AGA5802
Multi-object spectroscopy

- Multi-object spectrographs

(long slit, multi-slit, multi-fibers, IFU)

- Some applications

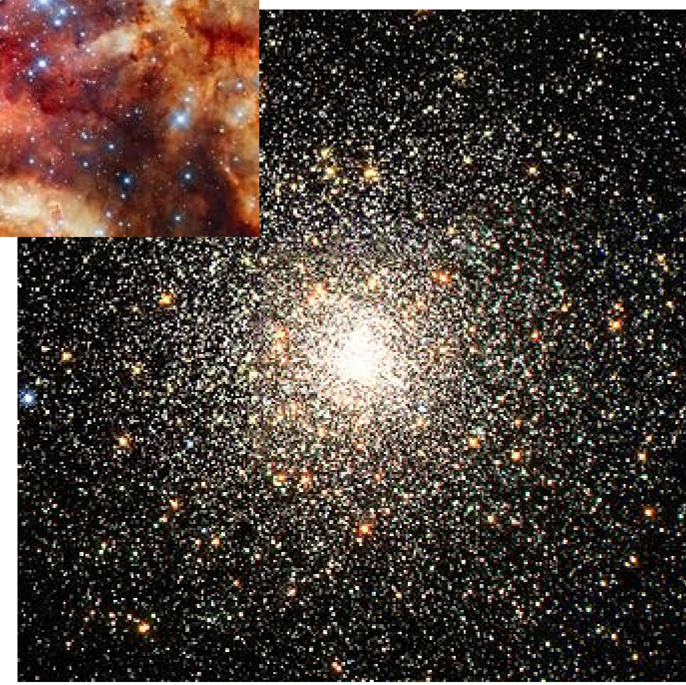
Bibliography: To Measure the Sky, Kitchin, Lena and others ...

Prof. Jorge Meléndez

Multi-object spectroscopy

- Why ?
- How ?

R136 region in the 30 Doradus Nebula. © Nasa



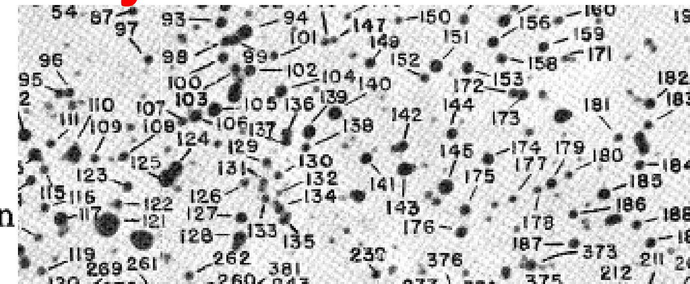
M80, HST

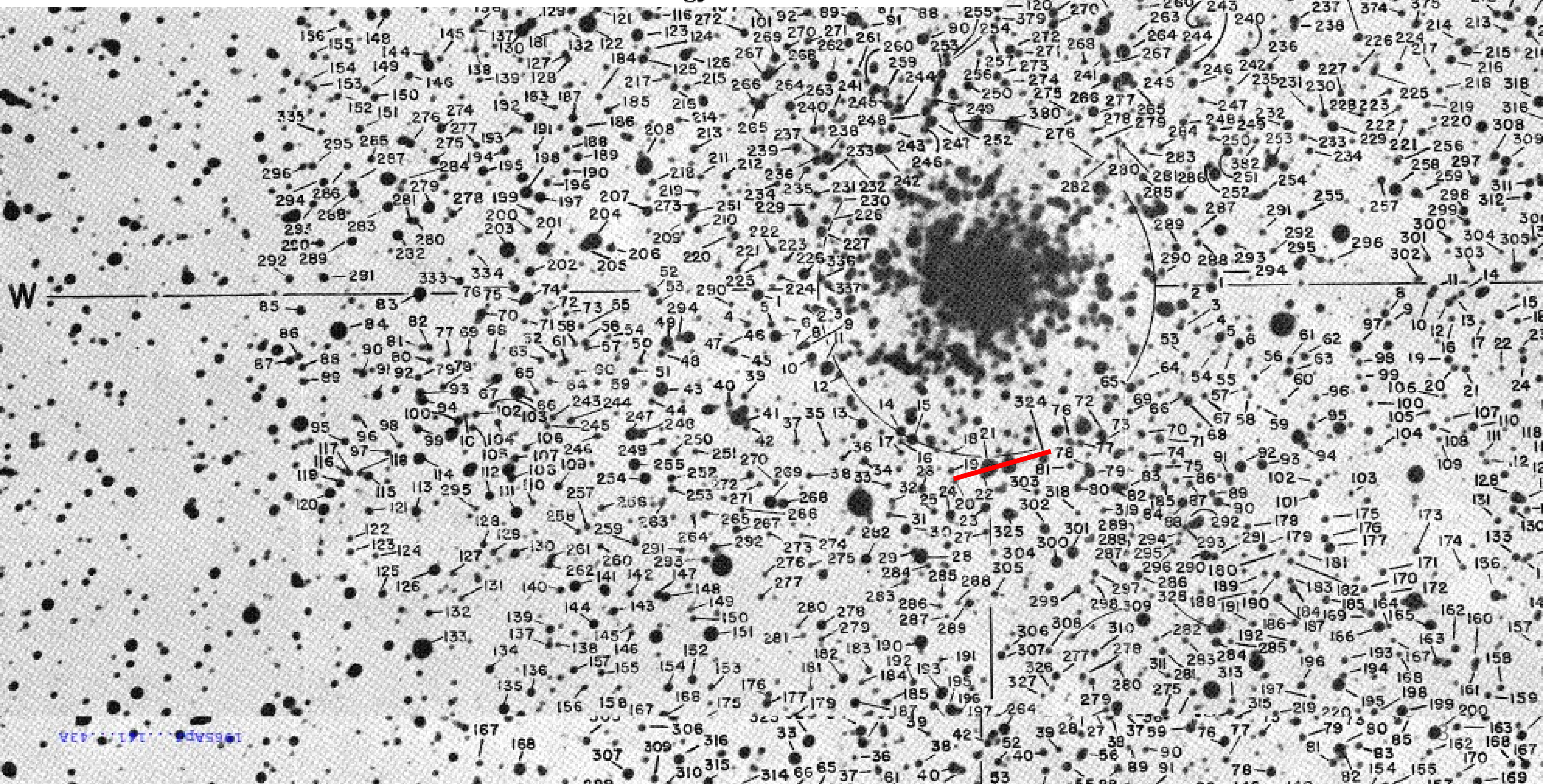
Multi-object spectroscopy

Put more than 1 object on the slit !

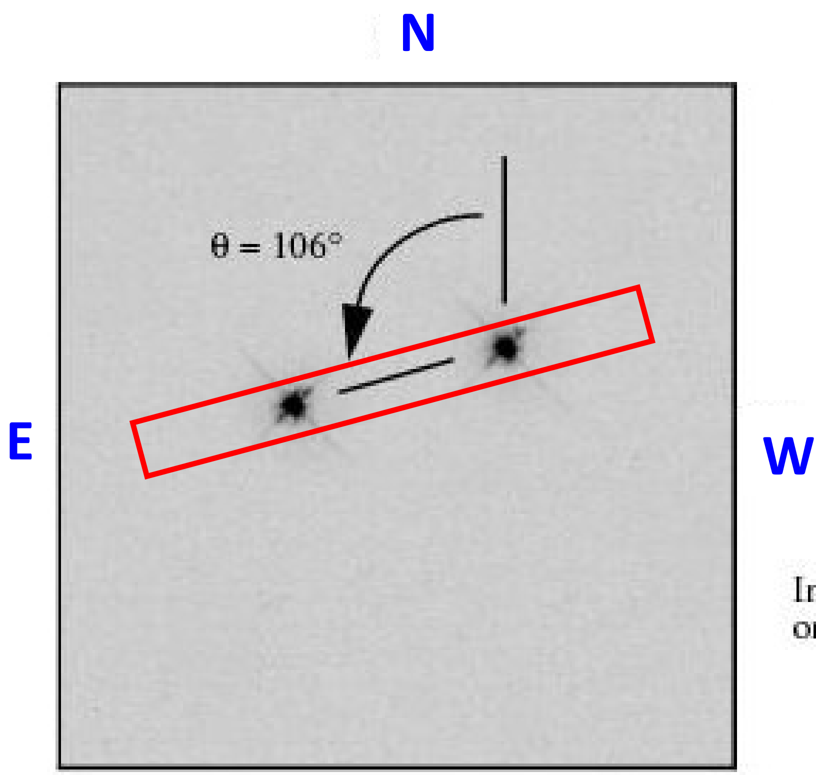
PROPERTIES OF THE GALACTIC NUCLEUS IN THE DIRECTION OF NGC 6522

HALTON ARP
Mount Wilson and Palomar Observatories Carnegie Institution of Washington
California Institute of Technology

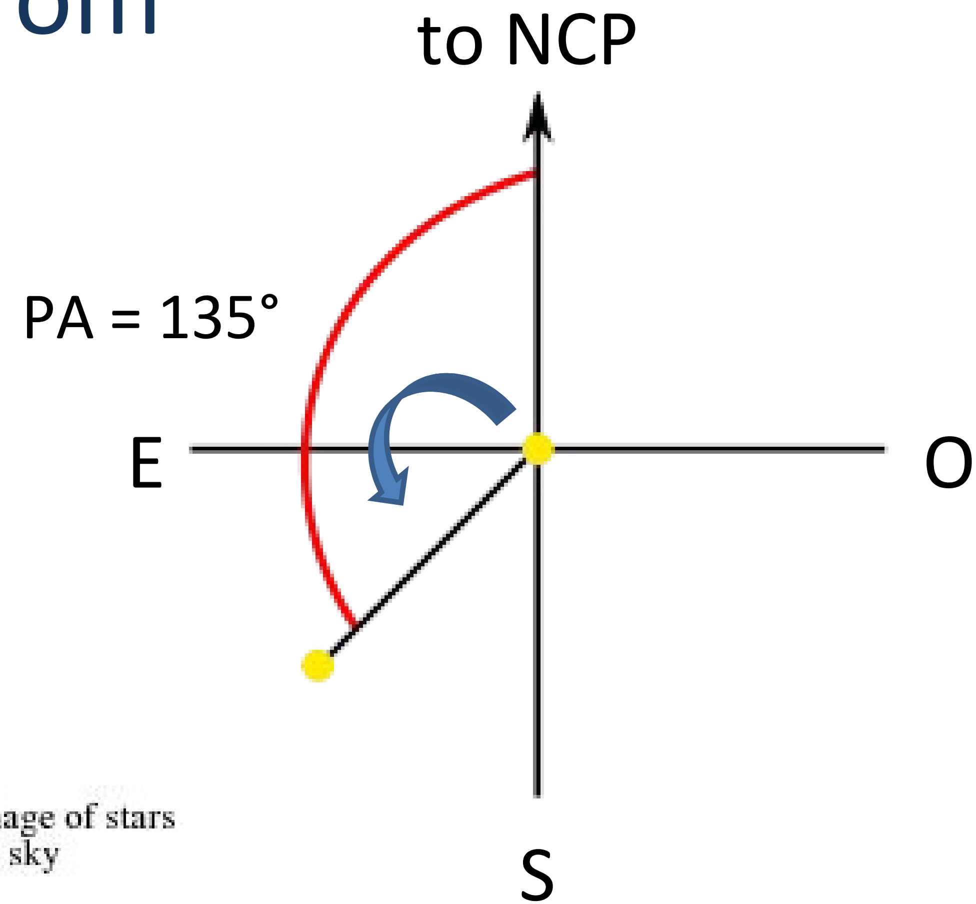




Position angle : from
N to E, S, W

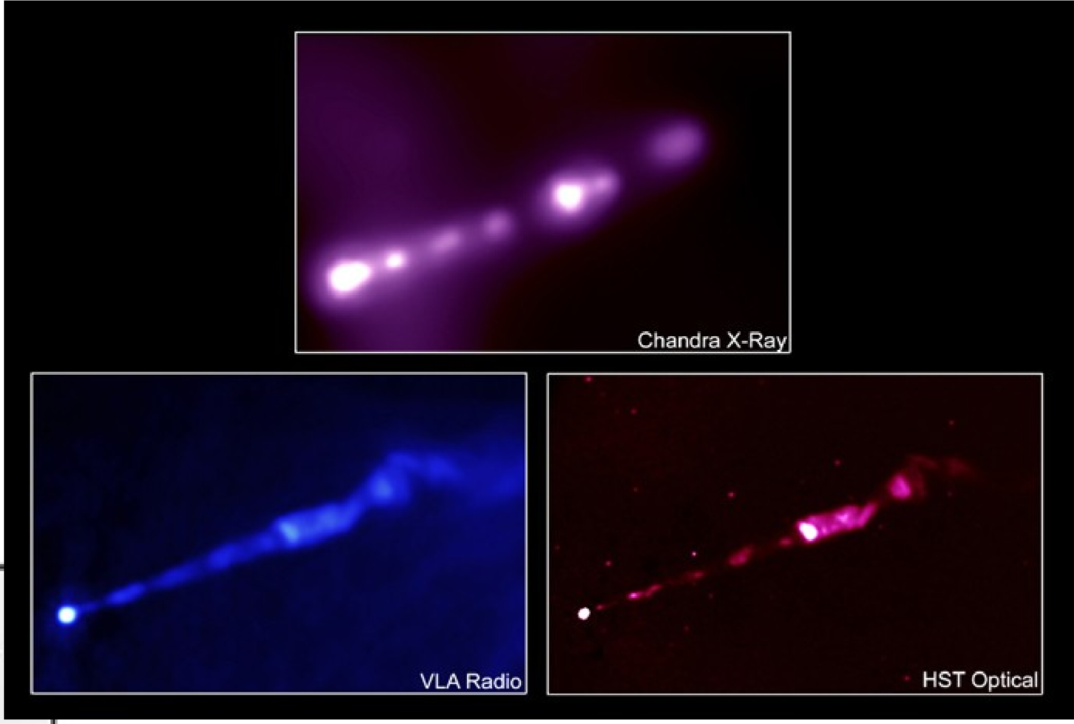


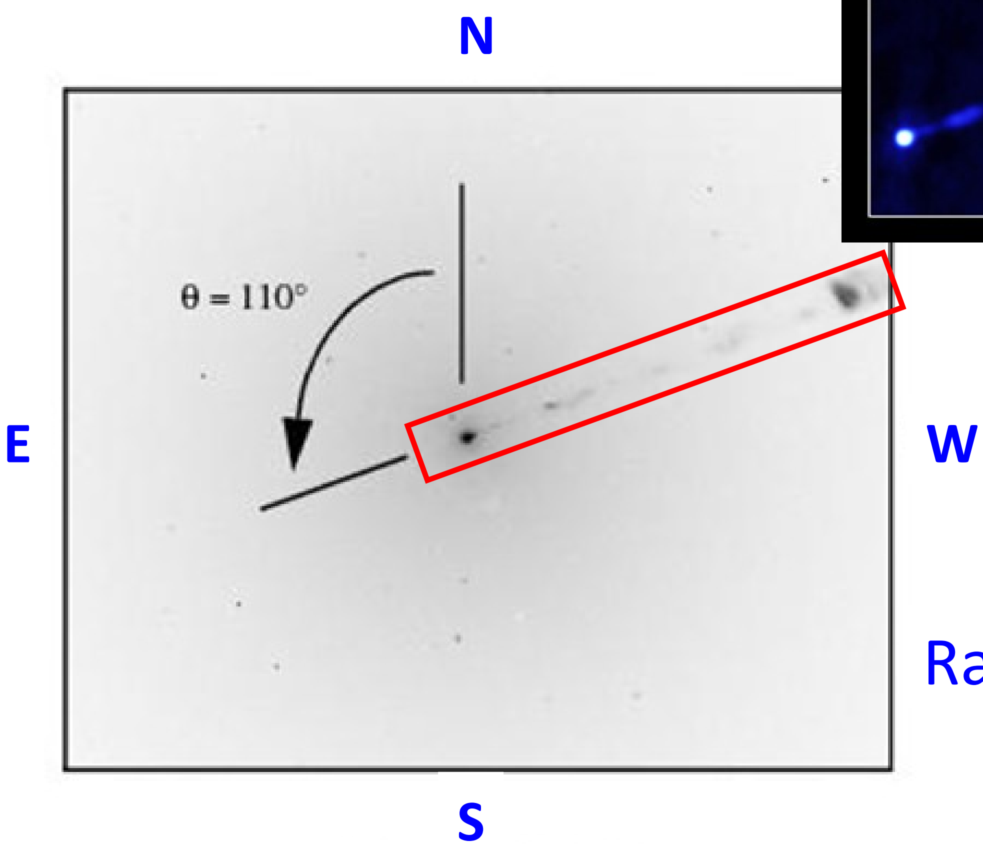
Binary stellar system



Veriffy always the definition adopted by the instrument (usually N → E.S.W.)

Position angle

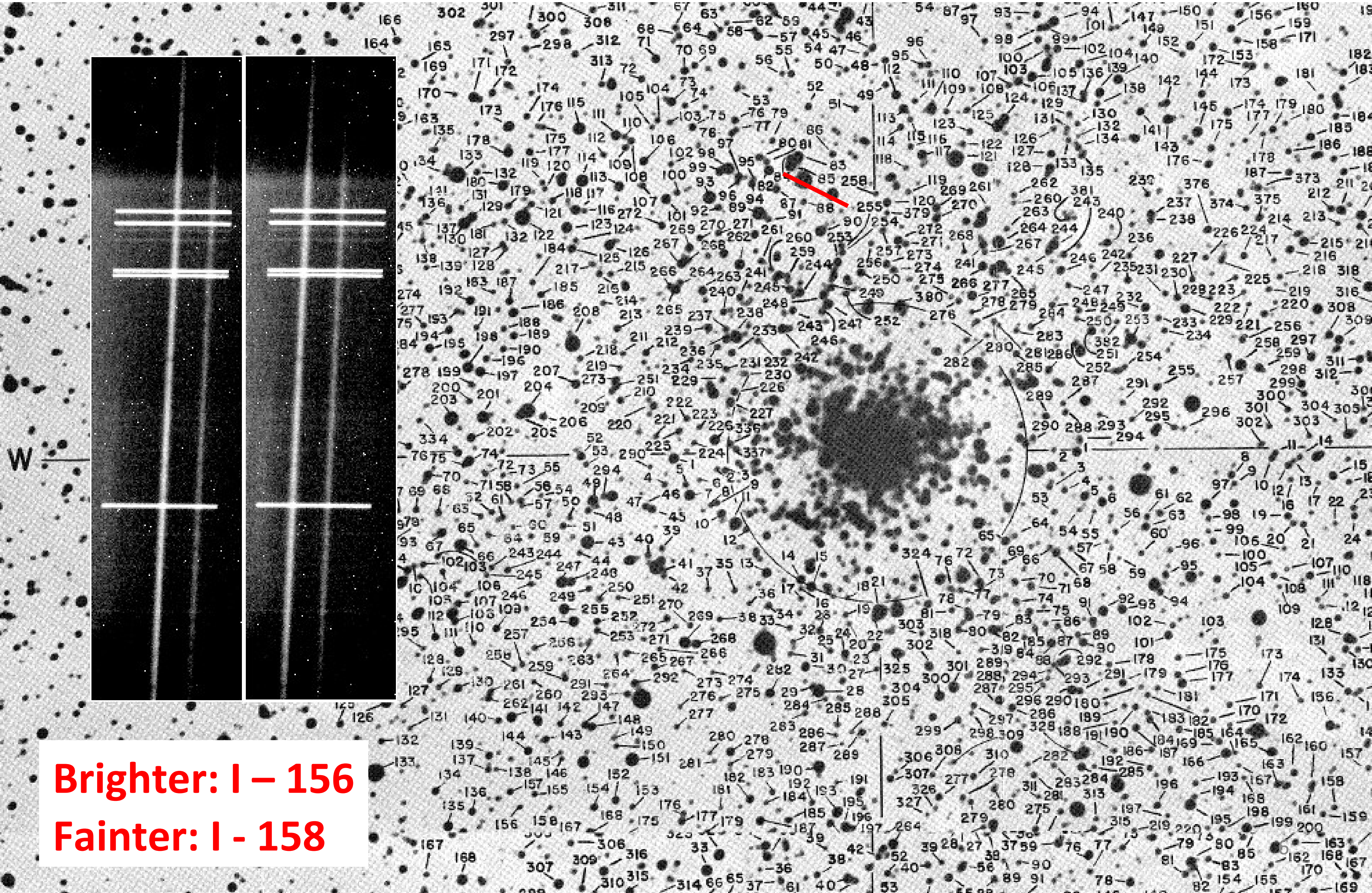




Radio galaxy with jet

Radio Galaxy (Virgo A) with jet

Observing bulge stars in the infrared with Phoenix : Echelle but single order …



A&A 484, L21–L25 (2008)
DOI: 10.1051/0004-6361:200809398

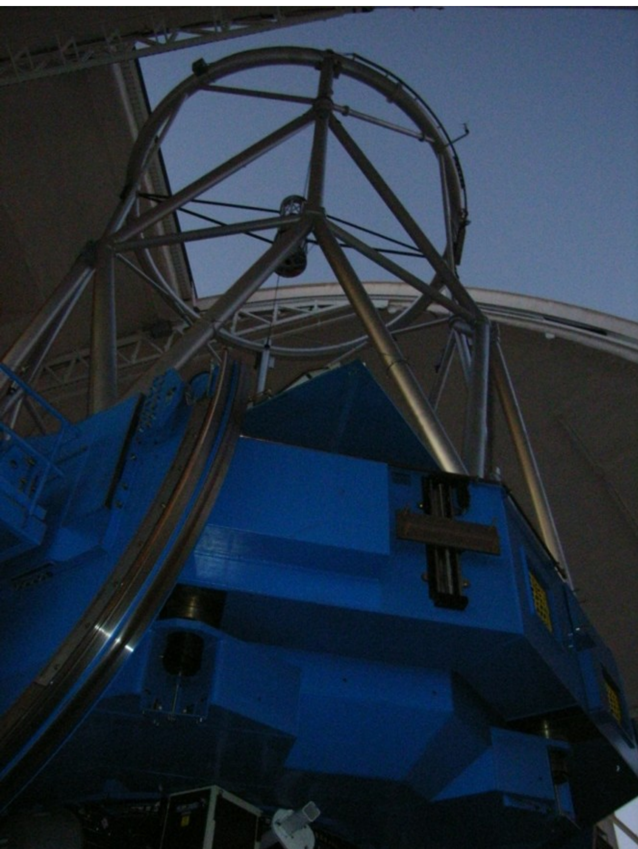
Astronomy & Astrophysics

Letter to the Editor

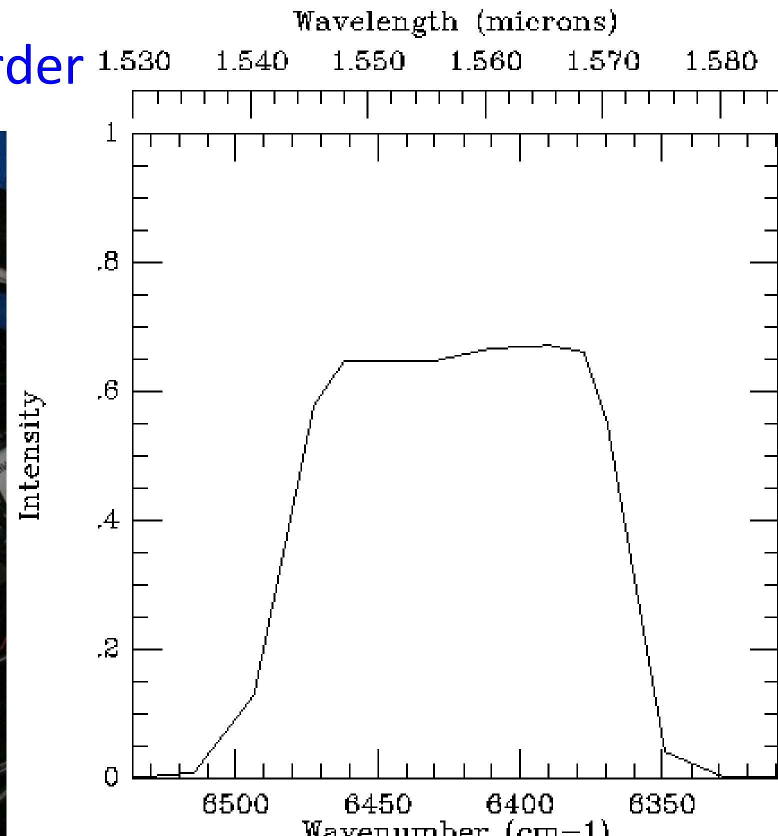
Chemical similarities between Galactic bulge and local thick disk red giant stars

J. Meléndez[1,2], M. Asplund[3], A. Alves-Brito[4], K. Cunha[5,6], B. Barbuy[4], M. S. Bessell[2], C. Chiappini[7,8], K. C. Freeman[2], I. Ramírez[9], V. V. Smith[5], and D. Yong[2]

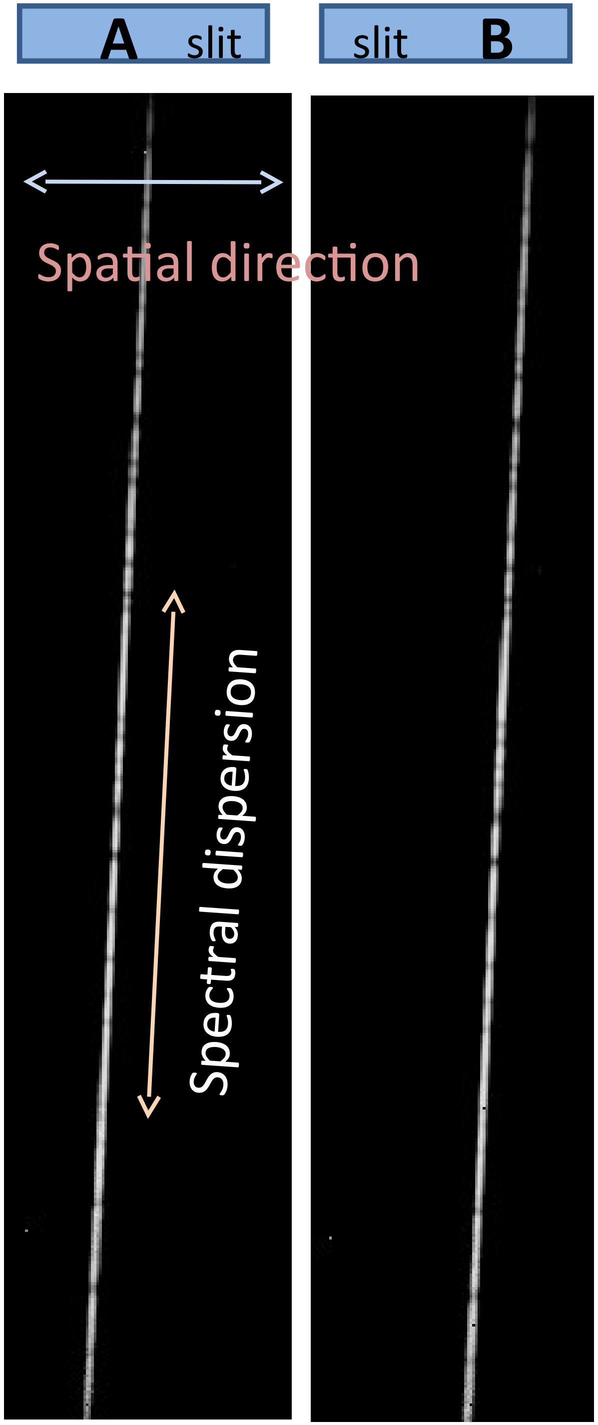
High resolution IR spectroscopy with Phoenix at Gemini

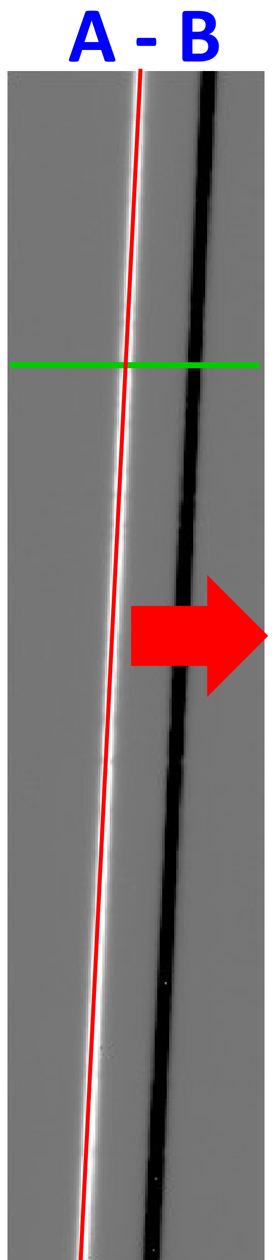


Echelle, but single order

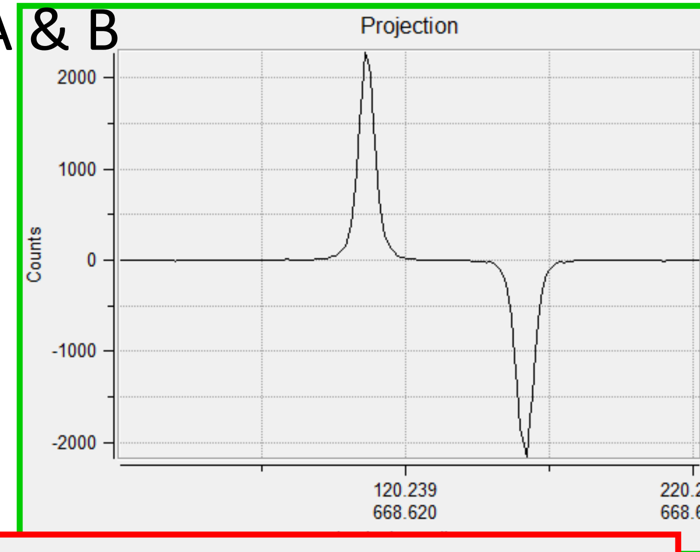


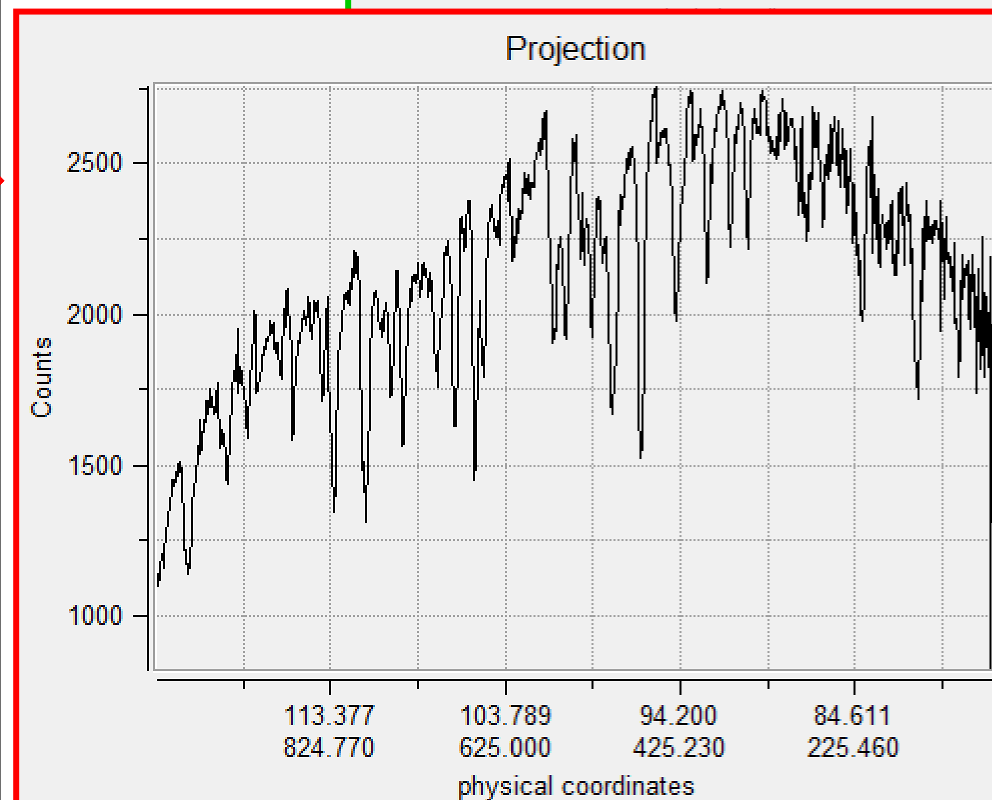
Data reduction in the infrared : one star observed at positions A & B





To subtract the sky (& dark) we do A-B and B-A





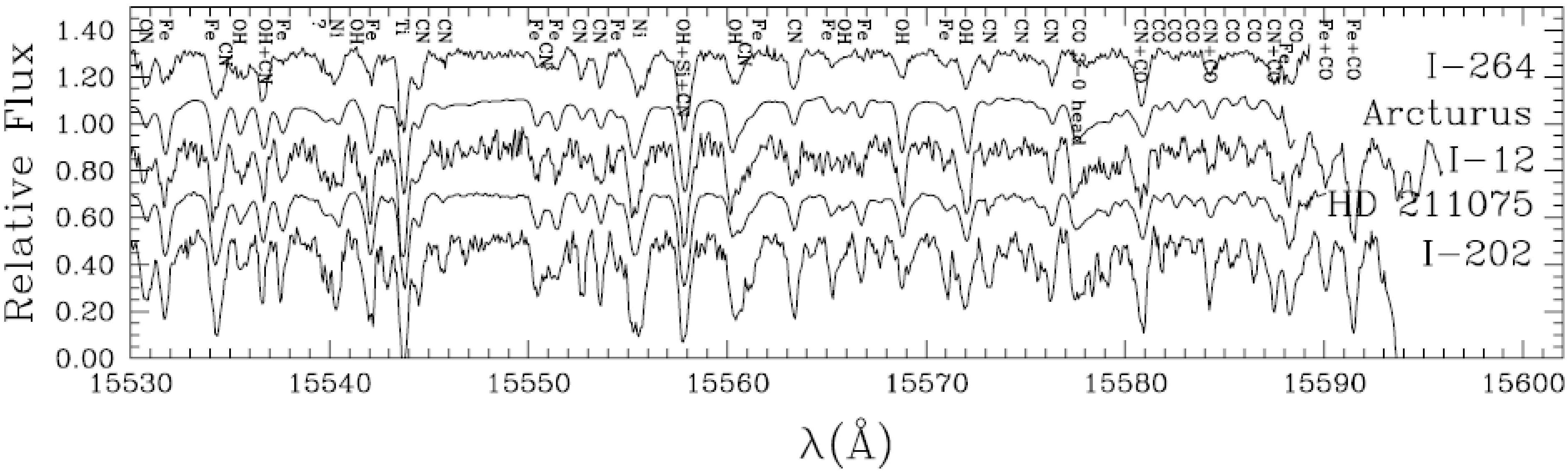


Fig. 1. Observed Phoenix spectra of selected bulge giants as well as thick (Arcturus = HD 124897) and thin (HD 211075) disk stars.

