Progress on 1.5m Aperture Telescope and Instruments: Solar UV, Visible and near IR Telescope (SUVIT)

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Solar Optical Telescope

<table>
<thead>
<tr>
<th>Space</th>
<th>Ground-based</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOT Φ1.5 m (planned 1980) resolve photon mean-free-path scale in the photosphere OSL Φ0.8 m (planned late 1980s)</td>
<td></td>
</tr>
<tr>
<td>Spacelab 0.3 m</td>
<td>NST Φ1.6 m (2009～)</td>
</tr>
<tr>
<td>Hinode/SOT Φ0.5 m (2006～) need more photons and resolution! Solar-C/Plan-B</td>
<td>GREGOR Φ1.5 m (2010?～)</td>
</tr>
<tr>
<td></td>
<td>ATST Φ4 m (2018?～)</td>
</tr>
</tbody>
</table>

Heritage of developments of Hinode/SOT and large-aperture ground-based telescope.
→ Technology is getting mature enough to build 1.5-m class space-borne telescope.
Basic requirements to the instrument

- **Telescope aperture and length**
  - $1.5m_\phi$
  - Fit within the H-IIA nose fairing

- **Spatial resolution**
  - 0.1" in UV
  - 0.16" in Vis/NIR (Diffraction limit of $1.5m_\phi$ at 1\(\mu\)m)

- **FOV**
  - $\sim200" \times 200"$ to cover a medium size AR with 4kx4k detector

- **Wavelength coverage (250 – 1100 nm)**
  - Shortest $\sim250$ nm to observe Mg II h/k.
  - Longest $\sim1100$ nm to observe He I 10830.

- **I/F between the telescope and the focal-plane instrument**
  - Collimated beam with $\sim\phi60$mm exit pupil to relax the tolerance of alignment.
Primary Mirror

Monolithic light-weight mirror for 1-1.5 m aperture are feasible

- 90% light-weighting: 100 – 150 kg (weight budget)
- Small gravity effect in horizontal configuration
  - WFE < 35 nm rms (optical performance)
  - coma < 4 nm rms (alignment)

Coating chamber can be accommodated with 1.5 m mirror

Structure model of the Sunrise 1-m aperture primary
Telescope Structure

Hinode/SOT truss structure of CFRP (CTE < 0.1 ppm/K)

Thermal stability ($\Delta T=5$ deg) in focus accommodate 1.5 m aperture and 3 m M1-M2 length Gregorian.
Conceptual Design for SUVIT

Telescope Assembly

UVVIR FPP

- Polarization Modulator
- Tip-Tilt Mirror
- Polarization Calibration Wheel with through hole
- Correlation Tracker
- Visible-IR Filtergraph
- (2D) Spectro-Polarimeter
- UV Filtergraph
- (2D) UV Spectrograph
### Positional Tolerance Study of φ1.5 m Gregorian

