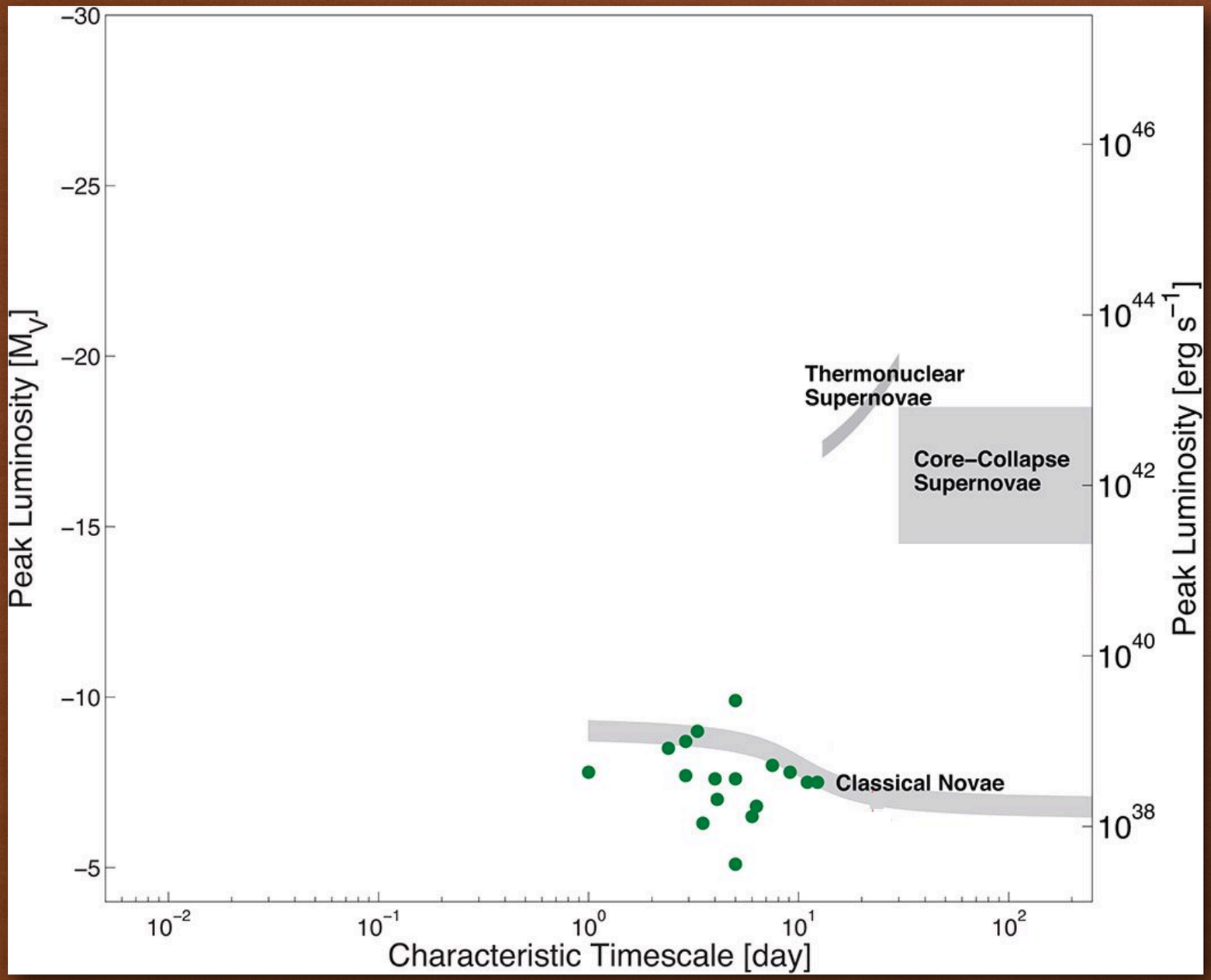
I RIVELATORI NELL'OTTICO DEL PROSSIMO FUTURO

ENRICO CAPPELLARO

Istituto Nazionale di Astrofisica
Osservatorio Astronomico di Padova

THE TRANSIENT SKY

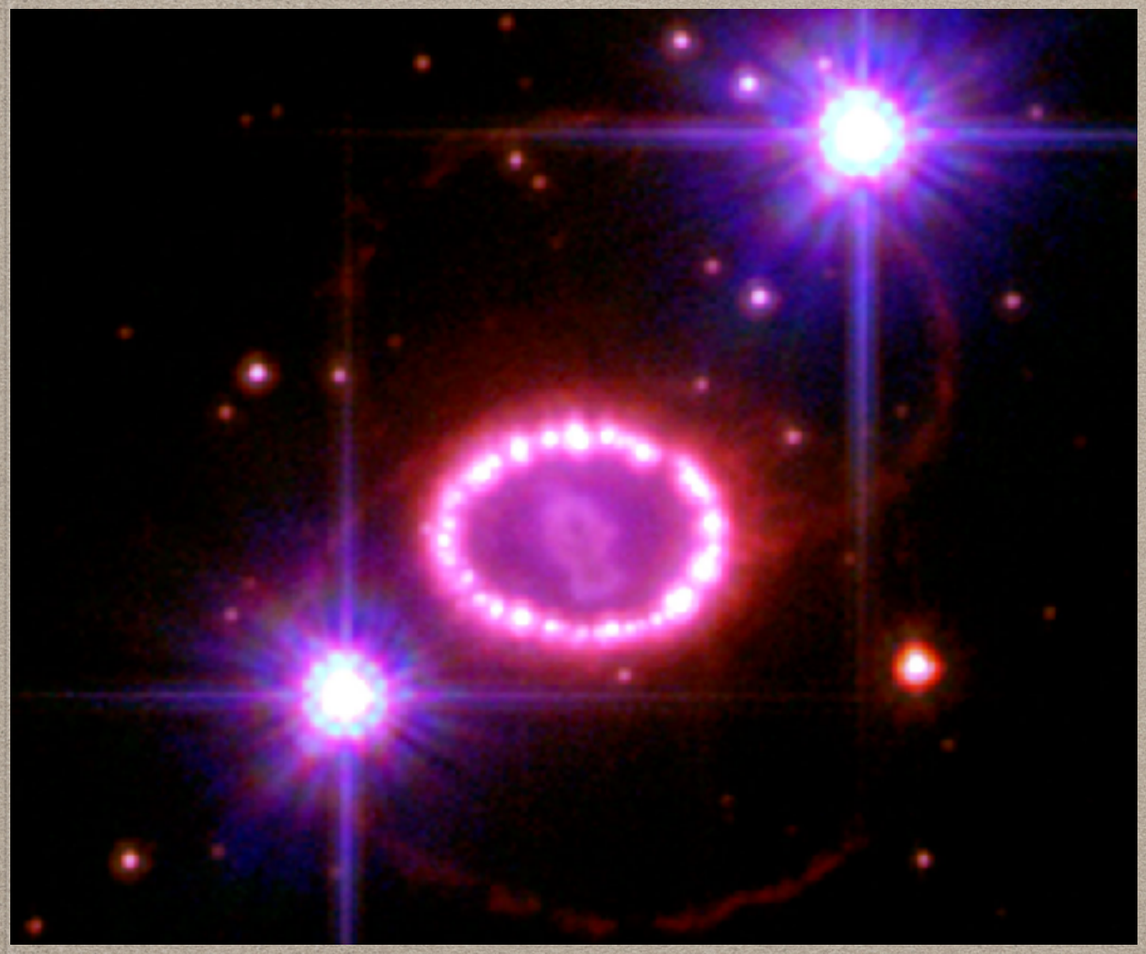
XX CENTURY



adapted from Nugent 2015

TRANSIENTS AND MULTI-MESSENGER

SN 1987A IN LMC



Progenitor direct identification

1-2 dozen progenitor detections

Detection of two dozen neutrinos

still unique

where is the neutron star (or the BH) ?

TRANSIENTS AND MULTI-MESSENGER

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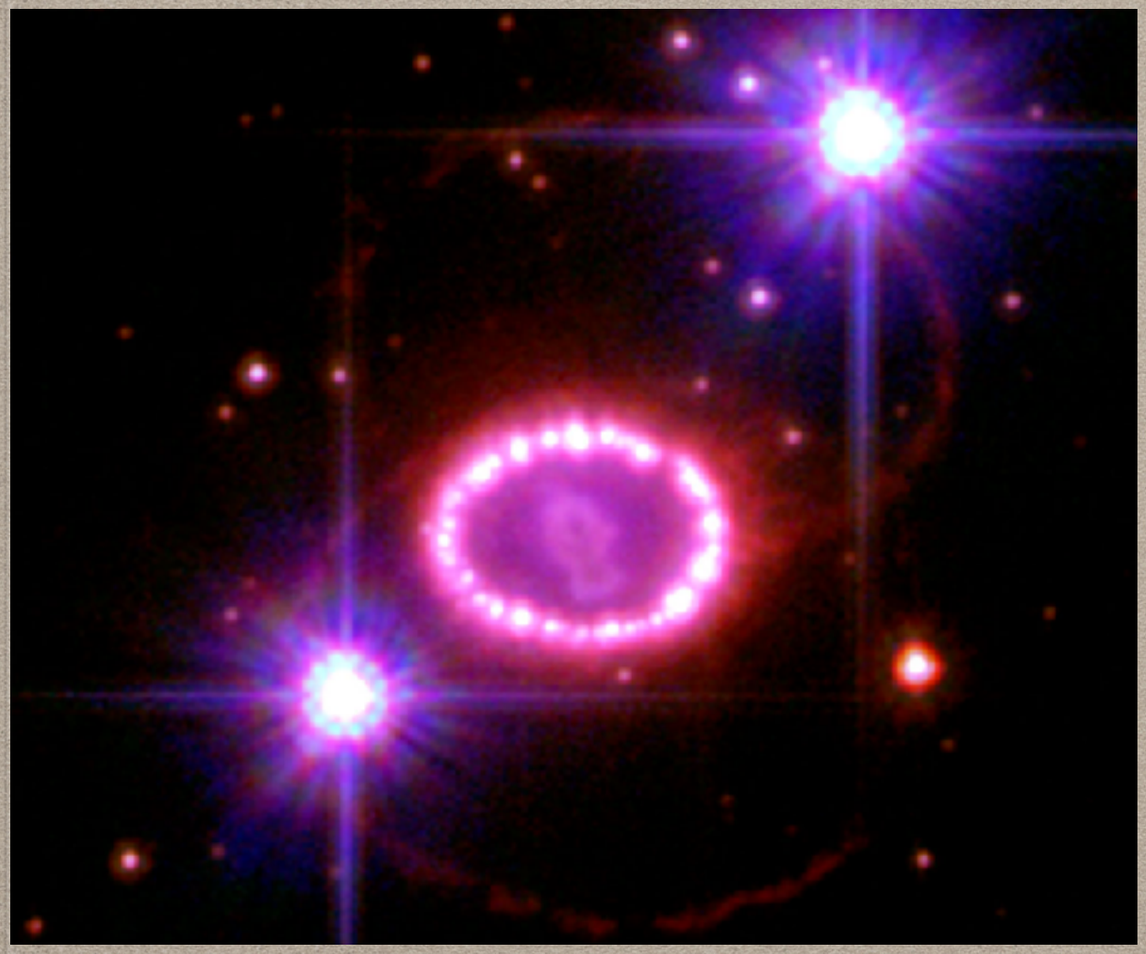

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1985 Super-Kamiokande upgraded
1987 Nearest optical SN in ~400yr

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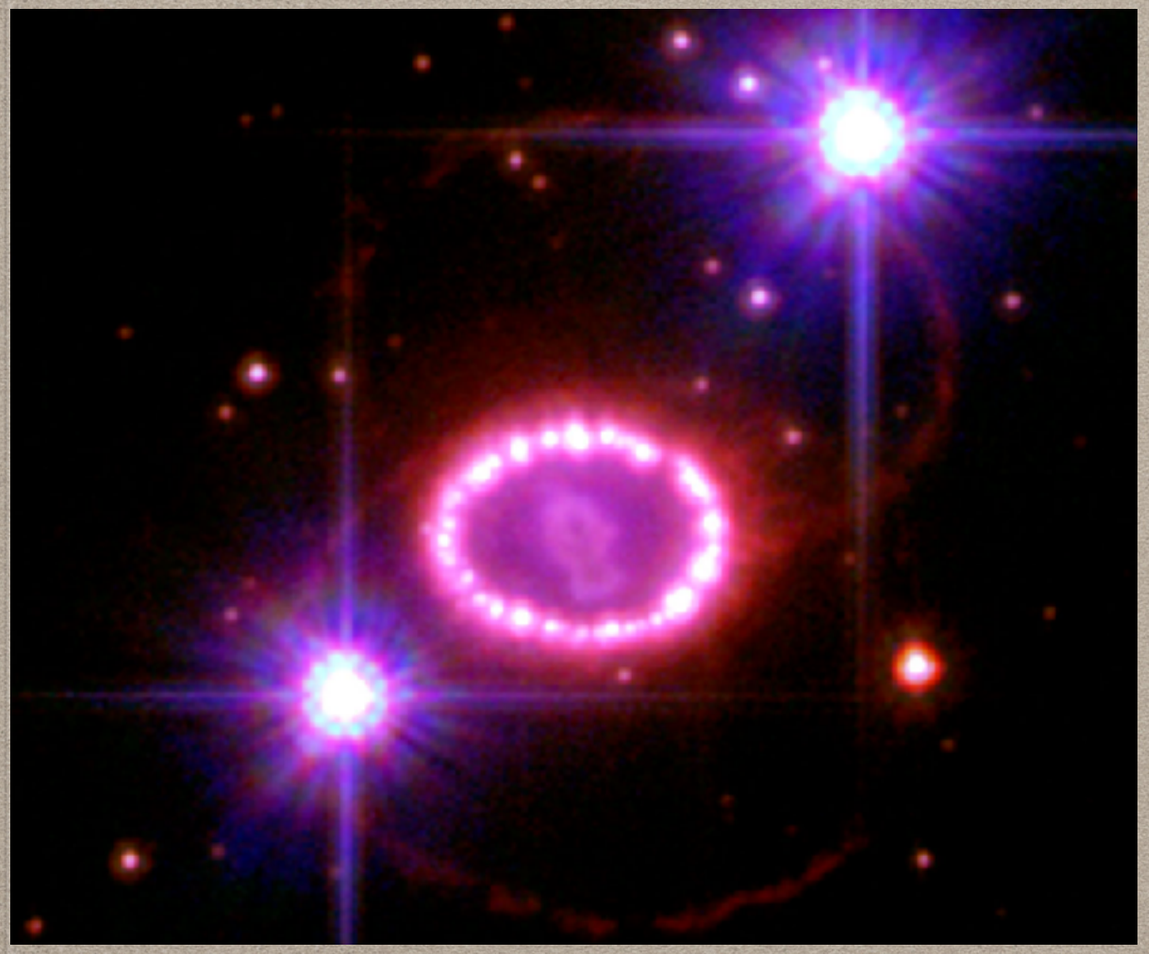


Progenitor direct identification

1-2 dozen progenitor detections

Detection of two dozen neutrinos *still unique*

where is the neutron star (or the BH) ?

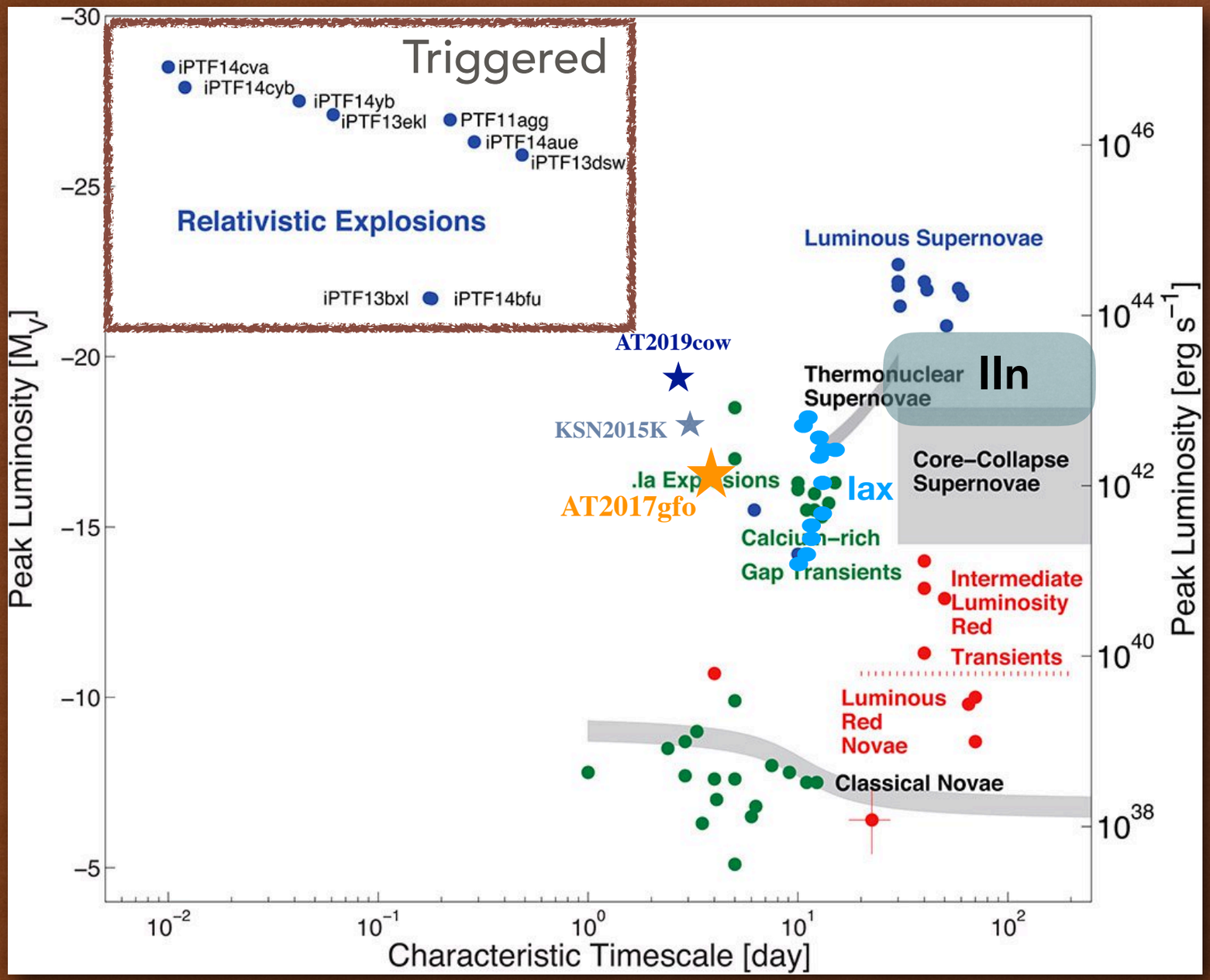
1985 Super-Kamiokande upgraded
1987 Nearest optical SN in ~400yr

Schmitz & Gaskell 1988: ..... very common SN type .....

Pastorello et al 2012: ..... 1-3% of all core-collapse

THE TRANSIENT SKY

2020



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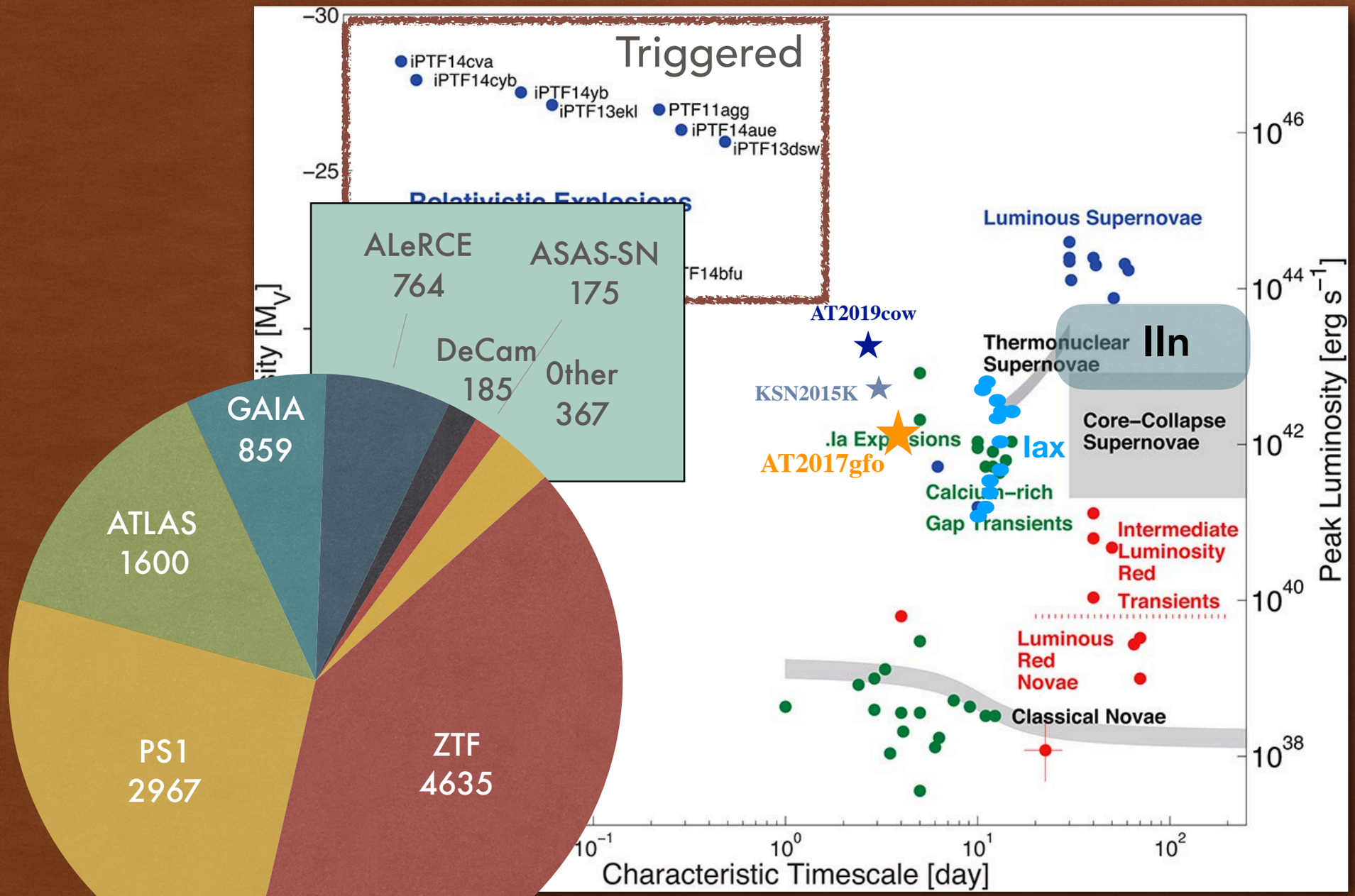
THE TRANSIENT SKY

2020

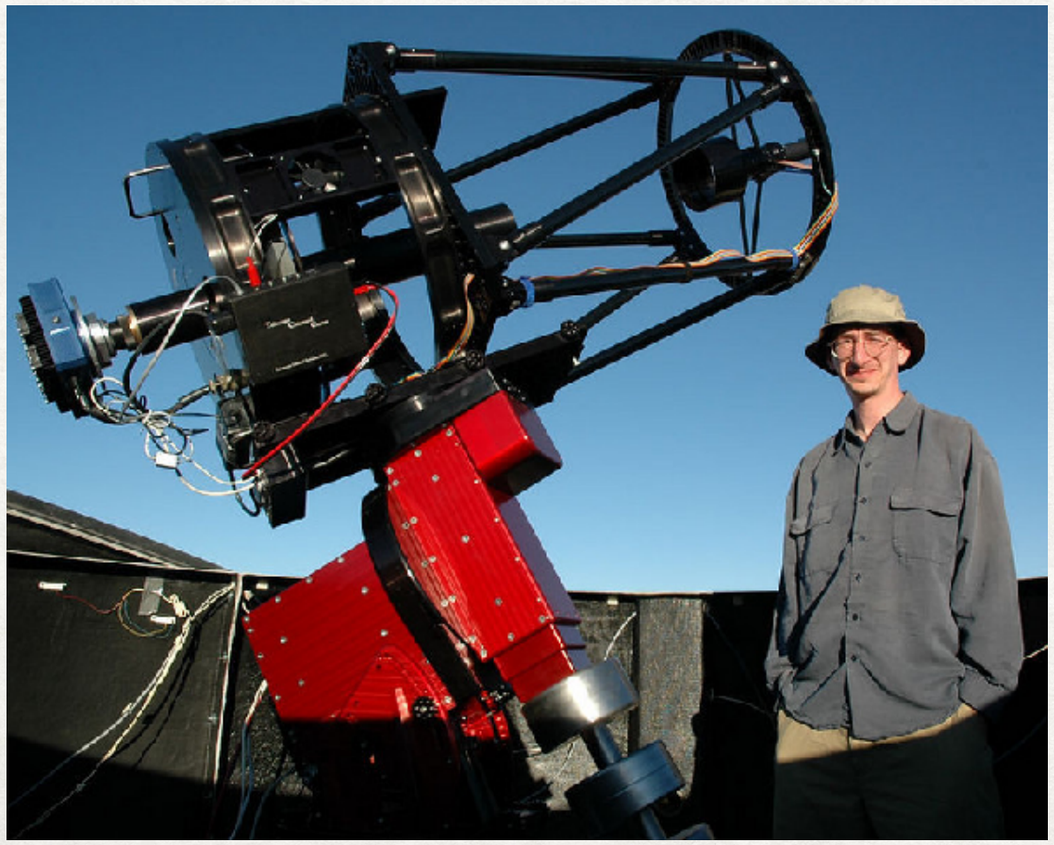


adapted from Nugent 2015

INSTRUMENTS FOR TRANSIENTS

10 cm .... 10 m

PROMPT 40 CM



VLT 8.2M

FOCUSING ON OPTICAL COUNTERPARTS OF GWS

SEARCH

- wide field
- galaxy targeted

IDENTIFY

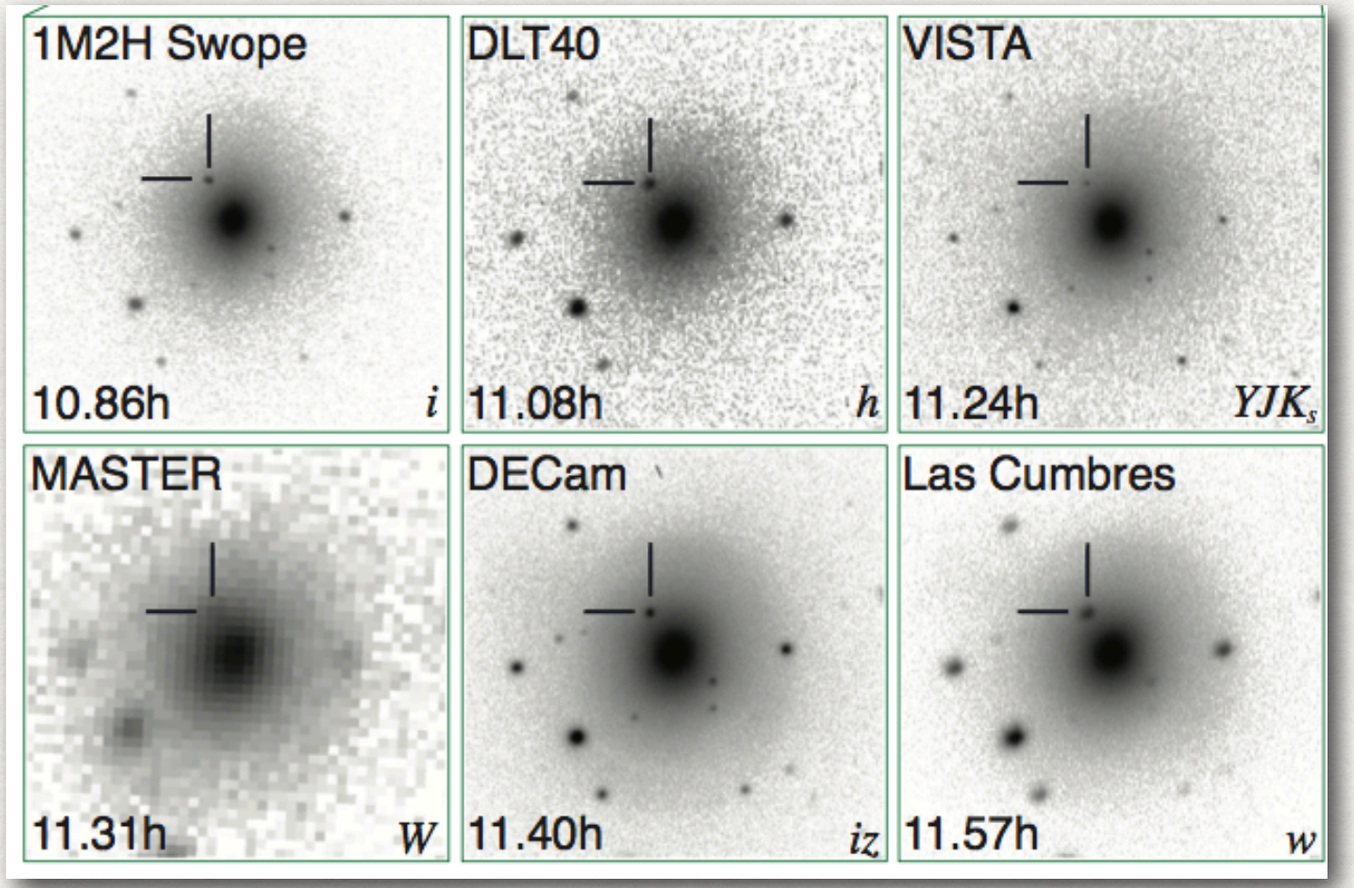
- light curve & colors
- low resolution spectroscopy