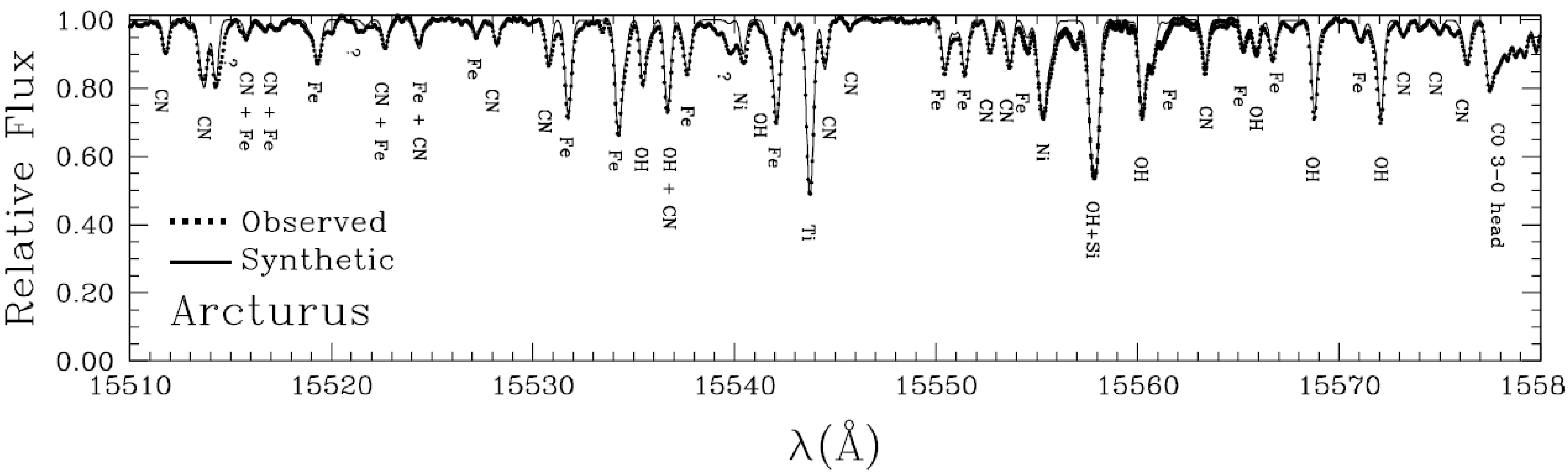


Fig. 7. Observed (dotted line) and synthetic (solid line) spectra of Arcturus in the region 1.551−1.558 μm.

Long slit spectroscopy

Cut in the spatial direction for PA = 43°

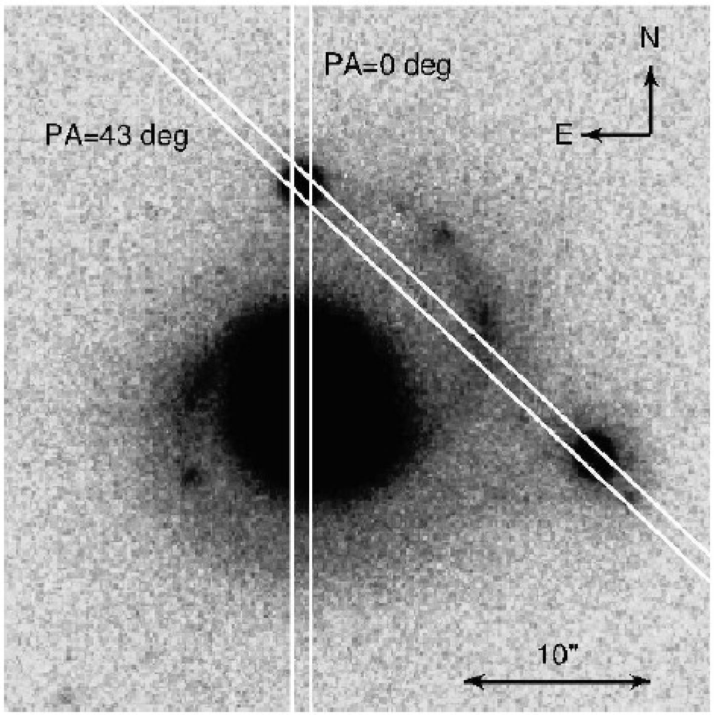


Fig. 2. ISAAC *J*-band image of I Zw 1 overlaid with the two slit settings used for the ISAAC long-slit spectroscopy. The slit for PA = 0° includes the QSO of I Zw 1 and the northern source, the slit for PA = 43° includes the northern source and the likely western companion.

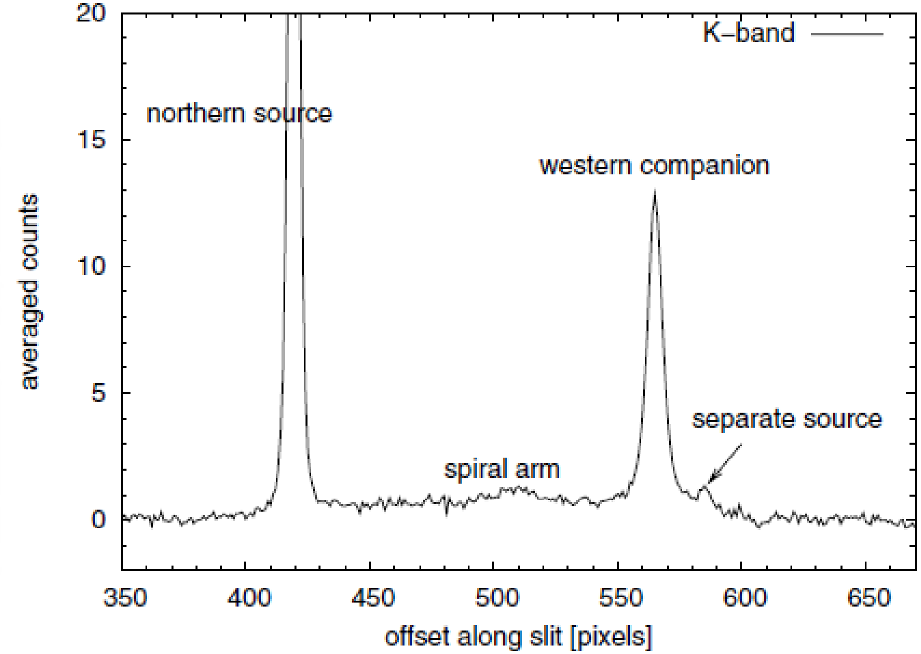
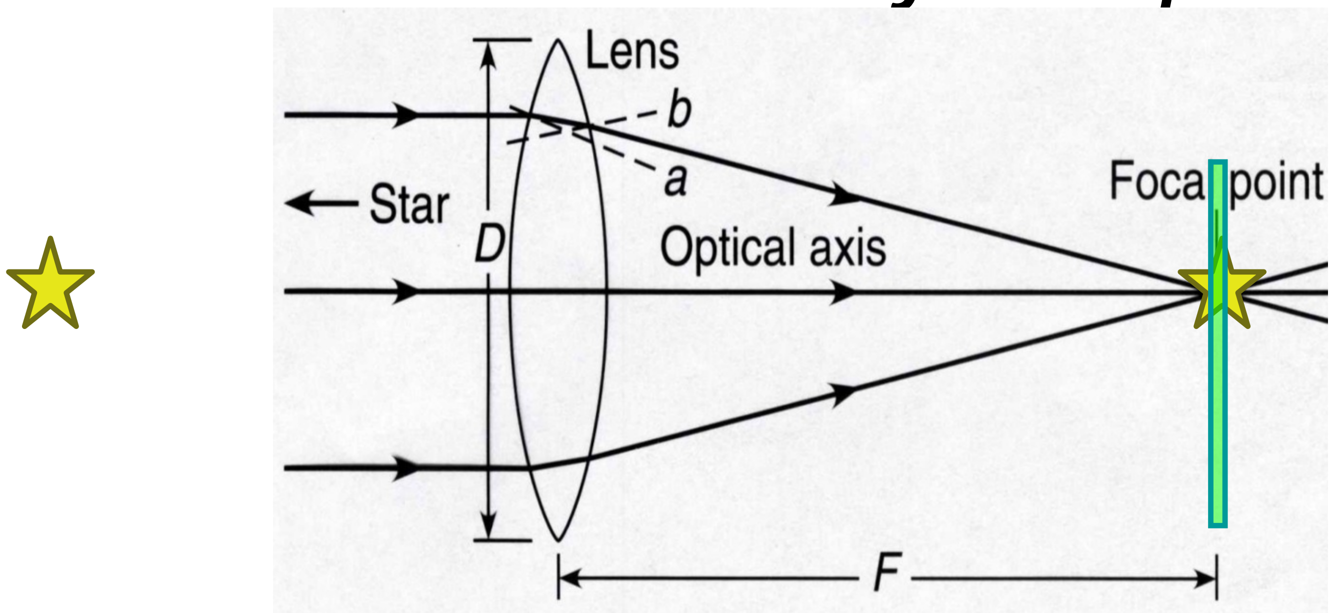
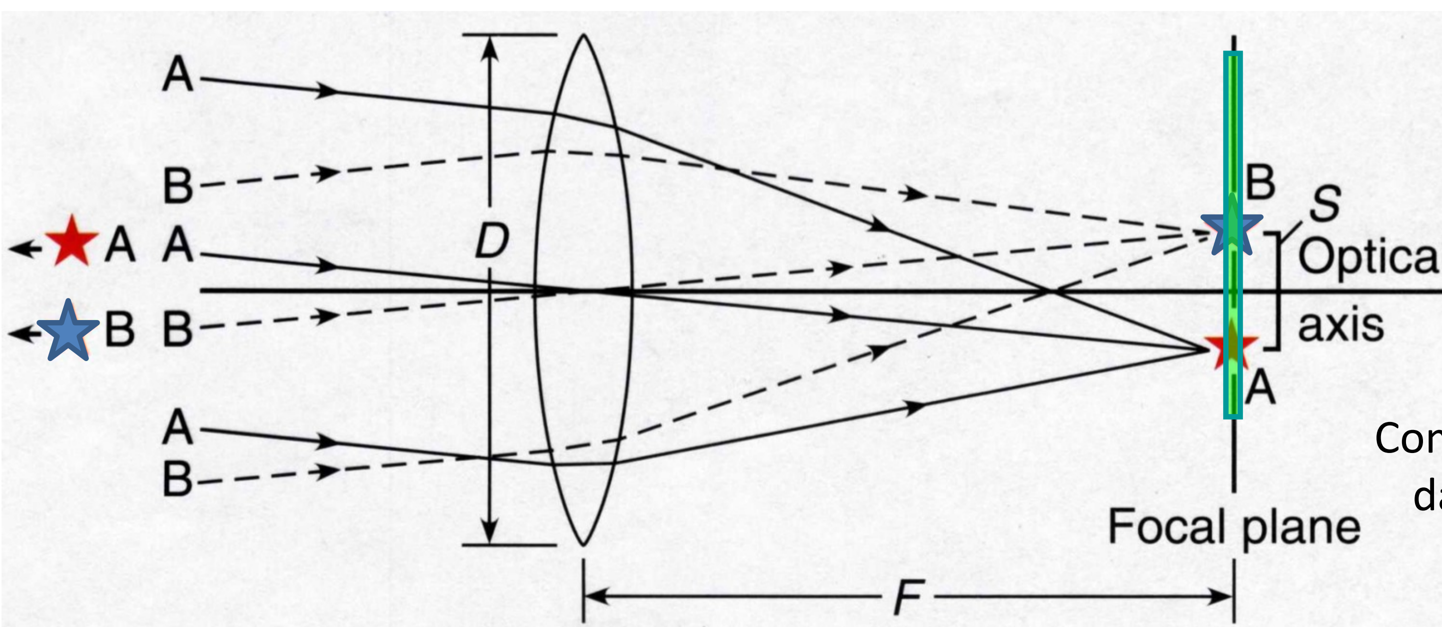


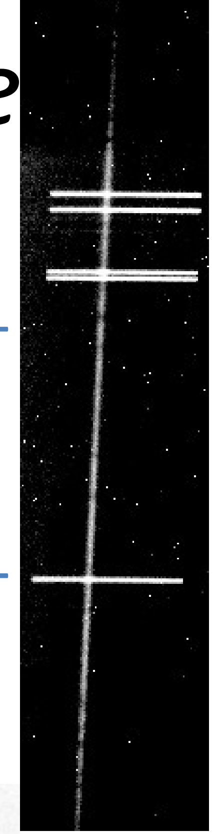
Fig. 4. Cut along the spatial axis of the two-dimensional *K*-band spectrum obtained for the PA = +43° setting (see Fig. 2). The cut consists of an average over almost all the spatial lines of the image.

Slit on the *focal plane*



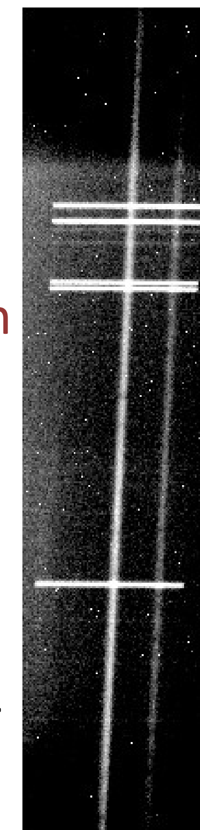


Spectral dispersion



Sky lines
(infrared)

Spatial direction



Comprimento da fenda no detetor

Multi-slit spectroscopy

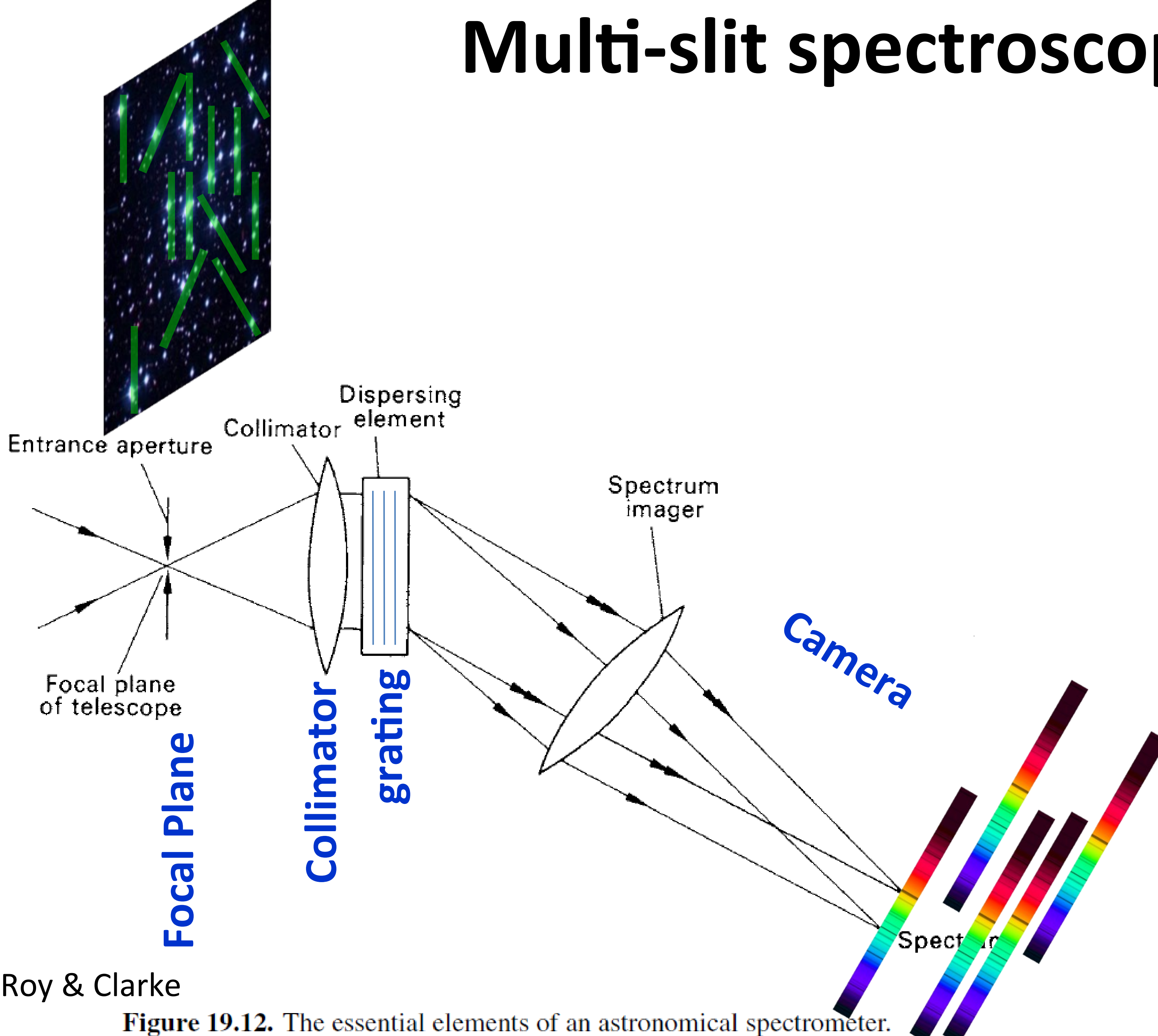
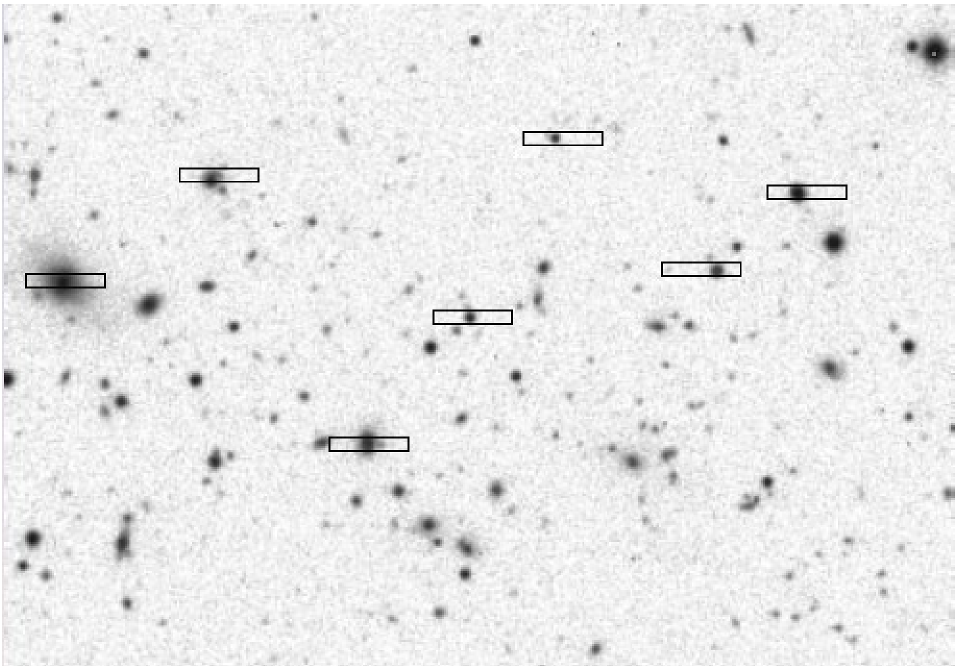
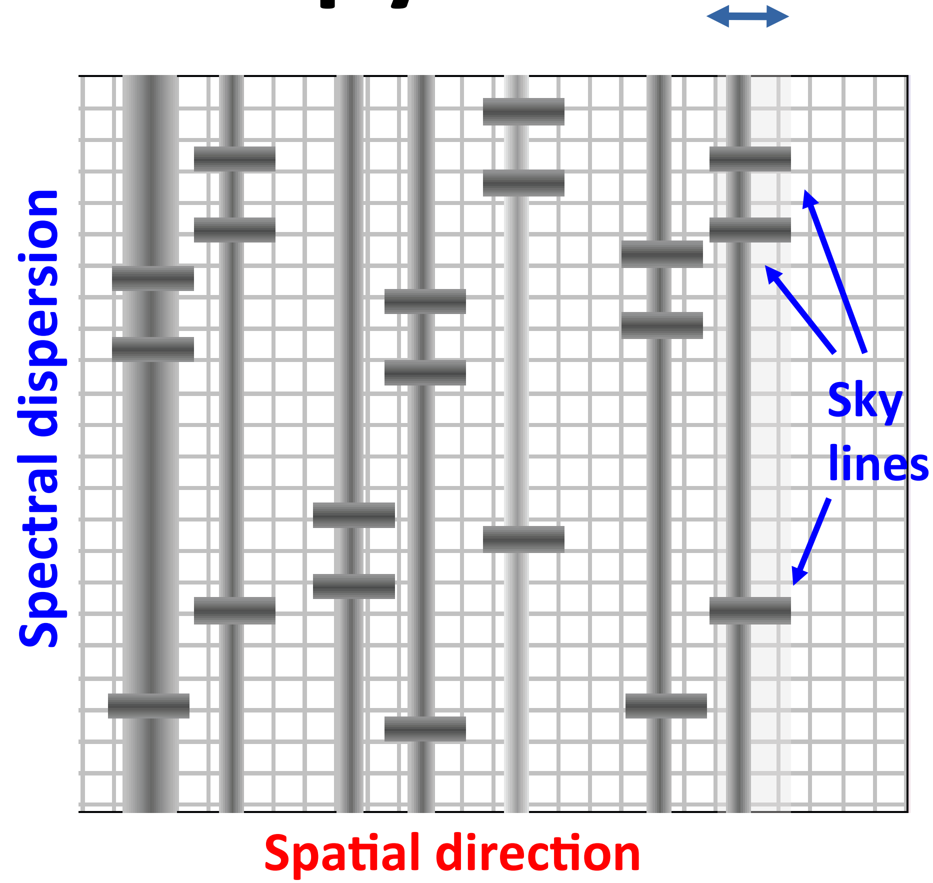


Figure 19.12. The essential elements of an astronomical spectrometer.

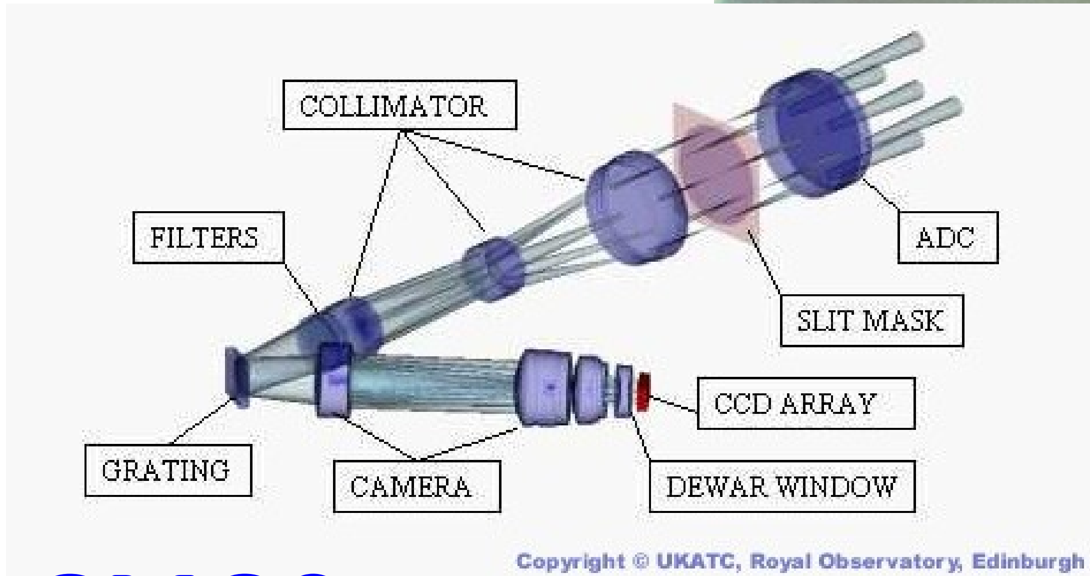
Multi-slit spectroscopy



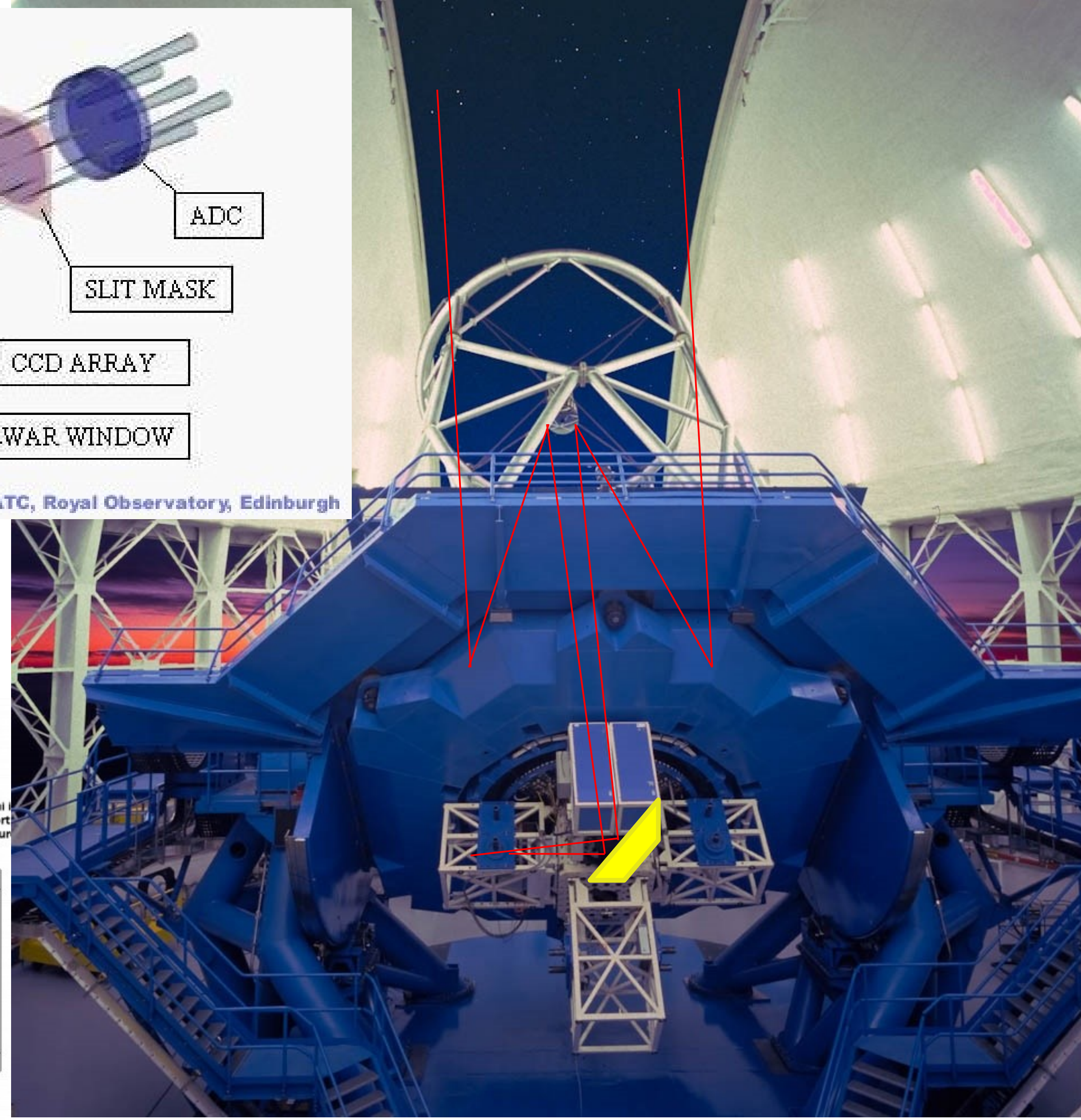
Slits at the focal plane

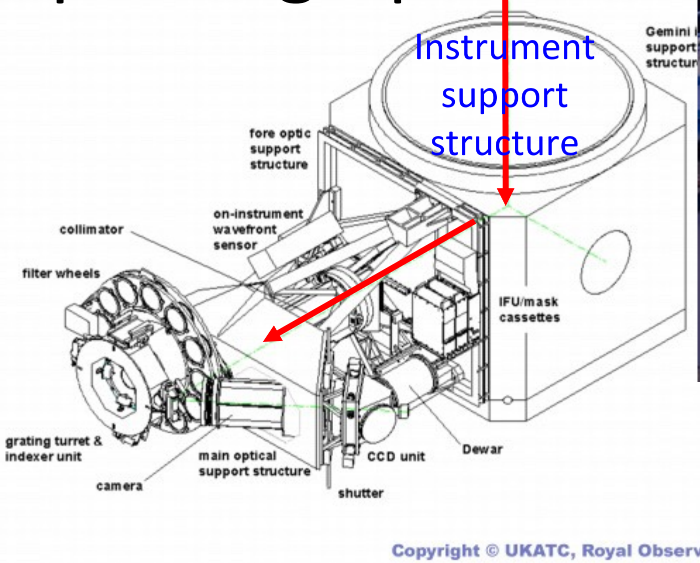


Spectra on the CCD



GMOS Gemini **M**ulti-**O**bject **S**pectrograph





GMOS

- 2 **G**emini **M**ulti-**O**bject **S**pectrographs : GN & GS
- 5.5 arcminute field of view
- Imaging
- 0.36-0.94 μm long-slit spectroscopy
- 0.36-0.94 μm multi-slit spectroscopy
- Integral Field Unit (IFU), to obtain spectra from a 35 arcsec^2 area with a sampling of 0.2 arcsec

Instrument	Pixel Size (arcsec)	Imaging Field of View ($arcsec^2$)
GMOS-N (original EEV and upgraded e2v DD)	0.0728	330 x 330
GMOS-N (Hamamatsu)	0.0807	330 x 330
GMOS-S (original EEV)	0.073	330 x 330
GMOS-S (Hamamatsu)	0.080	330 x 330

