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Octocam – a New Workhorse Instrument for Transient Follow-up at Gemini South

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Abstract. Octocam is an 8-channel VIS and NIR imager and spectrograph to be installed at Gemini South in 2022. It provides simultaneous imaging in *g'*,*r'*,*i'*,*z*,*Y*,*J*,*H*,K_S bands or simultaneous spectroscopy at a resolution of ∼4000, together with high time-resolution options. Additional capabilities such as spectropolarimetry or an Integral Field Unit could be added as an upgrade later. These properties makes it very well suited as a follow-up instrument for transient searches. It is planned as a dedicated follow-up instrument for LSST, and will start operations at the same time as the LSST main survey. Octocam was conceived as a consortium consisting of South-West Research Institute in San Antonio, Texas, IAA-CSIC in Granada, FRACTAL SLNE in Madrid, and George Washington University.

Keywords. Instrumentation: spectrographs, instrumentation: photometers, stars: variables

1. Introduction and History

The commencement of large transient surveys such as ZTF or LSST will require dedicated follow-up instrumentation to characterise the newly discovered objects, since the surveys themselves often do not provide enough information. Transient sources can have very different natures and properties, so the instruments best suited to following up need to be versatile, offer different observing modes, and cover a broad wavelength range. This report describes Octocam, a new workhorse instrument to be installed at Gemini South in early 2022. Octocam was specifically conceived as a follow-up 'machine' for LSST, and is therefore on a tight schedule to be ready by the start of the LSST main survey.

The Octocam concept has been developing gradually over the past 10 or so years. It was originally proposed in a smaller version in 2008 as a project for Calar Alto Observatory in Spain, and in 2009 it was put forward in a new instrument call at the Gran Telescopio Canarias (de Ugarte *et al.* 2010). Unfortunately both proposals were unsuccessful. In 2015 a call was issued by the Gemini Observatory to fund a feasibility study for a new workhorse instrument called 'Gem4#3'. Octocam was selected, and a feasibility study was successfully concluded in October 2015 (de Ugarte Postigo *et al.* 2016). In 2016 a call for construction was issued, and was won by the original Octocam consortium. The conceptual design phase started in April 2017, the conceptual design review was passed in the summer of 2017, and (as of January 2018) Octocam was in the preliminary design phase.

2. Science Cases and Drivers

The main science driver of Octocam is the rapid characterisation of transients discovered by large surveys and to synergise with other facilities in the 2020s. Since the large survey facilities of the 2020s will not themselves be able to characterise the vast majority of transients detected, OCTOCAM will make an important contribution. However, there are also many other fields which can profit from such an instrument that offers both a broad wavelength span and different capabilities (see e.g. Thöne *et al.* 2016). OCTOCAM therefore gathered a science team of over 50 researchers from very different research areas representing the Gemini community.

Broad coverage is especially important for studying sources over a large range of redshifts or at very high ones; the coverage of OCTOCAM will enable us to determine (say) the redshift of a galaxy or characterise a Gamma-ray burst (GRB) at $z = 20$ by detecting the Lα dropout, or investigate the interstellar medium in a GRB host up to redshifts of at least $z = 15$. It is also important for characterising transients whose properties are not yet known and for which there is therefore no previous knowledge as to which parts of the spectrum will be the most interesting or critical for determining the transient's properties.

For studies of supernovæ, black holes and neutron stars, broad wavelength coverage in imaging and spectroscopy is crucial for disentangling different emission properties, and for probing the different elements produced in those events. High time-resolution is important for varying sources that vary very rapidly (e.g., X-ray binaries in outburst), or events such as transients of exoplanets or trans-neptunian objects.

3. Instrument Design

3.1. *Design drivers*

OCTOCAM will be able to deliver simultaneous broad-band imaging or spectroscopy over its full wavelength range, combined with high time-resolution (if desired). Its design has been influenced strongly by experience with previous instruments for transient follow-ups, among them GROND (Greiner *et al.* 2008), X-shooter (Vernet *et al.* 2011), ULTRACAM (Dhillon *et al.* 2016) and HiPERCAM (Dhillon *et al.* 2016). It will cover a combination of temporal resolution, spectral resolution and spectral coverage that is so far unprecedented. Our goal is to make the instrument as simple as possible while optimising its design for different wavelength ranges. The design needs to be efficient, simple, compact, with only a small number of moving parts, and also light-weight since it is going to be mounted at the Cassegrain focus of Gemini South.

The wavelength range of OCTOCAM will cover the full span between the near-UV cutoff (fixed at ~3700 Å by the silver coating of the main mirror) and the Ks band at 23,500 Å. That will enable us to observe (for example) the [O II] doublet at λ3727, 3729 Å at $z = 0$ to Hα at $z = 2.5$. We chose a medium resolution of 3500–4500, which is sufficient to resolve the NIR sky lines while also providing enough signal to detect the continua of faint sources. Furthermore, the instrument will be able to observe at high time-resolution down to a few milliseconds both in imaging and spectroscopy. The basic capabilities and requirements of the instrument are summarised in Table 1.

3.2. *Optical, mechanical and detector design*

OCTOCAM has eight independent channels for its eight different spectral regions, which requires some optimisation for the different wavelengths covered. At the same time, there is only one common focal plane placed inside the NIR channel cryostat, so as to avoid thermal emission. The instrument is placed on a common backbone to reduce issues due to differential flexure of different channels. A choice of slits will be available for spectroscopy; the current plan is to include ones that are $0''.55$, $0''.7$, $0''.9$, $1''.1$ and $5''$ wide. The instrument will also have a retractable Atmospheric Dispersion Corrector, and will allow for later upgrades to a small full-range integral field unit and spectropolarimetry.

