Joint proposals with optical telescopes

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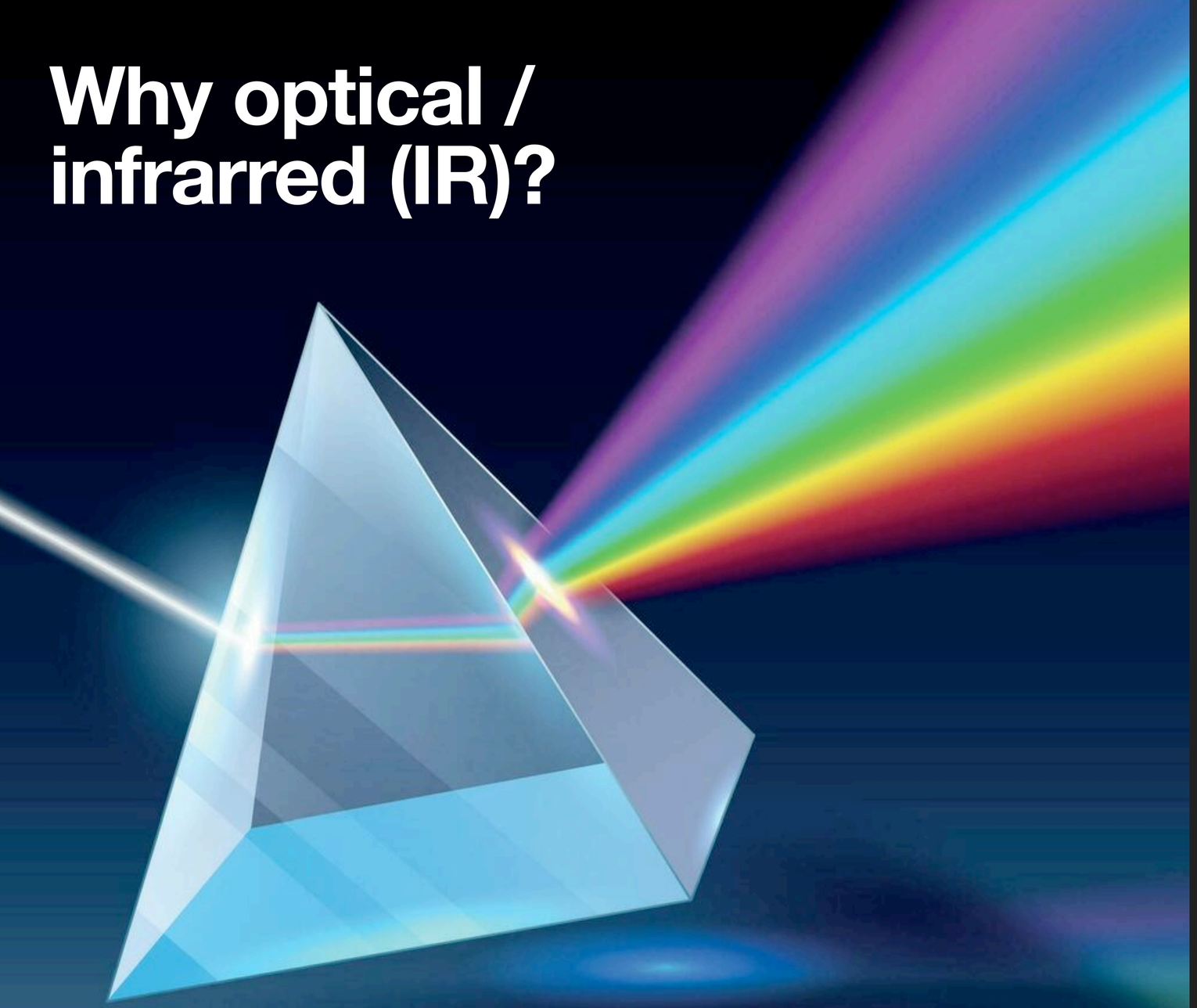
2nd CTAO School

Sn 2023ixf

GTC/OSIRIS

This work is part of the Project RYC2021-032991-I, funded by MICIU/AEI/ 10.13039/501100011033, and the European Union "NextGenerationEU"/

Why optical / infrarred (IR)?



- Spectroscopy and photometry (+polarimetry) provide additional information
  - Velocities, densities, orbital parameters…
  - Useful for modeling
- Bright events can be interesting to be triggered
  - Novae, SNe, AGNs…

The IAC and the Observatories

Public research consortium

1. State Administration (Ministry of Science and Innovation)
2. Canary Islands Regional Government
3. University of La Laguna
4. Spain's Scientific Research Council

International cooperation

✧ More than 60 collaborative agreements active with institutions that operate scientific facilities at the IAC's Observatories and other research centers.

Slide from Nayra Rodríguez Eugenio

The Observatories of the Canary Islands

Pioneers of Astronomy in Spain

Slide from Nayra Rodríguez Eugenio

Towards the **Cherenkov Telescope Array Observatory**

CTAO

@ORM

Observatorio
Roque de los Muchachos

MAGIC 2

MAGIC 1

LST-1

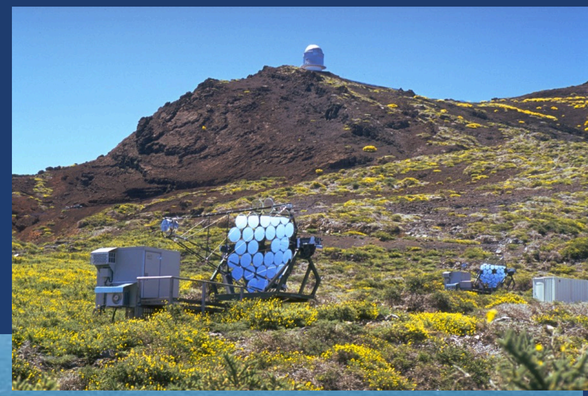
LST-2

LST-4

LST-3

CTAO

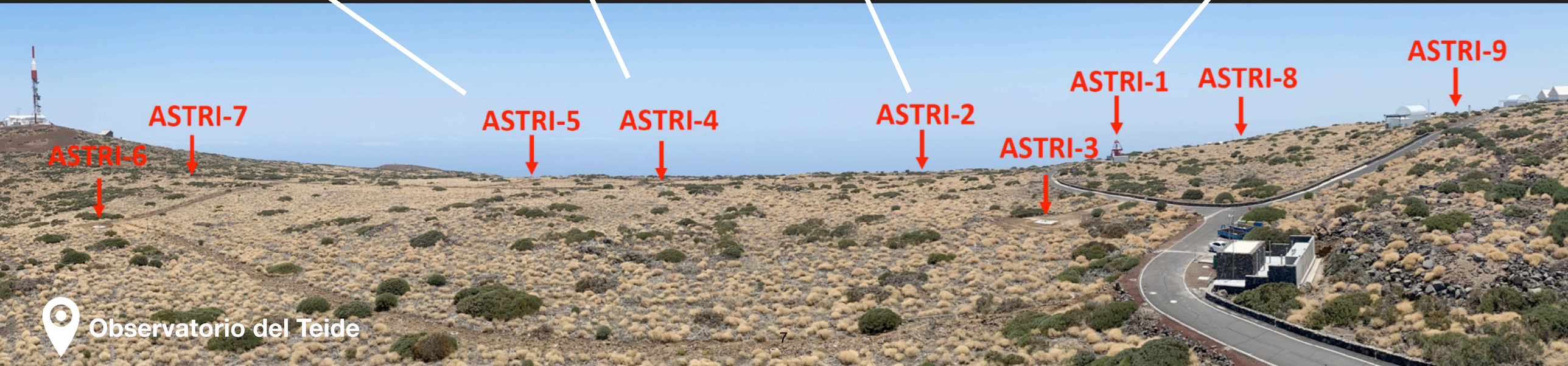
HEGRA



HEGRA (1987-2002)
Particle detectors, gamma telescopes
Showers above 1 TeV (detection of Mrk501 at 16 TeV)
First stereo observations

Observatorio
Roque de los Muchachos

ASTRI Mini-Array @OT



The Observatories of the Canary Islands

Only observatory worldwide with access to all frequencies from Earth

Slide from Nayra Rodríguez Eugenio

The Observatories of the Canary Islands

Pioneers of Astronomy in Spain

Piazzi Smyth 1856

- Showed **for the first time** that **high altitude** sites provide **clear advantages** for astronomical observing.
- Observations in Tenerife, from sea level to the Guajara mountain (2,717 m) and Altavista (3,250m) close the peak of Teide.

The Observatories of the Canary Islands

Pioneers of Astronomy in Spain

Jean Mascart, 1910

- Purpose of observing the approach of Halley’s comet in Tenerife
- So satisfied with the conditions for astronomical observation on the mountains of Tenerife, that he **proposed the setting up of an international observatory** on Guajara mountain

The Observatories of the Canary Islands

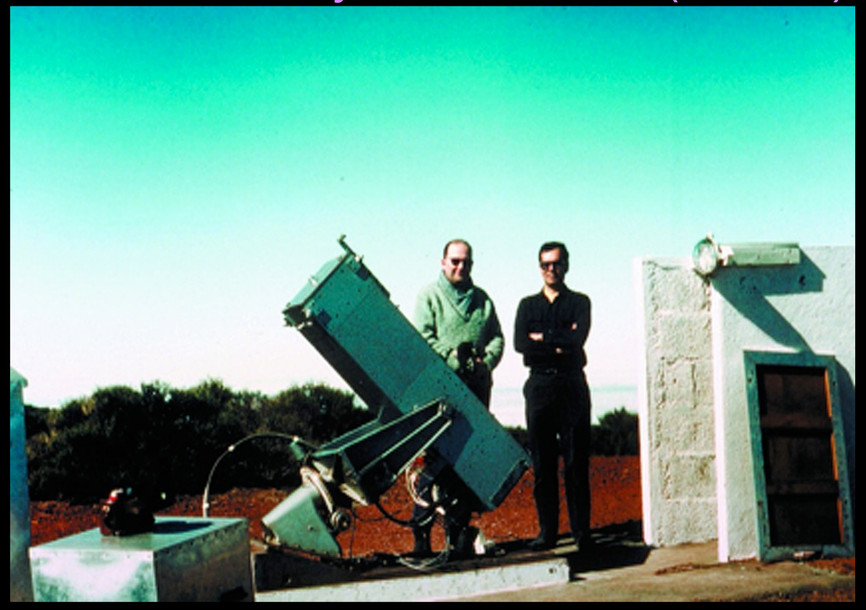
Pioneers of Astronomy in Spain

Solar eclipse, 1959

- Studies were initiated of the **astronomical conditions** in the region of Izaña
- **the Teide Observatory was officially created**

1964-
1975

1st professional telescope, 1964
from University of Bordeaux (France)



Slide from Nayra Rodríguez Eugenio

The Observatories of the Canary Islands

Pioneers of Astronomy in Spain

Agreement on Cooperation in Astrophysics 26 May 1979

I. Disposiciones generales

MINISTERIO
DE ASUNTOS EXTERIORES

16122 *ACUERDO de Cooperación en materia de Astrofísica y Protocolo entre los Gobiernos del Reino de España, del Reino de Dinamarca, del Reino Unido de Gran Bretaña e Irlanda del Norte y del Reino de Suecia, hechos en Santa Cruz de la Palma (Canarias) el 26 de mayo de 1979.*

ACUERDO DE COOPERACION EN MATERIA DE ASTROFISICA

Los Gobiernos del Reino de España, del Reino de Dinamarca, del Reino Unido de Gran Bretaña e Irlanda del Norte y del Reino de Suecia:

— Deseosos de fomentar las relaciones de cooperación científica entre estos países;
— Conscientes de la importancia de esta cooperación para el mejor desarrollo de sus relaciones;
— Teniendo en cuenta su común interés en el fomento de la investigación en el campo de la Astrofísica;
— Reconociendo las ventajas que puede aportar a la Ciencia una estrecha cooperación internacional;
— Reconociendo que en España, especialmente en Tenerife y La Palma, existen áreas que ofrecen condiciones únicas para la observación astronómica;
— Teniendo presente el gran interés manifestado por diversas Instituciones Científicas europeas en la instalación de potentes telescopios en las Islas Canarias;
— Considerando la decisión del Gobierno del Reino de España de facilitar el uso de los Observatorios del Instituto de Astrofísica de Canarias a la comunidad científica internacional en las Islas Canarias y, de acuerdo con esta decisión, de autorizar el uso por las Instituciones Científicas de las Partes Contratantes de tales Observatorios con fines de investigación astrofísica en los términos establecidos en el presente Acuerdo, y supuesto que los Organismos firmantes señalados en el artículo 3 establezcan un Protocolo con el Consejo Superior de Investigaciones Científicas de España (en lo sucesivo denominado C. S. I. C.);
— Han acordado lo siguiente:

ARTICULO 1

En el presente Acuerdo se utilizarán los términos que a continuación se expresan en el sentido con que se definen en este artículo:

(1) «Instituto de Astrofísica de Canarias» (en lo sucesivo denominado I. A. C.): Institución Científica perteneciente al C. S. I. C. y establecida por él, con la colaboración de la Universidad de La Laguna y la Mancomunidad Provincial Interinsular de Cabildos de Santa Cruz de Tenerife, con el fin de promover la investigación astrofísica en las Islas Canarias, y que comprende los laboratorios y equipos situados en La Laguna y los Observatorios delimitados en el Anejo al presente Acuerdo.

(2) «Instalación telescópica»: Colectores de radiaciones y servicios instrumentales que le son propios y se hallen instalados en el mismo edificio.

(3) «Organismo firmante»: Organismo que, estando establecido en el territorio de una de las Partes Contratantes y ostentando su nacionalidad, es firmante del Protocolo mencionado en el artículo 3 del presente Acuerdo.

(4) «Institución usuaria»: El I. A. C. y aquellas Organizaciones científicas que, estando establecidas en el territorio de una de las Partes Contratantes y ostentando su nacionalidad, son autorizadas para utilizar las instalaciones y servicios del I. A. C. para la investigación astrofísica mediante la firma de un acuerdo sobre instalaciones telescópicas con el I. A. C.

(5) «Servicios comunes»: Los servicios necesarios en los Observatorios para soporte de su infraestructura y de sus instalaciones telescópicas.

ARTICULO 2

Las Partes Contratantes fomentarán la cooperación para fines pacíficos en el campo de la investigación astrofísica entre los Organismos científicos de sus respectivos países.

ARTICULO 3

(1) Para el desarrollo de esta cooperación se concluirá un Protocolo que regulará los aspectos concretos de la misma entre los Organismos que se indican a continuación y que ostentan la nacionalidad de las respectivas Partes Contratantes:

— El Consejo Superior de Investigaciones Científicas, de España.
— La Secretaría para la Investigación, de Dinamarca.
— El Consejo de Investigación Científica, del Reino Unido.
— La Real Academia de Ciencias, de Suecia.

(2) La firma del presente Acuerdo por las Partes Contratantes supone la aprobación del Protocolo por las Autoridades competentes de cada una de las Partes Contratantes de conformidad con los procedimientos establecidos en sus respectivos países.

(3) El Protocolo podrá ser modificado por acuerdo unánime de los Organismos firmantes.

ARTICULO 4

La cooperación en materia de Astrofísica podrá realizarse, entre otras, de las siguientes formas:

(a) Intercambio de información sobre la investigación científica en Astrofísica.
(b) Intercambio de científicos, expertos y personal técnico.
(c) Realización común y coordinada de programas de investigación tecnológica.
(d) Utilización común y coordinada de instalaciones científicas o técnicas.
(e) La instalación y uso de telescopios e instrumentos en los Observatorios del I. A. C.

from B.O.E 161, 6 July 1979 (Law/Official Gazette of the Spanisch Government)

Slide from Helmut Dannerbauer

The Observatories of the Canary Islands

Pioneers of Astronomy in Spain

Agreement on Cooperation in Astrophysics 26 May 1979

Agreement on Cooperation in Astrophysics 26 May 1979

between Spain, Denmark, UK and Sweden

- **Recognizing that there are in Spain, especially in Tenerife and La Palma, areas providing unique conditions for astronomical observations.**

- **Bearing in mind the great interest shown by various European scientific Institutions in the installation of powerful telescopes on the Canary Islands.**

16 Articles, setting the general framework for astrophysical collaborations between Spain and international partners.

Slide from Helmut Dannerbauer

The Observatories of the Canary Islands

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Article 5b, allocation of observing time:

i) Spain shall have at its disposal at least 20% of the observing time of each of the telescopes and instruments installed in the observatories…

ii) The allocation of at least an additional 5% of the observing time of each of the telescope installations …

-> see later *International Time Programme*

Slide from Helmut Dannerbauer

The Observatories of the Canary Islands

Pioneers of Astronomy in Spain

IAC, Teide and Roque Observatories officially inaugurated in 1985

The Observatories of the Canary Islands

Pioneers of Astronomy in Spain

Over the last 40 years:

> 60 institutions of 20 countries

6 international consortia (institutes from 10 additional countries)

> 700 people directly working for Astrophysics in the Canary Islands

Austria
Belgium
Checz Rep.
Denmark
Finland
France
Germany
Italy
Japan

Mexico
Spain
Sweden
The Netherlands
United Kingdom
USA

Consortia:

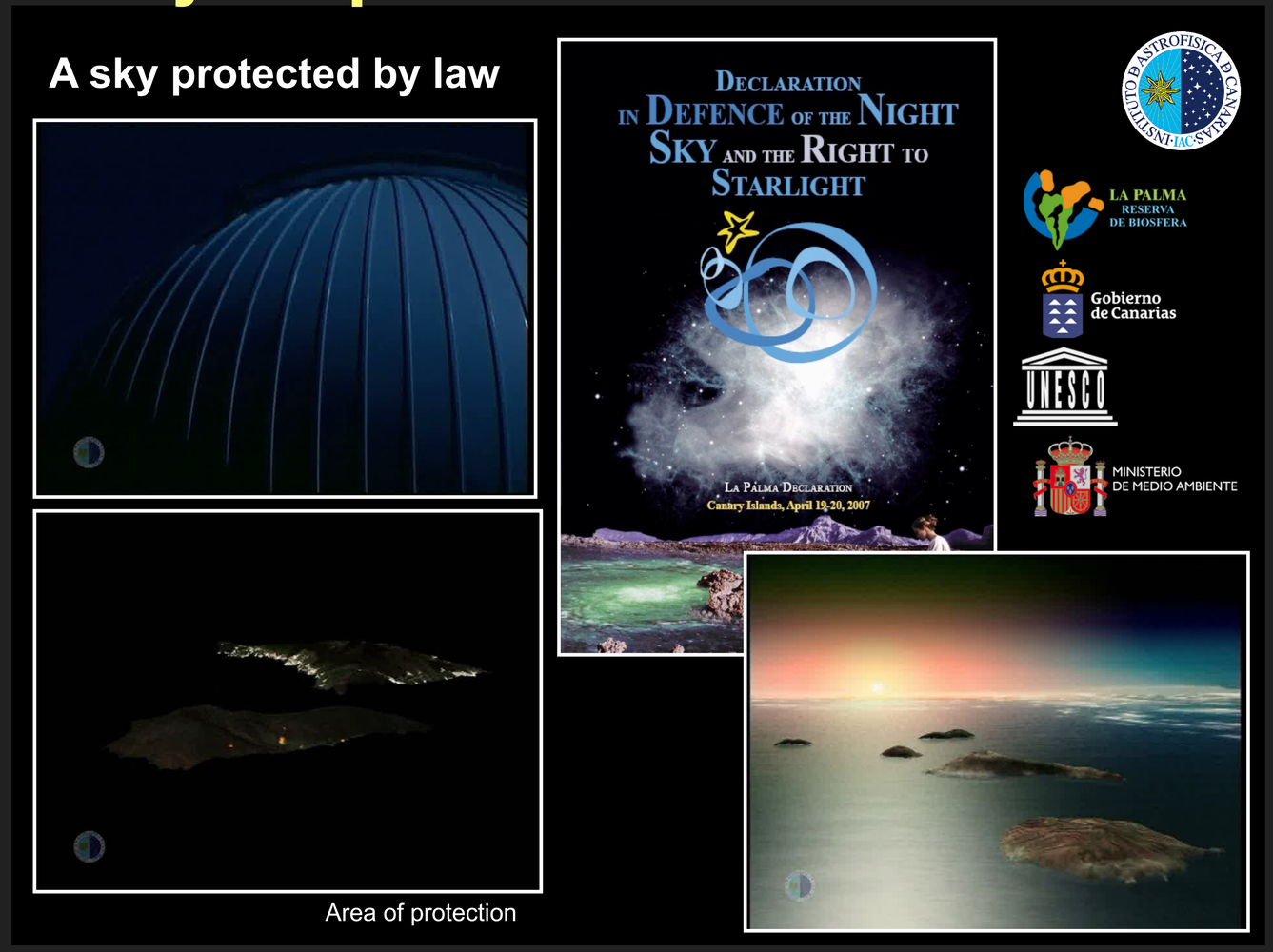
- European Space Agency
- MAGIC Consortium
- FACT Collaboration
- 4LST Consortium
- CTA Observatory

TMT

Slide adapted from Nayra Rodríguez Eugenio

The Observatories of the Canary Islands

Pioneers of Astronomy in Spain

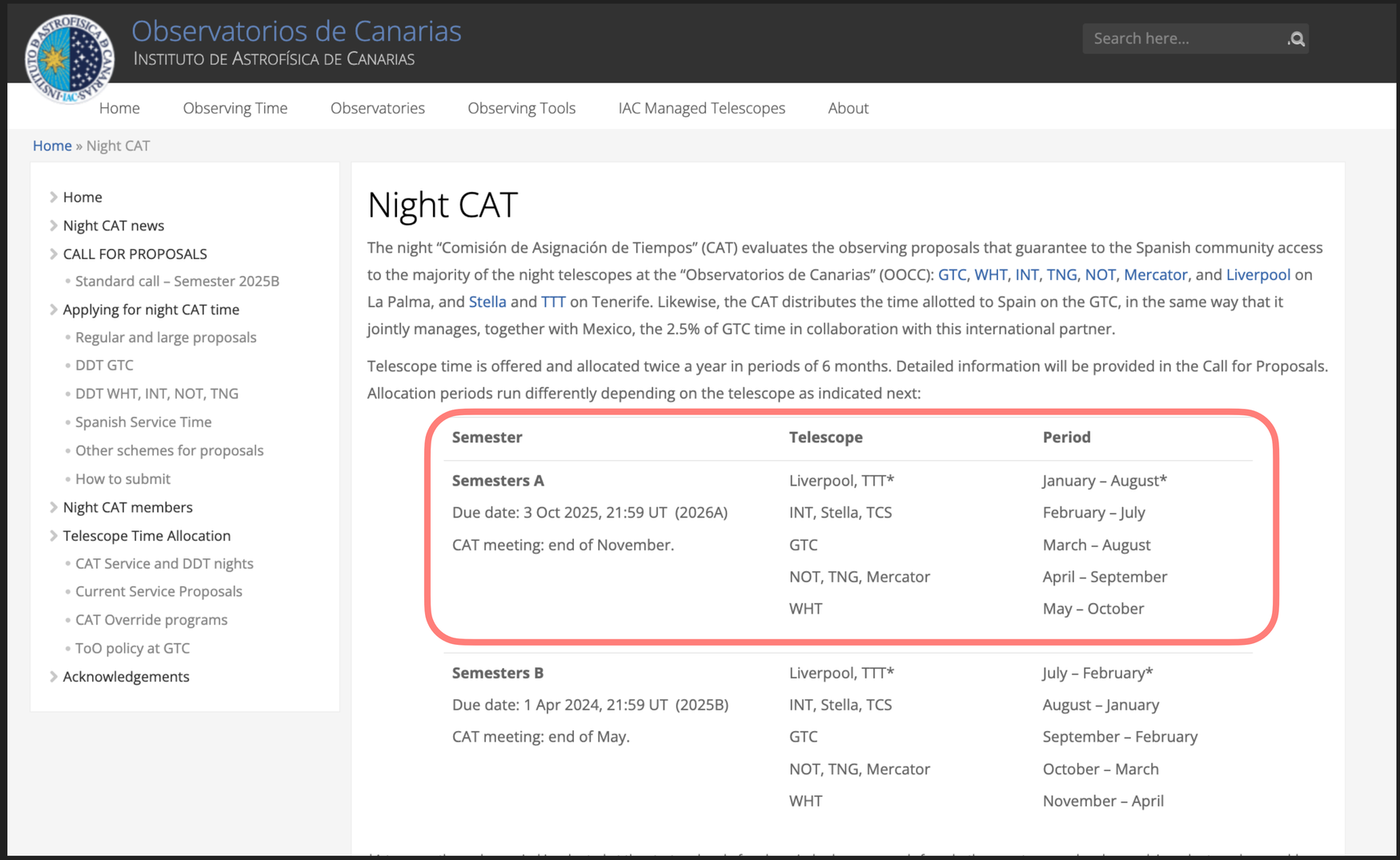


Slide from Nayra Rodríguez Eugenio

- A pioneering law at national and international level
- Approved by the Spanish Parliament in 1988

Time allocation

Spanish CAT



Observatorios de Canarias
INSTITUTO DE ASTROFÍSICA DE CANARIAS

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Home » Night CAT

- Home
- Night CAT news
- CALL FOR PROPOSALS
  - Standard call – Semester 2025B
- Applying for night CAT time
  - Regular and large proposals
  - DDT GTC
  - DDT WHT, INT, NOT, TNG
  - Spanish Service Time
  - Other schemes for proposals
  - How to submit
- Night CAT members
- Telescope Time Allocation
  - CAT Service and DDT nights
  - Current Service Proposals
  - CAT Override programs
  - ToO policy at GTC
- Acknowledgements

Night CAT

The night "Comisión de Asignación de Tiempos" (CAT) evaluates the observing proposals that guarantee to the Spanish community access to the majority of the night telescopes at the "Observatorios de Canarias" (OOCC): GTC, WHT, INT, TNG, NOT, Mercator, and Liverpool on La Palma, and Stella and TTT on Tenerife. Likewise, the CAT distributes the time allotted to Spain on the GTC, in the same way that it jointly manages, together with Mexico, the 2.5% of GTC time in collaboration with this international partner.

Telescope time is offered and allocated twice a year in periods of 6 months. Detailed information will be provided in the Call for Proposals. Allocation periods run differently depending on the telescope as indicated next:

Semester	Telescope	Period
Semesters A	Liverpool, TTT*	January – August*
Due date: 3 Oct 2025, 21:59 UT (2026A)	INT, Stella, TCS	February – July
CAT meeting: end of November.	GTC	March – August
	NOT, TNG, Mercator	April – September
	WHT	May – October
Semesters B	Liverpool, TTT*	July – February*
Due date: 1 Apr 2024, 21:59 UT (2025B)	INT, Stella, TCS	August – January
CAT meeting: end of May.	GTC	September – February
	NOT, TNG, Mercator	October – March
	WHT	November – April

https://research.iac.es/OOCC/night-cat/

Time allocation

International Time Program

https://www.iac.es/en/observatorios-de-canarias/international-scientific-committee

ITP – International Time Programme

- 5% of observing time at each available telescope: GTC, WHT, TNG, NOT, LT, STELLA and Mercator
- call is once per year end of February/begin of March
- 80hrs resp. 15nights per telescope facility per semester
- encouraged to request several telescopes
- proposers from any country can lead proposals, proposing team must contains astronomers from at least three CCI countries
- any Spanish institution shall have the right to join approved programmes if it wishes and has the approval of the IAC

Slide from Helmut Dannerbauer

Time allocation

International Time Program

https://www.iac.es/en/observatorios-de-canarias/international-scientific-committee

Any country can request permission to install its telescopes at the Observatorios de Canarias (OOCC) by subscribing to the International Agreement and Protocol and signing a (Third Level) Agreement with the IAC specifying the instrument to be installed. Under the terms of this agreement, Spain provides the site in return for a package that includes at least 20% of the available observing time.

ITP proposal submission now open: 5% of observing time at each telescope will be available for the International Time Programme (ITP): CALL FOR PROPOSALS (pdf) and APPLICATION FORM (docx), which is open to all research organizations. The deadline for proposals for the ITP for 2025-26 is 7 March 2025 at 23:59 UTC.

By submitting a proposal for the ITP time, all proposers and co-proposers declare that they have read, and agree to abide by, the CCI ITP Code of Conduct.

SHORT TITLE OF PROPOSAL:

Observing Period: 2025B & 2026A (and 2026B & 2027A if requesting 2 years)
(Awards will be communicated in June, 2025)

Principal Researcher; Please, fill in all the information.

Family Name:

Name:

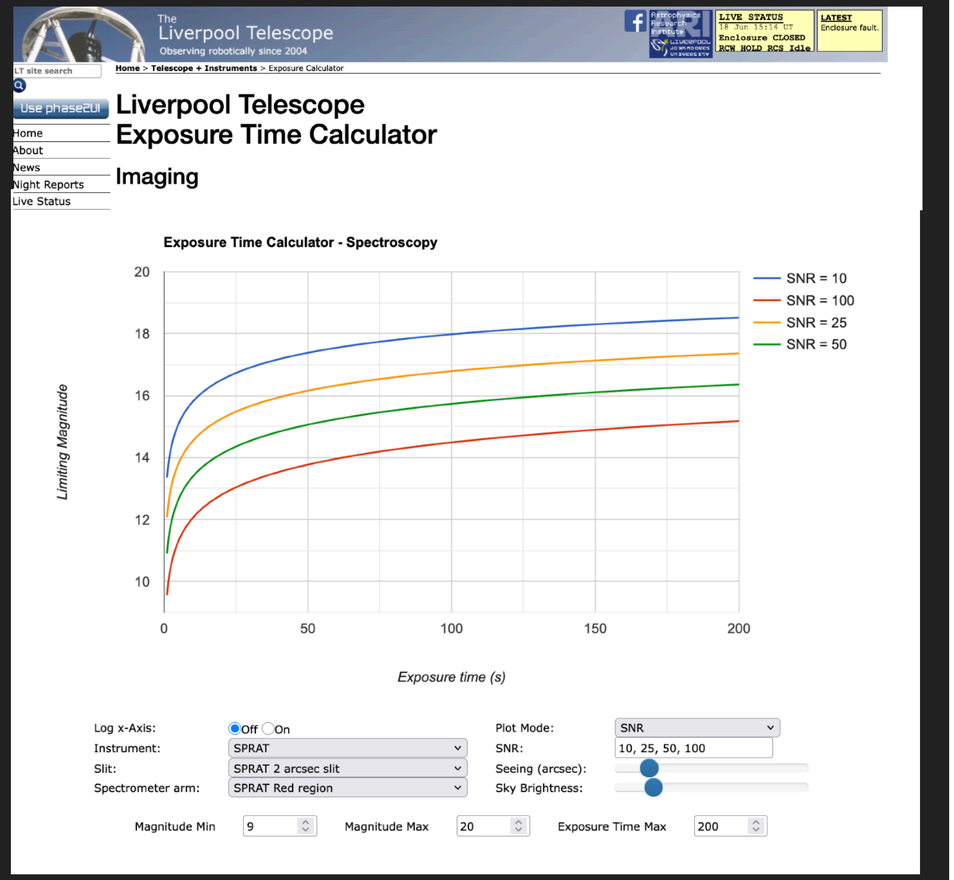
Degree:

Present position:

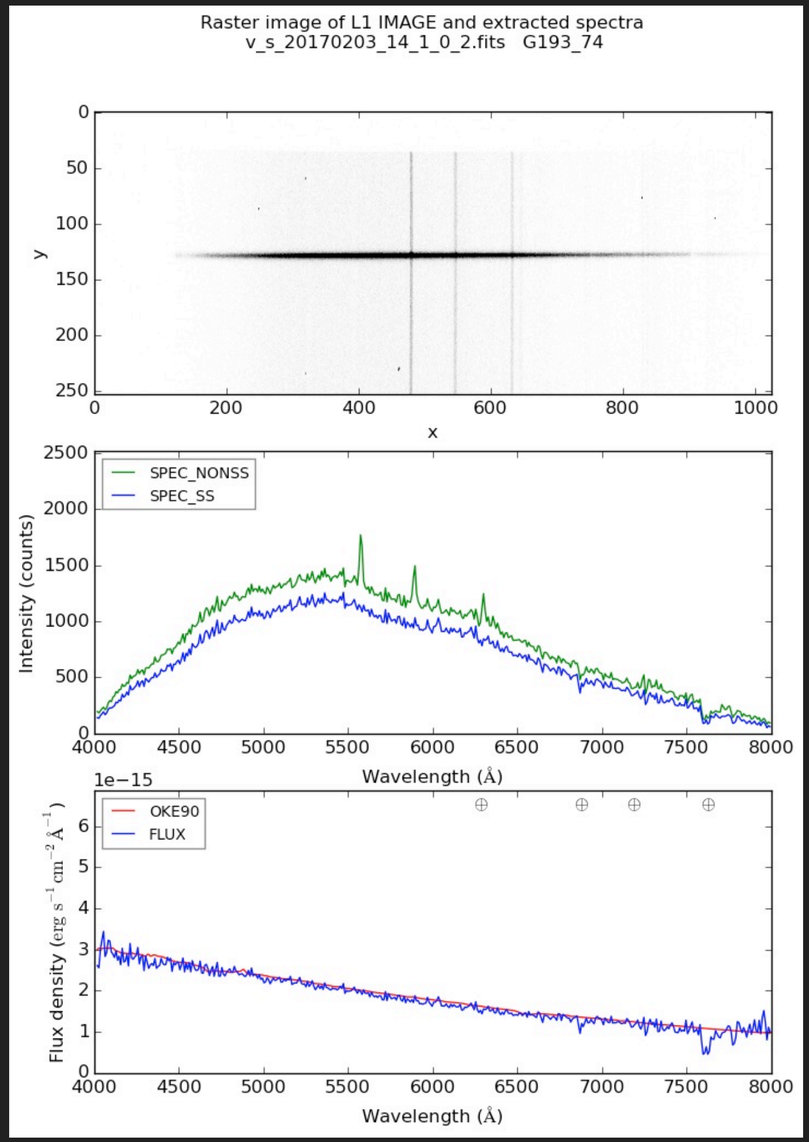
Preparing your observations and products

e.g. Liverpool

Exposure calculator



Quicklook



Code

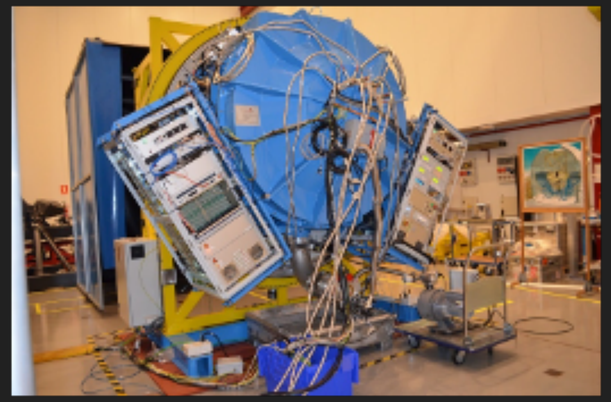
Plotting with astropy, specutils and matplotlib