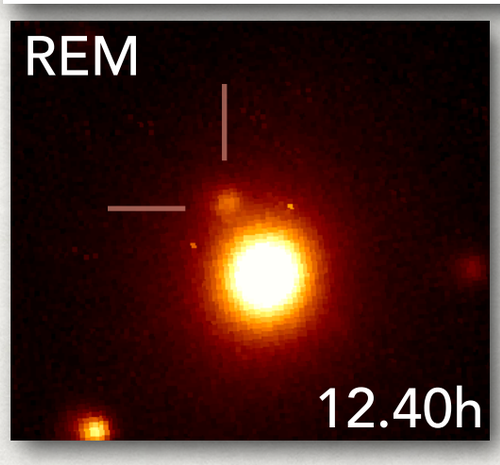
FOLLOW-UP

- multi-band light curve
- high S/N optical/infrared spectroscopy
- integral field spectroscopy
- polarimetry
- high resolution imaging

DISCOVERY OF THE KILONOVA

SSS17A = DLT17CK = AT2017GFO





	UT	phase
GW detection	12:41	0.00
Sunset in Chile	22:27	9.77
optical discovery	23:33	10.87
Twilight	23:40	10.98
discovery GCN	01:05	12.40

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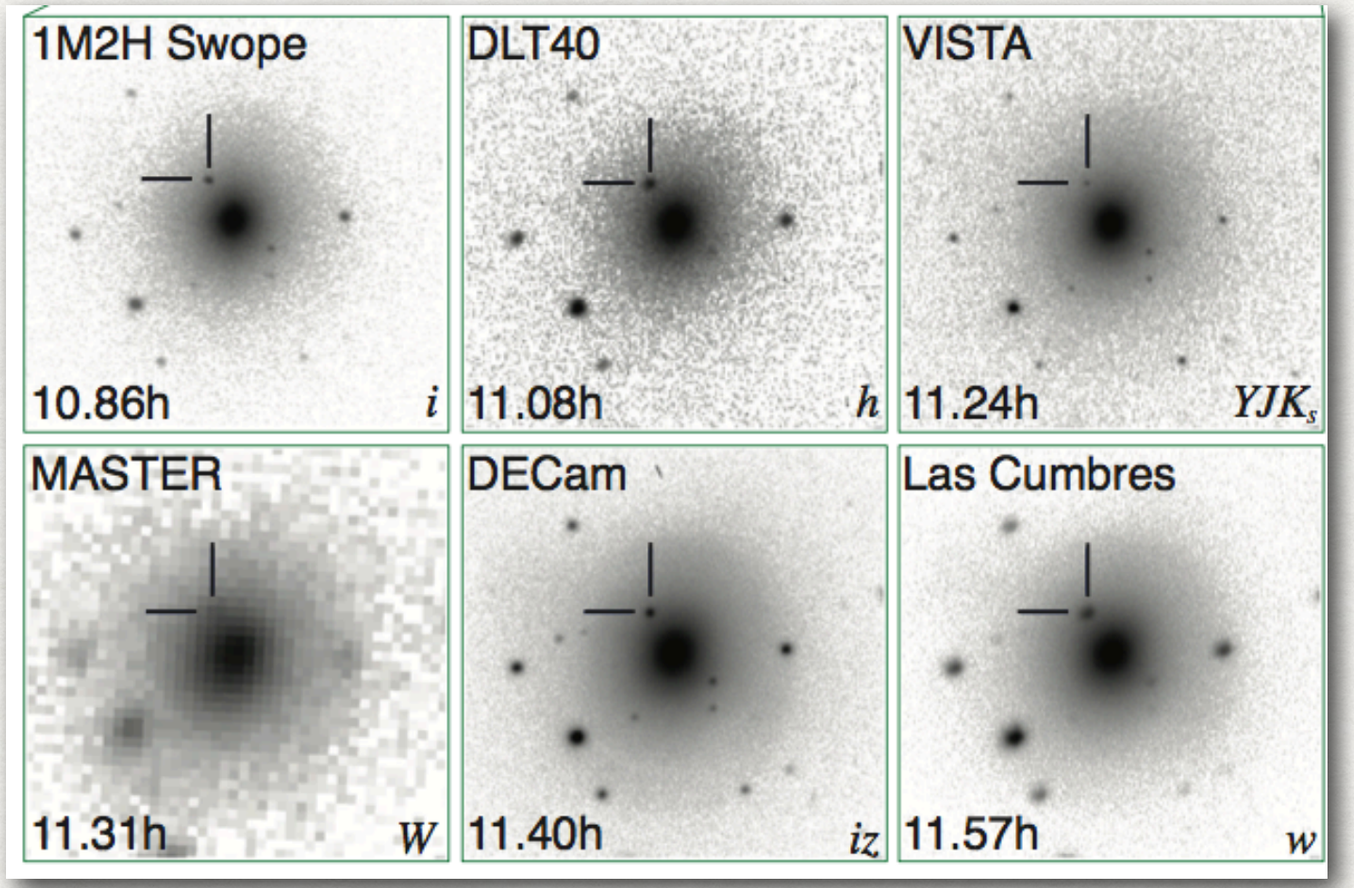

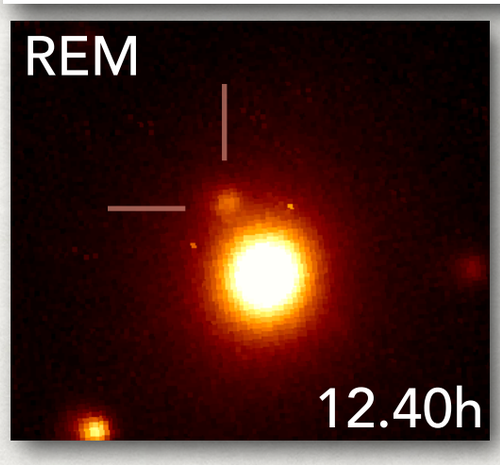

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KILONOVAE ARE EASY TO FIND

DISCOVERY OF THE KILONOVA

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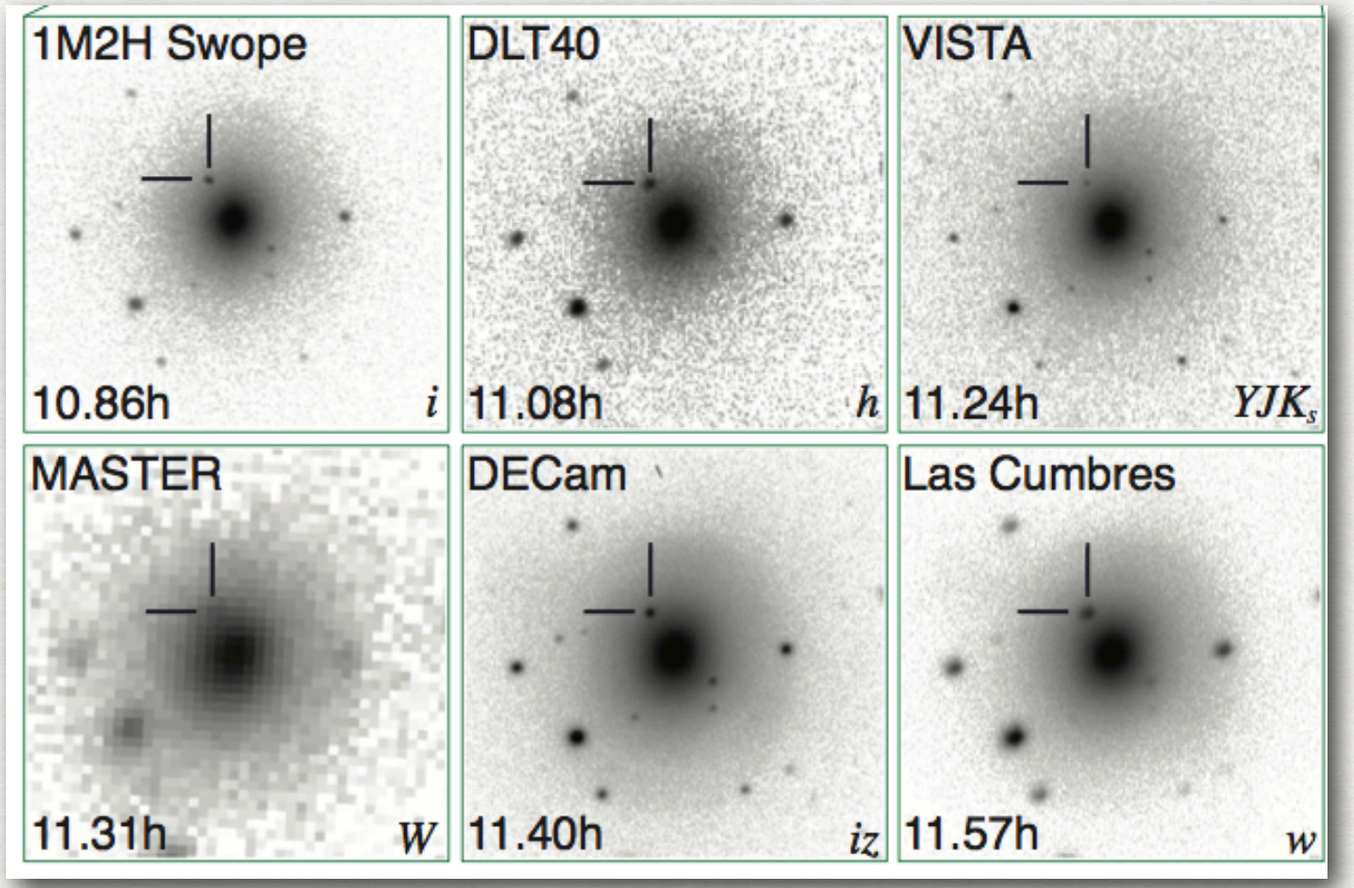

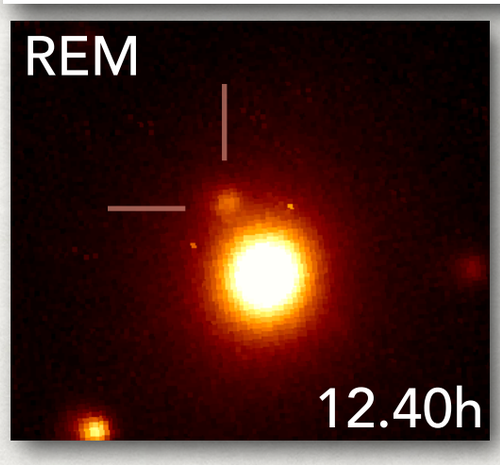

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ESO PARANAL (CHILE)

UT1 (Antu)

NACO
FORS2
KMOS

UT2 (Kueyen)

FLAMES
X-SHOOTER
UVES

UT3 (Melipal)

SPHERE
VISIR
CRIRES (2019)

VST

OmegaCAM

UT4 (Yepun)

AOF
HAWK-I
SINFONI
MUSE

LGSF

4LGSF

VISTA

VIRCAM

VLT

Incoherent combined
Coudé focus:
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VLTI

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GRAVITY
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VST 2.6m

1 sq.deg

0.21 arcsec/pix

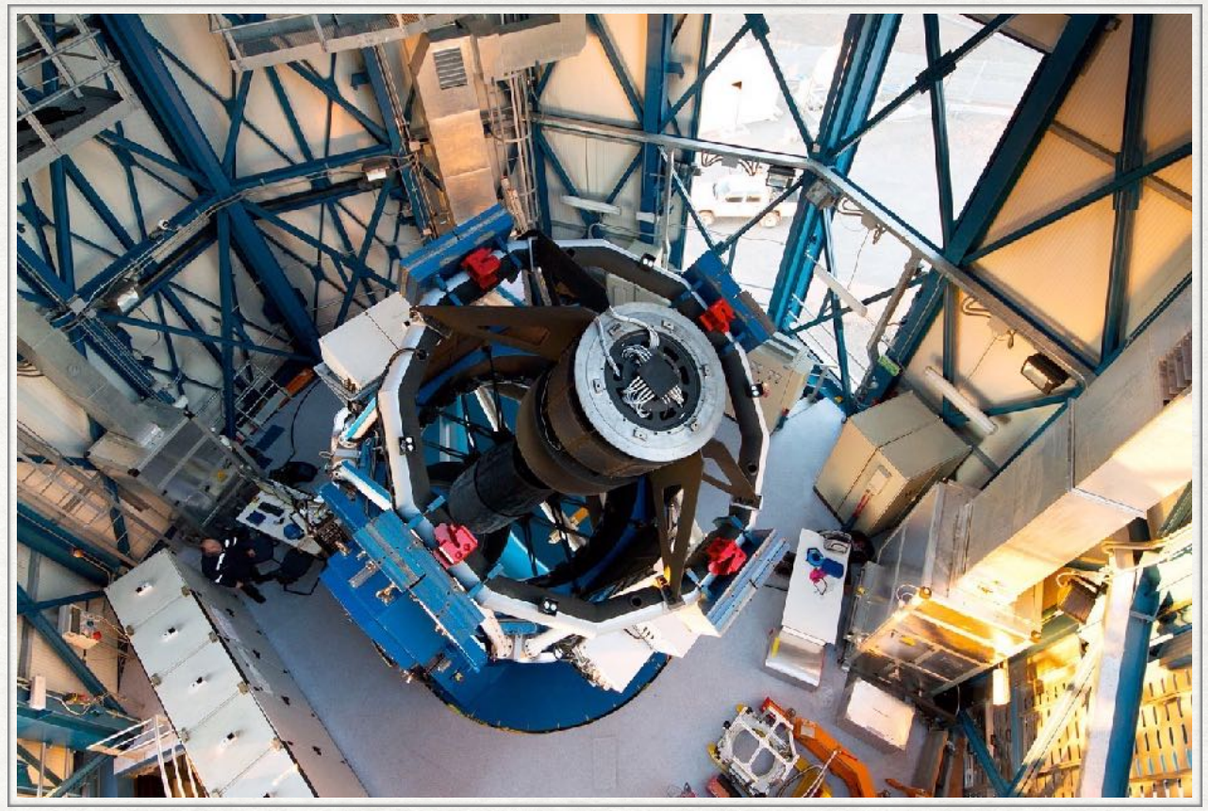
STRENGTHS

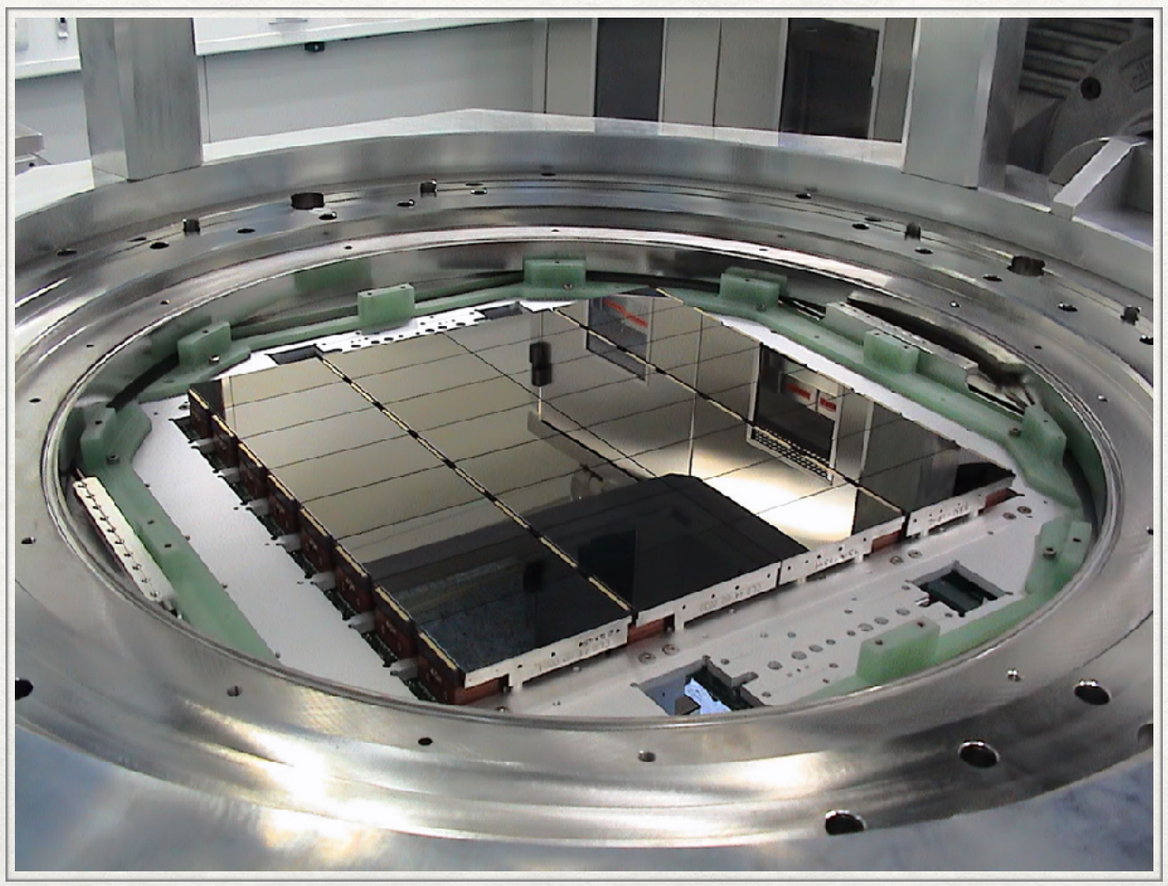
LOCATION

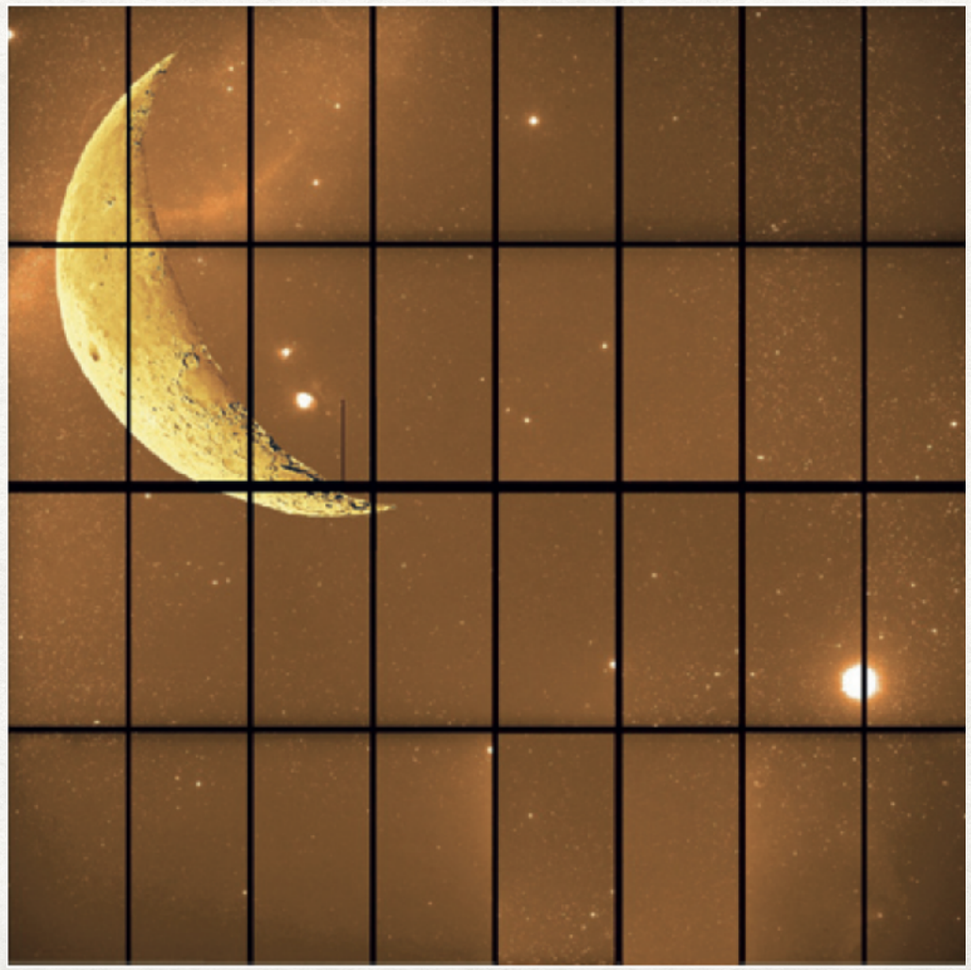
DEPTH

RESOLUTION

OPERATION MODE







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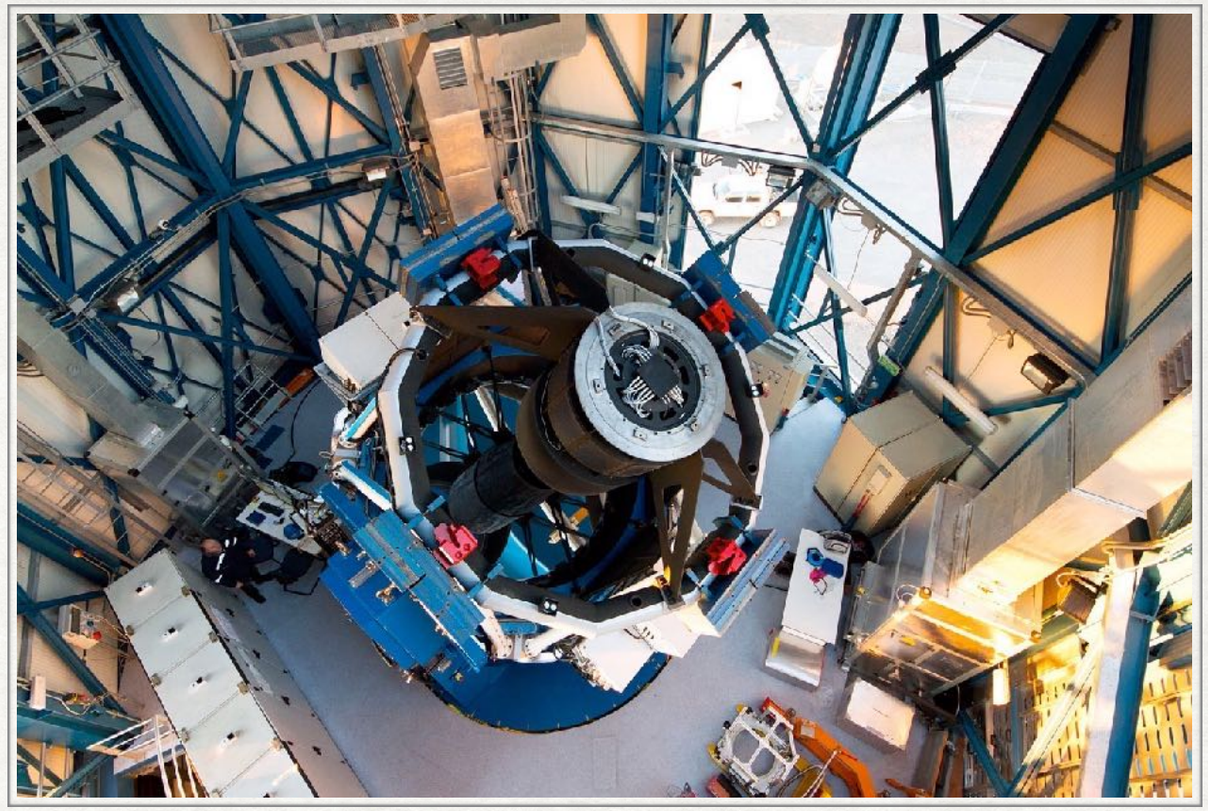
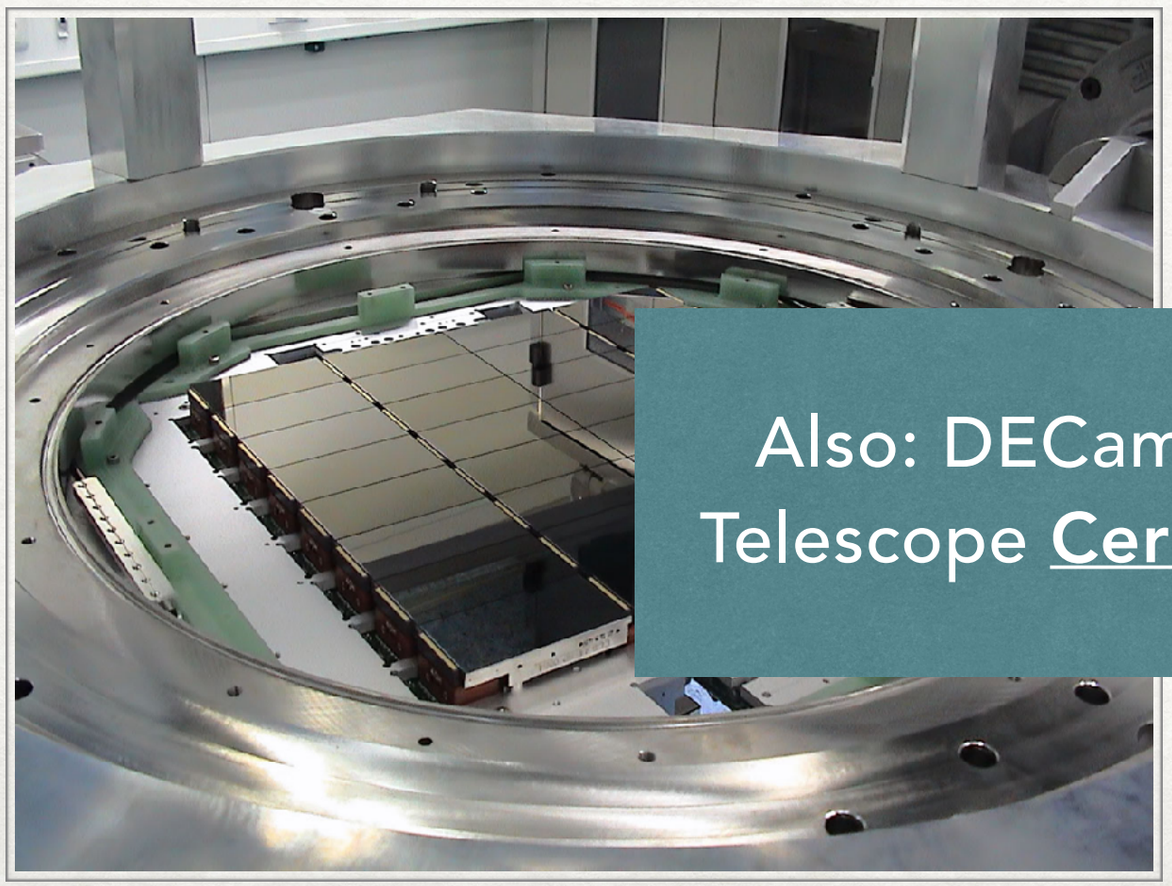




Also: DECam at the **4m** Blanco Telescope **Cerro Tololo** (**3 sq.deg**)

The bottle neck is transient classification

BRIGHT

Asiago 1.8m + AFOSC

Padova-Asiago Supernova Group

Home
About the Group
Asiago Supernova Catalogue
Supernova Classifications
• SN this year
• SN full list
• other transients
ESO/TNG Large Programs

Group reserved
SNGROUP
SUDARE

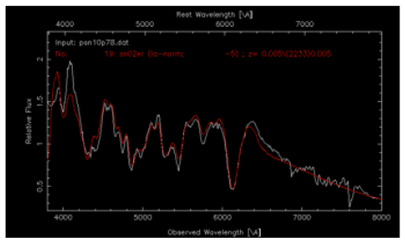
External links
GELATO
PESSTO

The Asiago Transient Classification Program

Presentation
The program started in 2011 with the aim to classify all transients that are accessible from Asiago and are bright enough for our telescope/instrumentation. We use mainly the 1.82m Copernico telescope of Cima Ekar and, if not available, the 1.22m Galileo telescope of the Pennar station. Occasionally transients classified by our group with other facilities (eg. TNG) are included in the database.
Transient classification information and spectra (fits format) are made immediately available at our site. The spectra are semi-automatic reduction with archive calibration data. Please keep this in mind when using them.
For SN classification we compare the output of two automatic SN classification codes: Gelato (Harutyunyan et al. 2008, A&A 488, 383) and SNID (Blondin and Tonry 2007, Ap.J. 666, 1024).