GMOS imaging field = 5,5 x 5,5 arcmin

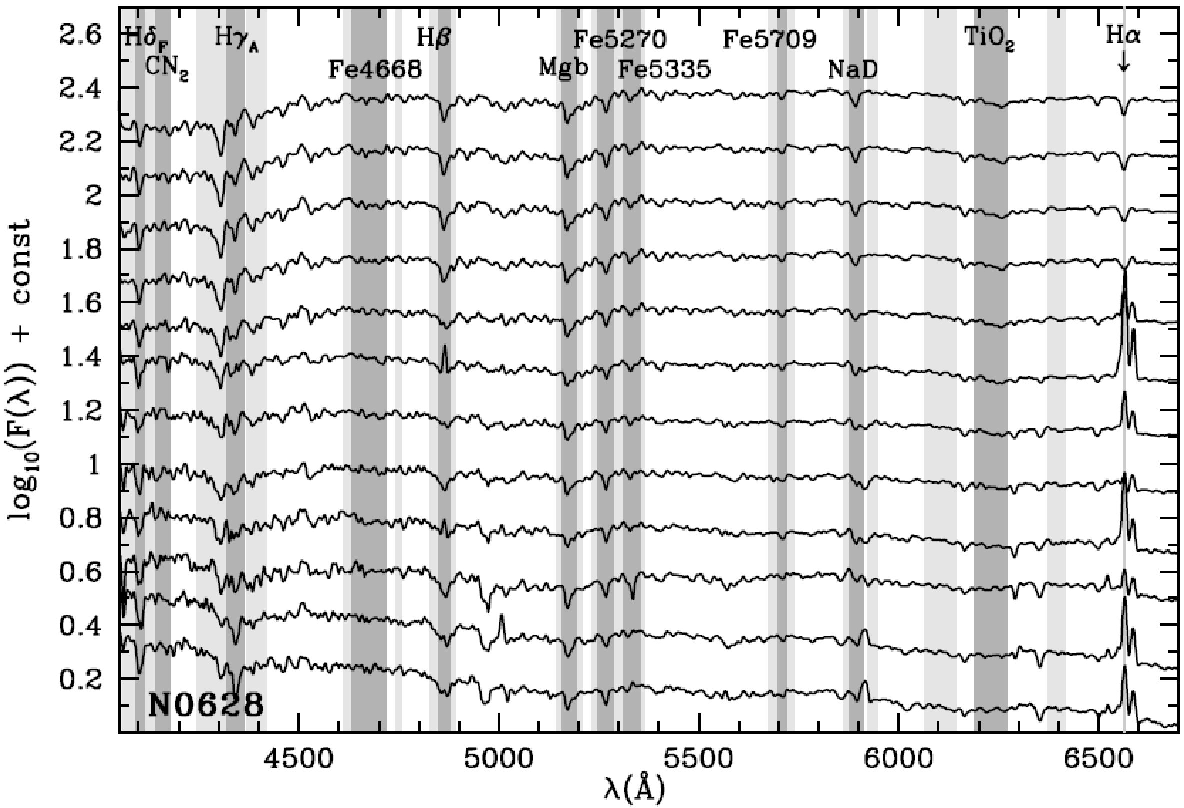
GMOS imaging

NGC 628 = M 74

GMOS long-slit

The slit has some length, rather than being a “hole”, because we need to observe the sky emission as well

Resolving power	Slit width	Slit length(s)
8800	0.25 arcsec	330 arcsec
4400	0.5 arcsec	330 and 108 arcsec
	0.75 arcsec	330 and 108 arcsec
	1.0 arcsec	330 and 108 arcsec
	1.5 arcsec	330 and 108 arcsec
	2.0 arcsec	330 and 108 arcsec
500	5.0 arcsec	330 arcsec



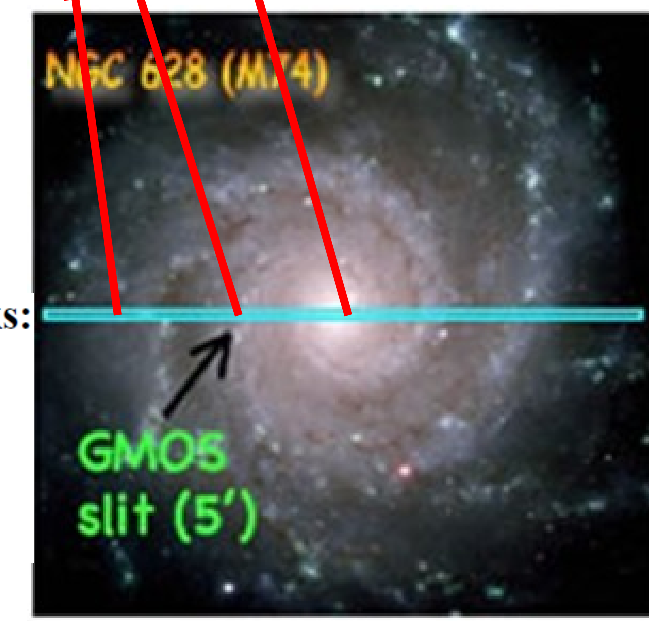
Rad (″)	S/N (/Å)
0.0	93.2
0.9	71.6
3.0	59.1
5.2	63.4
9.4	54.0
15.6	55.7
23.5	50.7
35.2	52.5
51.6	50.2
80.4	50.3
106.8	50.7
113.7	50.1

GMOS long-slit

2009 MNRAS, 395, 28

Stellar Population and Kinematic Profiles In Spiral Bulges & Disks: Population Synthesis of Integrated Spectra

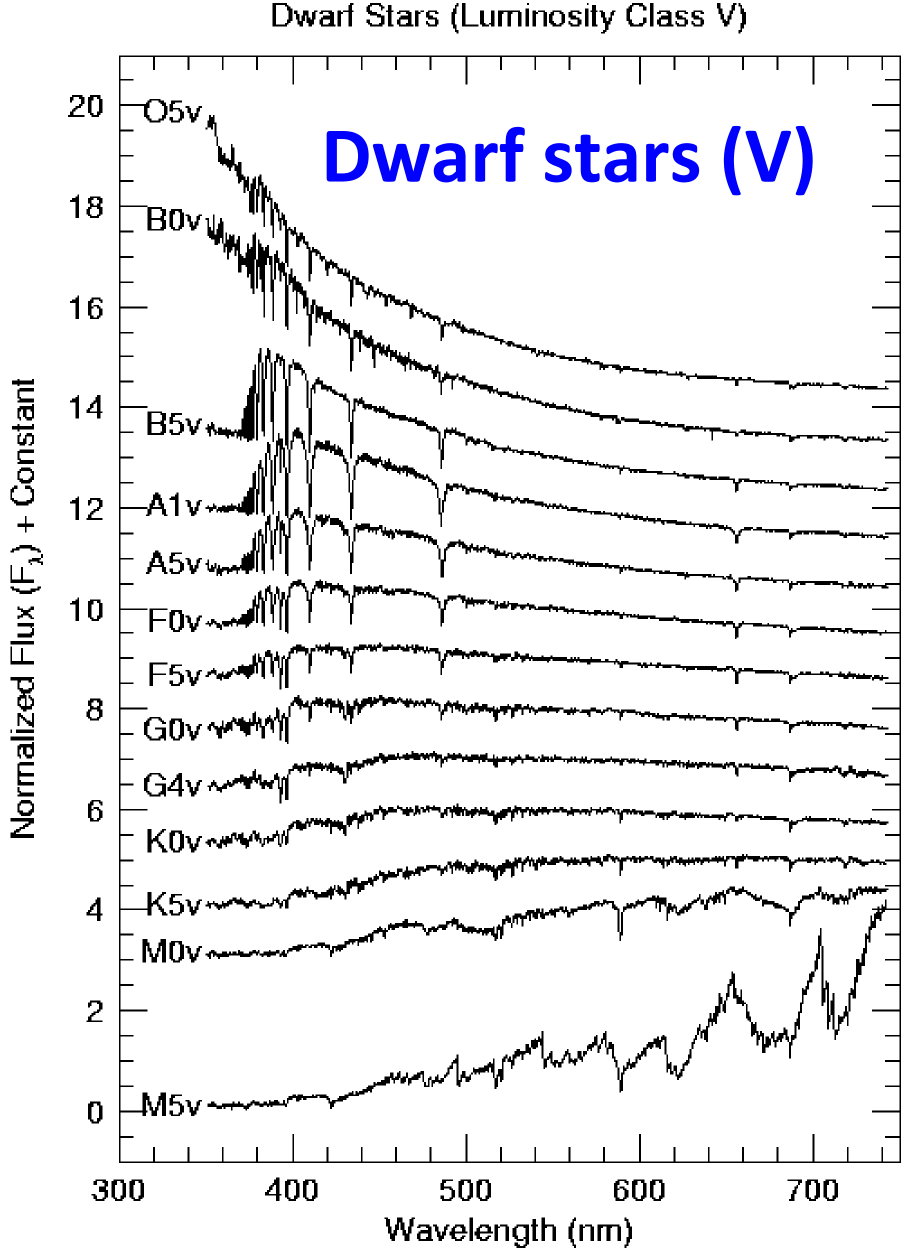
Lauren A. MacArthur[1*], J. Jesús González[2]†, and Stéphane Courteau[3]‡
[1] *Department of Astrophysics, California Institute of Technology, MS 105-24, Pasadena, CA 91125*
[2] *Instituto de Astronomia, Universidad Nacional Autónoma de México, Apdo Postal 70-264, Cd. Universitaria, 04510 México*
[3] *Department of Physics, Engineering Physics & Astronomy, Queen's University, Kingston, ON K7L 3N6, Canada*

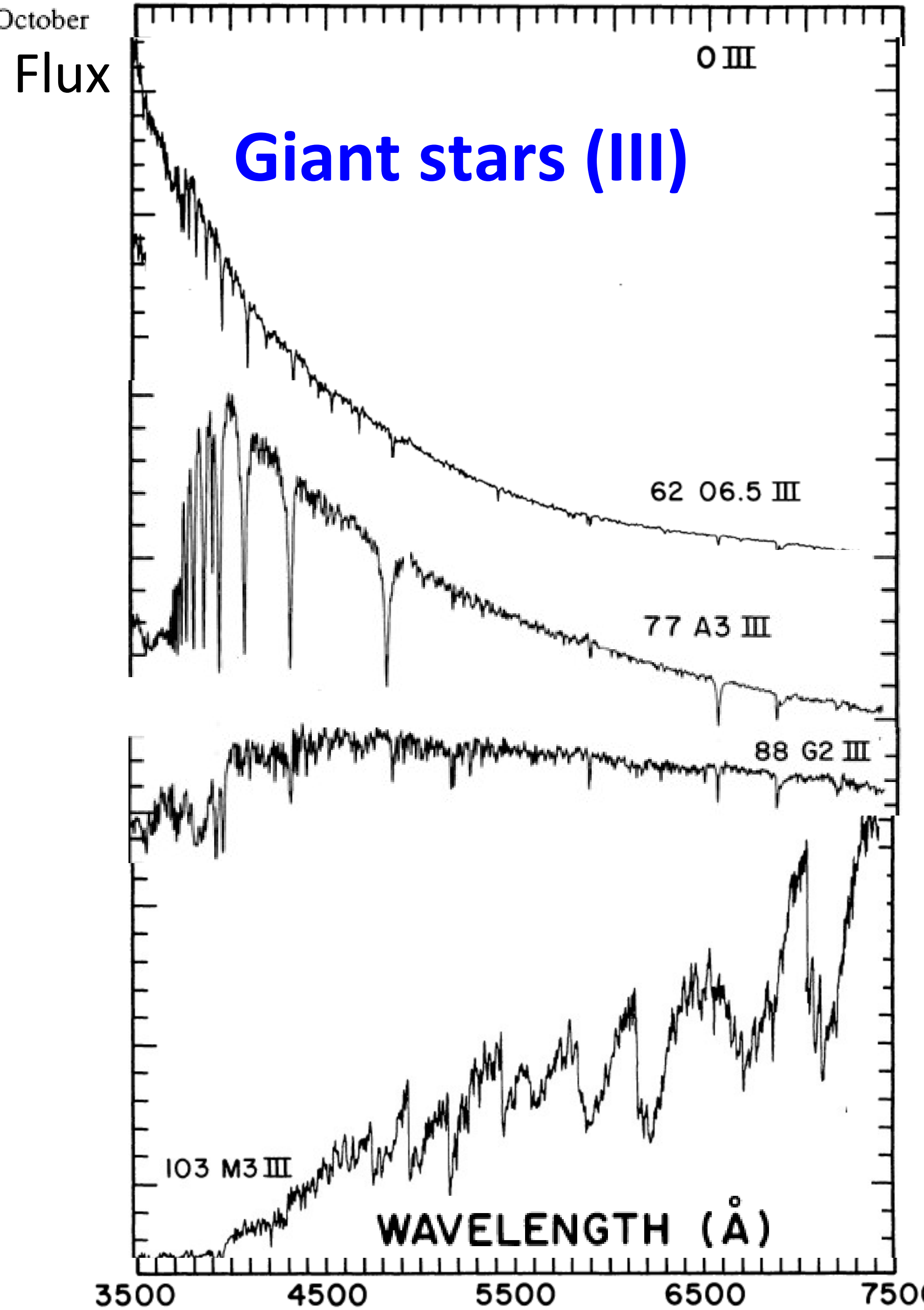


THE ASTROPHYSICAL JOURNAL SUPPLEMENT SERIES, 56:257–281, 1984 October

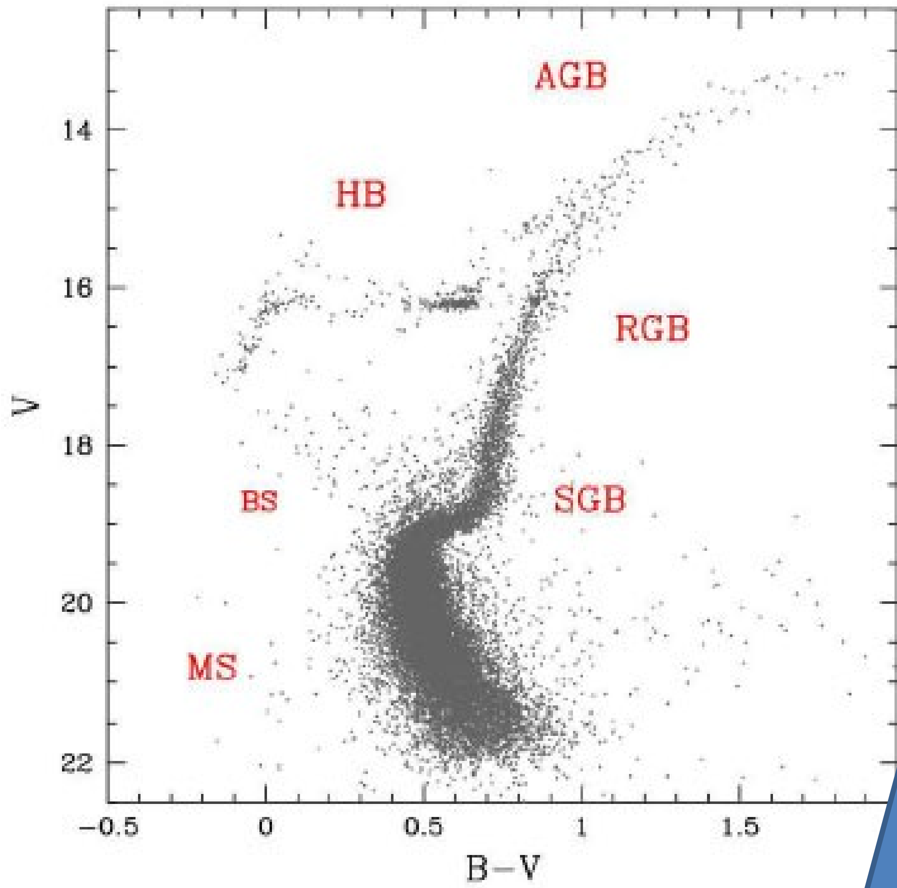
A LIBRARY OF STELLAR SPECTRA

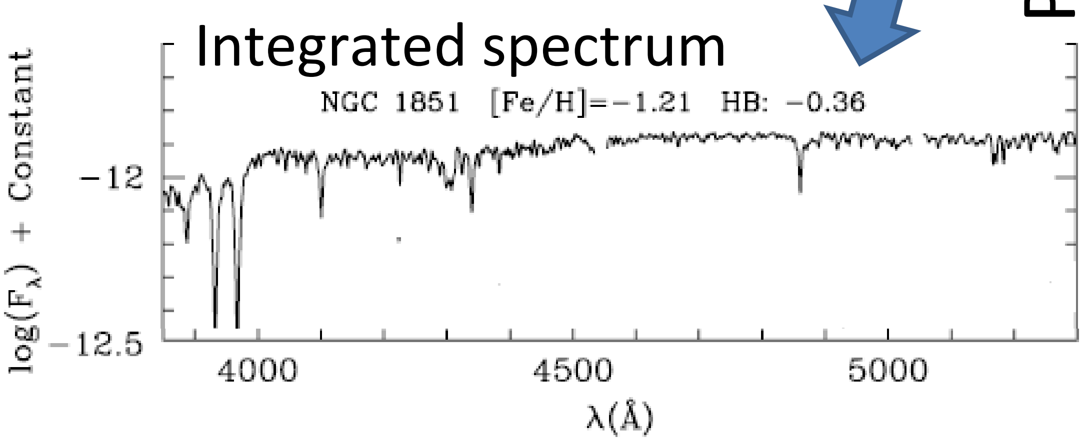
GEORGE H. JACOBY AND DEIDRE A. HUNTER
CAROL A. CHRISTIAN

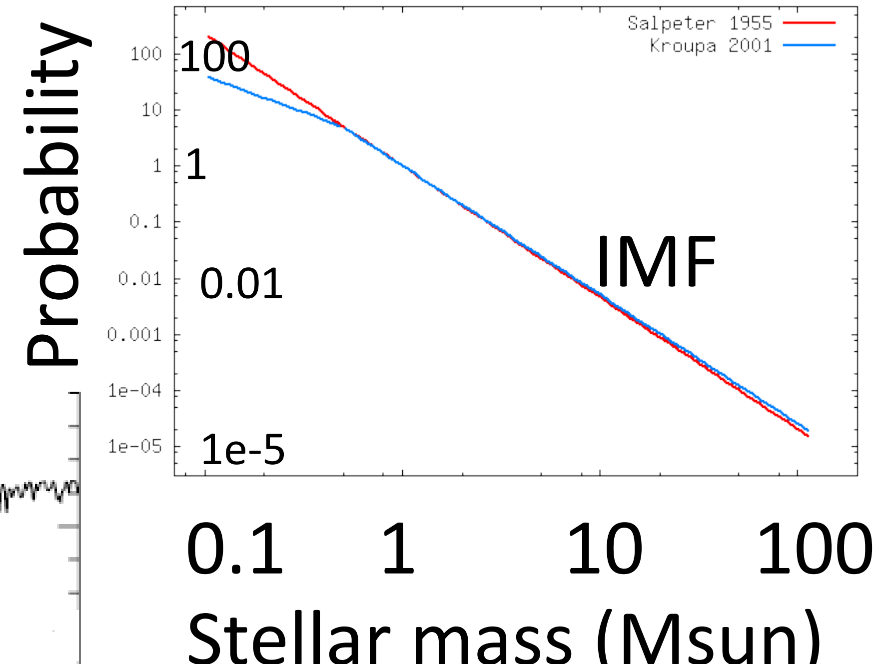




Cluster NGC 1851







simple stellar populations (SSP) models
For several ages and metallicities

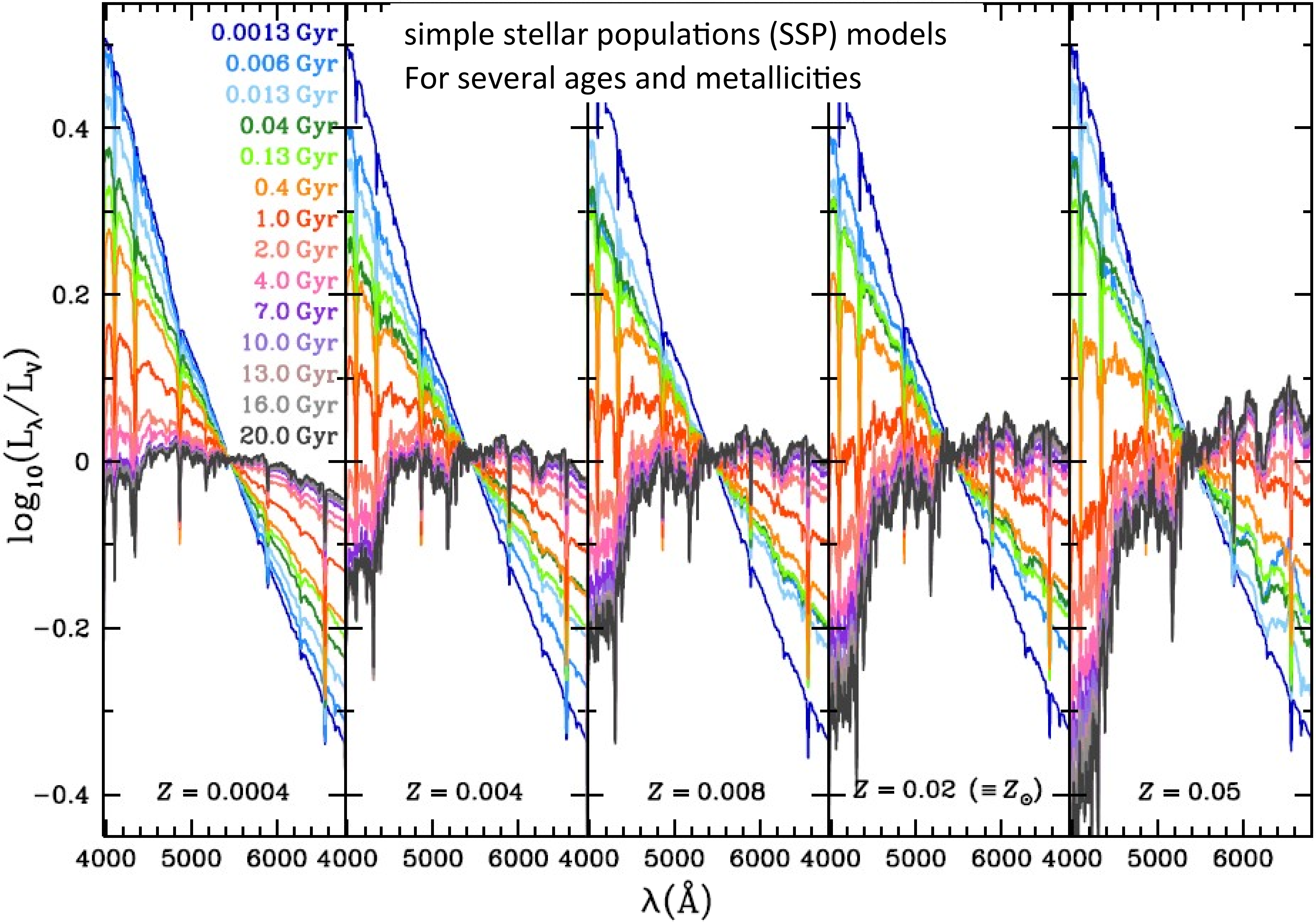


Figure 2. Spectra of the 70 SSP templates used in the population synthesis fits. Metallicity increases from left to right. Different ages have different colours and are labeled in leftmost panel. All spectra are normalized to their V-band flux.

MacArthur et al. 2009

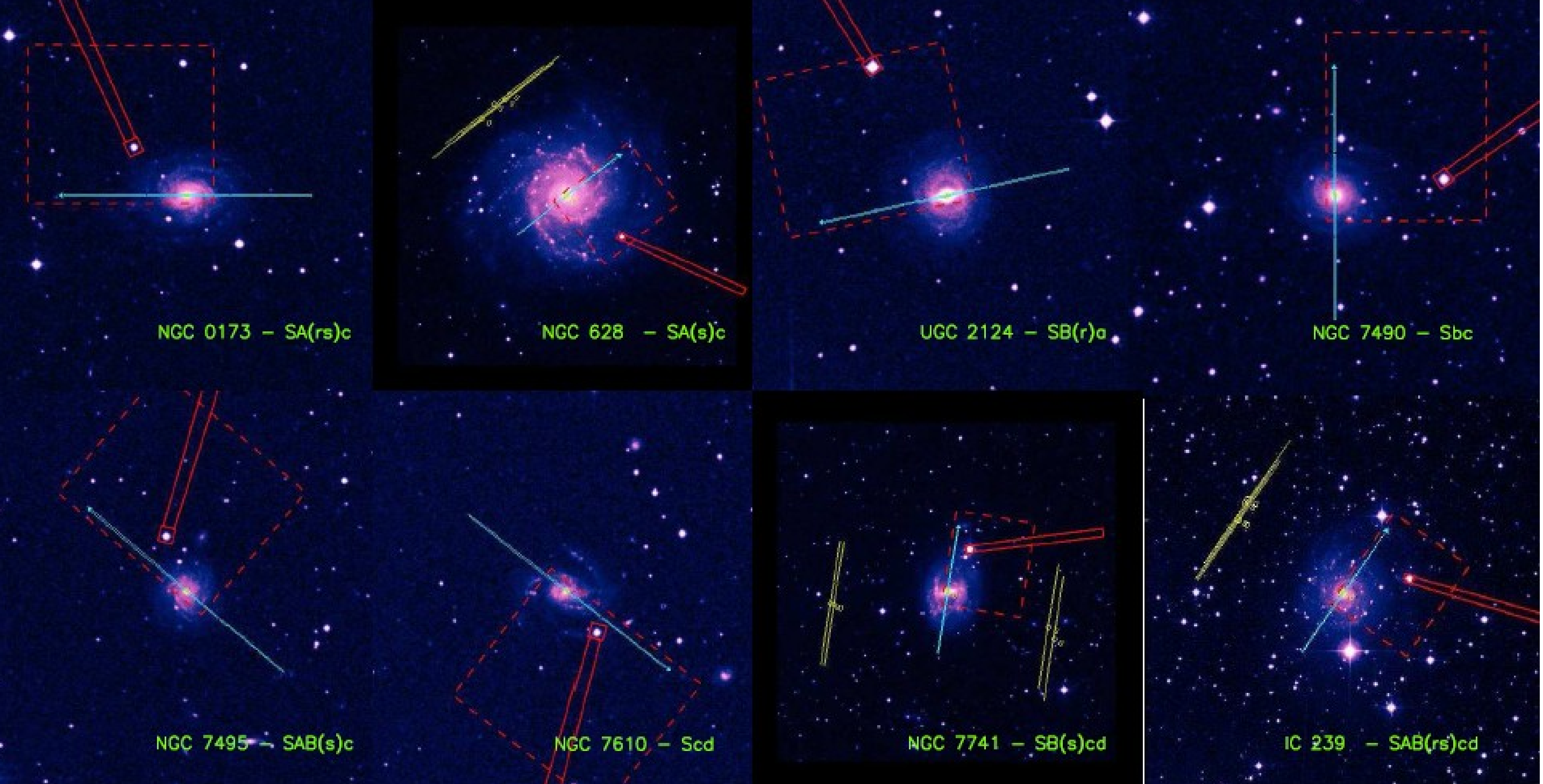


Figure 1. Observational set-up for the eight galaxies in our sample. The background images are from the Canadian Astronomy Data Centre's Digitized Sky Server (CADC; http://cadcwww.dao.nrc.ca/). The blue line represents the slit, the red (dashed) box and long arm represent the FOV of the GMOS wavefront sensor camera, with the box at the end of the arm centered on the guide star. The panels for large galaxies (NGC 628, NGC 7741, and IC 239) also show, as yellow lines, the sky offset positions. The FOV for the CADC pictures differ in all the panels but the slit length is everywhere the same (5′).

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Stellar Population and Kinematic Profiles In Spiral Bulges & Disks: Population Synthesis of Integrated Spectra

Lauren A. MacArthur[1]*, J. Jesús González[2]†, and Stéphane Courteau[3]‡
[1]*Department of Astrophysics, California Institute of Technology, MS 105-24, Pasadena, CA 91125*
[2]*Instituto de Astronomia, Universidad Nacional Autónoma de México, Apdo Postal 70-264, Cd. Universitaria, 04510 México*
[3]*Department of Physics, Engineering Physics & Astronomy, Queen's University, Kingston, ON K7L 3N6, Canada*

GMOS long-slit

GMOS long-slit

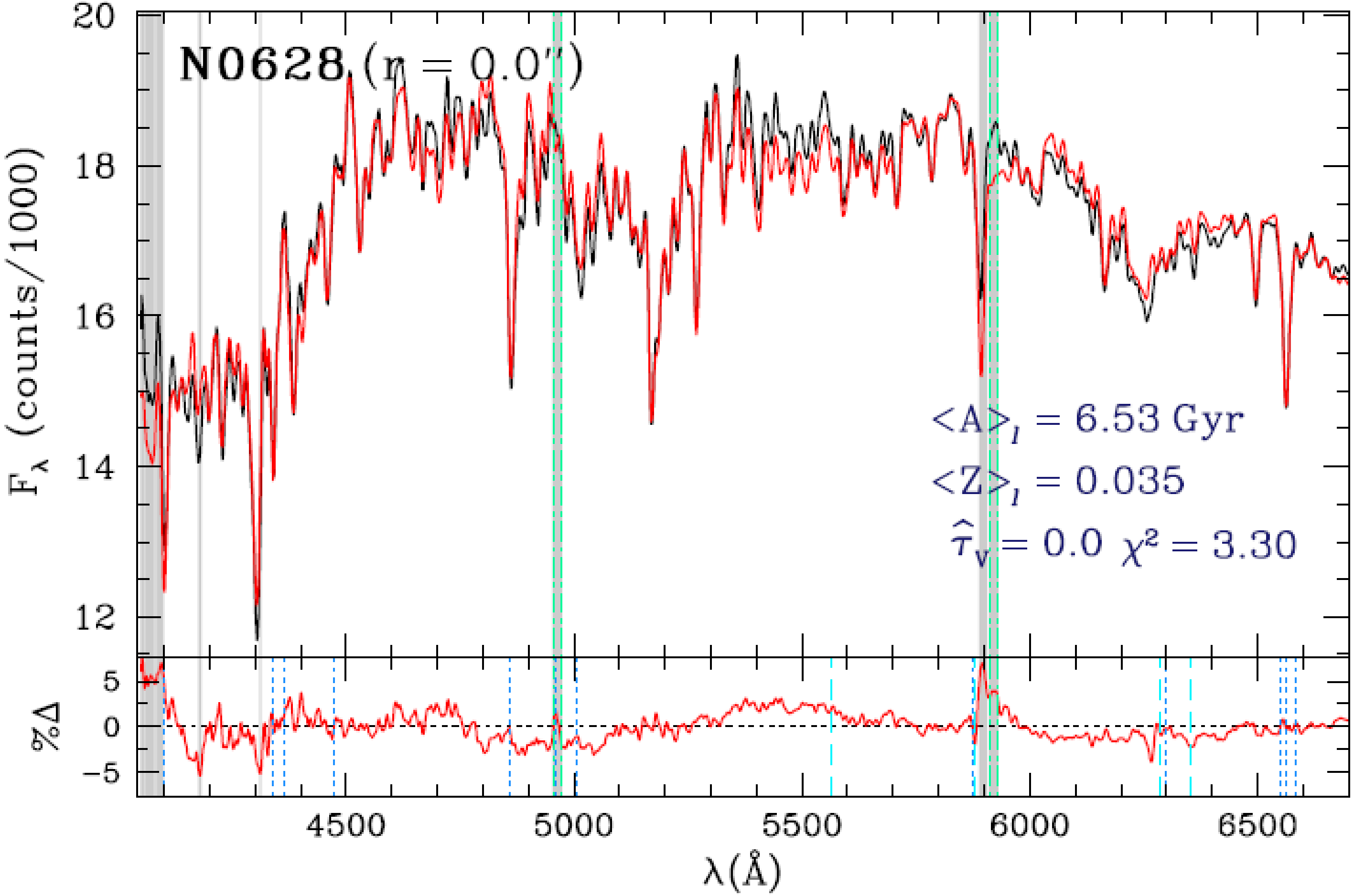

Figure 3. Central observed spectra (black) and full population synthesis fit (red)

2009 MNRAS, 395, 28

Stellar Population and Kinematic Profiles In Spiral Bulges & Disks: Population Synthesis of Integrated Spectra