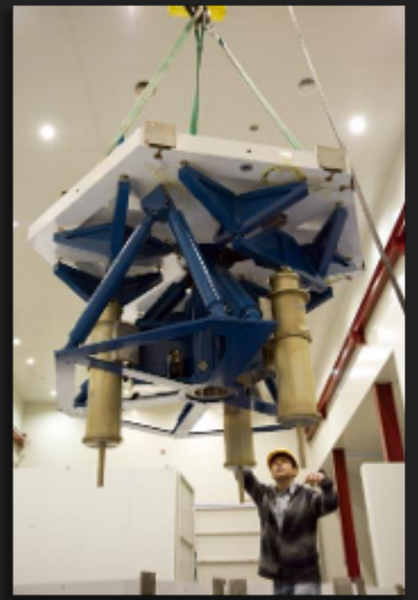
Following is a minimal example of using specutils and Astropy to plot SPRAT spectra in Python.

```
from astropy.io import fits
from astropy import units as u
from matplotlib import pyplot as plt
from astropy.visualization import quantity_support
import astropy.wcs as fitswcs
import specutils as sp
quantity_support()

f=fits.open("FILENAME.FITS")

# For SPRAT and LOTUS this is the Sky Subtracted Spectrum.
# Other extensions are available!
extension = 3

# FITS are stored as 2D NAXIS1 x 1 arrays. Read and convert to a 1D NAXIS vector.
specarray = f[extension].data
specdata = specarray[0]
specheader = f[extension].header
f.close()

flux = specdata * u.Unit("adu")

# create WCS Wavelength Calibration, picking the required keywords from the fits header
my_wcs = fitswcs.WCS(header={'CTYPE1':specheader['CTYPE1'], 'CUNIT1':'Angstrom',
                             'CRVAL1':specheader['CRVAL1'], 'CDELT1':specheader['CDELT1'],
                             'CRPIX1':specheader['CRPIX1'] })

sp1d = sp.Spectrum1D(flux=flux,wcs=my_wcs) # create Spectrum1D object
plt.plot(sp1d.spectral_axis,sp1d.flux)
plt.show()
```


https://telescope.livjm.ac.uk/

Telescopes at OCAN





The Observatories of the Canary Islands

OT

DIÁMETRO	TELESCOPIO
	CILBO
	AMOS-CI
	AstMon
11	TIZON
20	Automatic Seeing Monitor (DIMMA)
40	GroundBIRD
43	COAST
50	MONS
61	PIRATE
70	Vacuum Tower Telescope
50, 43, 8	Optical Telescope Array
80	IZN-1
80x2	TTT
82	IAC-80
90	THEMIS
100	SONG
100	OGS
100	Artemis
100x2, 40x2	LCOGT
120x2	STELLA
150	GREGOR
152	Telescopio Carlos Sánchez
225x2	QUIJOTE I – II
400	ASTRI
	Laboratorio Solar: Mark-I, GONG

ORM

DIÁMETRO	TELESCOPIO
	CILBO
	AMOS-CI
12x4	SuperWASP
20	Automatic Seeing Monitor (DIMMA)
30	Automatic Seeing Monitor (DIMMA)
36x16	CLASP
40x16	GOTO
45	Dutch Open Telescope
97	Swedish Solar Tower
100	Jacobus Kapteyn Telescope
100	Super-WASP Alsubai Follow-up Telescope
120	Mercator Telescope
200	Liverpool Telescope
250	Isaac Newton Telescope
256	Nordic Optical Telescope
300	First G-APD Cherenkov Telescope
350	Telescopio Nazionale Galileo
420	William Herschel Telescope
1040	Gran Telescopio Canarias
1700x2	MAGIC I y II
2300	LST-1

from Álex Oscoz

The Observatories of the Canary Islands

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Private, check if agreement

Operators

Robotic

Robotic

Operators

ORM

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from Álex Oscoz

IAC

The Observatories of the Canary Islands

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200	Liverpool Telescope	← Robotic
250	Isaac Newton Telescope	←
256	Nordic Optical Telescope	←
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1700x2	MAGIC I y II	
2300	LST-1	

from Álex Oscoz

IAC

Gran Telescopio Canarias

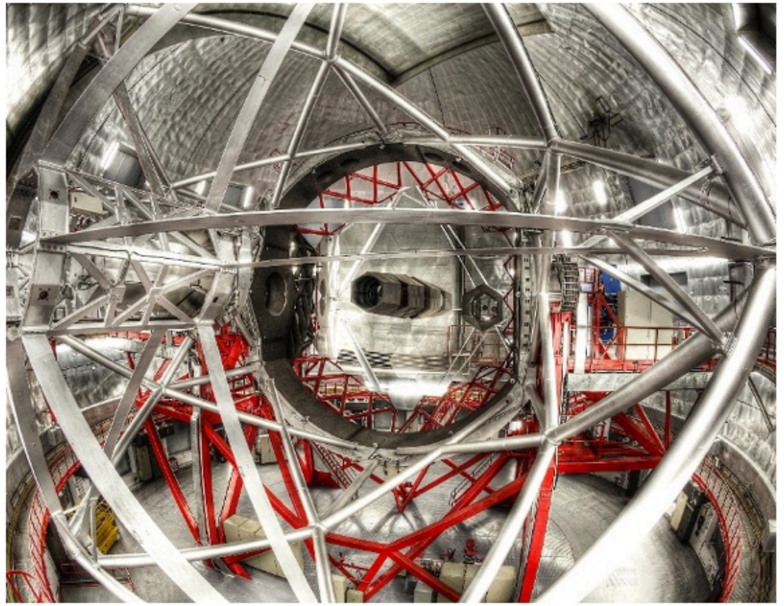
10.4 m Optical and Infrared telescope (largest worldwide)

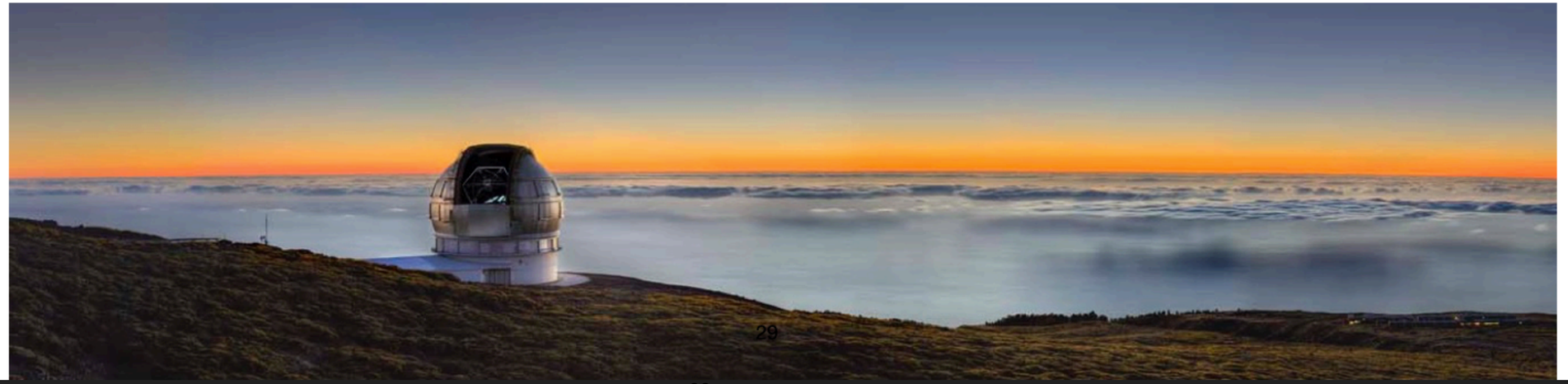
GTC

Gran Telescopio Canarias (GTC)

10.4 m Optical and Infrared telescope

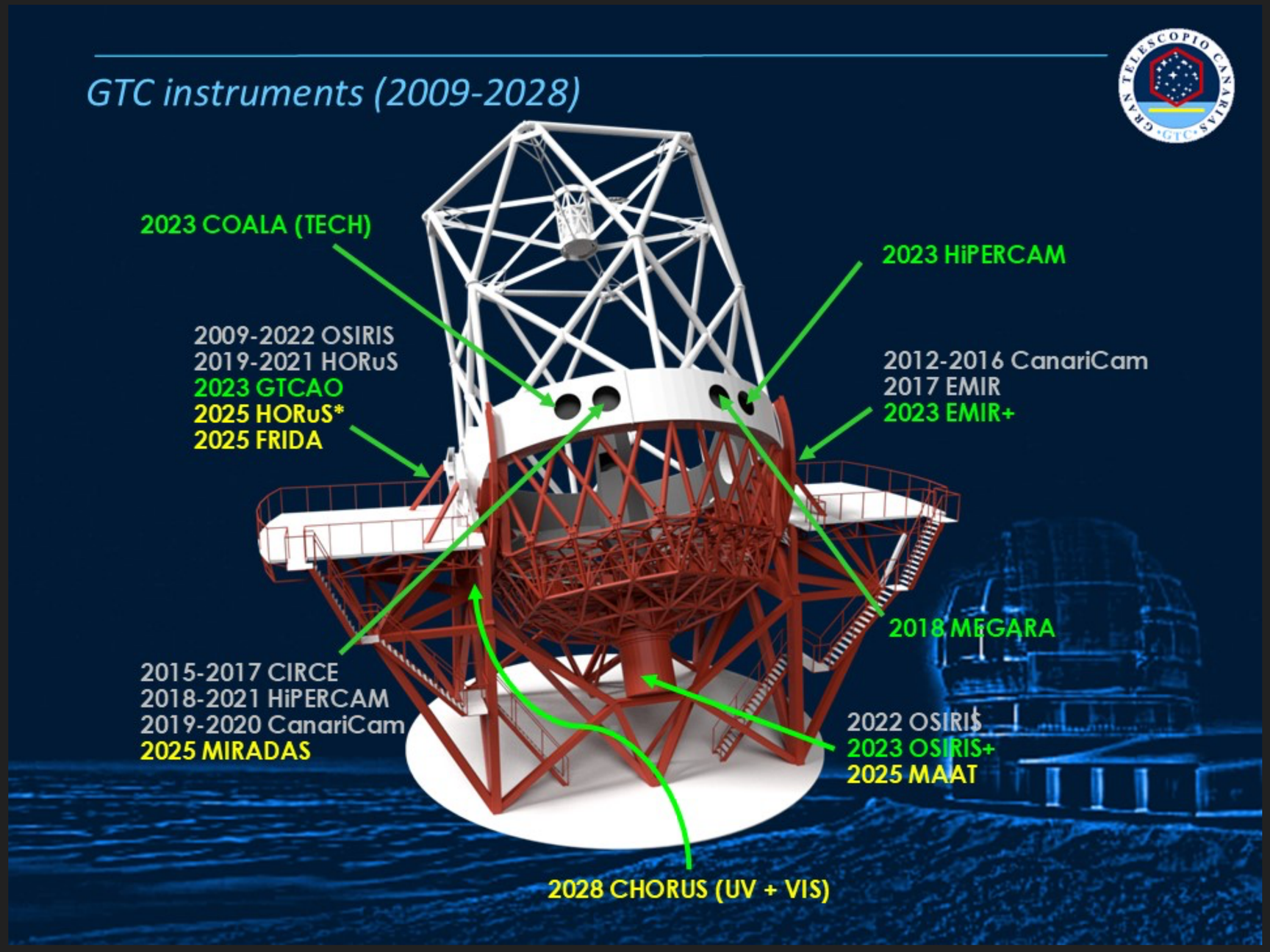
- Located at 2267 m a.s.l.
- GTC telescope is an initiative of the Instituto de Astrofísica de Canarias (IAC). Start of the operation in 2009
- Funded by Spain (90%), México (5%), and the University of Florida (2.5-5%)
- Effective collecting area 73 m^2. **Largest optical telescope in the world**
- Effective focal length 169.9 m —> plate scale 1.21 arcsec mm^{-1}

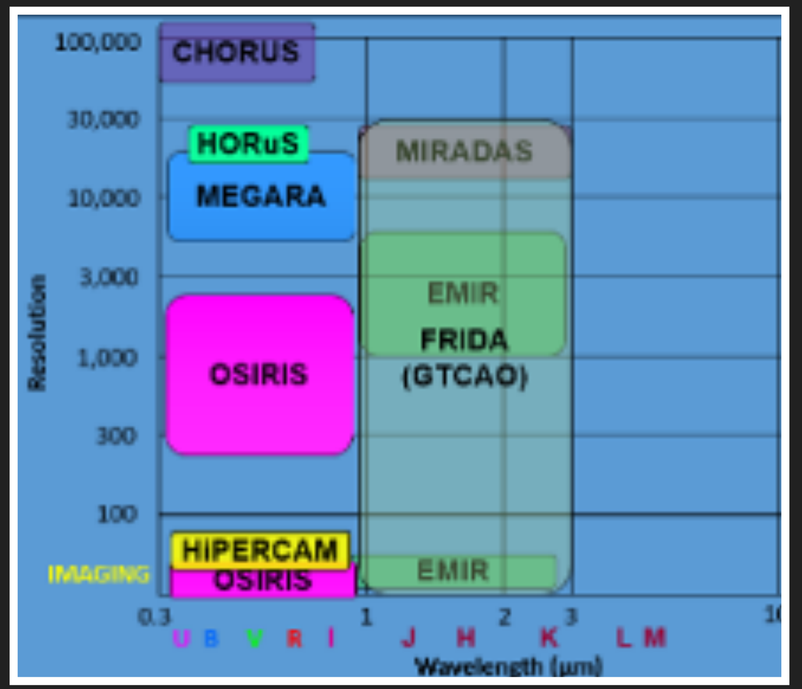




Slide from Pepa Becerra

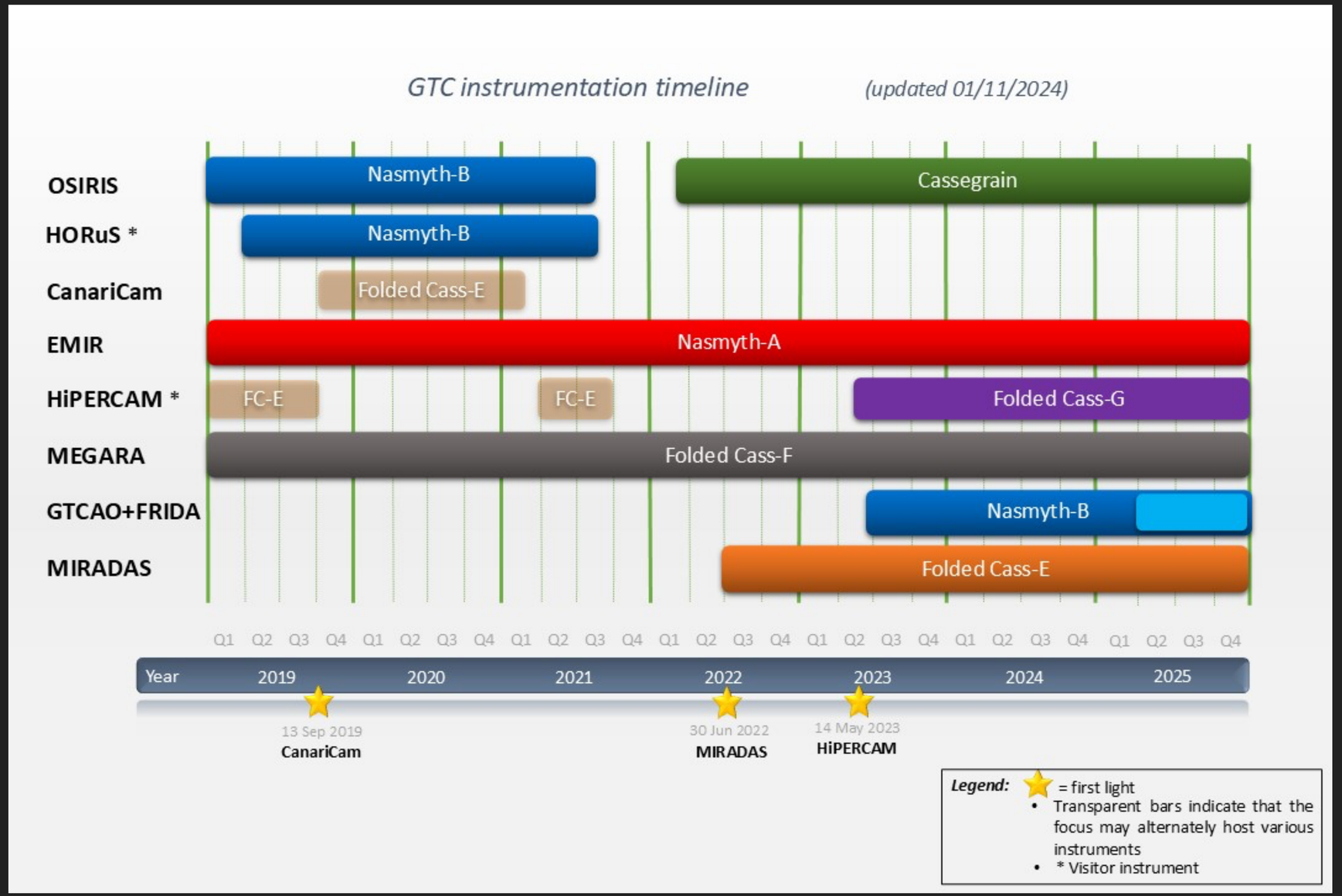
GTC





Material from Marcos Reyes

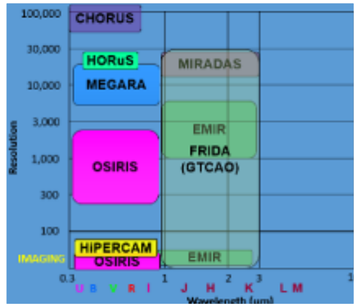
GTC



Slide from Pepa Becerra

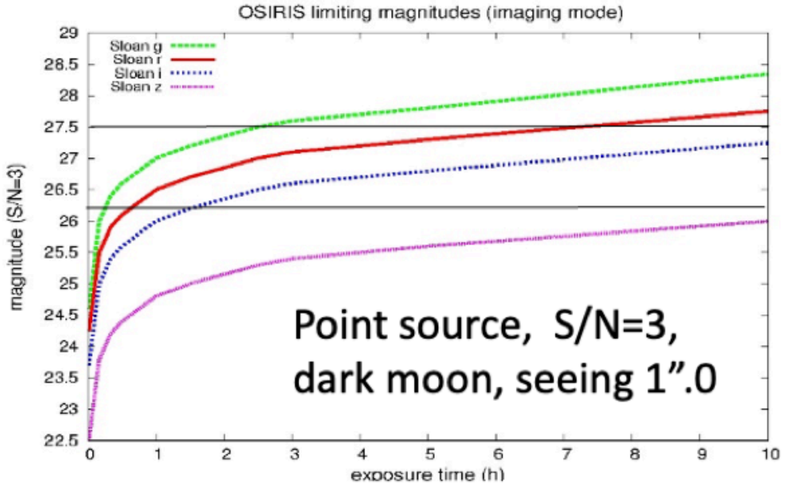
GTC

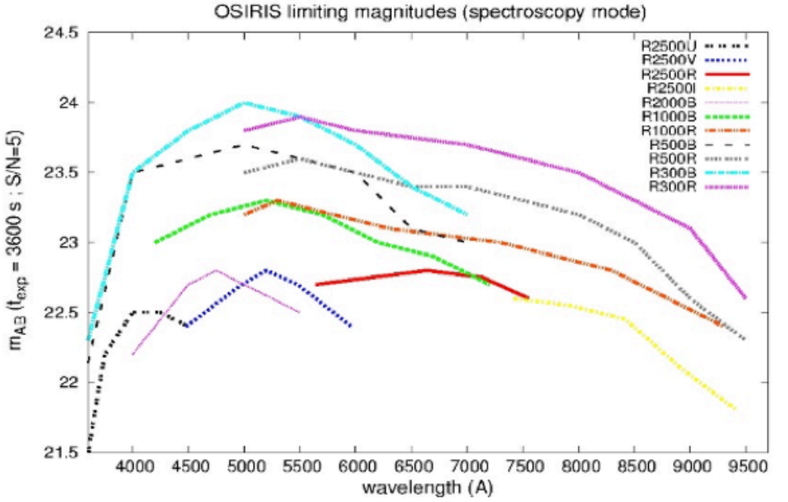
OSIRIS/OSIRIS+



Common-user instrument since 2009 (Nasmyth B), moved to Cassegrain in 2022, upgraded to a new blue sensitive 4k x 4k monolithic CCD in December 2022 (**OSIRIS+**).

Spectral Range	0.36-1.00 µm
Detector	E2V CCD231-84-1-E74
Plate Scale	0.125 arcsec pix^{-1}
Field of view	7.8 x 7.8 arcmin^2
Imaging modes	Broad-band Medium band Tunable Filters Fast photometry
Spectroscopic modes	long-slit mask MOS
Spectral resolution	300 to 2500

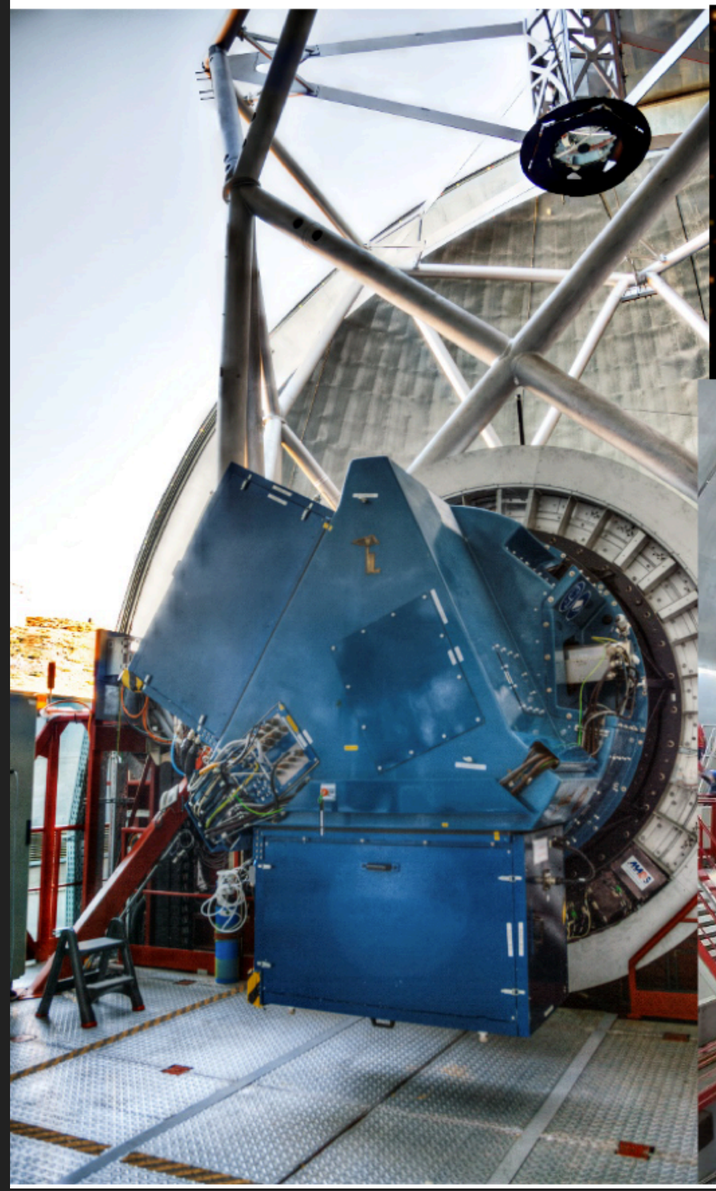


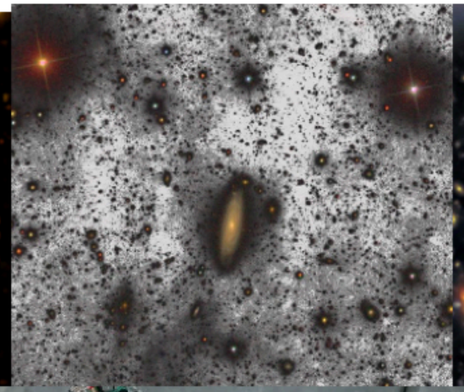


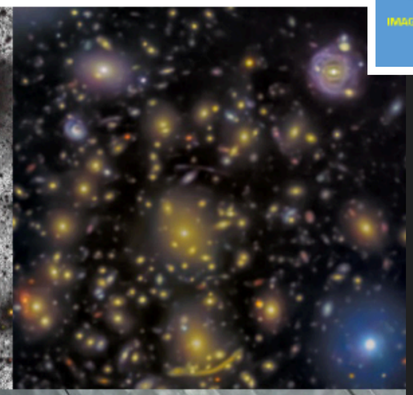
Slide from
Pepa Becerra

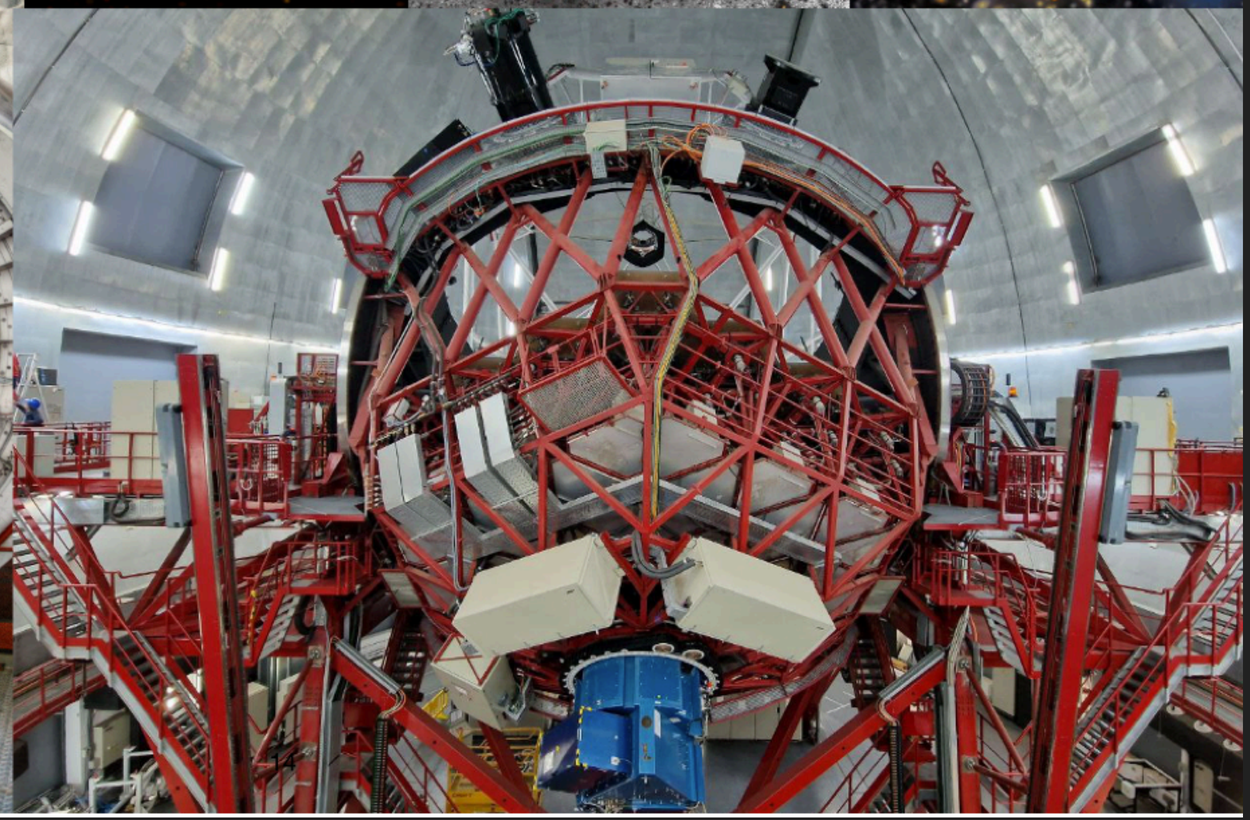
GTC

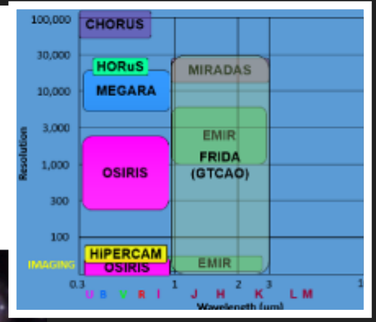
OSIRIS/OSIRIS+







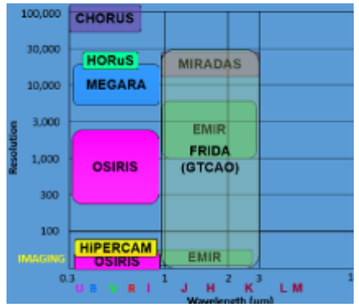




Slide from
Pepa Becerra

GTC

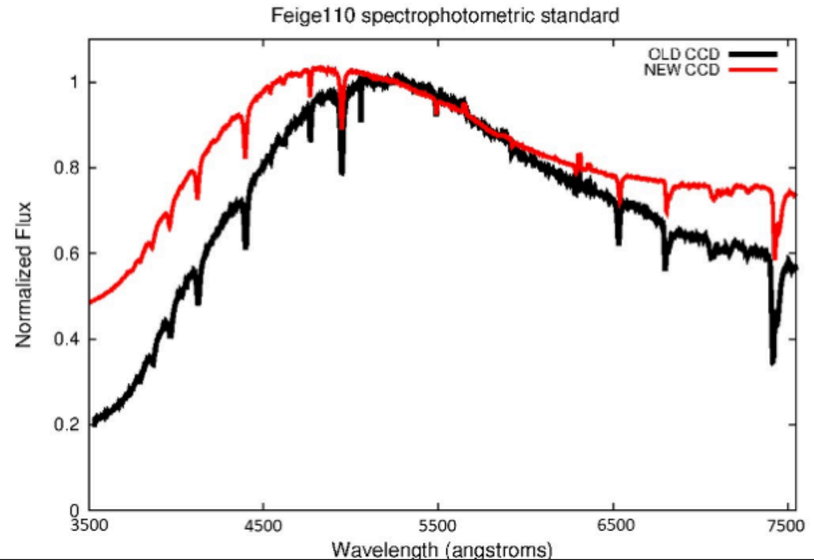
OSIRIS+ (new detector)



- **Notable sensitivity gain** at bluer wavelengths (0.5-1.2 mags) but also some improvement in the red.

