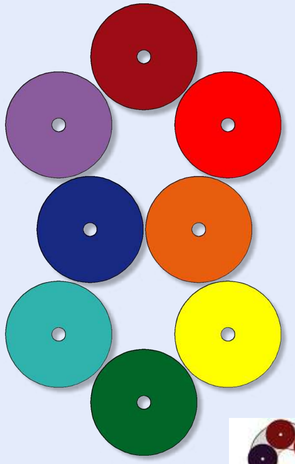
GTC-CTA Synergies IPARCOS meeting
17 December 2019

GATOS

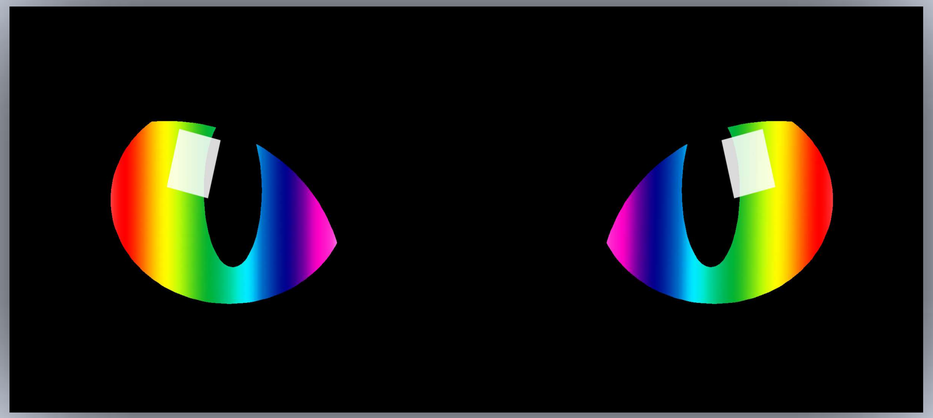
Antonio de Ugarte Postigo
IAA-CSIC
DARK/NBI

Universidad Complutense de Madrid

The history of GATOS

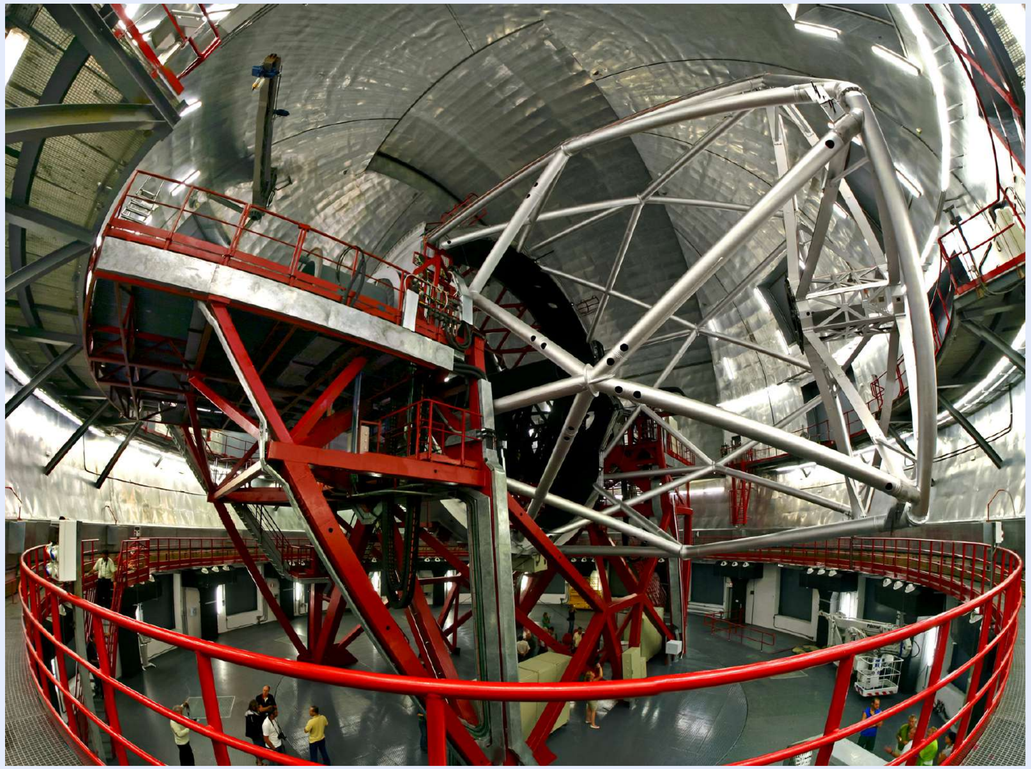


- 2010 OCTOCAM for GTC
- 2014 OCTOCAM for Gemini GIFS (100 kUSD)
- 2016 OCTOCAM wins RfP for Gemini-S (15 MUSD)
- 2017 OCTOCAM ==> SCORPIO
- 2018 GATOS presented for GTC
- 2020? GTC funds the construction of GATOS?



GTC instrumentation

1. (ELMER): VIS imager and spectrograph (never used)
2. OSIRIS: VIS imager and spectrograph, tuneable filters, multi object
3. CanariCam: MIR imager and spectrograph, polarimetry
4. CIRCE: NIR imager (visitor)
5. EMIR: NIR imager and spectrograph, multiobject
6. MEGARA: VIS fibre-fed spectrograph
7. HiPERCAM: VIS multiband fast imager (visitor)
8. HORS: VIS high-resolution spectrograph (visitor)
9. MIRADAS: NIR multi-object spectrograph
10. FRIDA: NIR AO imager and spectrograph
11. Ultra stable hi-res spectrograph