<table>
<thead>
<tr>
<th>M1–M2 (cm)</th>
<th>300</th>
<th>280</th>
<th>250</th>
<th>220</th>
<th>OTA 150</th>
</tr>
</thead>
<tbody>
<tr>
<td>f1 (cm)</td>
<td>246.6</td>
<td>231.467</td>
<td>208.467</td>
<td>185.167</td>
<td>116.9617</td>
</tr>
<tr>
<td></td>
<td>(F1/1.64)</td>
<td>(F1/1.54)</td>
<td>(F1/1.39)</td>
<td>(F1/1.23)</td>
<td>(F1/2.34)</td>
</tr>
<tr>
<td>f2 (cm)</td>
<td>45.7633</td>
<td>41.775</td>
<td>35.9961</td>
<td>30.4184</td>
<td>26.247</td>
</tr>
<tr>
<td>Defocus 1 μA20 (Strehl)</td>
<td>0.0367 (0.983)</td>
<td>0.0415 (0.980)</td>
<td>0.0508 (0.968)</td>
<td>0.0636 (0.951)</td>
<td>0.0178 (0.997)</td>
</tr>
<tr>
<td>Defocus 3 μA20</td>
<td>0.1245 (0.832)</td>
<td>0.1522 (0.748)</td>
<td></td>
<td></td>
<td>0.057 (0.967)</td>
</tr>
<tr>
<td>Decenter 10 μA31</td>
<td>-0.0359 (0.994)</td>
<td>-0.0432 (0.991)</td>
<td>-0.0588 (0.983)</td>
<td>-0.0831 (0.966)</td>
<td>-0.0125 (0.999)</td>
</tr>
<tr>
<td>Decenter 50 μA31</td>
<td>-0.216 (0.791)</td>
<td>-0.294 (0.653)</td>
<td>-0.4156 (0.4267)</td>
<td></td>
<td>-0.0625 (0.98)</td>
</tr>
<tr>
<td>Tilt 10” B31</td>
<td>0.0908 (0.960)</td>
<td>0.0996 (0.952)</td>
<td>0.1161 (0.936)</td>
<td>0.1379 (0.910)</td>
<td>0.01897 (0.998)</td>
</tr>
<tr>
<td>Tilt 50” B31</td>
<td>0.454 (0.362)</td>
<td>0.498 (0.289)</td>
<td>0.581 (0.190)</td>
<td></td>
<td>0.0948 (0.955)</td>
</tr>
</tbody>
</table>
## Baseline Optical Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>SOT-OTA (SOLAR-B)</th>
<th>SUVIRT-OTA (SOLAR-C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entrance pupil (mm)</td>
<td>500</td>
<td>1500</td>
</tr>
<tr>
<td>M1–M2 distance (mm)</td>
<td>1500</td>
<td>2800 (&lt;4500)</td>
</tr>
<tr>
<td>M1 outer diameter (mm)</td>
<td>560</td>
<td>1580</td>
</tr>
<tr>
<td>clear aperture</td>
<td>509</td>
<td>1513</td>
</tr>
<tr>
<td>radius (focal)</td>
<td>2339.4 (1169.7)</td>
<td>4629.34 (2314.67)</td>
</tr>
<tr>
<td>conic const.</td>
<td>-0.9706</td>
<td>-0.990927</td>
</tr>
<tr>
<td>M2 outer diameter (mm)</td>
<td>159</td>
<td>340</td>
</tr>
<tr>
<td>clear aperture</td>
<td>147</td>
<td>320.5</td>
</tr>
<tr>
<td>radius (focal)</td>
<td>524.94 (262.47)</td>
<td>835.494 (417.747)</td>
</tr>
<tr>
<td>conic const.</td>
<td>-0.3996</td>
<td>-0.548155</td>
</tr>
<tr>
<td>HDM outer diameter (mm)</td>
<td>32.83</td>
<td>48.37</td>
</tr>
</tbody>
</table>
Baseline Telescope Design
Spot Diagram

-0.0390, 0.0000 DEG

0.0390, 0.0000 DEG

0.0000, 0.0000 DEG

0.0000, -0.0390 DEG

0.0000, 0.0390 DEG

SURFACE: IMA  

THROUGH FOCUS SPOT DIAGRAM

SOLAR-C GREGORIAN G3  
THU OCT 8 2009  UNITS ARE μm,  AIRY RADIUS : 7.364 μm  
FIELD :  1  2  3  4  5
RMS RADIUS :  2.478  2.478  1.703  2.478  2.478
GEO RADIUS :  3.981  3.981  2.155  3.981  3.981
SCALE BAR :  20  REFERENCE : CHIEF RAY

GREG_G3_2800.ZMX  
CONFIGURATION 1 OF 10
Collimating Optics

Trade off study among
1. All reflective
2. Lens (SiO2, CaF2)
3. Composite lens-Cassegrain design

• Chromatic aberration
• Thermal stability in focus

All reflective option is promising
Spot diagram for Gregorian + 3-mirror collimator
Heat dump path from M1 and M2 in case of Solar-B OTA

To sun-shade & thermal shield tube ($\varepsilon = 0.75$)

Thermal input to secondary mirror (2.3W)

Thermal input to primary mirror (21W)

To cold plate ($\varepsilon = 0.75$)

Radiation to cold plate

Front aperture
Sun-shade (CFRP)
Top ring
Top spider
Mirror support (Super invar)
Secondary mirror (ULE)
Heat dump mirror
Upper truss
Thermal shield tube (CFRP)
Center section
Optical bench unit
Primary mirror (ULE)
Mirror support (Super invar)
Cold plate (Aluminum)
Structure Model of φ1.5 m Telescope: Scaled-up model of OTA

Termal properties of surfaces are of end-of-life except for M1 and M2.