ZPs	OSIRIS	OSIRIS+*
u'	25.7	26.9
g'	28.85	29.3
r'	29.3	29.4
i'	28.85	29.0
z'	28.15	28.3

Filter	Surface mag limits (3sigma; 10"x10" boxes) mag/arsec2 (1.5 h on source)	Limiting magnitude (5sigma; r=1") mag (1.5 h on source)
Sloan u	30.3	26.0
Sloan g	31.5	27.3
Sloan r	31.0	26.6

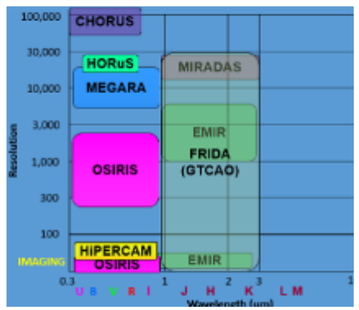


Slide from Pepa Becerra

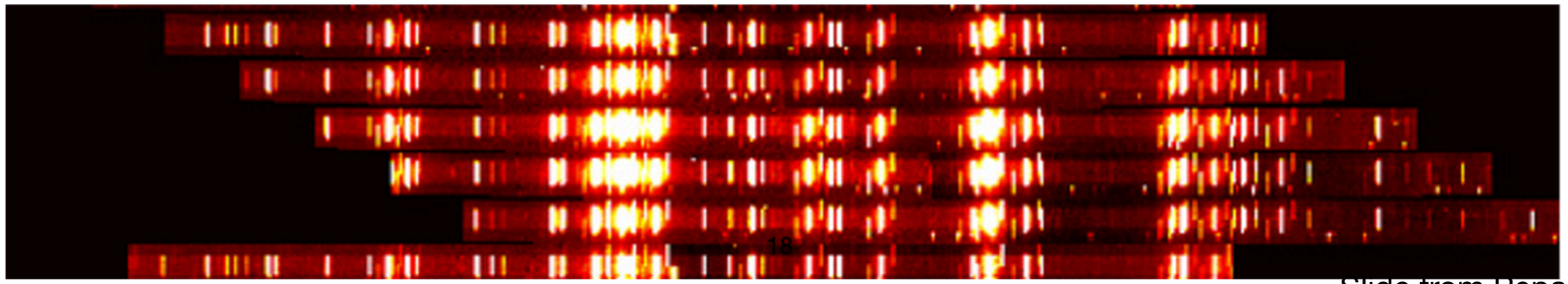
GTC

EMIR

NIR imager and multi-object spectrograph



Spectral Range	0.9-2.5µm[1.1-2.5µm]	*MOS mode*	
Detector	HAWAI2 2048^2	*F.O.V.*	6.7 x 4 $arcmin^2$ (55 slitlets)
Spectral resolution	1000 (YJ, HK) 5000,4250,4000 (JHK)	*Sensitivity*	**K~20.1 in 2h @ S/N=5 (continuum)**
Spectral coverage	1 single window/exp.		$1.4x10^{-18}$erg/s/cm^2/Å @ S/N=6 (line)
Imaging modes	Broad/narrow band	*Imaging mode*	
Plate Scale	0.2 arcsec pix^{-1}	*F.O.V.*	6.7 x 6.7 $arcmin^2$
Image quality	θ_{80} < 0.3 arcsec	Sensitivity	**K~22.0 in 1h, for S/N=3 & 0.6 arcsec aperture**

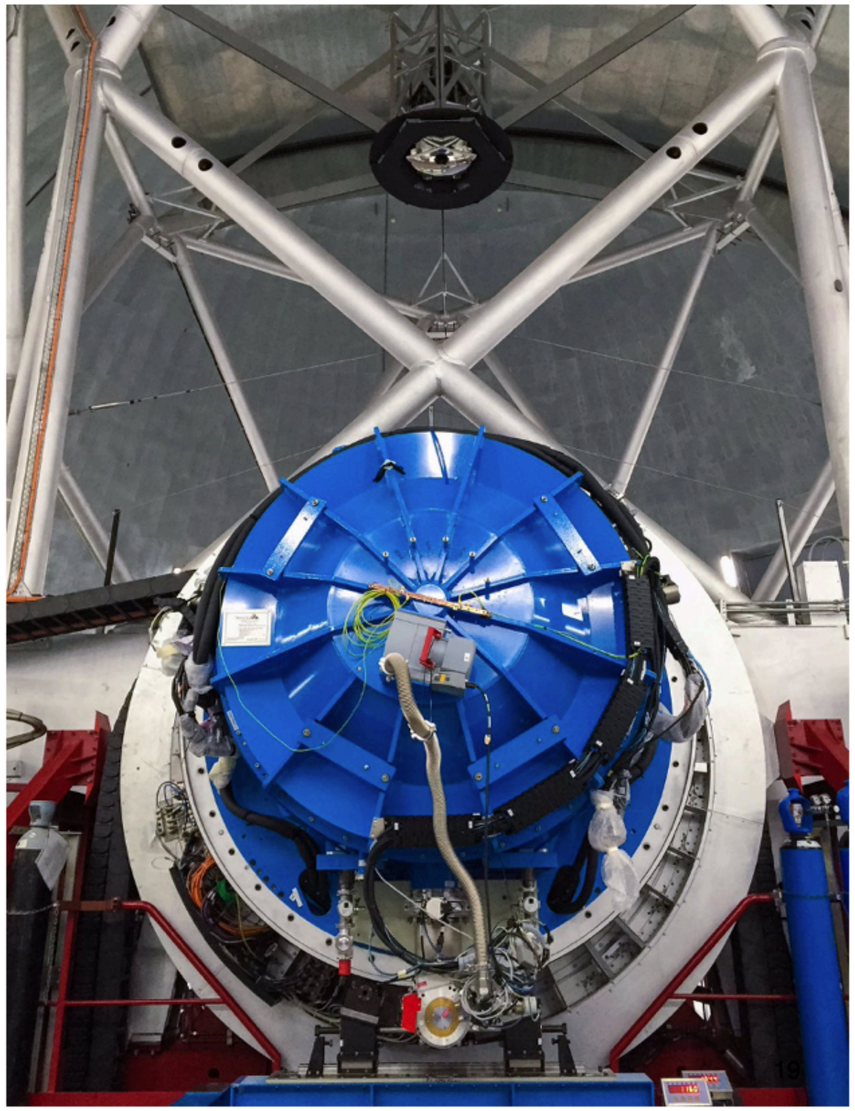


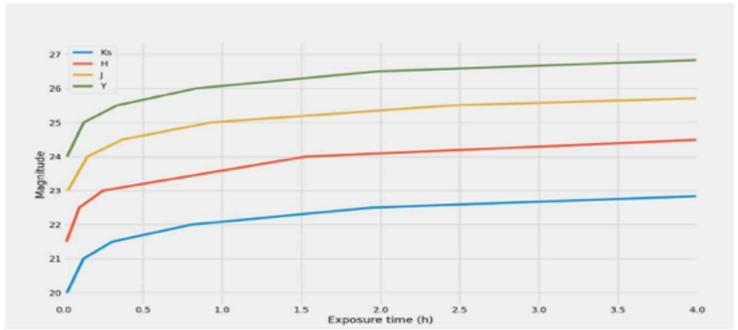
Slide from Pepa Becerra

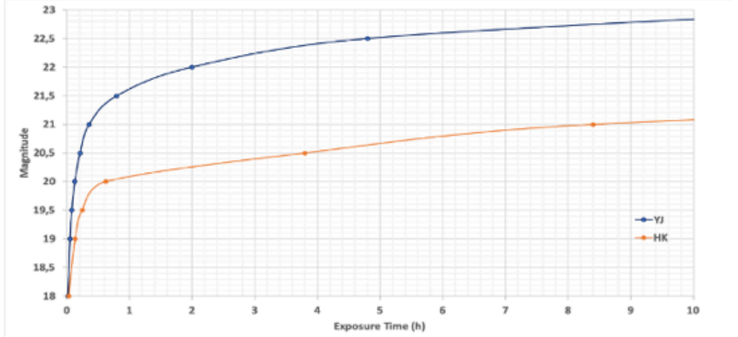
GTC

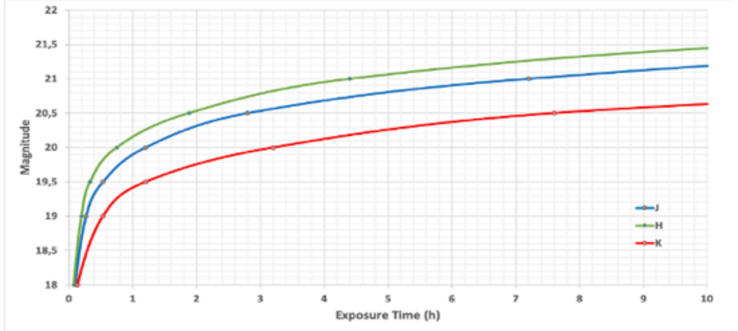
EMIR (detector upgrade 2023)

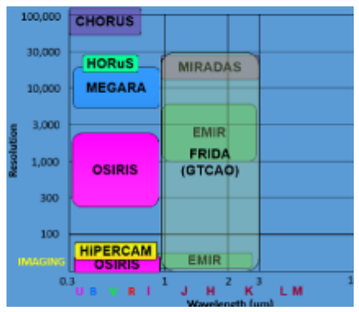
NIR imager and multi-object spectrograph









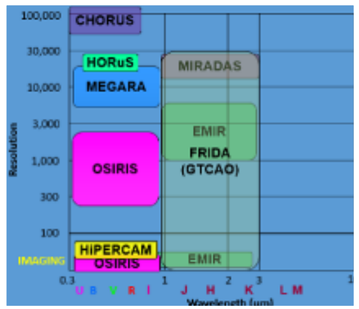


Slide from Pepa Becerra

GTC

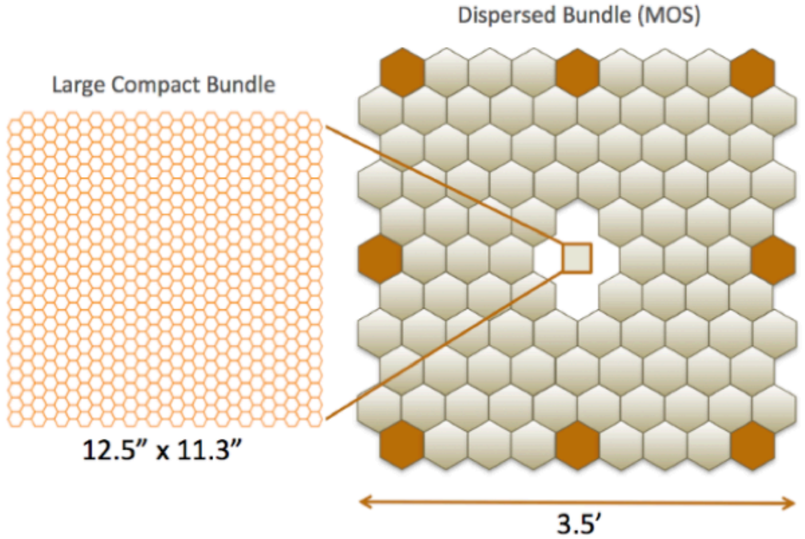
MEGARA

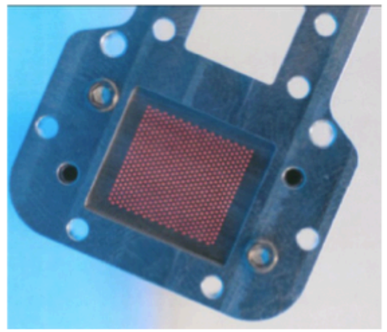
Optical medium-res multi-object spectrograph

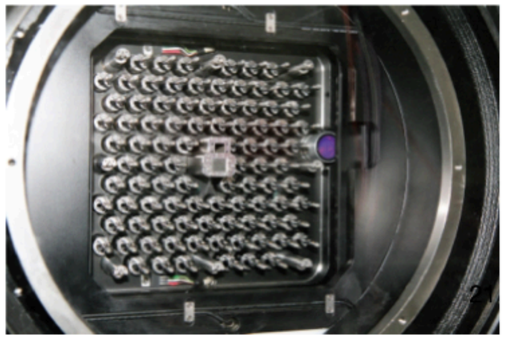


Common-user instrument since 2018 (FCass-F).

Spectral range	0.365-1.000 µm
Detector	E2V CCD231-84-1-E74
IFU field of view	12.5 x 11.3 arcsec^2
IFU spaxel size	0.62 arcsec
MOS	92 x 7-fiber mini-IFUs*
MOS field of view	3.5 x 3.5 arcmin^2
Spectral resolution	6000 to 20000
# of spectra	650







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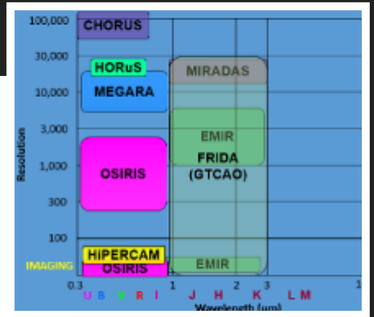
GTC



CHORUS

Canary Hybrid Optical High-Resolution Ultra-stable Spectrograph

Developed by National Observatories of Chinese Academy of Sciences (NAOC-NIAOT) within the framework of our 2016 Collaboration Agreement.

Subsystems	UV band Spectrograph (UVS)	Visible band Spectrograph (VIS)
Location	Below Nasmyth Platform B	Coudé room
Fiber configuration	Φ1.2" aperture on the sky SCI-C	Φ1.2" aperture on the sky SCI-A, SCI-B
Spectral resolution	R≥25,000	R≥110,000
Wavelength coverage	310-420nm	420-780nm
Wavelength calibration precision	—	~ 10cm/s with LFC
Calibration	Ordinary single fiber calibration	Sim.-Calibration, Sky subtraction
Instrument daily stability	—	Inside Instrument Vacuum Chamber at~16° C (±2° C) ±0.001° C /night Operation pressure in IVC ≤0.001 mbar
Instrument efficiency (from input fiber to detector front)	≥ 17% at peak, ≥ 5% at minimum	≥ 17% at peak, ≥ 8% at minimum

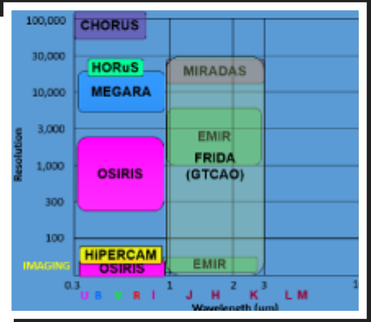
Slide from Pepa Becerra

Slide from Pepa Becerra

GTC

CHORUS

Canary Hybrid Optical High-Resolution Ultra-stable Spectrograph

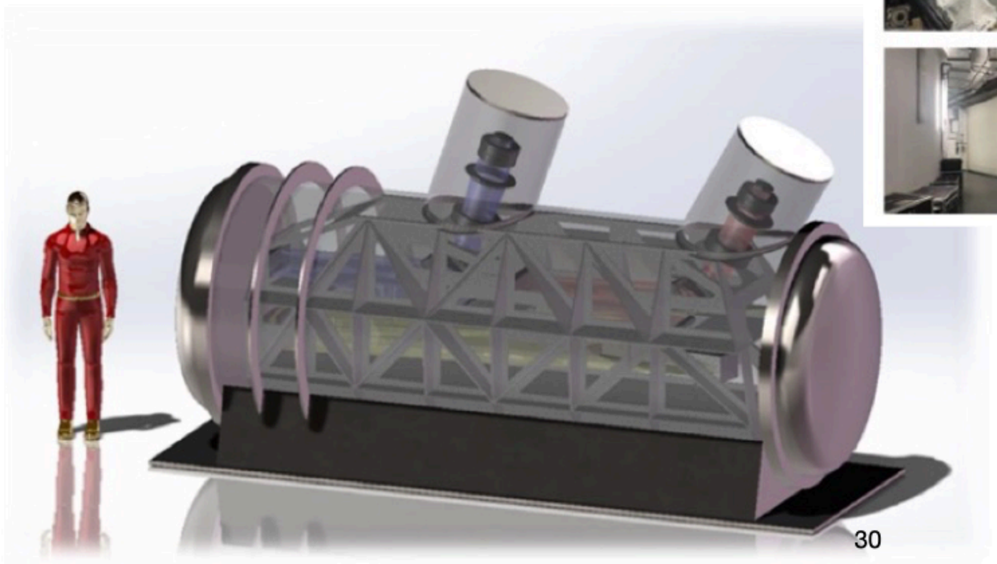


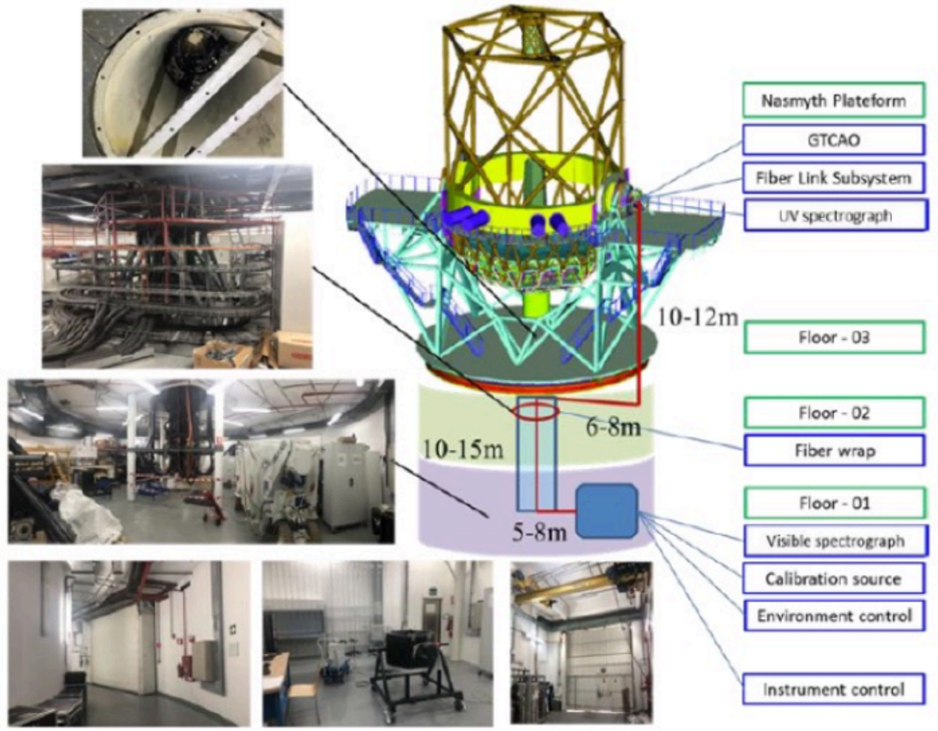
Two separated bands:

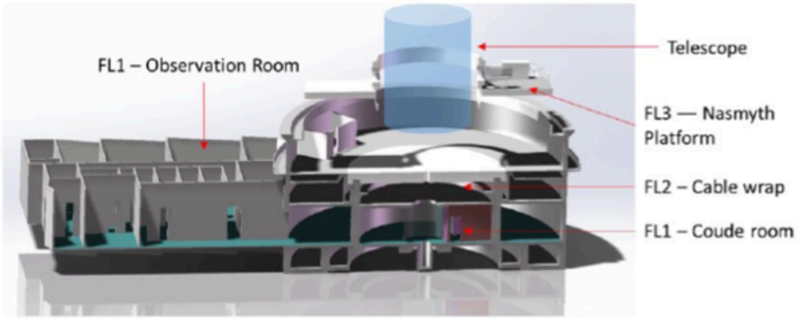
UV @ 310 – 420nm (R > 25000)
Visible @ 420 – 780nm (R>110000)

CAS officially approved the funding for CHORUS. **PDR at IAC held in Sept 2023.**

Instrument delivery 2027.



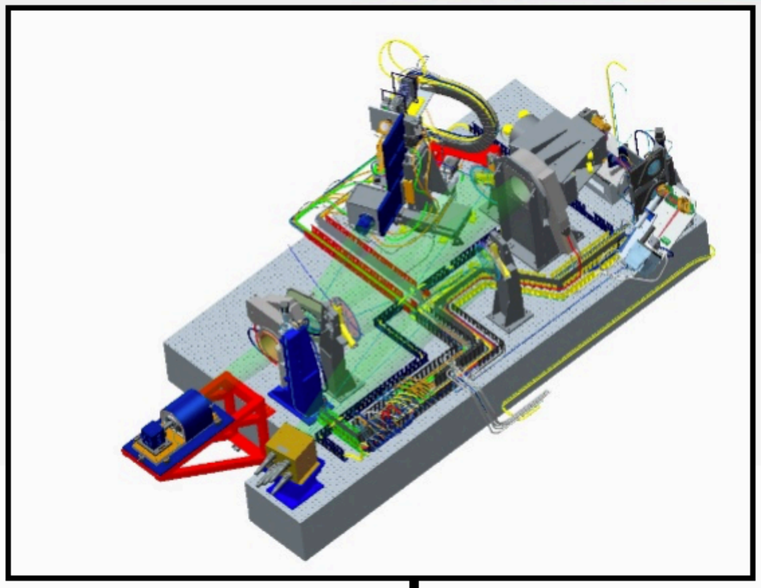




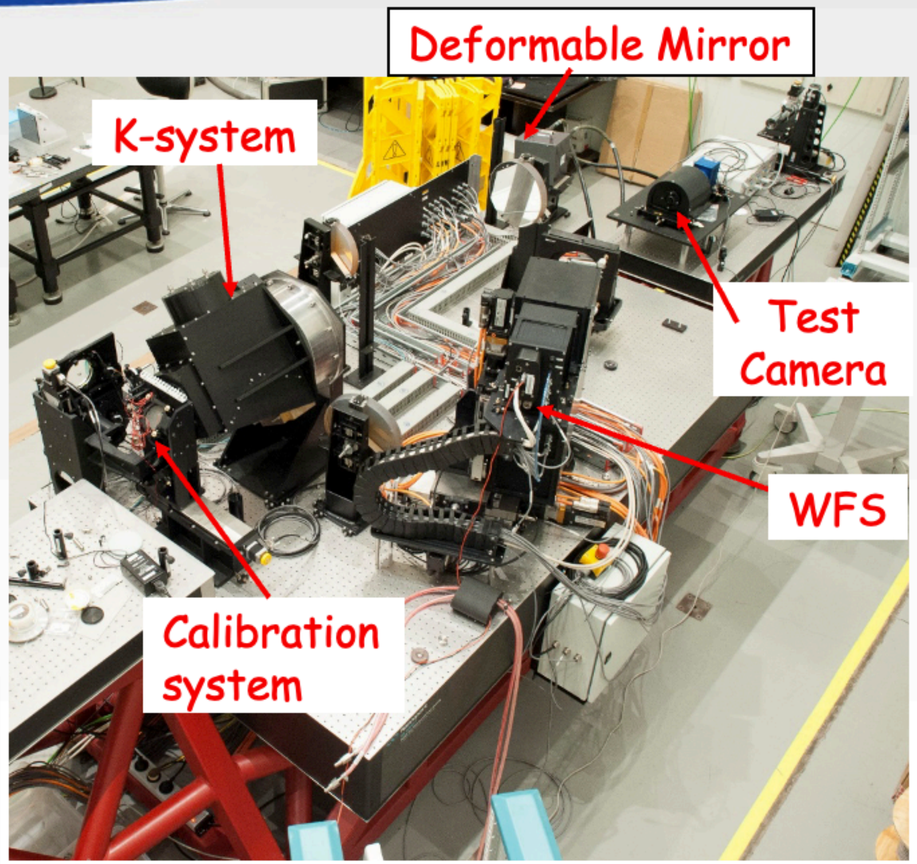
Slide from Pepa Becerra

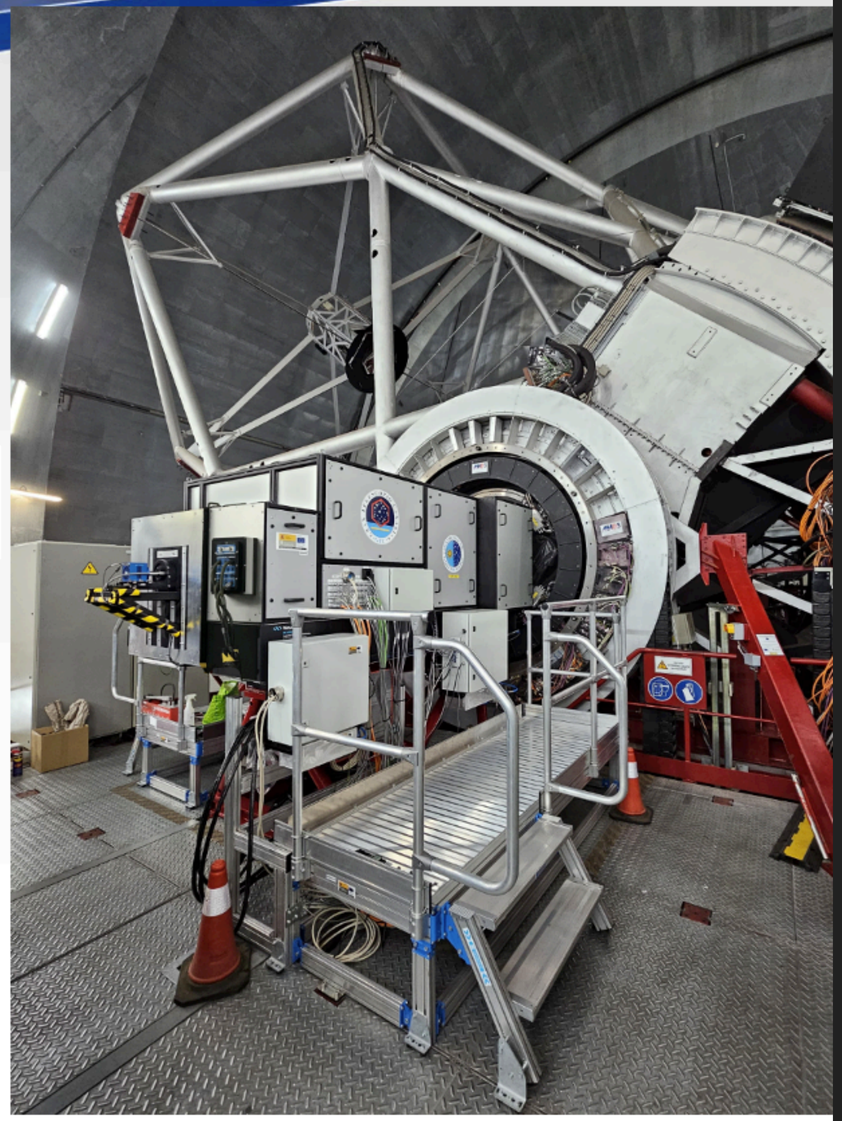
GTC Instrumentación para el GTC

GTCAO/LGS



- Adaptive Optics NGS + LGS
- DM-373 actuators, pupil conjugated
- FoV: 1.5 arcmin
- WFS: Shack-Harmann 20x20
- GTC M2 for tip-tilt correction
- First light: 2023



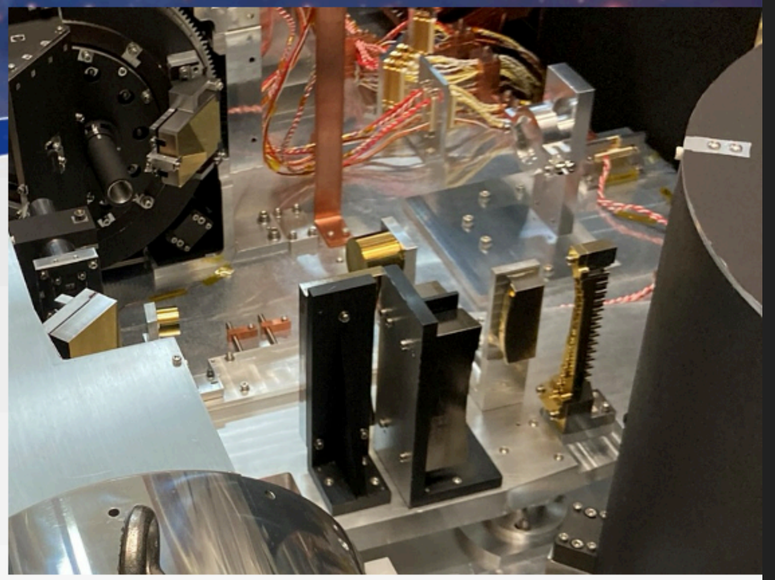


Slide from Marcos Reyes

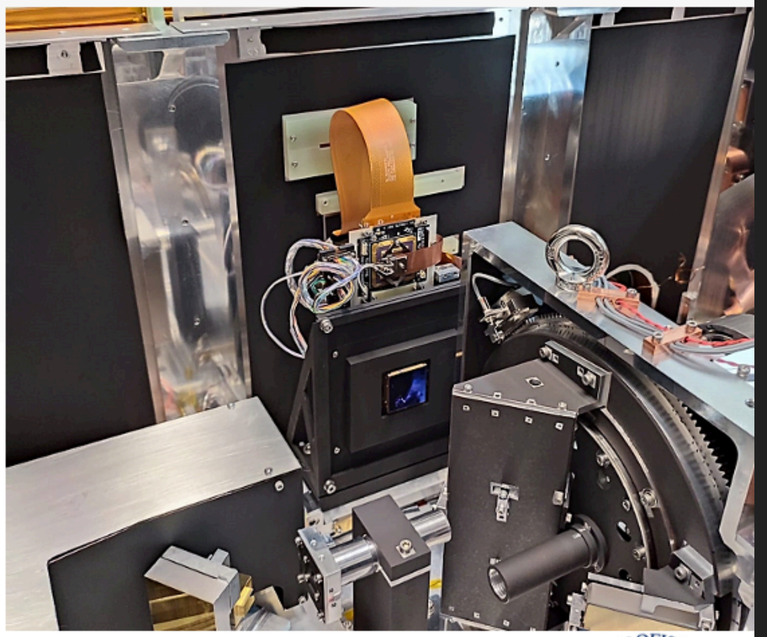
GTC Instrumentación para el GTC

FRIDA

- **Main scientific aims:** Instrument for GTCAO. High redshift at kpc scales. Study of galaxies in the near Universe with high spatial resolution. Studies of a large number of galactic sources. Resolve stars in Andromeda.
- **Participant Institutions:** Main Partner: UNAM (México). IAC. UF. UCM.
- **IAC Responsibility:** Design, integration and tests of the detector unit, based on a H2RG, 2048x2048 pix. High Level Control Software.
- **Main technical characteristics:**
  - Imaging Mode: Scales: 0.01, 0.02 and 0.04 "/pix,
    FOV: 20.48"x20.48" (J, H bands); 40.96"x40.96" (K band)
  - Spectroscopy (IFS): Scales: 0.01x0.02, 0.02x0.04, 0.04x0.08 arcsec/pix
    (30 slices, 64x2 px/slice) FOV: 0.60x0.64, 1.20x1.32, 2.40x2.64 arcsec^2
    R: 1,500, 4,000 and 30,000
- **Status, milestones and plan:**
  - Engineering grade detector and software for AIV in operation, jun-2024
  - Plan: Integration and test of Science grade detector: T2 2025. Complete laboratory AIV: T4 2025.



Detail of the IFU in FRIDA during AIV

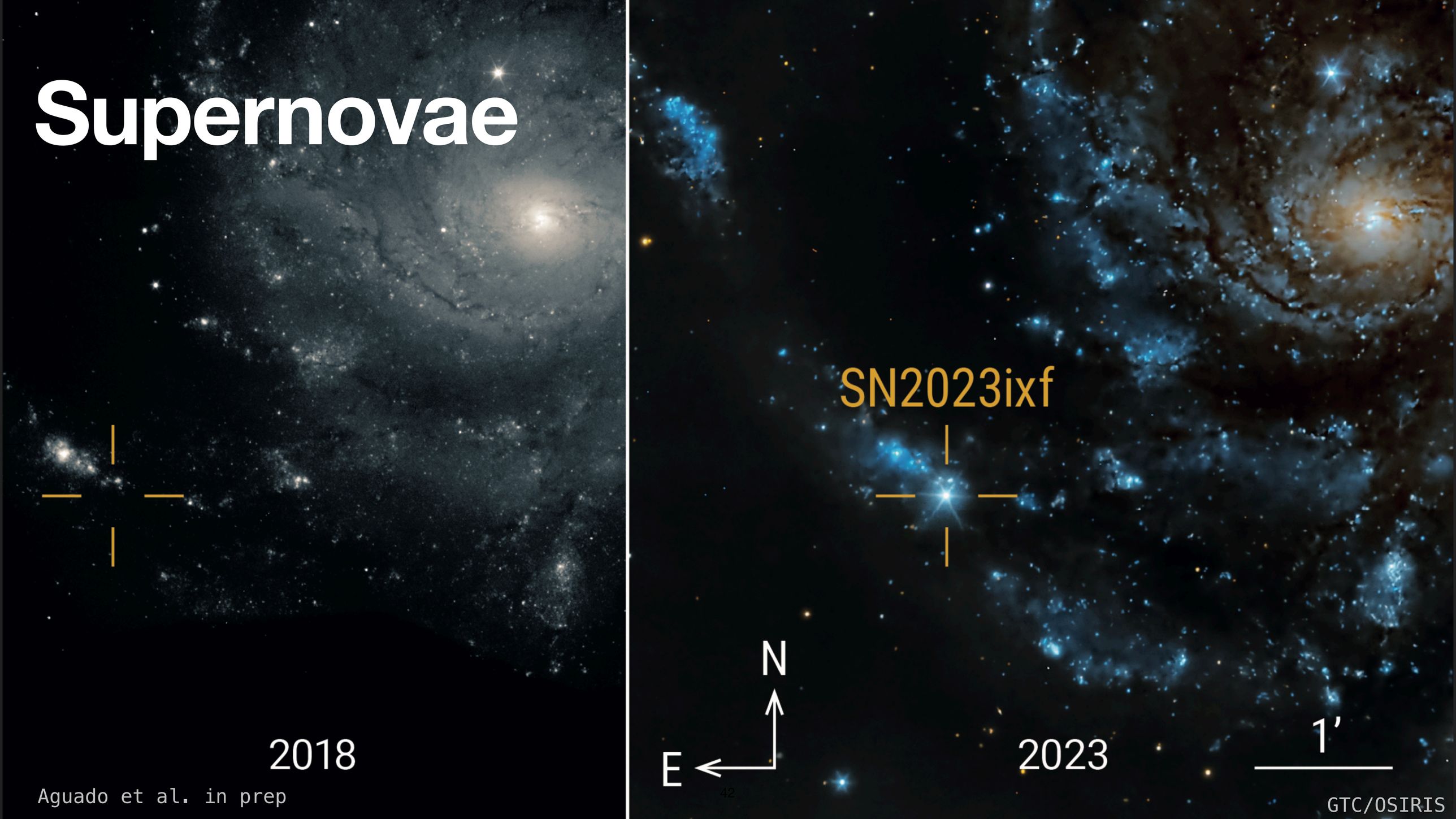


H2RG Engineering grade detector during AIV

Slide from Marcos Reyes

High-resolution spectroscopy

Supernovae



Aguado et al. in prep

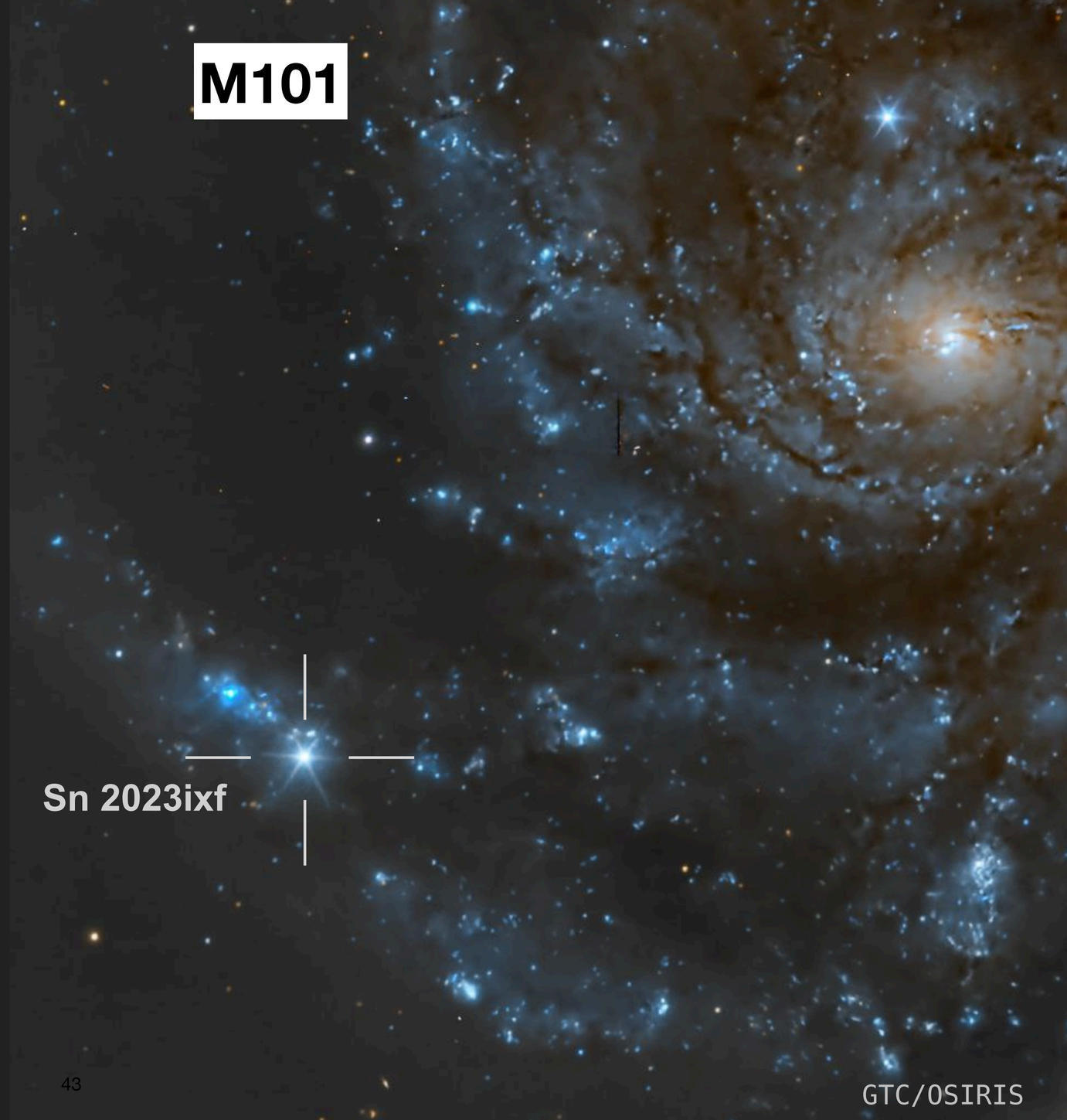
GTC/OSIRIS

SN 2023ixf

Closest (6.4 Mpc, z= 0.0008) and one of the brightest (10.9 mag) CCSNe in the last decade