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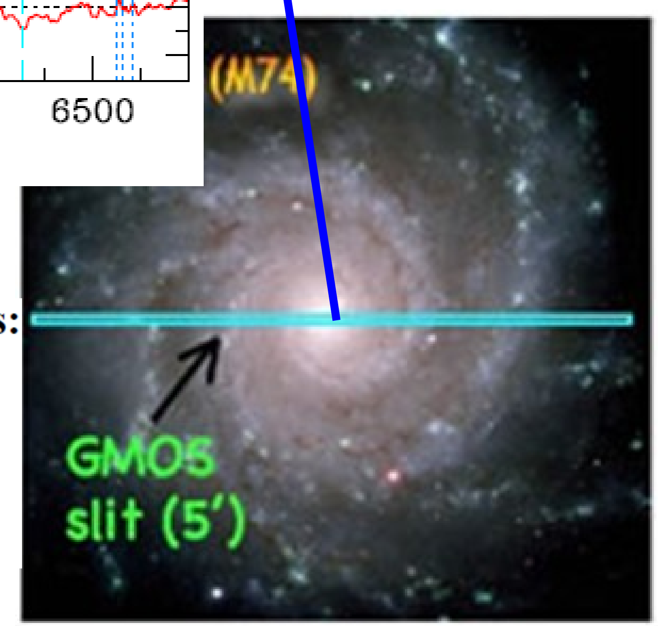
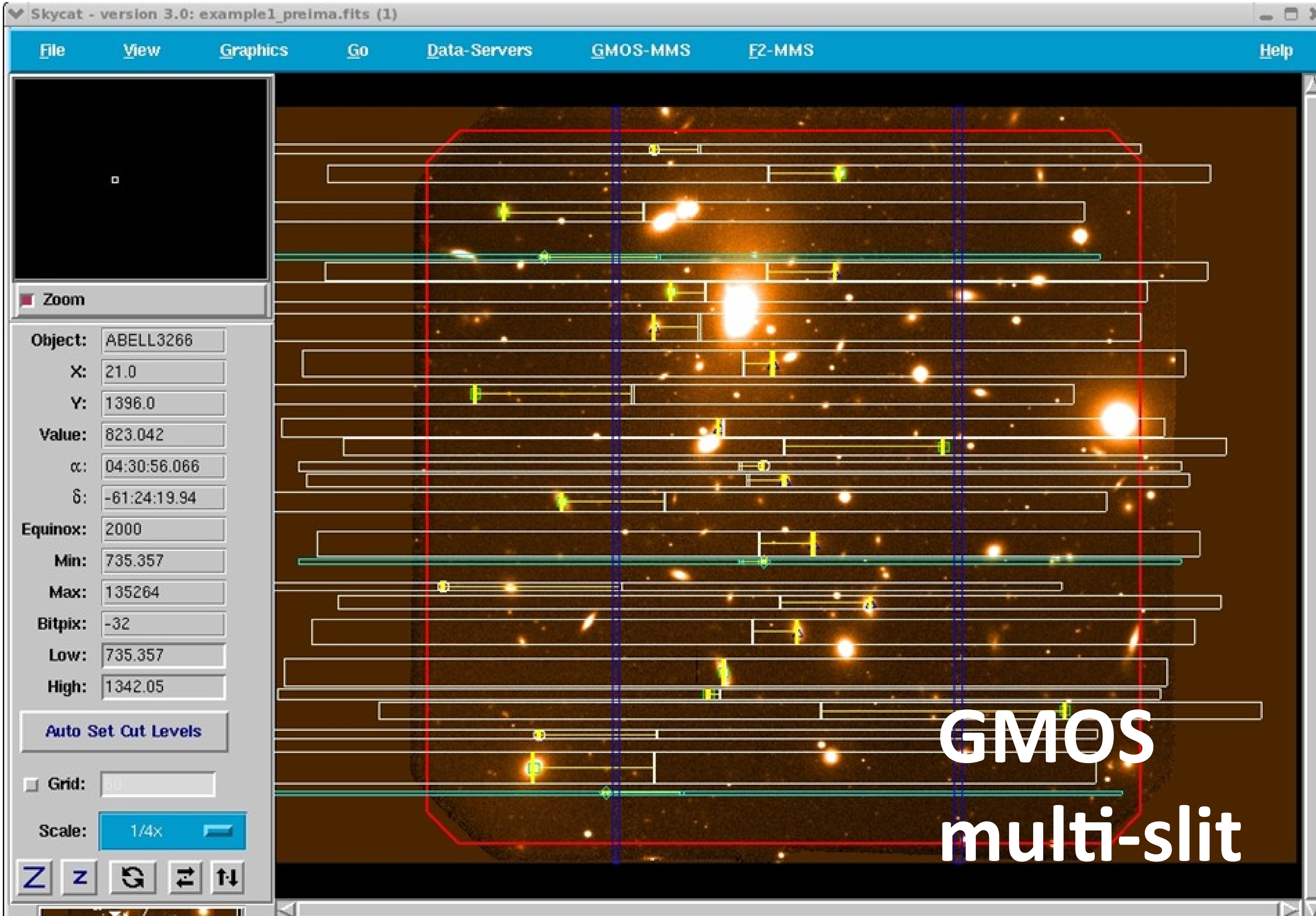
[1]*Department of Astrophysics, California Institute of Technology, MS 105-24, Pasadena, CA 91125*
[2]*Instituto de Astronomia, Universidad Nacional Autónoma de México, Apdo Postal 70-264, Cd. Universitaria, 04510 México*
[3]*Department of Physics, Engineering Physics & Astronomy, Queen's University, Kingston, ON K7L 3N6, Canada*



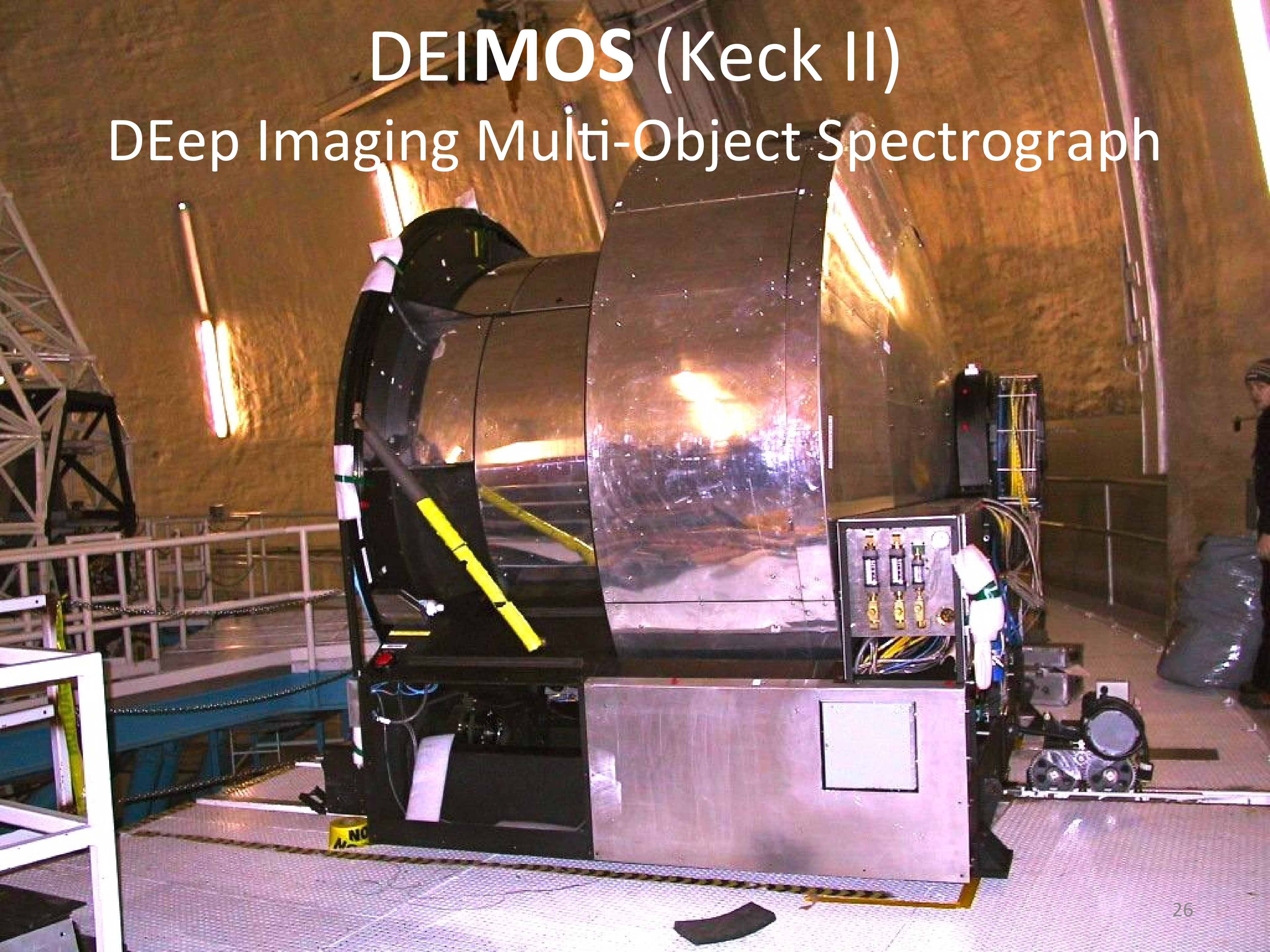
GMOS multislit

- With a 5.5 arcmin field of view, 30-60 slits can typically be located in a single mask
- maximum of several hundred slits when using narrow-band filters
- Slit widths 0.5 arcsec or larger
- Masks designed from GMOS direct imaging
- Masks designed from object catalogs
- R (max) ~ 4000

Object slits (white & yellow) with the alignment stars (cyan) , CCD gaps (blue) and the mask area (red) plotted over the GMOS pre-imaging. This plot is used to check the masks

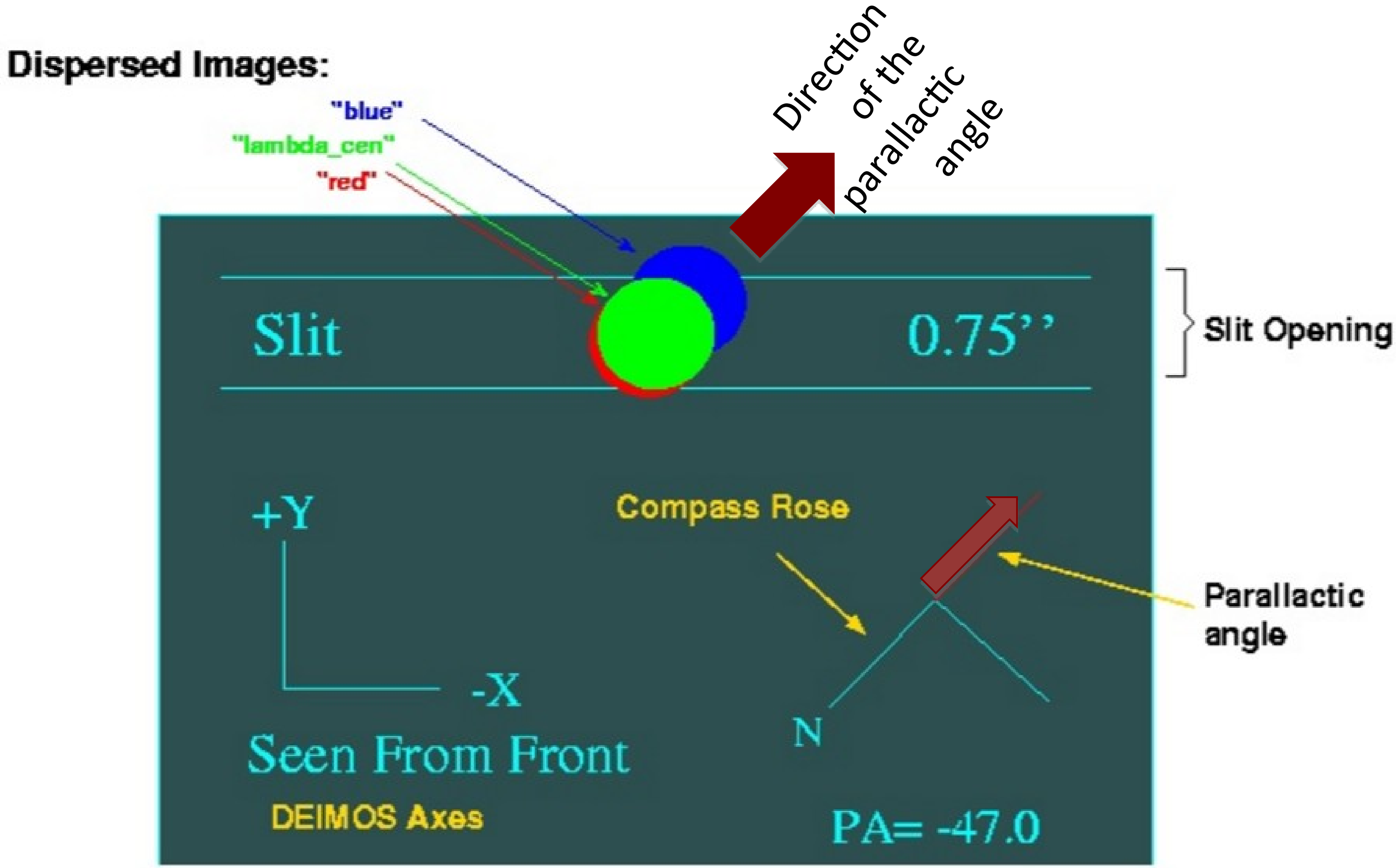


DEI**MOS** (Keck II)
DEep Imaging Multi-Object Spectrograph



DEI**MOS** (Keck II)

- generous slit length spanning 16.6 arcmin on sky (vs. 5,5 arcmin for Gemini GMOS or 7 arcmin for FORS2/VLT)
- large 8k×8k detector mosaic featuring eight CCDs
- advanced, closed-loop flexure compensation system achieving image stability of ±0.25 px over 360° of instrument rotation
- wide spectral coverage (up to 5000 Å per exposure)
- high spectral resolution (up to R≈6000)
- multi-slit spectroscopy of 100+ resolved targets per mask or 1000+ targets with narrow-band filters
- IDL-based data reduction pipeline



https://www2.keck.hawaii.edu/inst/deimos/dsim.html

If you don't have a preferred orientation on the sky, then put the slit at the **parallactic angle** (position from the object to the Zenith), also known as slit in the "vertical" position.

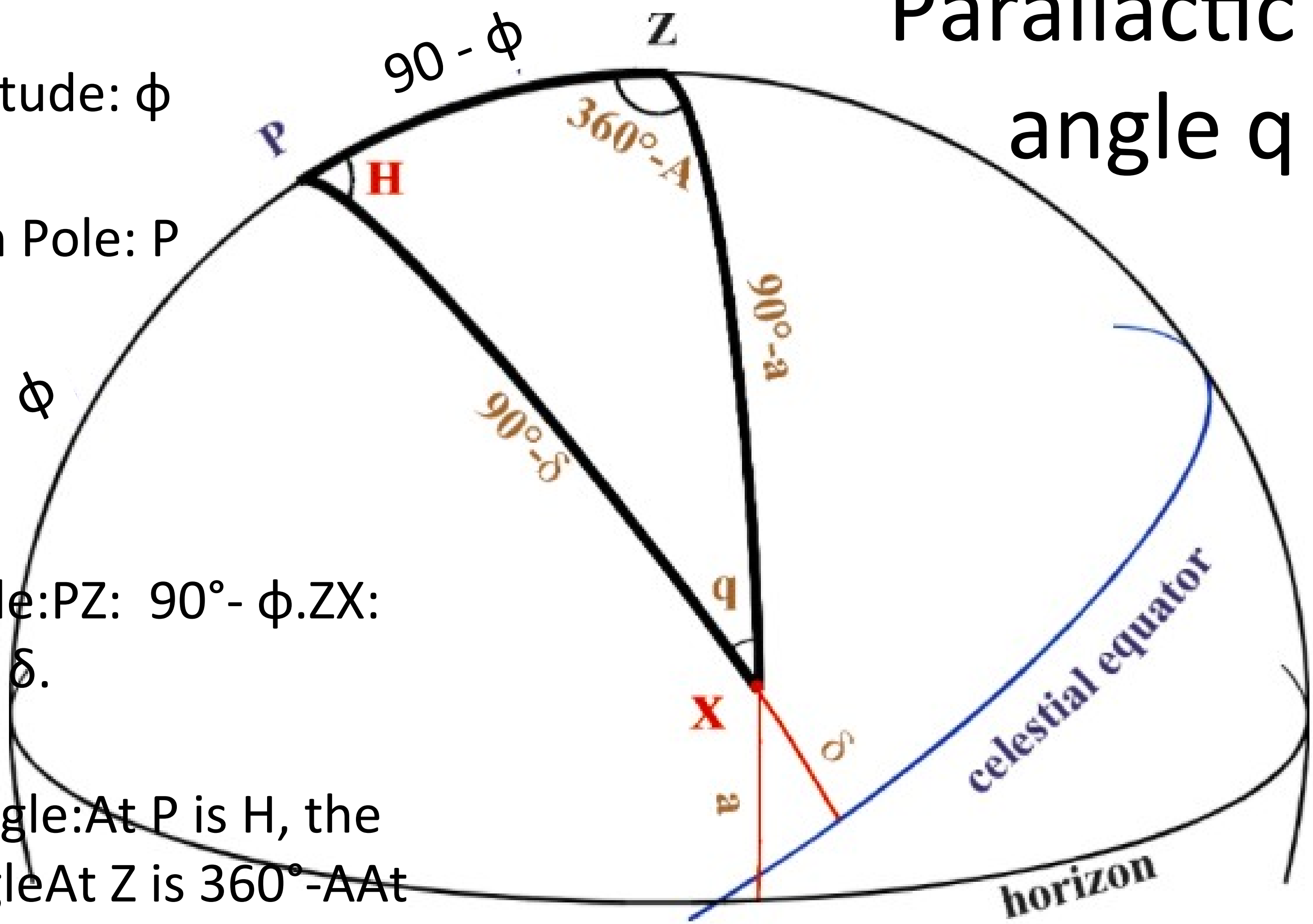
→ slit aligned vertically, to avoid losses in the blue to UV region

Parallactic angle q

Object: X
Observer's latitude: ϕ
Zenith: Z
Celestial North Pole: P
Declination: δ
Azimuth: A
Altitude: a

Sides of triangle:PZ: 90°- ϕ.ZX: 90°- a.PX: 90°- δ.

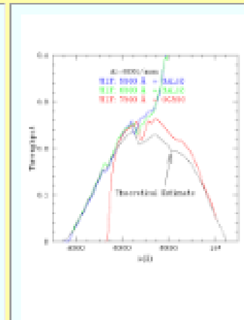
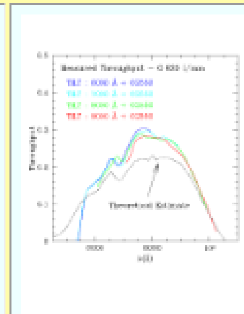
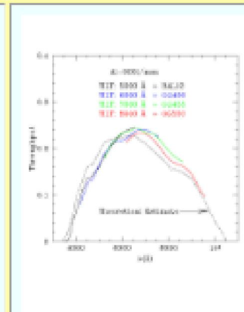
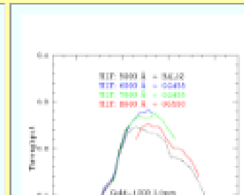
Angles of triangle:At P is H, the local Hour AngleAt Z is 360°-AAt X is q, the **parallactic angle**



http://star-www.st-and.ac.uk/~fv/webnotes/chapter7.htm

If you don't have a preferred orientation on the sky, then put the slit at the parallactic angle q, a.k.a. as "vertical" position.

https://www2.keck.hawaii.edu/inst/deimos/gratings.html

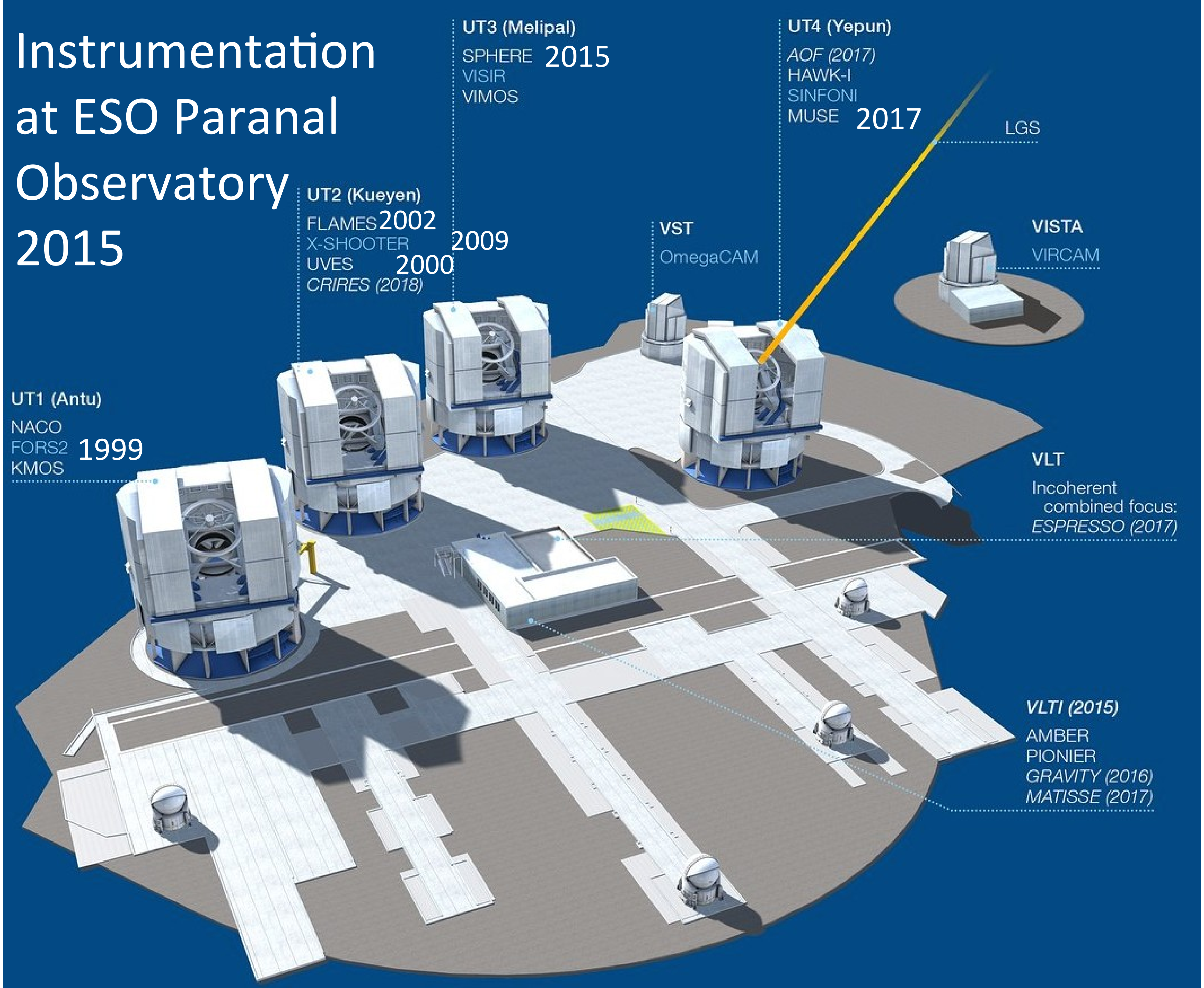
Grating Name	Grooves [l mm^{-1}]	Blaze Wavelength [Å]	Dispersion [Å pix^{-1}]	Spectral Length (8192 px) [Å]	FWHM resolution (1" slit) [Å]	Efficiency
600ZD	600	7500	0.65	5300	3.5	
830G	830	8640	0.47	3840	2.5	
900ZD	900	5500	0.44	3530	2.1	
1200G	1200	7760	0.33	2630	1.1–1.6	

https://www2.keck.hawaii.edu/inst/deimos/filter_list.html

Long-Pass Order-Blocking Spectroscopy Filters

Filter Name	Composition	Cut-on Wavelength [Å]	Notes
BAL12	??	N/A	"Clear" filter for spectroscopy without an order-blocker.
GG400	3GG400 + 3WG305	4000	
GG455	3GG455 + 3WG305	4550	
GG495	6GG495	4950	
OG550	6OG550	5500	

Instrumentation at ESO Paranal Observatory 2015



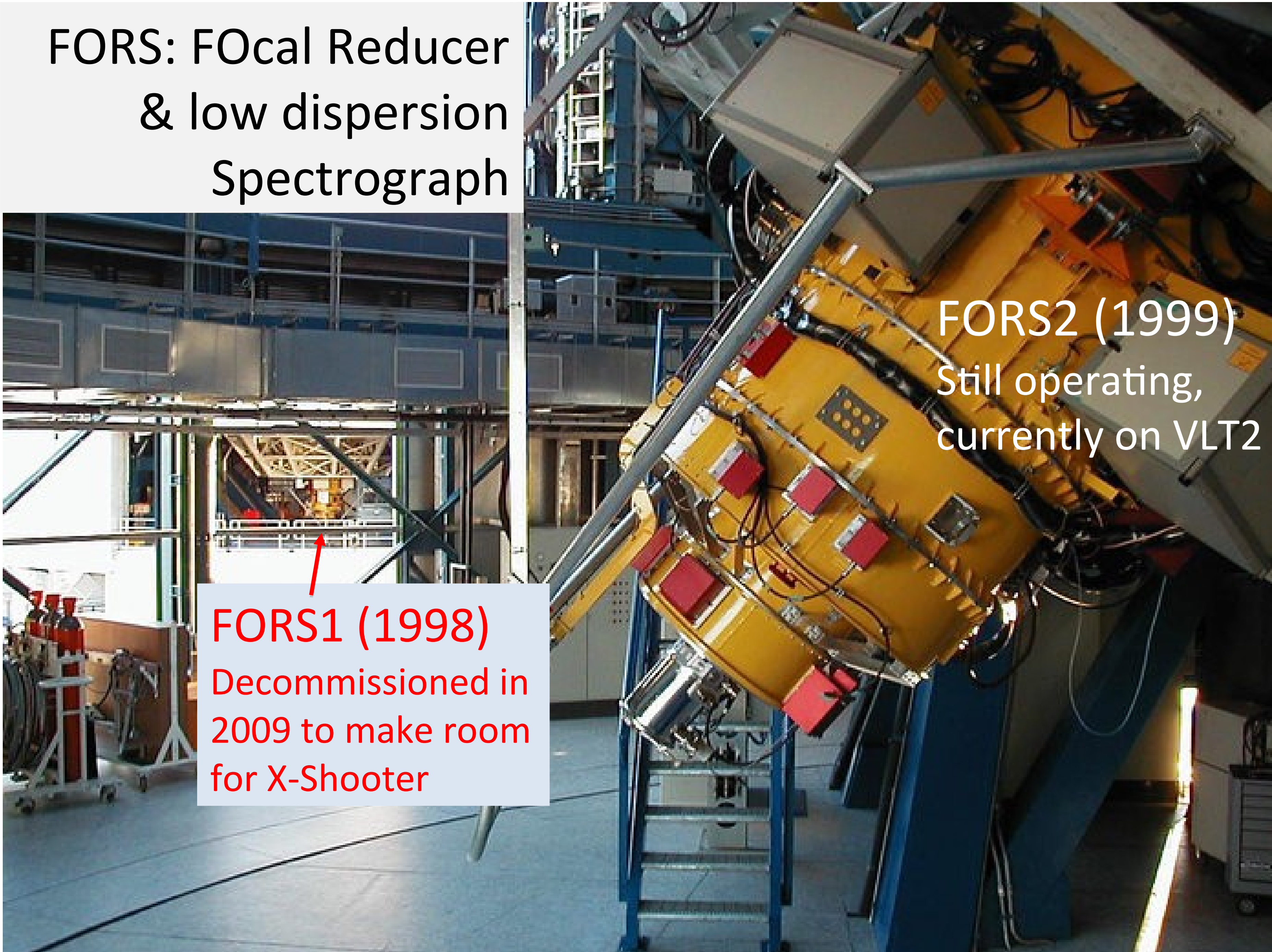
The Focal Reducing Imager and Spectrograph FORS,

built for the optical 16-metre 'Very Large Telescope'
of the 'European Southern Observatory'

Doctoral thesis, Harald Nicklas, Göttingen 2005

Partnership: Göttingen, München, Heidelberg

FORS: FOcal Reducer & low dispersion Spectrograph



São Paulo, as seen from Butantã, 6 May 2018

f/2.8 (F = 16 mm) wide field lens

Focal reducer → wider field

f/2.8 (F = 16 mm) X 0.75 → f/2.1 (F = 12mm)

Focal reducer → wider field

f/2.8 (F = 16 mm) X 0.75 → f/2.1 (F = 12mm)

Beautiful spiral galaxy NGC 1232.
It was one of the first images taken by the fantastic FORS instrument at VLT/ESO, 1998

FORS2

Field 6.8' x 6.8’ or 4.25' x 4.25’

Reduce focal ratio by 4.4 or 2.2

- Imaging

Instrument Mode	Mag-limit
Direct Imaging (E2V)	U=25.9 B=27.6 V=27.3 R=26.6 I=25.8
Direct Imaging (MIT)	U=24.5 B=27.1 V=27.0 R=26.7 I=25.7 z=24.7

MIT is the default CCD (2kx4k); E2V is more sensible in the blue, but strong fringing above 650nm [only visitor mode]

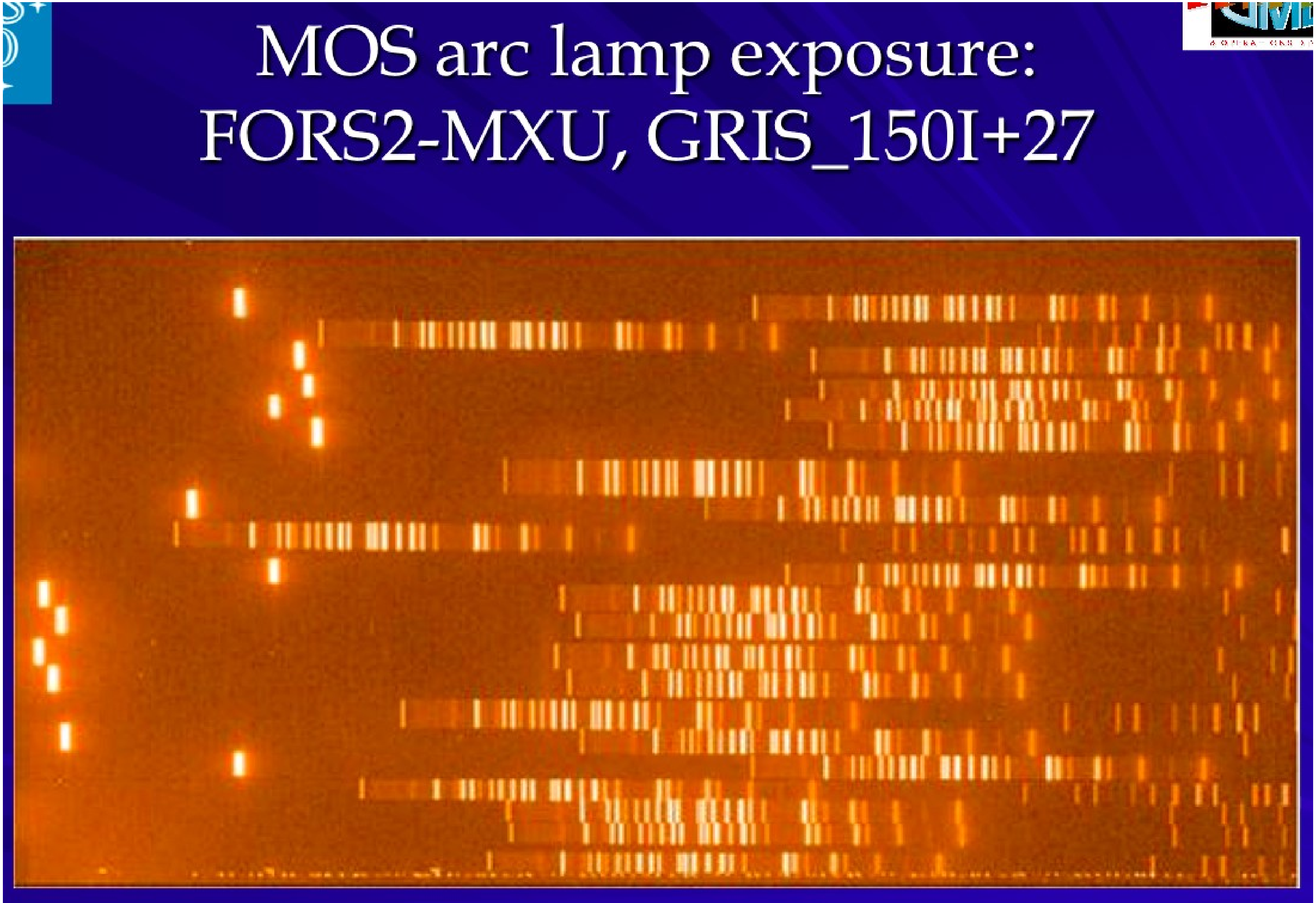
- Spectroscopy

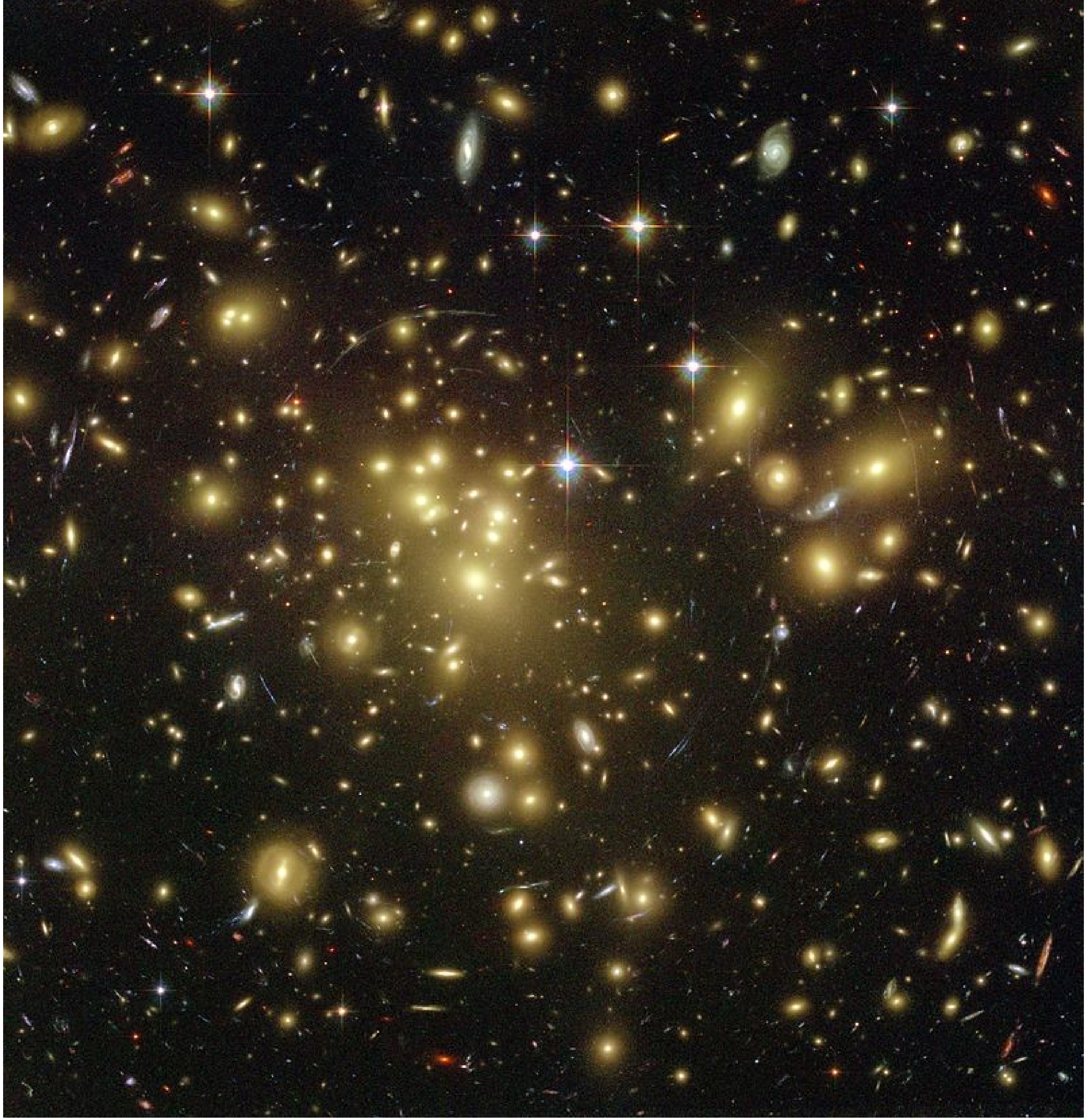
Instrument Mode	Rs = λ/Δλ	Mag-limit
Longslit Spectroscopy [1]	260-2600	R=24.2-23.3
MOS - movable slits [2] 19 slits	260-2600	R=24.2-23.3
MXU - exchangeable masks 80 slits or <470 narrow regions	260-2600	R=24.2-23.3
Spectropolarimetry	260-2600	R=19.2-17.2

[1] In longslit spectroscopy, there is a set of 9 slits with fixed width between 0.3'' and 2.5''.