Last transient observed

2013eu=PSN J10242231+7836235 in UGC 5609
Discovered by: G. Cortini
L. Tomasella, A. Pastorello, S. Benetti, E. Cappellaro, P. Ochner and M. Turatto, Osservatorio Astronomico di Padova, Istituto Nazionale di Astrofisica, report that an optical spectrogram of PSN J10242231+7836235 = SN 2013?? (range 340-820 nm; resolution 1.3 nm) obtained on Aug 12.82 UT with the Asiago\ 1.82-m Copernico Telescope (+ AFOSC), shows it to be normal type-Ia supernova. Adopting for the host galaxy (UGC 5609) a recessional velocity of 2778 km/s (Falco et al. 1999, PASP 111, 438 via NED), a good match is found with several type-Ia supernovae a few days before the B band maximum light. An expansion velocity of about 13000 km/s is derived from the minimum of the Si II 635nm line. The Asiago classification spectra are posted at URL http://sngroup.oapd.inaf.it; classification was made via GELATO (Harutyunyan et al. 2008, A.Ap. 488, 383) and SNID (Blondin and Tonry 2007, Ap.J. 666, 1024).



Last five entries in database

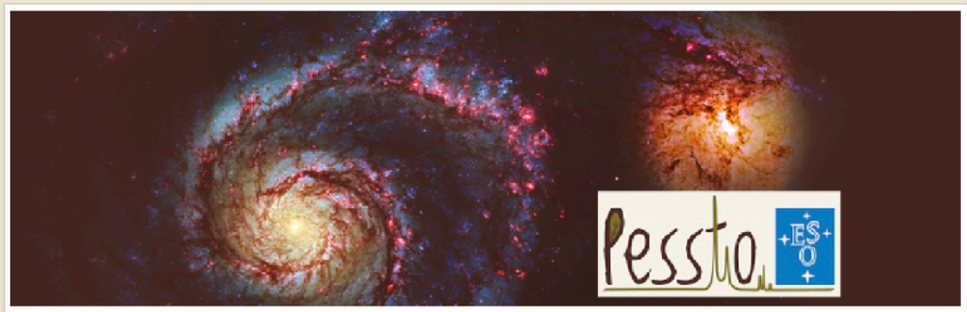
sn	galaxy	RA	DEC	discoverer	type	redshift	ref	class	fits
2013fj	PGC 68419	22:15:28.51	+15:34:04.1	ISSP	Ia	0.033570	CBET3654		fits
2013ff	NGC 2748	09:13:38.8	+76:28:10.8	ISSP	Ic	0.004923	CBET3647		fits
2013ew	anonymous	22:10:09.69	+11:16:47.9	LSSS-SP	Ia-91T like	0.056	CBET3629		fits
2013ev	IC1296	18:53:18.45	+33:03:52.7	ISSP	II	0.017	CBET3627		fits
2013eu	UGC 5609	10:24:22.31	+78:36:23.5	G. Cortini	Ia	0.009266	CBET3625		fits

ESO NTT 3.5m + EFOSC2 + SOFI

- 90n per year : 10n/month
- public survey 2012-2017 - extended 2018-2020

Pessto

home
about
contact
news
feeder surveys
pessto members
classifications (1178)
followup targets (342)
pessto data



1178 transients classified by PESSTO so far

342 transients are being followed by PESSTO

MEDIUM

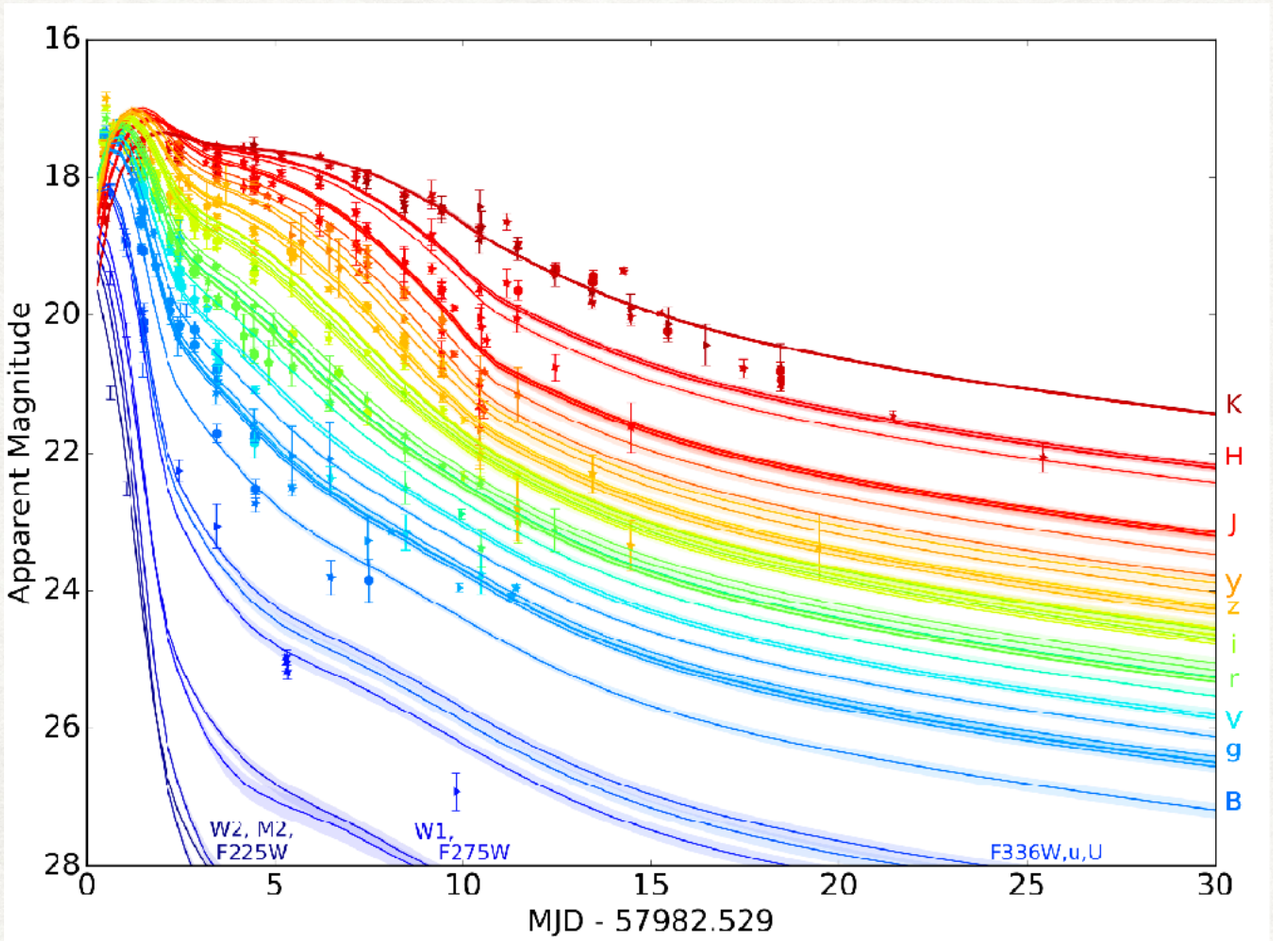
FAINT

ngrave

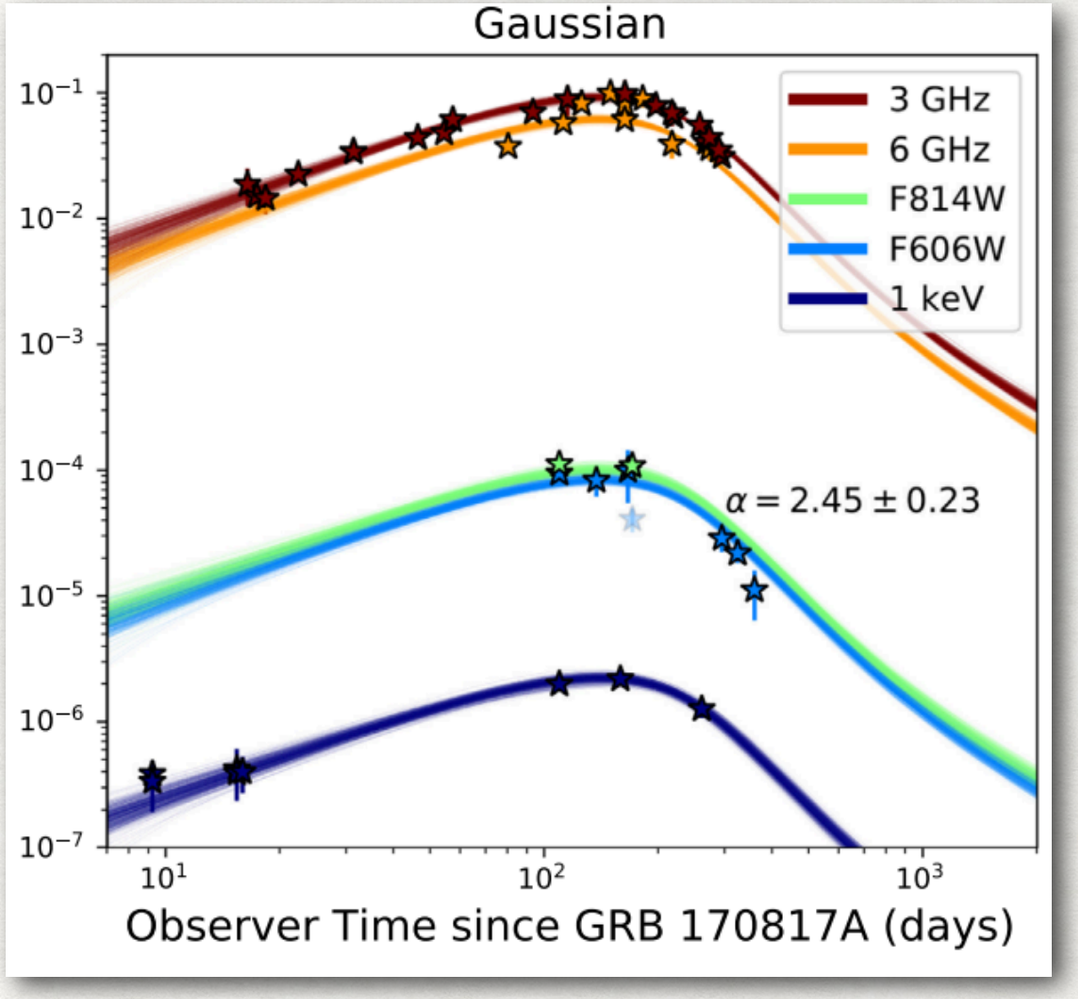
ESO VLT
X-SHOOTER
FORS2

LIGHT CURVE MODELLING

Villar et al. 2018



Lamb et al. 2019



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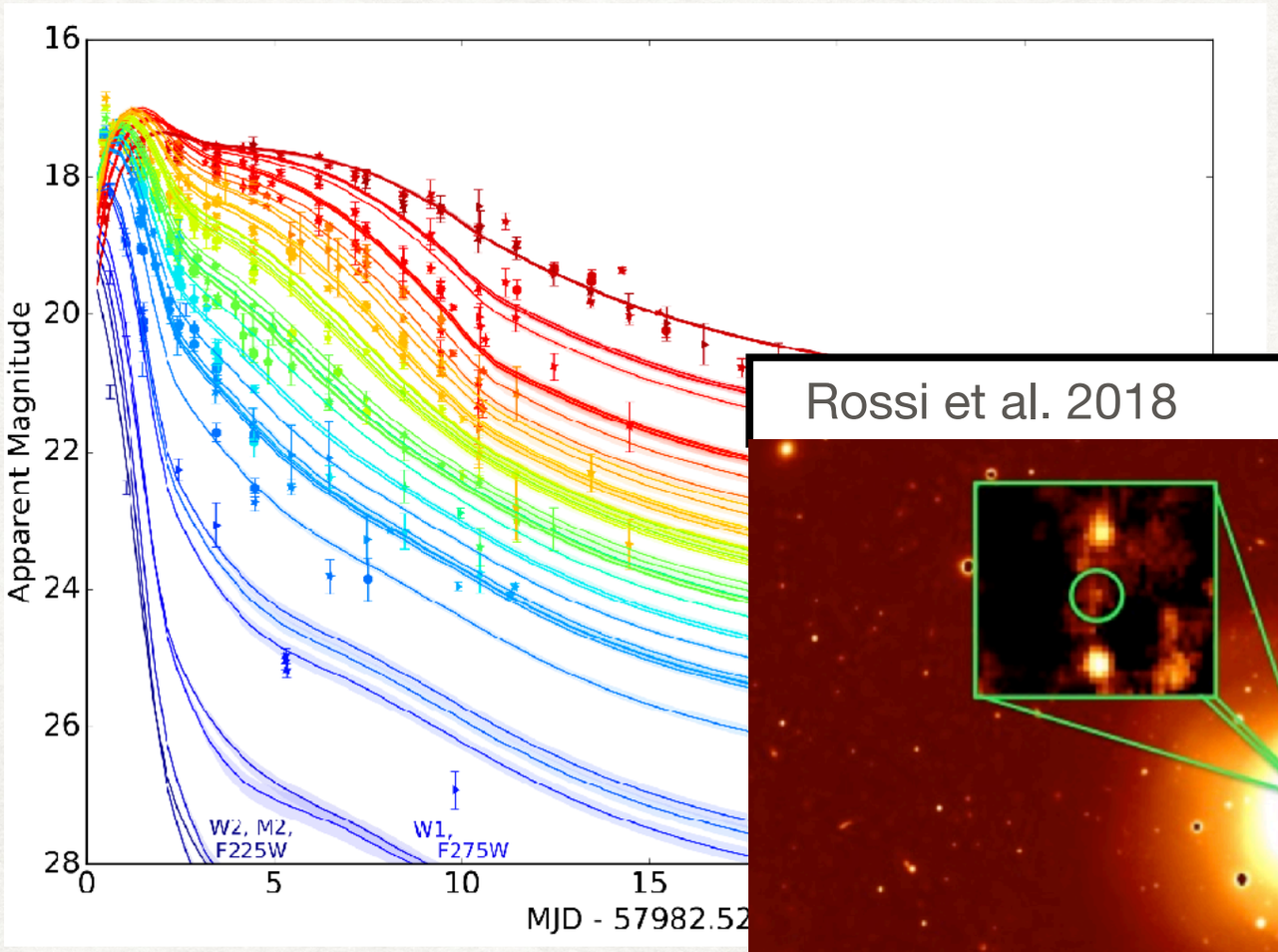
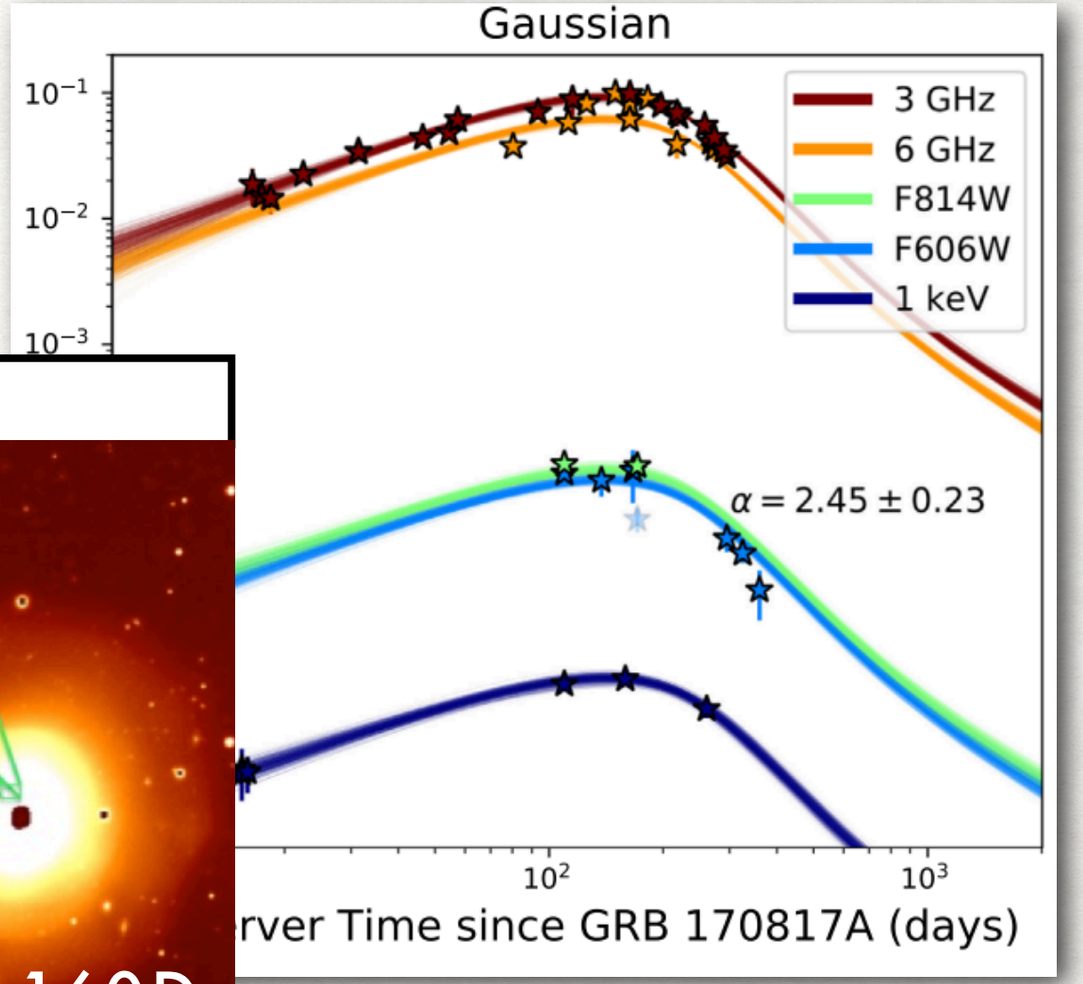