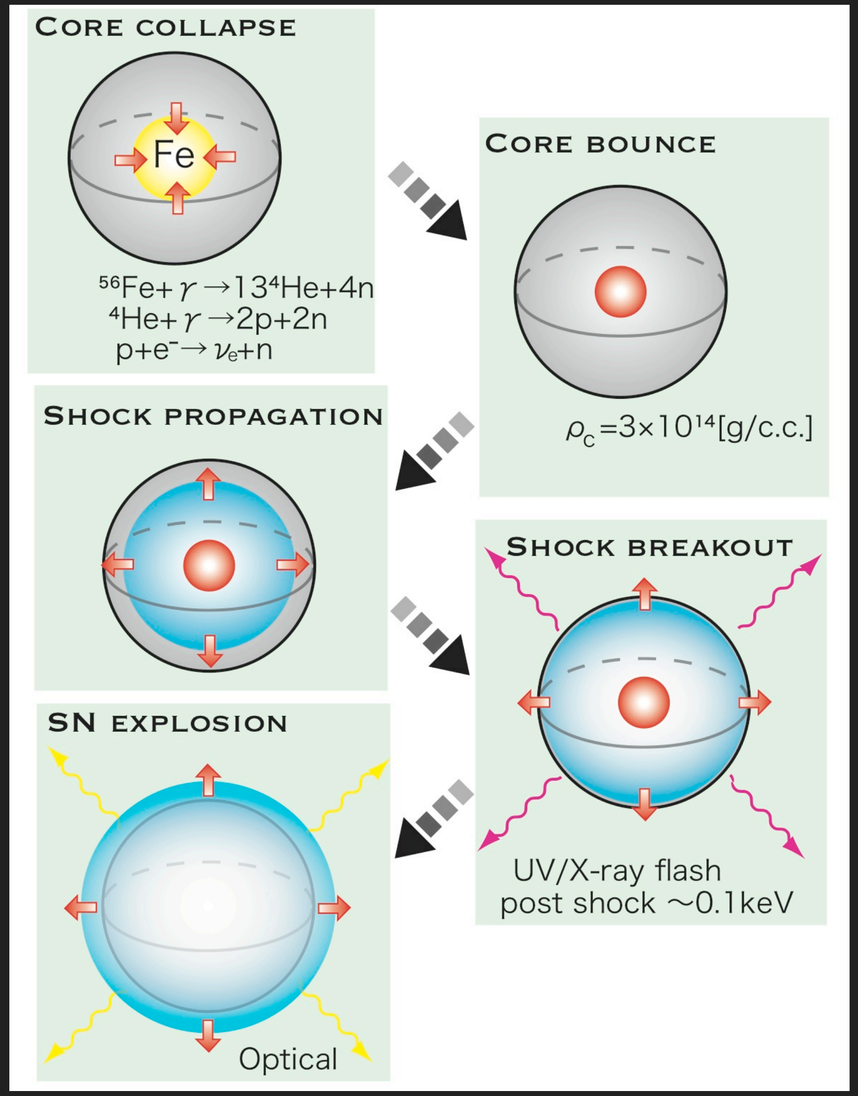
- Extensive worldwide campaign
- **DDT** and **ToO** observations with several **ORM and OT facilities** triggered by **IAC** members

Discovery: May 19, 2023
(by K. Itagaki, amateur)



Core-collapse supernovae (CCSNe)

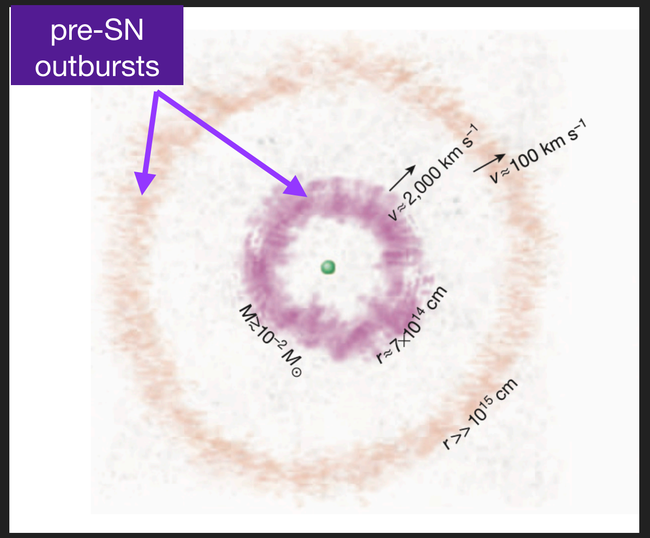
Collapse of a massive star

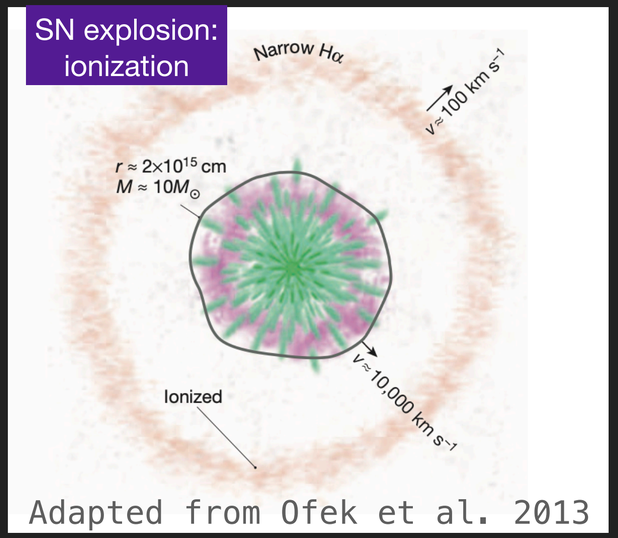


From http://th.nao.ac.jp/MEMBER/suzuki/research.html

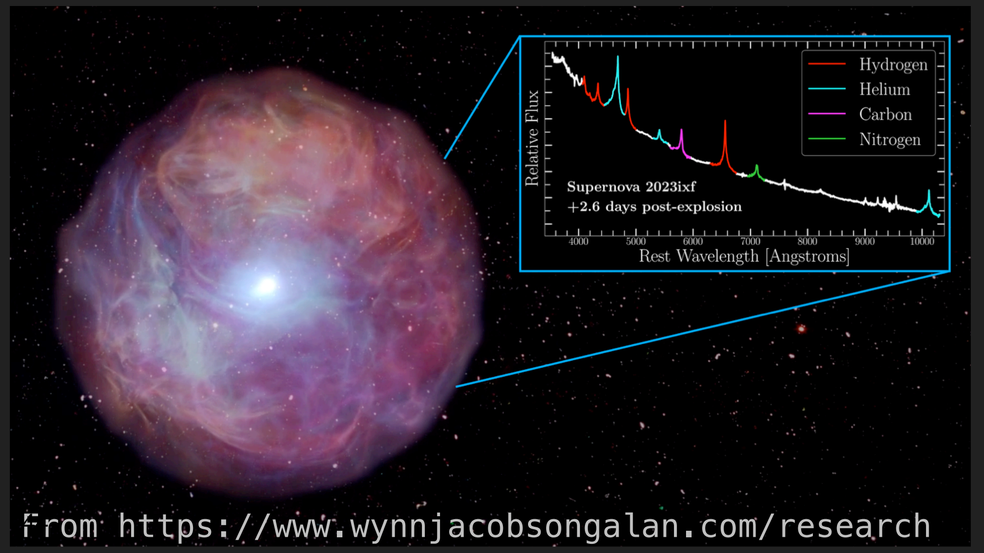
Flash spectroscopy

measuring the ionized circumstellar material (CSM) / pre-outburst



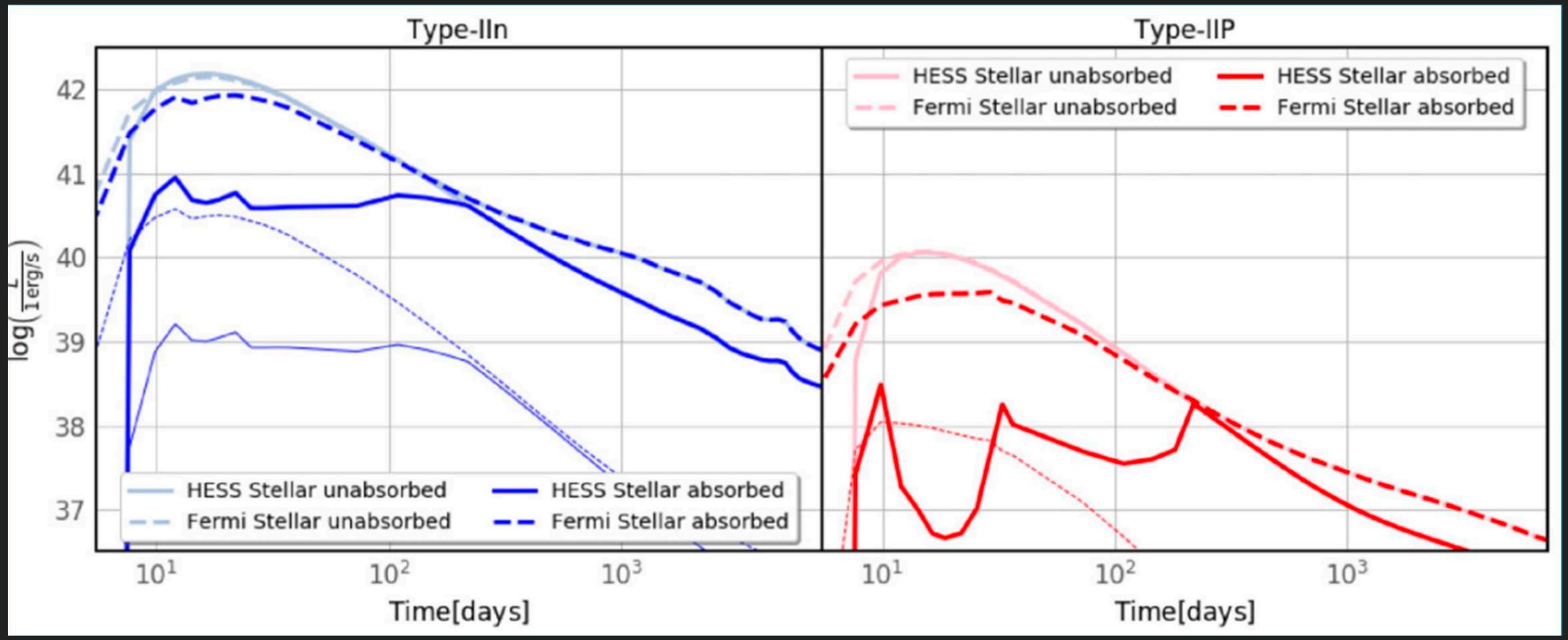


Adapted from Ofek et al. 2013



From https://www.wynnjacobsongalan.com/research

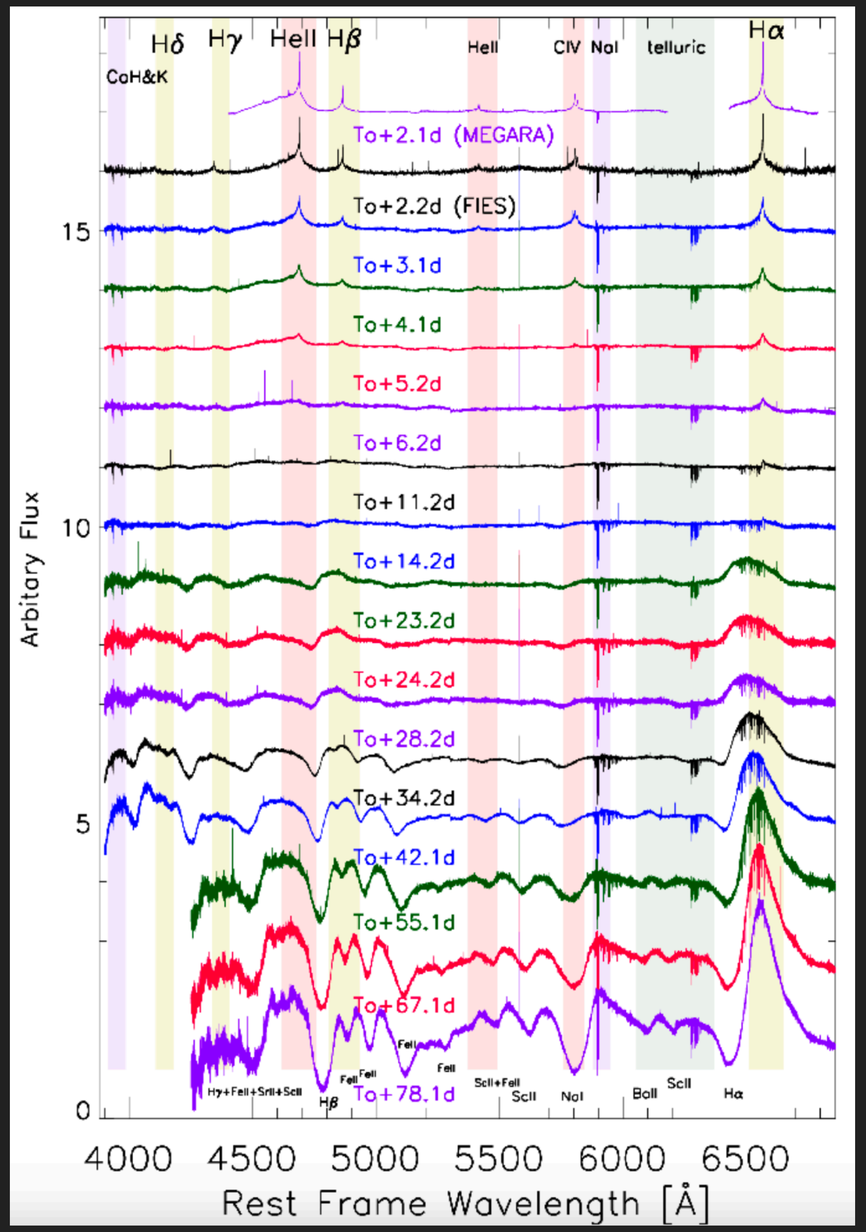
Potential gamma-ray emission



Brose et al. 2022

SN 2023ixf: exploiting the Canary Island observatories at their fullest

Spectroscopy



Aguado et al. in prep

Earliest high-resolution spectra recorded!

MEGARA @GTC (10.4m)

+ GTC/MEGARA
+ GTC/OSIRIS

Paper II in prep.

FIES @NOT (2.5m)

+Polarimetry

Poidevin et al. in prep

HARPS-N @TNG (3.6m)

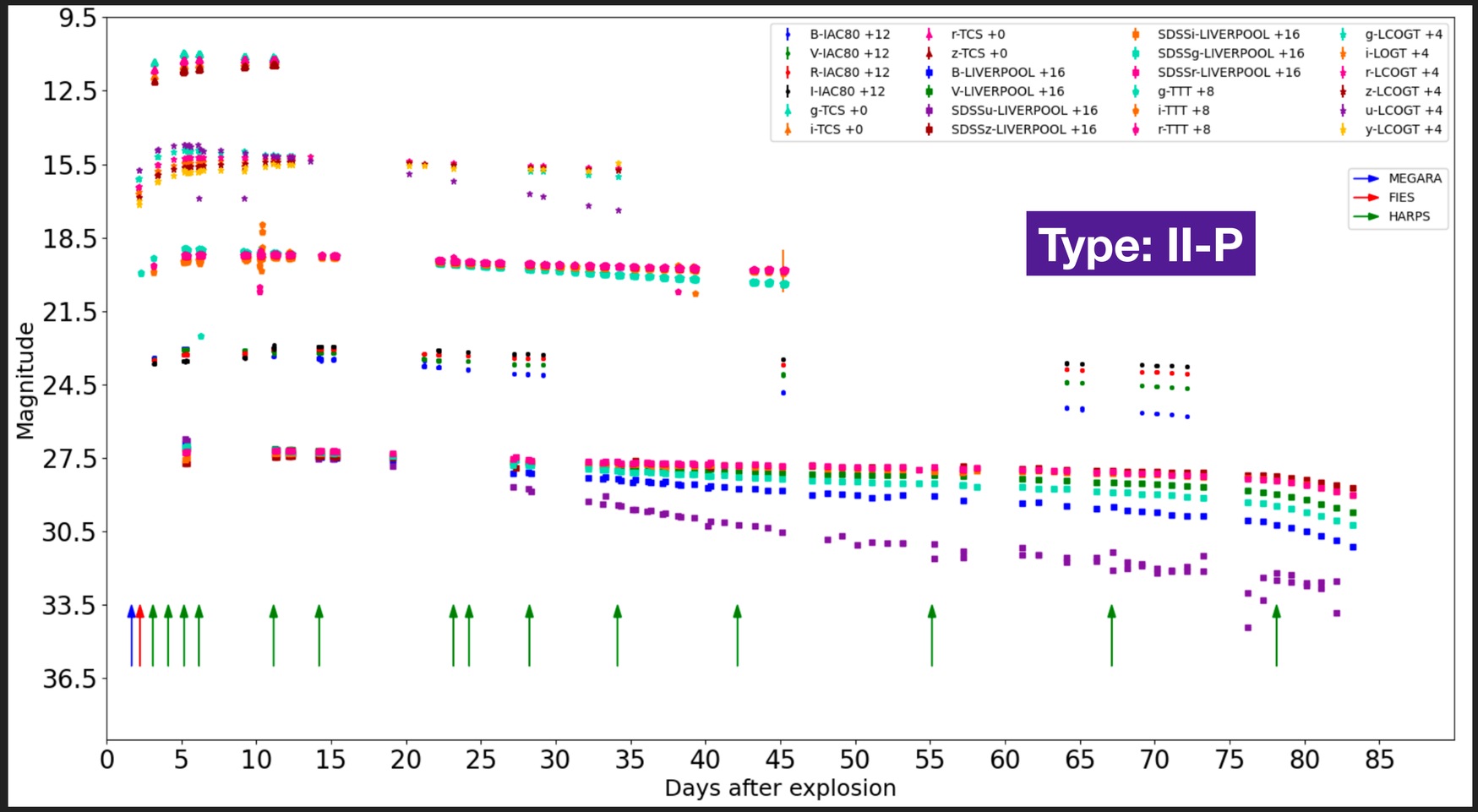
+ Gamma-rays (MAGIC+LST1)

ALO as CA in prep

SN 2023ixf: exploiting the Canary Island observatories at their fullest

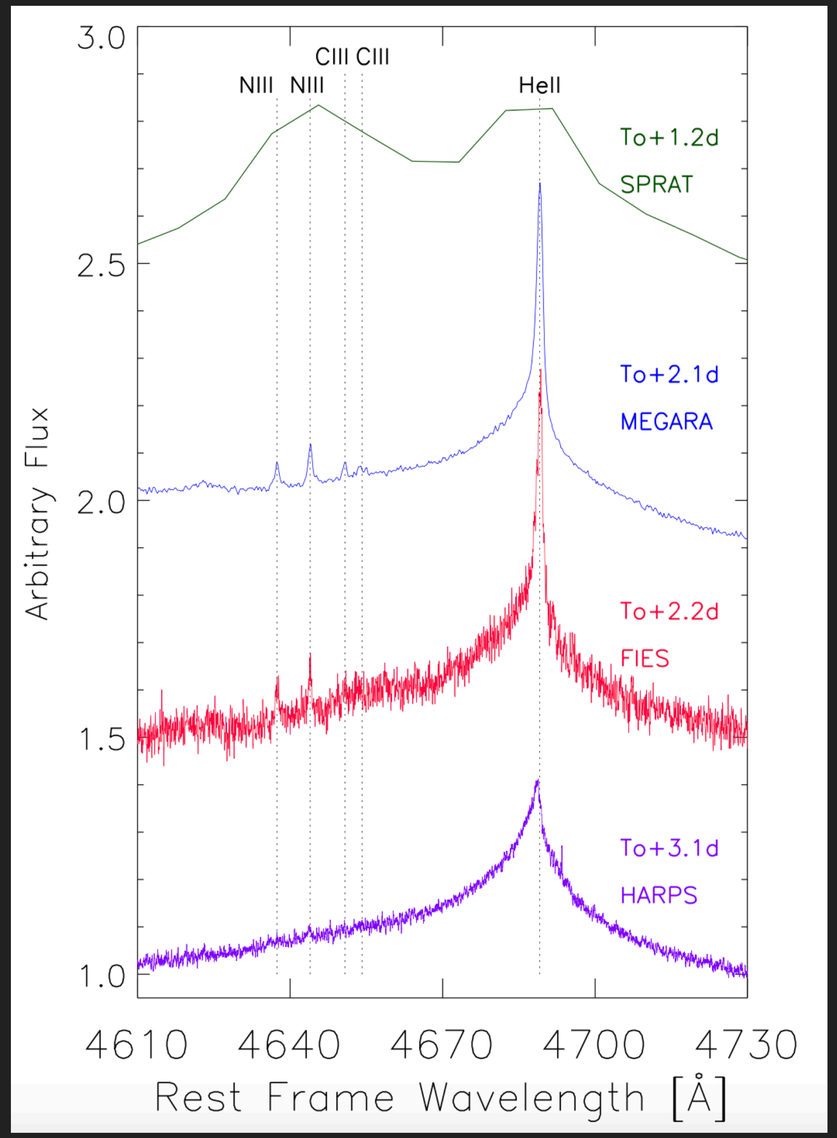
Photometry

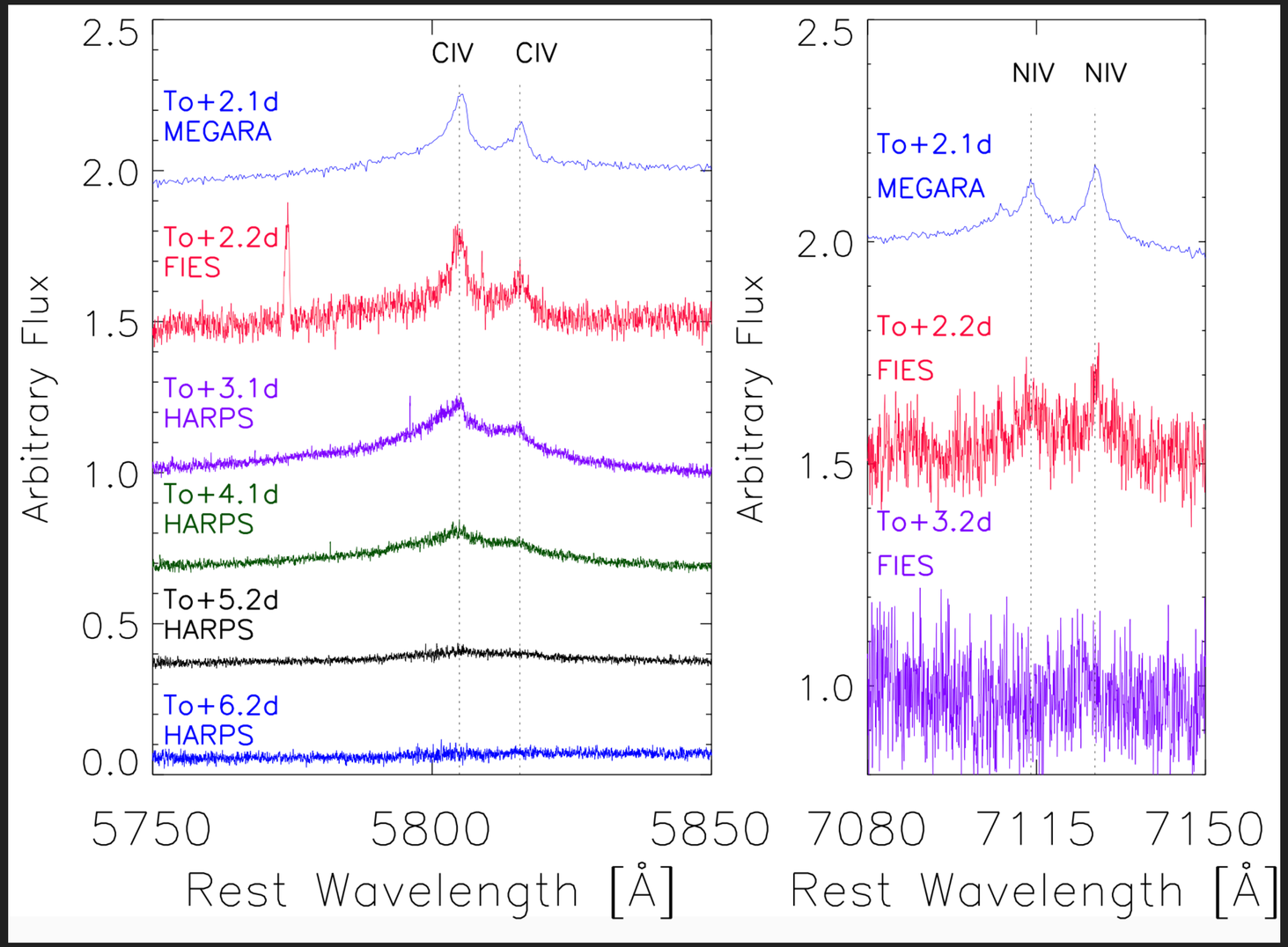
IAC-80, TCS, Liverpool, TTT and Las Cumbres telescopes



Aguado et al. in prep

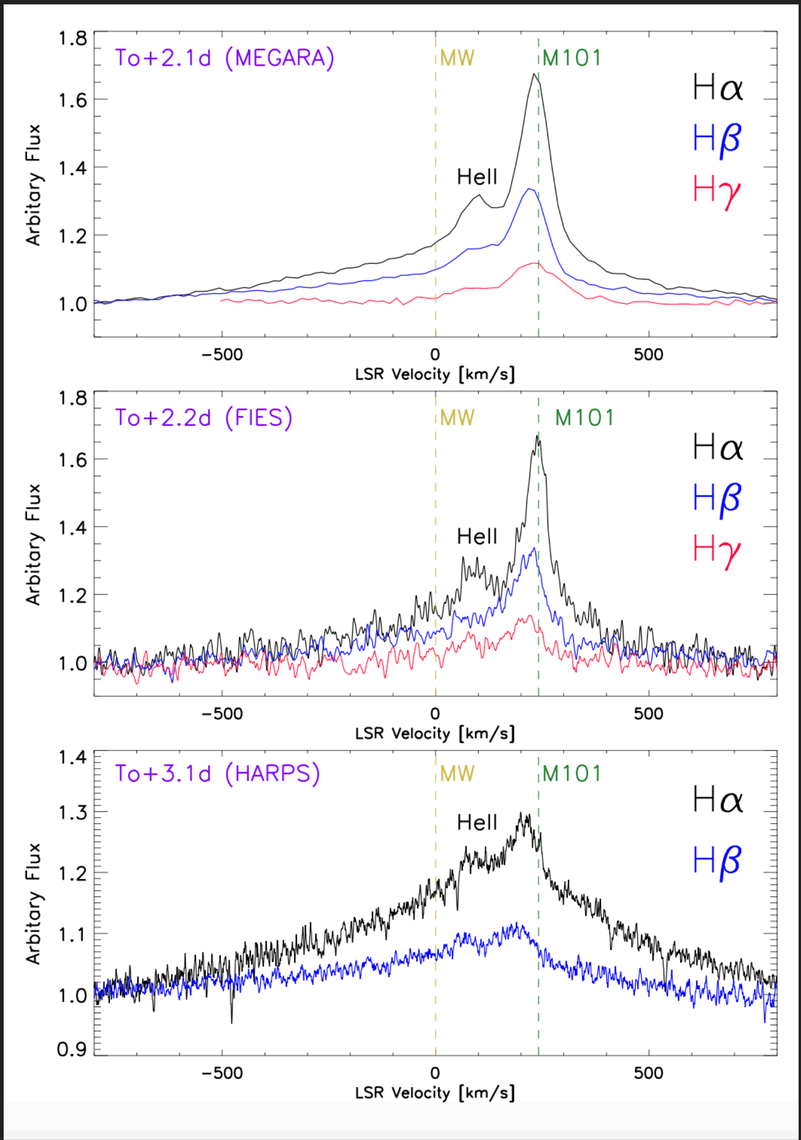
SN 2023ixf: flash ionization





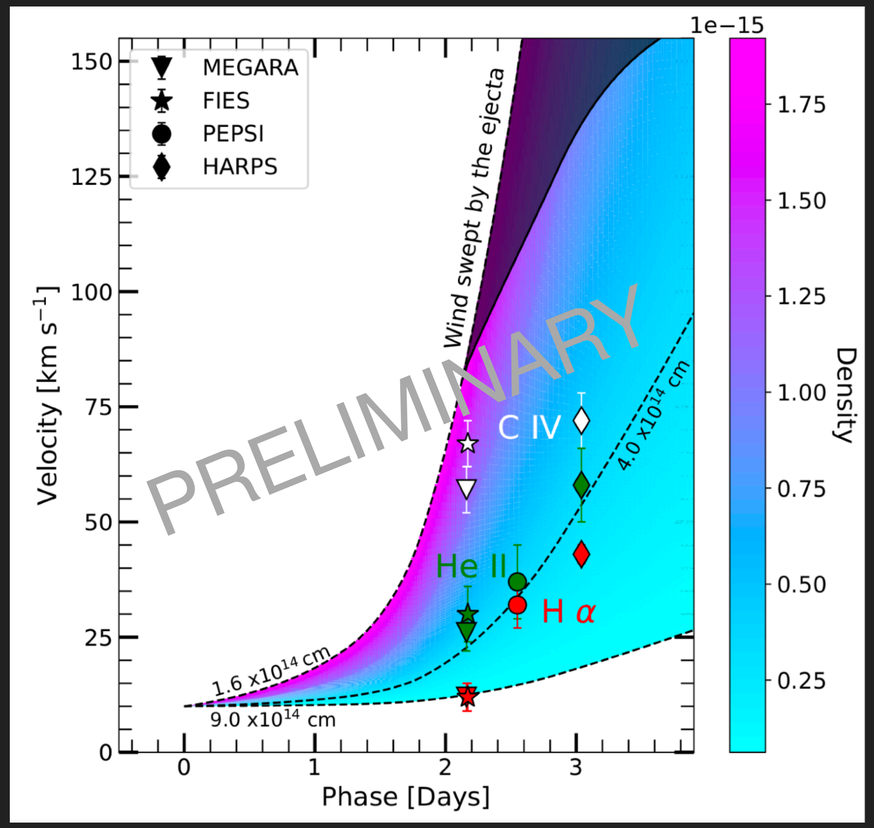
Aguado et al. in prep

SN 2023ixf: radiative acceleration



Aguado et al. in prep

Radiative acceleration



Aguado et al. in prep

See also: Smith et al. 2023, Zimmerman et al. 2023

Do I always need high-resolution?

No

Low-resolution

In operation

- **IO:O**
  Optical Wide Field Camera
- **RISE**
  Fast-readout Wide Field Camera
- **SPRAT**
  SPectrograph for the **R**apid **A**cquisition of **T**ransients
- **FRODOSpec**
  Fibre-fed **RO**botic **D**ual-beam **O**ptical **Spec**trograph **[currently offline]**
- **MOPTOP**
  Multicolour **OPT**imised **O**ptical **P**olarimeter
- **LIRIC**
  Liverpool **I**nfra-**R**ed **I**maging **C**amera **[currently offline]**
- **SkyCam**
  - **SkyCamA**: fixed 180° FOV all-sky camera mounted inside telescope enclosure
  - **SkyCamO**: fixed 180° FOV all-sky camera mounted outside telescope enclosure
  - **SkyCamT**: piggyback medium FOV (10–20°) camera with telephoto lens, co-pointed with LT
  - **SkyCamZ**: piggyback 1° camera in 200mm Newtonian telescope, co-pointed with LT.