Situation in 2025

1. ~~(ELMER): VIS imager and spectrograph (never used)~~
2. OSIRIS: VIS imager and spectrograph, ~~tuneable filters~~, multi object
3. ~~CanariCam: MIR imager and spectrograph, polarimetry~~
4. ~~CIRCE: NIR imager (visitor)~~
5. EMIR: NIR imager and spectrograph, multiobject
6. MEGARA: VIS fibre-fed spectrograph
7. HiPERCAM: VIS multiband fast imager (visitor) ?
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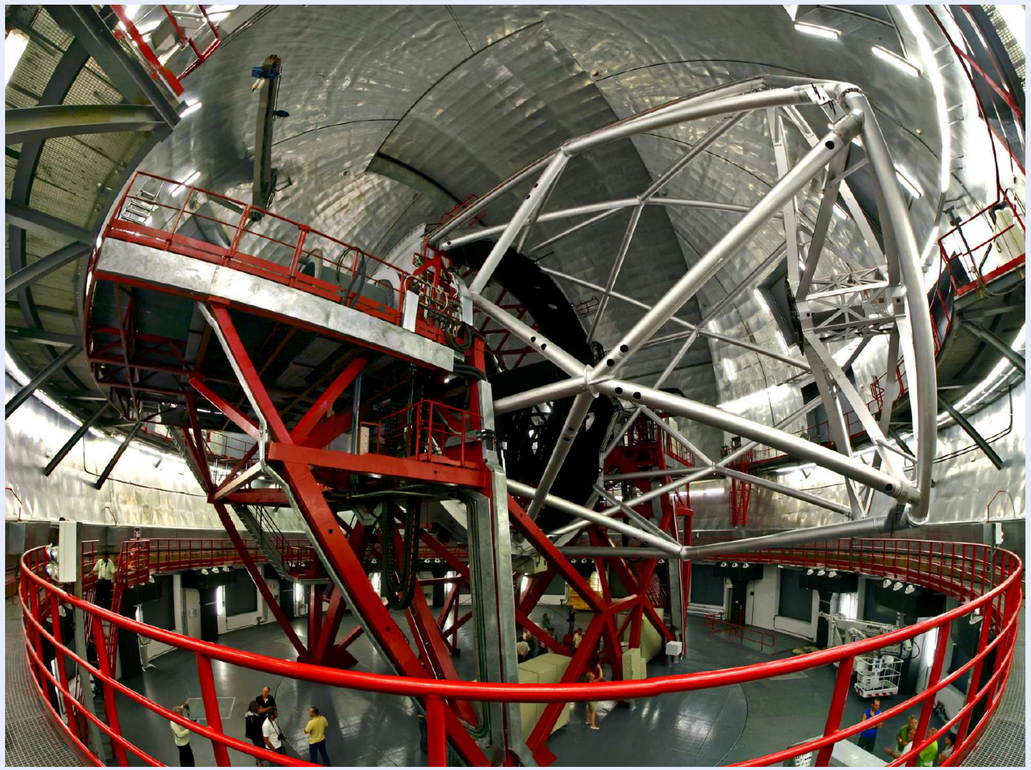
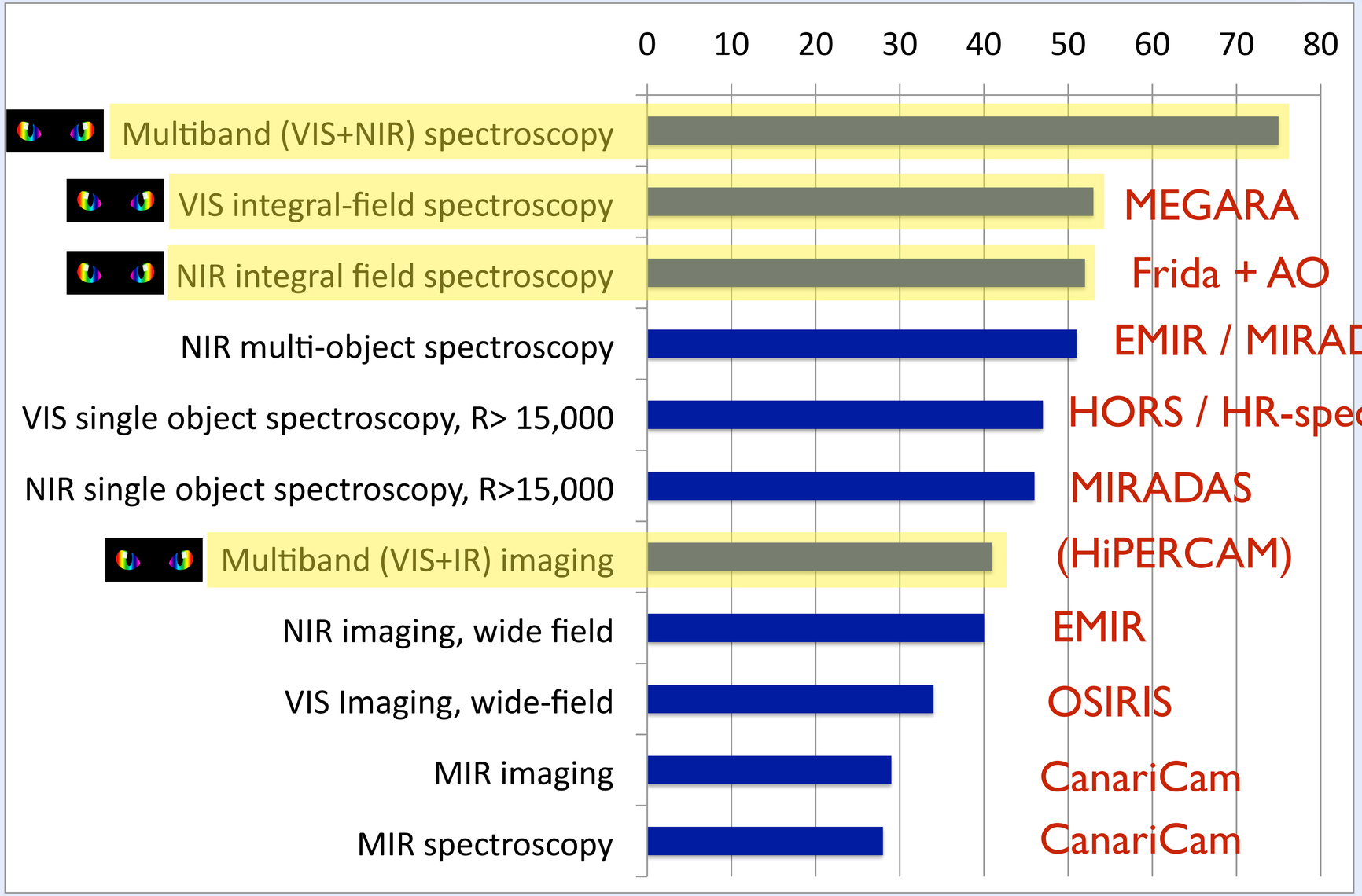
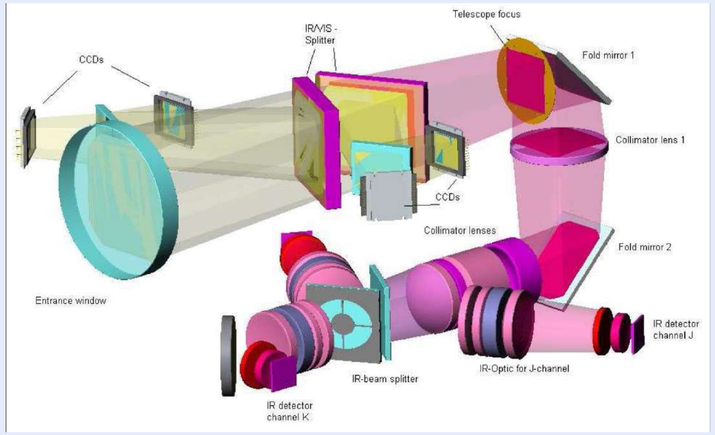


GUC Survey

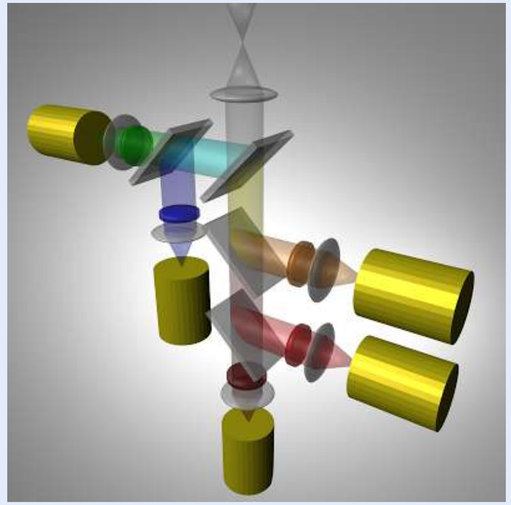

0
10
20
30
40
50
60
70
80
Multiband (VIS+NIR) spectroscopy
VIS integral-field spectroscopy
MEGARA
NIR integral field spectroscopy
Frida + AO
NIR multi-object spectroscopy
EMIR / MIRADAS
VIS single object spectroscopy, R> 15,000
HORS / HR-spec
NIR single object spectroscopy, R>15,000
MIRADAS
Multiband (VIS+IR) imaging
(HiPERCAM)
NIR imaging, wide field
EMIR
VIS Imaging, wide-field
OSIRIS
MIR imaging
CanariCam
MIR spectroscopy
CanariCam