[2] In multiobject spectroscopy one may have 19 slitlets

Calibration arcs for multi-slit MXU





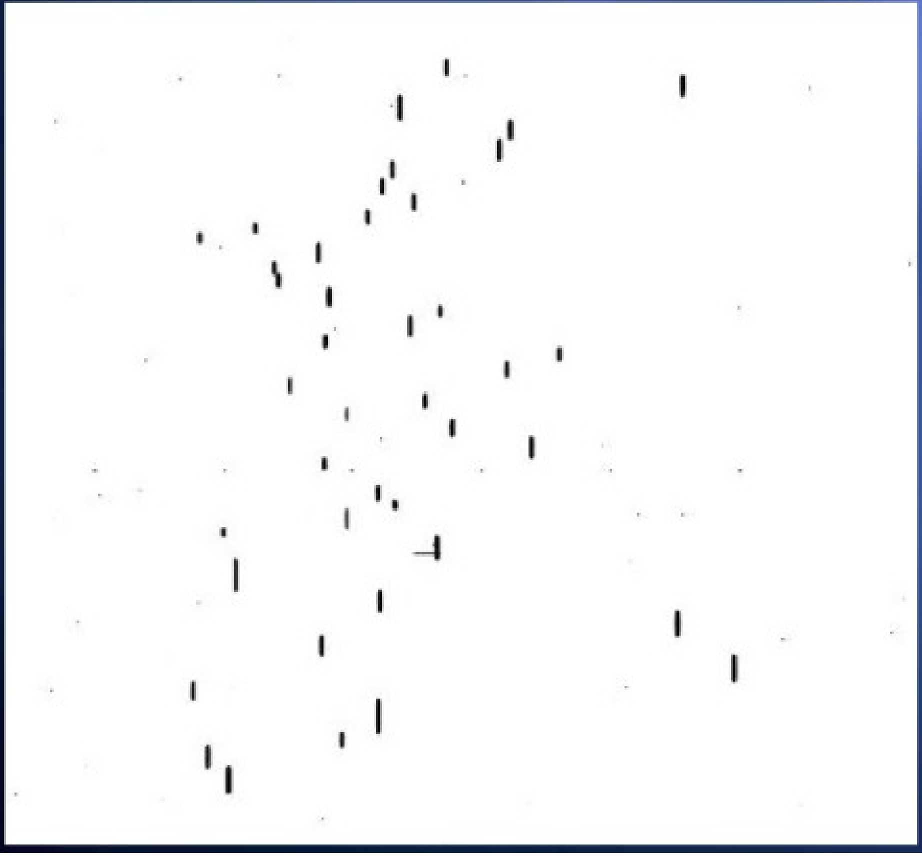
Abell 1689
© Hubble

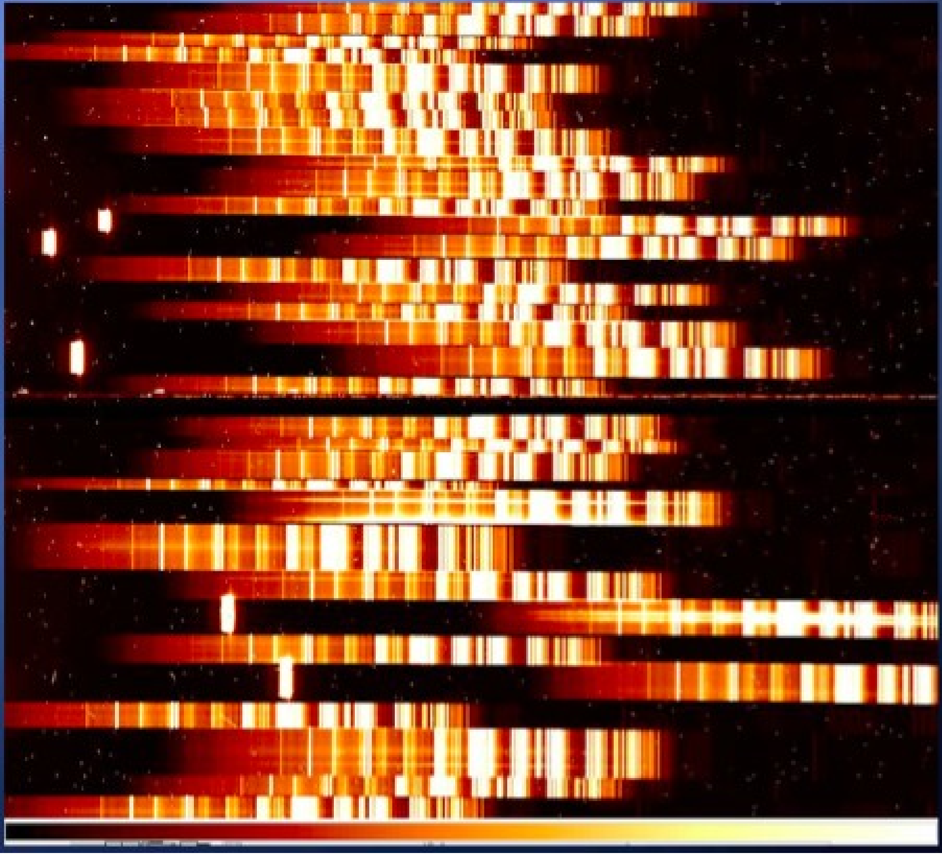
THE INSTRUMENT: FORS2

- field of view 7'x7' (2048x2048 pix)
- GRISM GRIS_150I
- MOS MODE (MXU)

Ultra compact dwarf galaxies in Abell 1689

© Guillermo, Melanie, Emanuela, Micaela





VLT/FORS2 spectroscopy in the GOODS-South field

Vanzella et al. 2004

Great Observatories Origins Deep Survey

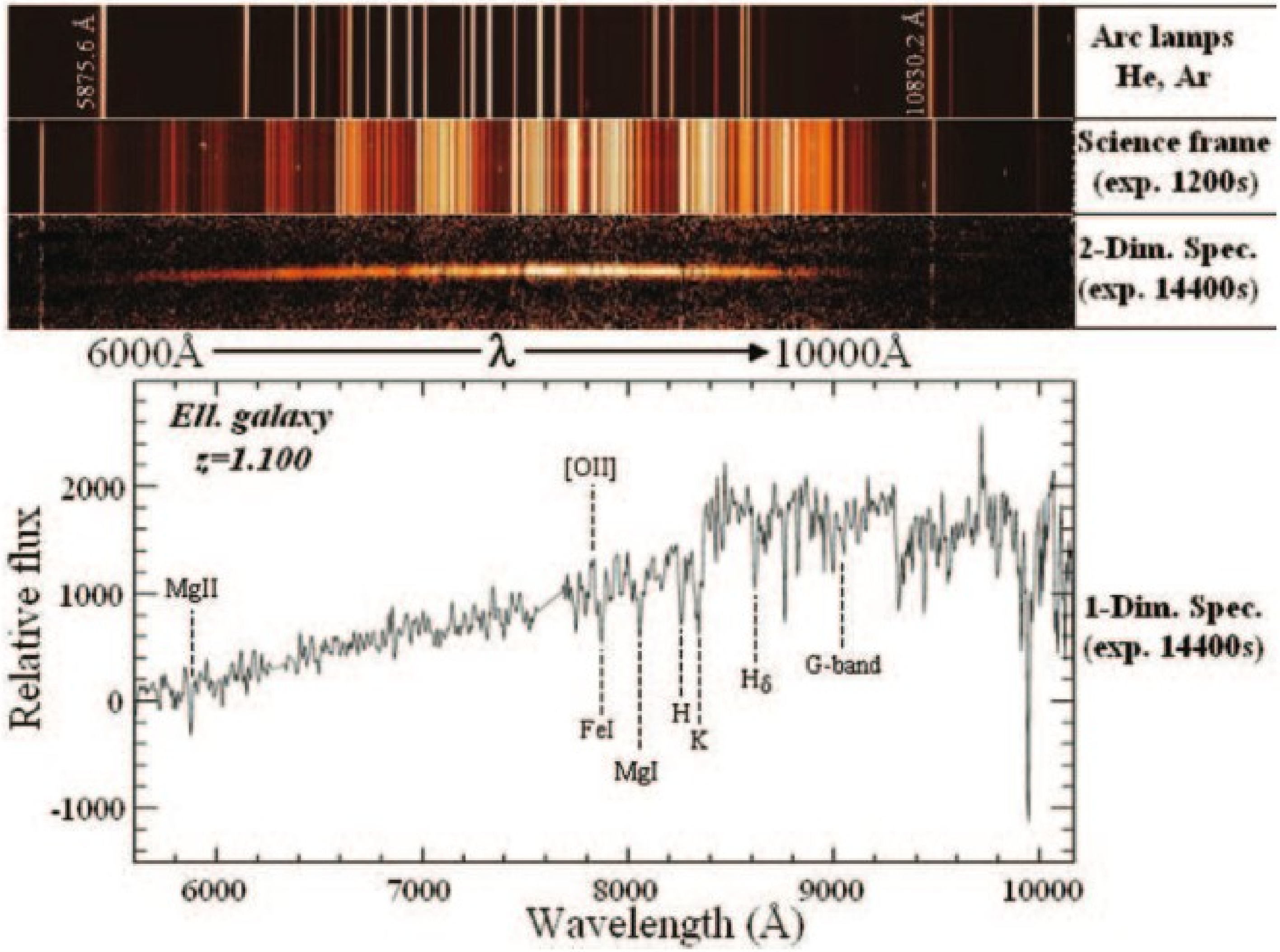
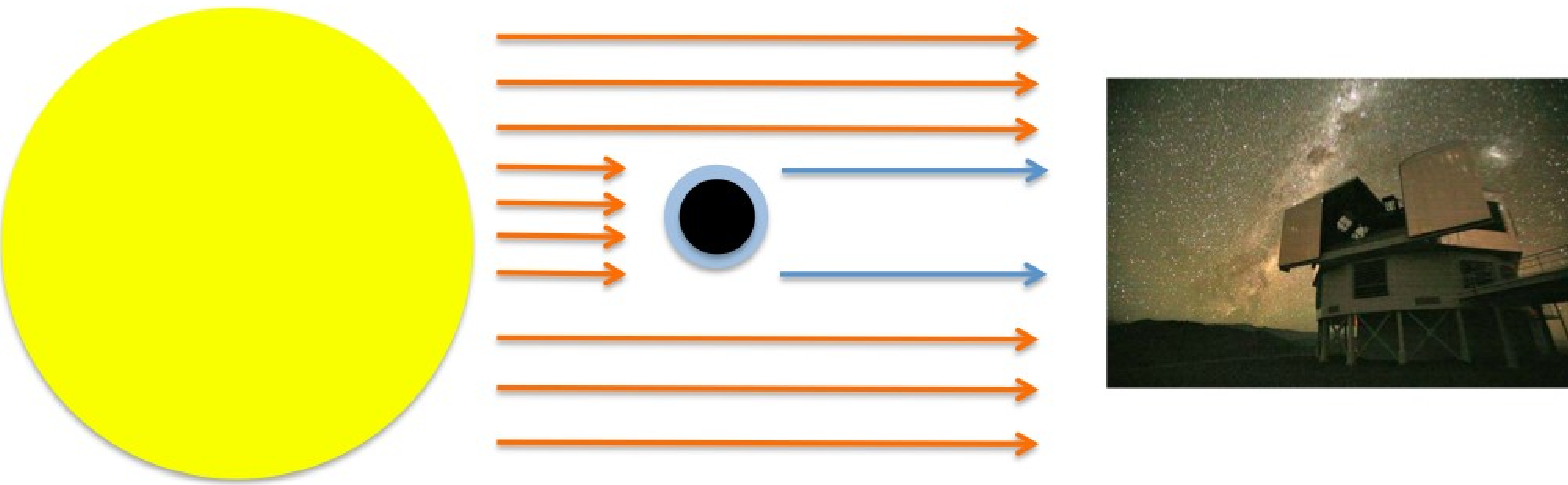


Figure 1: Typical FORS2 data products for an individual slit of the multi-object mask. From the top of the figure: the 2-D spectrum of the arc lines used for the wavelength calibration, a 2-D science exposure (1200 seconds), the final flat-fielded and sky-subtracted 2-D spectrum (co-addition of 12 exposures for a total of 4 h), and at the bottom the 1-D spectrum with the identification of the main absorption and emission lines (in this example an elliptical galaxy at z = 1.100, GDS J033217.46-275234.8).

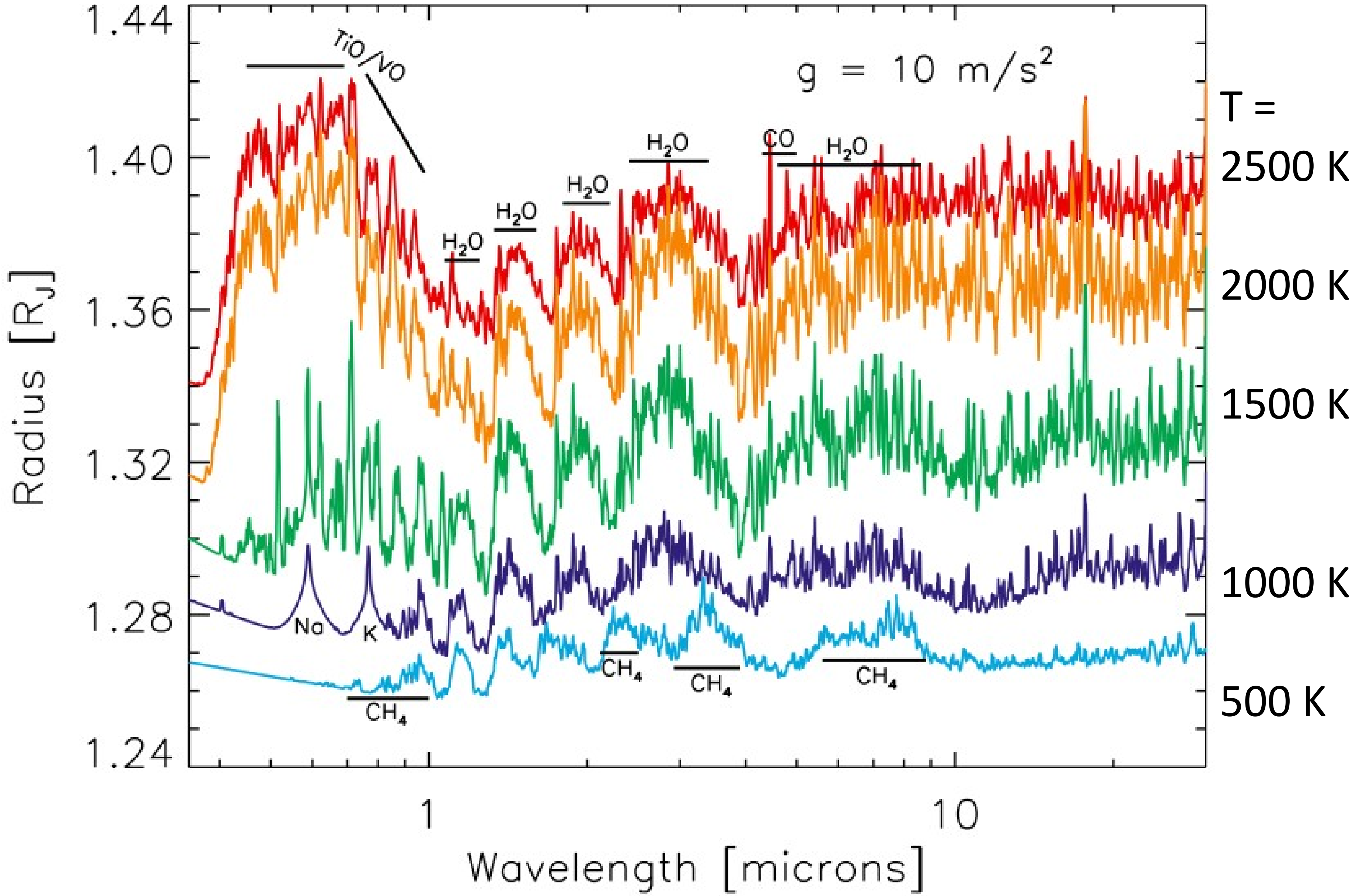
EXOPLANET ATMOSPHERES
Transits: Transmission Spectroscopy



The key point is that the edge of the planet is 'fuzzy' rather than sharp due to the atmosphere.

Therefore, the transit depth (apparent size of the planet) depends on the wavelength of light.

Models of transit spectroscopy: planet radius vs. λ



Fortney et al. 2010, ApJ, 709, 1396

Exoplanets with FORS2: WASP17

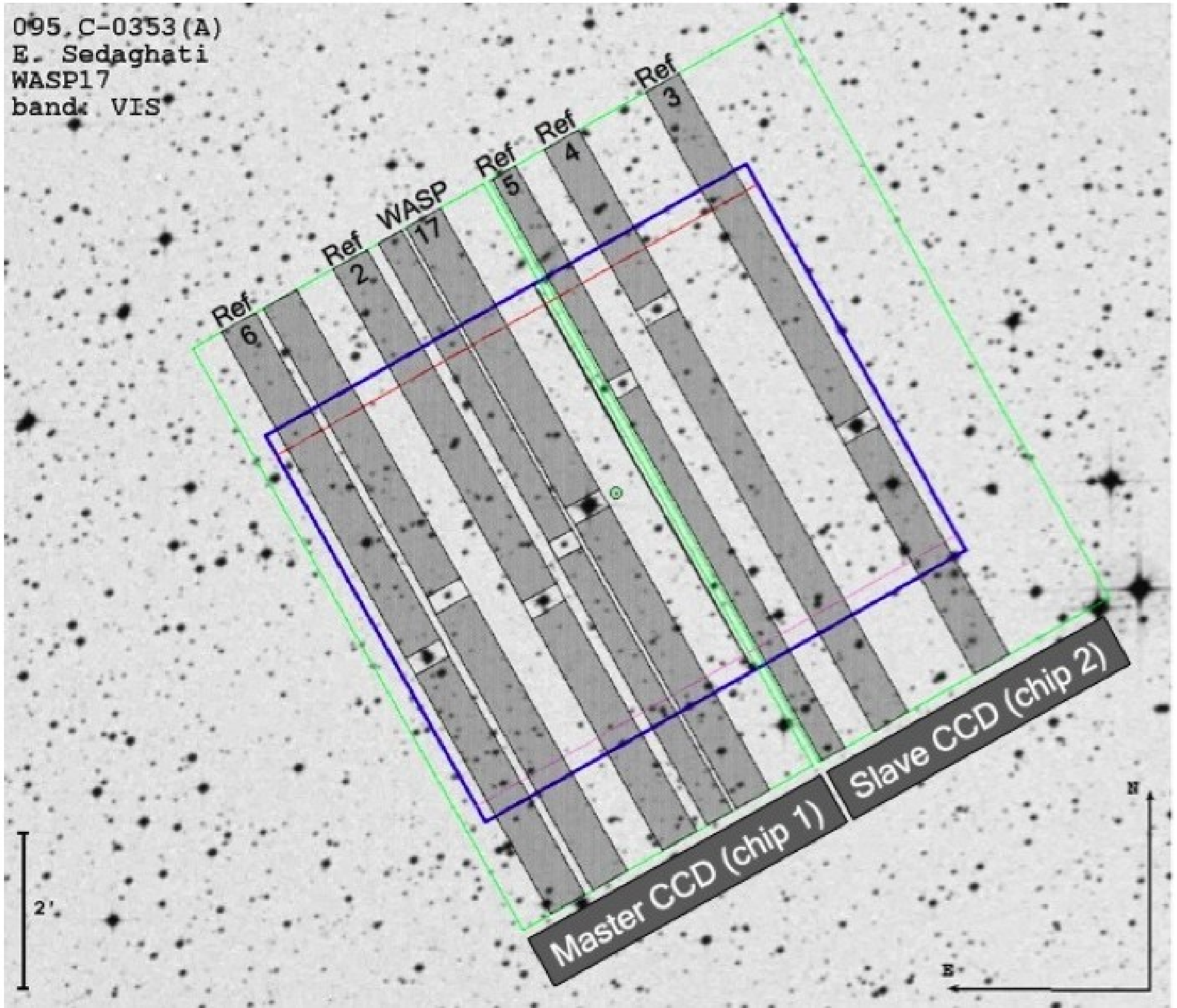
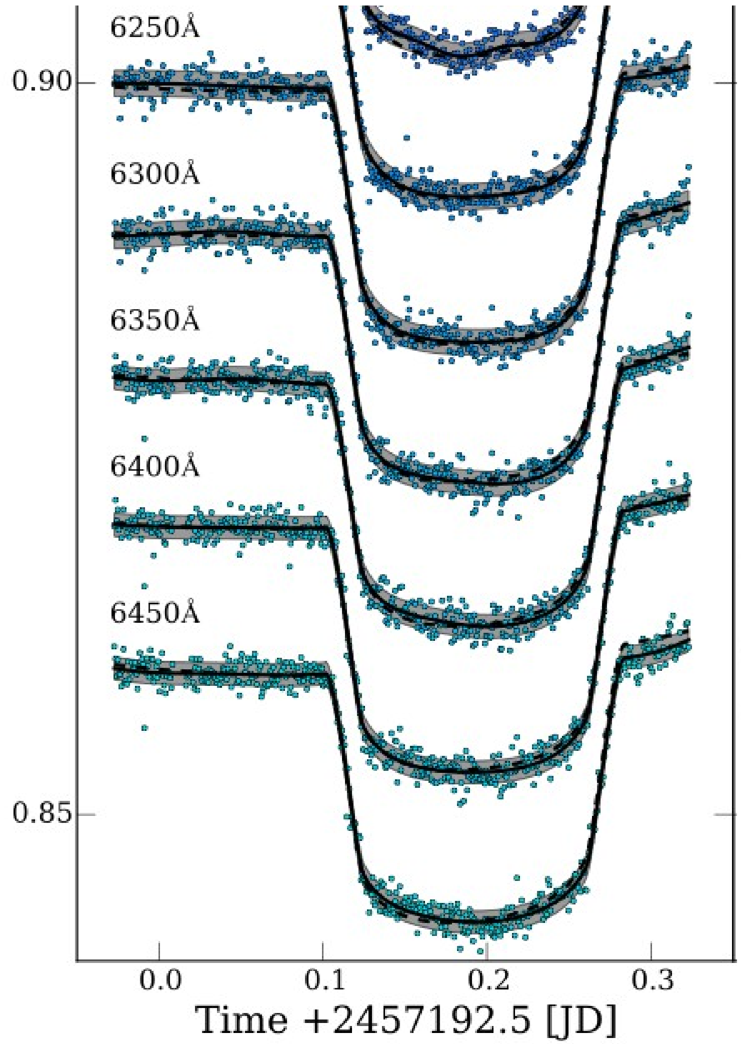


Fig. 1. 10′ × 10′ plot encompassing the FoV of FORS2 (green box) and the area covered by the 2 (2k × 4k) MIT chip mosaic (in blue). The exact design and location of the MXU slits, with the relevant target designations are also shown. The grey regions are the sections of the CCD used for recording the individual stellar spectra.

Sedaghati et al. 2016



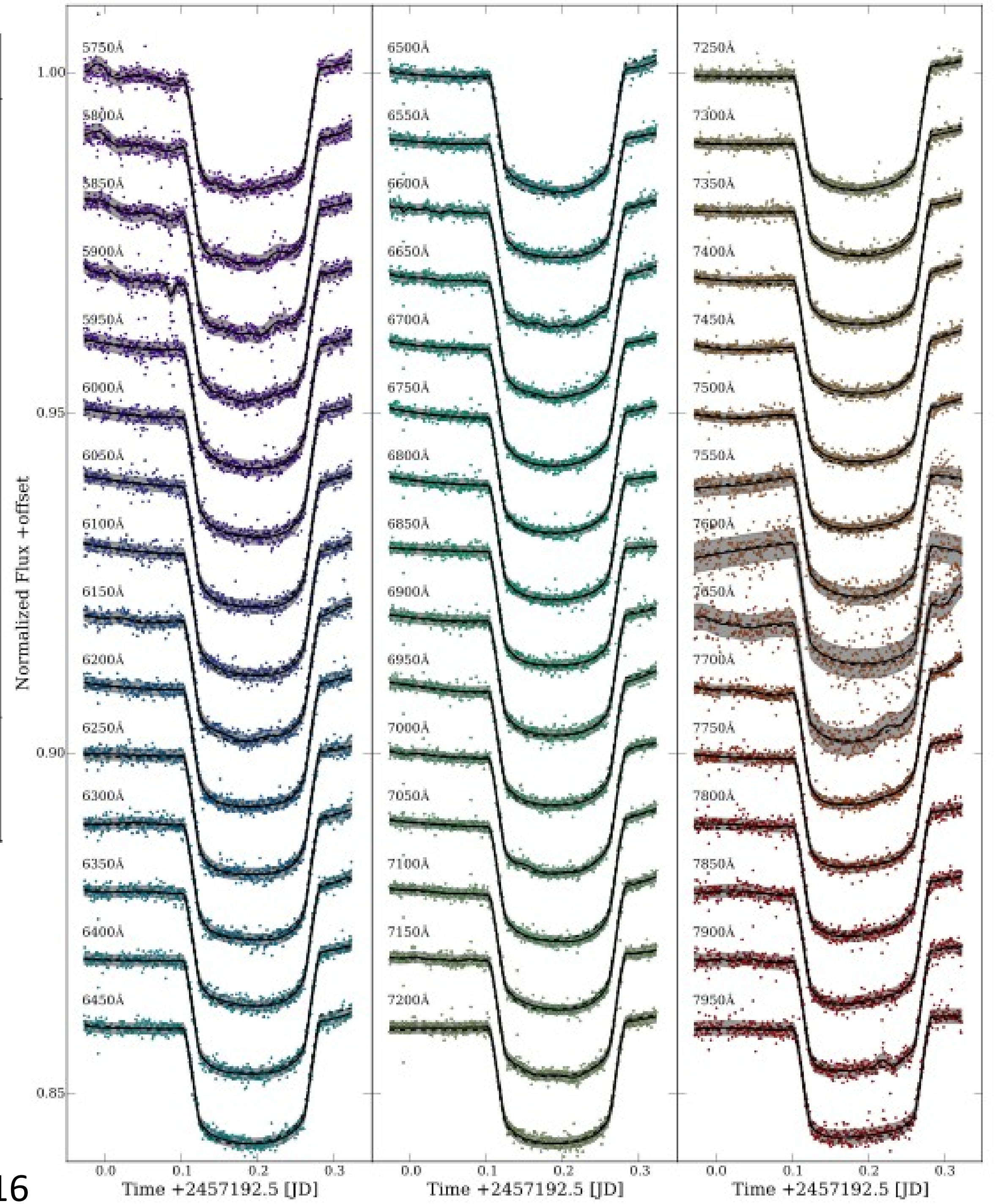


Fig. 7. Spectrophotometric light curves for the transit of WASP-17b, produced with bins of 100 Å

Sedaghati et al. 2016

Potassium detected in WASP-17?