The **Telescope Autoguider** is described on the Telescope Specifications page.

- Photometry and spectroscopy
- Ritchey-Chrétien Cassegrain optics
- 2-m robotic telescope
- SPRAT: low resolution R=350 (18Å).

Low-resolution

Las Cumbres

OT (+ worldwide)

- 1-m and 0.4-m telescopes at OT
- Photometry and spectroscopy (both low and high)

Science Imagers

Name	Telescope Class	Pixel scale "/pix (std. binning)	Field of view	Overhead per frame	Filter options
MuSCAT	2-meter	0.27 (bin 1x1)	9.1'x9.1'	6s or 46s	SDSS g'r'i'zs fixed
Sinistro	1-meter	0.389 (bin 1x1)	26'x26'	28 s	21
QHY600	0.4-meter (Delta Rho 350)	~0.74 (bin 1x1)	1.9° x 1.2 °	4 s	13
Inventoried instruments					
SBIG 6303	0.4-meter	0.571 (bin 1x1)	29'x19'	14 s	9
Spectral	2-meter	0.300 (bin 2x2)	10'x10'	19 s	18
Merope	2-meter	0.278 (bin 2x2)	5'x5'	29 s	18
SBIG	1-meter	0.464 (bin 2x2)	15.8'x15.8'	15 s	21

FLOYDS (2-meter)

FLOYDS is a cross-dispersed, low resolution spectrograph, installed at both 2-m telescopes. The wavelength coverage is extremely broad -- with 540-1000nm in first order and 320-570nm in second order, recorded in a single exposure. Resolution varies from R=400 to R=700, and is roughly 0.35 nm/pixel in 1st order and 0.17 nm/pixel in second order. Each FLOYDS has a set of four (30" long) slits with widths of 1.2", 1.6", 2.0", and 6.0". These project to 3.5, 4.4, 4.9, and 14.4 pixels respectively on the detector. Acquisition and guiding is done robotically via a separate camera which images the slit and produces a 6.4'x4.3' field of view.

FLOYDS DETAILED DESCRIPTION | FLOYDS PIPELINE

NRES (1-meter)

LCO's Network of Robotic Echelle Spectrographs (NRES) consists of four identical high-resolution (R~53,000), precise (≤ 3 m/s design goal), optical (380-860 nm) echelle spectrographs, each fiber-fed (~2.9" per fiber width) by one of two 1 meter telescopes and a ThAr calibration source. The anticipated long-term accuracy for NRES is better than 3 m/s in less than an hour for stars brighter than V = 11. Like all instruments at LCO, scheduling, observing, and data reduction are autonomous, and all data will be publicly available after a proprietary period. NRES nodes are installed at our sites in in Chile, Texas, Israel, and South Africa and are currently available for science observations.

NRES PERFORMANCE | NRES DATA PIPELINE | NRES DIAGNOSTIC PLOTS

NRES INSTALLATION | NRES DESIGN AND MOTIVATION | NRES TARGET ACQUISITION

NRES WAVELENGTHS BY ORDER

Filters

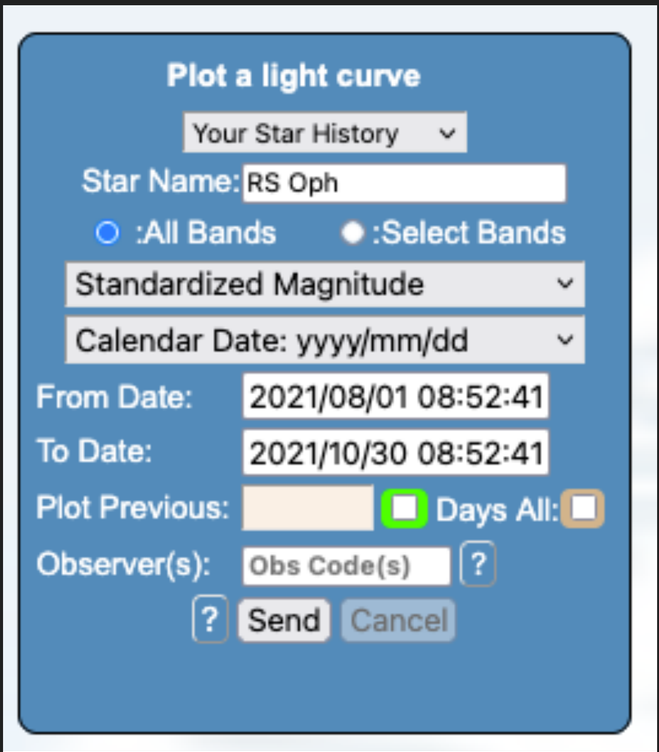
The Sinistro imagers on LCO's 1m telescopes use 75mm square filters in 18 or 21 capacity filterwheels. Standard loadout is a complete Johnson-Cousins/Bessell set (UBVRI) and a SDSS/PanSTARRS set (u'g'r'i'z_sYw).

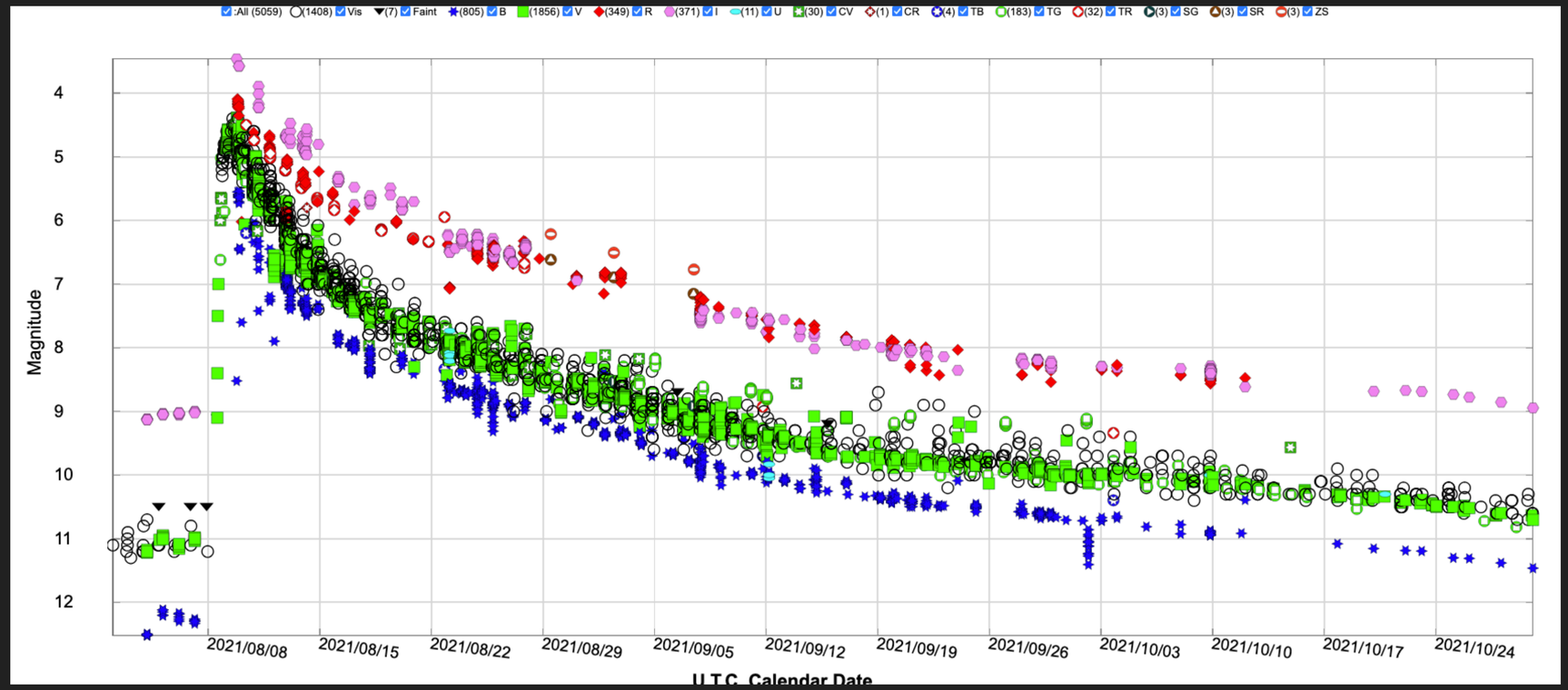
The QHY600 imagers on LCO's 0.4m telescopes use 50mm diameter round filters. The available filters are Johnson-Cousins/Bessell UV, and the SDSS/PanSTARRS set (u'g'r'i'z_sw) with the exception of Pan-STARRS Y.

Public data: Public photometry: American Association of Variable Star Observers (AAVSO)

AAVSO

(worldwide)

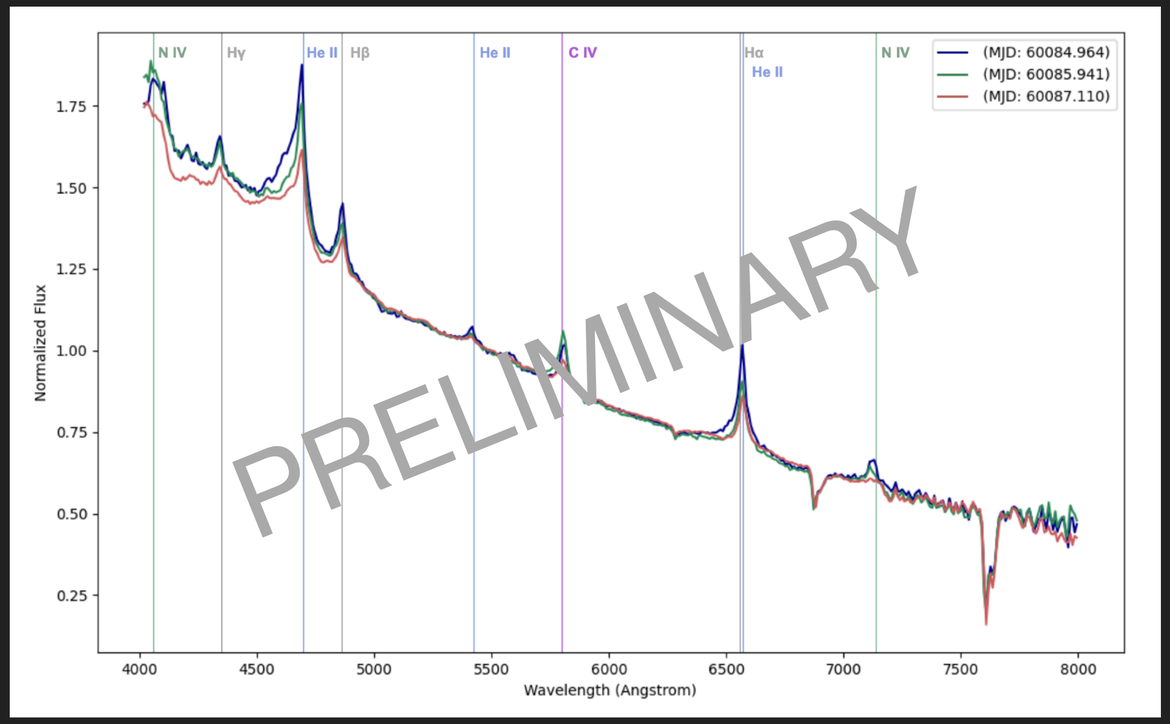




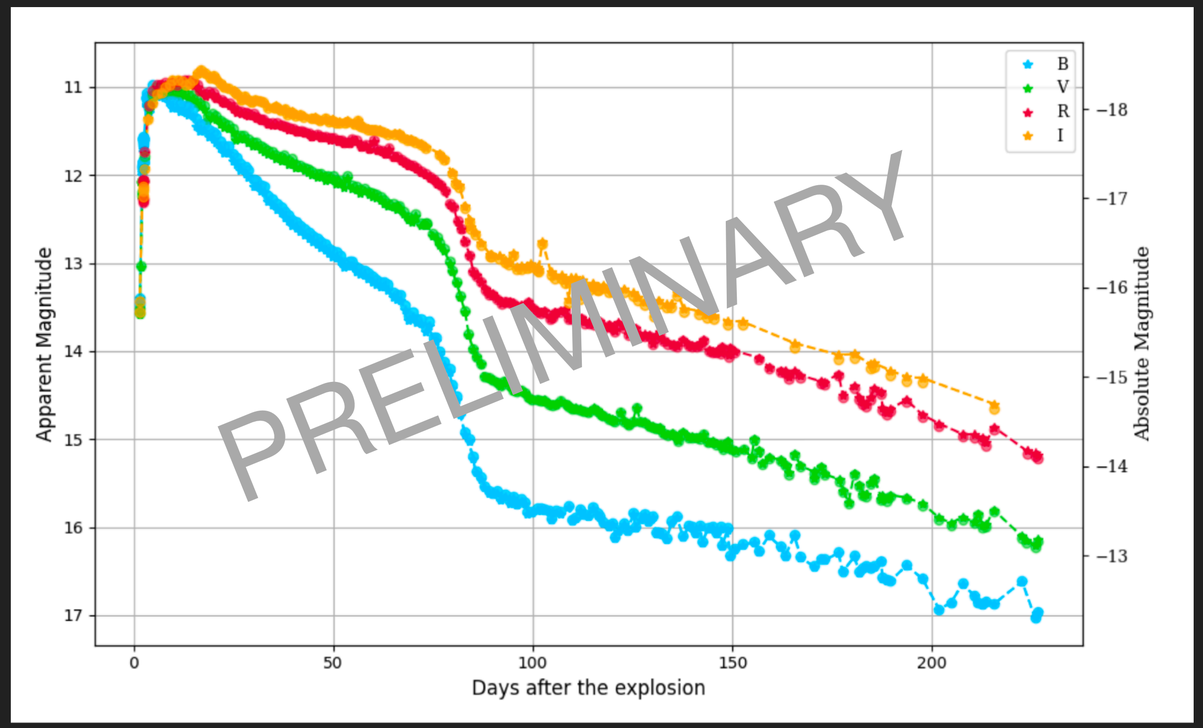
- Amateur astronomers
- https://www.aavso.org/LCGv2/

Low-resolution + public data

LIVERPOOL



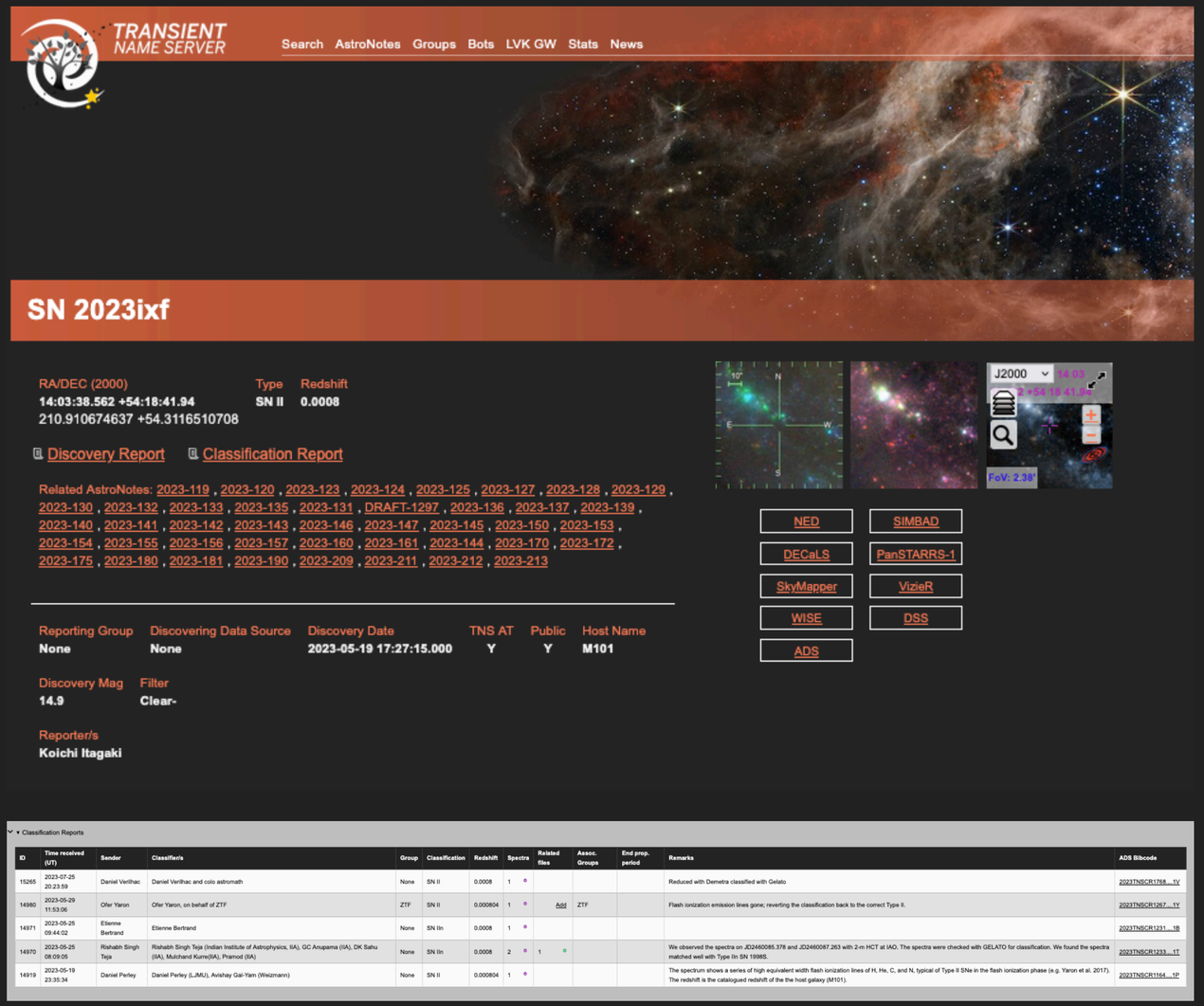
AAVSO Photometry

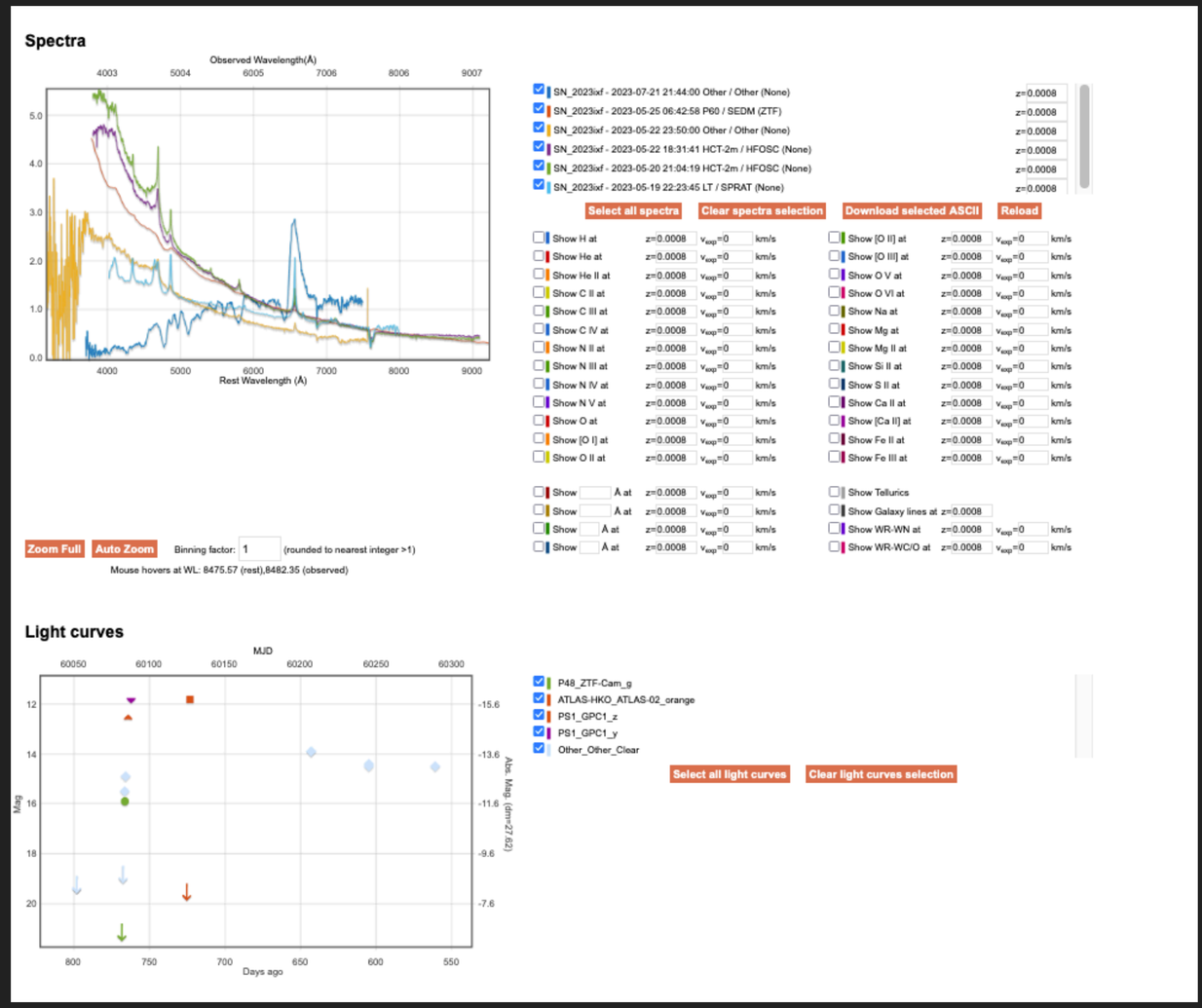


MAGIC+LST in prep (ALO as CA)

- Early-time low-resolution spectroscopy
- Photometry evolution -> public data: https://www.aavso.org/LCGv2/

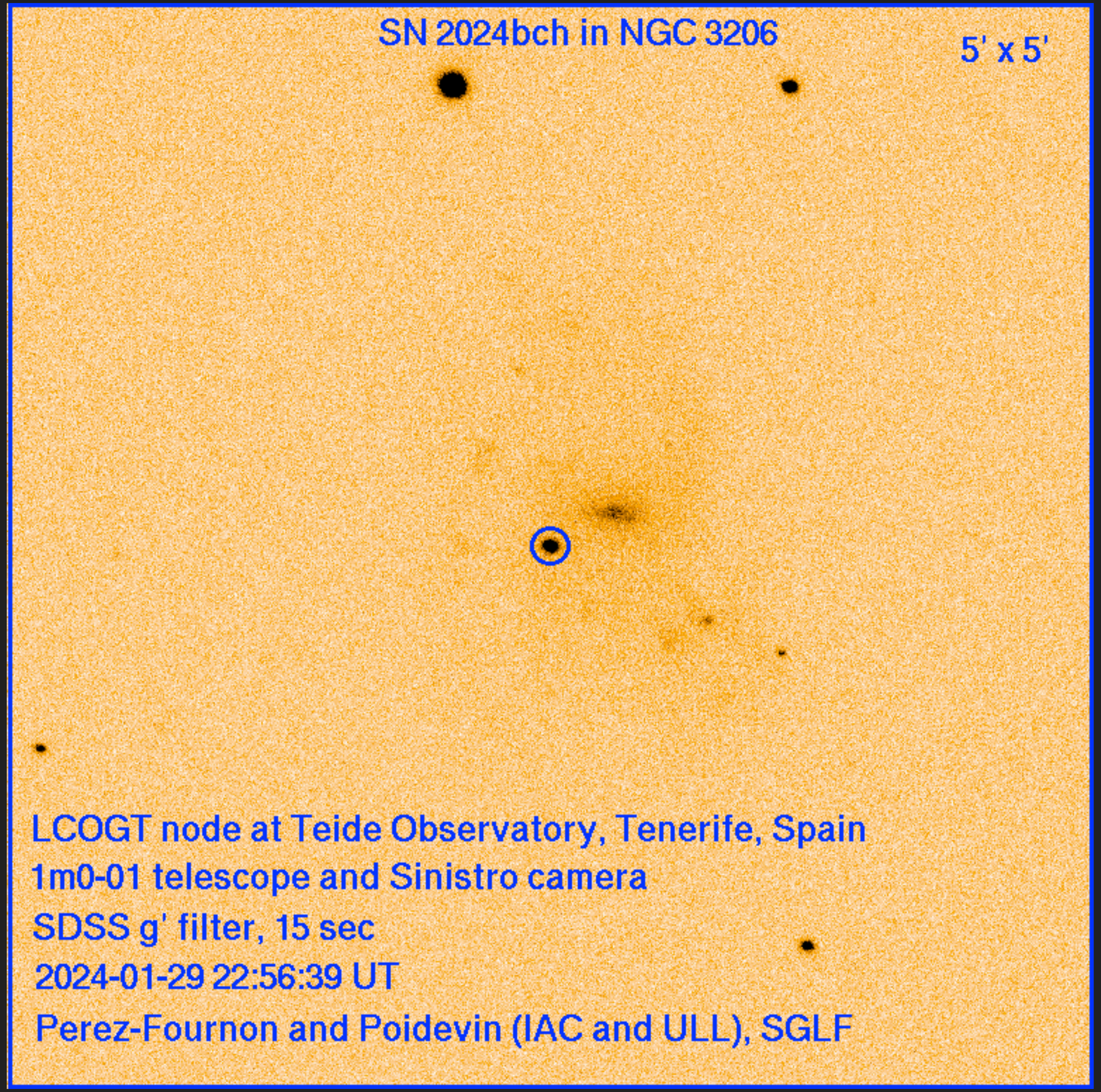
Public alerts (& data): Transient Name Server





- https://www.wis-tns.org/
- Official IAU mechanism for reporting new astronomical transients such as supernova candidates

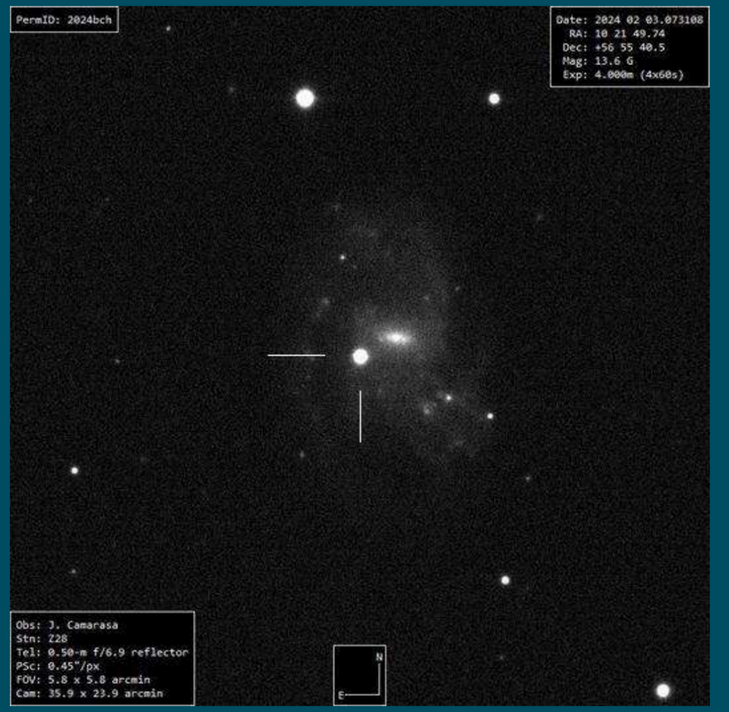
SN 2024bch


SN 2024bch in NGC 3206
5' x 5'
LCOGT node at Teide Observatory, Tenerife, Spain
1m0-01 telescope and Sinistro camera
SDSS g' filter, 15 sec
2024-01-29 22:56:39 UT
Perez-Fournon and Poidevin (IAC and ULL), SGLF

SN 2024bch

SN 2024bch

- CCSN of type IIn-L.
- T0 = Jan 28, 2024
- D = 17-20 Mpc
- 14 h of LST-1 over 6 nights.
- Our firsts:
  - ✓ First ULs on a IIn-L SN
  - ✓ First ULs down to 100 GeV



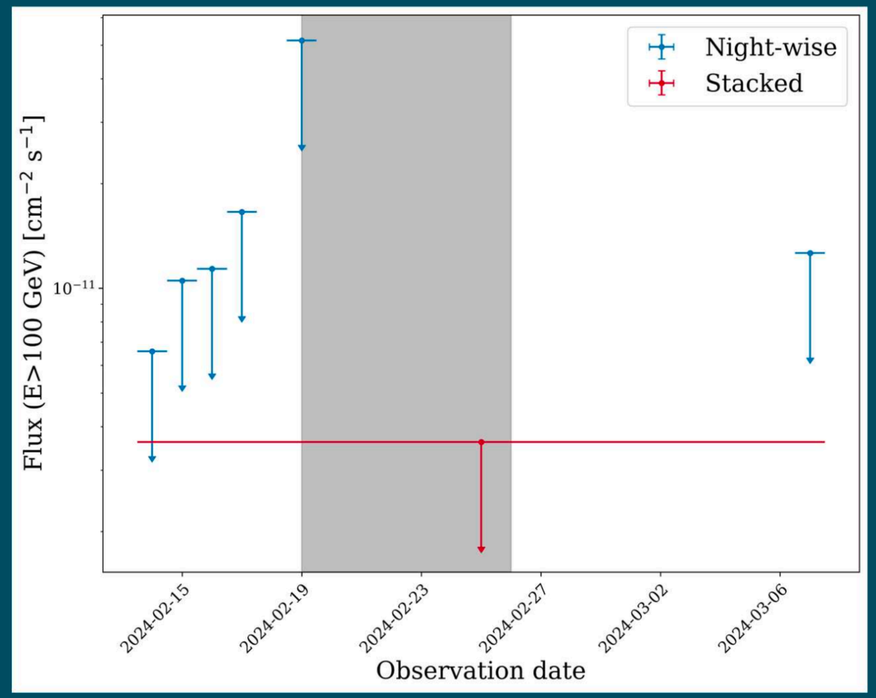
Slide from Andrea Simongini

SN 2024bch

How to use ULs

We apply a simple toy model to derive physical parameters from our differential flux ULs.

We use optical data to constrain the properties of the ejecta, the progenitor and the photosphere.



LST Coll subm.

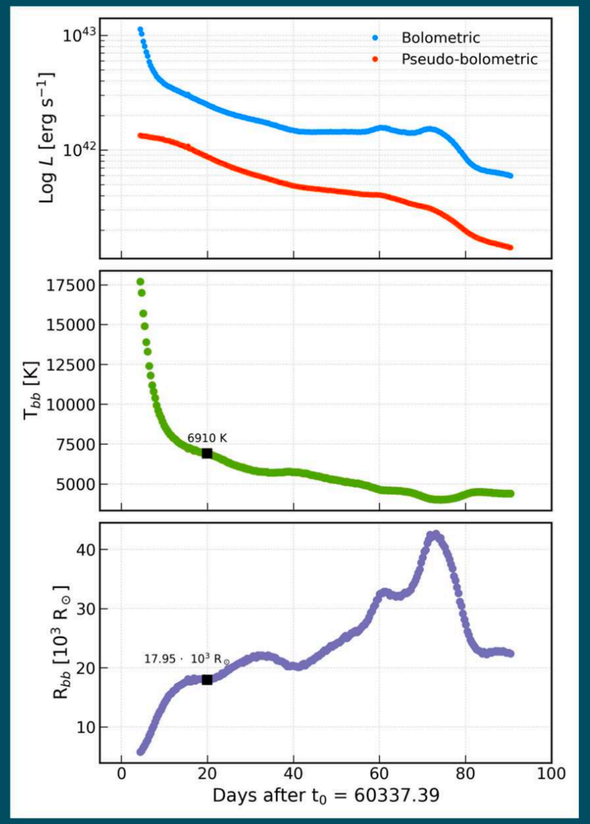
Slide from Andrea Simongini

SN 2024bch

Modelling

$$\rho_{CSM} \propto \sqrt{F_\gamma(E_0, t, d)}$$

We derive the relative density of the CSM from our gamma-flux ULs. This puts constraints on the nature of the CSM and the pre-explosion mass ejection of the progenitor. The evolution of the photosphere is an indication of what to expect from gamma-gamma absorption.



LST Coll subm.

Slide from Andrea Simongini

SN 2024bch

Results

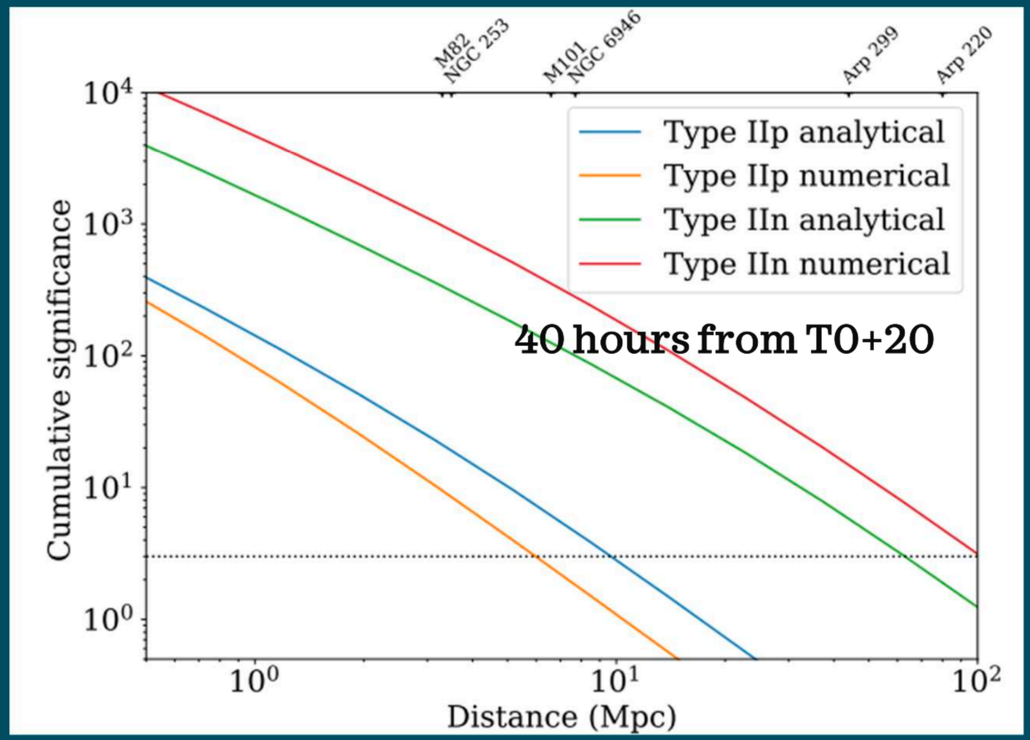
- We constrain $\rho_{CSM} \leq 10^{-4} \frac{M_\odot}{yr} \frac{s}{km}$ indicating a low density CSM.
- The photospheric evolution suggests that at the bulk of LST-1 observations (T0+20 days), the gamma-gamma attenuation could have had a minimum impact.
- From optical analysis we constrained progenitor's properties: combining optical + VHE results we conclude that the progenitor was a Red Super Giant.

