any complex structures such as galaxies, mergers, nebulae, winds, or jets benefits from the 2-dimensional field-of-view. The various advantages of 3DS are discussed in Roth *et al.* (2004).

Certain IFUs, such as the PPak fiber bundle (Kelz *et al.* 2006), provide very high instrumental grasp, i.e., light collecting power. The availability of 2-D information allows spatial binning of spectra to improve the signal-to-noise, in particular for low surface brightness objects, even further. For projects where flux collection, rather than spatial resolution is an issue, binning the IFU spaxels has the same effect as increasing the aperture size of a telescope. In case the spatial position of the target is not known well enough (e.g., optical counterparts of X-ray sources, γ-ray bursts, or because the target is too faint to be visible at the acquisition system), the integral-field provides an increased error circle to ensure that the target is not missed altogether. If the location of spectral features is uncertain (e.g., because the redshift is unknown a priori), 3DS is the only technique that can reliable detect these. For extra-galactic or cosmological applications, the 3D-data cube corresponds to a volume in space, which otherwise can only be recorded with time-consuming scanning techniques using tunable filters (Bland-Hawthorn 2006).

2. Relevance for Antarctica

While the above advantages of 3DS are of general nature, some of them are particularly important at a remote location such as in Antarctica, where highly autonomous or robotic telescopes are required (Ashley *et al.* 2004). The case stated here is applicable to the optical/near-IR domain, i.e. to future spectroscopic instrumentation and related science cases as proposed for a PILOT-like telescope (Burton *et al.* 2005).

Given the environmental conditions in Antarctica (Storey *et al.* 2005), it is desirable to reduce the amount of movable components as a potential source of failure. 3DS completely

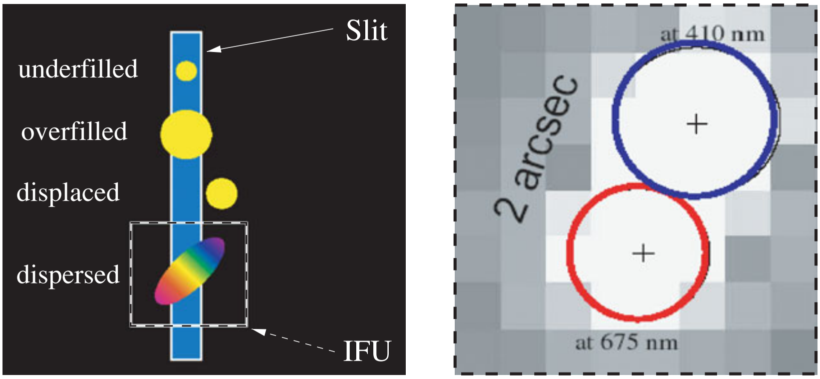

Figure 1. *Left*: Sketch of the common problems present in classical slit-spectroscopy. From top to bottom: under-filling and over-filling of the slit, mispointing, atmospheric dispersion and parallactic misalignment. *Right*: A re-constructed image of a star, observed with an integral–field-unit (IFU) at an air mass of 1.7. Despite a dispersion of $2''$ between 410 nm and 675 nm, the IFU records the entire flux, avoiding any slit-losses or chromatic errors.

avoids the need for a (rotatable) filter wheel, any slit width or angle adjustments or an ADC. If the IFU is fiber-coupled, the subsequent instrumentation can be mounted remotely from the telescope in a stable and climatized environment. This would imply that the telescope and fiber-link needs to be adapted to the Antarctic conditions, but not the spectrograph as such. The background subtraction, in particular for the OH-bands in the NIR, is improved by IFS. Furthermore, IFS may be operated with a nod-&-shuffle mode (Roth *et al.* 2002) or fiber Bragg gratings (Bland-Hawthorn 2006) may be used for future fiber-coupled instruments. The precision requirements for telescope pointing, target acquisition, guiding and tracking are less stringent for IFUs, which greatly relaxes the demands on the accuracy of drives, gears and motors for the telescope and reduces frequent re-calibrations due to any ice-drift.

In summary, the use of innovative IFUs eliminates much of the complexity, present in classical spectroscopy (Kelz 2004). It relaxes acquisition requirements and removes critical, movable parts from the system. This simplifies the instrumental design and minimizes potential sources of failure. 3DS allows a fast and reliable 'point-and-expose' observational approach, which is ideally suited for remote or robotic observations. At the same time, it offers multiplex and time-saving advantages for a broad range of scientific projects, ranging from stellar population studies to cosmology, that are proposed for a large telescope at Antarctica.

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