<table>
<thead>
<tr>
<th>名称</th>
<th>吸収率 $\alpha$</th>
<th>入射量(W)</th>
<th>吸収量(W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>主鏡</td>
<td>$\alpha_1$</td>
<td>0.118</td>
<td>2074.9</td>
</tr>
<tr>
<td>排熱鏡</td>
<td>$\alpha_H$</td>
<td>0.1</td>
<td>1830.1</td>
</tr>
<tr>
<td>副鏡</td>
<td>$\alpha_2$</td>
<td>0.118</td>
<td>76.2</td>
</tr>
<tr>
<td>コリメータ</td>
<td>$\alpha_3$</td>
<td>0.11</td>
<td>19.4</td>
</tr>
<tr>
<td>合計</td>
<td></td>
<td></td>
<td>431.4</td>
</tr>
</tbody>
</table>

※$\alpha$の値はICDパッケージより抜粋（中間報告と異なる）

<table>
<thead>
<tr>
<th>OTA</th>
<th>OTA吸収量(W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>22.3</td>
</tr>
<tr>
<td>0.15</td>
<td>27.2</td>
</tr>
<tr>
<td>0.1</td>
<td>2</td>
</tr>
<tr>
<td>コリメータ</td>
<td>TBD</td>
</tr>
<tr>
<td>合計</td>
<td>52</td>
</tr>
</tbody>
</table>

※OTA熱設計中間報告より
Solar-C Solar Synchronous Polar Orbit same as Hinode
Temperatures for Polar Orbit
Solar-C Geosynchronous Orbit

【高温ケース2 静止軌道】
軌道条件（冬至）
太陽光強度 = 1421 (W/m²)
アルベド係数 = 0.2
地球IR強度 = 261 (W/m²)
β = -23.4°（軌道傾斜角 = 0°）
高度 = 36000km

赤道傾斜 23.4°
赤道面＝軌道面
太陽方向

北極方向

Solar-C
Temperatures for Geosynchronous Orbit

- 副鏡支持部: -56°C
- 副鏡: -24°C
- HDM円筒: 45°C
- HDM円筒スパイダー: -51°C
- HDM鏡面: 100°C
- 主鏡: 49°C
- コールドプレート: 17~31°C
Sensitivity study with radiator area modification

1) Mod-1 Expand radiator area at Shield Tube

2) Mod-2 Enhance conduction at HDM inner spider
   AlBe (210W/mK) x 3 spiders
   ↓
   AlBe (210W/mK) x 6 spiders

3) Mod-3 Expand HDM cylinder
Mirror Coating Issue

Hinode/OTA: M1 and M2 have a protected Ag coat (solar light absorption $\alpha \sim 6.5\%$) which is not suitable for UV observation (not capable of reflecting UV light shorter than 360 nm).

A typical coating for UV is Al+MgF2. However, the coating has a large $\alpha$ of $\sim 12\%$ and overall reflectivity in visible and IR is lower than the Ag coating.

→ The development of UV-reflective and low solar absorption coating is under study.
Degraded (EOL) Reflectivity for Al+MgF2 Coating

Assume that the solar absorption $\alpha$ increase by 0.05 in the end of life (EOL).