Slide from Andrea Simongini

Potential gamma-ray emission

Is there hope?

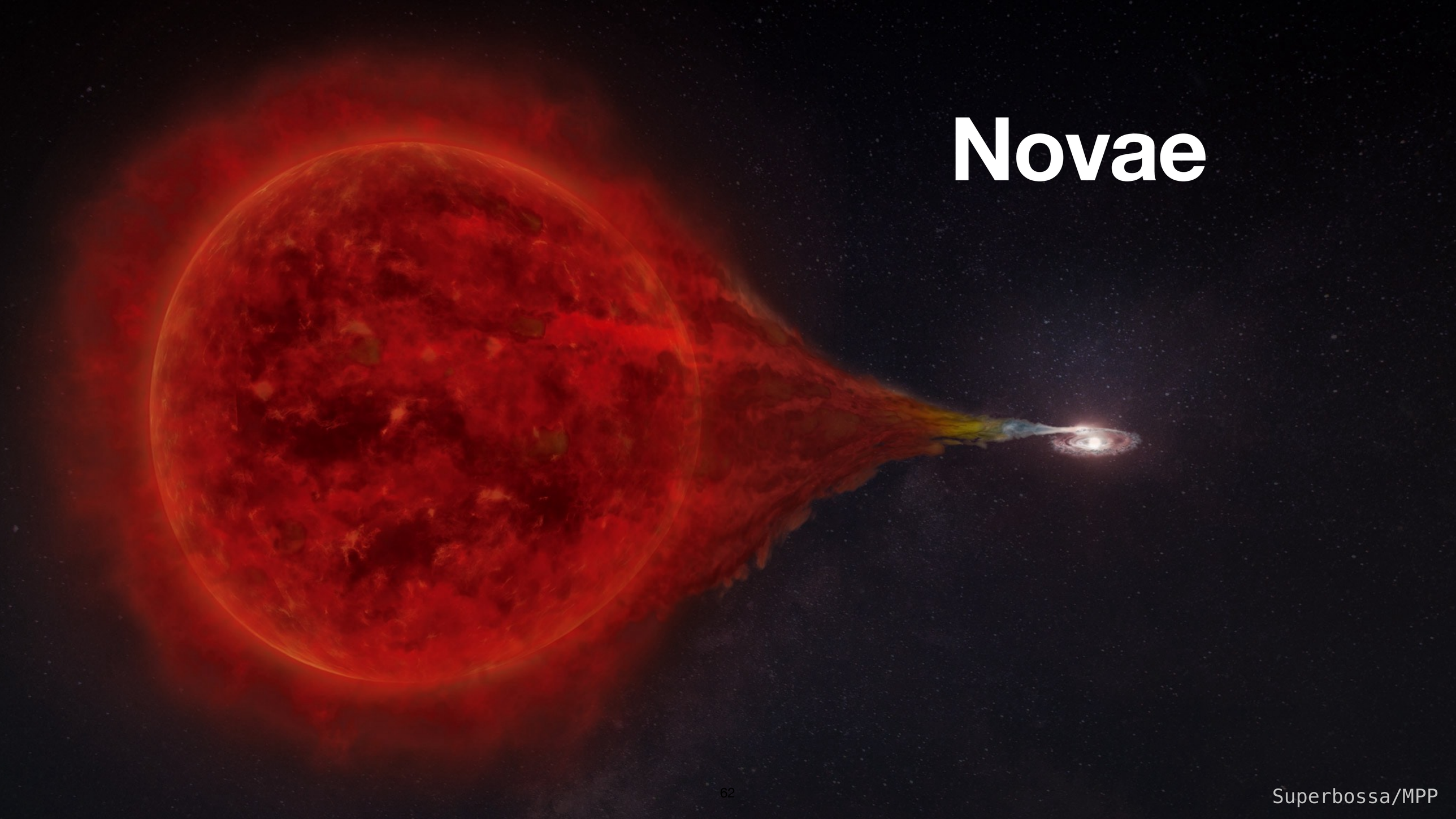
- The expected horizon of detectability of CTAO is around 7-10 Mpc for type II-P and 70 Mpc for type IIn.
- Current IACTs can still make the difference: the improved sensitivity and lower energy threshold of the MAGIC+LST-1 configuration may catch a big explosion!



Credits: Fabio Acero

Slide from Andrea Simongini

Novae



Superbossa/MPP

Novae

Classical novae
Main sequence + WD

Credit: ESO / M. Kornmesser

- Roche-lobe overflow
- Long (no) recurrency : > 10^4 years

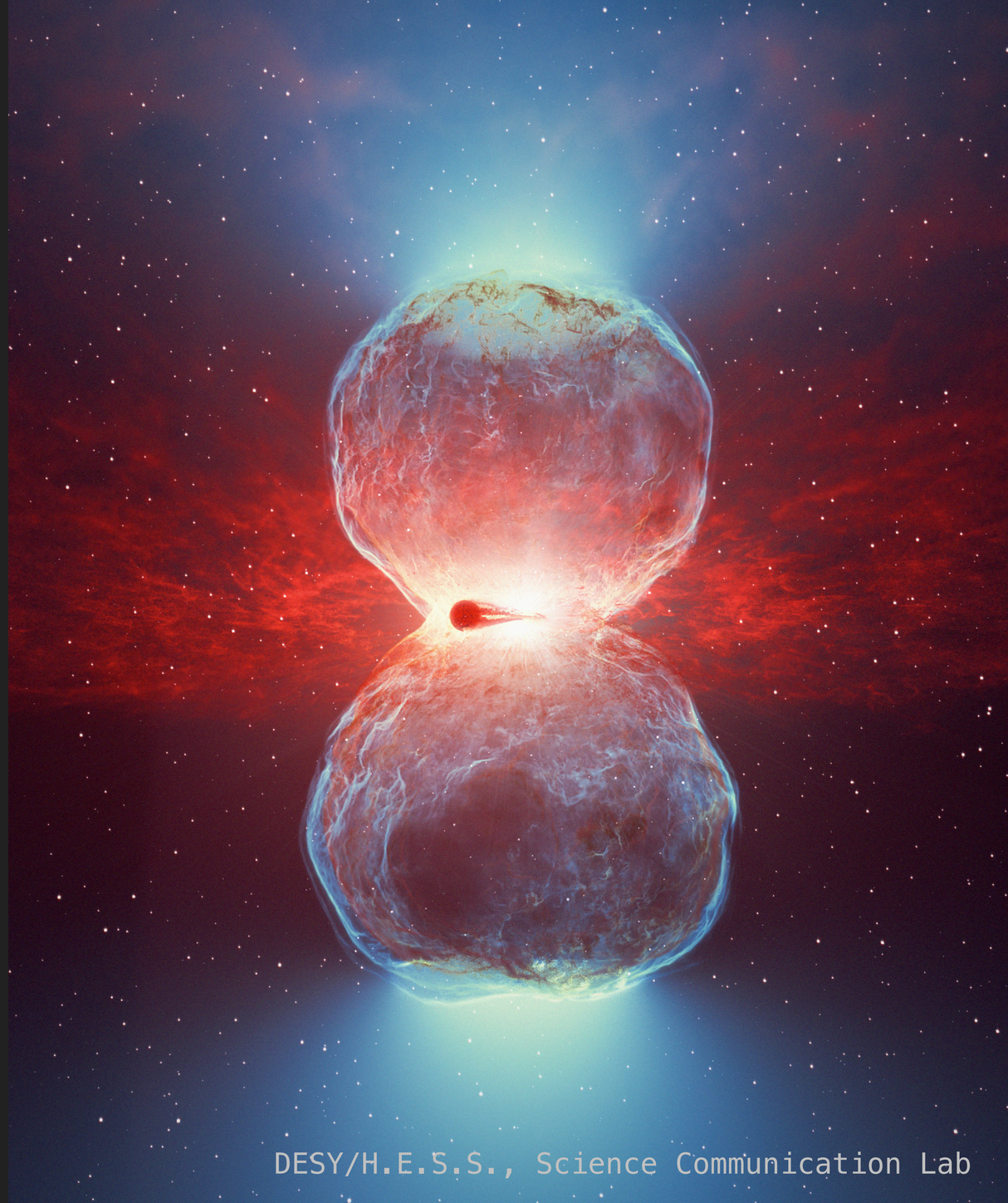
Symbiotic novae
Red giant (RG) + WD

- Accretion from stellar wind
- Some novae show repeated outbursts within a human lifetime: **recurrent novae (RN)**

RS Oph

Closest (6.4 Mpc, z= 0.0008) and one of the brightest (10.9 mag) CCSNe in the last decade

- RS Oph is a Galactic recurrent symbiotic nova
  - WD + M0-2 III RG star
  - major outbursts every ~15 years
  - Nine eruptions between 1898 and 2021
    - Latest outburst: August 2021



DESY/H.E.S.S., Science Communication Lab

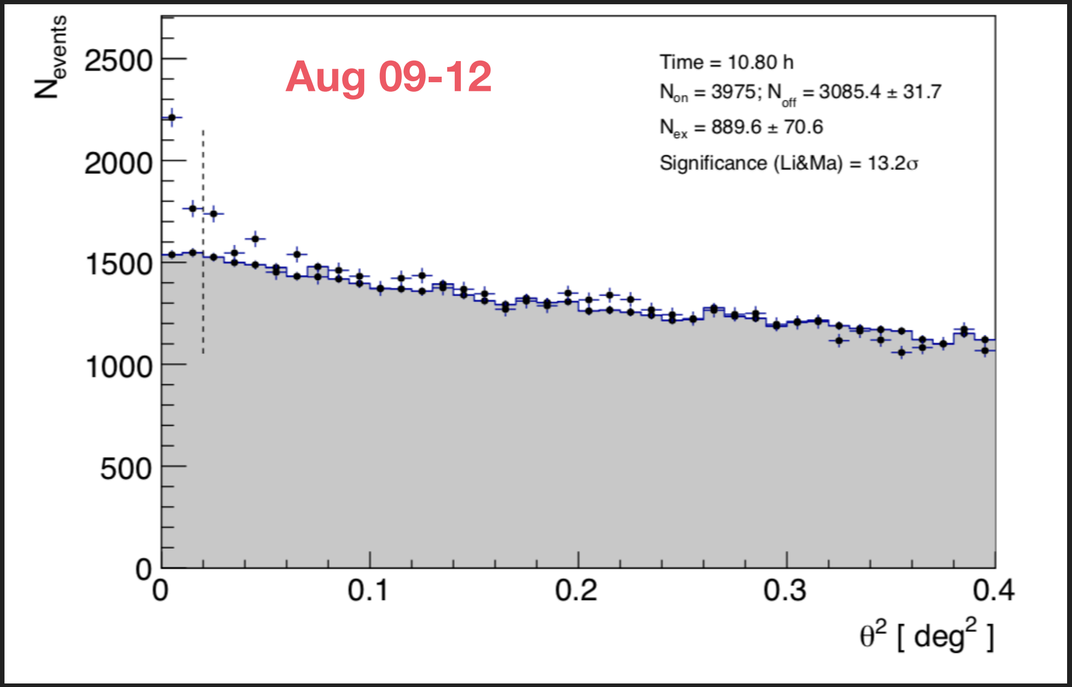
RS Oph

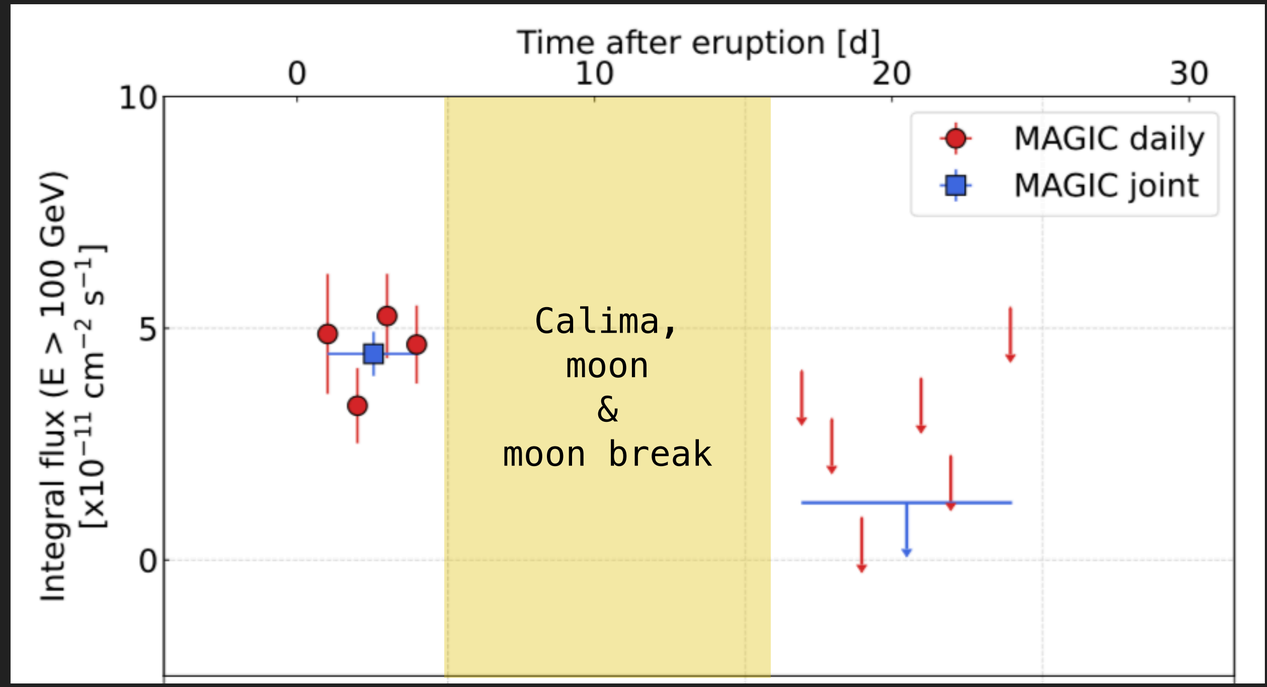
Timelime of the events

- Aug 08, 22:20 UT: RS Oph in outburst
- Aug 09, 00:35 UT: **Optical notice** (Geary, vsnet-alert 26131, Aug 8, 22:21 UT)
  - Estimated **mag= 5**
- Aug 09, 05:05: **Fermi-LAT** reports discovery at >100 MeV(ATel 14834)
- Aug 09 12:23 UT: MAGIC ToO request

RS Oph

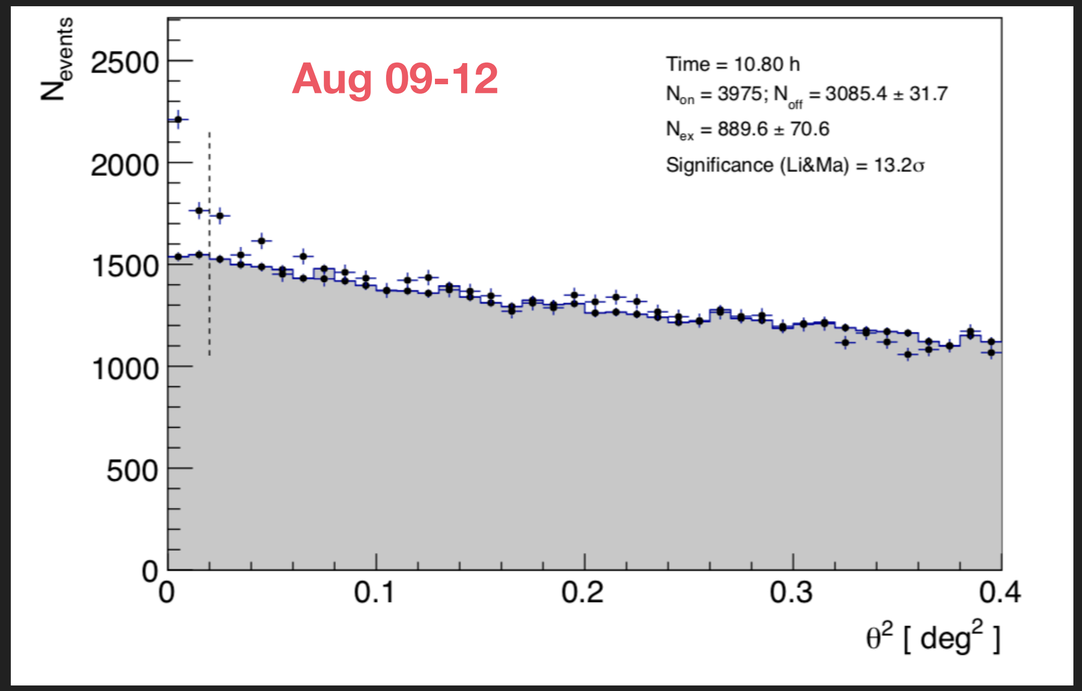
(Symbiotic) novae established as a new type of VHE emitter

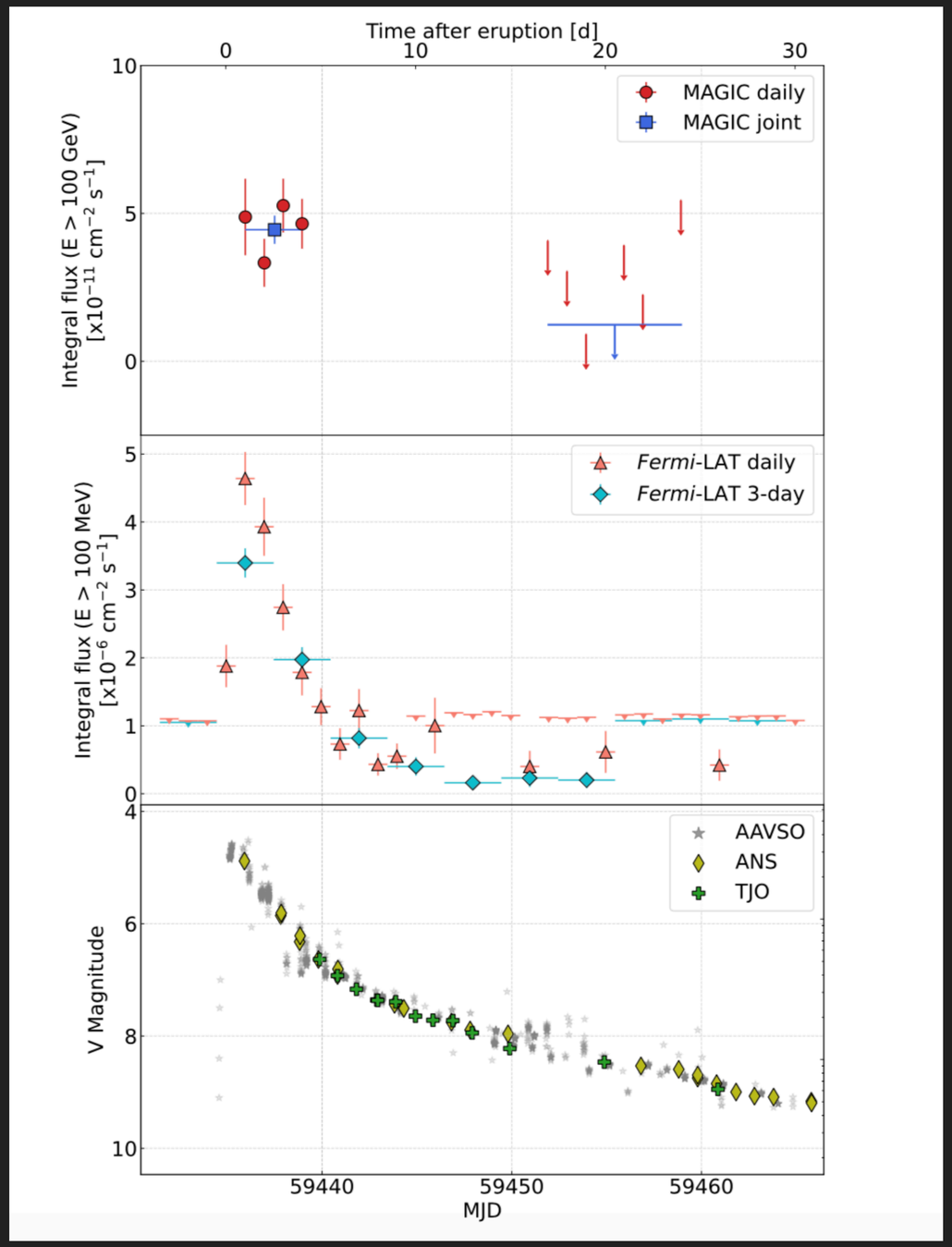




Acciari et al. 2022

RS Oph



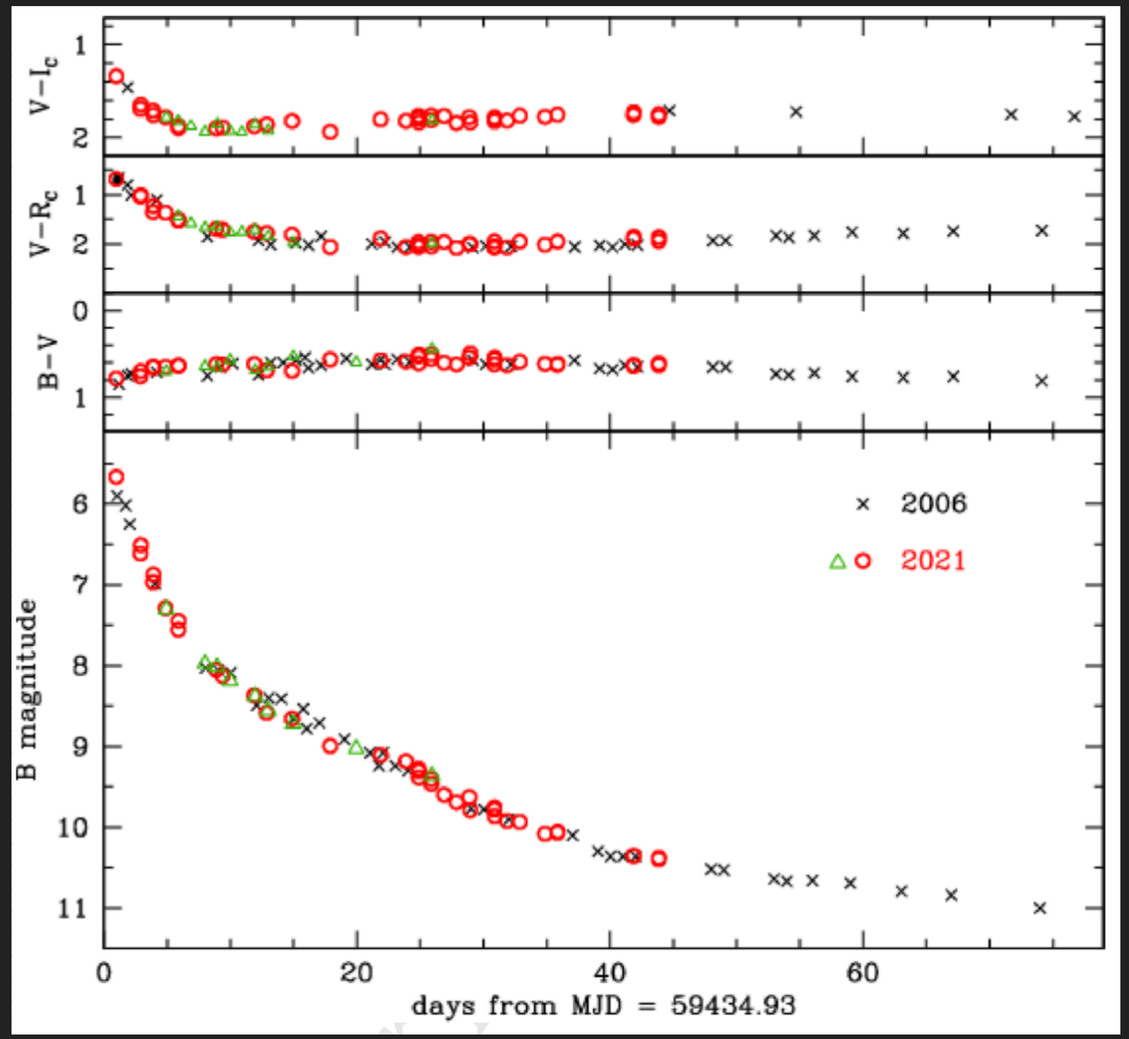


Acciari et al. 2022

RS Oph

- During the nova outburst the photospheric emission creates the dominant radiation field

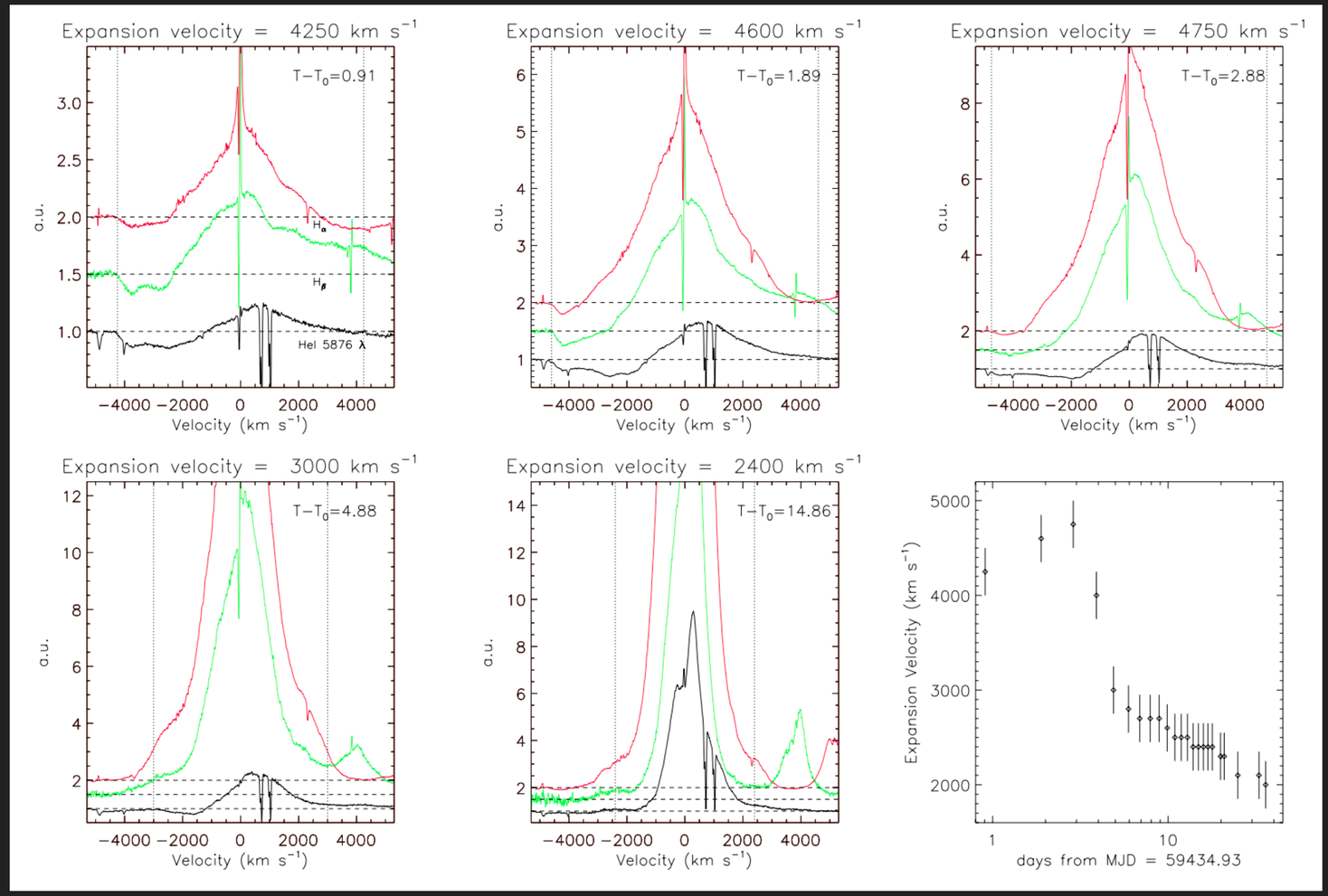
- **Photometry**
  - Performed with TJO and ANS telescopes
  - During the first 4 days (contemporaneous with MAGIC) the emission can be described* by the photosphere temperature dropping from **Tph = 10,800 K to 7,680 K and radius Rph = 200 R⊙**
    - Similar to those from 2006 outburst



Acciari et al. 2022

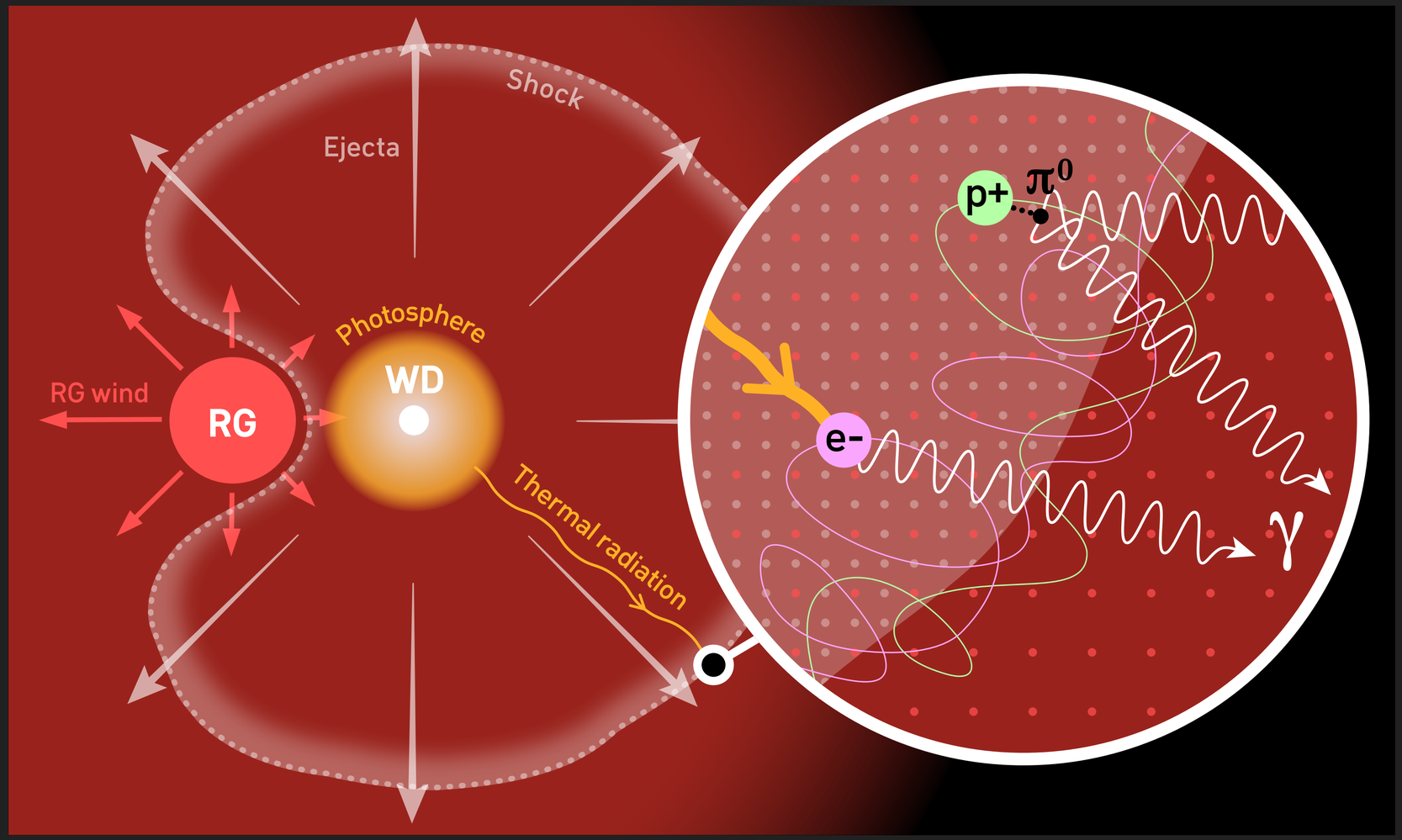
RS Oph

- **Spectroscopy**:
  - Varese 0.84 m and Catania 0.91 m telescopes
  - **4,500 ± 250 km s–1 for the ejecta expansion** at the earliest stage (during the VHE gamma-ray detection by MAGIC).