Design guidelines

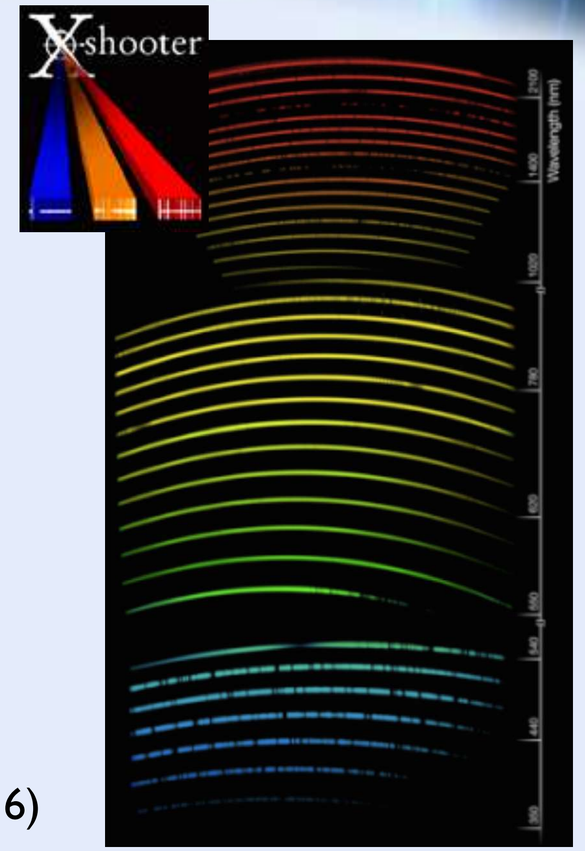
- Learn from previous instruments:
  OCTOCAM = X-shooter + GROND + HiPERCAM!



GROND (Greiner et al. 2009)



HiPERCAM (Dhillon et al. 2016)



X-shooter (Vernet et al. 2011)

- Uncovered region of space
  temporal resolution – ***spectral coverage*** – *spectral resolution*

- **Your ideal transient follow-up machine!**

Efficiency!

Throughput

Quantum efficiency

Operation

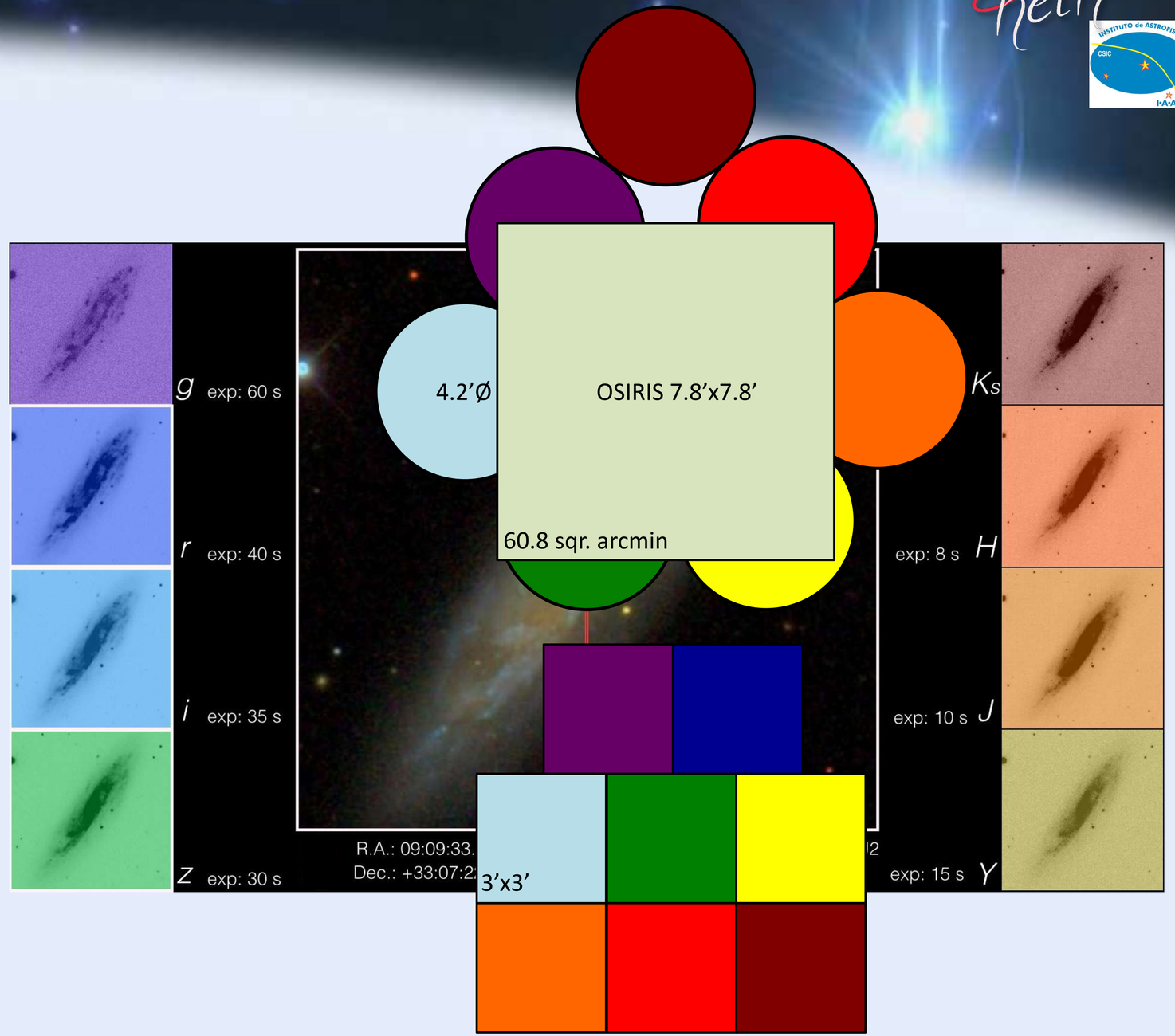
Calibration

Maintenance

Simultaneity!