<table>
<thead>
<tr>
<th>名称</th>
<th>吸收率 $\alpha$</th>
<th>入射量(W)</th>
<th>吸收量(W)</th>
<th>変更前</th>
</tr>
</thead>
<tbody>
<tr>
<td>主鏡</td>
<td>$\alpha_1$</td>
<td>0.168</td>
<td>2074.9</td>
<td>348.6</td>
</tr>
<tr>
<td>排熱鏡</td>
<td>$\alpha_H$</td>
<td>0.1</td>
<td>1726.3</td>
<td>165.4</td>
</tr>
<tr>
<td>副鏡</td>
<td>$\alpha_2$</td>
<td>0.168</td>
<td>71.9</td>
<td>12.1</td>
</tr>
<tr>
<td>コリメータ</td>
<td>$\alpha_3$</td>
<td>0.11</td>
<td>18.6</td>
<td>2.0</td>
</tr>
</tbody>
</table>

合計 | 528.2 | 431    |
## Predicted temperatures for optics

<table>
<thead>
<tr>
<th>T (degC)</th>
<th>Polar orbit</th>
<th>Geosyn c. orbit</th>
<th>Polar orbit with Mod-1</th>
<th>Polar orbit with Mdd-1 and Mod-2</th>
<th>Polar orbit with Mod-1 and Md-2 and Mod-3</th>
<th>Polar orbit +Mod-1 α+0.05 @M1&amp;M2</th>
<th>Geosync +Mod-1 α+0.05 @M1&amp;M2</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1 surface</td>
<td>61</td>
<td>49</td>
<td>52</td>
<td>52</td>
<td>52</td>
<td>80</td>
<td>70</td>
</tr>
<tr>
<td>M2 Surface</td>
<td>-2 ～-7</td>
<td>-24</td>
<td>-12 ～-8</td>
<td>-12 ～-8</td>
<td>-12 ～-7</td>
<td>0 ～4</td>
<td>-17 ～-16</td>
</tr>
<tr>
<td>HDM surface</td>
<td>109 ～111</td>
<td>100</td>
<td>103 ～104</td>
<td>77 ～78</td>
<td>60 ～61</td>
<td>63 ～64</td>
<td>51</td>
</tr>
<tr>
<td>CLU</td>
<td>34 - 37</td>
<td>22-24</td>
<td>24 - 27</td>
<td>24 - 27</td>
<td>24 - 26</td>
<td>41</td>
<td>29</td>
</tr>
</tbody>
</table>
Heat dump path from M1 necessary

To sun-shade & thermal shield tube ($\varepsilon = 0.75$)

To cold plate ($\varepsilon = 0.75$)

Radiation to cold plate

Front aperture
Sun-shade (CFRP)
Top ring
Top spider
Mirror support (Super invar)
Heat dump mirror
Upper truss
Secondary mirror (ULE)
Thermal shield tube (CFRP)
Center section
Optical bench unit
Mirror support (Super invar)
Primary mirror (ULE)
Cold plate (Aluminum)
Off-axis Gregorian

Pro
• no central obscuration, lower scattered light, higher contrast images
• more freedom in designing HDM at primary focus, direction of reflected light and cooling method

Con
• larger instrumental polarization (may be calibrated with continuum and sunspot obs.)
• harder to fabricate and validate M1 and M2 mirrors alignment
• higher non axi-symmetric structural and thermal deformation of telescope
Off-Axis Gregorian

The same optical parameters except for off-centered M1

Plane HDM

2800mm

1200mm

3D LAYOUT

OFF-AXIS PARABOLA FOR UNOBSCURED GREGORIAN
THU OCT 8 2009

OFF-AXIS_GREG2800_1000.ZMX
CONFIGURATION 1 OF 1
### Preliminary choices of spectrum lines (most deluxe configuration)