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Table 1. Basic capabilities and requirements of OCTOCAM

Requirement	OCTOCAM
Simultaneous spectral range	Photometry: grizYJHK$_S$ Spectroscopy: 3700-23500 Å simultaneous and continuous excluding atm. bands
Field of view	3×3 rectangular or 254 diameter circular 3′ longslit
Plate scale	0.18″/pixel
Spectral resolution	> 3500 in g′, 4100 – 4500 in other bands
Average efficiency	Imaging: 46% Spectroscopy: 30%
Maximum full-frame rate	VIS: 50ms for 30×30pix window at 50kHz (in driftscan mode) NIR < 50ms at 10 kHz
Observing modes	Multiband imaging Wide band spectroscopy (long slit) High time-resolution (imaging and spectroscopy)

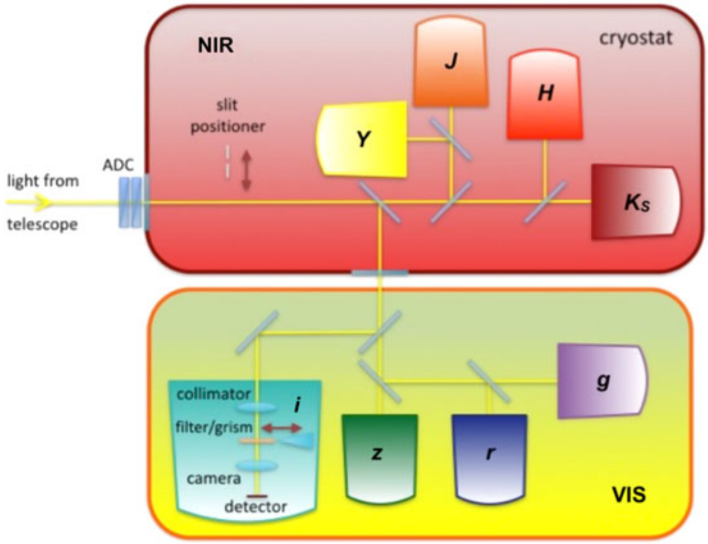

Figure 1. Schematic layout of the OCTOCAM design. The slit positioner is placed at the focal plane of the telescope.

The optical design of OCTOCAM is a classical collimator–grating–camera design that includes high-efficiency volume phase holographic grating grisms. Filters will only be introduced in the blue-most channel, which has a broader coverage than the standard g′-filter width, and will also include NIR filters to avoid thermal noise. The instrument's design is optimised such that we reach average efficiencies of 30% in spectroscopy and 46% in imaging overall. The mounting at the Cassegrain focus requires a very compact design, which makes the mechanical design somewhat challenging. At the same time, the different parts of the instrument need to be easily accessible for reasons of maintenance. The NIR section of the instrument will be cooled by closed-cycle coolers and a pre-cooling system, while the VIS section will be kept at ambient temperatures. Separate cooling for the VIS detectors will need to be included as they are outside the main cryostat.

OCTOCAM will employ state-of-the-art detectors, selecting different models for the VIS and the NIR. For the VIS channels, a 4k×4k e2v CCD231-84 with frame-transfer

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capabilities will be used to allow for a windowing mode needed for very high time-resolution. Full-frame time-resolution of 250 ms in imaging and 20 s in spectroscopy will be possible, while ∼100 ms in windowing mode and resolutions down to 10 ms in drift scan mode will be obtained. The detectors are very similar to those used in HiPERCAM (Dhillon *et al.* 2016), except for their larger size. In the NIR, 2k×2k Hawaii-2RG detectors with 32 readout channels were chosen; those are a very widely-used and are a well-known detector type in IR astronomy.

4. The Future of the Project

Unfortunately, business arrangements between members of the consortium have not worked according to plan, and OCTOCAM has been searching for a new principal investigator (PI).†

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† The original OCTOCAM consortium was comprised of four partners: (1) South-West Research Institute (SwRI) in San Antonio, Texas, as the main contractor with AURA and the Gemini telescope, (2) IAA-CSIC in Granada, (3) FRACTAL SLNE in Madrid, Spain and (4) George Washington University (GWU) in Washington DC as subcontractors of SwRI, USA. Each node had different tasks: (1) SwRI provided the main project manager (PM), the systems engineering and the work packages of detectors, detector cooling, electronics and instrument software, (2) IAA-CSIC had provided the original idea of the instrument, the PI and the deputy project manager, (3) FRACTAL was to be responsible for the opto-mechanical design and the instrument cryogenics, and (4) GWU was to provide the project scientist (PS) and at a later stage the data reduction pipeline. The parallel PM scheme was chosen to facilitate the management of two main nodes that were the most geographically distant, namely the USA and Spain, a scheme which had proved to work well during the feasibility study in 2015. However, SwRI decided at the end of the conceptual design phase to ease out the Project Manager fully from the IAA-CSIC node under alleged concerns of risks and schedule, and at the same time to limit the role of the PI. The unwillingness of SwRI to honour the initial contract, and of IAA-CSIC to consolidate this change by accepting modifications to the signed contract, resulted in the unilateral decision of SwRI to cancel the contract 'for convenience'. The effect of these actions may have had uncertain consequences for the project, but it now has a new PI and its name is changed to SCORPIO.