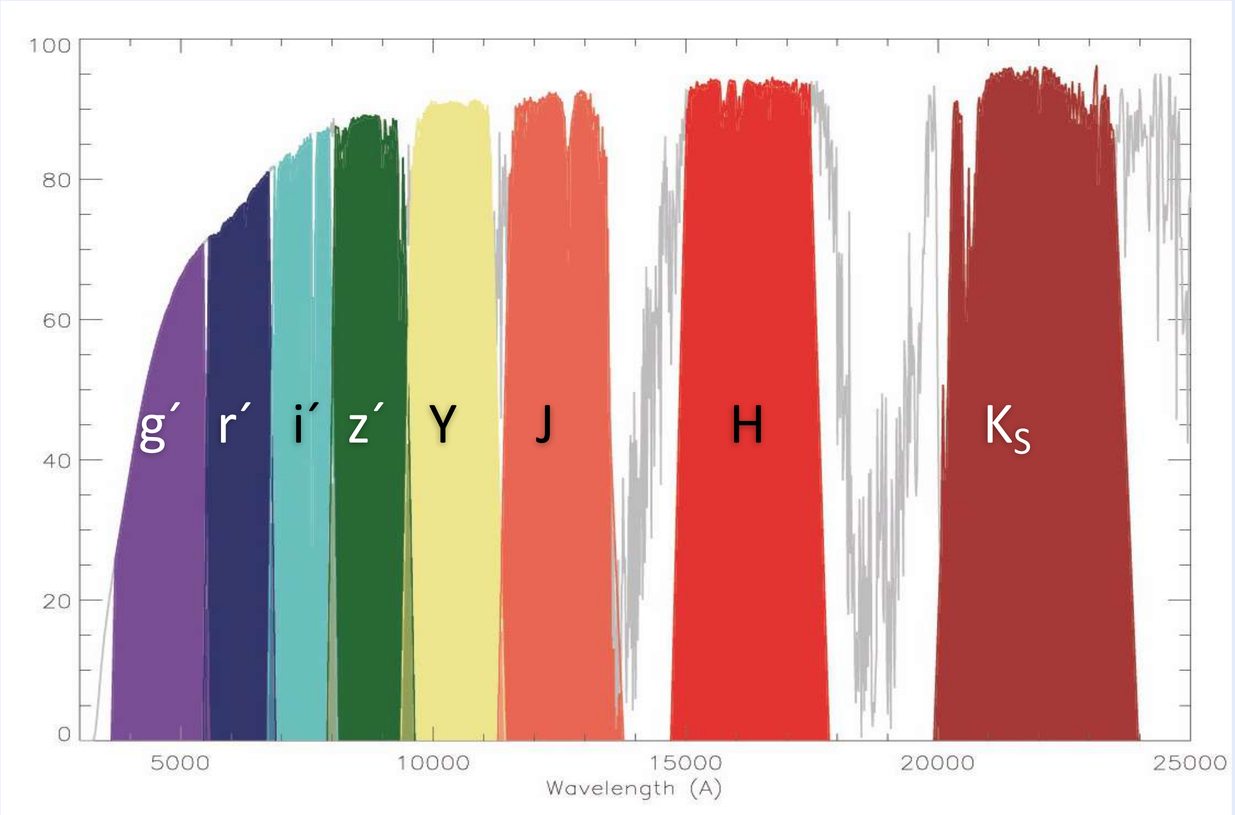
Imaging

- Simultaneous VIS/NIR
  g', *r'*, *i'*, *z'*, *Y*, *J*, *H*, K_S
- Negligible overheads
  - No filter change time loss
  - No readout time loss
- 3'x3' or 4.2'Ø field of view
  - 3'x3'x8 = 72 sqr. Arcmin
  - 4.2'Øx8 = 112 sqr. Arcmin



Spectroscopy

- Wavelength range: 3700 Å to 23,500 Å
  [OII] 3727/29 Å at $z = 0$ (blue end), Hα at $z = 2.5$ (red end)
- Resolving power ~4000:
  - Look between NIR sky lines
  - Continuum of faint sources
  - Velocity fields of galaxies
- Long slit (180”)



High time resolution

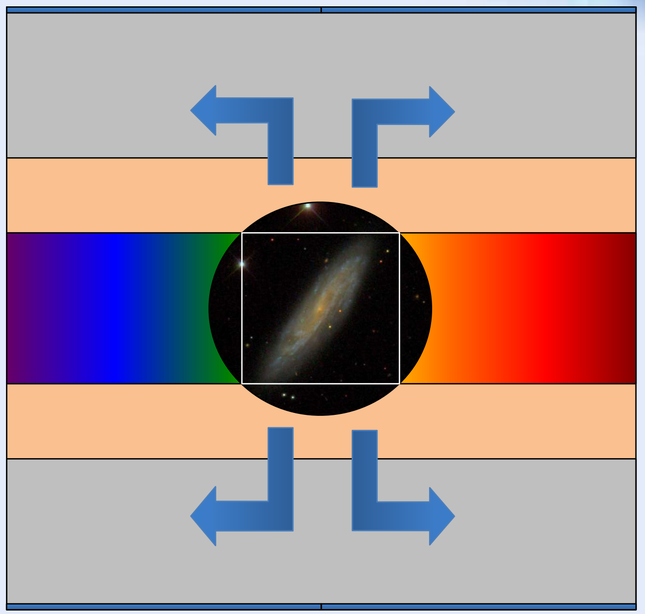
- Frame transfer in the VIS
  e2v CCD 231-84