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Spectrum line</th>
<th>wavelength</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vis/UV broadband imager</td>
<td>UV continuum</td>
<td>~250nm</td>
<td>High res. Img of photosphere</td>
</tr>
<tr>
<td></td>
<td>Mg II h/k</td>
<td>280nm</td>
<td>High res img of chromosphere</td>
</tr>
<tr>
<td></td>
<td>CN band</td>
<td>388nm</td>
<td>Granules and magnetic elements</td>
</tr>
<tr>
<td></td>
<td>G-band</td>
<td>430nm</td>
<td>Granules and magnetic elements</td>
</tr>
<tr>
<td>Vis/NIR narrowband imager</td>
<td>Mg I b2</td>
<td>512nm</td>
<td>Low chromosphere V and B</td>
</tr>
<tr>
<td>+He D3</td>
<td>Fe I</td>
<td>525nm</td>
<td>Photosphere B</td>
</tr>
<tr>
<td></td>
<td>Na ID1 (D2)</td>
<td>589nm</td>
<td>Low chromosphere V and B</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>High photosphere</td>
</tr>
<tr>
<td></td>
<td>Hα</td>
<td>656nm</td>
<td>High chromosphere V</td>
</tr>
<tr>
<td></td>
<td>Ca II IRT</td>
<td>854nm</td>
<td>High chromosphere T, V and B</td>
</tr>
<tr>
<td>UV/Vis/NIR spectrometer</td>
<td>Mg II h/k</td>
<td>280nm</td>
<td>High chromosphere T and V</td>
</tr>
<tr>
<td>+Ca II IRT weaker line</td>
<td>Ca II IRT</td>
<td>854nm</td>
<td>High chromosphere T, V and B</td>
</tr>
<tr>
<td></td>
<td>He I</td>
<td>1083nm</td>
<td>High chromosphere V and B</td>
</tr>
</tbody>
</table>
Block diagram of the optical configuration

Telescope → p. modulator → UV/Vis/NIR spectrometer

Vis/NIR narrowband imager

Vis/UV broadband imager

Detector → spectrometer → Detector

Detector → narrow-band filter → Detector

Detector → broad-band filter → Detector
### Pixel size and FOV of the instruments

<table>
<thead>
<tr>
<th></th>
<th>FOV</th>
<th>Pixel size</th>
<th>Exposure</th>
<th>Note.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UV-Vis-NIR telescope</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broad band</td>
<td>164&quot; x 164&quot;</td>
<td>0.04&quot;</td>
<td>&lt; 1sec</td>
<td>• 2.5 pix sampling of 0.1&quot; res.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• 4Kx4K detector</td>
</tr>
<tr>
<td>Narrow band</td>
<td>246&quot; x 246&quot;</td>
<td>0.06&quot;</td>
<td>&lt; 1sec</td>
<td>• 2.5 pix sampling of 0.16&quot; res.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• 4Kx4K detector</td>
</tr>
<tr>
<td>Spectrometer</td>
<td>246&quot; x 246&quot;</td>
<td>0.06&quot;</td>
<td>1sec (S/N~1600)</td>
<td>• 2.5 pix sampling of 0.16&quot; res.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• 4K pix along slit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.12&quot;</td>
<td>10sec (S/N~10^4)</td>
<td></td>
</tr>
</tbody>
</table>
Basic requirements on TF (preliminarily)

- Wavelength range: TBD (a possibility 5000 – 8700A)
- Band width (FWHM): ~100mA (50~70mA)
- Strehl: >0.9
- FOV: ~200 arcsec w/phi1.5m (TBR)
- Free spectral range: >5A
- Tuning range: +/- 5A
- Tuning speed: <50ms
- Tuning resolution: <5mA
- Repeatability: <2mA
- Uniformity
  - Wavelength: 5mA (TBD)
  - Transmission: 5%
- Stability
  - Wavelength: 5mA /day
  - Transmission (flat): 1% /day
- Parastic light: <2%
- Ghost: <1%
Choice of tunable filter

Lyot filter vs. Fabry Perot

Need Bubble-free design!
All elements can be attached with index matching oil?.
<table>
<thead>
<tr>
<th></th>
<th>Lyot filter</th>
<th>Fabry Perot</th>
</tr>
</thead>
<tbody>
<tr>
<td>F (Speed of incident beam)</td>
<td>F~ 40</td>
<td>F ~ 200 (air space) ~ 90 (LiNb)</td>
</tr>
<tr>
<td>Necessary diameter of filter (D=1m, FOV=3’)</td>
<td>~40mm</td>
<td>~180mm, ~80mm</td>
</tr>
<tr>
<td>Transmission</td>
<td>~ 5%</td>
<td>~ 70%</td>
</tr>
<tr>
<td>Simultaneous 2-polarization</td>
<td>impossible</td>
<td>possible</td>
</tr>
<tr>
<td>Simultaneous multi wave len</td>
<td>(in principle possible)</td>
<td>impossible</td>
</tr>
<tr>
<td>Structure</td>
<td>Complex</td>
<td>High accuracy</td>
</tr>
<tr>
<td>Oil</td>
<td>Necessary</td>
<td>Free</td>
</tr>
<tr>
<td>Control device</td>
<td>Rot. waveplate or liquid crystal</td>
<td>Piezo or LiNb</td>
</tr>
<tr>
<td>Past experience</td>
<td>SOT/Hinode</td>
<td>LASCO C1/SoHO</td>
</tr>
<tr>
<td>Concern</td>
<td>- Contact of opt. elem.s (avoiding bubble)</td>
<td>- Mount and control for high accuracy surfaces (thermal/mech. stress)</td>
</tr>
<tr>
<td></td>
<td>- Mounting calcites</td>
<td>- Endurance of coaring</td>
</tr>
<tr>
<td></td>
<td>- Outgas</td>
<td>- Stability of inhomogeneity</td>
</tr>
<tr>
<td></td>
<td>- Calcite availability</td>
<td></td>
</tr>
</tbody>
</table>