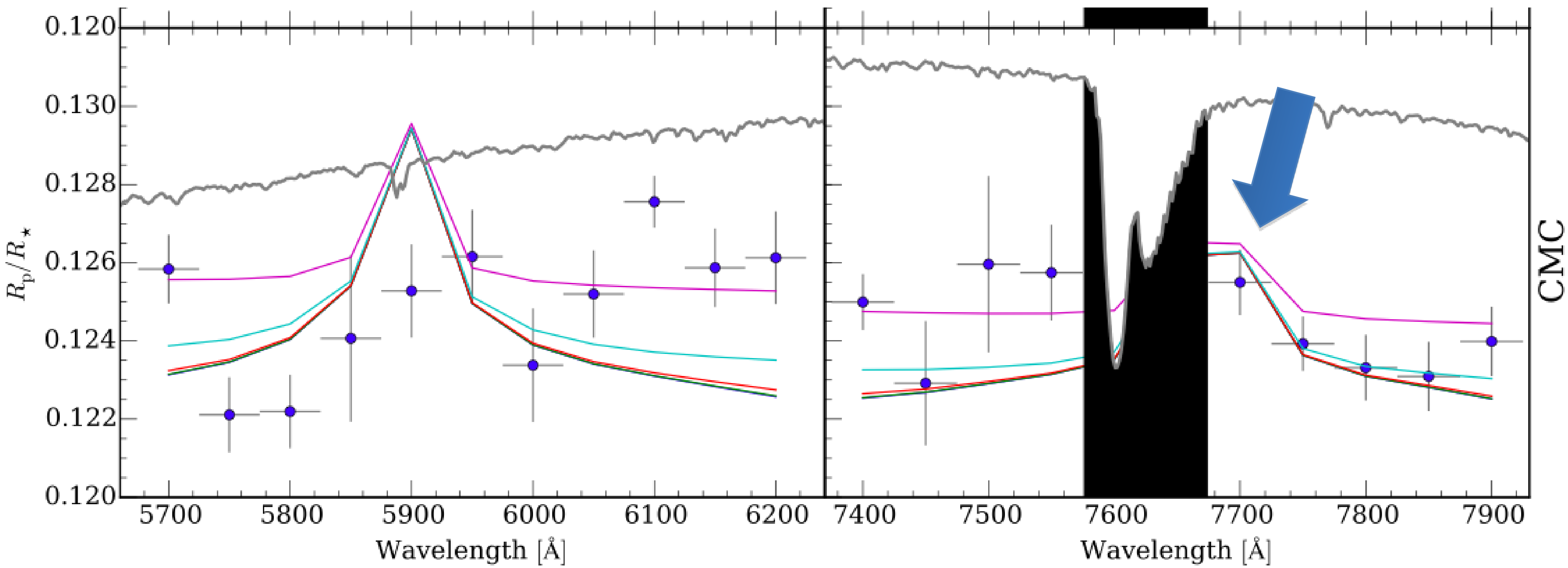
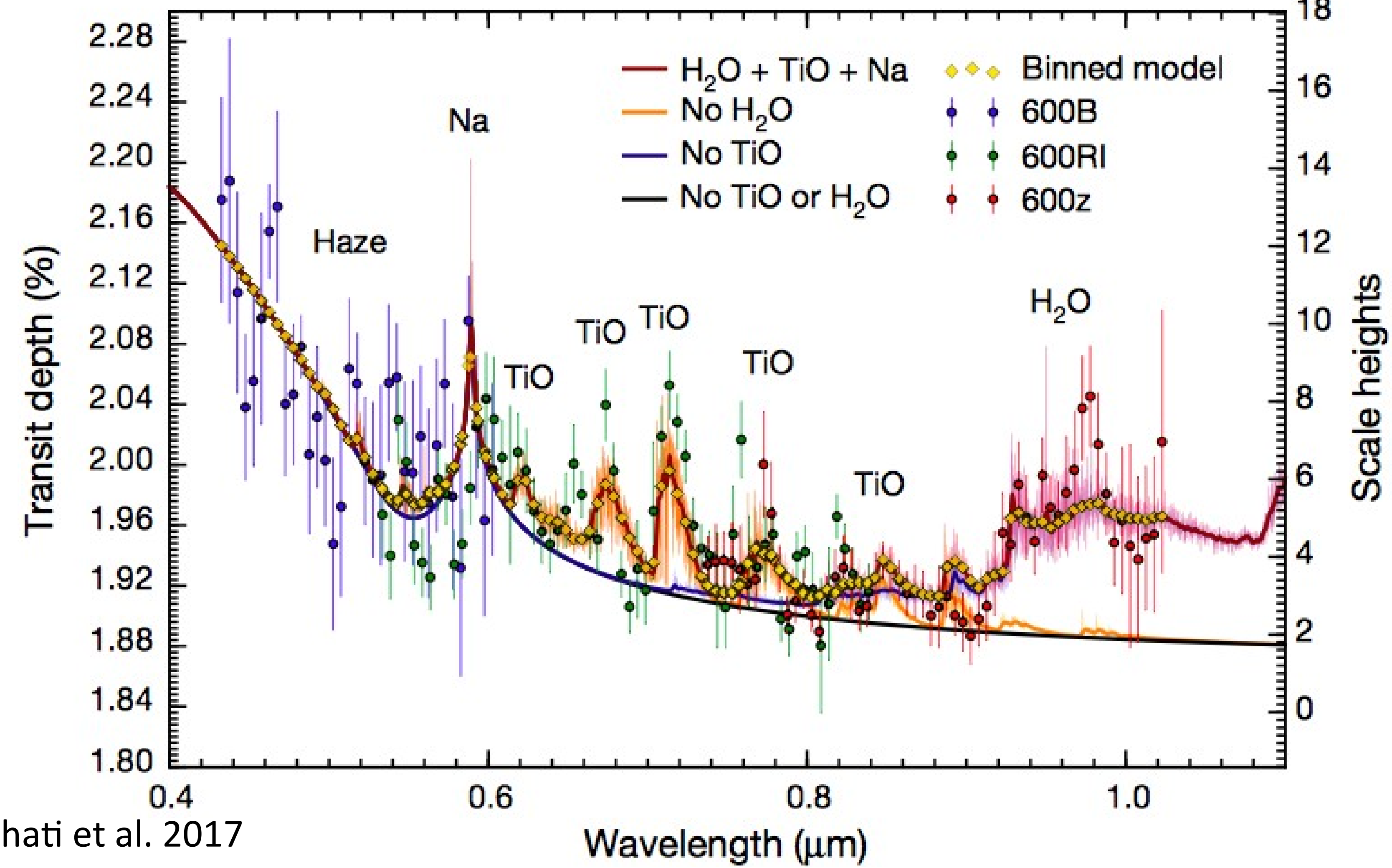


Fig. 11. Transmission spectrum reproduced with 50 Å-wide bins, as compared to Fig. 10, for domains where the possible presence of optical absorbers, such as sodium (*left column*) and potassium (*right column*), would result in an increased planetary radius. The theoretical atmospheric models are also overplotted in addition to the inferred radii, and their colours correspond to those in Fig. 10, which have again been binned to the resolution of the spectrum and plotted for 1.6 scale heights, as was performed for the overall spectrum. It must be noted that these models have not been fitted to the data points and the transmission spectrum data have not been used as a priori for the production of the model atmospheres. The black shaded region in the right column highlights the region where telluric absorption as a result of the O_2 (A) lines introduces significant systematics in the light curves produced in this region.

Sedaghati et al. 2016

https://www.eso.org/public/usa/images/eso1729b/

TiO (& H_2O) detected in exoplanet WASP-19b with FORS2/VLT



Sedaghati et al. 2017

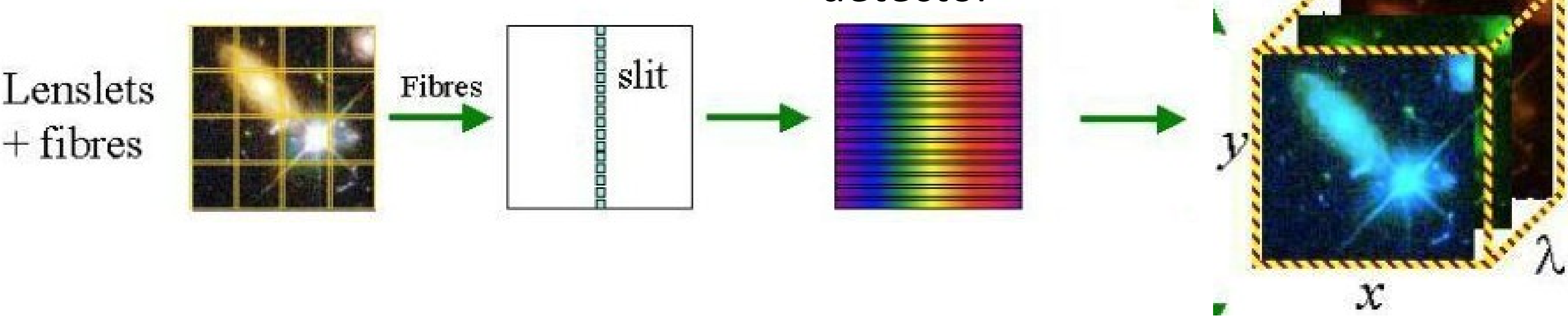
Figure 2 | WASP-19b transmission spectrum. Blue, green and red data points correspond to observations made using the 600B, 600RI and 600z grisms, respectively. The best-fitting spectrum is shown as a red curve and yellow points at a representative R = 3,000

Integral Field Spectroscopy (IFU)

Microlenses
+ fibers

slit

Spectra on
detector



GMOS IFU

- Lenslet array (containing 1500 elements) in the pre-slit slice the focal plane into many components.
- Each lenslet is coupled to a fiber.
- The fibers end at the slit of the spectrograph.
- The science field of view is 35 square arcsec (5"x7") and is sampled by 1000 elements. The sky is sampled by the remaining 500 elements which are located ~1 arcmin away from the science field

https://www.gemini.edu/sciops/instruments/gmos/integral-field-spectroscopy/basic-design

Default

GMOS IFU Basic Design

Gemini Observatory > Sciops > Instruments > GMOS > Integral Field Spectroscopy

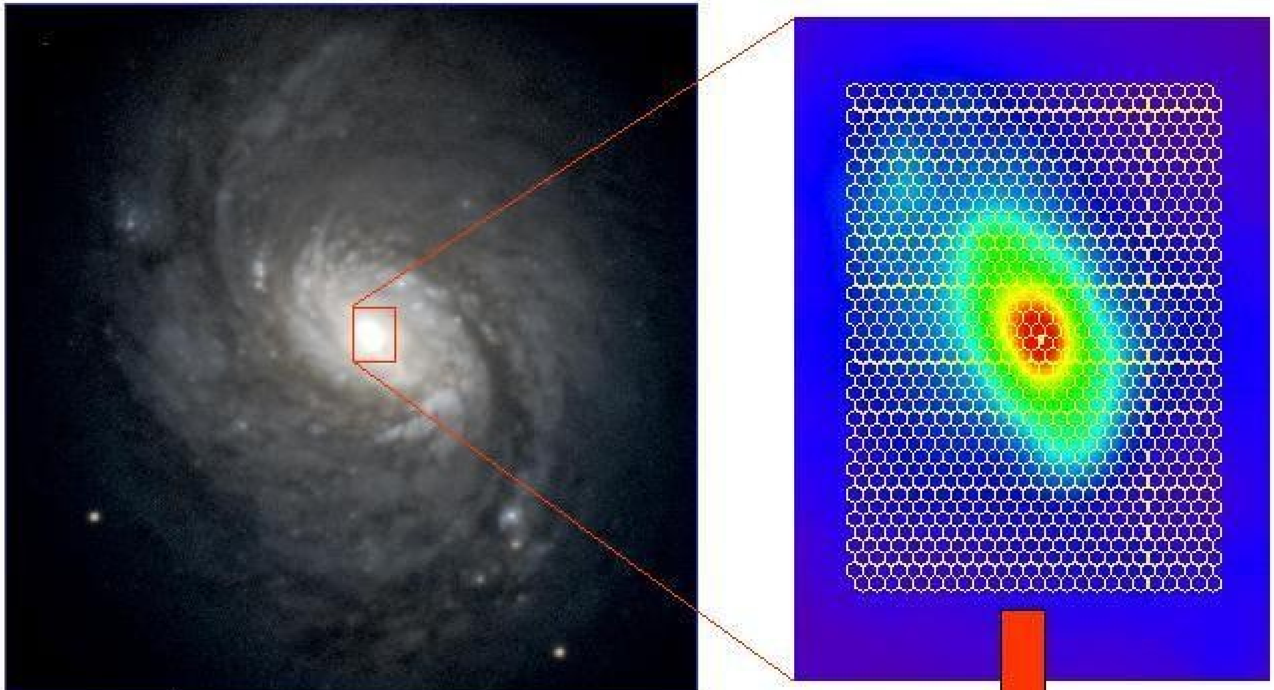
Lenslet/fiber design	Hexagonal lenslets fully sample the FOV, fibers redirect the light to "slits" for effective detector use	
Easy deployment	Slides into the focal plane similar to a slit mask	
Wavelength range	0.4-1.1 microns	
IFU format	Two fields separated by 1 arcminute	
Projected diameter of individual lenses	0.2" Each lens 0.2", in total cover 5"x7" arcsec	
Two-slit mode	all fibers used (half in each field) for maximum FOV, but with limited spectral coverage	
One-slit mode	half the number of fibers and FOV for extended wavelength coverage	
Fields of View (FOV):	**two-slit mode:**	**one-slit mode:**
"Object" FOV	5" x 7" (1000 lenslets)	5" x 3.5" (500 lenslets)
Nod & Shuffle FOV (GMOS-S only)	5" x 5" (700 lenslets)	5" x 2.5" (350 lenslets)
"Sky" FOV	5" x 3.5" (500 lenslets)	5" x 1.75" (250 lenslets)

The overall design of the IFU is shown below. The IFU is stored in one of the three mask cassette slots and it is inserted into the beam as if it were a slit mask. Two pick-off mirrors direct light from the focal plane through fore-optics in the enlarger body and onto the lenslet arrays. Fibers then reformat the focal plane into two pseudo-slits that pass the light into the rest of the spectrograph. Either of these slits can be masked off in order to get more wavelength coverage but half the field-of-view ("one-slit" mode). The GMOS-S IFU also includes masks for allowing use of Nod & Shuffle.

University of Durham

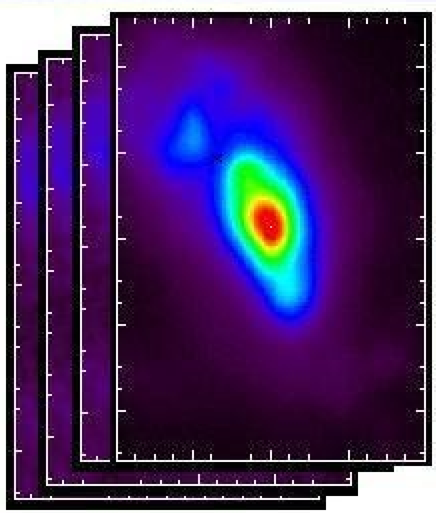
GMOS Integral Field Unit observes NGC1068

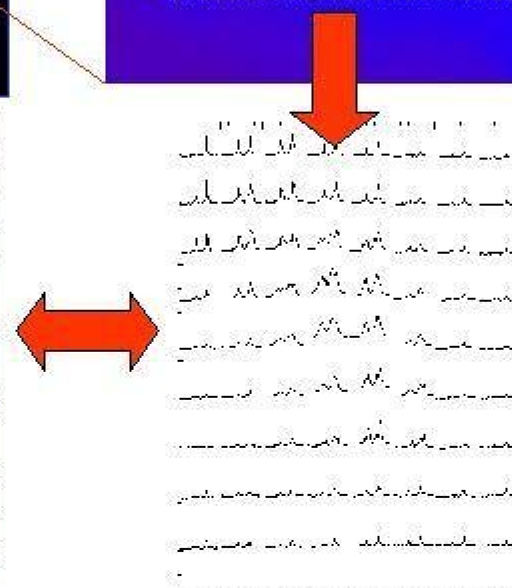
Image taken by GMOS without using the IFU



The GMOS IFU records a spectrum for each pixel

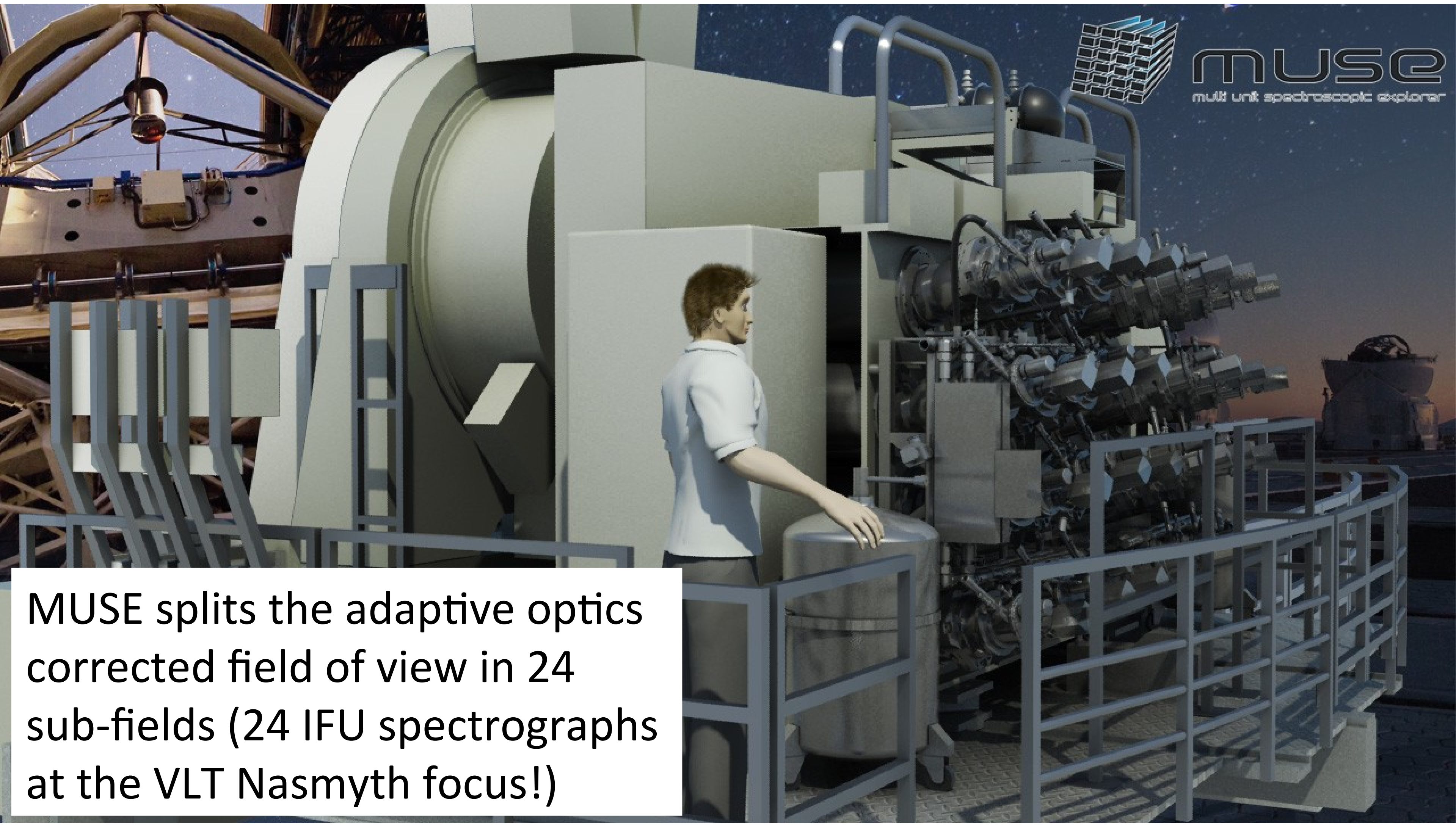
One image at each wavelength





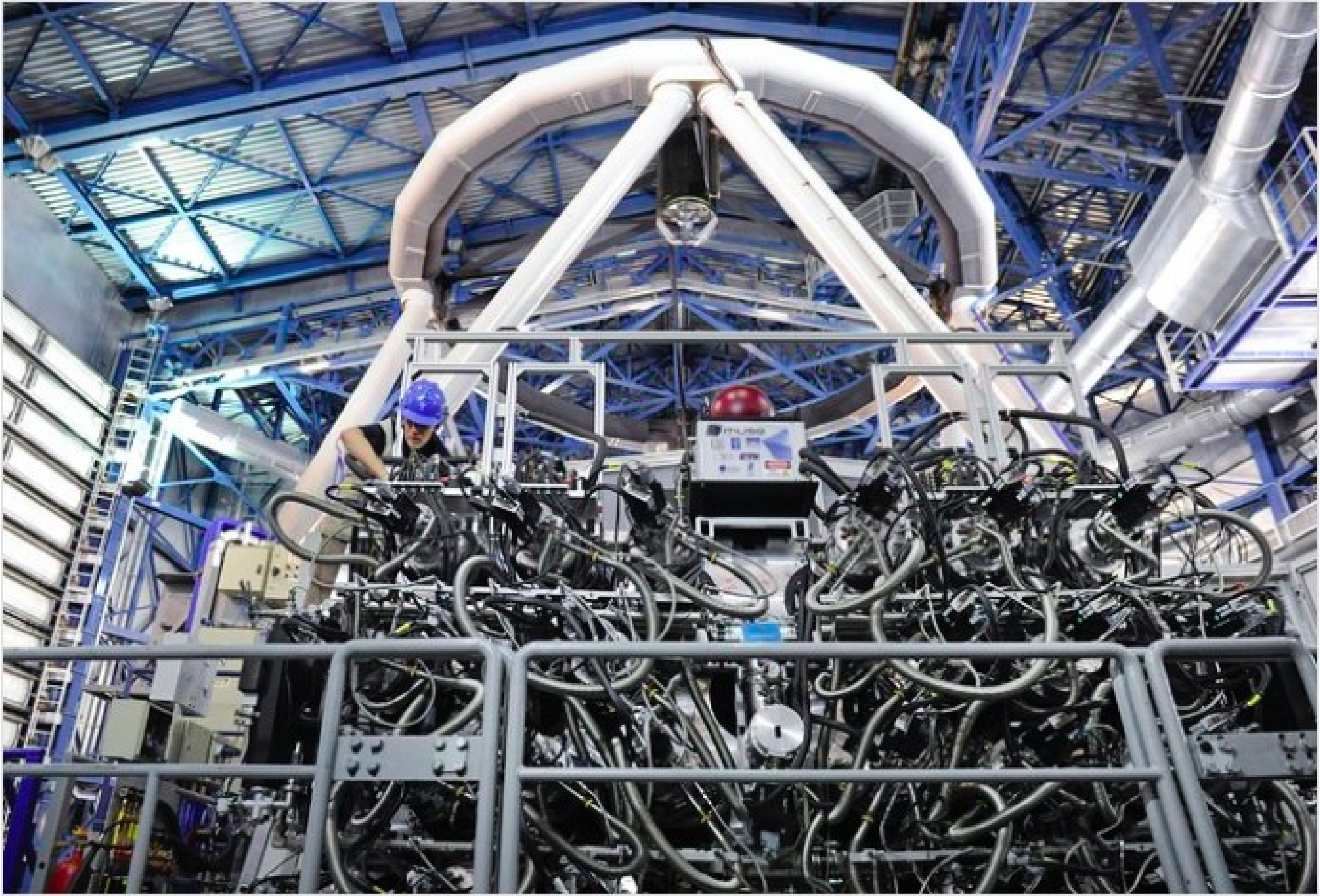
One spectrum for each pixel in the image

MUSE (Multi Unit Spectroscopic Explorer) at the VLT/ESO: IFUs to the next level



MUSE splits the adaptive optics corrected field of view in 24 sub-fields (24 IFU spectrographs at the VLT Nasmyth focus!)

The MUSE instrument on the VLT: equipped with 24 continuous flow cooling systems



The MUSE instrument is one of the most recent additions to the instrument complement of the VLT. It has 24 detectors, each of which needs its own continuous flow cooling systems. Such innovative systems were first developed at ESO for the

Number of modules	24
Wavelength range MUSE/VLT has a wide field with the same pixel scale (0.2" / pixel) as GMOS/Gemini, but covering 60x60" rather than 5x7"	480 – 930 nm (nominal) 465 – 930 nm (extended)* Wavelength range excluded for AO observations (Na Notch filter): 582 – 597 nm (nominal) 578 – 599 nm (extended)
Resolving power	1770 (480 nm) – 3590 (930 nm) (WFM) 1740 (480 nm) – 3450 (930 nm) (NFM)
Spectral sampling	0.125 nm/pixel
Detectors (per module)	4k x 4k e2V CCD
Field of view Wide field: Narrow field:	59.9" x 60.0" (WFM) 7.42" x 7.43" (NFM)
Spatial pixel scale	0.2" / pixel (WFM) 0.025" / pixel (NFM)
Throughput (total atmosphere, telescope and instrument)	14 % (480 nm) 33 % (750 nm) 14 % (930 nm)

Splitting the MUSE field of view into 24 sub-fields (→ 24 IFU spectrographs)

1.1.2.5 Spectral format

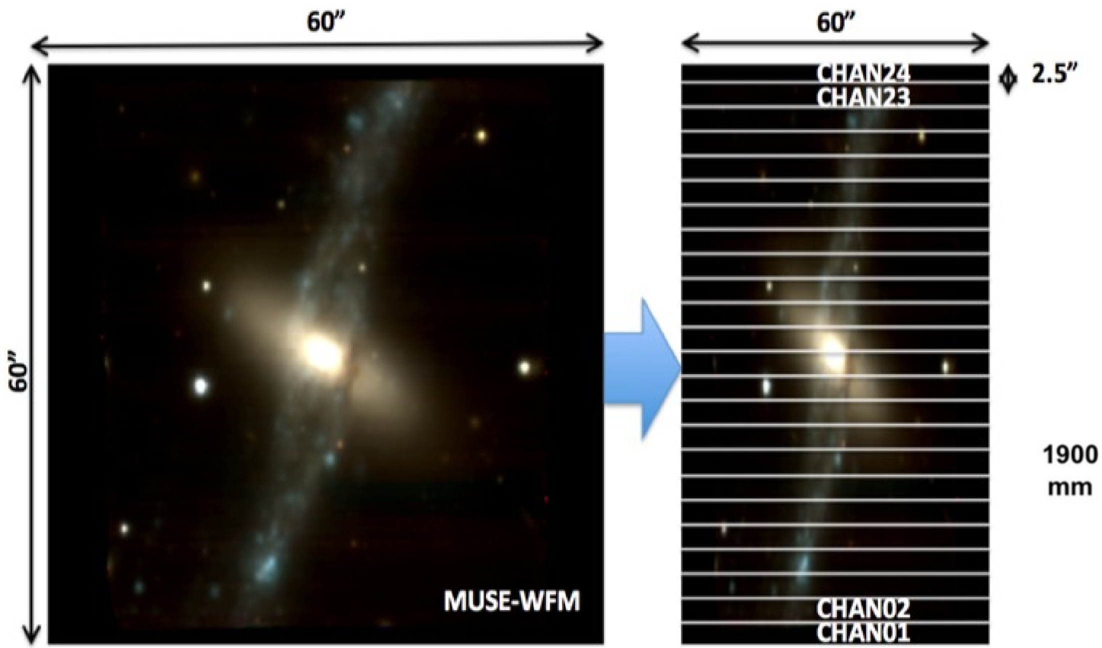
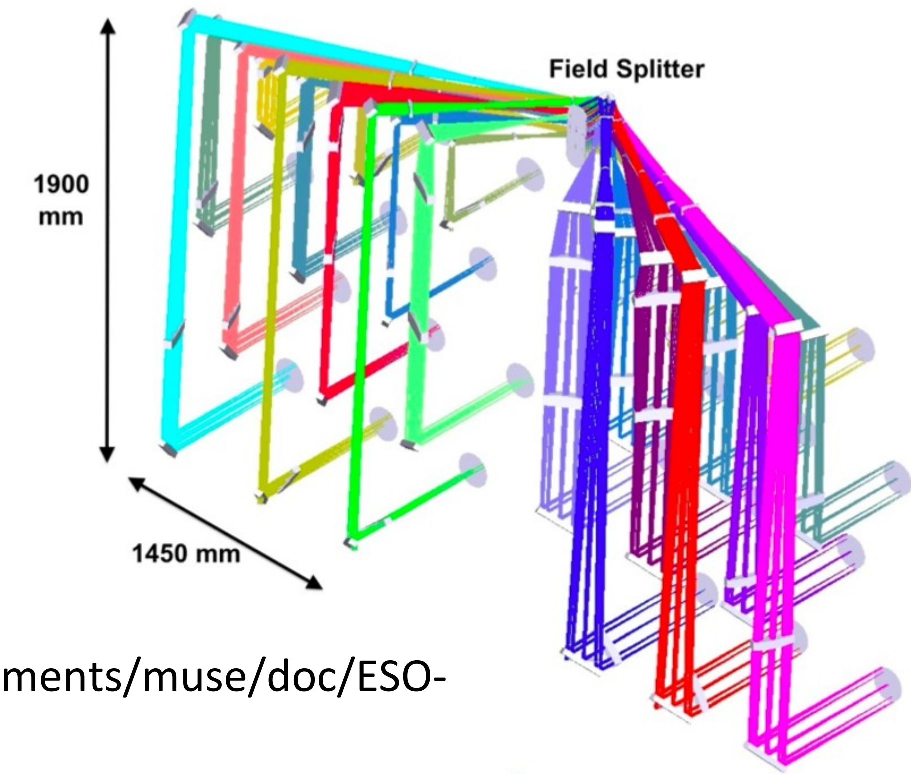
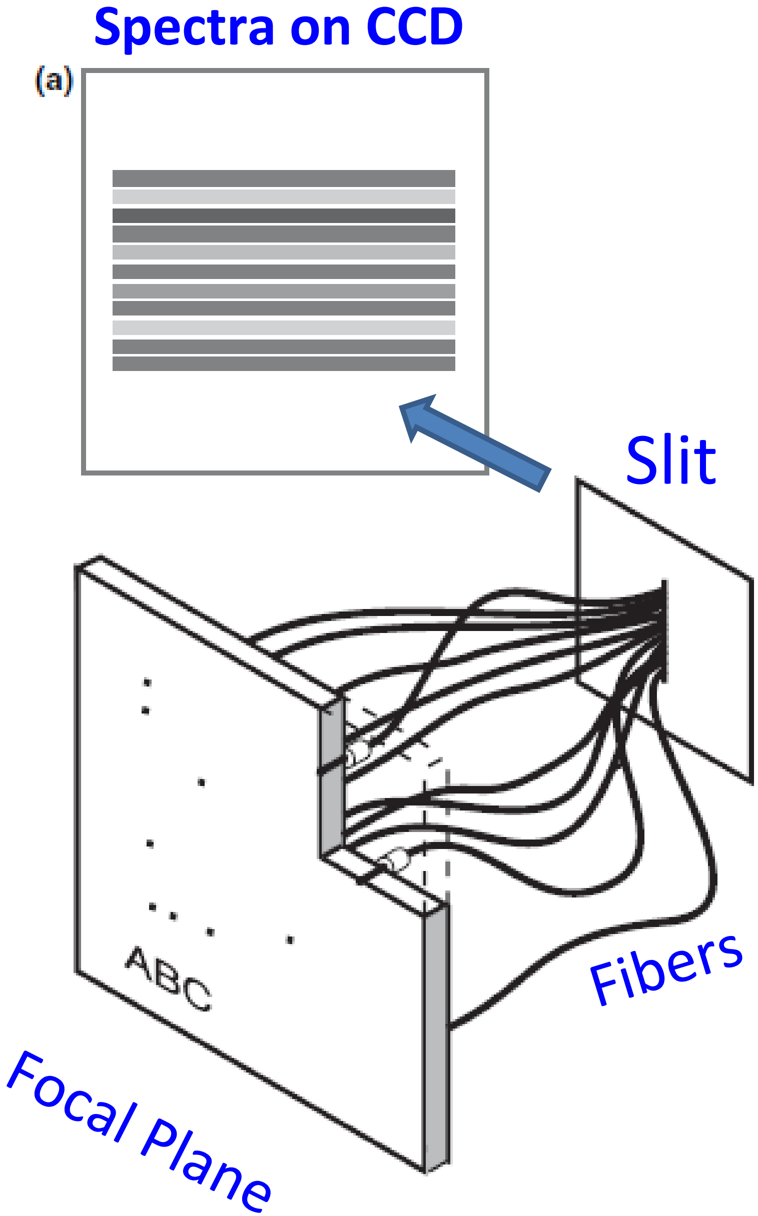


Figure 10: Overview of the splitting of the field-of-view from the fore-optics to one of the MUSE detectors. Left: splitting of the MUSE FOV into 24 sub-fields entering each channel. Center: shape of the



https://www.eso.org/sci/facilities/paranal/instruments/muse/doc/ESO-261650_MUSE_User_Manual_8p2.pdf

Multi-object spectroscopy with fibers



M80 globular cluster

Good for not-so-close objects, allows to cover a wide field

Fibers are positioned using *magnetic buttons*

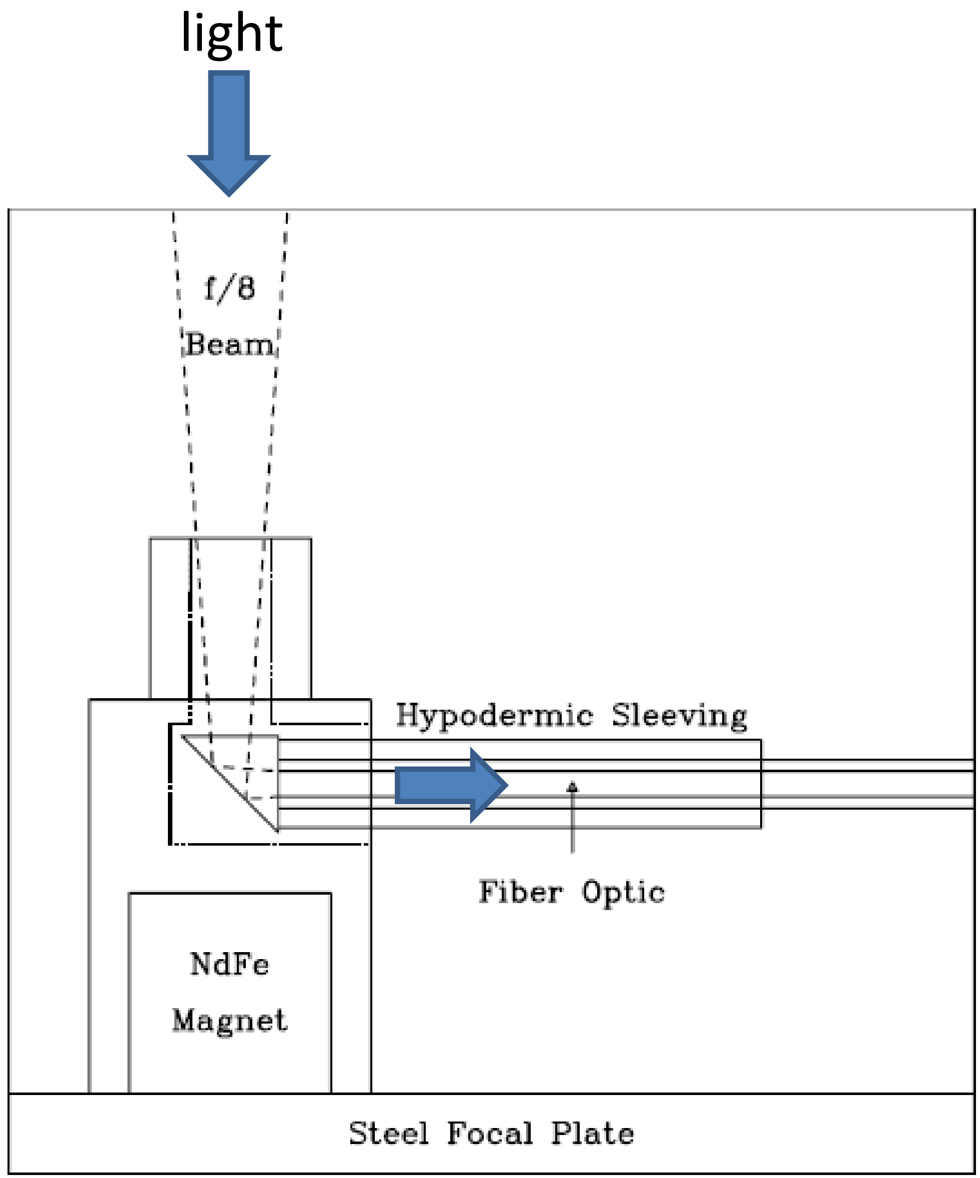


Figure 1: Schematic view of a fiber button on the focal plate.