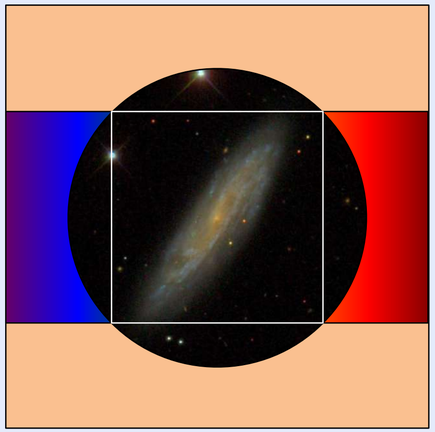
- HAWAII-2RG+SIDECAR in the NIR

✴ Full frame > 4Hz

✴ Window > 20 Hz

✴ Drift scan > 100 Hz



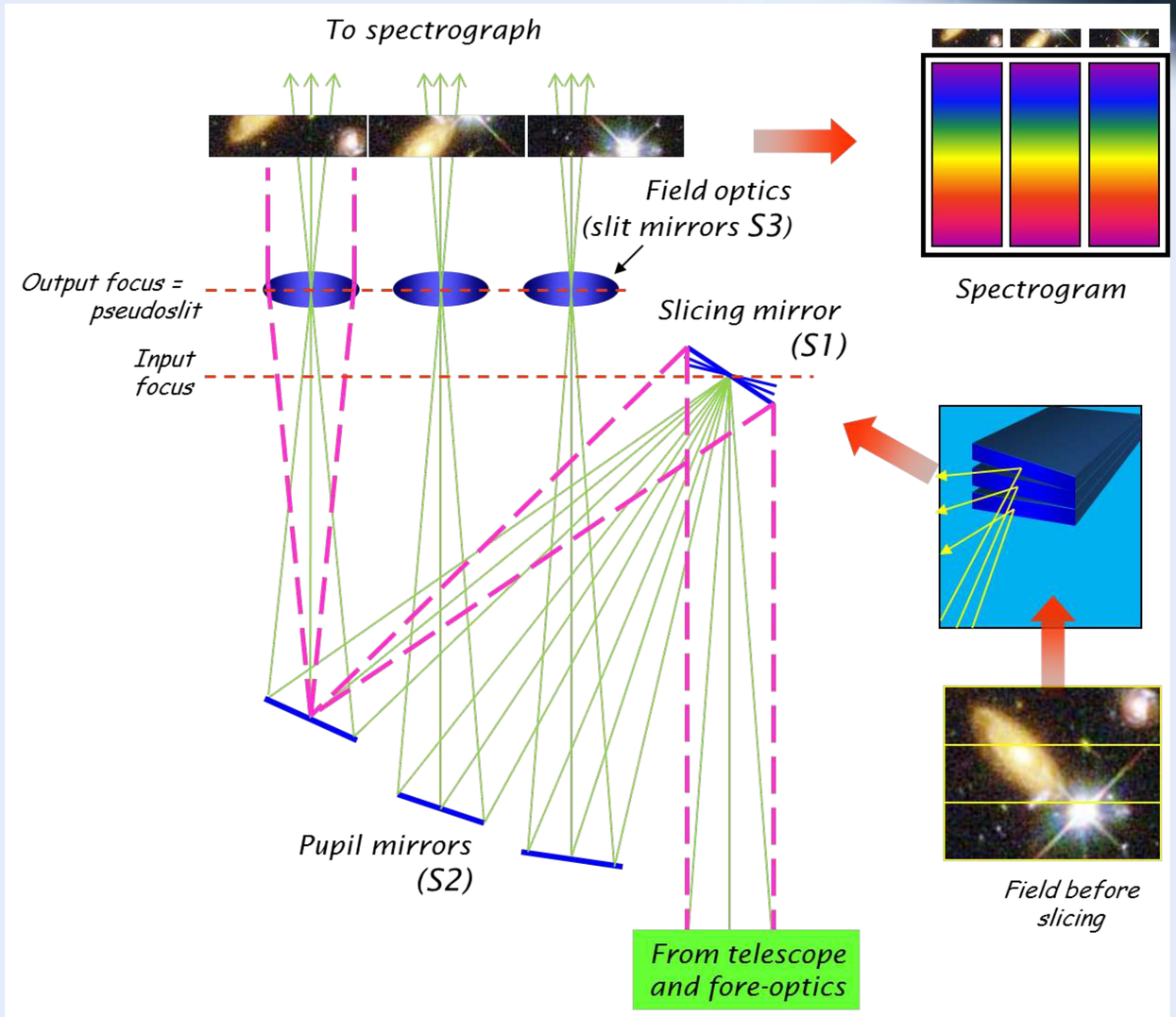


Integral field spectroscopy

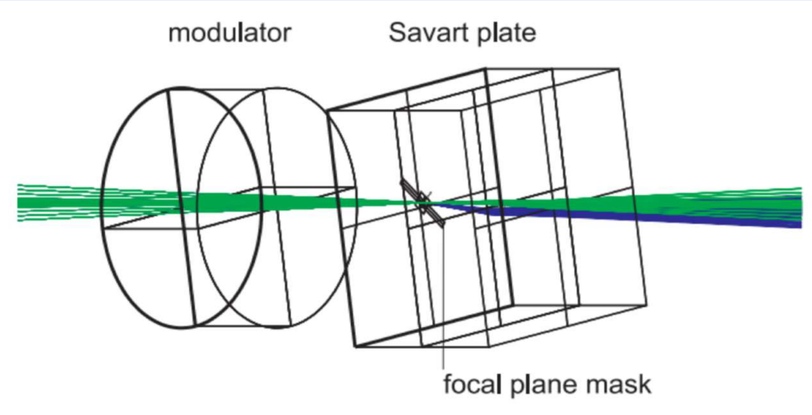
- Image slicer 9.7”x6.8”
- 17 0.4” resolution elements

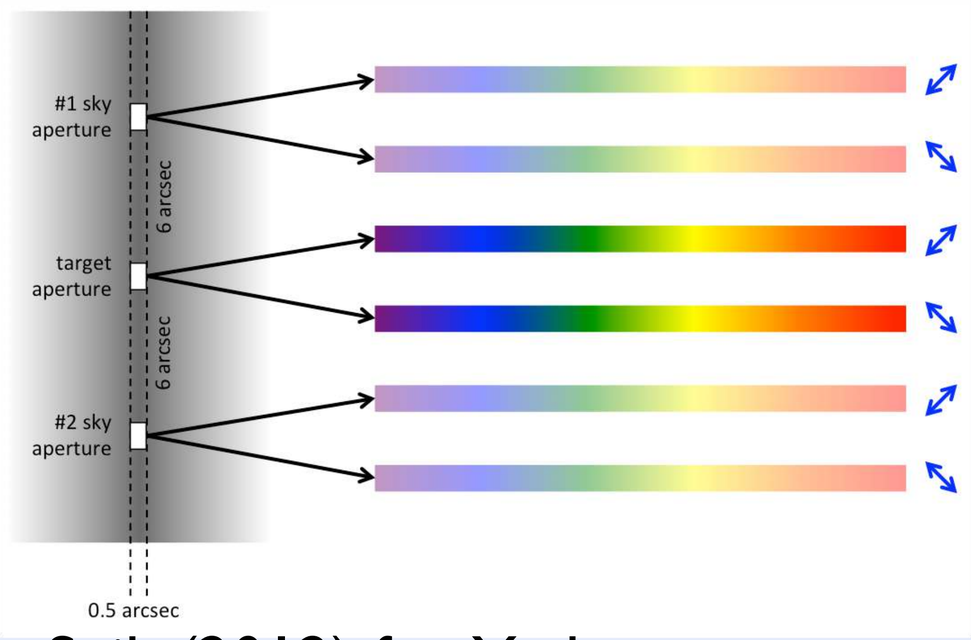
- Wavelength coverage UV+IR!
- Full spectral resolution at any seeing

- An additional AO-IFU has been also designed:
  3.6”x2.5” with 0.08” slitlets



Spectropolarimeter



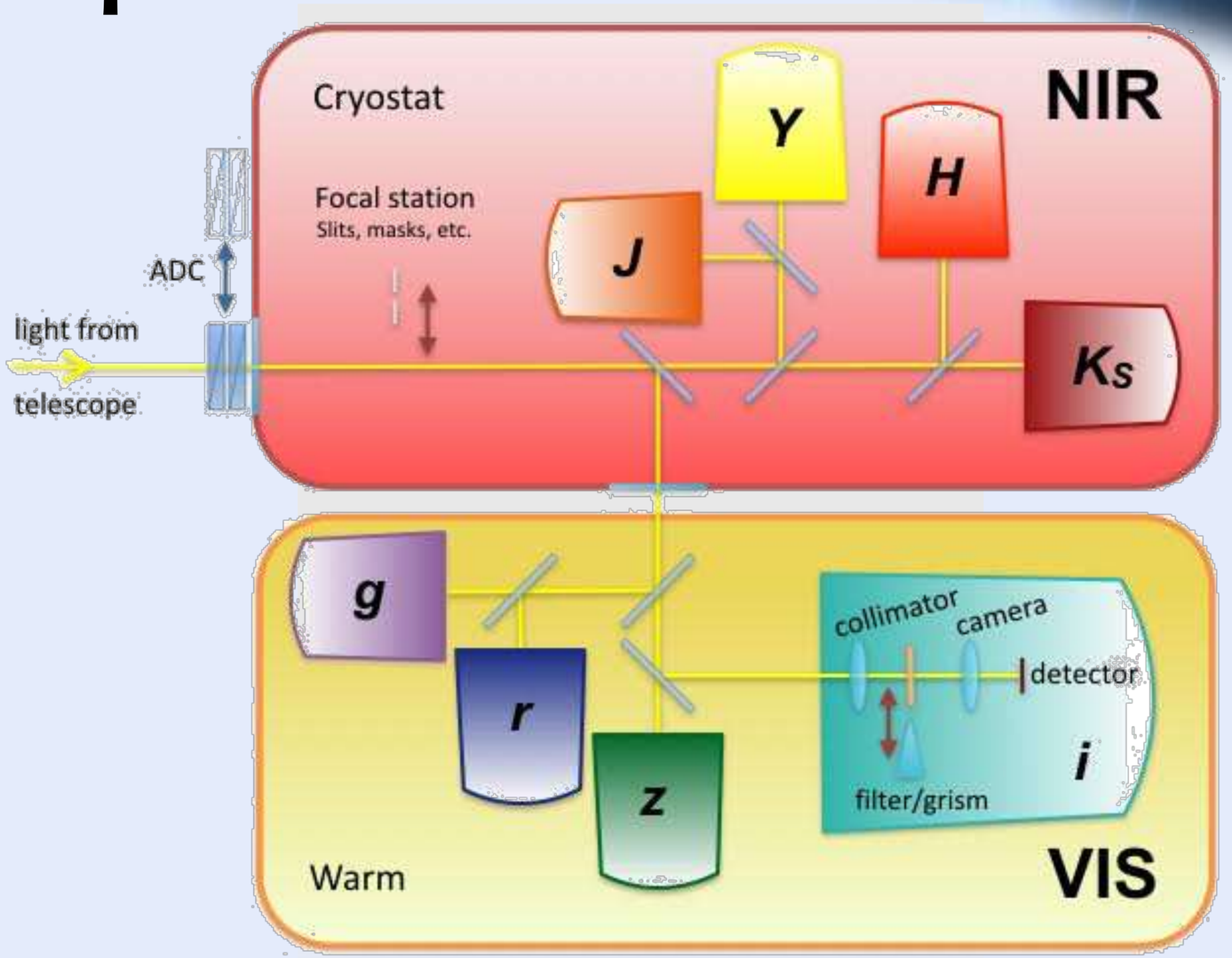


Based on the design by Frans Snik (2012) for X-shooter

1. Spectropolarimetry of full range
2. Low resolution single shot spectropolarimetry
   - Structure and magnetism in SNe
   - Stellar physics
   - Characterisation of transients