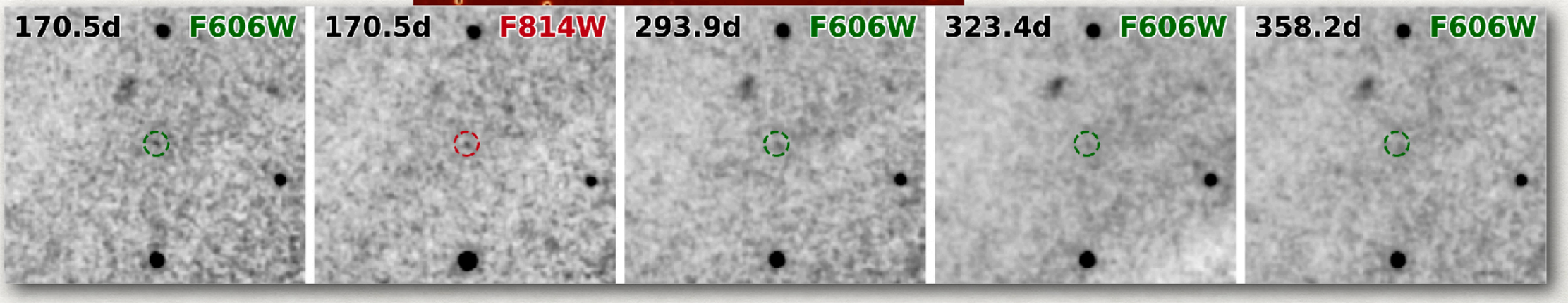
Rossi et al. 2018

Lamb et al. 2019

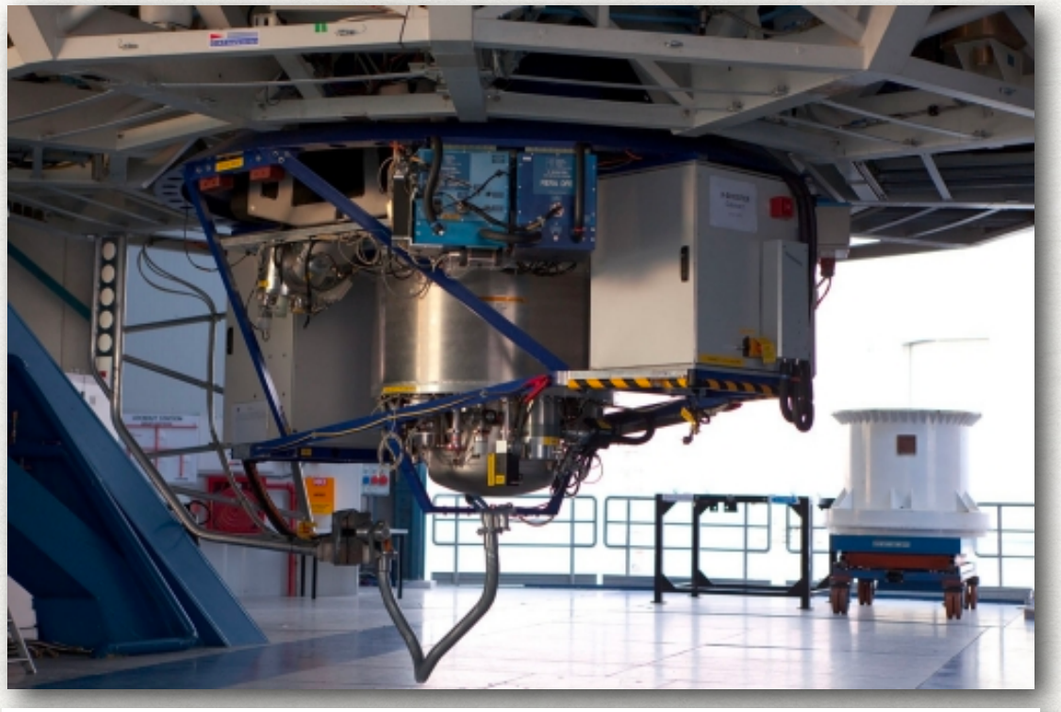


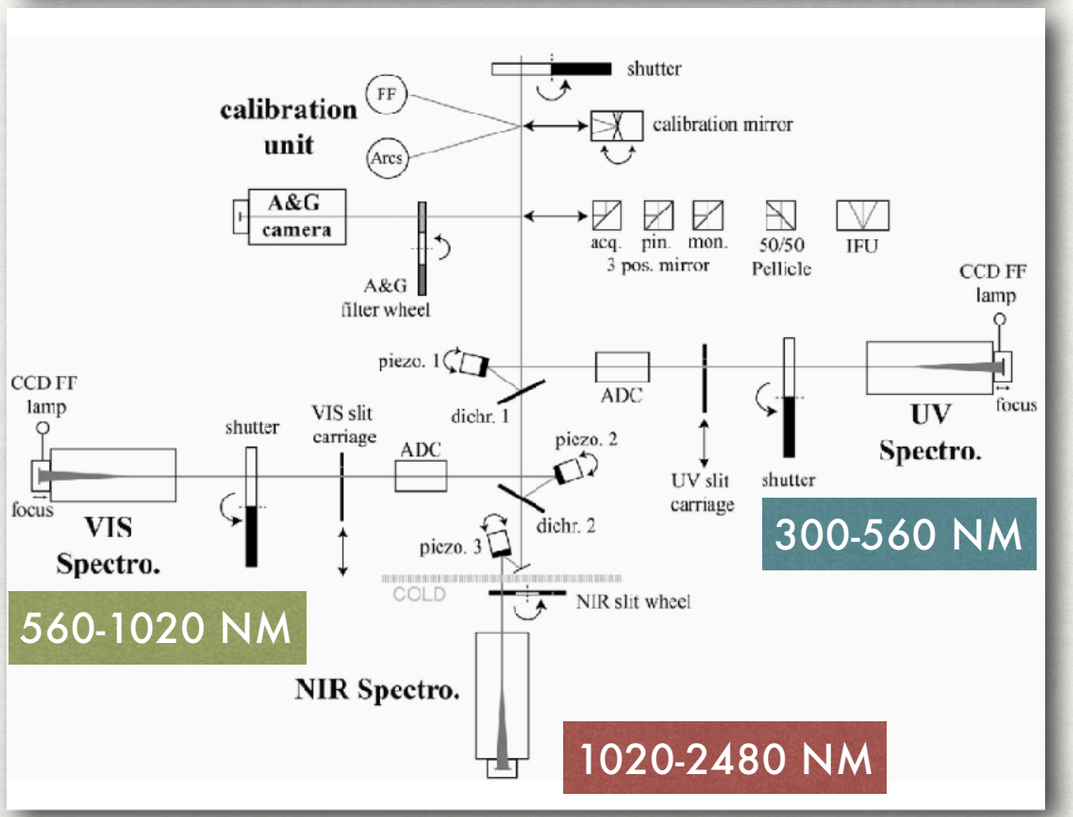
Lamb et al. 2019

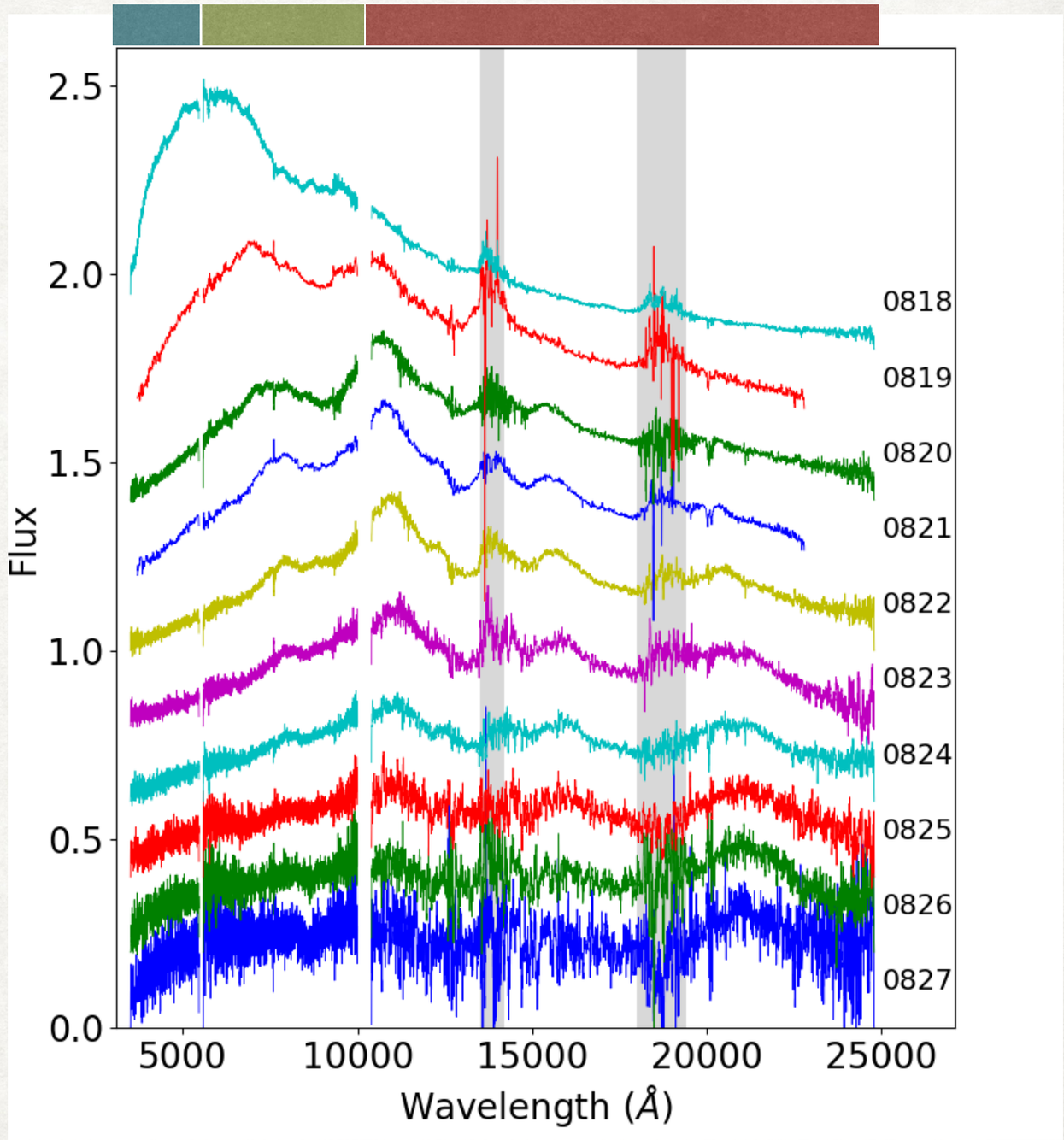
HST



X-SHOOTER FOR THE KILONOVA

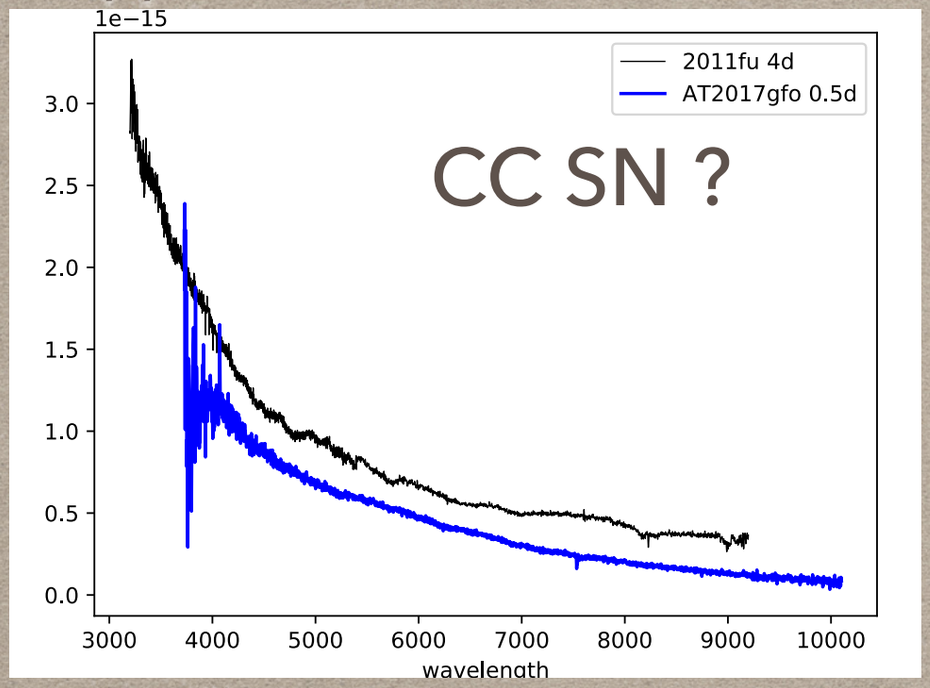






DISCOVERY OF A KILONOVA

Shappee et al. 2017



model by Kasen et al. 2013

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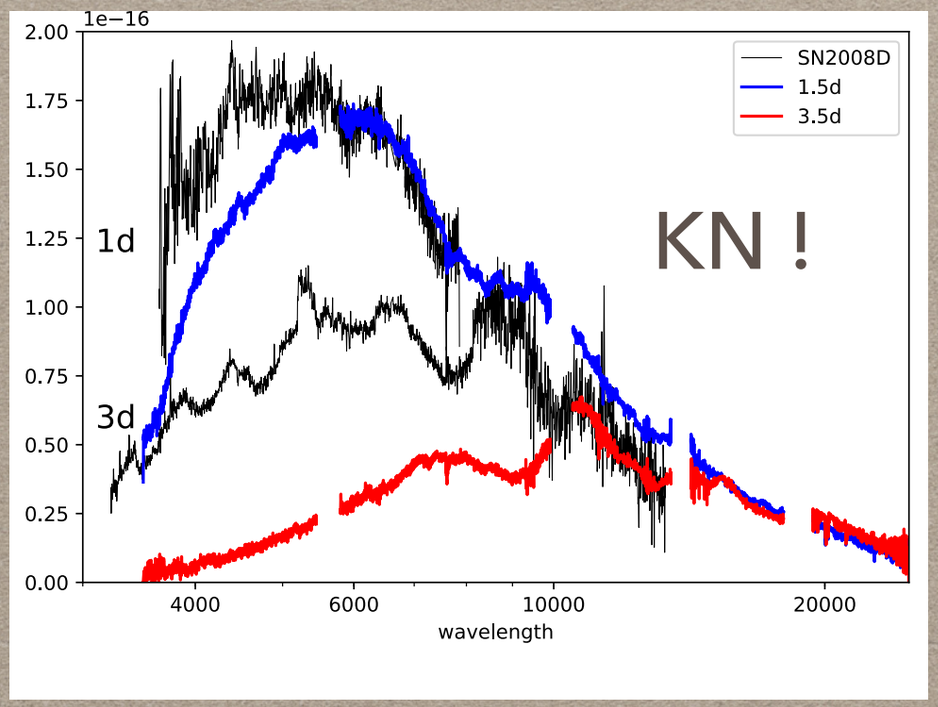

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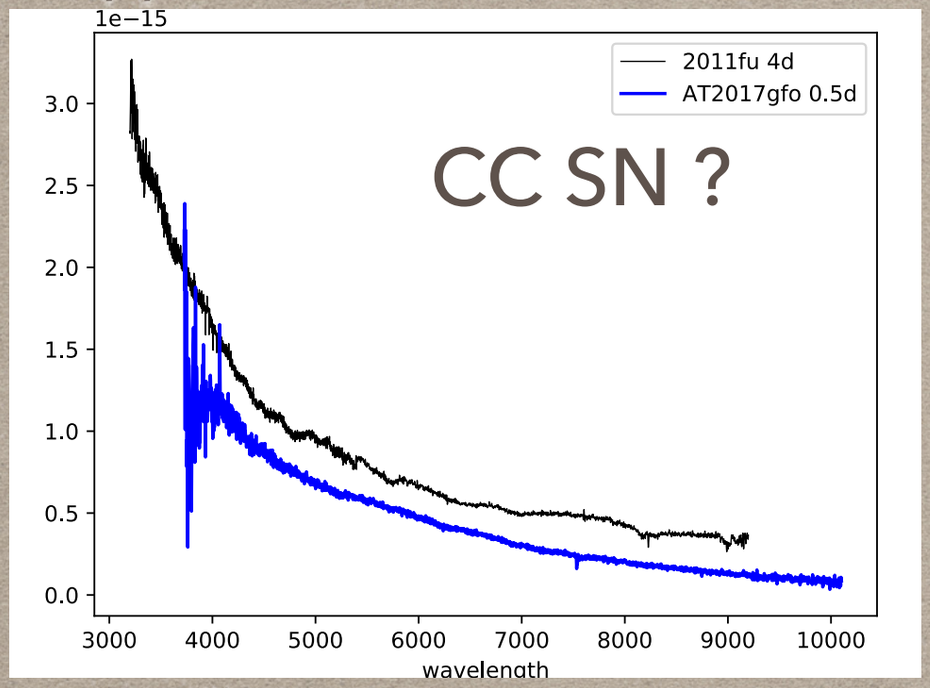

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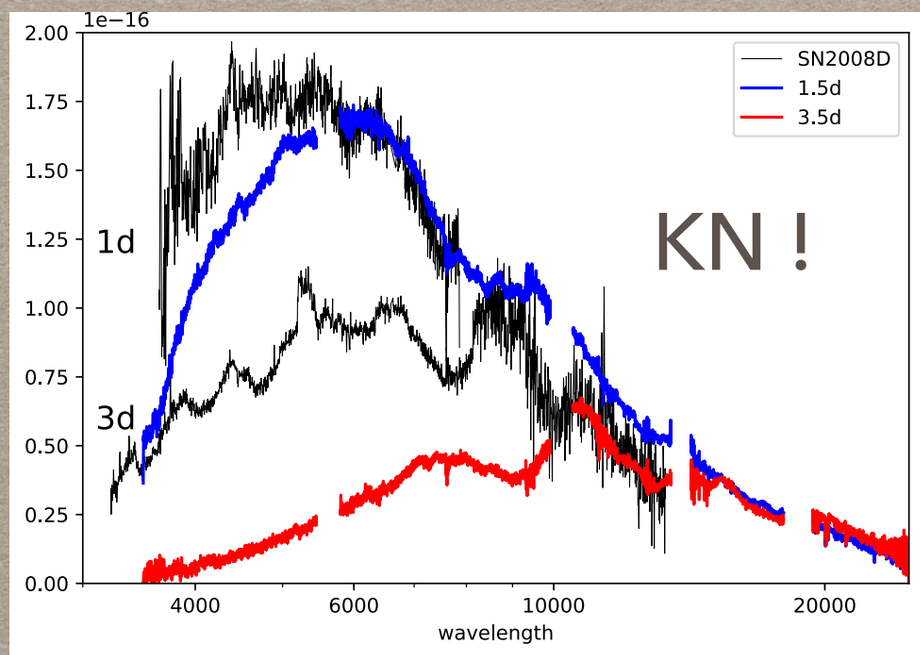

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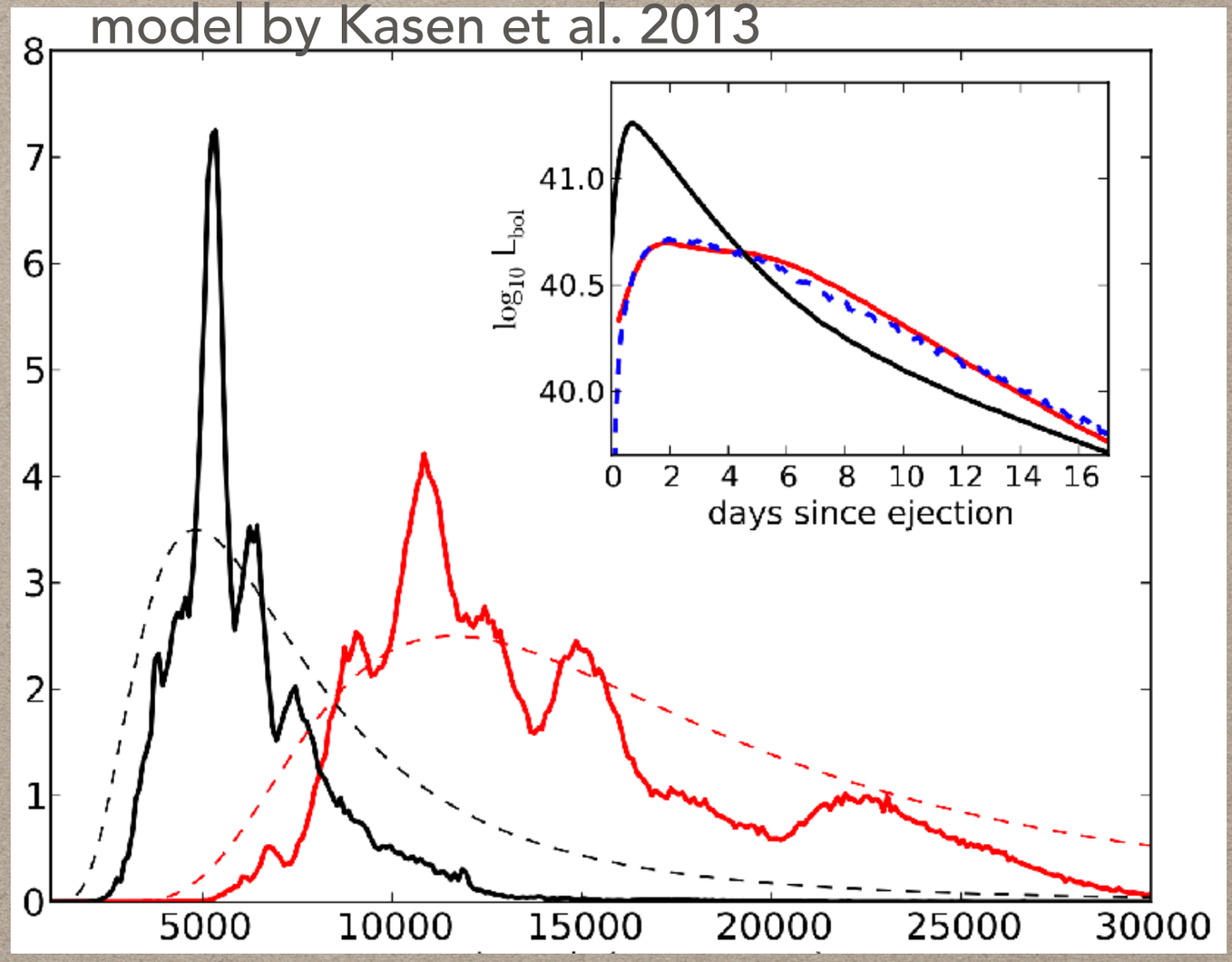

Kilonova models predict nucleosynthesis of r-process elements. Lanthanides dominate radiation transport because of high opacity

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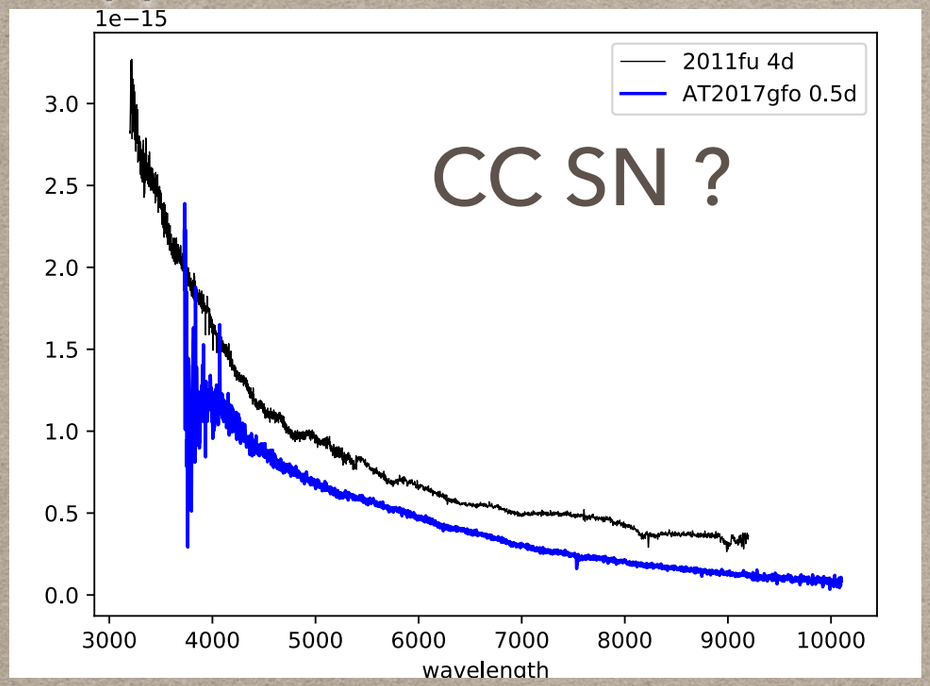

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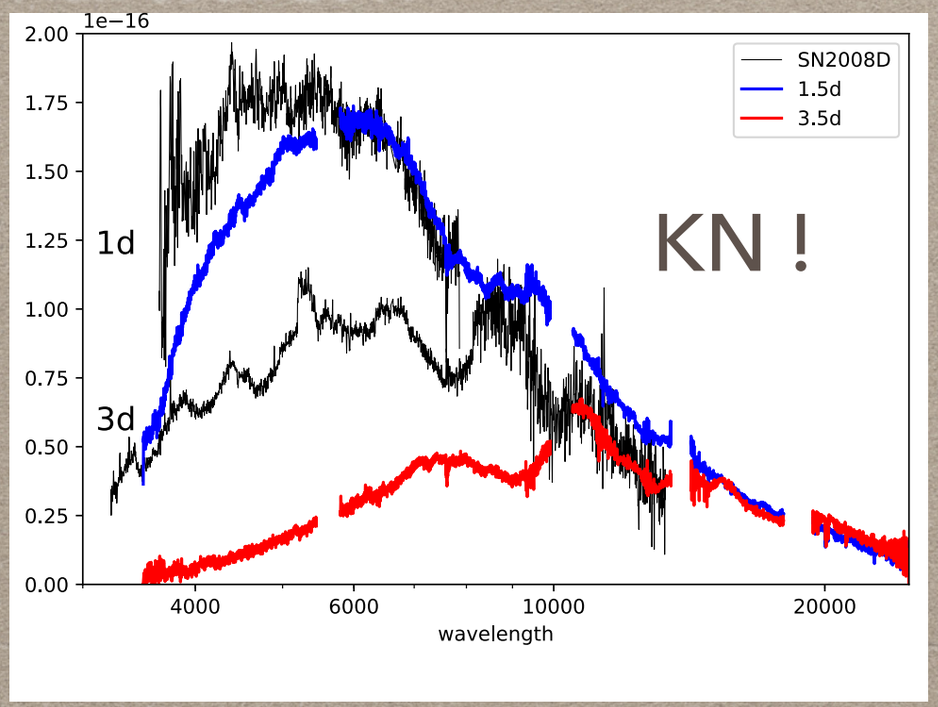

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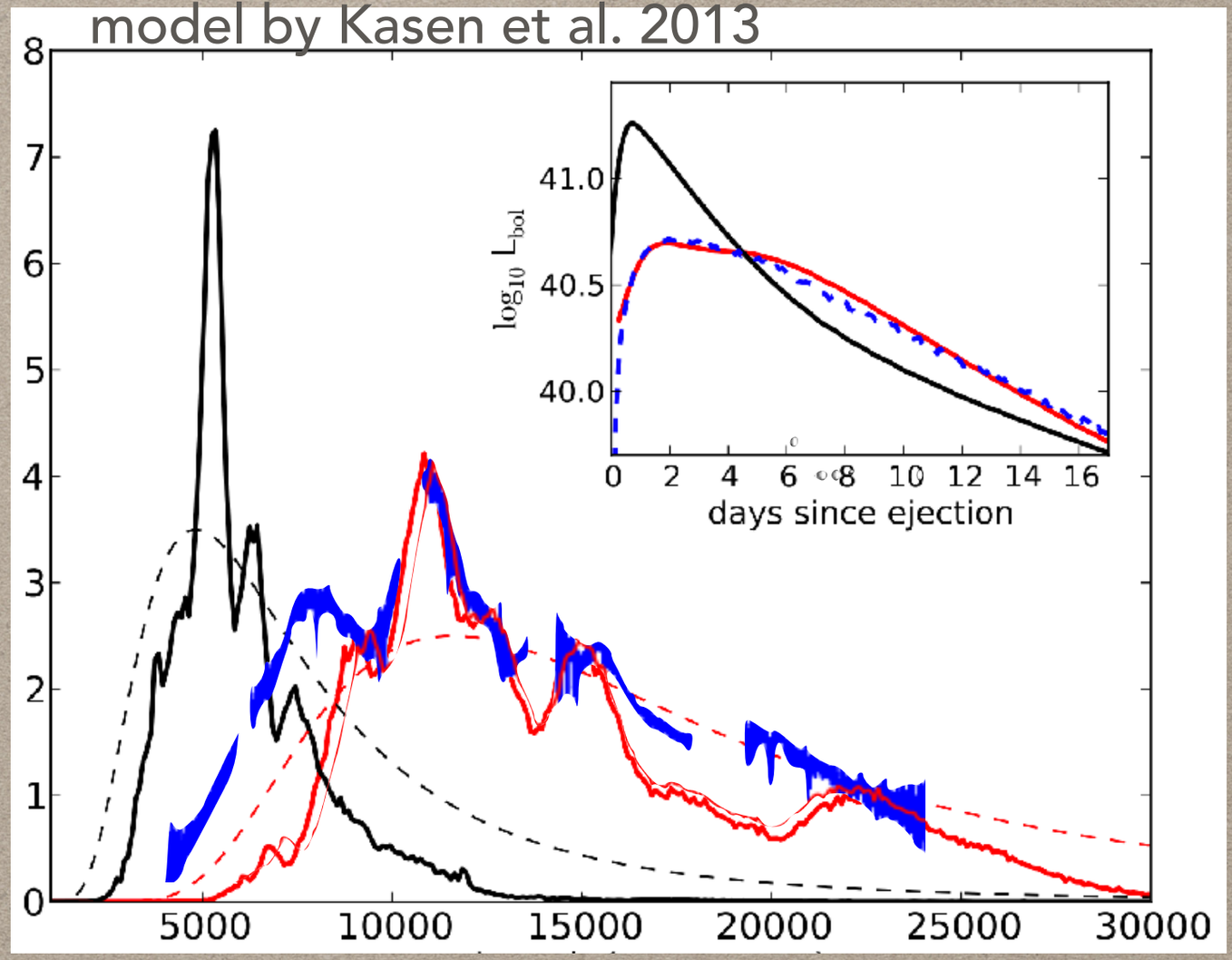
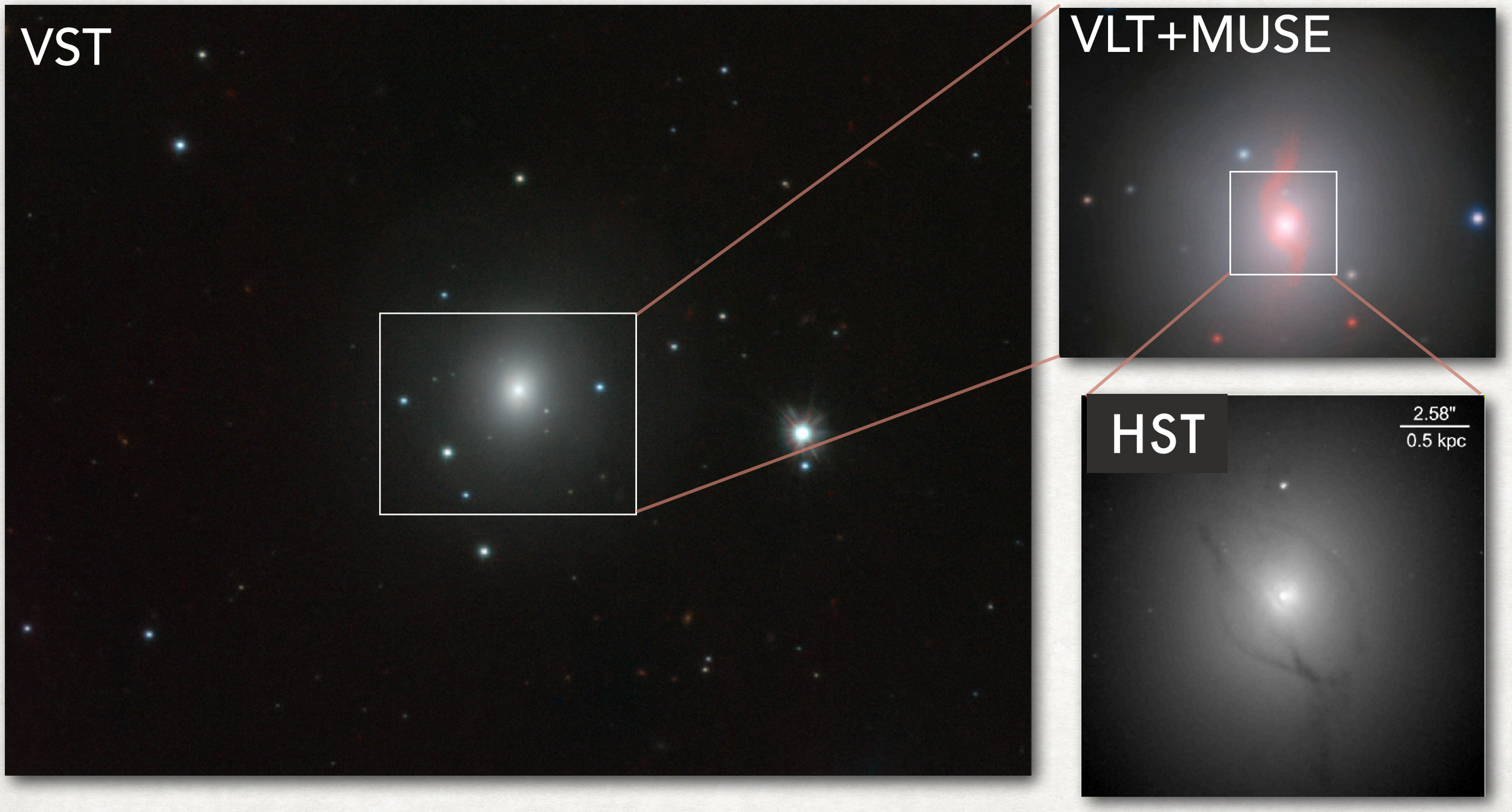