The 2dF robotic fibre positioner which feeds the AAOmega spectrograph is mounted at the *prime focus* on top of the AAT 3,9m telescope.

Spectrograph is at the coude room (38 m de fibras opticas)

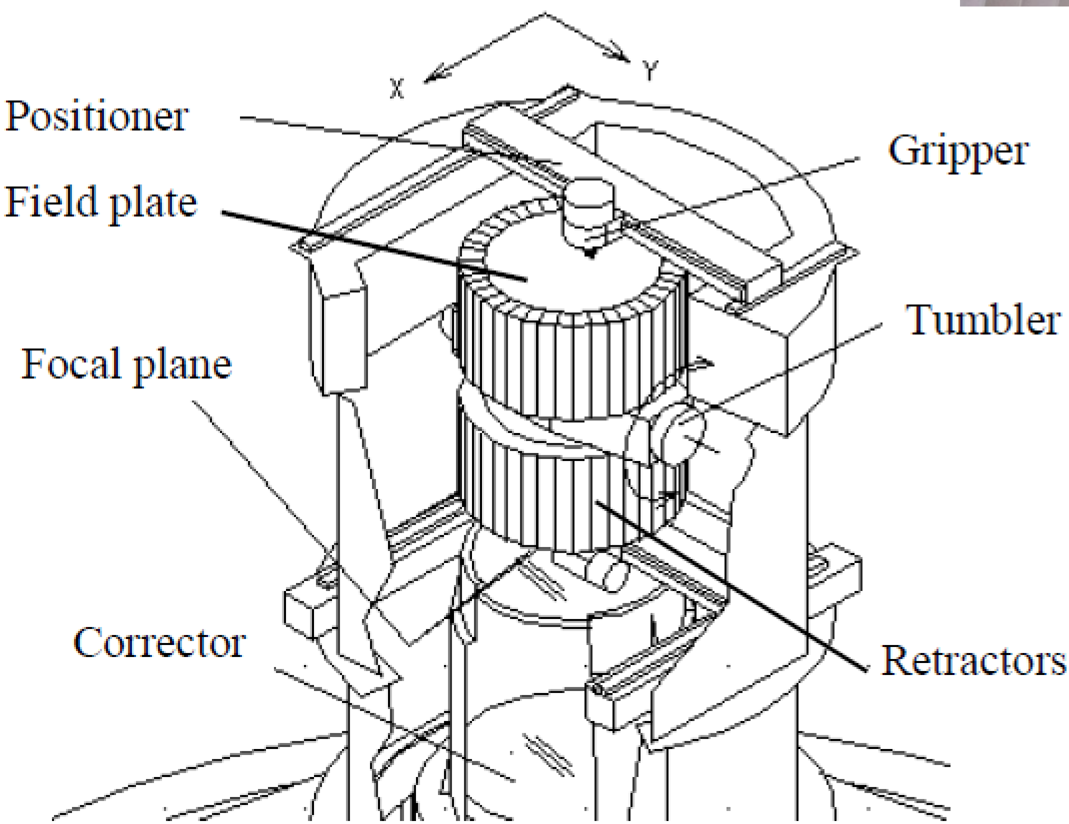
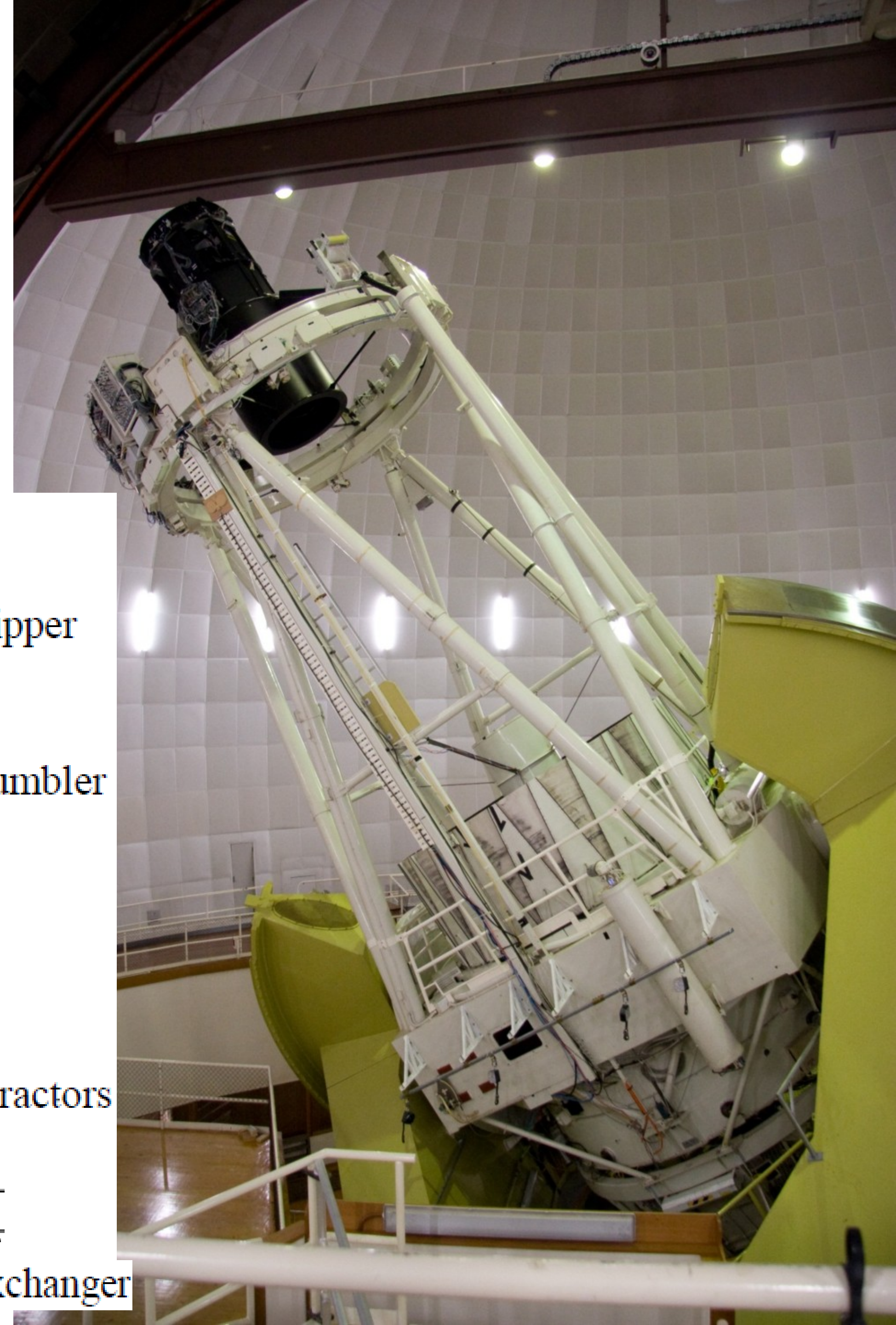
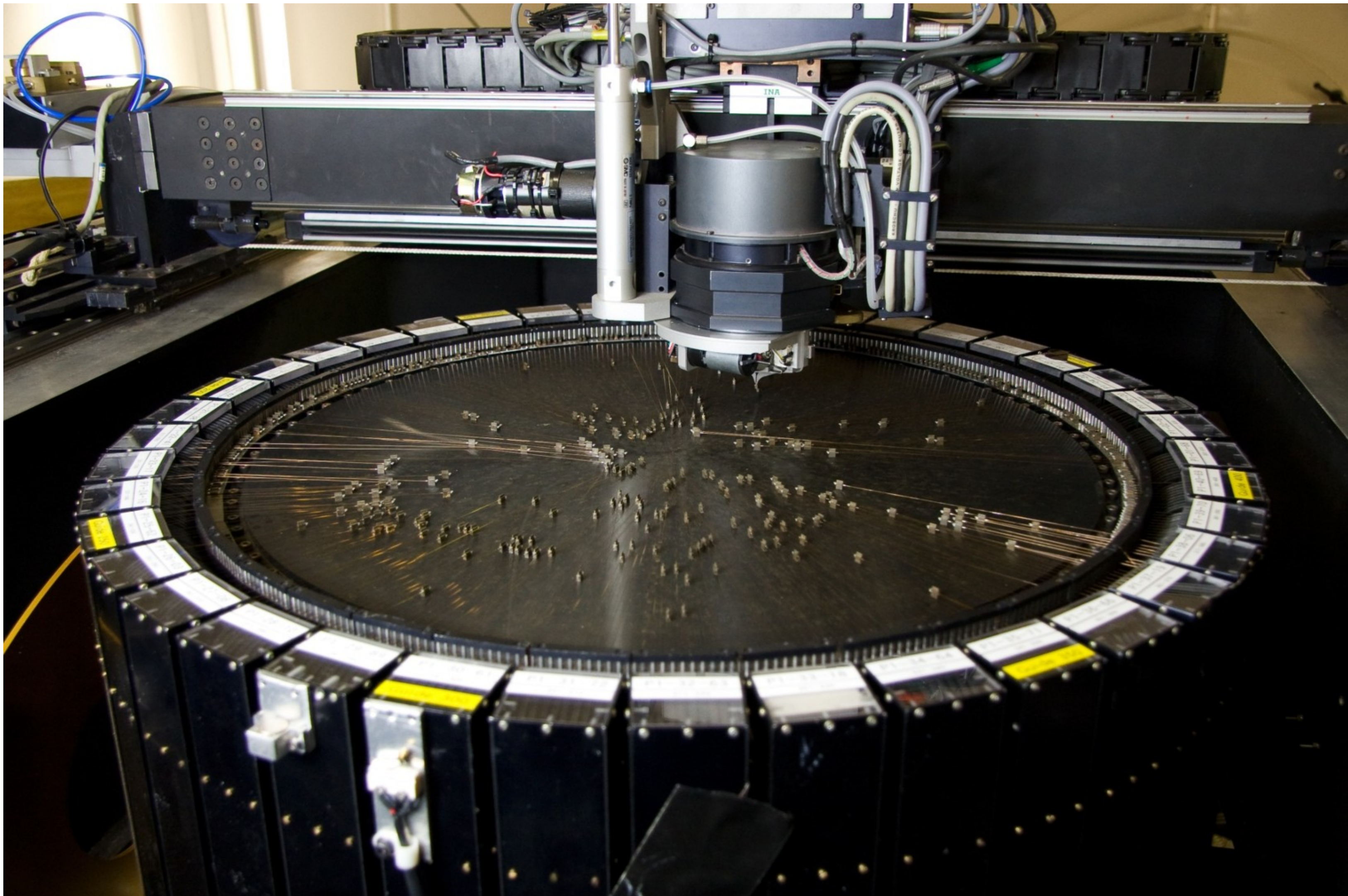


Figure 2 Cutaway view of 2dF postioner and plate exchanger

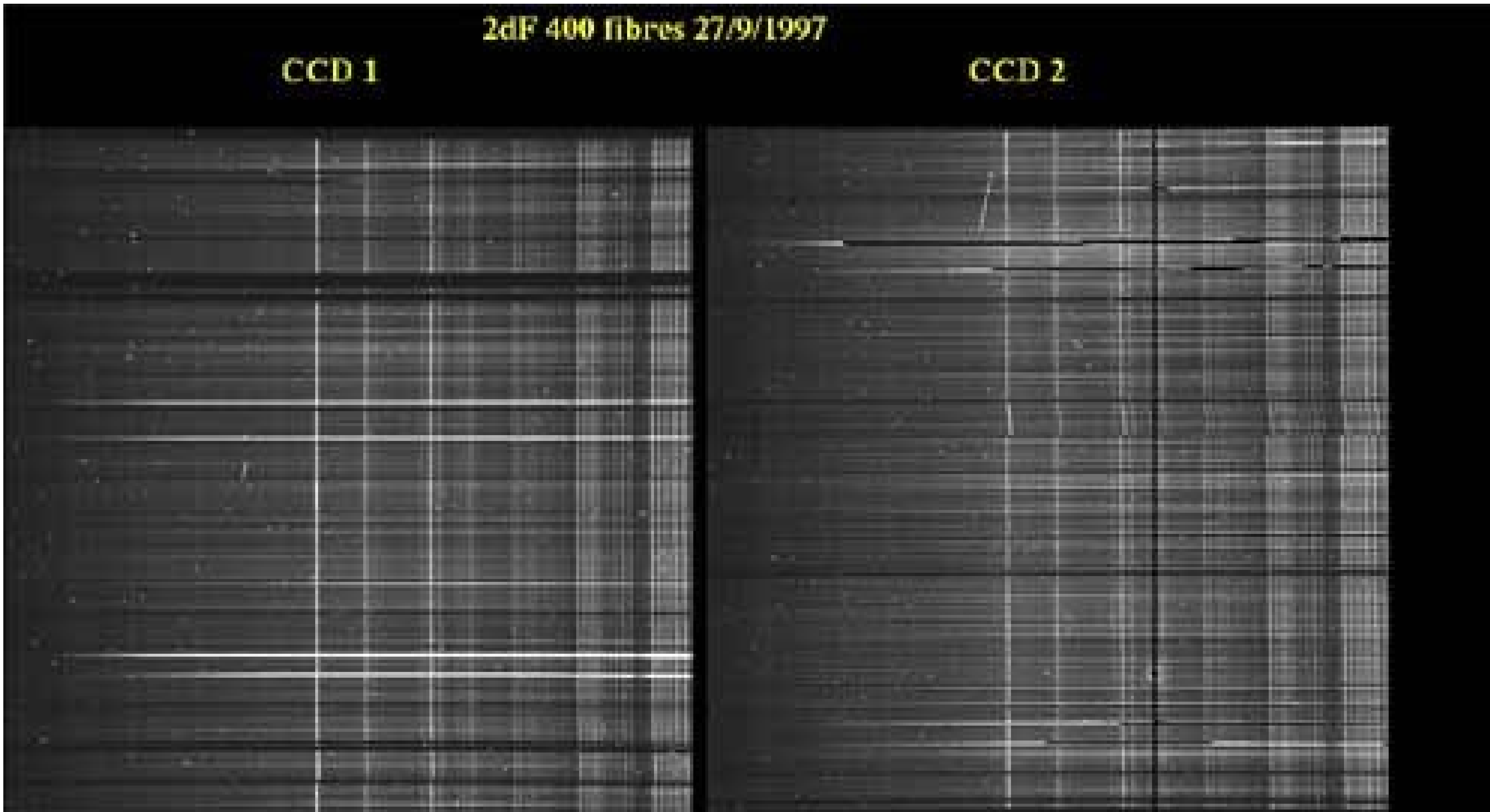


The 2dF robotic fibre positioner

The metal *field plate* is seen populated with *fibre buttons* which are used to relay the light from astronomical targets down to the AAOmega spectrograph. The *robot gripper* is seen hovering over a button which it is about to move to a new target position.



Old 2dF (one arm)
Almost 400 spectra (200 in each CCD)

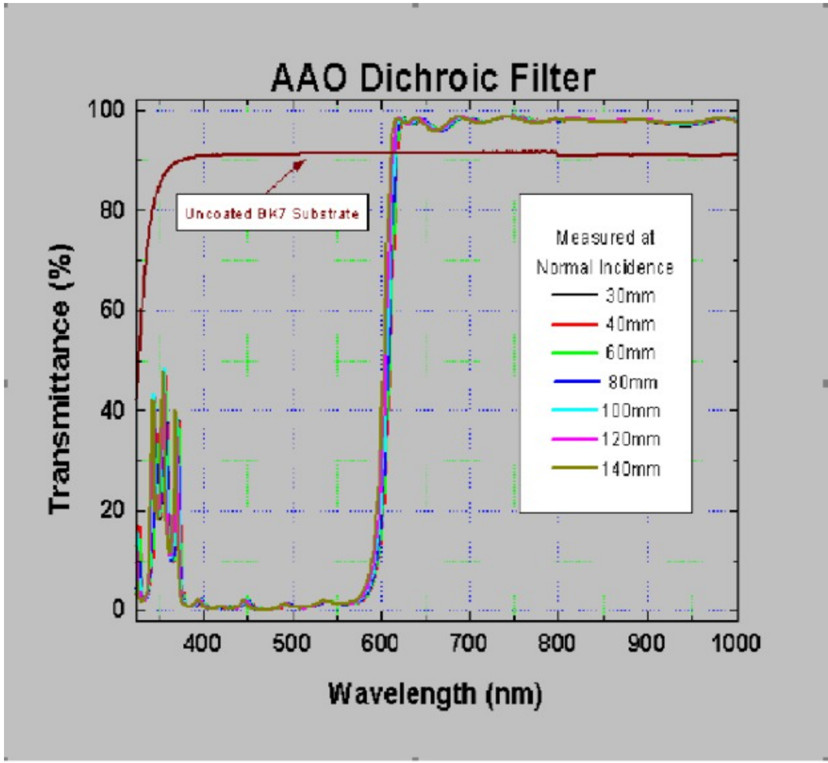


Latest 2dF AAOmega spectrograph (2005)

- 2 degree field of view (compared to 5-25 arcmin in 8-10m telescopes)
- About 400 fibers
- Two arms covering full optical range 370-850nm, or 470-950 nm at R ~ 1300
- Resolving power up to

R ~ 10 000 is possible but with smaller spectral coverage

- Simultaneous robotic configuration for next field



Almost 400 spectra for red arm (and 400 more spectra on blue side)

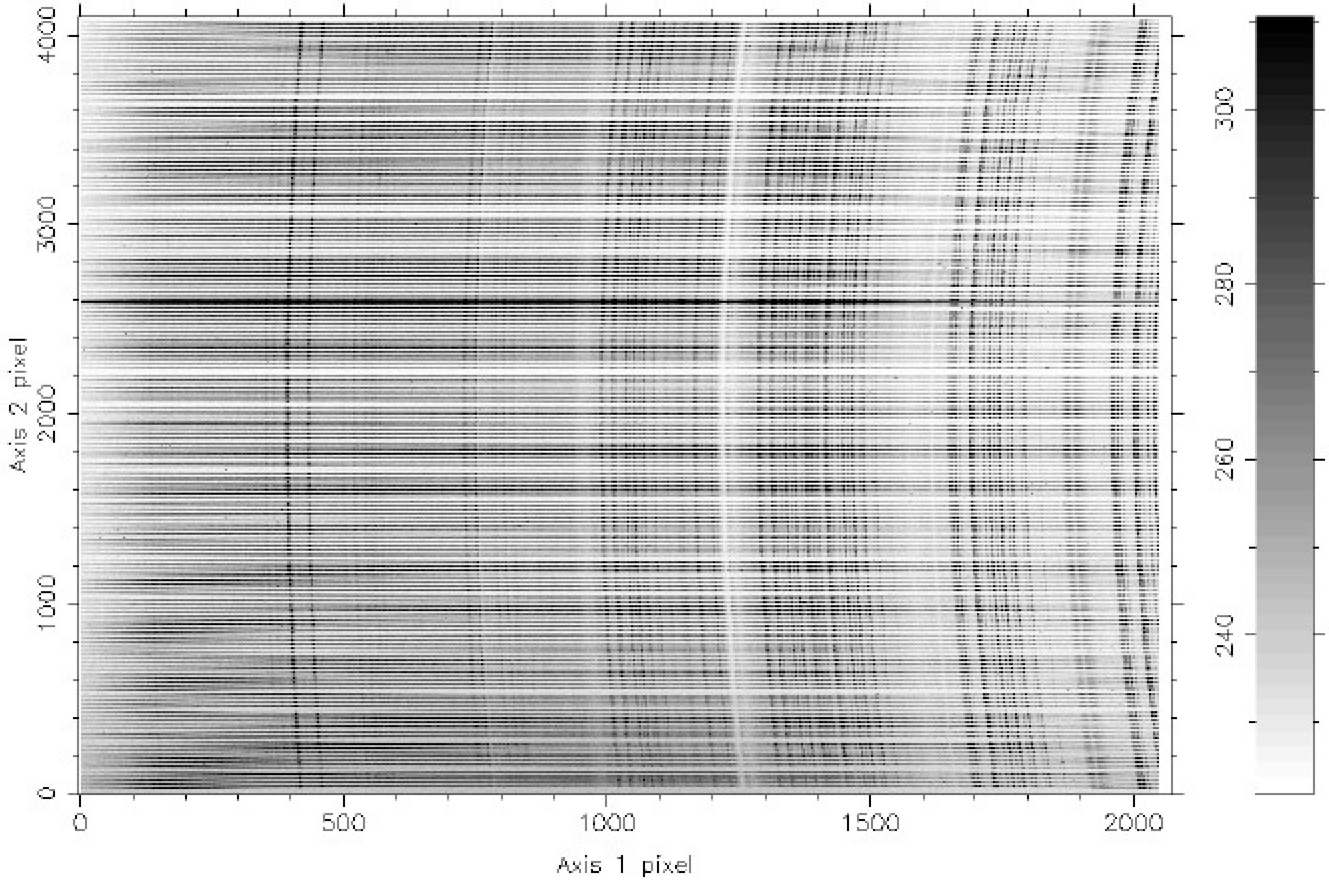


Figure 3. This 2hour (4×1800sec) raw AAOmega frame shows the full 2D CCD frame containing the 392 science fibre spectra. Dispersion runs left to right in the low resolution red (λ_{cen}=7250Å, R∼1300) unextracted spectra. Note the spectral curvature in the unsubtracted sky emission lines.

Sky subtraction with 2dF/AAOmega

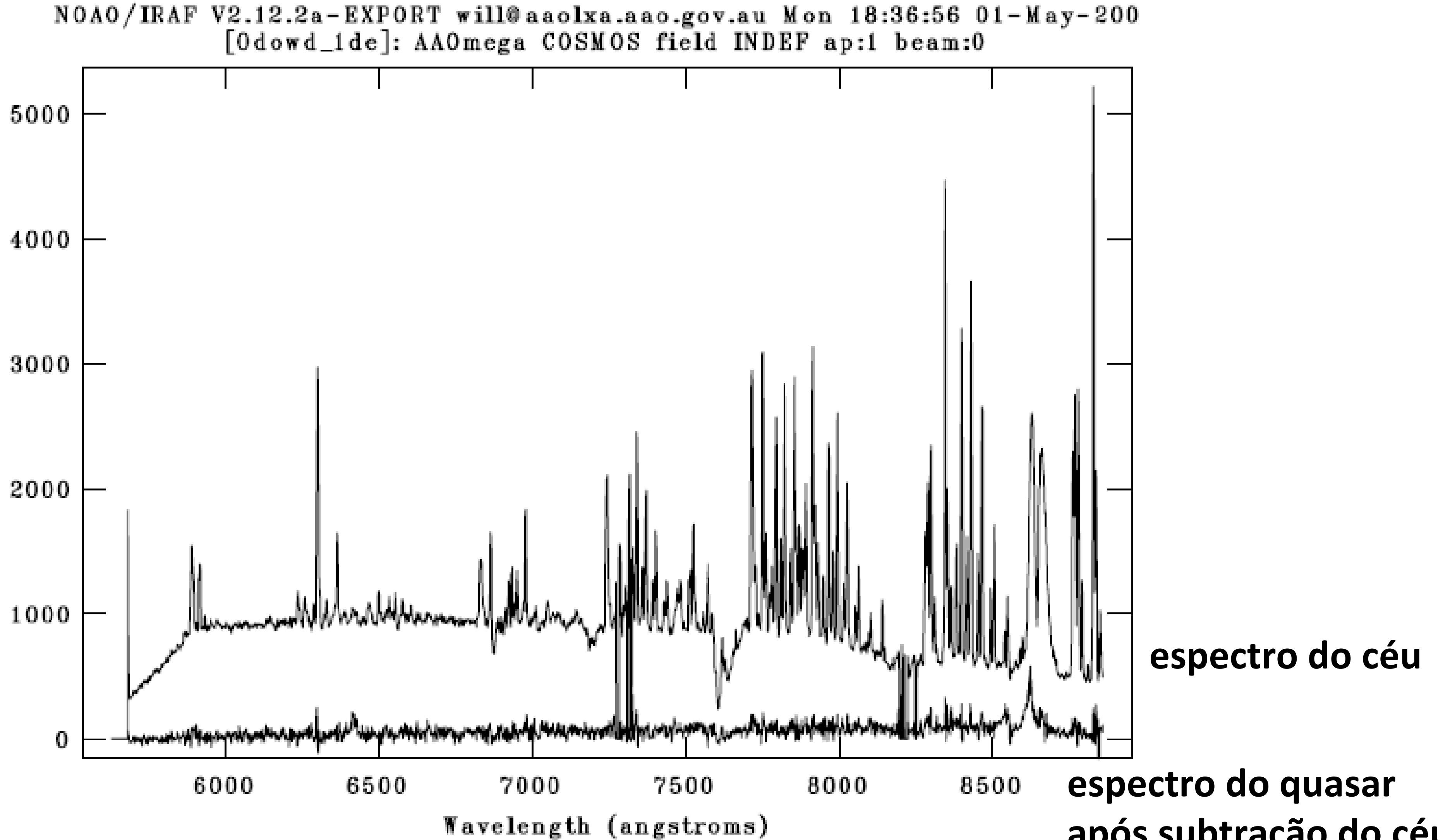


Figure 4. An example spectrum shows the ~1% sky subtraction which can be routinely achieved with AAOmega. The lower trace shows the spectrum of the underlying faint quasar target once the strong night sky spectrum (upper trace) has been subtracted. Bad pixel masking has not yet been full integrated into the reduction software, as evidenced by the two

Automatic reduction at 2dF AAOmega

400 blue spectra + 400 red spectra !

http://www.aao.gov.au/2df/aaomega/aaomega_2dfdr.html

Astronomy | Instrumentation | Observing | Images

2dfdr Software

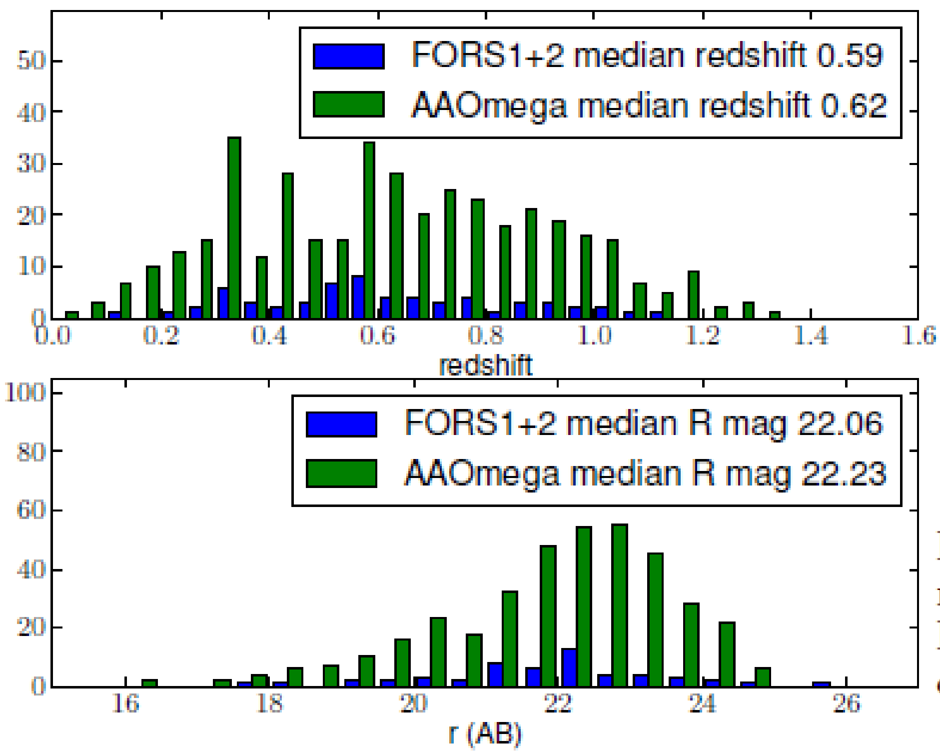
`2dfdr` is an automatic data reduction pipeline dedicated to reducing multi-fibre spectroscopy data (with current implementations for AAOmega with either the 2dF or SPIRAL IFU top ends, 2dF, 6dF, FMOS and the older Spiral). A graphical user interface is provided to control data reduction and allow inspection of the reduced spectra. It is being continually developed at the AAO in response to user feedback. You **can** reduce most of your data by simply pressing **SETUP+START** in the Graphical User Interface.

An Efficient Approach to Obtaining Large Numbers of Distant Supernova Host Galaxy Redshifts

http://adsabs.harvard.edu/abs/2012arXiv1205.1306L

C. Lidman[A,B,Q], *V. Ruhlmann-Kleider*[C], *M. Sullivan*[D], *J. Myzska*[A,E], *P.*

Abstract: - We use the wide–field capabilities of the 2dF fibre positioner and the AAOmega spectrograph on the Anglo-Australian Telescope (AAT) to obtain redshifts of galaxies that hosted supernovae during the first three years of the Supernova Legacy Survey (SNLS). With exposure times ranging from 10 to 60 ksec per galaxy, we were able to obtain redshifts for 400 host galaxies in two SNLS fields, thereby substantially increasing the total number of SNLS supernovae with host galaxy redshifts. The median redshift of the galaxies in our sample that hosted photometrically classified Type Ia supernovae (SNe Ia) is $z \sim 0.77$, which is 25% higher than the median redshift of spectroscopically confirmed SNe Ia in the three–year sample of the SNLS. Our results demonstrate that
rographs on 4m telescopes to efficiently
ost galaxies over the large areas of sky
nova surveys, such as the Dark Energy



AAOmega no telescópio AAT de 4m é mais produtivo que o FORS no VLT de 8m (campo de apenas 7' x 7')

Figure 3: A comparison of the host redshift and magnitude distributions obtained with FORS1 and FORS2 with the host and magnitude distributions obtained with AAOmega.