Acciari et al. 2022

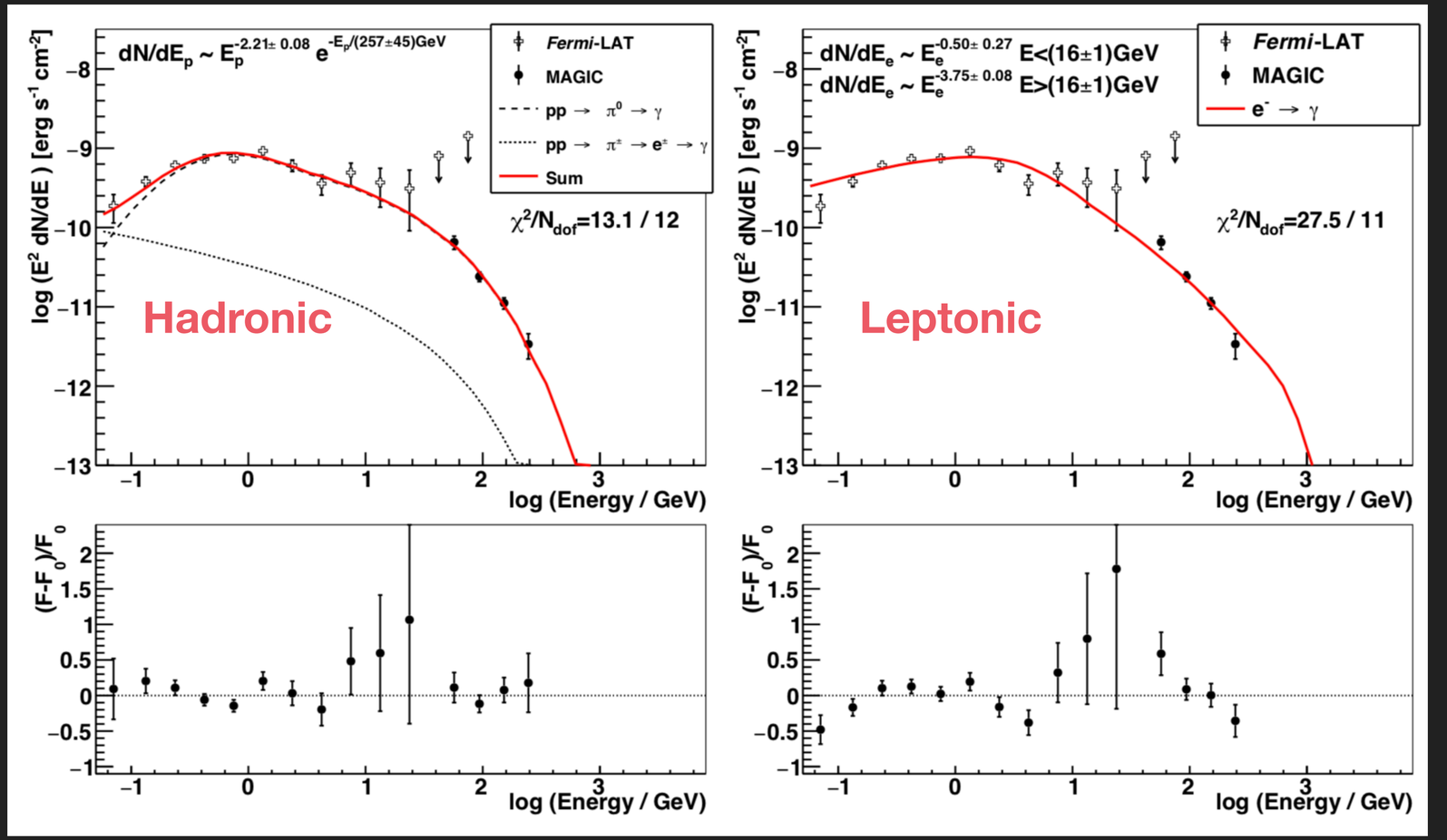
RS Oph



- **Protons**: **pp interaction on nova ejecta** (with some contribution from RG wind)
- **Electrons**: **IC on thermal radiation of the WD photosphere**
- Modeling: particles are injected and either cool down completely (electrons) or we gather their emission during the acceleration time (protons)

Acciari et al. 2022

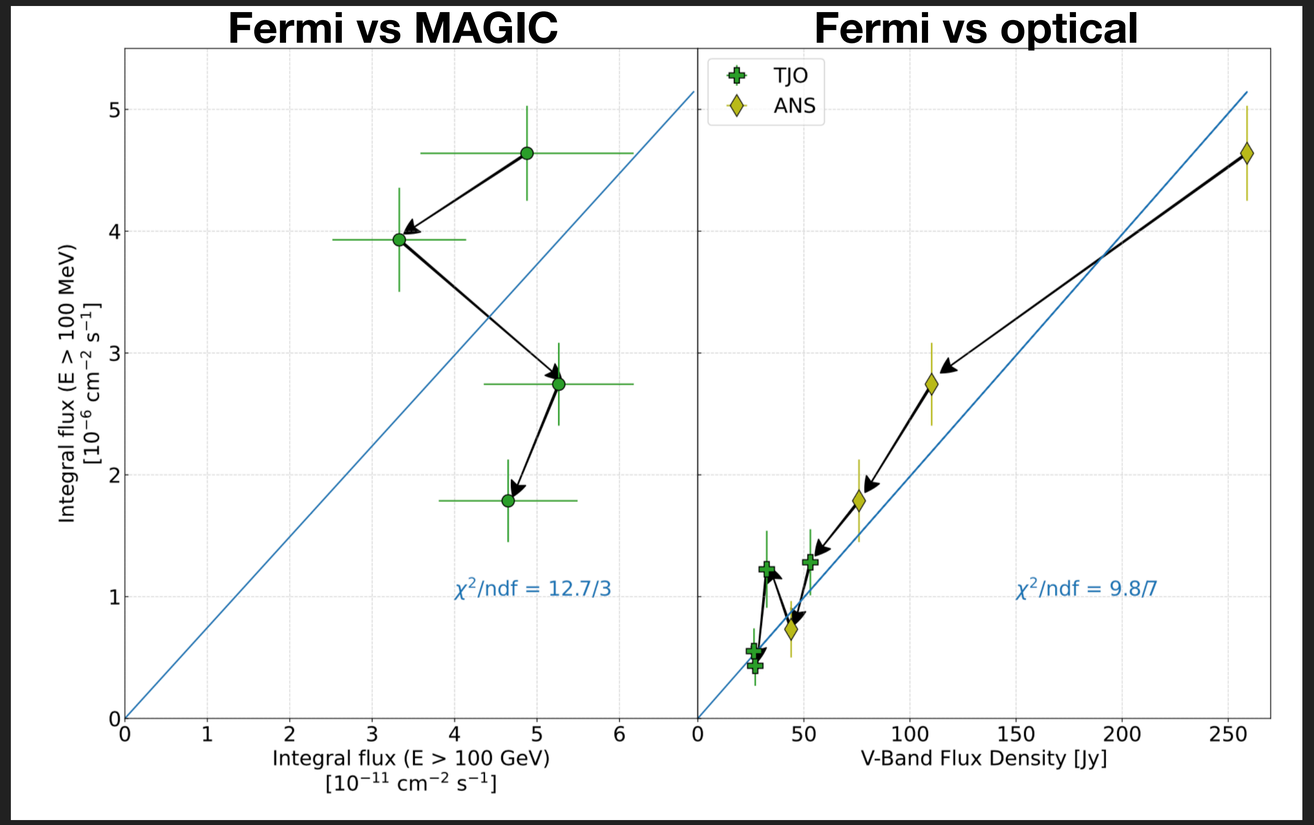
RS Oph



- Joint Fermi-LAT +MAGIC spectrum can be described as a single, smooth component spanning from 50 MeV to 250 GeV
- Protons are favored

Acciari et al. 2022

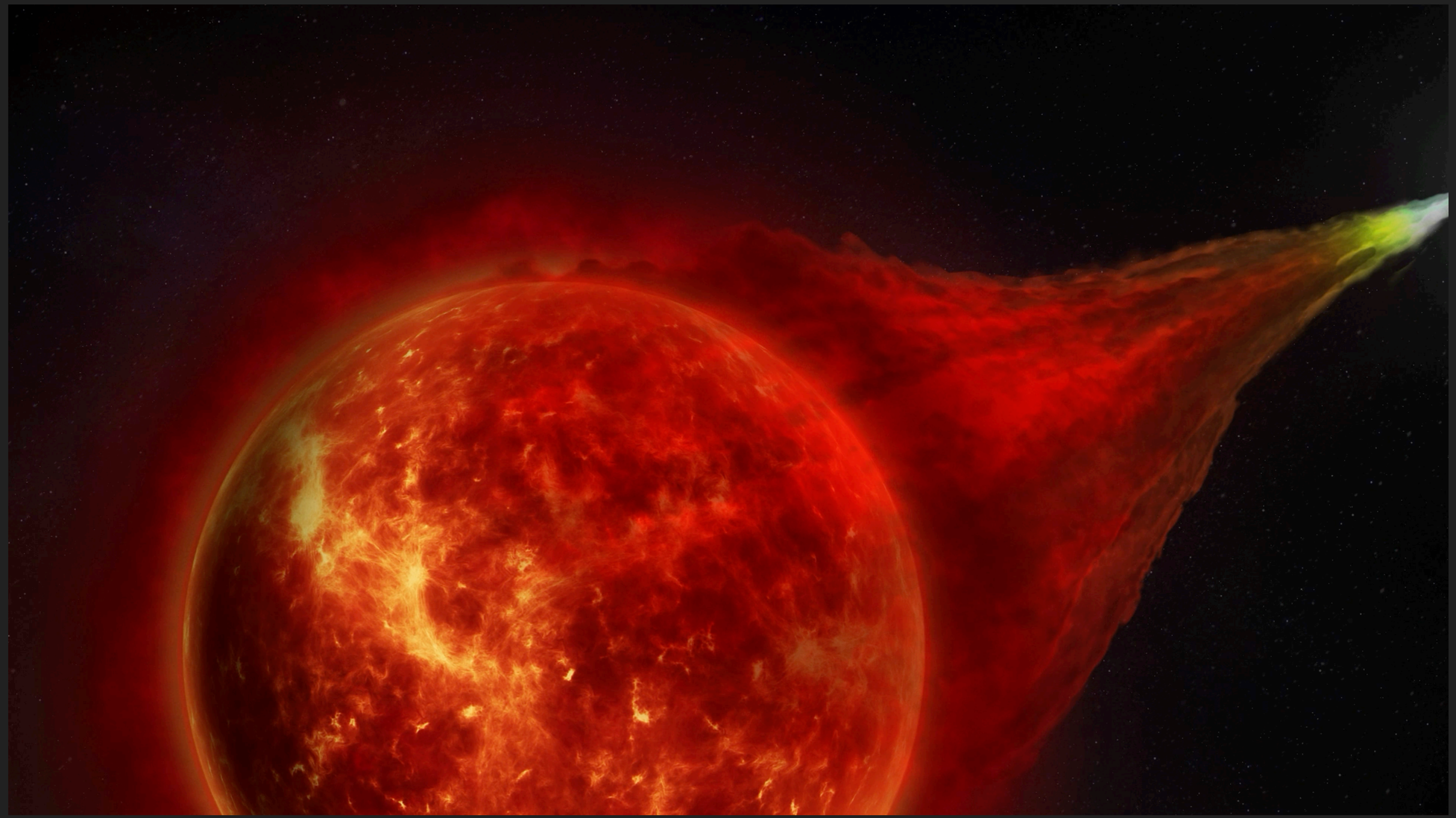
RS Oph



- VHE rougly flat, while HE decays faster: can be explained as hardening of the emission during its decay
- HE and optical emission show similar decay: not expected in IC model, since the distance from the photosphere will evolve with time and hence IC emission should decay faster
- **Protons** are favored

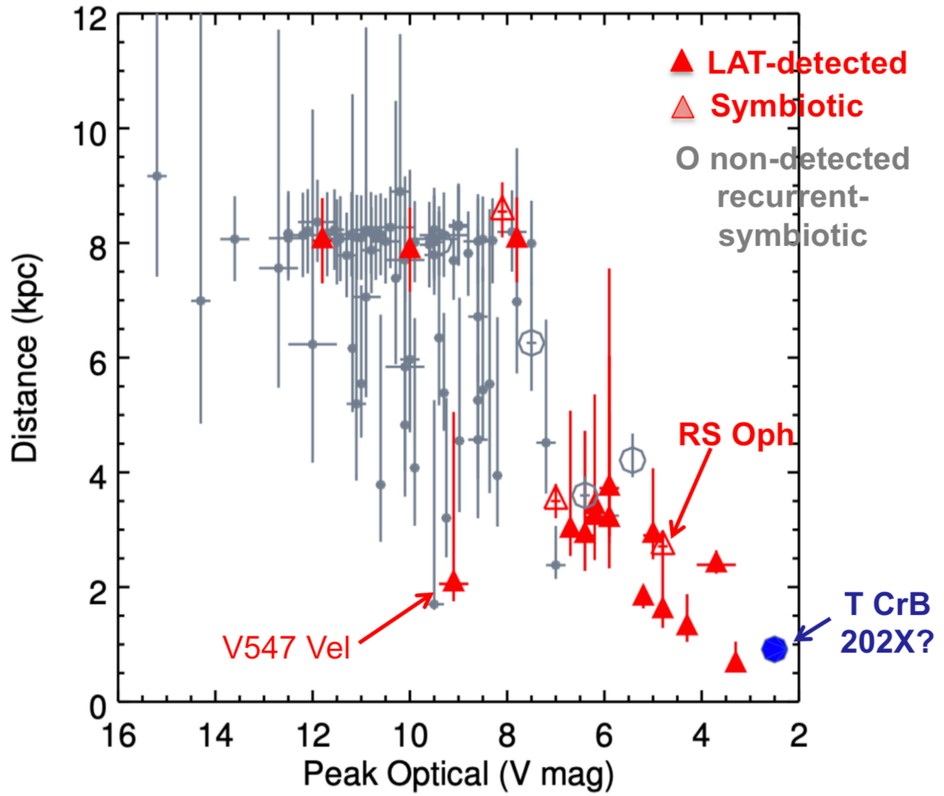
Acciari et al. 2022

RS Oph



Superbossa/MPP

T CrB: when is it happening?



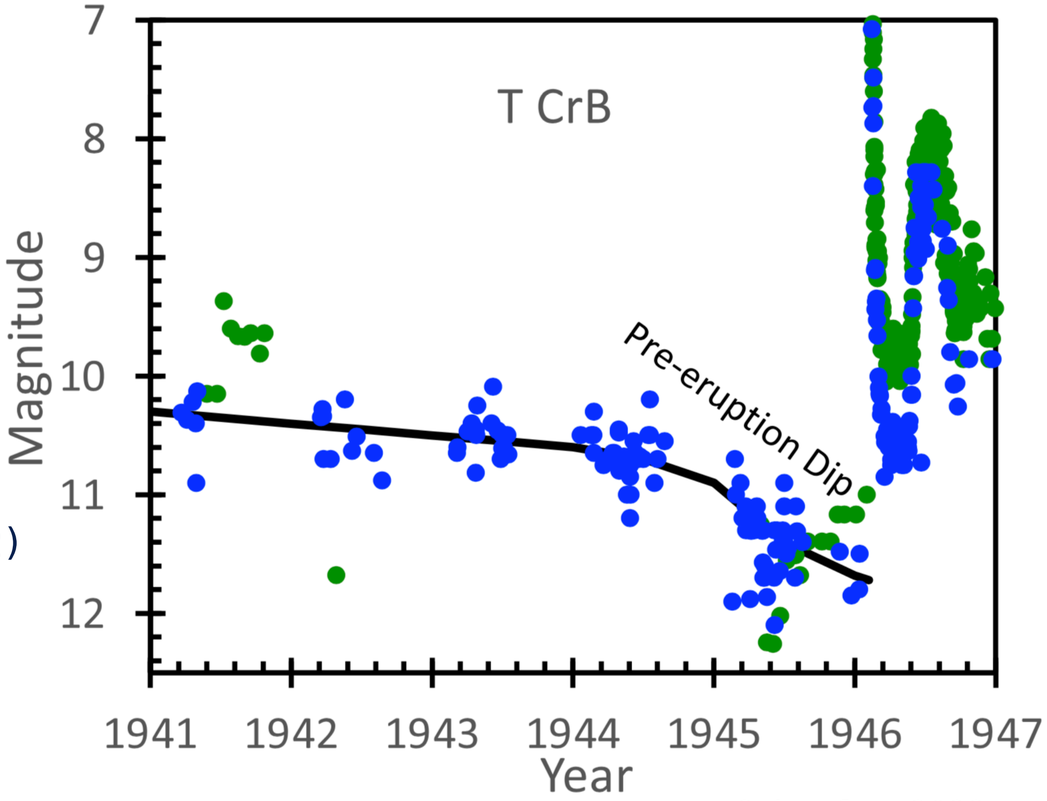
Data from Schaefer (2022), except V~5 inferred in V959 Mon 2012; added V407 Cyg 2010

From T. Cheung (VGGRS VI)

RN Symbiotic nova

WD (1.37±0.13) M⊙

M4 III



Schaefer 2022

- **Closest known RN symbiotic nova**, D = 0.91 +/- 0.02 kpc (Schaefer 2022)
  - Recurrency period of about **~80 years**
  - Two peaks
- Optical first **peak at mag~2**
- 3x closer than RS Oph; naively scale by distance => ~10x brighter?

Inmediate future?: T CrB

- **Increase in the accretion rate, but not in luminosity** (ATel #17030)
  - The equivalent width of the hydrogen lines doubled from 21.01.2025 to 09.02.2025
  - Double-peaked shape with a central absorption to a single emission peak
    - Strong increase in the accretion rate, **which will eventually result in a nova eruption**, as predicted to occur this or next year (e.g., Schaefer et al. 2023).

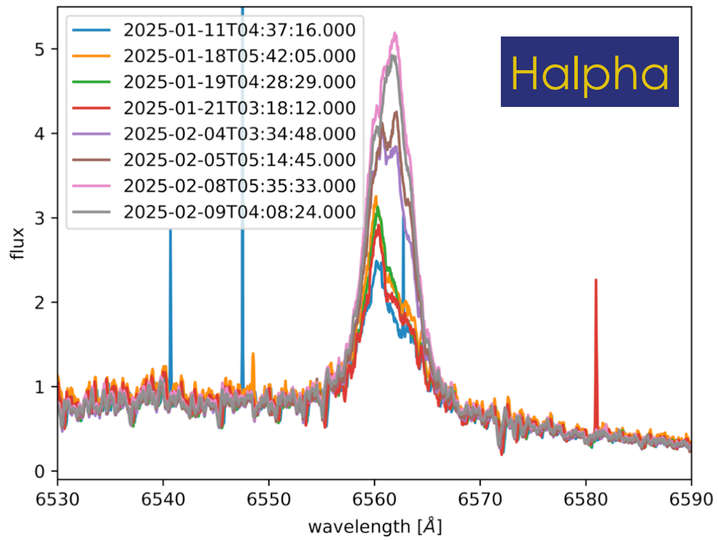
  - **No increase in the light curve** has been observed so far

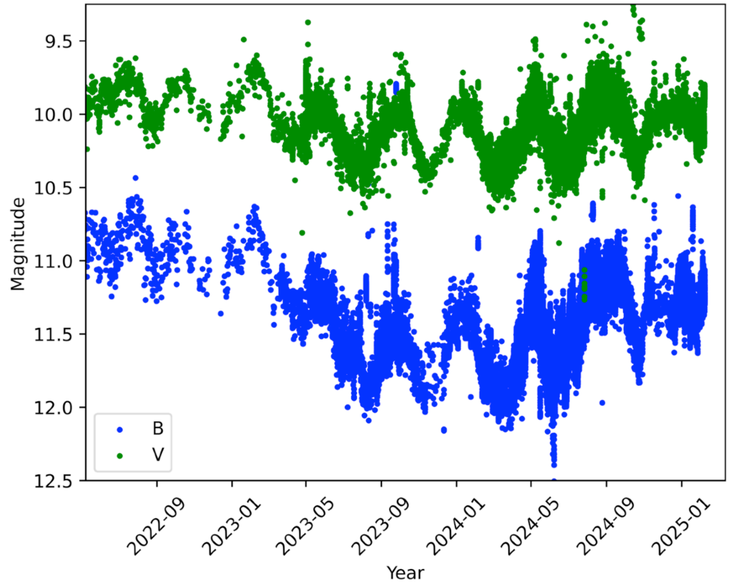
  - When? **Expected eruption date according to literature:**

    - **2024.4 ± 0.3** (Schaefer+ 2023)
    - **2025.5 ± 1.3** (Schaefer 2023)
    - **2025 Nov or June 2026** (Schneider 2025)

Table 1 Predicted days of eruption occurrence in 2024, 2025, 2026 and 2027 using 2431861 + N*227.5687

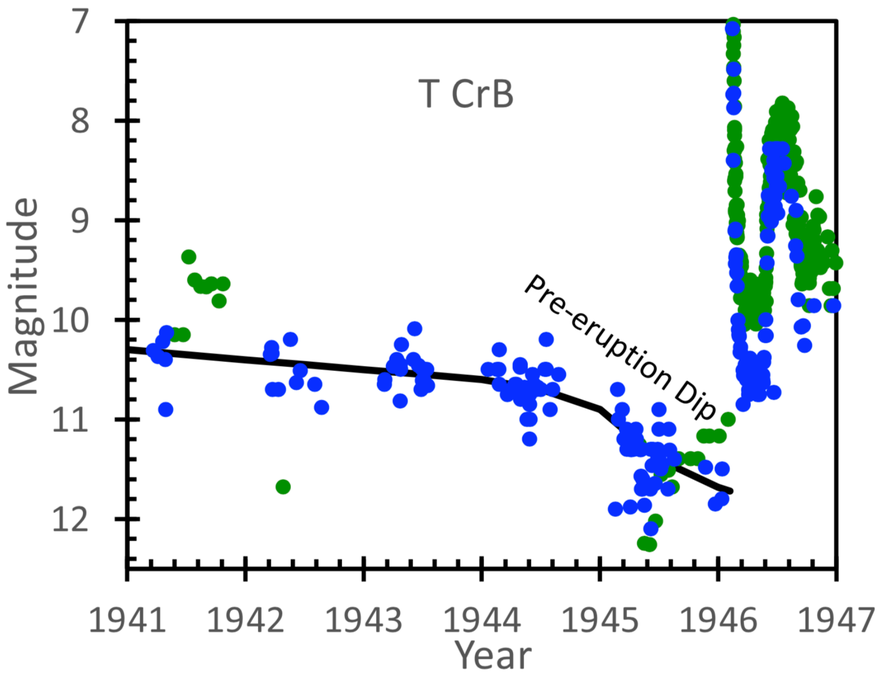
N	Julian day	Civil date
126	2460535	12 Aug 2024
127	2460762	27 March 2025
128	2460990	10 November 2025
129	2461217	25 June 2026

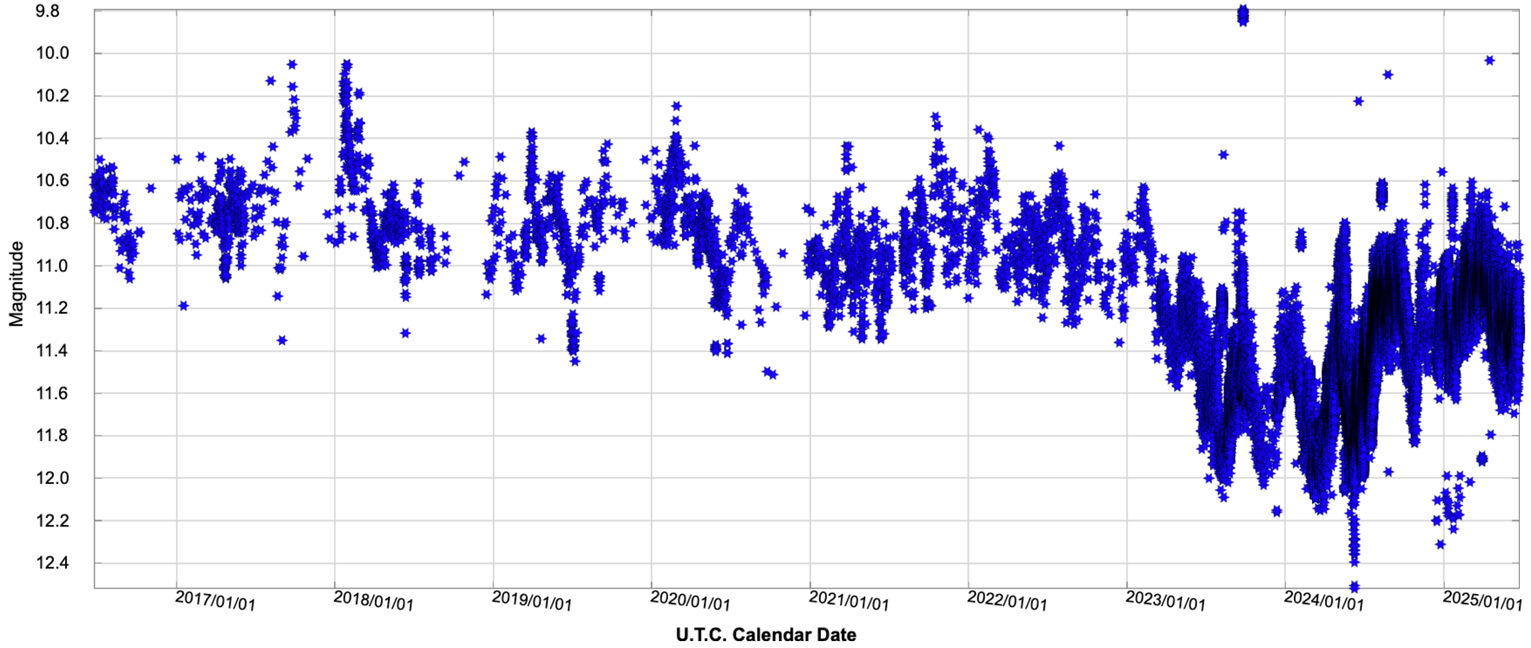




https://www.tls-tautenburg.de/en/news/tautenburger-wissenschaftler-beobachten-auffaellige-veraenderung-im-spektrum-der-wiederkehrenden-nova-t-crb-und-bleiben-wachsam-2

Inmediate future?: T CrB





Schaefer 2022

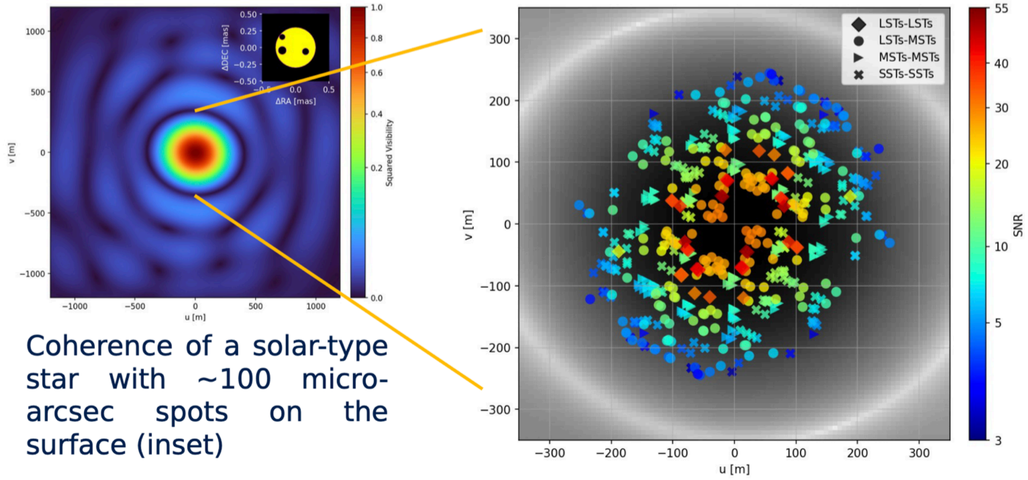
AAVSO (B band)

Stellar Intensity Interferometry

White paper in prep.

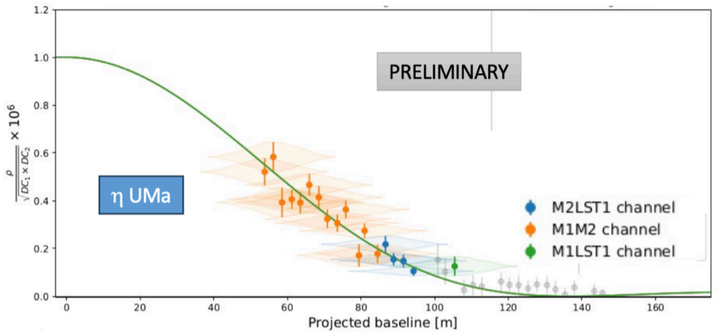
Data Challenge in prep.

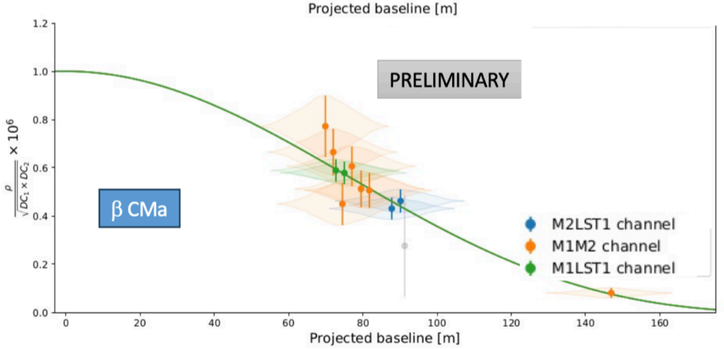
- Not included as KSP in CTA Consortium 2018
  - Working towards implementation in CTAO
- submas measurements of star's diameters



Coherence of a solar-type star with ~100 micro-arcsec spots on the surface (inset)

L. Zampieri, CTAO Symposium





J. Cortina, CTAO Symposium

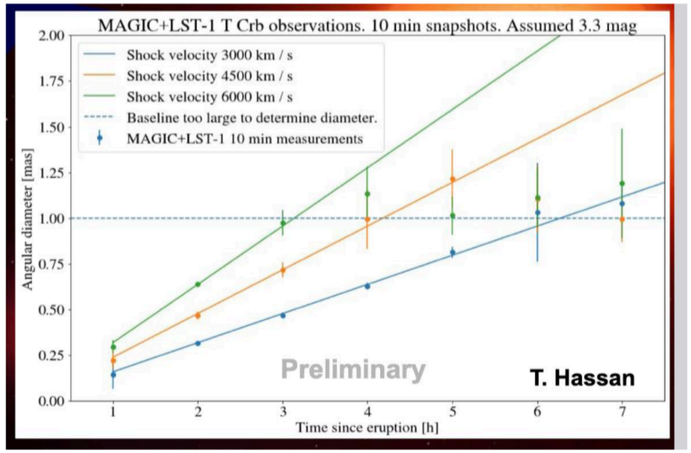
35

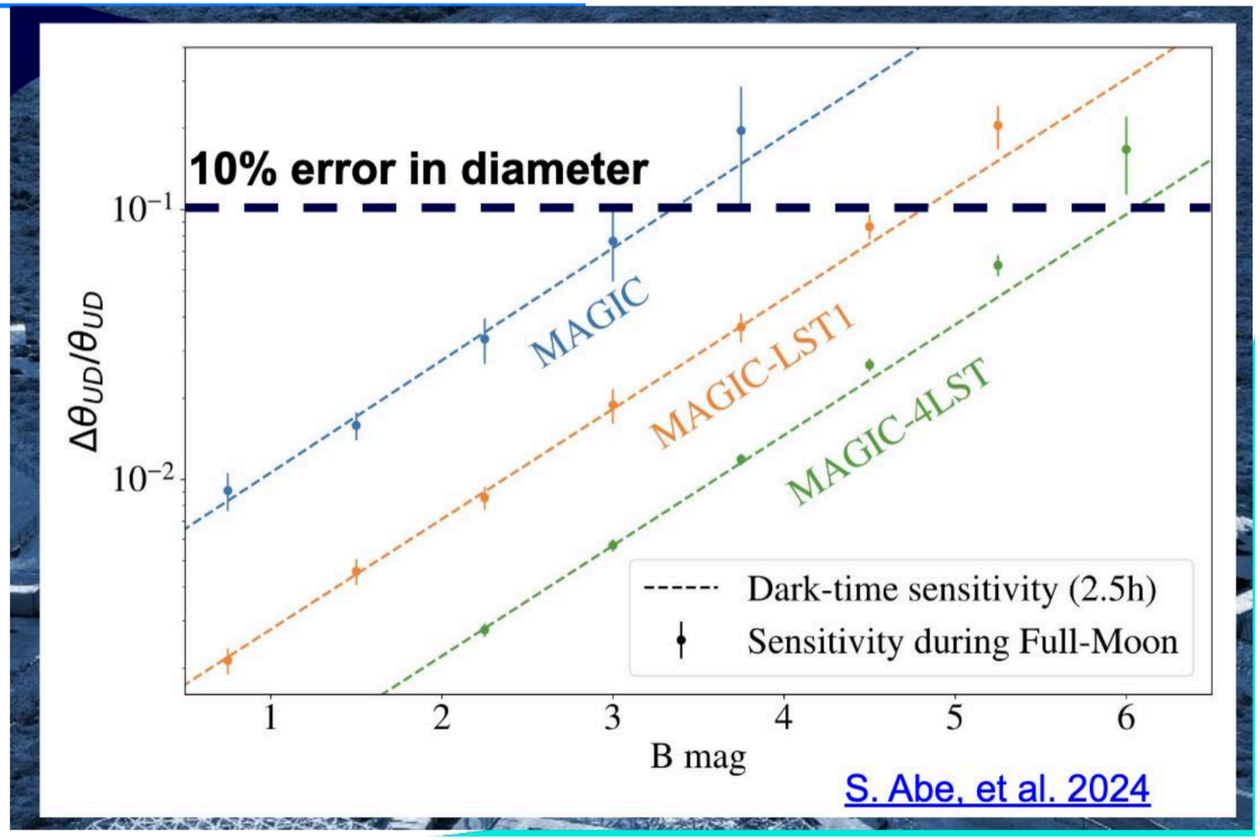
Stellar Intensity Interferometry

Status of SII in MAGIC and CTAO-LST1

Among science cases:

- **Novae**
- Be stars
- Colliding wind binaries





Slide from PHYS report CTAO Meeting

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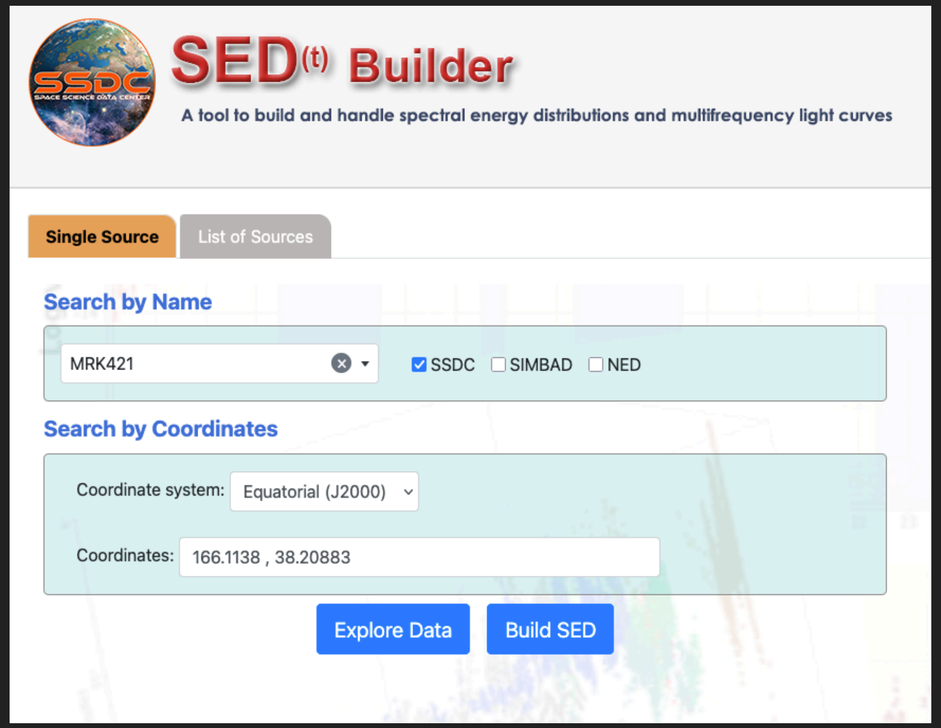
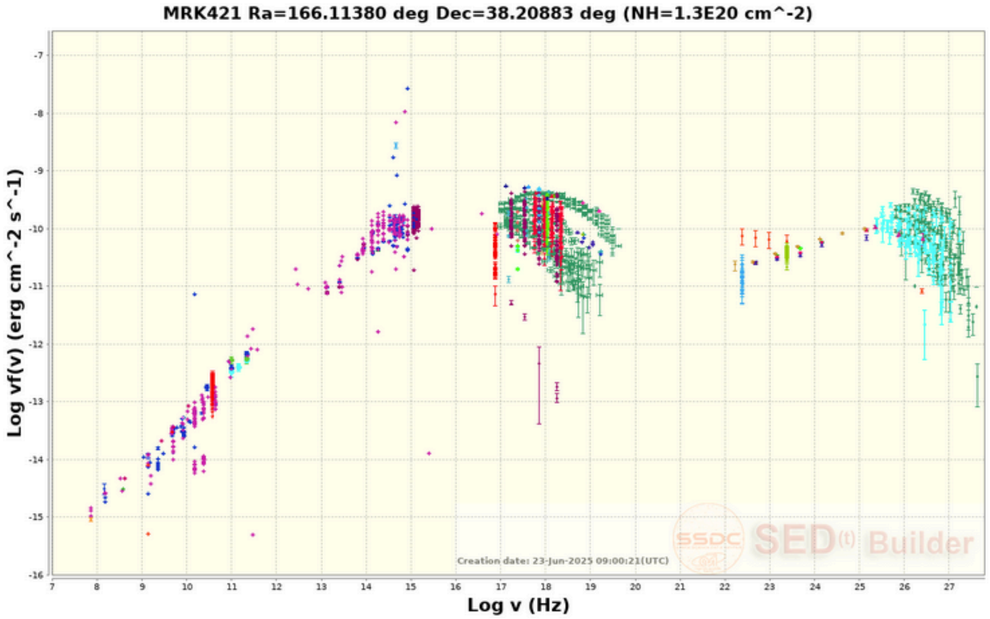
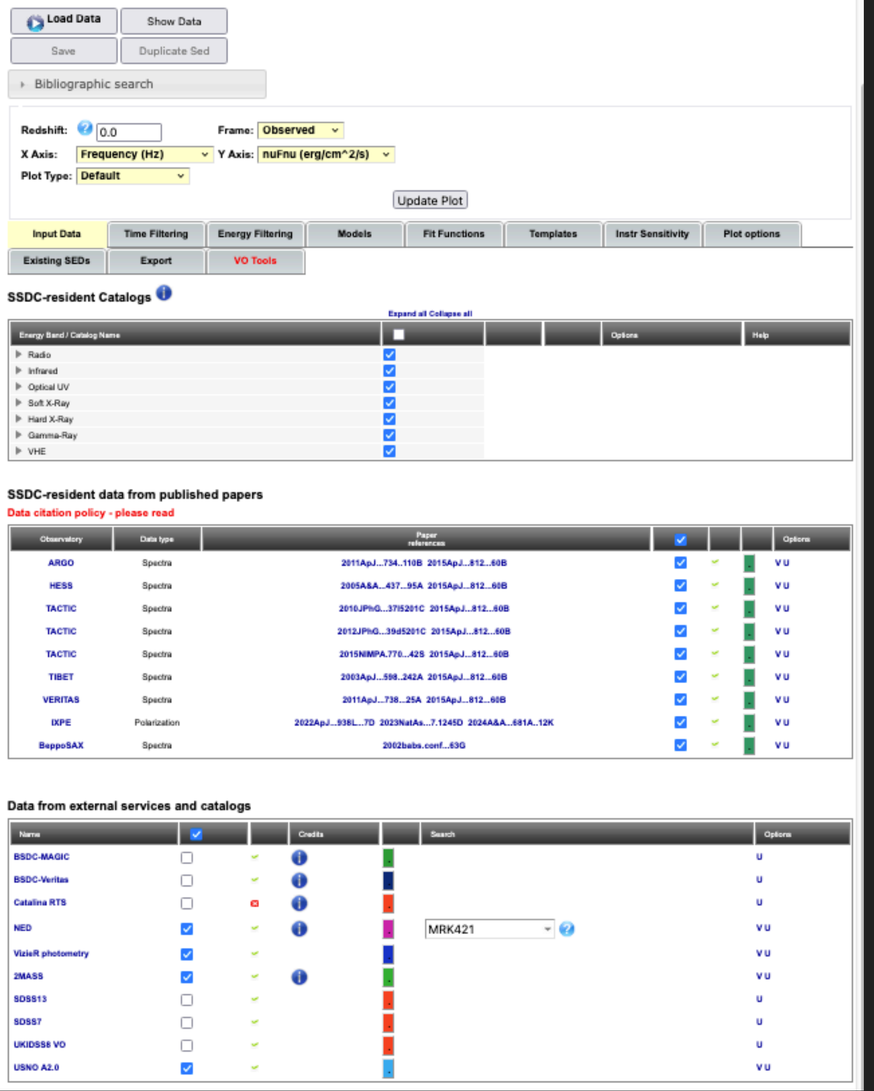
Public data: SED builder



- https://tools.ssdc.asi.it/SED/
- Specially used in the AGN community
- Be aware of data simultaneity

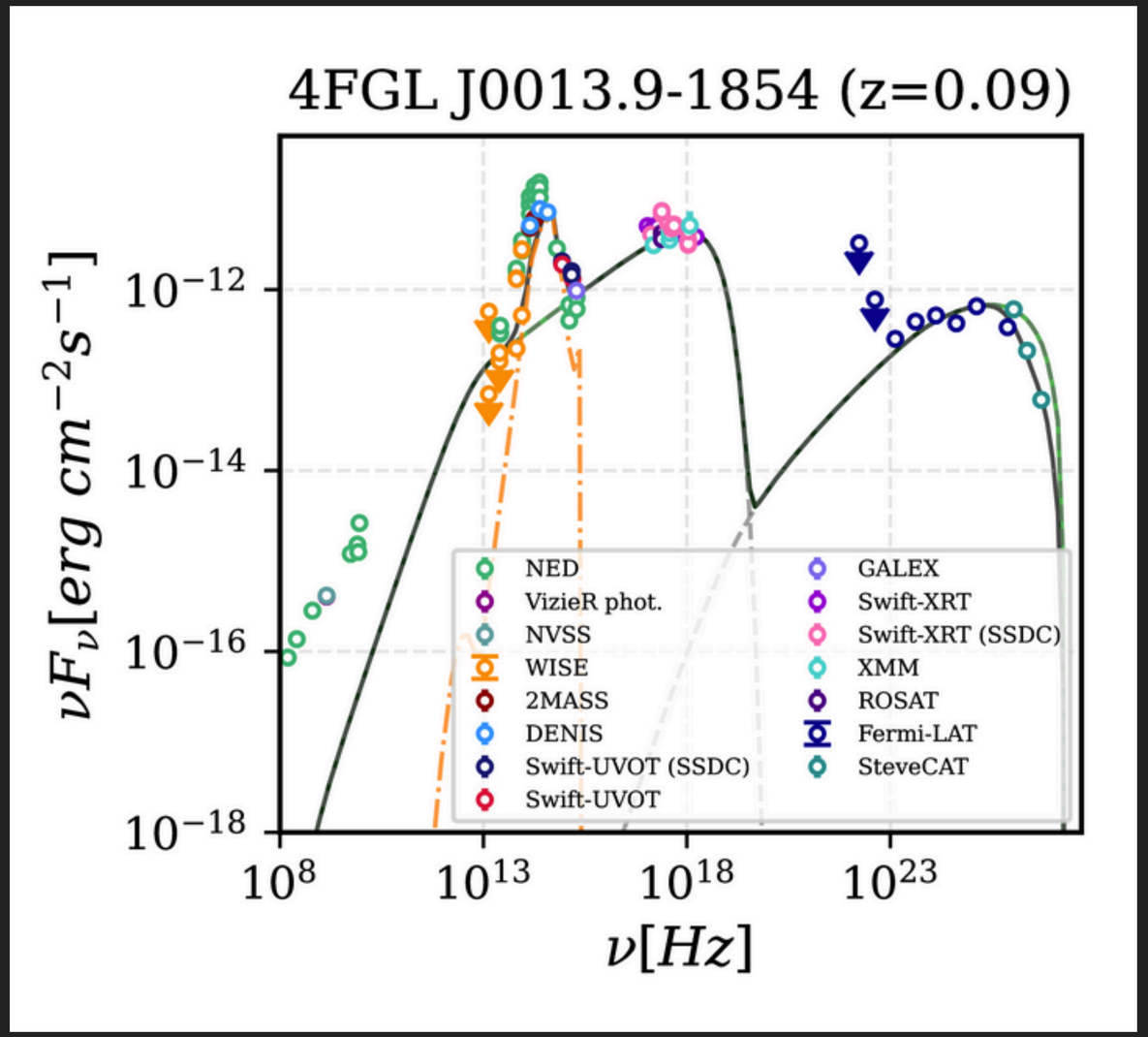
Public data: SED builder





- https://tools.ssdc.asi.it/SED/

Public data: SED builder

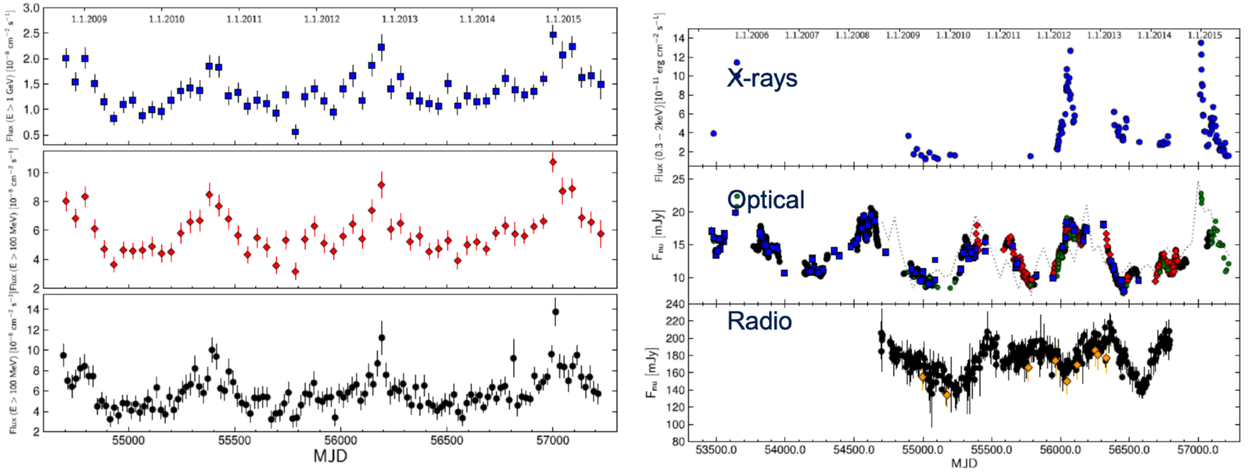


Láinez et al. 2025

AGNs: Triggering on optical

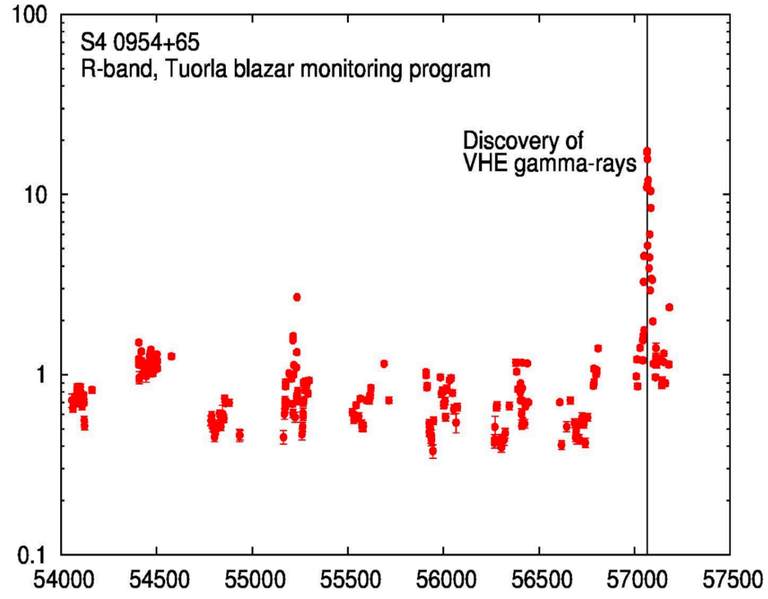
- MAGIC and HESS have dedicated optical support telescopes: KVA and ATOM
- Has been particularly useful for blazar observations
- Photometric long-term monitoring: to study the long term behavior, to define the flare conditions
- Before the Fermi era, the optical telescope was the main source of alerts for flaring AGN: e.g. with MAGIC >50% of blazar discoveries result of optical trigger

PG 1553+113: Fermi-LAT quasi-periodicity quasi-periodicity in other bands?



Ackermann et al. 2015, ApJ, 813, 41

- MAGIC has been triggering from optical observations since 2005
- Many discoveries (Mrk180, 1ES1011+496, S50716+714, B32247+381, ON325, H1722+119, S40954+65)



Adapted from Elina Linfors

CTAO: synergies with optical

Transients KSP (Science with Cherenkov Telescope Array)

Table 9.1 – Summary table of proposed maximum observation times for follow-up targets in the Transients KSP. Observations of Galactic transients could be extended beyond Year 3 of regular operations if new source classes with fast variability are discovered. The early phase, prior to array completion, is assumed to last for two years.

		Observation times (h yr^{-1} $site^{-1}$)			
Priority	Target class	Early phase	Years 1–2	Years 3–10	Years 1–10
1	GW transients	20	5	5	
2	HE neutrino transients	20	5	5	
3	Serendipitous VHE transients	100	25	25	
4	GRBs	50	50	50	
5	X-ray/optical/radio transients	50	10	10	
6	Galactic transients	150	30	0(?)	
	Total per site (h yr^{-1} $site^{-1}$)	390	125	95	
	Total both sites (h yr^{-1})	780	250	190	
	Total in different CTA phases (h)	1560	500	1520	2020

Science with CTAO (arXiv:1709.07997)

CTAO: synergies with optical

Transients KSP (Science with Cherenkov Telescope Array)

Simultaneous MWL follow-up observations should be arranged for all targets to maximize the scientific output. The best approach would be to collaborate with existing teams of experts (internal or external to CTA) that already have granted observing time in multiple facilities. Efforts are warranted to establish collaborations with such teams prior to the early science phase. Furthermore, a dedicated, on-site, 0.5-1 m class optical telescope can provide important benefits, including coordinated optical photometry to clarify various thermal and non-thermal processes and possibly polarimetry to obtain valuable complementary information on magnetic fields, density of ambient gas, etc.

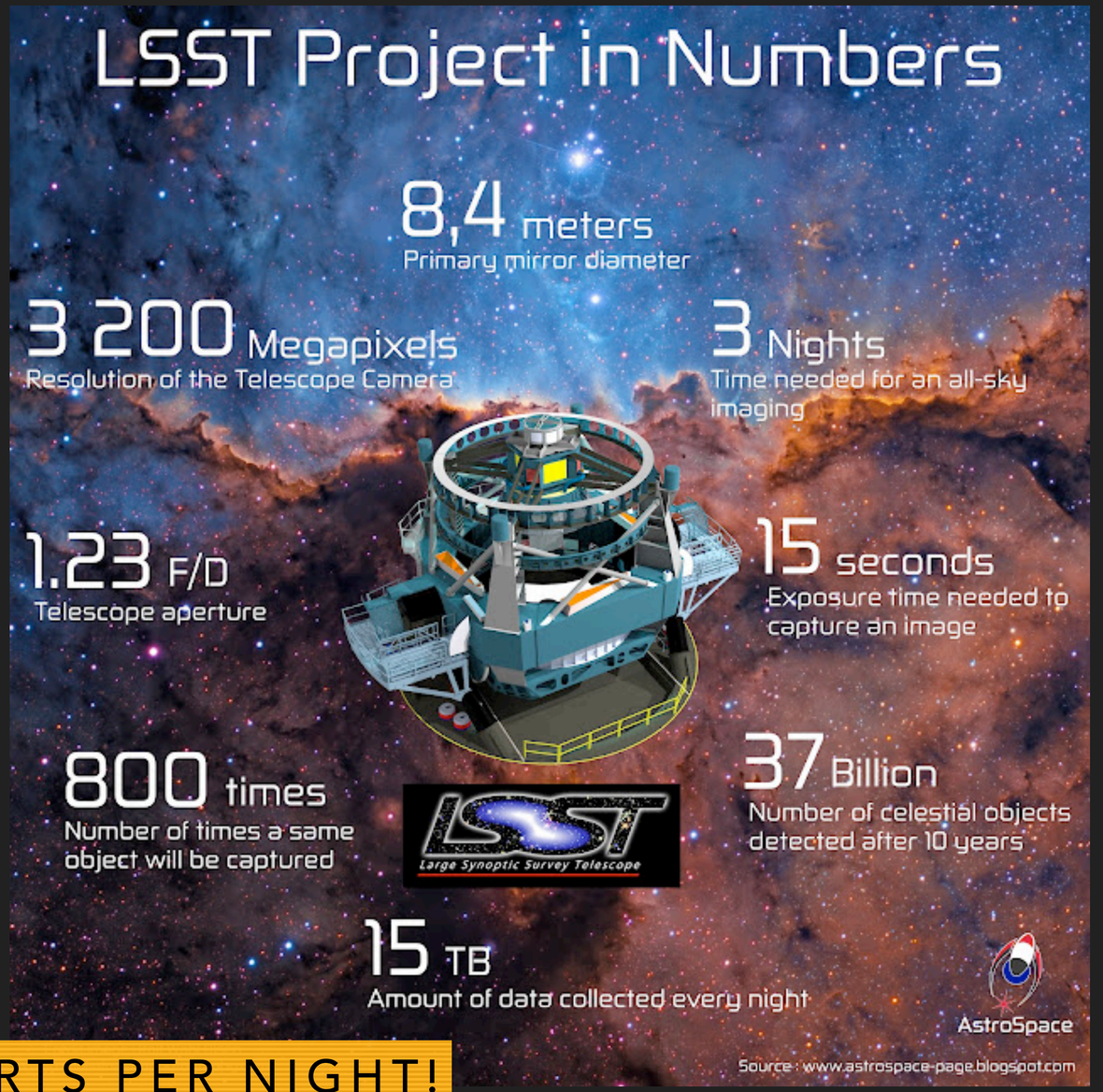
C) X-ray, optical, and radio transients: To exploit the potential of X-ray, optical, and radio transient factories, we suggest 50 h/yr/site during the early phase to test and tune the filter and trigger response system based on responding to promising bright transients. Thereafter, we consider 10 h/yr/site during regular operations to use the tuned filters to follow up on the many new transient alerts we expect to receive.

The systems for responding to X-ray alerts from Swift, INTEGRAL or SVOM are already well established for current IACTs and can be generally followed for CTA as well. Based on existing data, we do not expect the rate of alerts for transients of interest such as TDEs or SSBs to exceed those of GRBs. On the other hand, planning concrete strategies at this moment for follow-up to optical or radio transient factory alerts is challenging, due to numerous uncertainties concerning the actual performance of each facility, the latency for receiving different types of alerts, and the extent of the information that will be available. This is especially the case for fast transients such as FRBs. Nevertheless, a sketch of some possible strategies can be outlined for the relatively slower, Galactic transients. For example, optical transient factories are expected to discover large numbers of novae. Several novae have been detected by Fermi-LAT in HE gamma rays [288], and current IACTs are searching for VHE gamma rays from these objects, as predicted in some hadronic models. We expect that observations conducted by these and other high-energy facilities during the following years will provide a clearer picture as to what the best trigger conditions may be for follow-up with CTA. Possible filtering criteria could be based on optical magnitude (to select nearby objects), nova type (nature of the companion and expected physical behaviour), properties of the HE gamma rays detected by Fermi, etc. Similar exercises will also be conducted for other types of objects during the following years and prior to the early science of CTA, such that the optimal methodology can be developed for selecting the particular types of transient factory alerts that are most interesting for our aims.

Science with CTAO (arXiv:1709.07997)

The Vera Rubin (and large telescopes) era

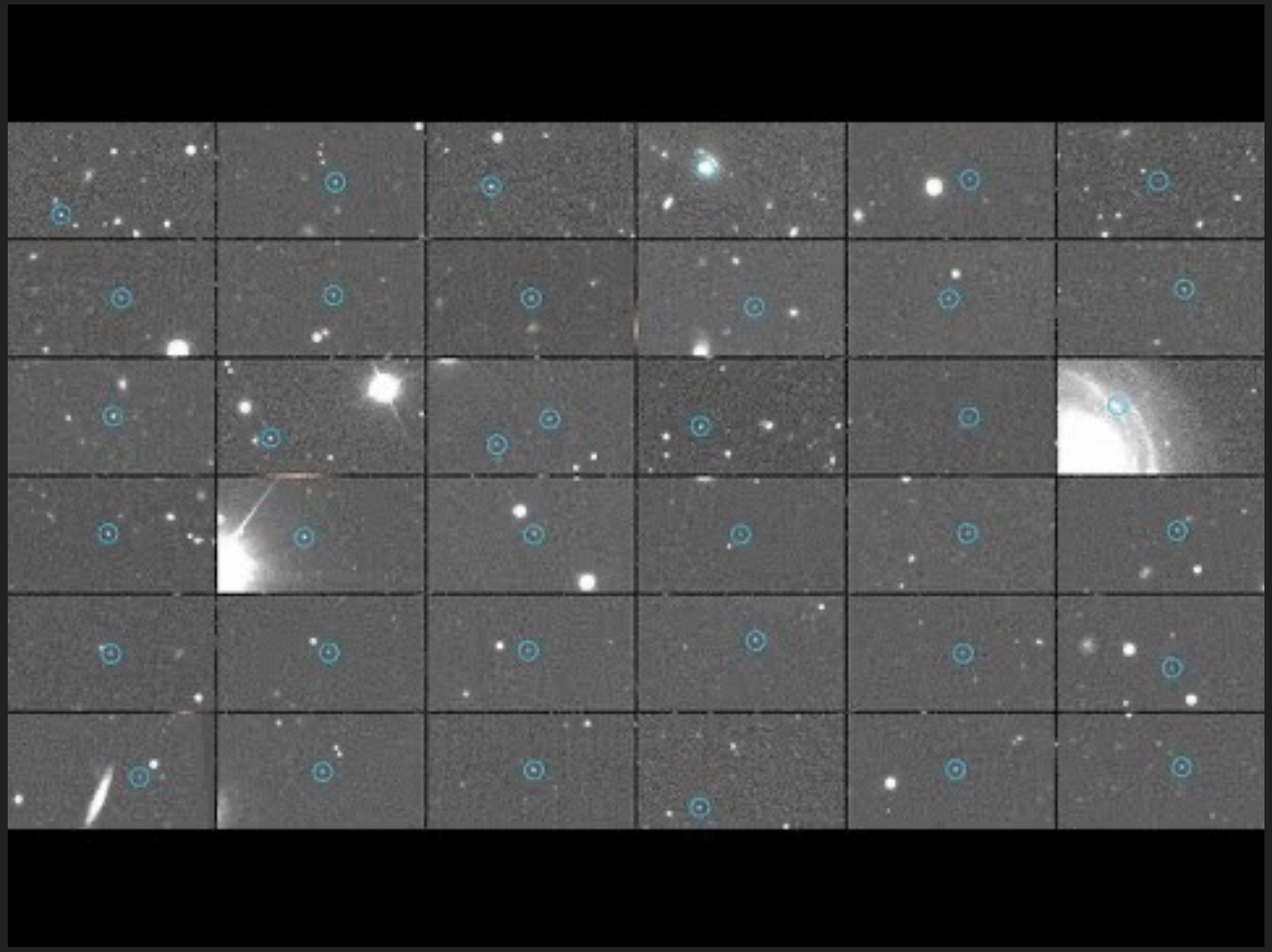
Check the press release: https://noirlab.edu/public/news/noirlab2521/?nocache=true&



10 MILLION ALERTS PER NIGHT!

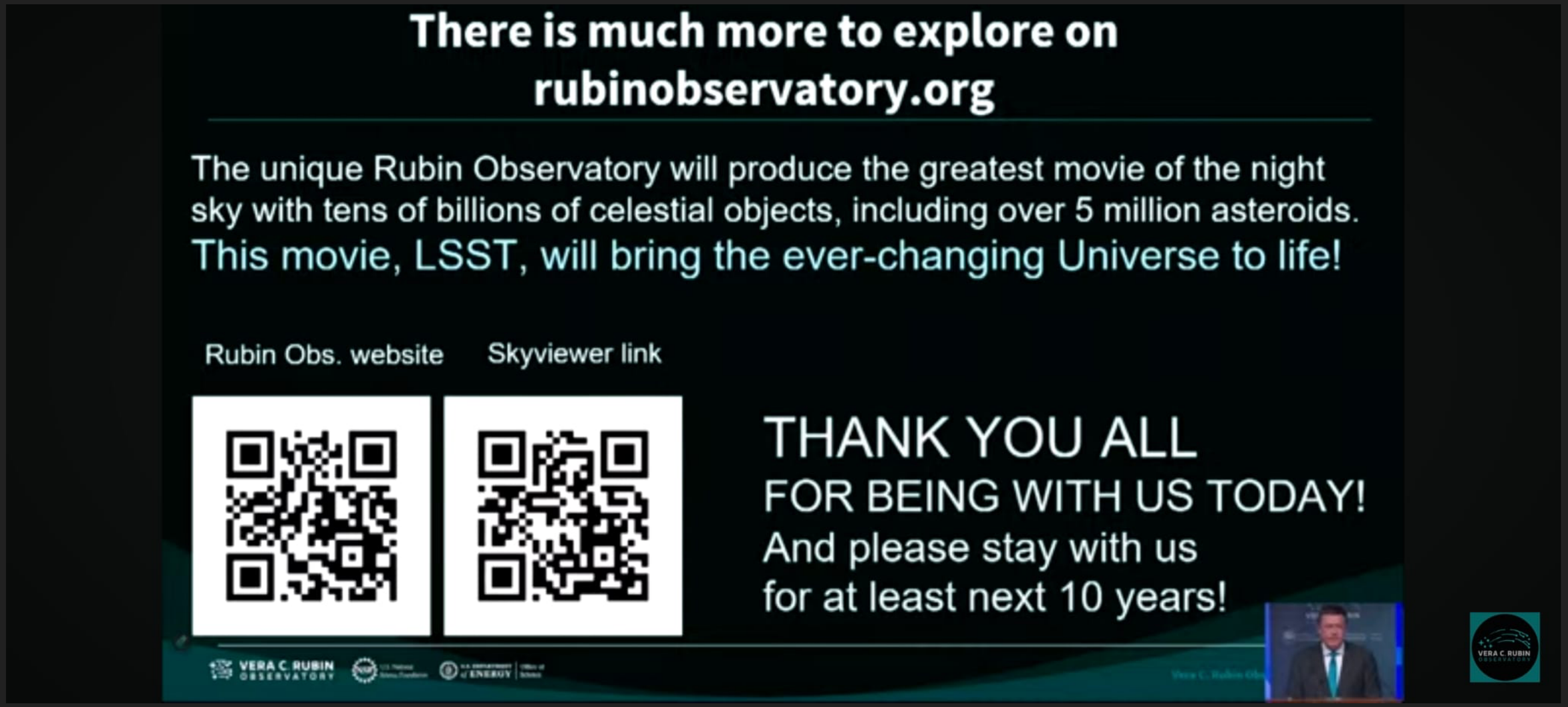
The LSST (and large telescopes) era

The LSST (and large telescopes) era



The LSST (and large telescopes) era

Check the press release: https://noirlab.edu/public/news/noirlab2521/?nocache=true&



Brokers: Fink

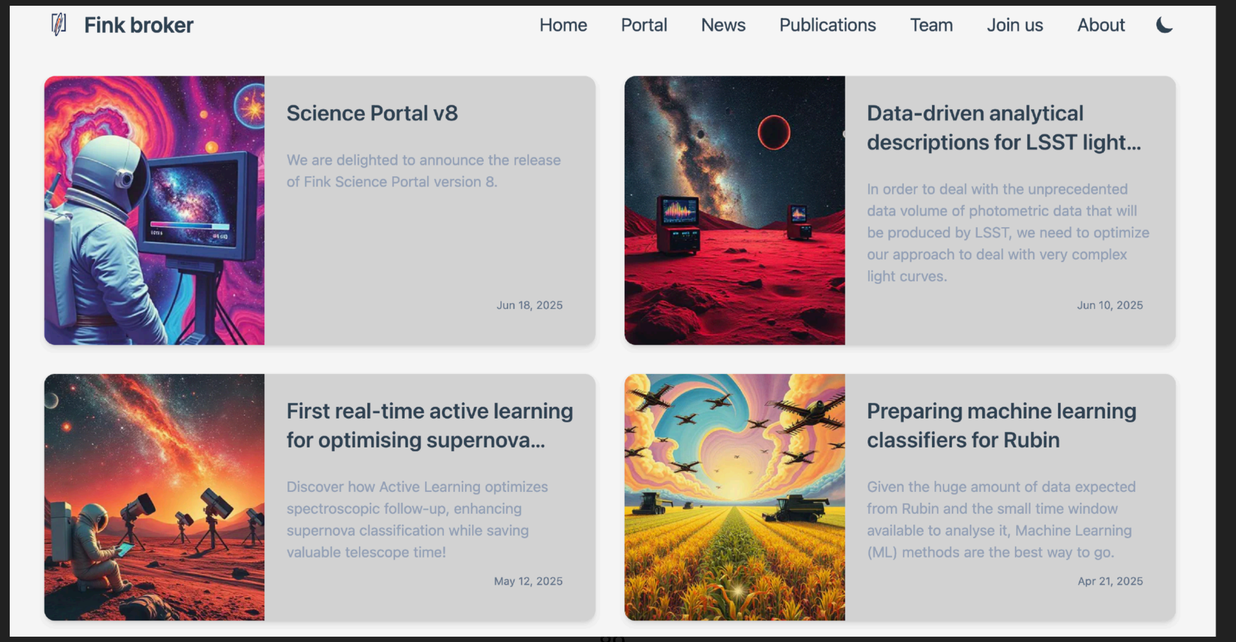
- Processes **time-domains alert** streams and connects them with **follow-up facilities** and science teams

- Fink broker has been selected as a **community broker to process the full stream of transient alerts from the Vera C. Rubin Observatory**

  - Since 2020, processing the alert stream from the Zwicky Transient Facility (ZTF).

We want Fink to be able to *filter, aggregate, enrich, consume* incoming data streams or otherwise *transform* into new streams for further consumption or follow-up processing. Following LSST LDM-612, Fink's ultimate objectives are (no specific order):

- redistributing alert packets
- filtering alerts
- cross-correlating alerts with other static catalogs or alert stream
- classifying events scientifically
- providing user interfaces to the data
- coordinating scientific activity among collaborators
- triggering followup observing
- for users with appropriate data rights, facilitating followup queries and/or user-generated processing within the corresponding Data Access Center
- managing annotation & citation as followup observations are made
- collecting classification and other information gathered by the scientific community



https://fink-broker.org/

Take-home message

- Canary Island observatories **plenty of optical/IR facilities**
- **Joint optical-gamma** observations are key for many sources
  - Special interest in the case of transient/variable events
  - Optical can help you:
    - Trigger your gamma-ray observations
    - Constraint different parameters -> modeling
- Make use of public tools and pages (AAVSO, SED builder), alerts

aloramas@iac.es