Kilonova models predict nucleosynthesis of r-process elements. Lanthanides dominate radiation transport because of high opacity

ENVIRONMENT: MUSE@VLT



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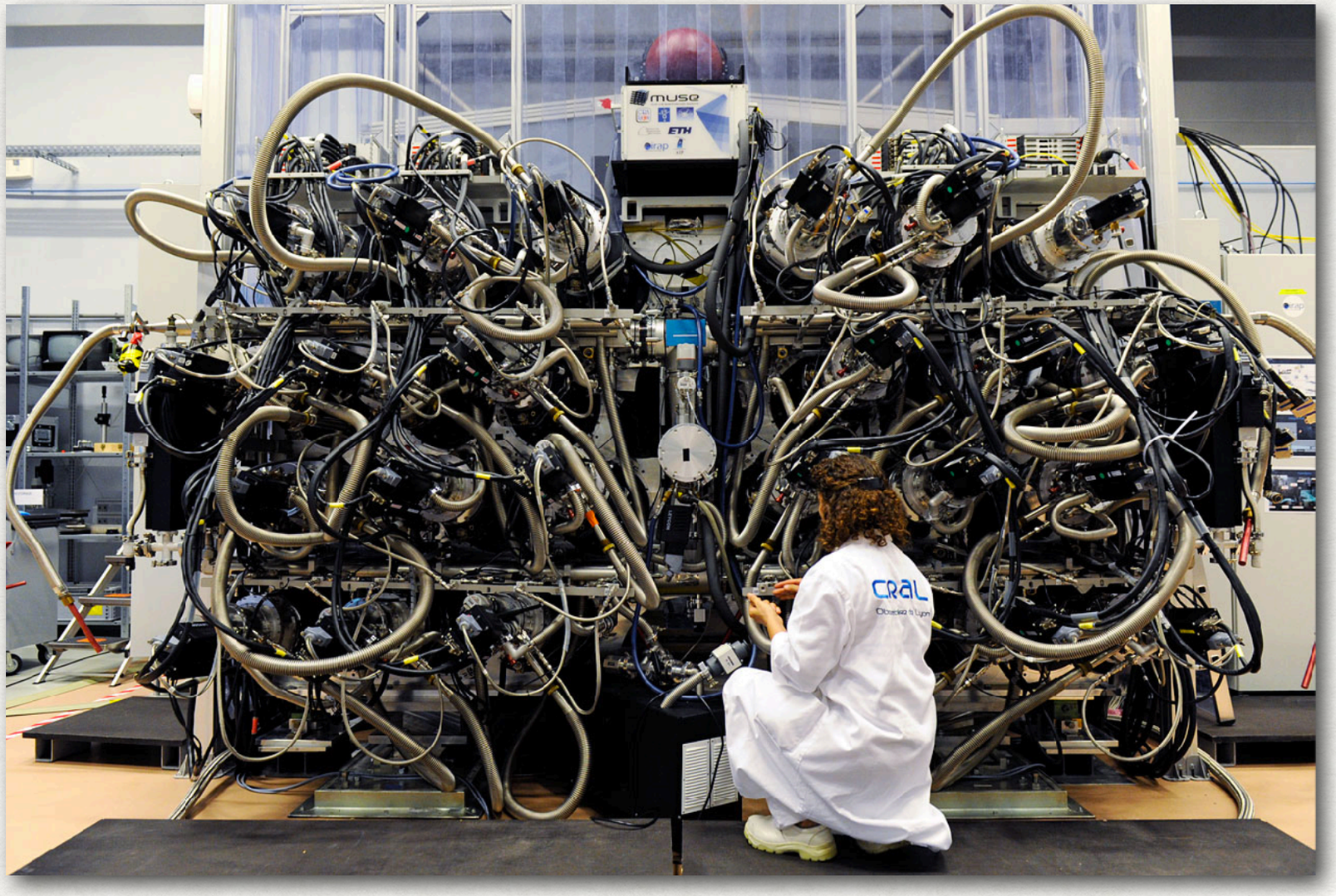
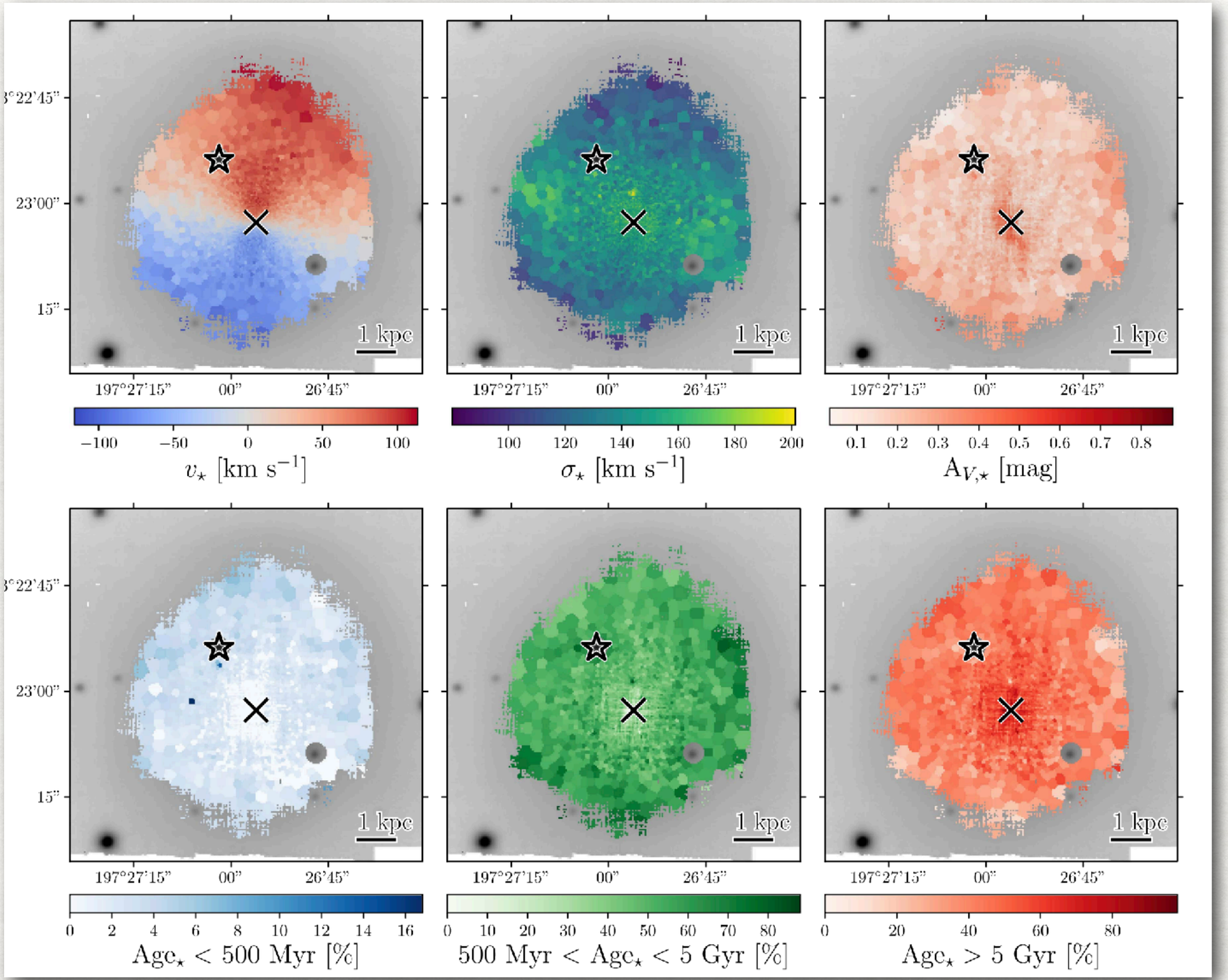


- Panoramic integral field spectrograph
- 24 IFU modules
- range 0.46-0.93 nm
- field of view 1arcmin
- spatial res. 0.3-0.4”
- spectral res. 2-4000

“monocromatic” imaging in 2Å bin along the spectral

spectrum for each position of the F0V in 0.3 arcsec bin

ENVIRONMENT: MUSE@VLT



FUTURE OF GW FOLLOW-UP

Nearby kilonovae are rare

GW170817

40 Mpc

M_{max} = -16 m_{max} = 17

search 0.1 - 1 m

0-3d

identification 2 - 4 m

3d V+2mag, K+0mag

follow-up 8- 10 m

15d V+6mag, K+2mag

FUTURE OF GW FOLLOW-UP

Nearby kilonovae are rare

	GW170817	NEXT
	40 Mpc M_{max} = -16 m_{max} = 17	100-400 Mpc m_{max} = 19-22
search 0-3d	0.1 - 1 m	0.5 - 4 m
identification 3d V+2mag, K+0mag	2 - 4 m	8 m
follow-up 15d V+6mag, K+2mag	8- 10 m	40 m

DEPTH

RESOLUTION
SPATIAL/SPECTRAL

RANGE
FIELD OF VIEW/
SPECTRAL RANGE

DEPTH

LARGER TELESCOPES

ADAPTIVE OPTICS

SPECIALISED INSTRUMENTS

RESOLUTION
SPATIAL/SPECTRAL

RANGE
FIELD OF VIEW/
SPECTRAL RANGE

DEPTH

LARGER TELESCOPES

ADAPTIVE OPTICS

SPECIALISED INSTRUMENTS

RESOLUTION
SPATIAL/~~SPECTRAL~~

RANGE
FIELD OF VIEW/
SPECTRAL RANGE

DEPTH

LARGER TELESCOPES

ADAPTIVE OPTICS

SPECIALISED INSTRUMENTS

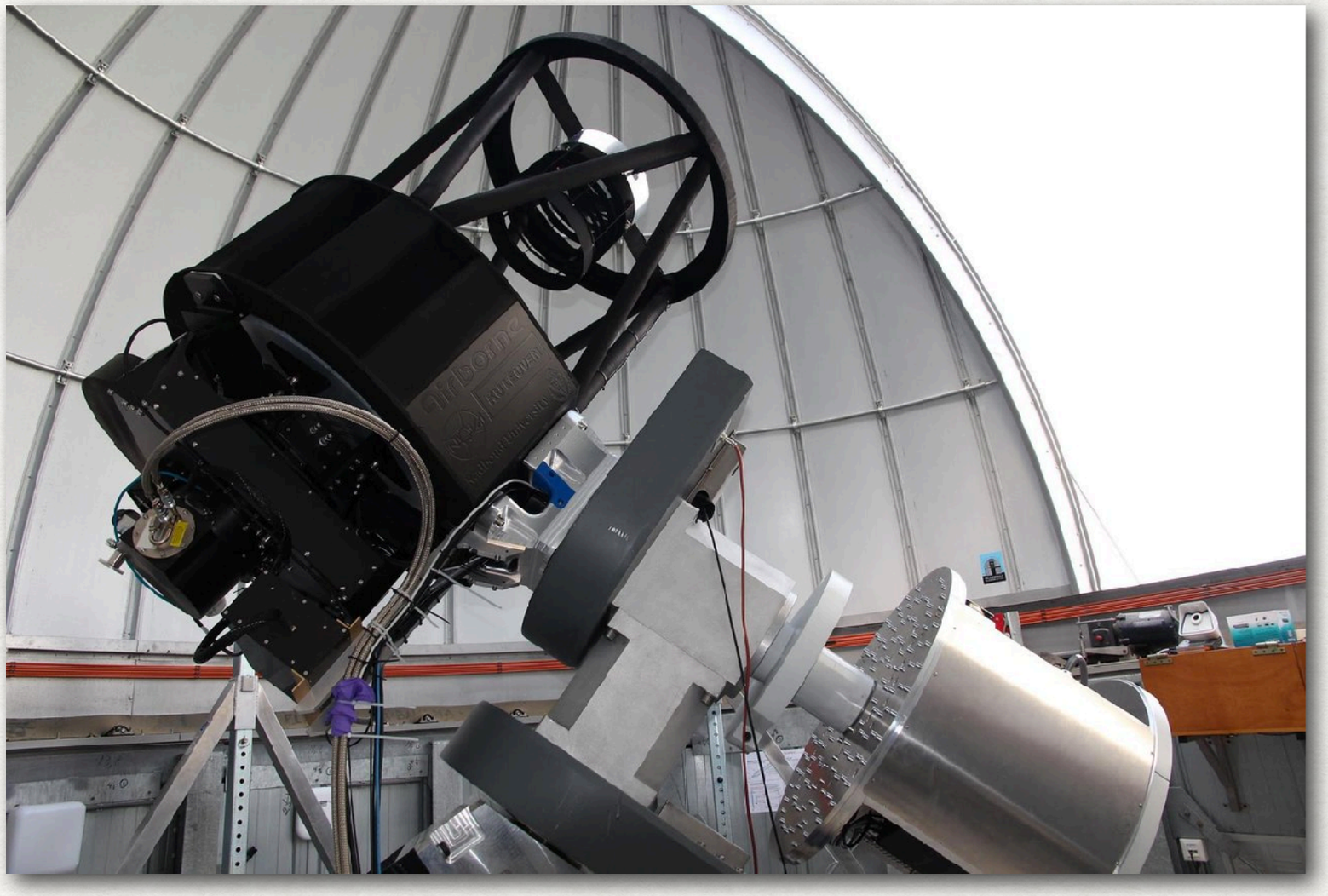
RESOLUTION
SPATIAL/~~SPECTRAL~~

RANGE
FIELD OF VIEW/
SPECTRAL RANGE

FLEXIBILITY / REACTION TIME

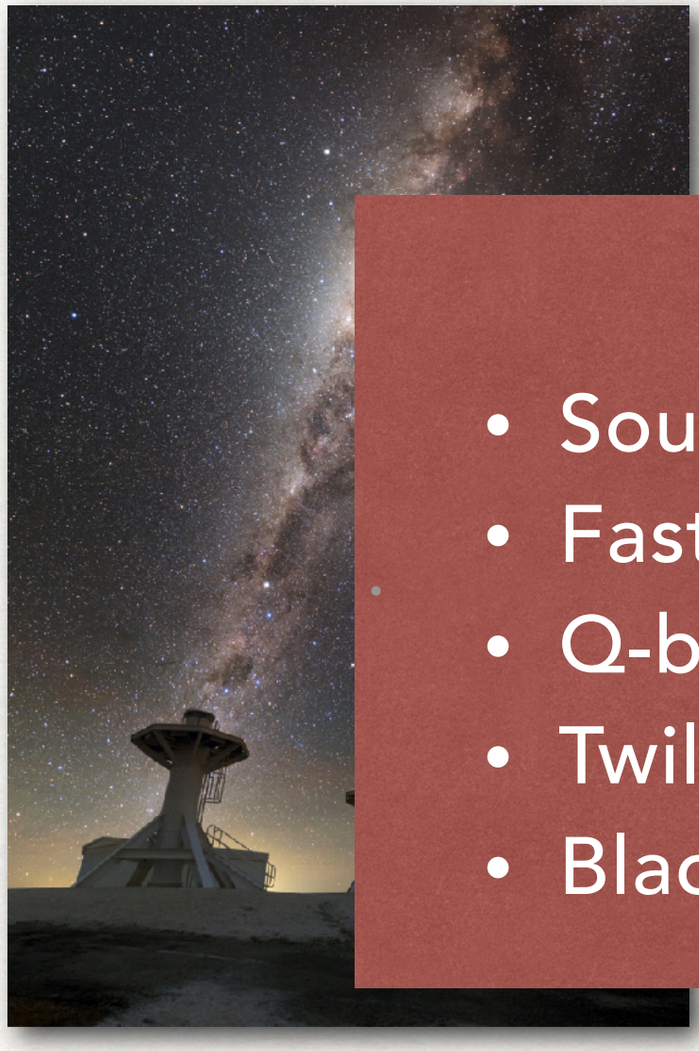
DATA REDUCTION/ MINING

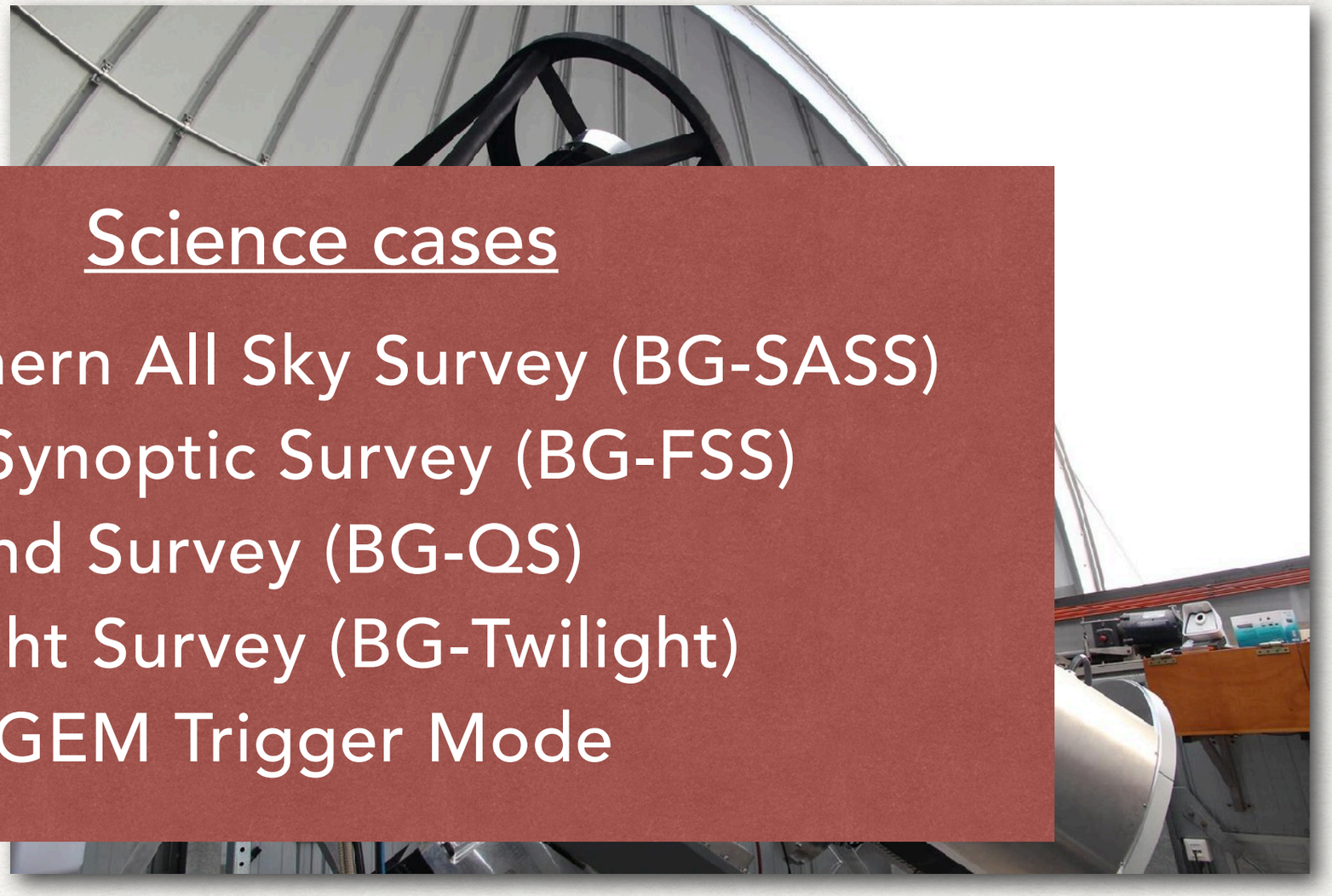
BLACK GEM



3 telescopes of 0.65m (15 telescopes in phase 2)
FoV 2.7 sq deg (3x 8.1 sq.deg 15x 40 sq.deg)
0.56 arcsec/pix
installed at ESO La Silla (Chile)
22 mag limit in 5 min

BLACK GEM





Science cases

- Southern All Sky Survey (BG-SASS)
- Fast Synoptic Survey (BG-FSS)
- Q-band Survey (BG-QS)
- Twilight Survey (BG-Twilight)
- BlackGEM Trigger Mode

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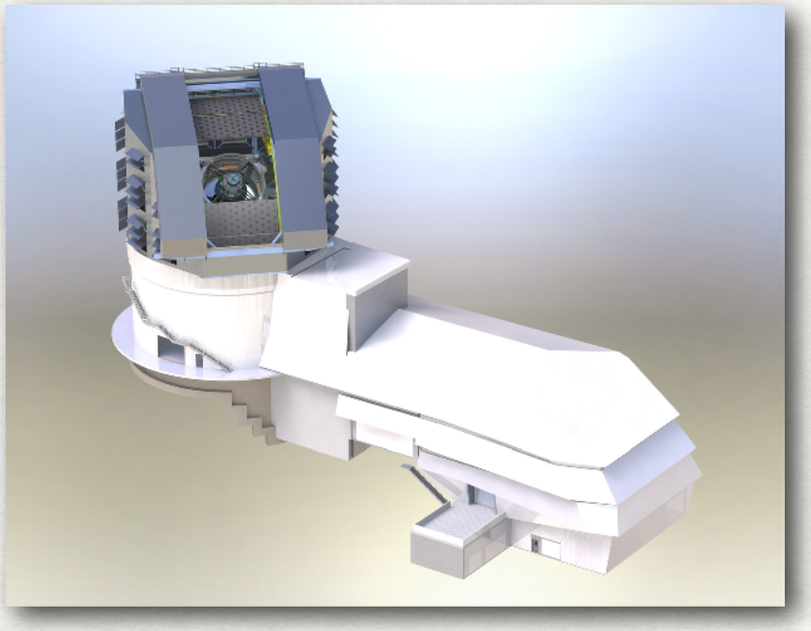
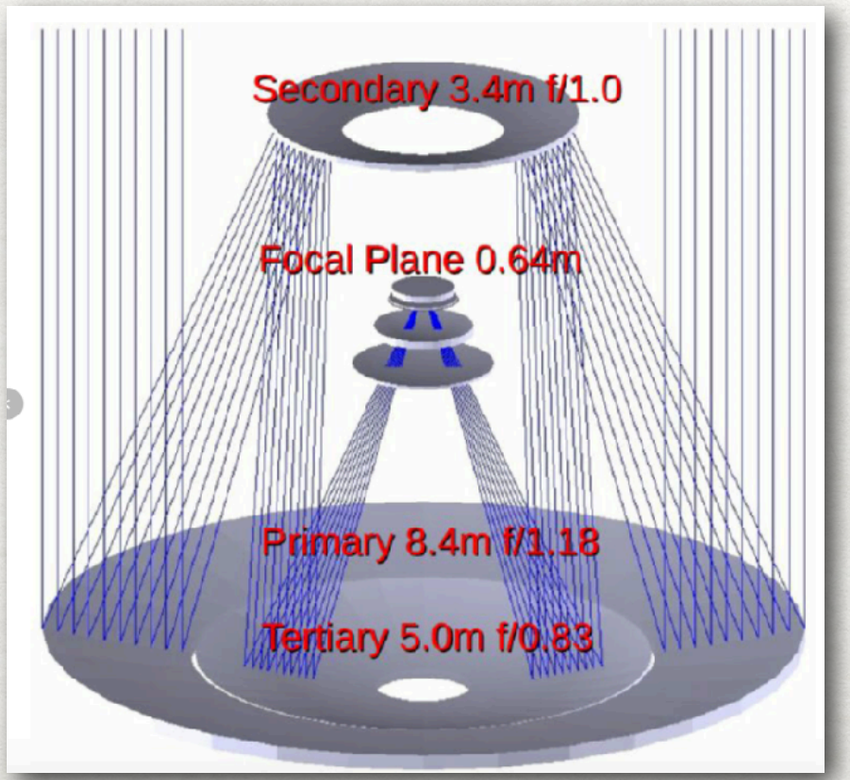
LSST: LARGE SYNOPTIC SURVEY TELESCOPE



Cerro Pachon (Chile)
8.4m mirror
9.6 sq. deg
0.2 arcsec/pixel
3.2 Gpix camera

start 2024



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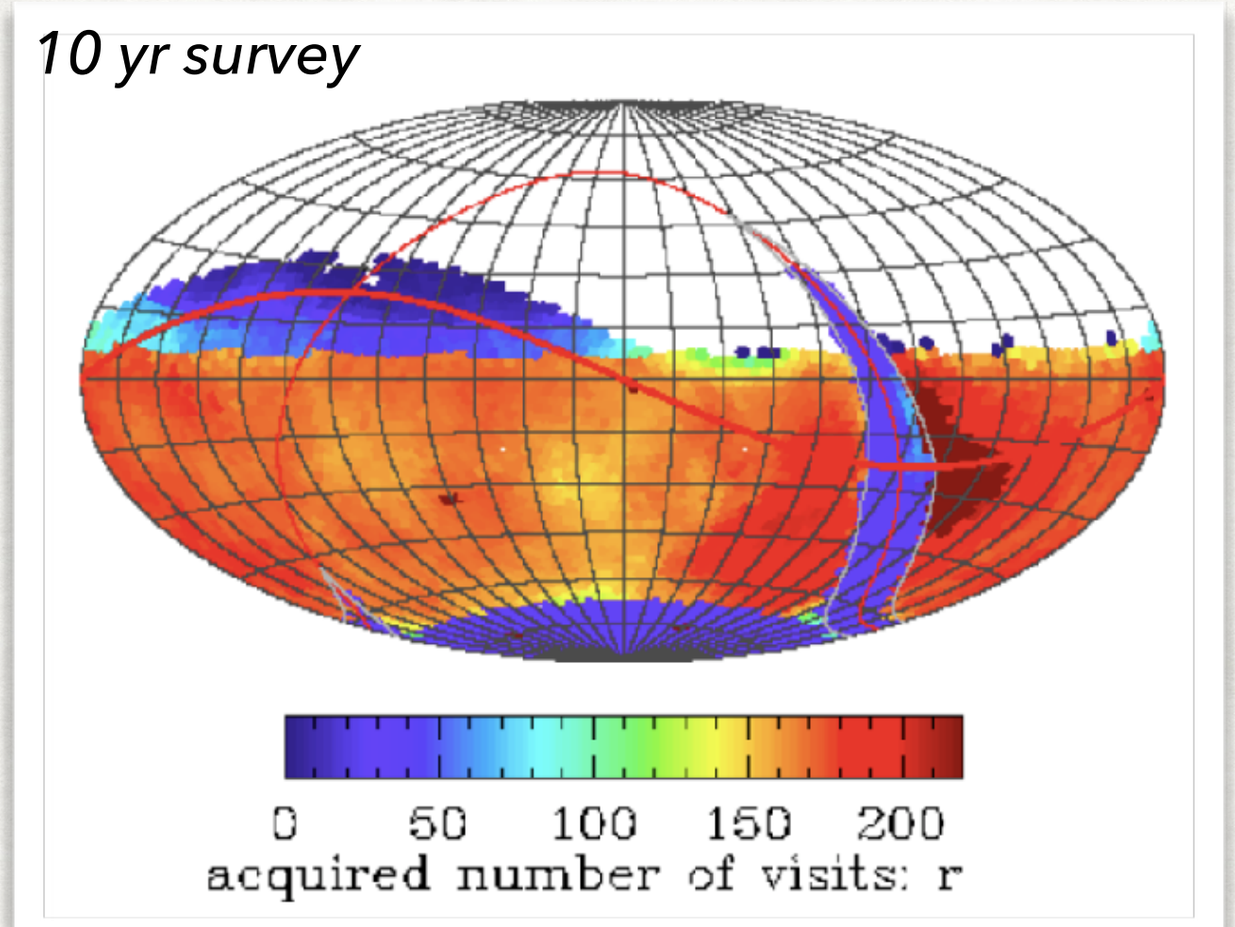