Optical design concept

- 8 independent channels
- Common focal plane <u>in cryostat</u> (avoid thermal noise)
- Common backbone (reduce flexures)
- Retractable ADC
- Different slits (0.55”, 0.7”, 0.9”, 1.1”, 5”)
- Allows IFU + polarimetry



Consortium

CAB
ASOCIADO AL NASA ASTROBIOLOGY INSTITUTE

INSTITUTO de ASTROFISICA de ANDALUCIA
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UNIVERSIDAD NACIONAL AUTONOMA DE MEXICO
POR MI RAZA HABLARA EL ESPIRITU

UNIVERSIDAD
COMPLUTENSE
MADRID

Fractal
SLNE

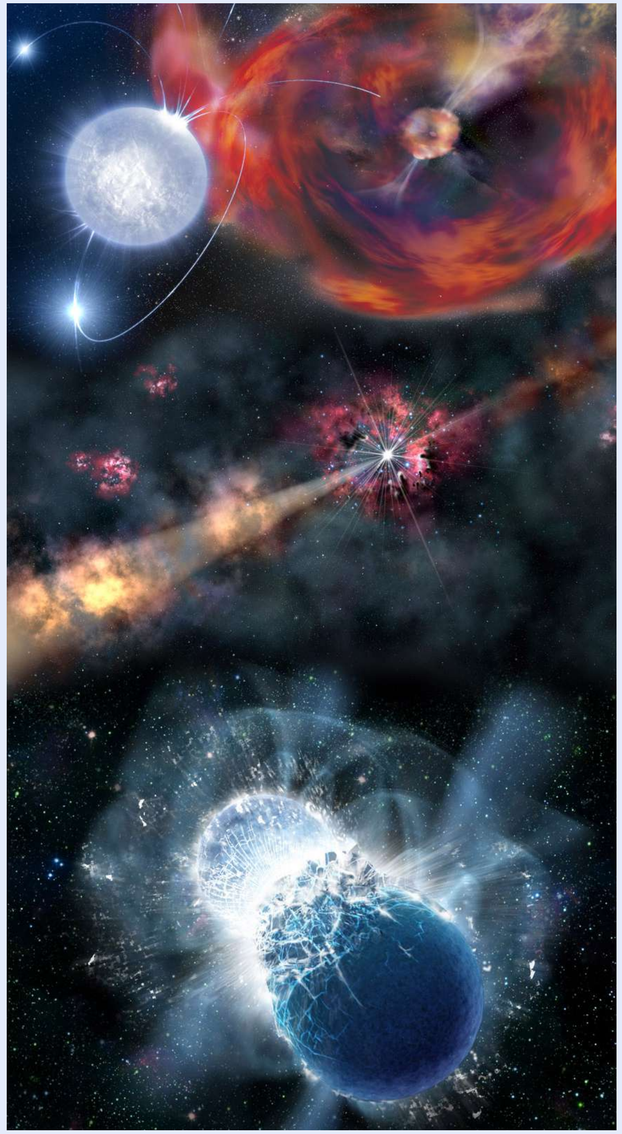
?

Specifications

Simultaneous spectral range	Photometry: *g'r'i'z'YJHK* [goal also *u'*-band] Spectroscopy: 3700-23500 Å [goal 3200 - 23500 Å]
Field of view	3'x3' rectangular, 254"diameter circular 3' long slit [goal 4.2'] **9.7"x6.8" (0.4" slitlets) IFU [goal 10.8" x 8.4"]** **3.6"x2.5" (0.08" slitlets) AO-IFU**
Plate scale	0.2"/pixel
Spectral resolution	> 3500 in g' [goal > 4000 in all the range] 4100 - 4500 in other bands
Expected efficiency (peak efficiency)	Imaging: > 42 % Spectroscopy: > 35 %
Maximum frame rate	> 4 Hz full frame > 20 Hz for 30x30pix window > 100 Hz drift scan
Observing modes	Multi-band imaging Broad-band spectroscopy (long slit) High time-resolution (img. & spectr.) **Integral Field Spectroscopy** **Spectropolarimetry**

Science drivers

for a workhorse instrument



- Transients
- X-ray binaries/transients
- TDEs
- AGNs
- Lensing
- High-redshift galaxies / intergalactic medium
- Supernovae
- SN remnants
- GRBs
- High-redshift Universe
- Trans-Neptunian objects
- Transiting exoplanets
- Asteroseismology
- Low-metallicity stars
- Massive stars / stellar winds
- Low mass binaries
- Brown dwarfs
- Interacting binaries
- Magnetars
- Isolated Neutron stars
- Gravitational wave follow-up

Breakthrough science in many fields

Synergies with CTA:

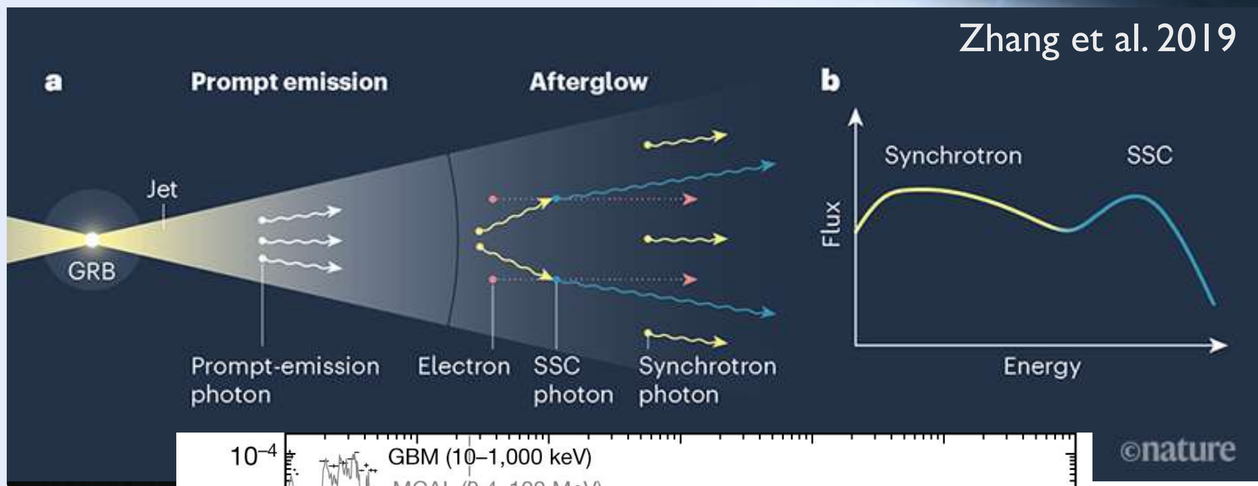
- Gamma-ray bursts
- Gravitational waves
- High-energy neutrinos
- Serendipitous VHE sources
- Triggers from other wavelengths (optical, radio, …)
- Occultations (Tarek Hassan's talk)
- Characterising VHE sources