Filter diameter, \[ L_{\text{min}} = \text{image size} = F \cdot D \cdot (W/60 \cdot 180 \cdot \pi) = 0.0003 \cdot F \cdot D \cdot W \] (cm, Telecentric)

D: aperture, cm, W: FOV, arcmin, F: F-ratio
Need of 2-dimensional spectroscopy

• Rapid motion of chromospheric materials are ubiquitously seen associated with eruptions, jets, and wave propagation.

• There are several options under investigation to achieve the 2D spectroscopy in SOLAR-C.
  – Double pass spectrograph
    • Slot spectroscopy with medium wavelength dispersion
  – Tunable filter-type instruments with rapid wavelength tuning
    • Fabry-Perot or Lyot
  – Integral field spectroscopy
    • Fiber-optics bundle or image slicer
Broadband imager layout

- Similar design with the HINODE broadband filter imager (BFI).
- The rotating shutter is located near the focal plane
- 0.04"/12μm pix, 4Kx4K
  \[ \rightarrow f \sim 2470\text{mm (F/41)} \]
  \[ \rightarrow \text{FOV 164"} \]
Spectrograph layout

- Littrow spectrograph design similar with the HINODE spectropolarimeter (SP)
- Multiple detectors for observing multiple spectrum lines
- 0.06"/12μm pix, 4K (along slit)
  → f ~ 1650mm (F/28)
  → FOV 246"

<table>
<thead>
<tr>
<th>λ</th>
<th>Order</th>
<th>dispersion</th>
</tr>
</thead>
<tbody>
<tr>
<td>2800A</td>
<td>73</td>
<td>7.0mA/12μm</td>
</tr>
<tr>
<td>8542A</td>
<td>24</td>
<td>21mA/12μm</td>
</tr>
<tr>
<td>10830</td>
<td>19</td>
<td>27mA/12μm</td>
</tr>
</tbody>
</table>

- Blaze angle: 56°
- Groove: 80 lines/mm
Narrowband imager layout

- Telecentric configuration to have uniform wavelength over FOV.
- Large F (F>150) at the Fabry-Perot etalon.
- The shutter is located near the exiting-pupil.
- 0.06"/12μm pix, 4Kx4K
  → f ~1650mm (F/28)
  → FOV 246"

f ~1650mm (F/28)
→ FOV 246"
Strawman layout of the focal-plane package

- Spectrograph
- Broadband imager
- Narrowband imager
Items to be further studied

• **Priority of the spectrum lines (wavelength coverage)**
  – Either spectrograph or filtergraph for each line

• Telescope thermal design
  – Radiator configuration for cooling M1
  – Development of UV-reflective and low solar absorption coating
  – Axi-symmetric vs. off-axis design

• Configuration of the narrowband filtergraph
  – Fabry-Perot or Lyot (telecentric or collimated)

• Configuration of the spectrograph
  – Multi-slit (or image slicer) or IFU (integral field unit) spectrograph to achieve high time res.
  – Multi-wavelength simultaneous obs. or multi-wavelength obs by switching filters (and tilting a grating).

• Availability of large format detectors
  – IR detector for He I 10830
  – UV enhanced detector for Mg II h/k