10.000 deg² per night

all (southern) sky every 3/4 nights

5-sigma point source depth
single visit 2 x 15 sec
g-band 25.0 mag × visit
27.0 mag on stacked

real time alert latency 60 sec

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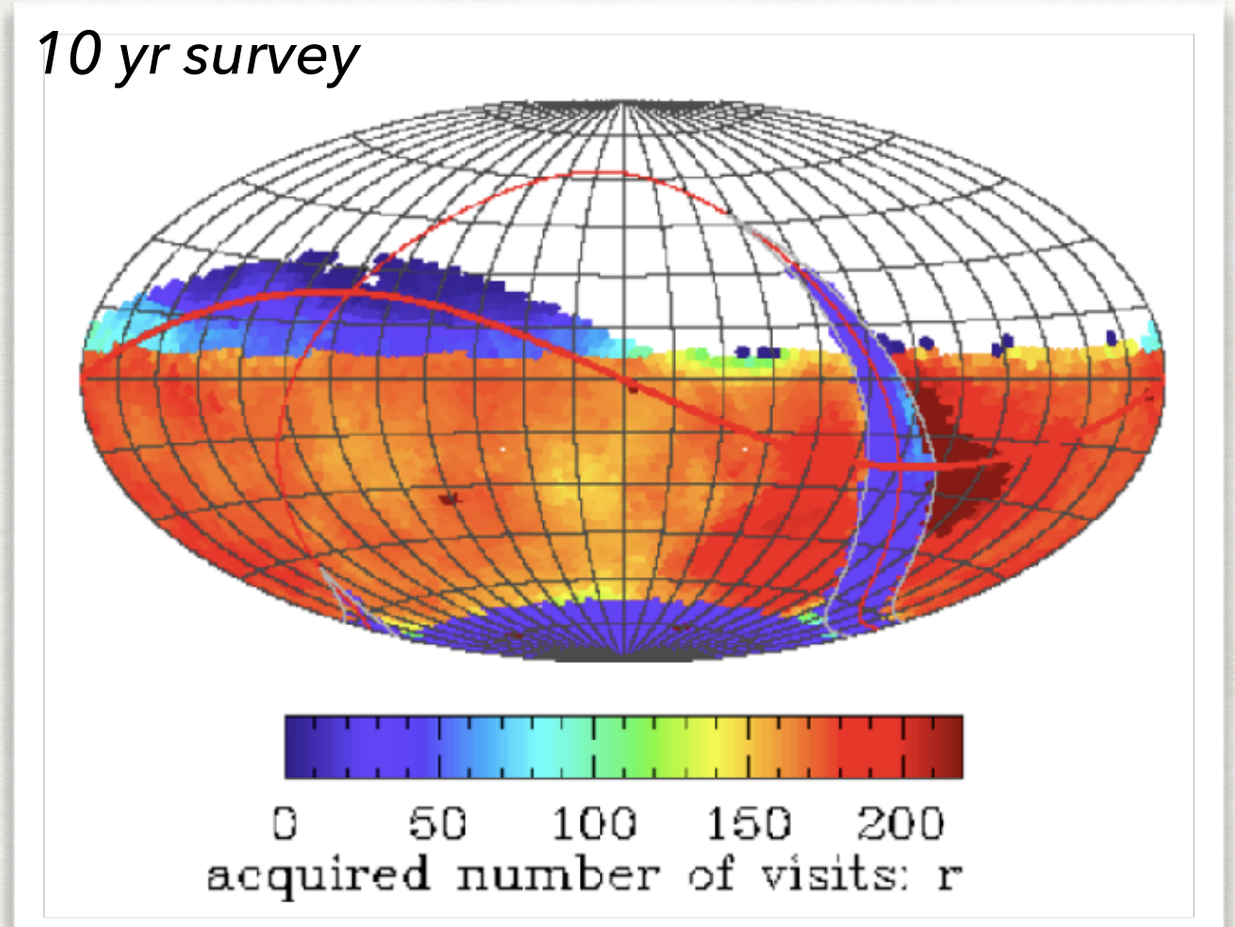

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all (southern) sky every 3/4 nights

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single visit 2 x 15 sec
g-band 25.0 mag × visit
27.0 mag on stacked

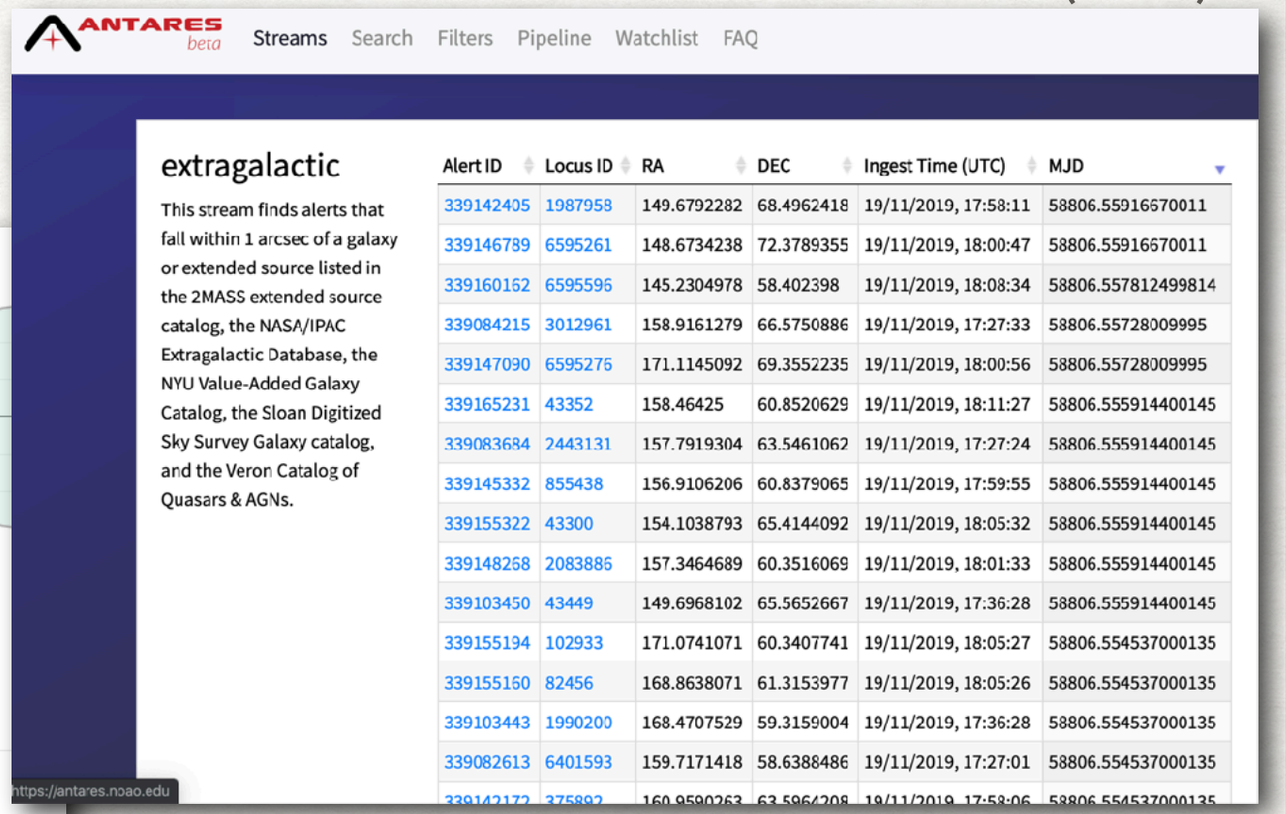
real time alert latency 60 sec

Current transient alert rate ~40 x night

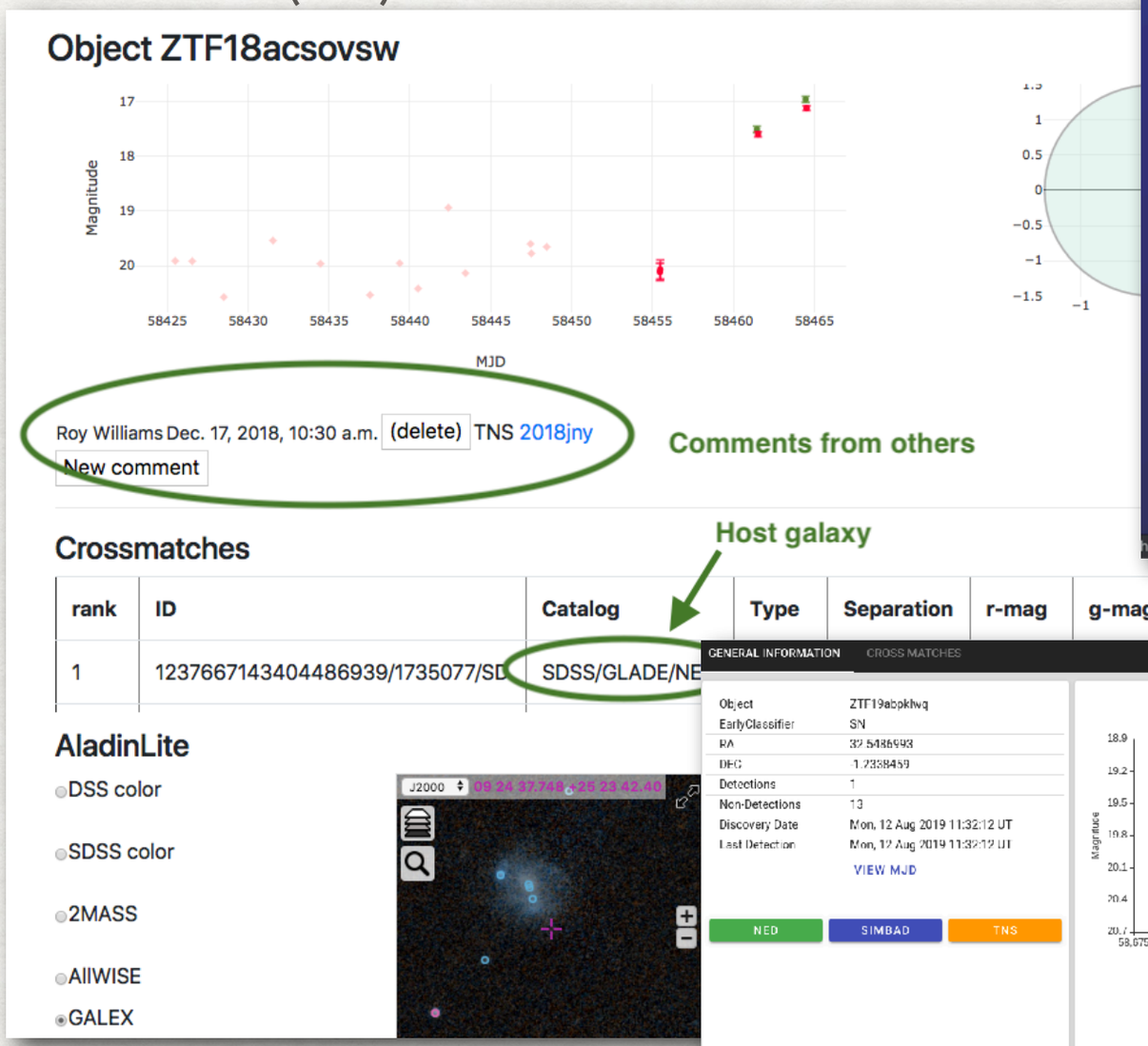
LSST alerts 10.000.000 x night

TRANSIENT BROKERS

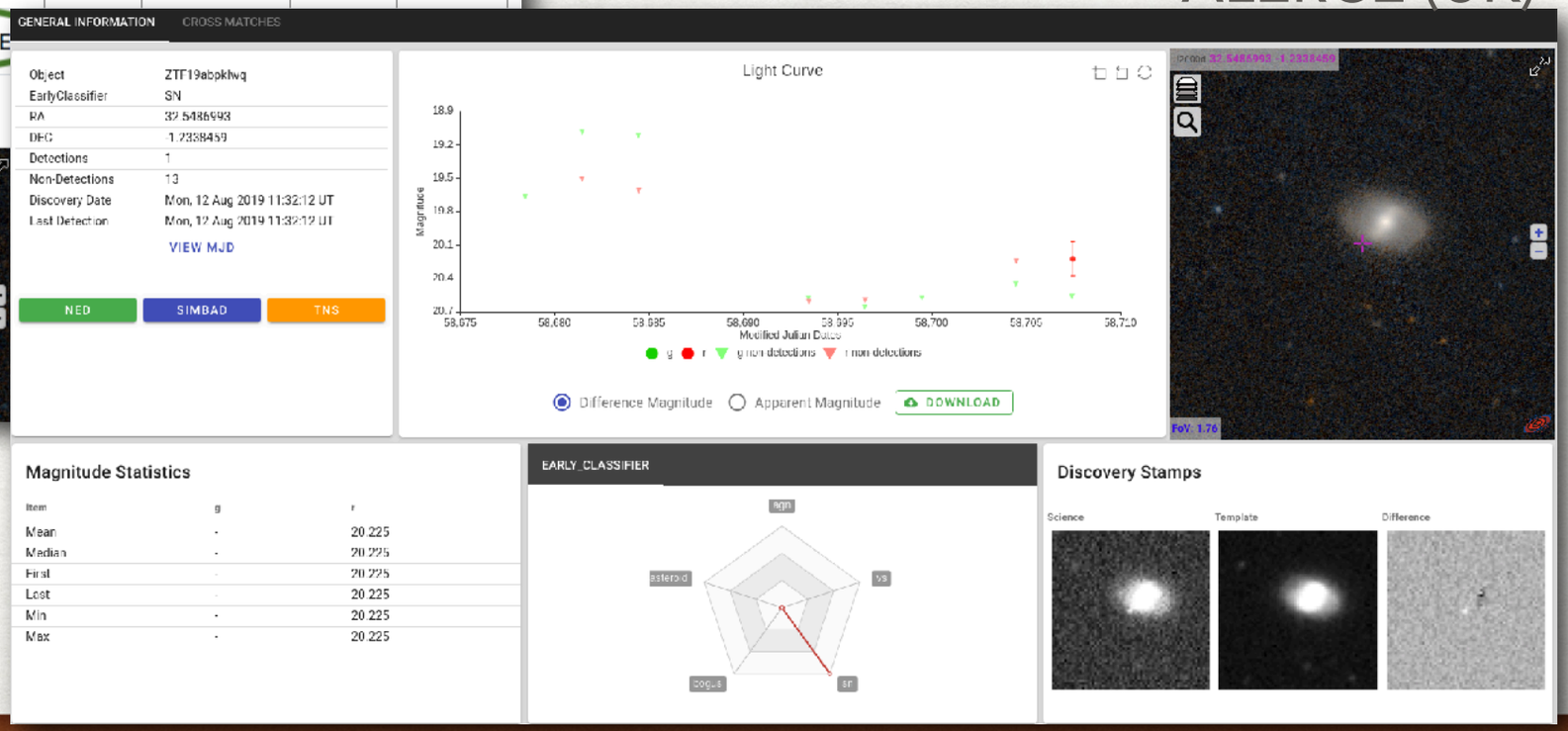
ANTARES (USA)



LASAIR (UK)

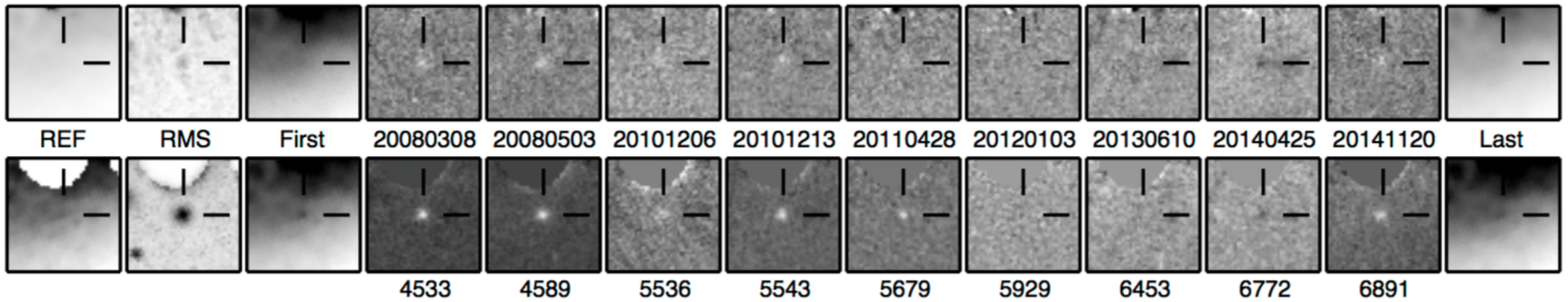


ALERCE (UK)

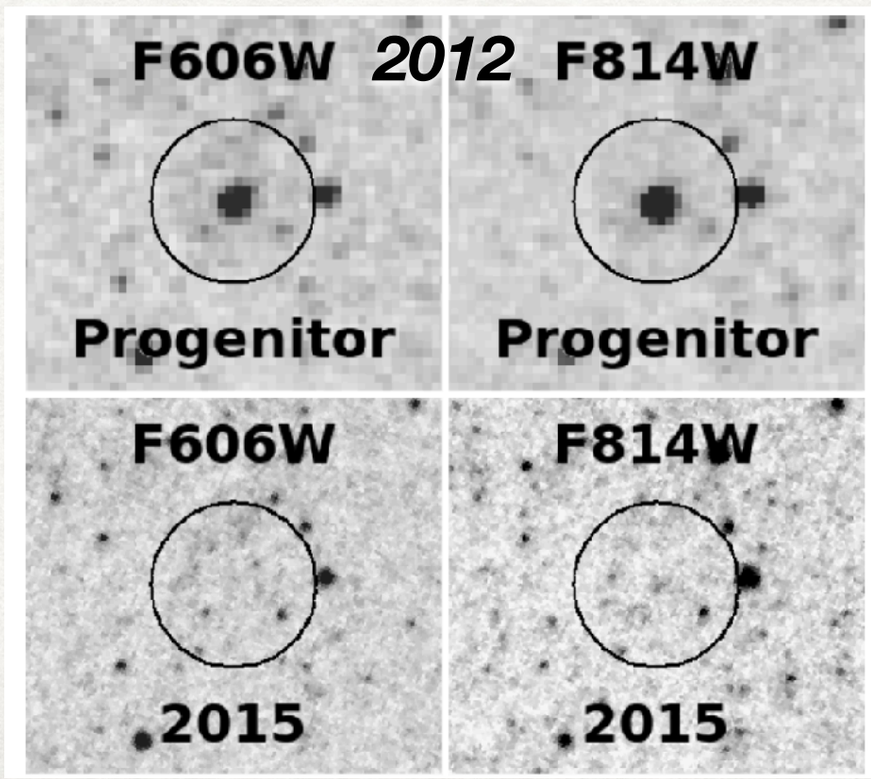


SEARCH FOR FAILED SUPERNOVAE

Gerke et al. 2015 MNRAS 450, 3289



Adams et al. 2017 *HST*



A best candidate for direct collapse to black hole of a 25 $M_\odot$ RSG star

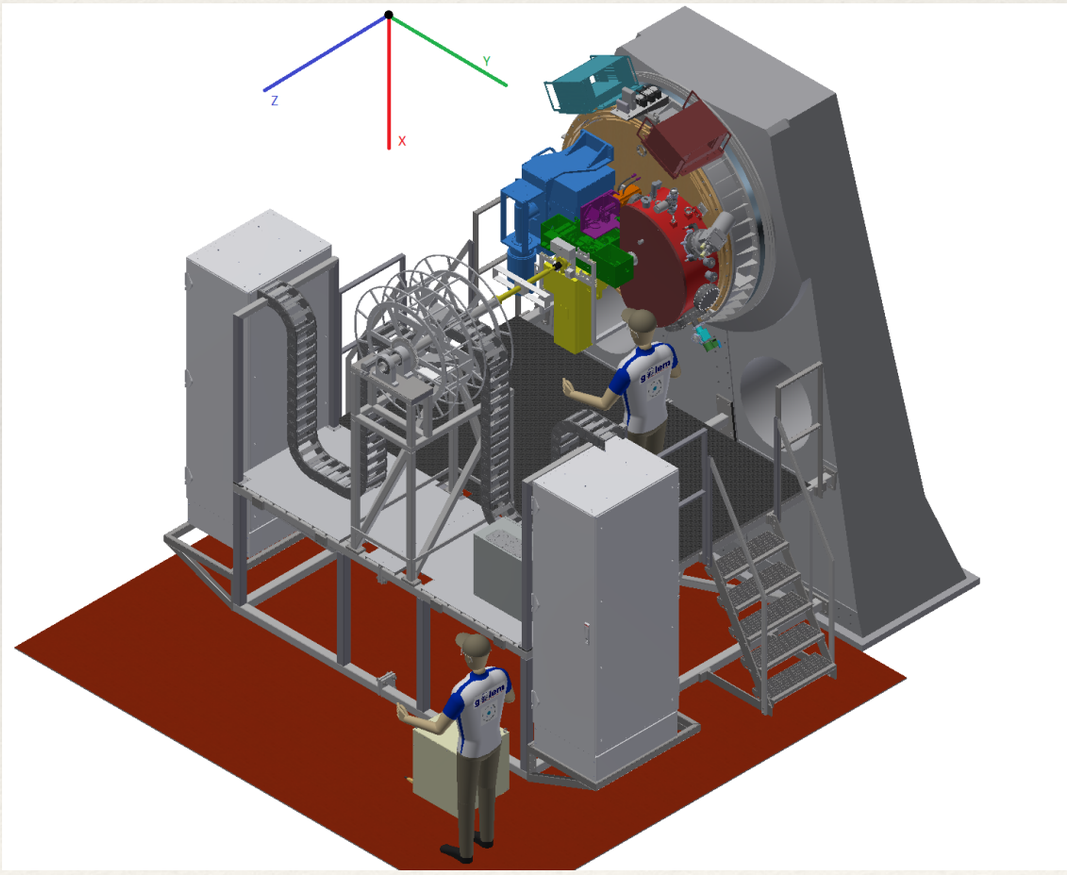
Not yet confirmed

SOXS

Son of X-Shooter

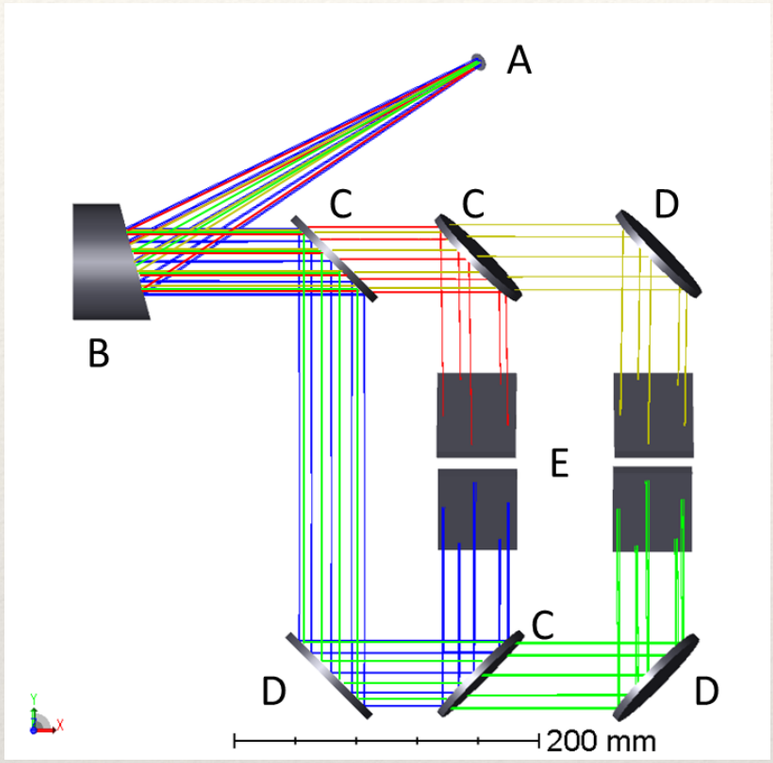
06/2014 ESO call for new instruments at NTT
05/2015 Selected by ESO out of 19 proposed
01/2022 in operation at La Silla