Observing strategy for transients

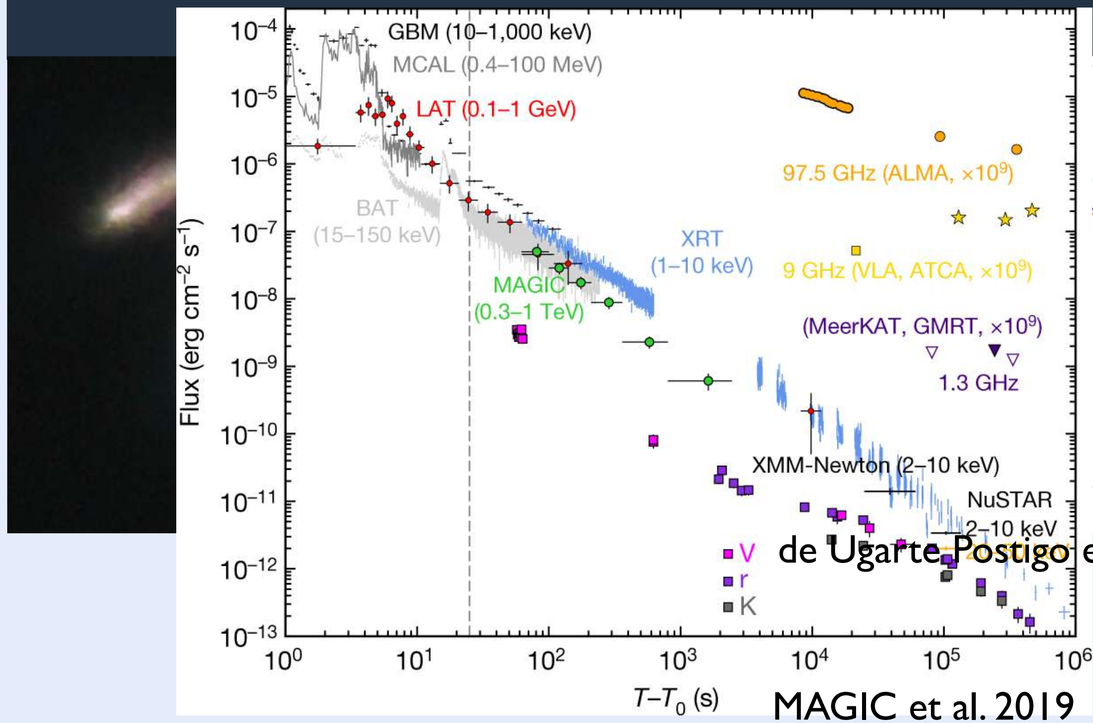
- Automated Rapid Response (as fast as possible!)
  - RRM trigger at CTA (start observing <1min)
  - RRM trigger at GTC (start observing <10 min)
    - Imaging (full SED *grizYJHKs* in <1 min)
    - Spectroscopy
    - Imaging
    - Spectroscopy
    - …
- Target of Opportunity (within the same night)
  - Simultaneous observations may not be needed
- From the observatory side:
  - Implement RRM at GTC
  - Fast switch between instruments at GTC
  - Coordinated observation tool

Gamma-ray bursts

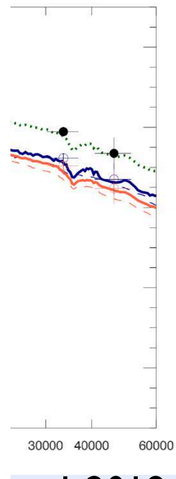
- Until now, only afterglow detections
- Simultaneous SED
- Late imaging/spectroscopy of afterglow and SN
- Host galaxy study (imaging/spectroscopy)
- Open questions:
  - How common are VHE in GRBs
  - Prompt emission?
  - How much does the environment influence?
  - How far can we detect them?
  - …



Zhang et al. 2019



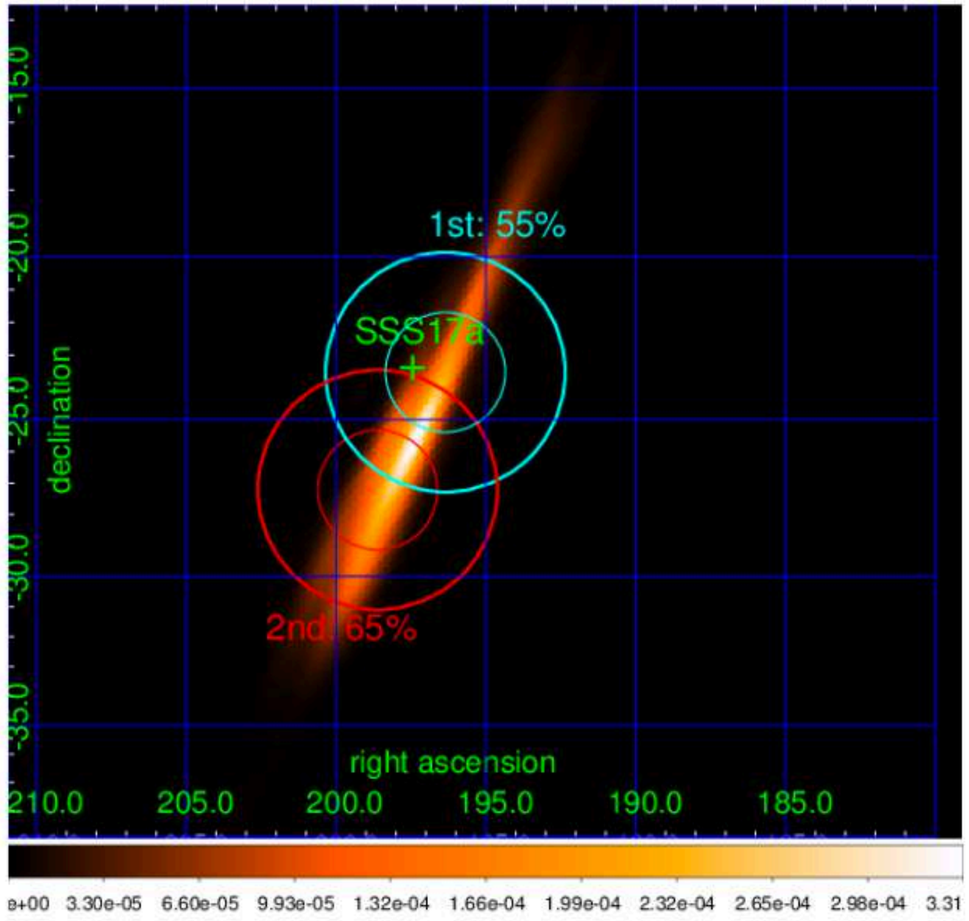
MAGIC et al. 2019



de Ugarte Postigo et al. 2019

Gravitational wave follow-up

- Large field of view (4.5 deg) suited for large error regions of GWs
- Probably only for on-axis events
- GTC/GATOS would be the ideal instrument for characterising counterparts once detected

