ELT Instrumentation Study

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Proposed Scope of the Study

- Four point instrument designs
  - Identify key drivers on telescope design
- Broad Look at other concepts
  - Plus the "what have we forgotten?" WP
- ADCs

Point Design Deliverables

- Link to the Science Case
- Design drivers on Telescope and AO systems
- Outline Design of instrument
  - indicating mass, volume, moments, handling, data rates etc
- Technical Risk Analysis
- Functions and Performance Requirements Document (FPRD)
- Outline Project Plan, including possible Work Breakdown Plan (over likely participant organisations)

Point Design Deliverables (2)

- Indicative costing, with effort (FTE) and hardware requirements
- Operational Concepts Definition Document (OCDD) setting out optimum operational mode
  - Classical?
  - "Particle Physics"?
- Calibration requirements statement
- Performance Simulator
- Assessment of resource requirements from telescope infrastructure
  - power, cryogen consumption, labour, likely room-temperature heat dissipation

WFSPEC

- Wide Field seeing-limited (or boundary-layer corrected) SPECtrometer
- Spectra of many objects over a field of several arcminutes
  - Large Scale Structure in the Universe, and its evolution
  - Evolution of the chemical structure of the IGM
  - Redshift surveys of very faint and distant galaxies
- Matching a seeing-limited image (or even a BLC image) to a reasonably small number of detector pixels is hard!
  - either impossibly fast final F/ratios
  - much larger physical pixels than currently in use
  - or use of smaller (sub)pupils

WFSPEC (2)

- Current assumptions with BLC: Delivered images will have 50% EED ~0."25 over a ~10' FOV from 0.5 μm to 2.2μm
- Issues
  - Do we need an *imager* ? (not currently included in this instrument concept) cf other large-spatial-volume options such as a smaller, much wider-field telescope
  - Information required for the assessment of likely performance of boundary-layer correction AO systems is lacking and getting it should be part of the WP

Planet Finder

- High dynamic-range (coronagraphic) imager/spectrometer
- "The Killer App"
  - Direct detection of planets around a large number of nearby stars, including *earth-like* planets
  - Time-dependent photometry and spectroscopy of planetary atmospheres
  - Searching for biomarkers in the Earth-like examples
- Challenges
  - Suppression of stray light, removal of the bright source, maximum possible concentration of the light from the star into the image core by very high-order AO (Strehl ratios >0.7 are sought)
  - Spectroscopy will be hard and photon-counting detectors are likely to be desirable

Planet Finder (2)

- Current AO assumptions: Strehl of >0.7 over a 5" FOV at 0.7, 1.0 μm
  - High-order AO is at the core of this instrument
  - Need close communication with (and participation in?) the AO WP studies
- Issues
  - The effects of segmentation on low-level image structure
  - Study of spectroscopic approaches, especially for the detection of (exo-) telluric features in the presence of earth's atmosphere is required

MOMSI

- Optical /NIR Multi-Object & Multi-field Spectrometer & Imager
- Core role – applicable to many science programmes
- Obtain images and/or spectra of many (exceedingly faint) objects over a field of order an arcminute using MCAO
  - How, when and from what present-day galaxies formed (deduced from their present sub-populations of stars)
  - Evolution of galaxies and pre-galactic objects: their structure, dynamics, and composition, from very high redshifts
  - Detection of the earliest luminous objects in the universe

MOMSI (2)

- For spectroscopy, picking off sub-fields will be essential
  - Link to Smart Focal Planes JRP
- For imaging, covering the FOV with detectors may be impractical
  - ~10^{12} pixels needed to sample the diffraction limit over an ~arcmin field
    - ~4000 of the largest current NIR arrays (2k×2k)
  - Alternative – pick off subfields for *imaging* as well
  - Allows modularity (but modules will still be physically large)
- Current AO assumptions: Strehl ranging from 0.2 at 0.5μm to 0.5 at 2.2μm with little PSF degradation over a 1' FOV
- Issues
  - Modular vs monolithic design approaches
  - Likely that the K band will be essential – implies that pickoff mechanisms, etc will need to operate cryogenically

MIDIR

- MID-IR diffraction-limited high-resolution spectrometer/imager
- The considerable sensitivity and extreme angular resolving power of an AO-corrected ELT in the mid-IR makes it potentially a powerful complement to large space telescopes such as the JWST
- The design of such an instrument is likely to be related to that of the Multi-Object MCAO Spectrometer/Imager
- Current AO assumptions: 1' FOV as for MOMSI but for Strehl ranging from 0.5 to 0.8

MIDIR (2) – Issues

- CELT study for a mid-IR prime focus instrument with its own AO system should be examined
- Though the OWL design is AO-friendly it has 5 surfaces ahead of any instrument, so for realistic coatings the overall emissivity is unlikely to be below 10%
  - A cold AO system may be necessary
  - This is a potential cost driver
- Strong pressure for a high dry site
- Large-format high-background detectors needed
  - Could be a substantial cost driver (development programme)
- Pressure to include twilight and daytime operations

Outline designs

- For instruments not selected for Point Designs
- Innovative instrument designs
  - Ensure that no new and original ideas likely to be important for ELT instrumentation have been omitted
- HiTRI – high time-resolution photo(polari)meter spectrometer
  - Expected only single point sources (optical pulsars, short-periods variables of several classes, AGNs and Blazars)
  - Photometric, polarimetric and time-resolved spectroscopic variations
  - Novel detector technologies will be explored (part of the “detectors” JRP covers this area)

Outline Designs (2)

- HISPEC – O/NIR high spectral resolution instrument
  - Absorption lines cosmology of elements other than hydrogen (how the heavy elements in the ISM/IGM/ICM evolved)
  - Stellar dynamics in nearby galaxies
  - Detailed examination of the physics of the galactic ISM
  - The field size required is *TBD – science input needed*
  - For several reasons (e.g. acquisition, efficiency) it should probably employ at least one IFU (perhaps a single MOMSI pickoff) even if it is a single-object instrument

Outline Designs (3)

- SCOWL – (SCUBA-3) submillimetre imager
  - SCOWL will carry out the first all-sky submm surveys at resolutions comparable to the Schmidt surveys in the optical (~10^6 gains over ALMA for this purpose)
  - It would provide the first deep observations at the peak of the FIR spectral energy distribution (200μm)
  - SCOWL could be an ideal poor-seeing and cirrus backup instrument
  - It would employ large arrays of TESs being developed for SCUBA-2

Outline Designs (4)

- GRB-catcher – fast-response broad-band imaging spectrometer
  - This instrument is designed for extremely rapid observations (ideally, response time of seconds: changeover during slew) of objects such a Gamma Ray Bursters which evolve on timescales of seconds to minutes
    - Probably one or more IFUs able to secure images and moderate resolution spectra in a range of simultaneous wavebands
    - Range from the blue end of the visible though the mid-IR
    - Each will probably require its own ADC and AO facility
  - Challenging instrument to design
  - Compromises in image quality may be needed in order to secure fast response times

Atmospheric Dispersion Correction

- For work in the Optical and NIR a new level of ADC will be required if milliarcsec resolution is to be achieved
- Serious constraints on the design of such systems
  - May require location in collimated beams
  - Optical components transmissive and will be large
  - Beyond ~1.6 μm will need to be cooled
  - Control may require real-time sensing
    - may add a dimension to the requirements on AO systems
- Issues
  - Short-timescale chromatic atmospheric effects and development of schemes for monitoring them
  - May be a serious shortage of specialist glasses