Consortium of 6 countries
Italy (INAF) 50%

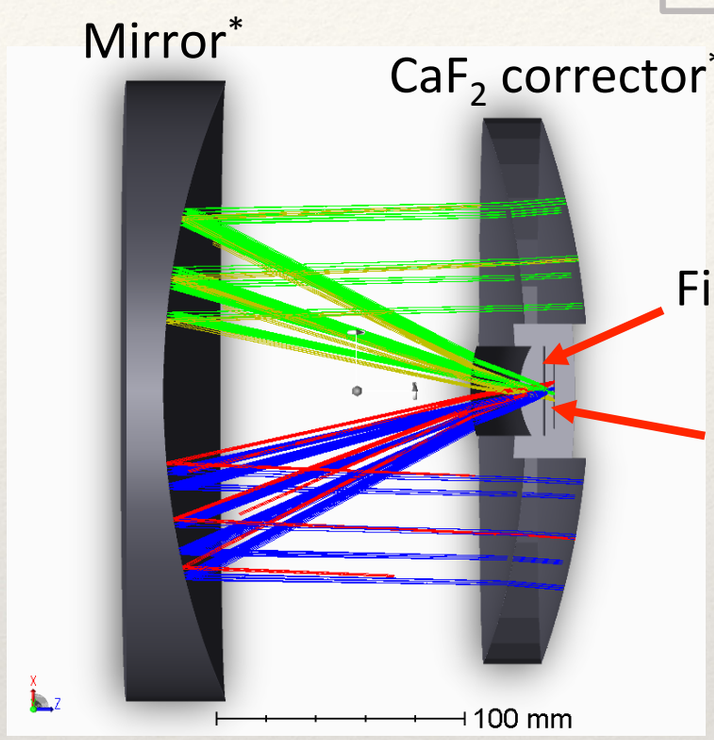


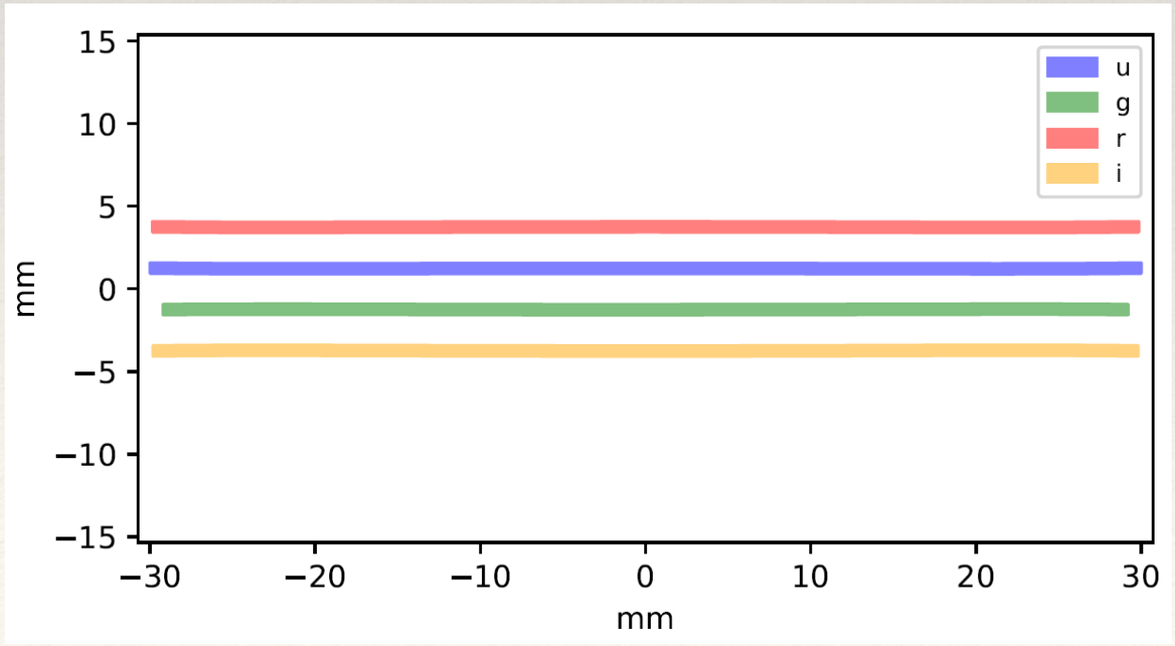
- Broad Band Spectrograph 350-20000 nm
- R~4500
- Two arms: UV-VIS (350-950 nm) +NIR (800-2000nm)
- “Photometric” acquisition camera 3.5 arcsin 0.3 arcsec/pix
- S/N ~ 10 in 1h exposure for R_{AB} =20.5

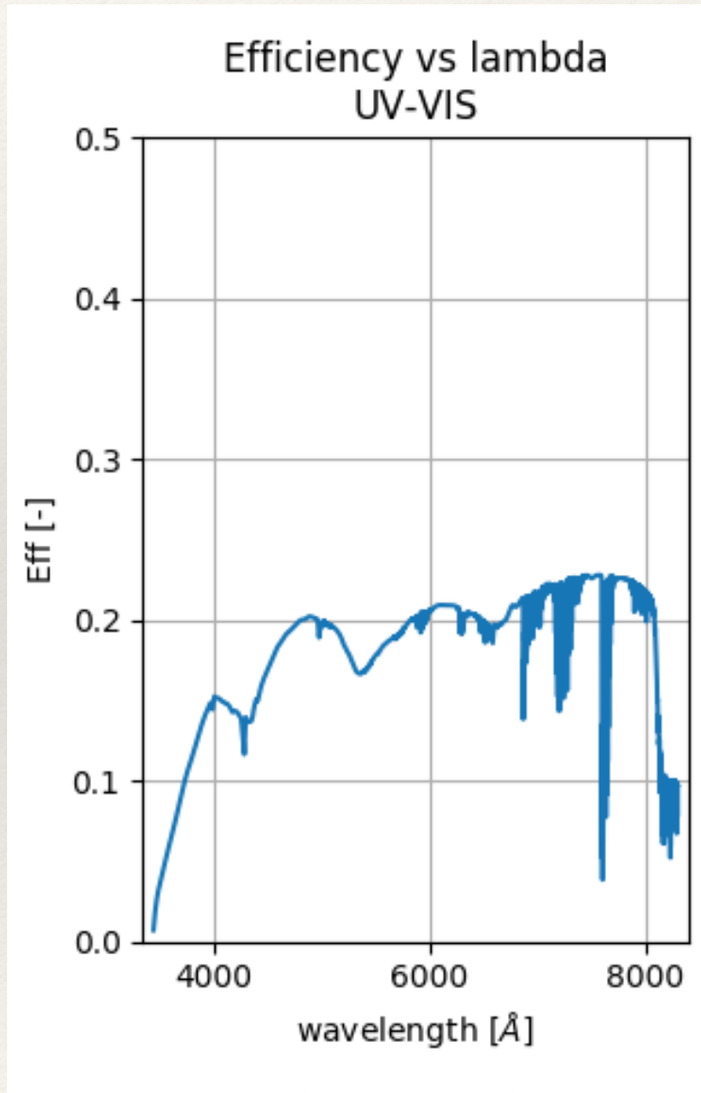
SOXS UV-VIS arm



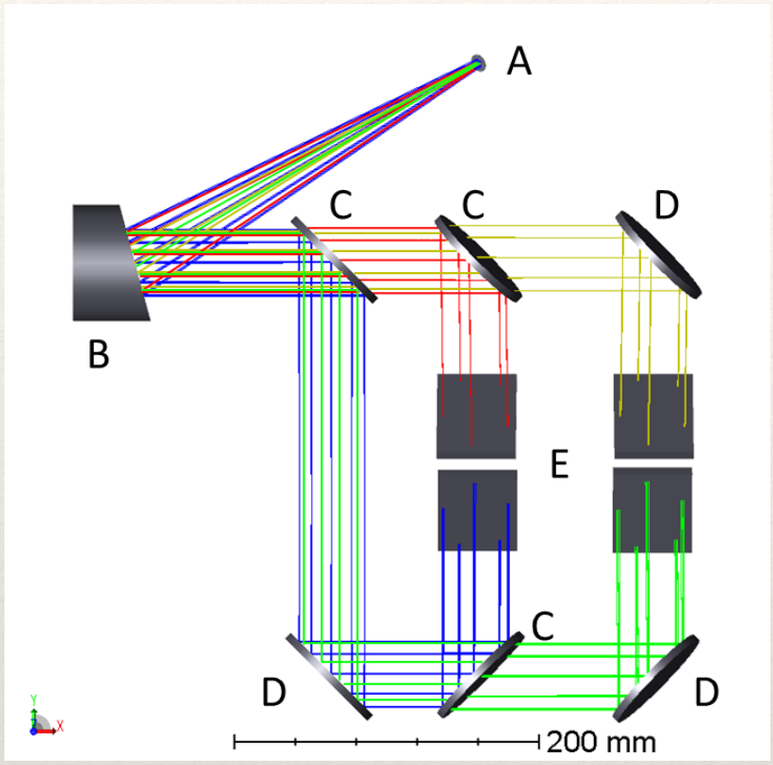
*Aspheric







SOXS UV-VIS arm



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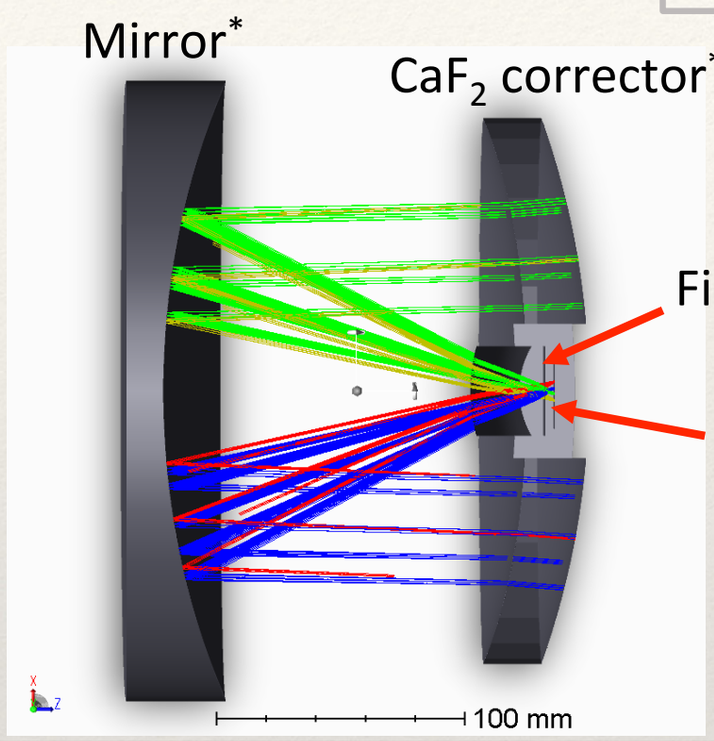
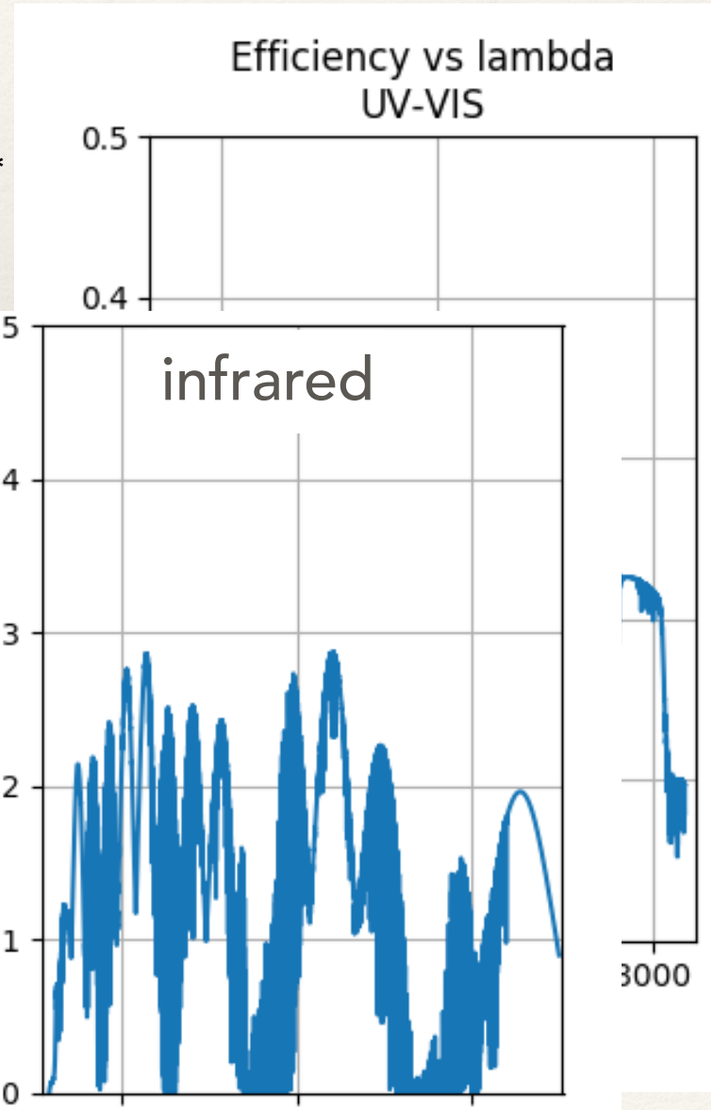
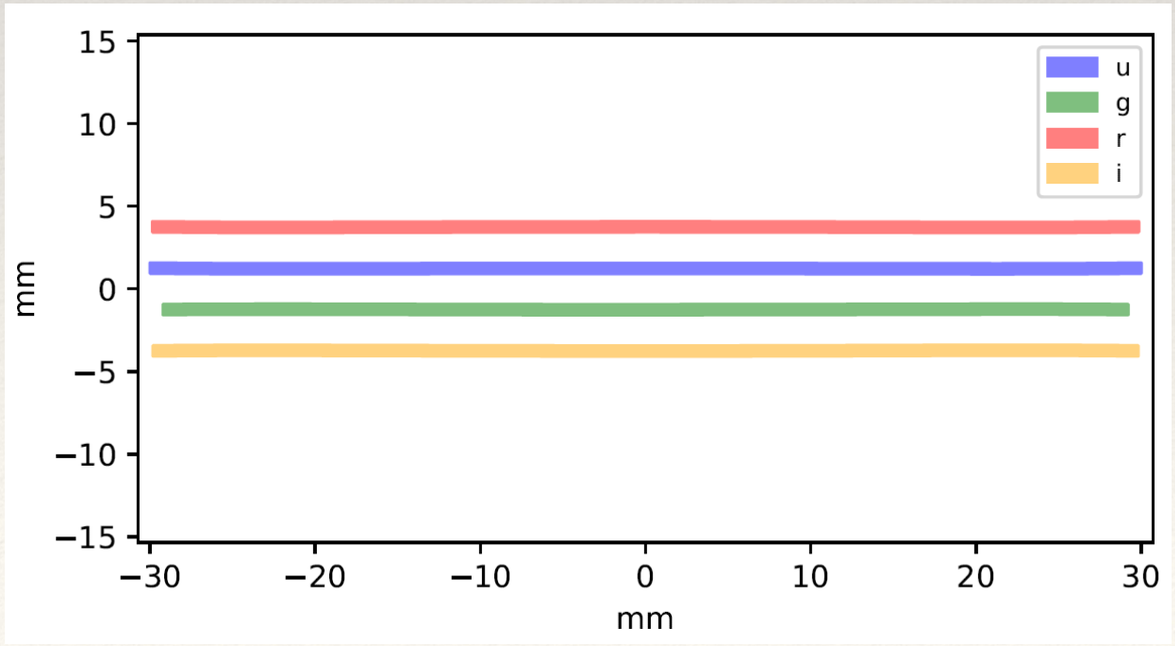
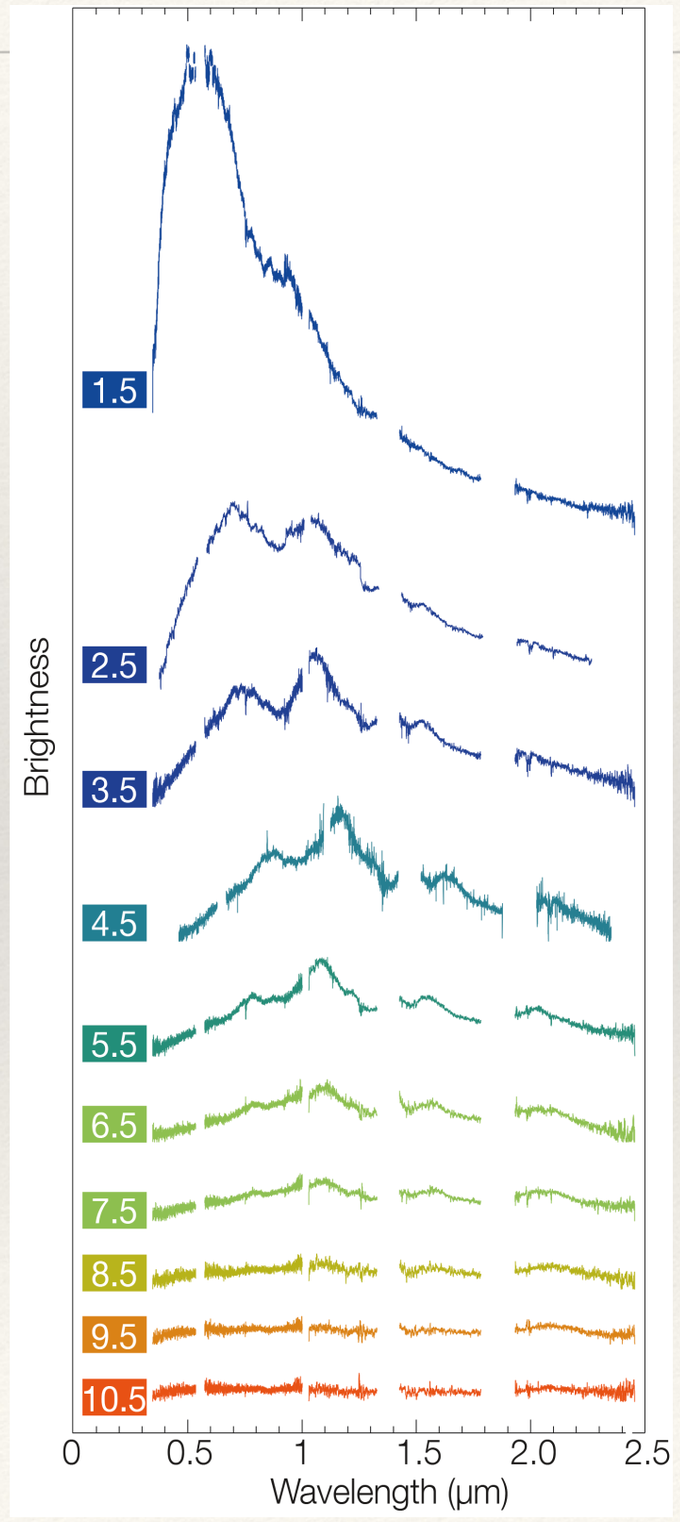


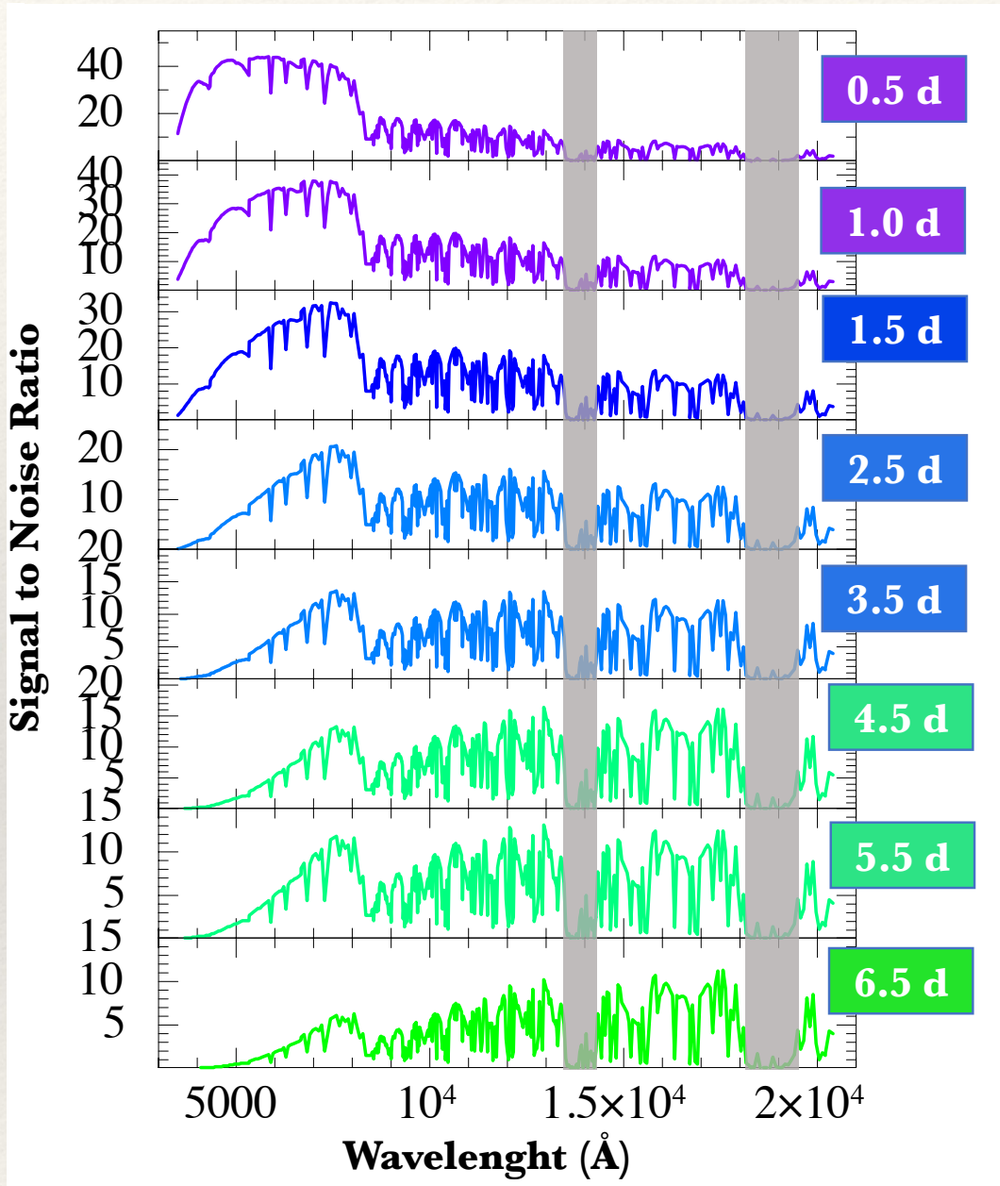




GW170817 with X-shooter

SOXS for GW sources





Preliminary SoXS ETC

http://192.167.38.34/

NEED TO GAIN A FACTOR 10

$$\frac{S}{N} = \frac{N_{phot}}{\sqrt{N_{bgk}}}$$

VLT->EELT factor ~ 5

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- Gain instrument efficiency

  not much room to improve detection efficiency … ? 20-30% ?

  use more of the collected photons (eg. SOXS) …. factor 2-3

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- Decrease the background (critical in infrared)

Night Sky Brightness
V = 21.6 mag/arcsec^2
K = 15.0 mag/arcsec^2

JWST - JAMES WEBB SPACE TELESCOPE

zodiacal light K~21
mag/arcsec^2

Mirror 6.5m
range 0.6 - 30 nm
L2 orbit
launch 2021
mission duration 10yr

Instrument	Science Requirement	Capability
NIRCam Univ.Az/LMATC 	Wide field, deep imaging ›0.6 μm - 2.3 μm (SW) ›2.4 μm - 5.0 μm (LW)	2.2' x 4.4' SW at same time as 2.2' x 4.4' LW with dichroic Coronagraph
NIRSpec ESA/Astrium 	Multi-object spectroscopy ›0.6 μm - 5.0 μm	9.7 Sq arcmin Ω + IFU + slits 100 selectable targets: MSA R=100, 1000, 3000
MIRI ESA/Consortium /UKATC/JPL 	Mid-infrared imaging › 5 μm - 27 μm Mid-infrared spectroscopy › 4.9 μm - 28.8 μm	1.9' x1.4' with coronagraph 3.7"x 3.7" – 7.1"x 7.7" IFU R=3000 - 2250
FGS/NIRISS CSA 	Fine Guidance Sensor 0.8 μm - 5.0 μm Near IR Imaging Slitless Spectrometer	Two 2.3' x 2.3' 2.2' x 2.2' R= 700 with coronagraph

JWST - JAMES WEBB SPACE TELESCOPE

zodiacal light K~21
mag/arcsec^2

Mirror 6.5m
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Instrument	Science Requirement	Capability
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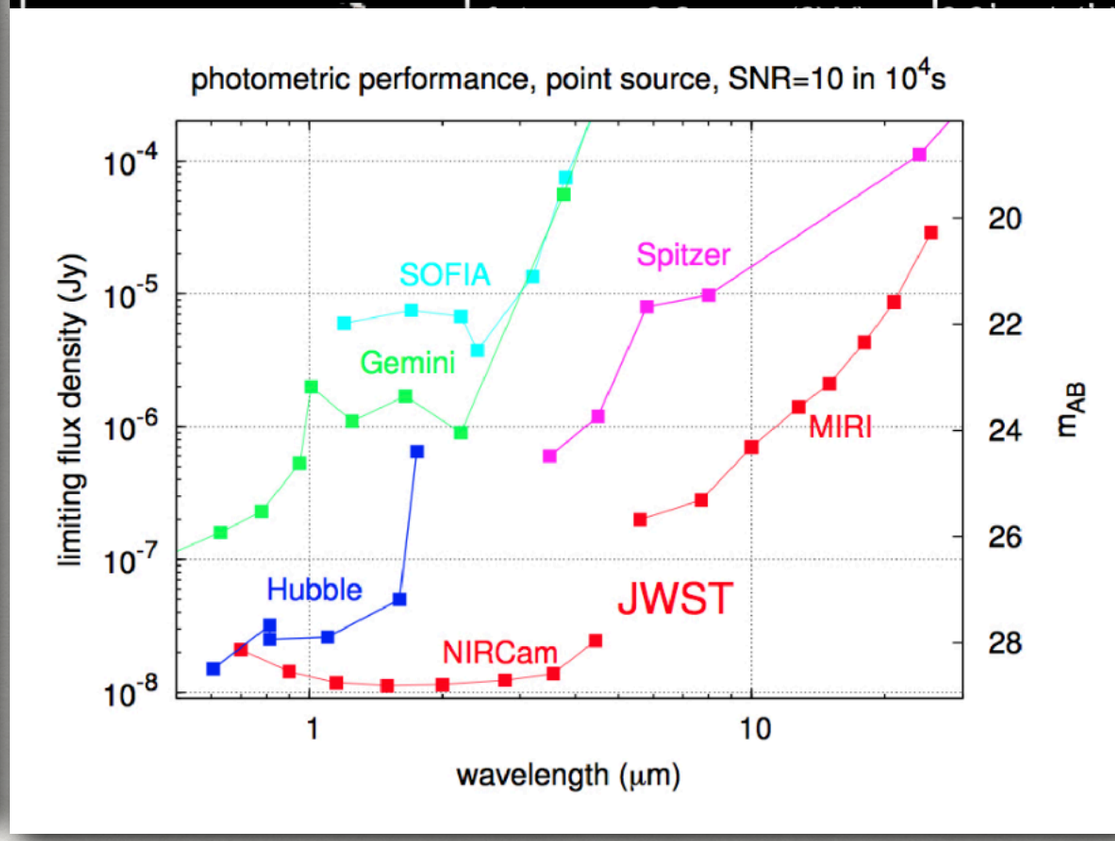
		in Ω + IFU + slits ble targets: MSA 0, 3000
		vith coronagraph
		7.1"x 7.7" IFU 250
		2.3'
		n coronagraph