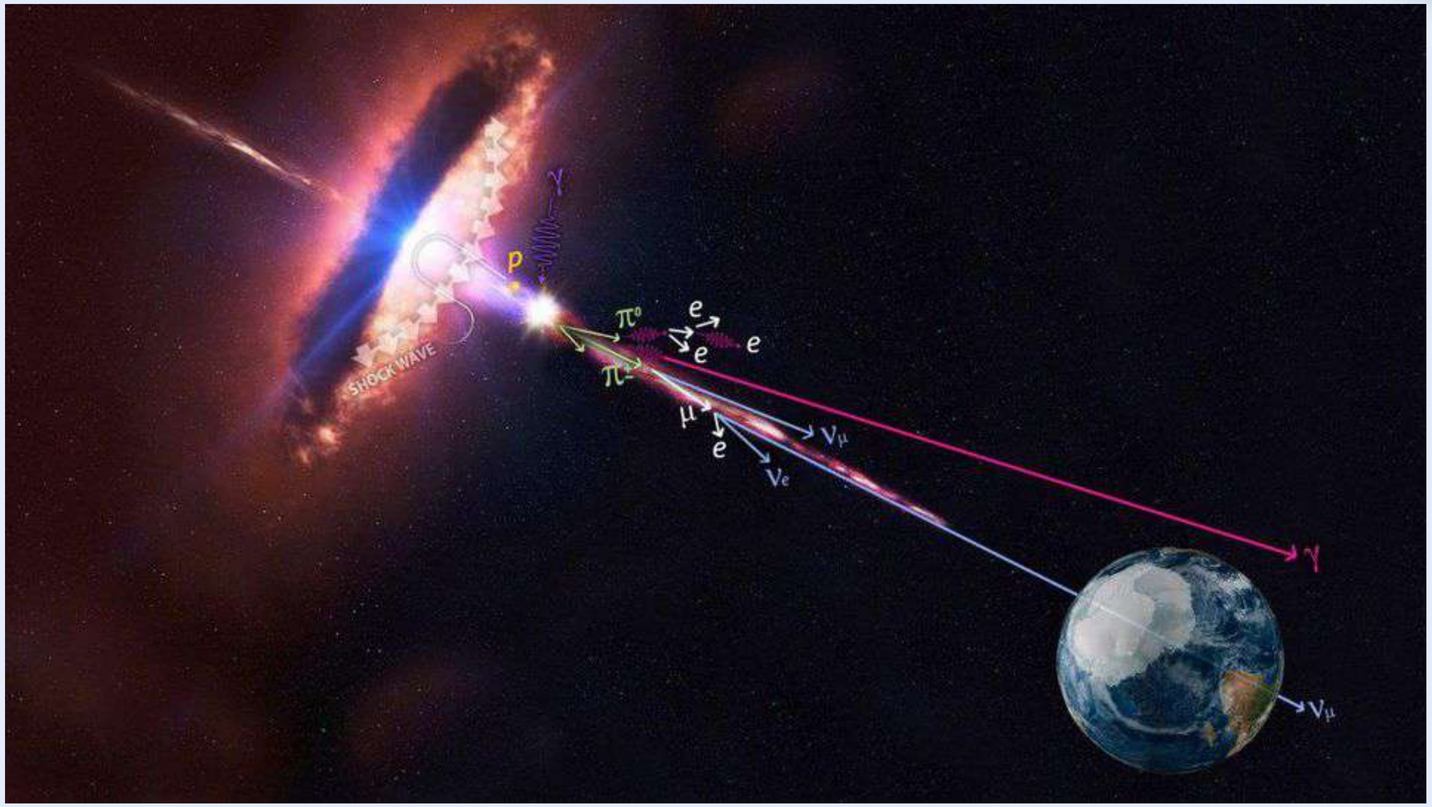


(b) Simulated CTA follow-up of GW170817

Schüssler et al. 2019

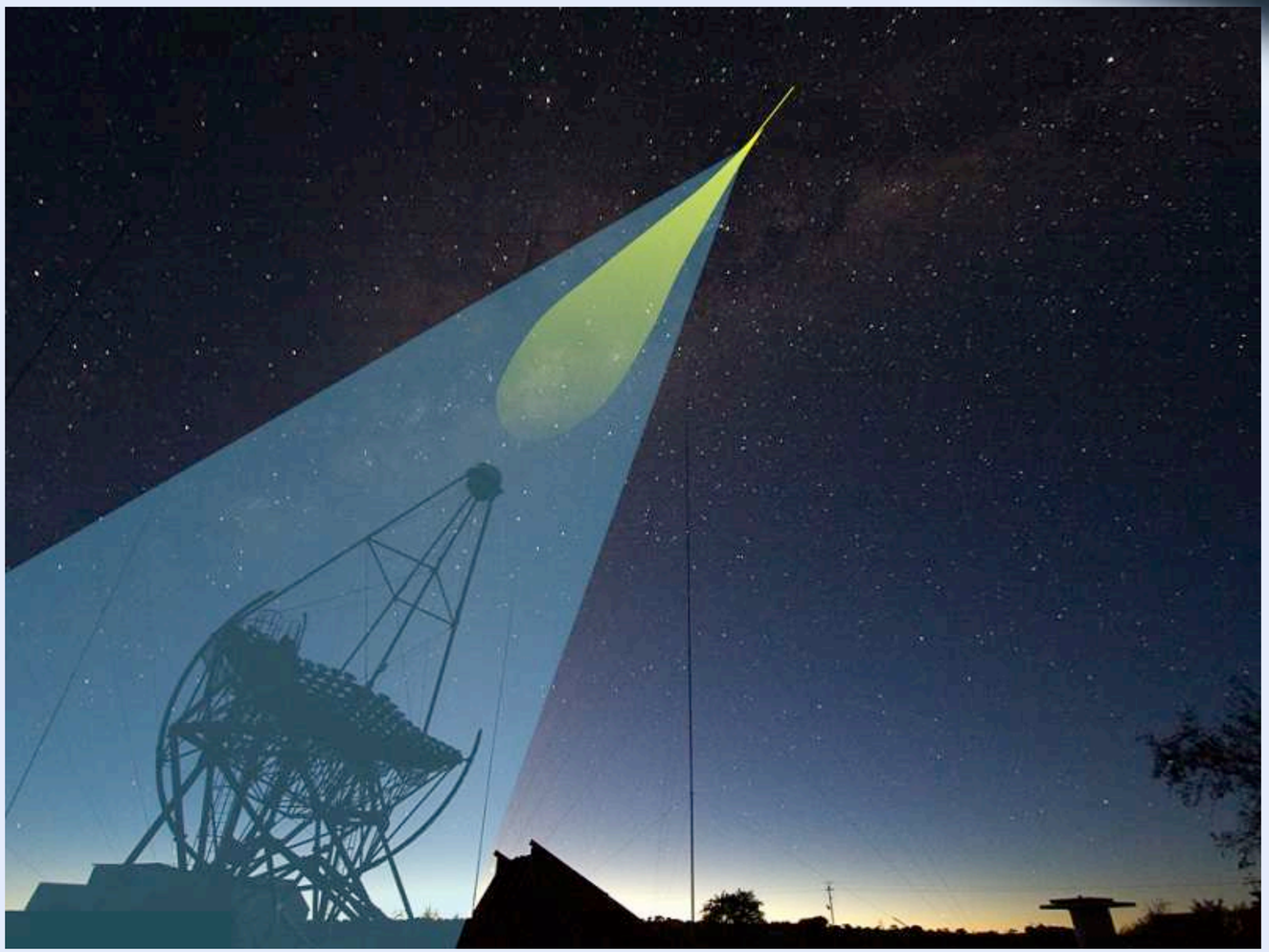
Neutrino sources

- Detections from IceCube
- Most efficient for Northern Hemisphere sources.
- Neutrino IC-170922A and TXS 0506+056 flaring blazar
- Optical/NIR observations:
  - Classify the target originating the neutrinos
  - Provide precise localisation to trigger other observations (radio)



Serendipitous VHE targets

- GATOS will fully characterise sources faster than any other instrument
- NIR capability will also allow to detect obscured sources
- Rapid data analysis allows a flexible observing strategies (trigger further observations)



How can GATOS complement CTA?

- Simultaneous VIS/NIR SED
- Precise localisation of VHE sources (needed to trigger other facilities)
- High-time resolution can allow to correlate variability
- Characterisation of VIS/NIR counterparts (imaging/spectroscopy/spectropolarimetry)
- Study of host environments

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Thank you