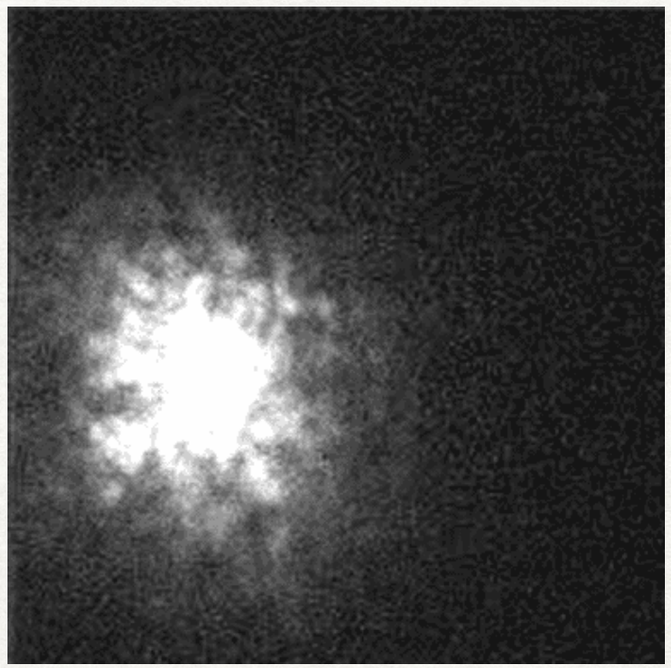


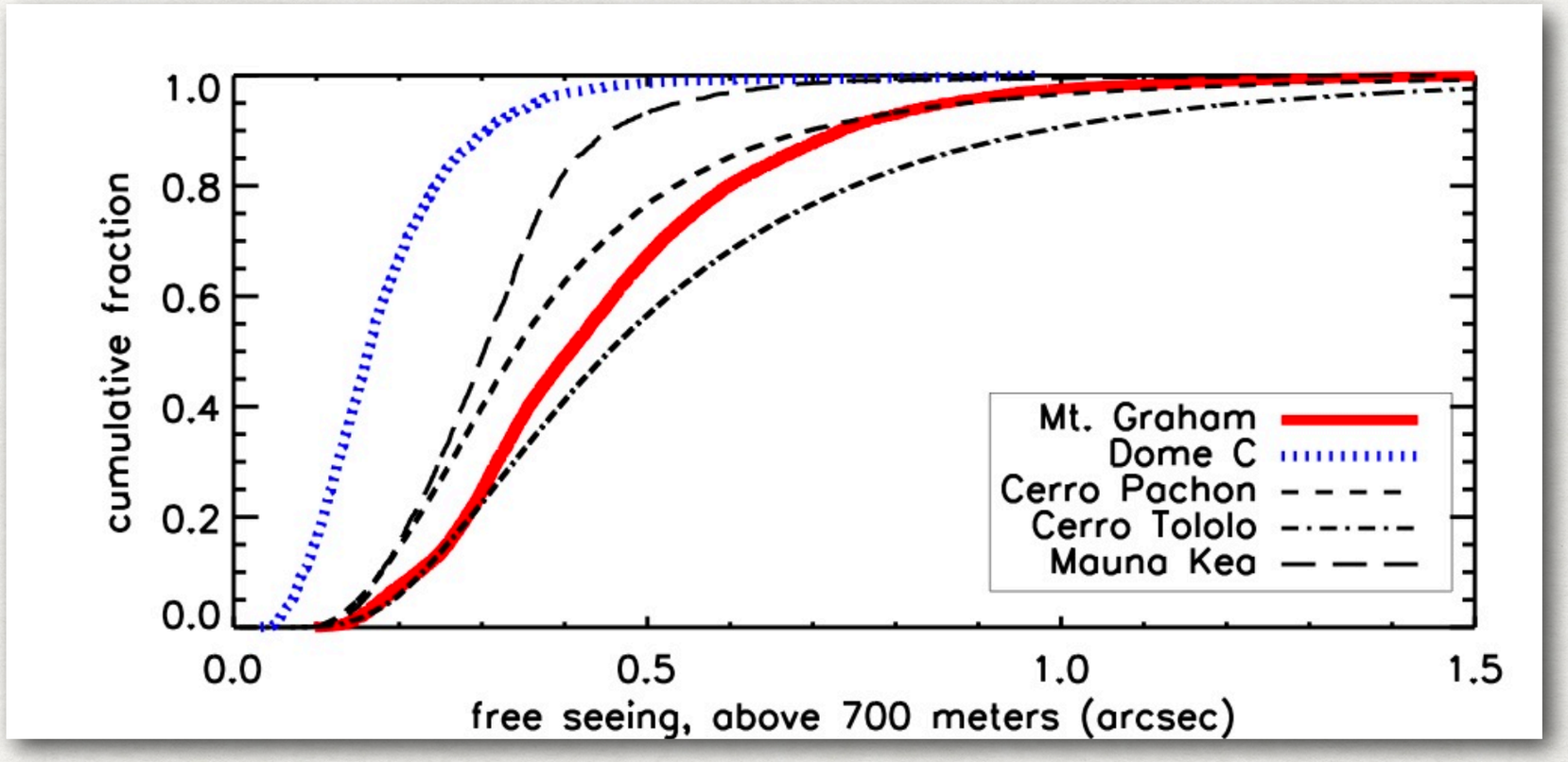
DECREASE THE BACKGROUND

GET A GOOD SEEING

Resolution = 1.22 λ / diameter

1m telescope R~ 0.1 arcsec





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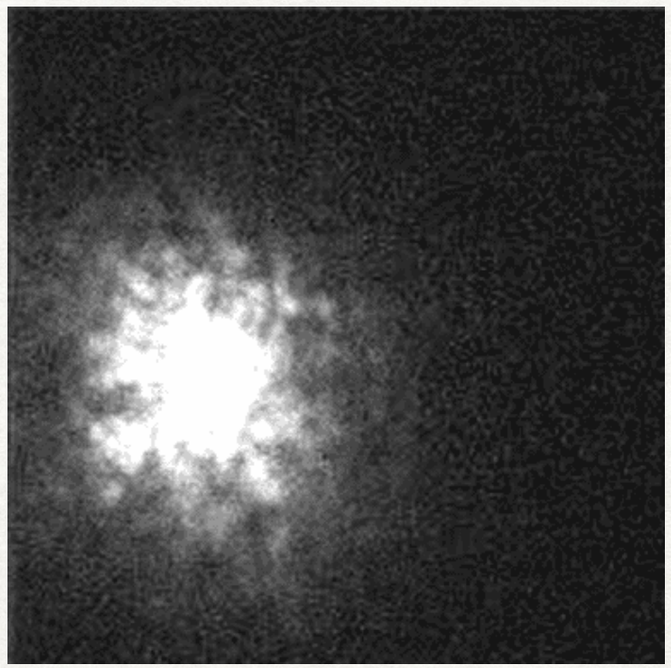
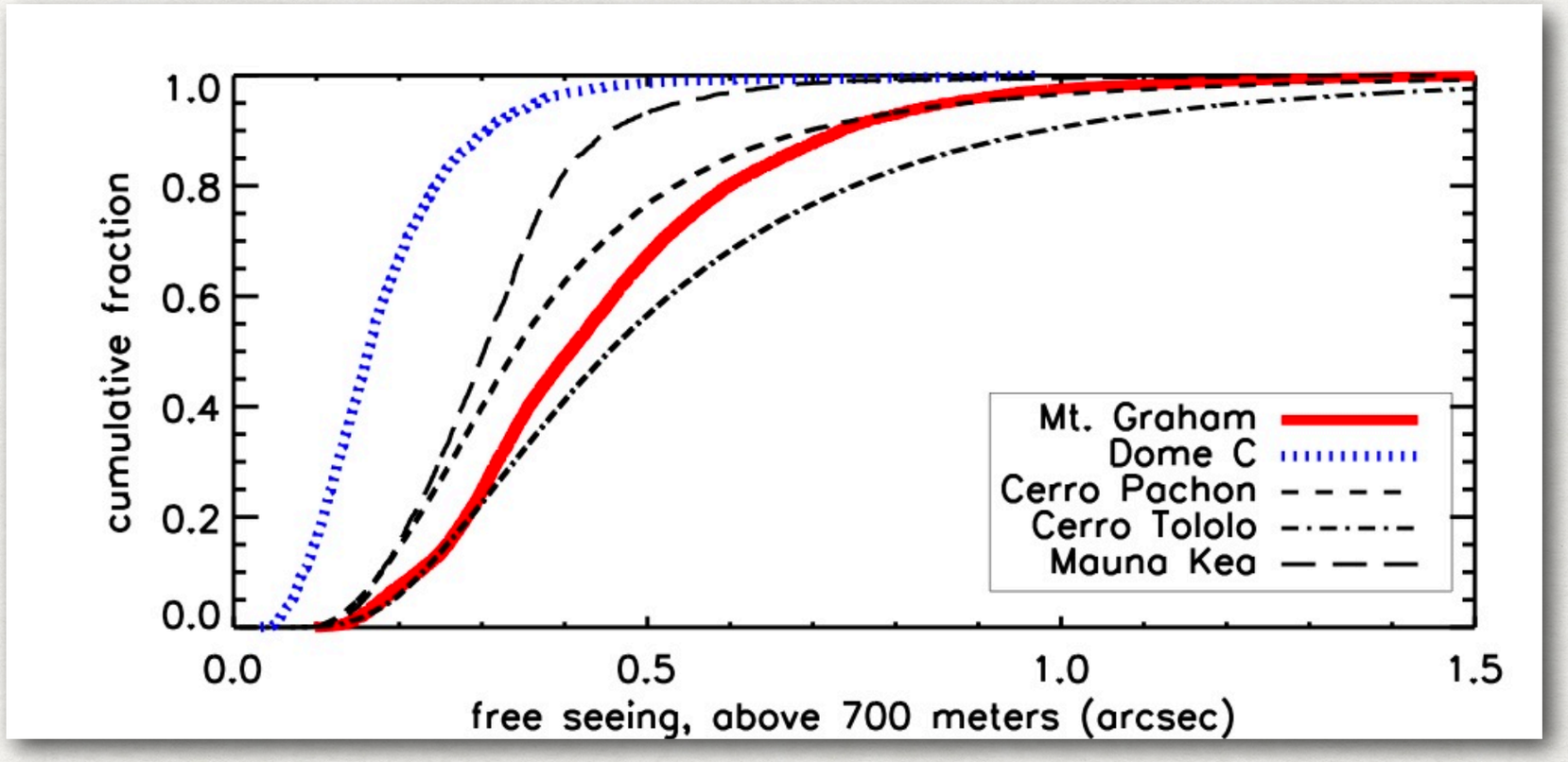
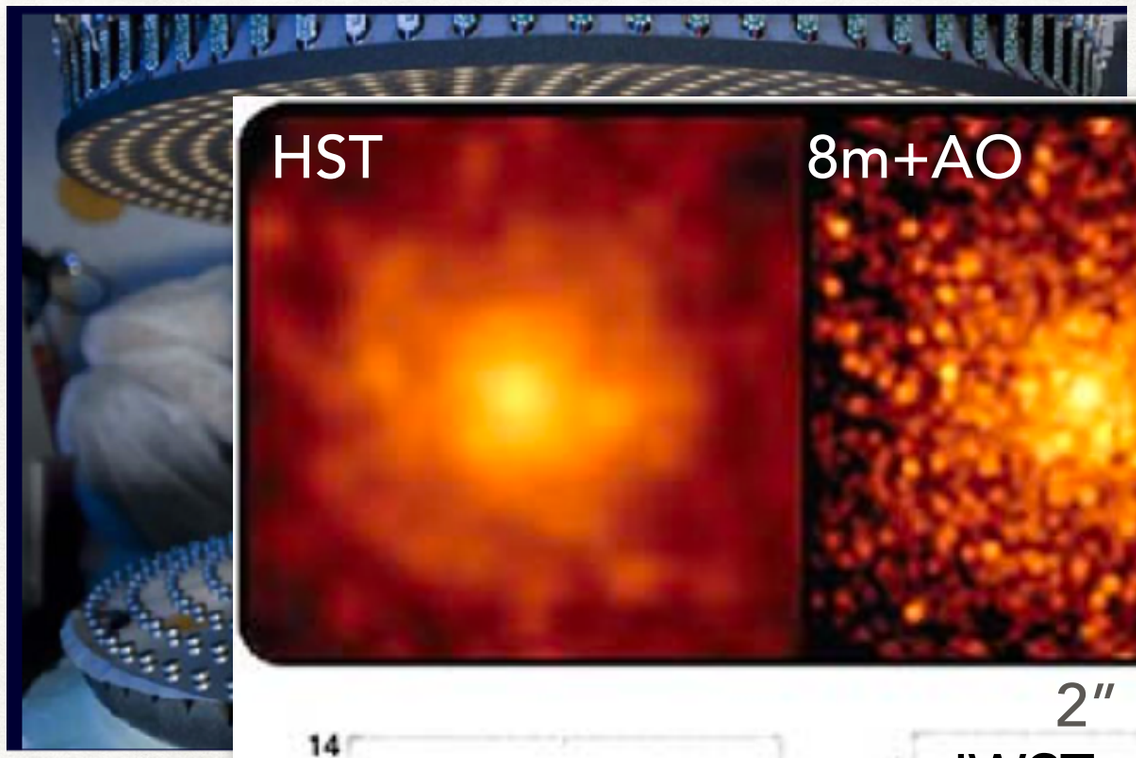
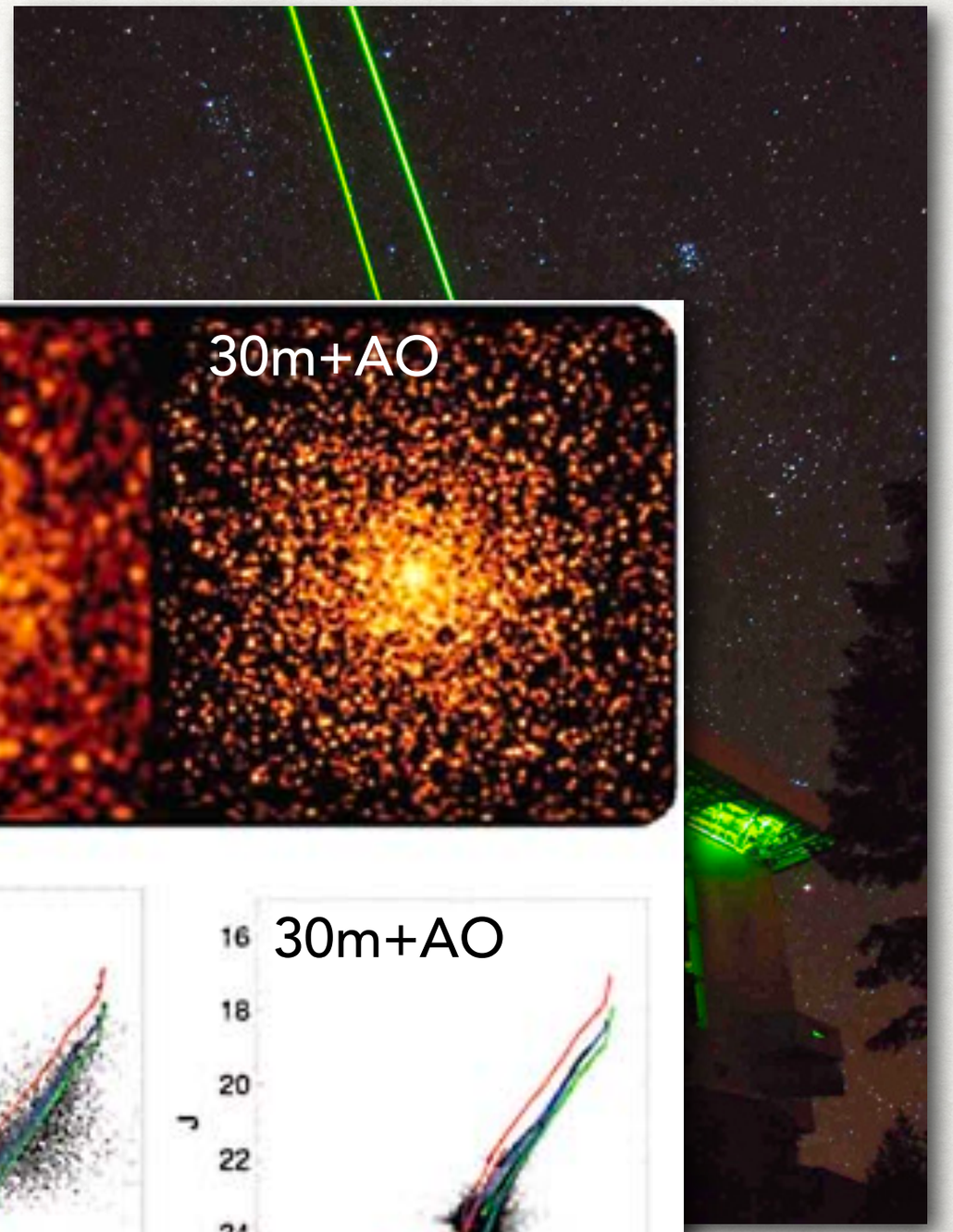




ADAPTIVE OPTICS

Diameter 911 mm
# of actuators 672
setting time <1.5 ms





E-ELT 39M TELESCOPE

798 segmenti da 1.4m
extreme adaptive optics

120 m

100 m

80 m

60 m

40 m

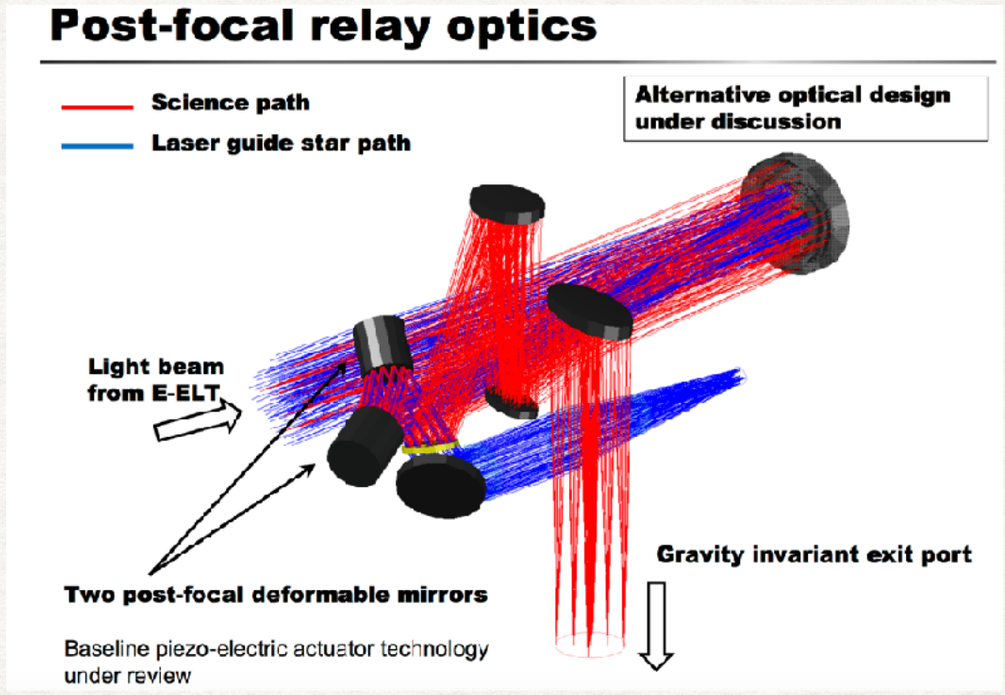
20 m

MAORY & MICADO @E-ELT

MAORY: Multi-conjugate Adaptive Optics RelaY for the ELT

two deformable mirrors piloted from 6 laser guide stars

18.5 Ml€ contract of INAF with ESO

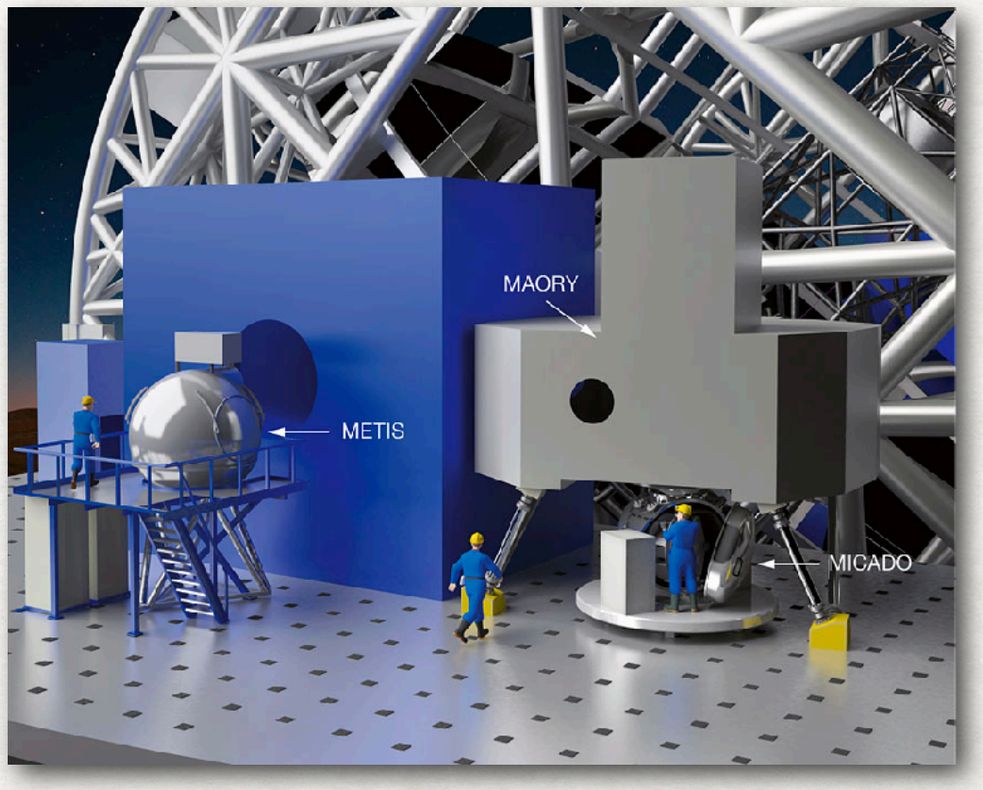


MICADO: Multi-AO Imaging CamerA for Deep Observations

0.8-2.4 nm

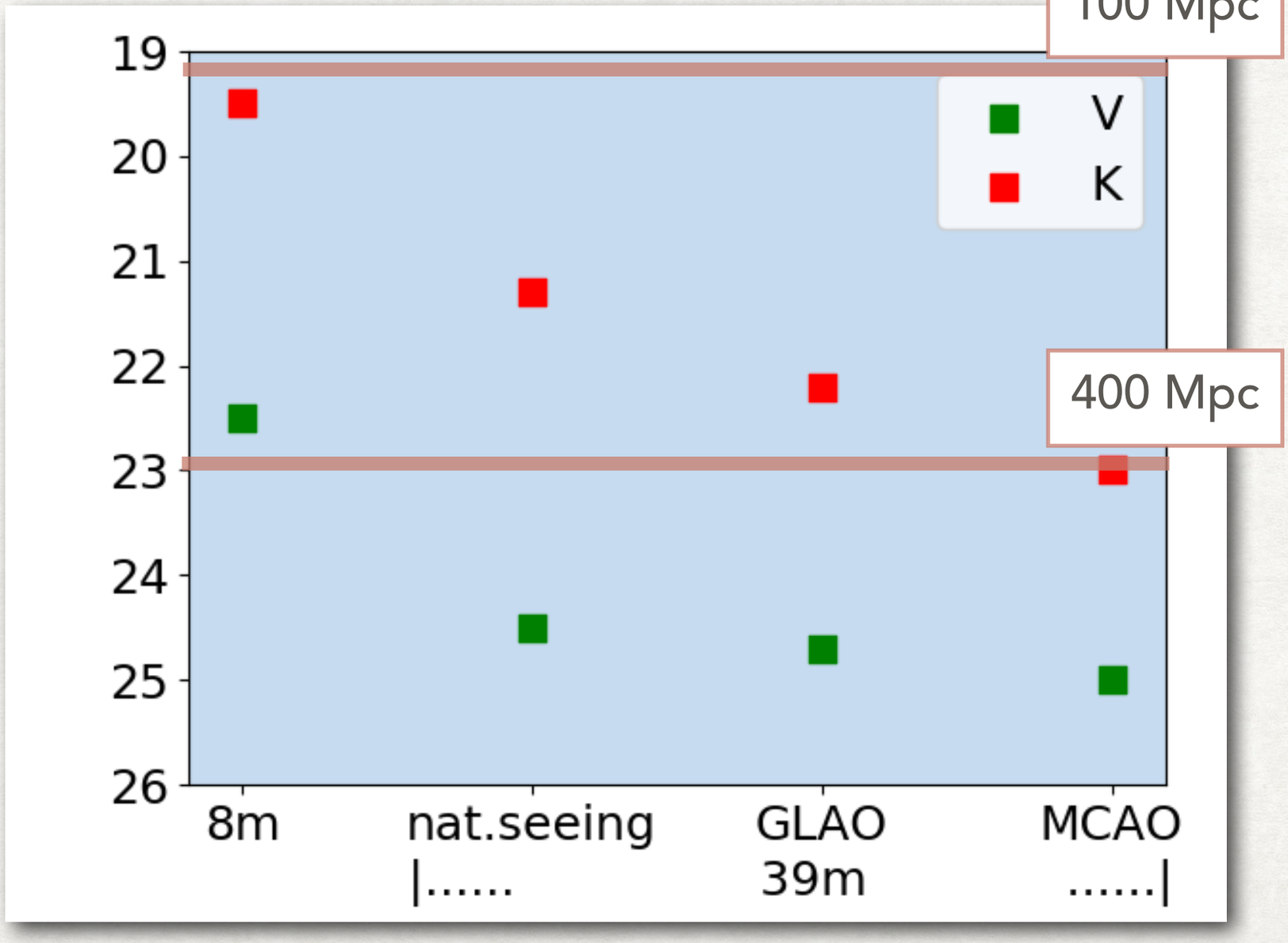
resolution 6-12x10^{-3} arcsec

spectroscopy R~8000



E-ELT 39M TELESCOPE

spectral resolution 5000
magnitude for limit S/N=5
exposure time 3600 sec



E-ELT 39M TELESCOPE

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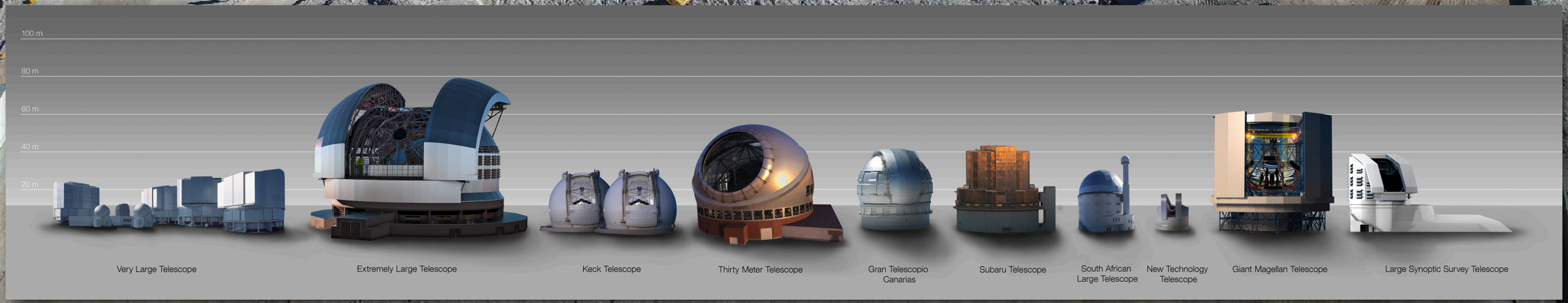

	CURRENT	NEXT
SEARCH	• poor Southern coverage • 21 mag lim	• Black GEM La Silla • LSST 25 mag lim
IDENTIFY	• opt/ir 20 mag 3h • no Northern X-Shooter equivalent	• SOXS opt/ir 20 mag 1h • ?
FOLLOW-UP	• VLT X-Shoother K=19 mag limit	• ESO E-ELT NIR K=23 mag lim • JWST MIR