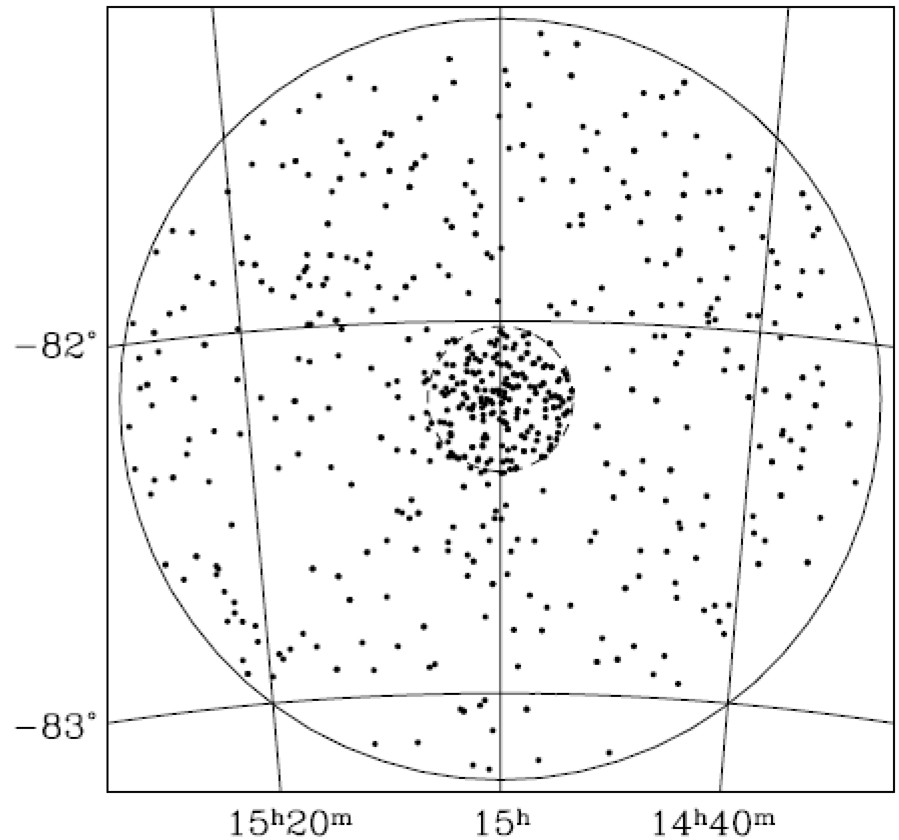
Mon. Not. R. Astron. Soc. **411**, 1536–1546 (2011)

Radial velocity and metallicity of the globular cluster IC4499 obtained with AAOmega★

Warren J. Hankey† and Andrew A. Cole

School of Mathematics & Physics, University of Tasmania, Private Bag 37, Hobart TAS 7001, Australia

The half-light and tidal radii of IC 4499 are 1.5 and 12.35 arcmin, respectively (Harris 1996). Fibres were preferentially allocated to the centre of the 2° field. Once the cluster centre was sampled as densely as possible with fibres, the spare fibres were allocated to stars outside the cluster centre in the same colour and magnitude



ure 2. Observed targets in a 2° field around IC 4499. The tidal radius shown by the dashed line; the fibre allocation was strongly weighted to ect targets within this radius.

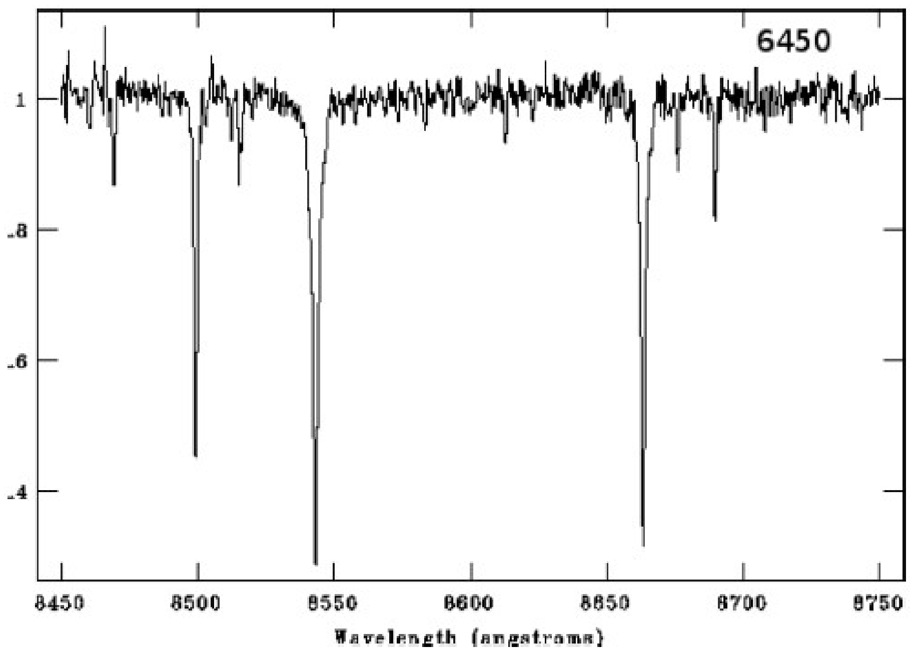
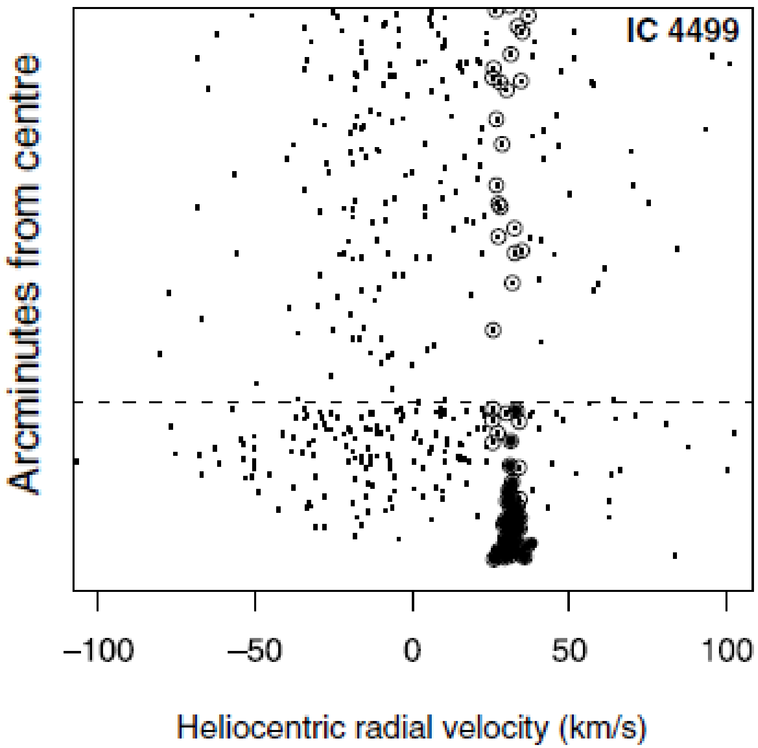


Figure 3. Typical spectrum of IC 4499 member RGB star showing the Ca II triplet and many weaker metal lines. Star ID 6450 in Table 3.

Confirmed members of cluster IC 4499



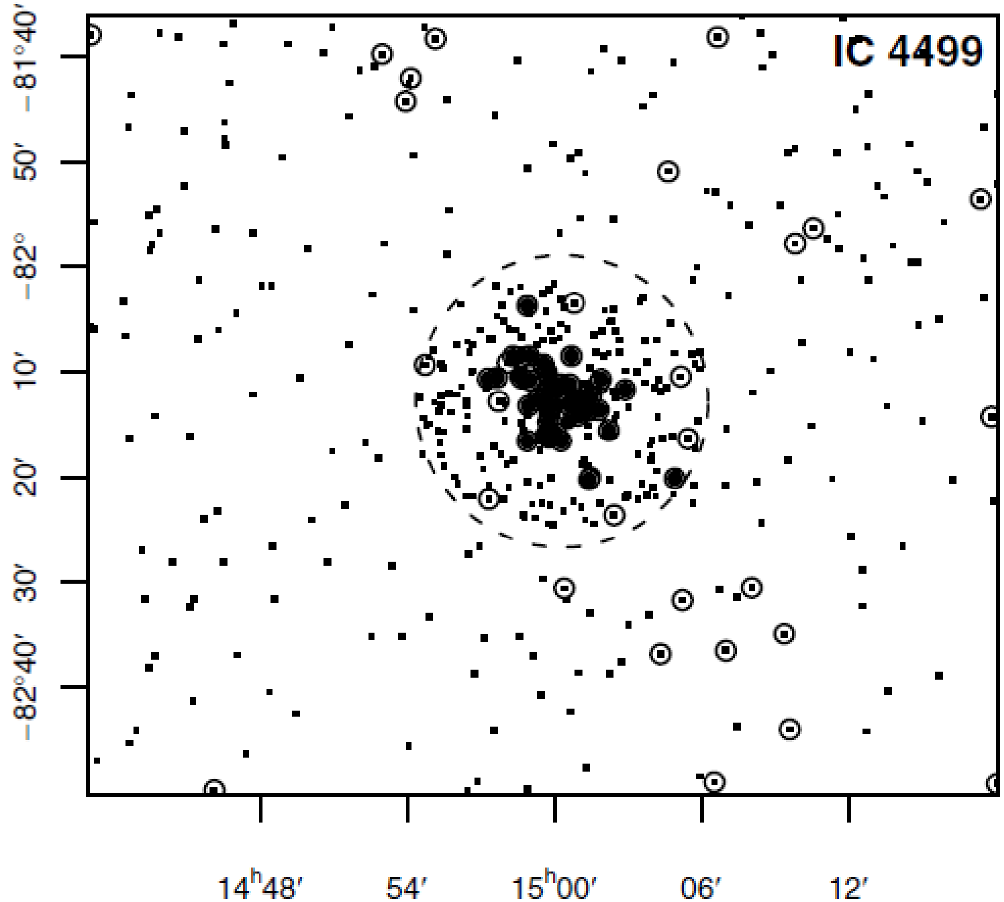


Figure 5. Cluster member map. Solid circles are cluster members. Open circles with similar velocities were rejected for lying outside the tidal radius (dashed line), as metallicity outliers, or for contaminated spectra.

Table 2. Summary of results.

Cluster	$N_\star$	W' (Å)	$K_{\rm HB}$ (mag)	[Fe/H]	Δ[Fe/H]	$V_{\rm r}$ (km s^{-1})	$\Delta V_{\rm r}$ (km s^{-1})
M68	51	2.59 ± 0.35	14.4[a]	−1.88 ± 0.13	0.11 ± 0.14	−98.6 ± 1.5	−4.2 ± 4.2
M4	70	4.90 ± 0.34	11.13	−1.12 ± 0.14	0.07 ± 0.14	65.7 ± 0.9	5.2 ± 1.1
M22	81	3.61 ± 0.46	12.21	−1.55 ± 0.17	−0.07 ± 0.17	−150.5 ± 1.3	−1.7 ± 1.5
IC 4499	43	3.70 ± 0.29	15.97	−1.52 ± 0.12		31.5 ± 0.4	

[a]Dall'Ora et al. (2006). Δ is difference of measured − literature value.

FLAMES (VLT/ESO) - Fibre Large Array Multi Element Spectrograph

- Field of view: 25 arcmin in diameter
- UVES mode is for high resolution

(R ~ 47 000) but only 8 objects

- GIRAFFE mode :

- MEDUSA submode up to 130 targets at R ~ 5600 - 25000

- IFU submode in small field 2x3arcsec

- ARGUS submode : larger IFU (12x7")

- Simultaneous UVES + GIRAFFE ok
- Pipeline (automatic data reduction)

Fiber positioning at FLAMES

(< 15 min while observations are being performed on the other plate)

The Fiber Positioner (OzPoz)

The OzPoz fibre positioner is based on the successful concept developed for 2dF at AAO: while one plate is observing, the other one is positioning the fibres for the subsequent observations. The dead time between two observations is therefore limited to less than 15 minutes, guaranteeing a very good night duty cycle. OzPoz has the capability to host up to 560 fibre per plate.

OzPoz is able to host up to four plates, but only two are used in the FLAMES configuration. Each of these two plates will feed GIRAFFE and the red arm of the UVES spectrographs.

Plate One is hosting

- **132 GIRAFFE MEDUSA buttons,**
- **30 GIRAFFE IFU buttons (15 objects plus 15 sky),**
- **8 UVES buttons.**

With Plate One it is possible to use UVES and GIRAFFE simultaneously.
Plate Two is hosting

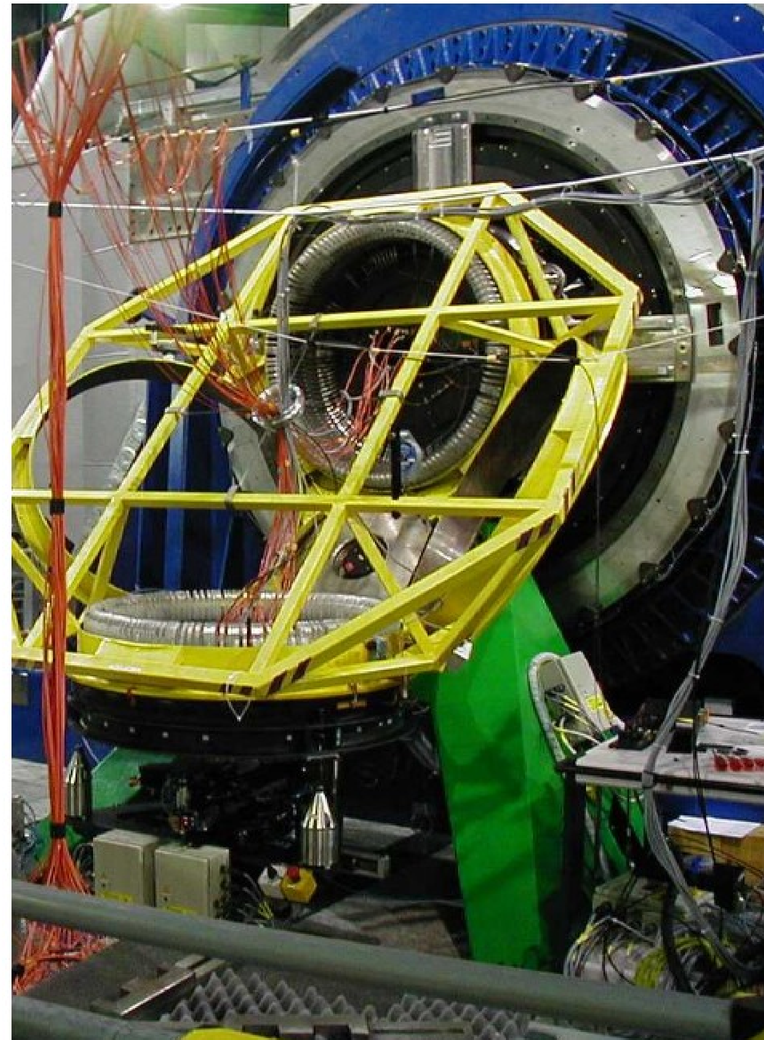
- **the same buttons as above,**
- **a central GIRAFFE IFU ``Argus" facility and 15 Argus-sky buttons.**

To these two plates, several buttons for centering and maintenance purposes have been added.
The **minimum object separation is 10.5 arcsec**. This minimum distance is entirely limited by the size of the magnetic buttons. OzPoz is able to position the fibres with an accuracy of better than **0.1 arcsec** (+ astrometric error). It has its own Observing Software and control electronics, as well as the necessary preparatory observing tools. Finally OzPoz is equipped with its own calibration system.

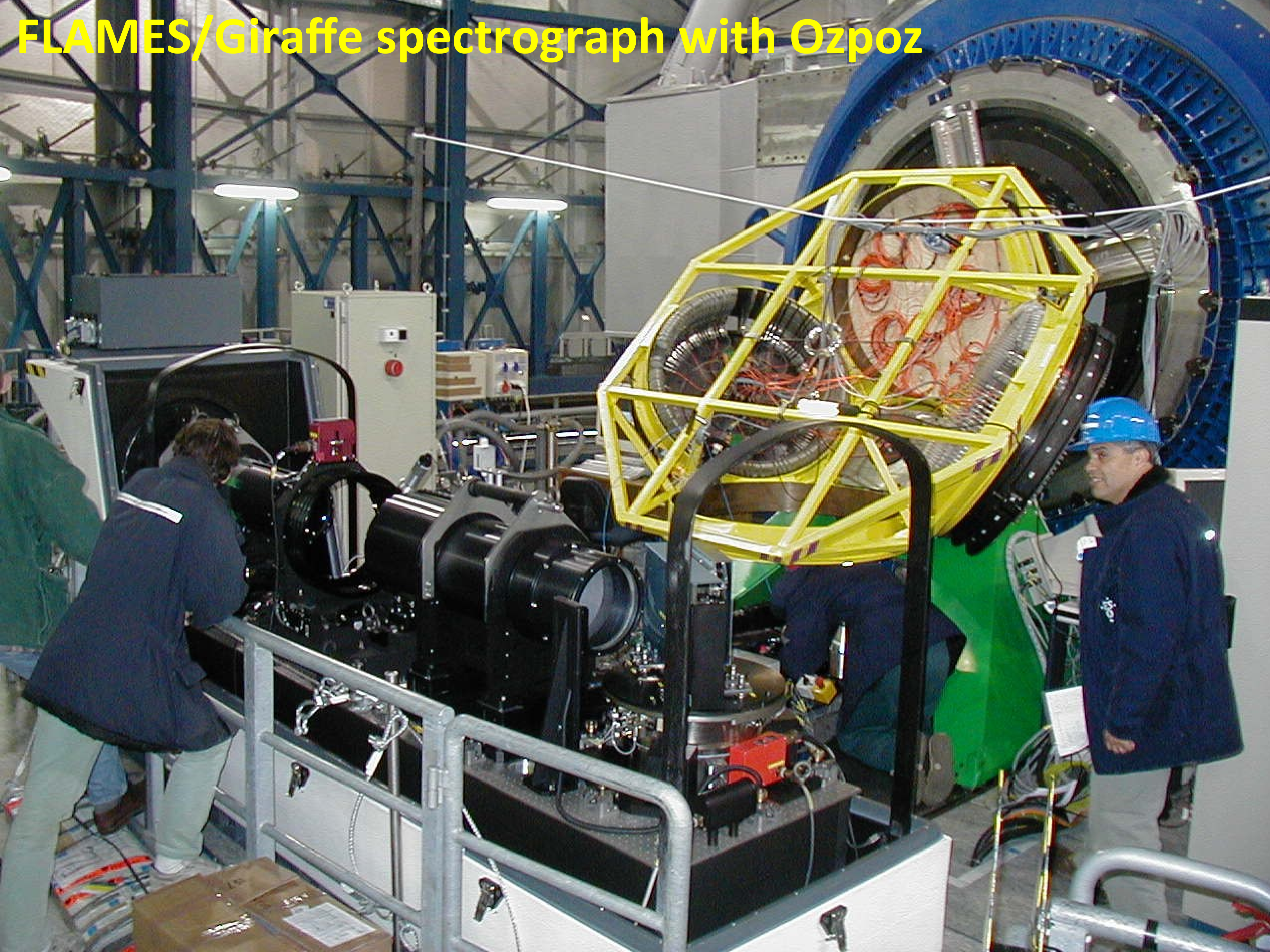
Very accurate calibrations can be obtained by rastering the fibre buttons with an r-theta arm, and repeating this procedure many times. Such calibrations are the only ones planned on a daily basis.

The Fibre Positioner (see ESO press realease 07-98) is being built by the AUSTRALIS Consortium, lead by the Anglo Australian Observatory (AAO, P.I. K. Taylor, Co-P.I. M. Colless).

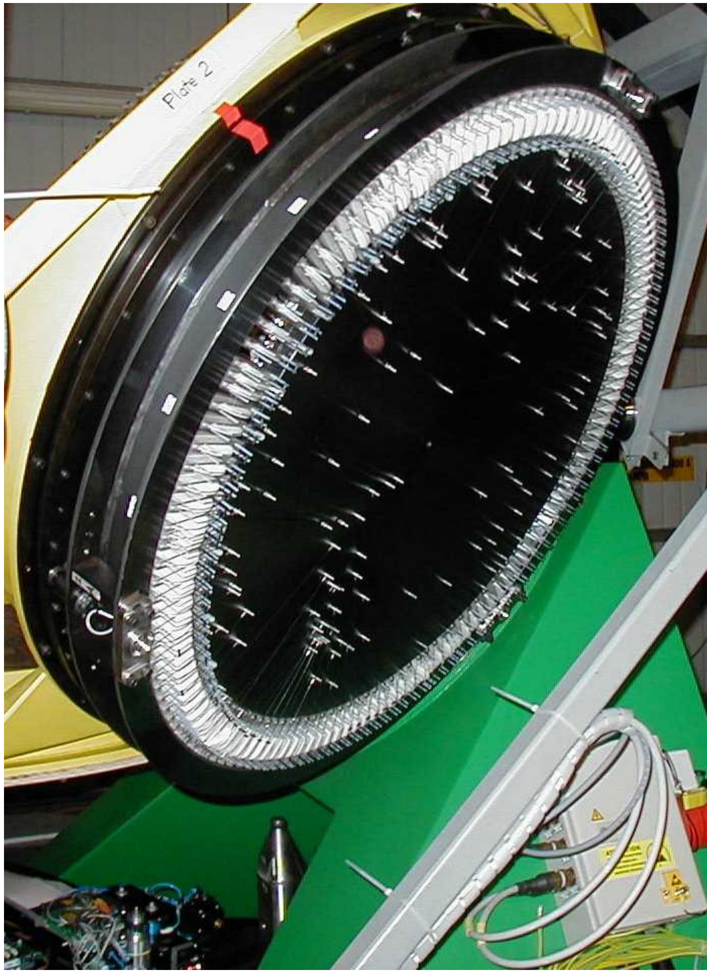
Further information about OzPoz can be obtained here.



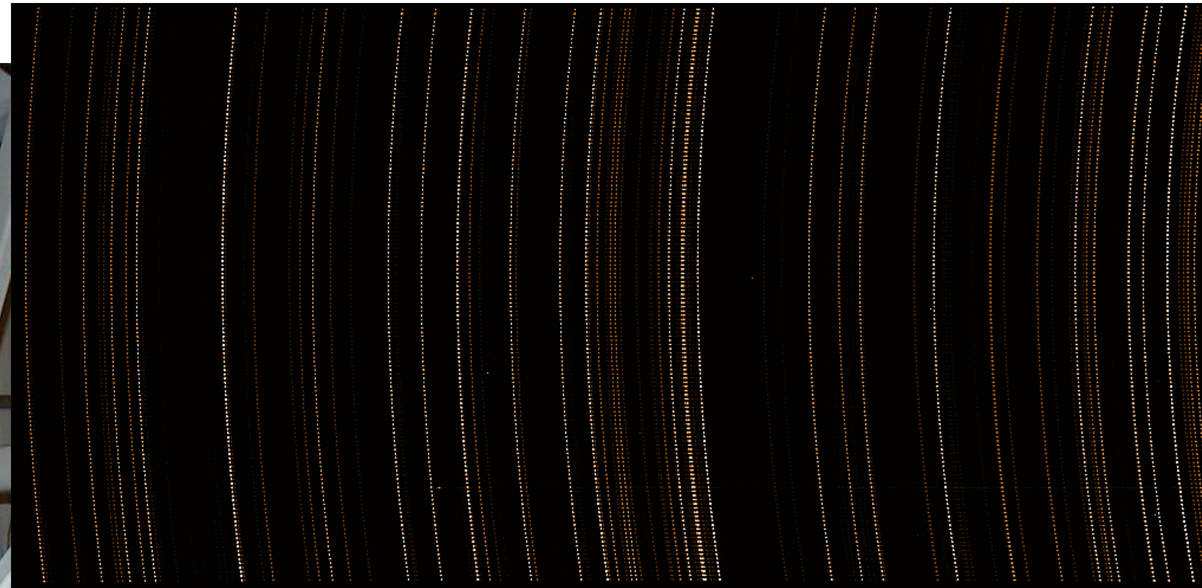
FLAMES/Giraffe spectrograph with Ozpoz



http://www.eso.org/sci/facilities/paranal/instruments/flames/inst/Giraffe.html



View of the back of one Ozpoz plate where all the fibres are attached with magnetic buttons



Th-Ar calibration in medusa mode using the HR9 setup. Lambda ncreases from right to left. The Y- axis gives the position along the slit

Flat-field image in medusa mode with the same HR9 setup. Wavelenghts are increasing from right to left. The vertical axis gives the position along the slit.

VLT/FLAMES spectroscopy of Red Giant Branch stars in the Carina dwarf spheroidal galaxy.⋆

B. Lemasle[1], V. Hill[2], E.Tolstoy[1], K. A. Venn[3], M. D. Shetrone[4], M. J. Irwin[5], T. J. L. de Boer[1], E. Starkenburg[1], and S. Salvadori[1]

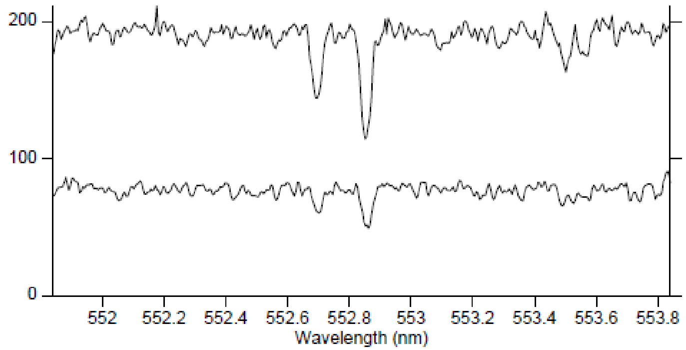
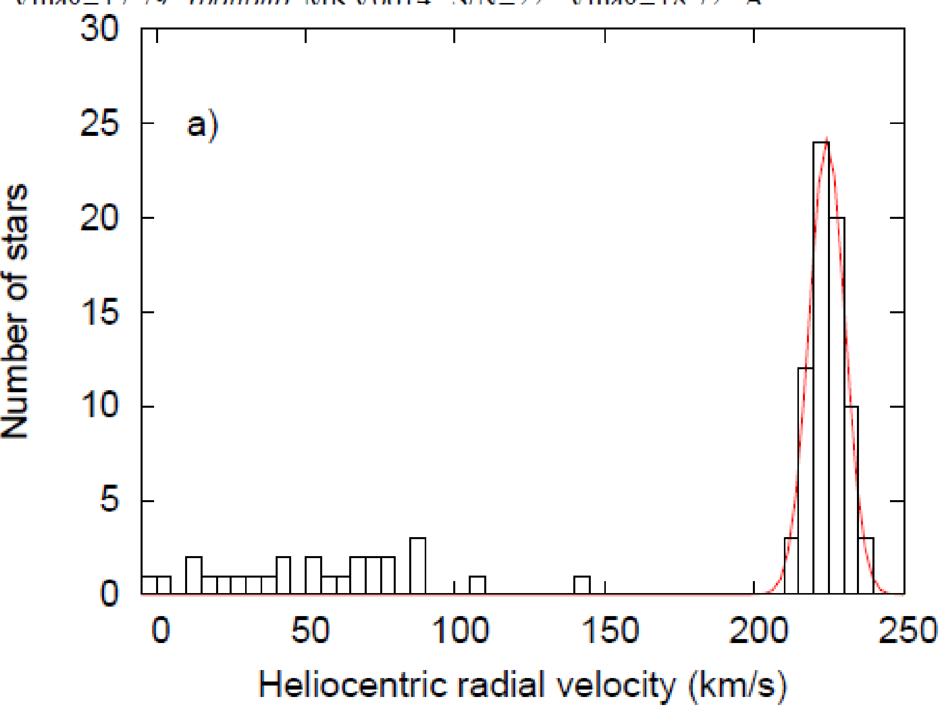
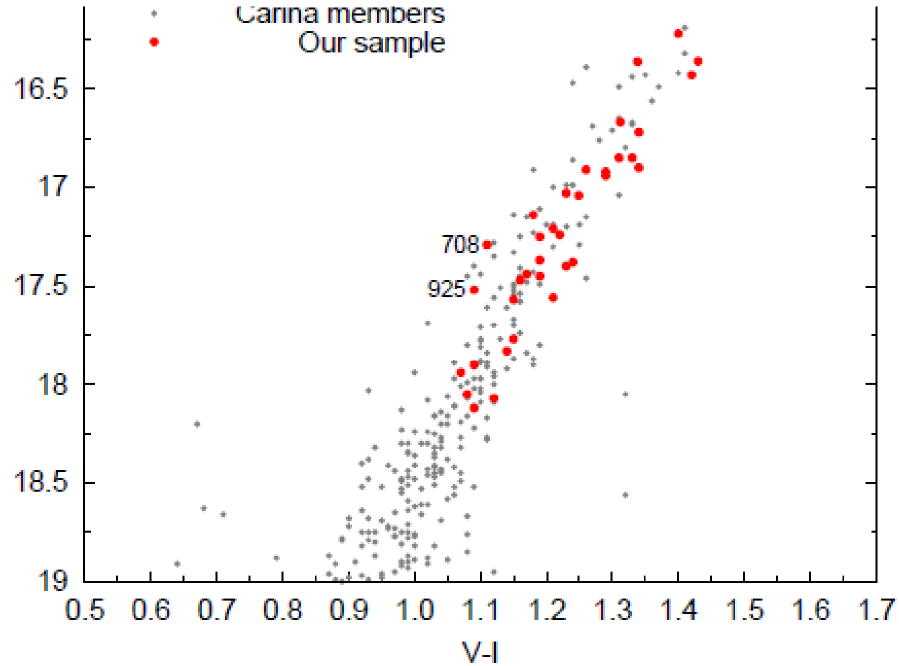


Fig. 1. Representative spectra of two stars of our sample, centered on the Mg line at 552.841 nm. *(top)* MKV0900: S/N=44, Vmag=17.79; *(bottom)* MKV0614: S/N=22, Vmag=18.72. A





.3. I vs. (V-I) CMD: our FLAMES/GIRAFFE sample is wn in red dots and other Carina members (from CaT) are wn in grey dots.

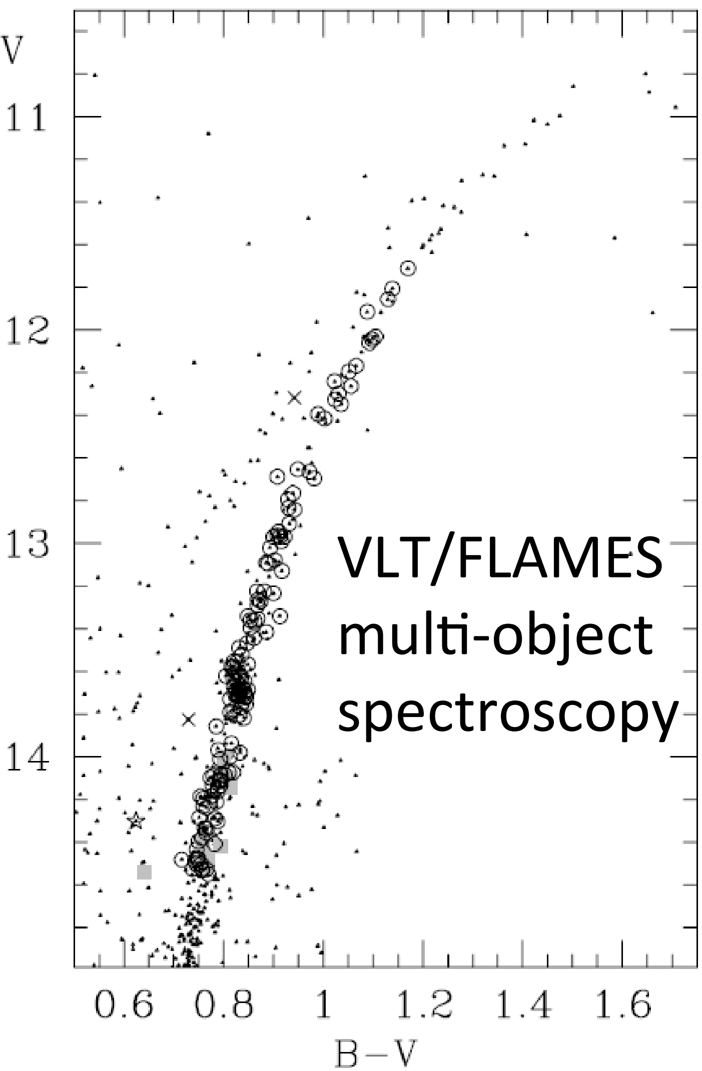
2012A&A...538A.100L

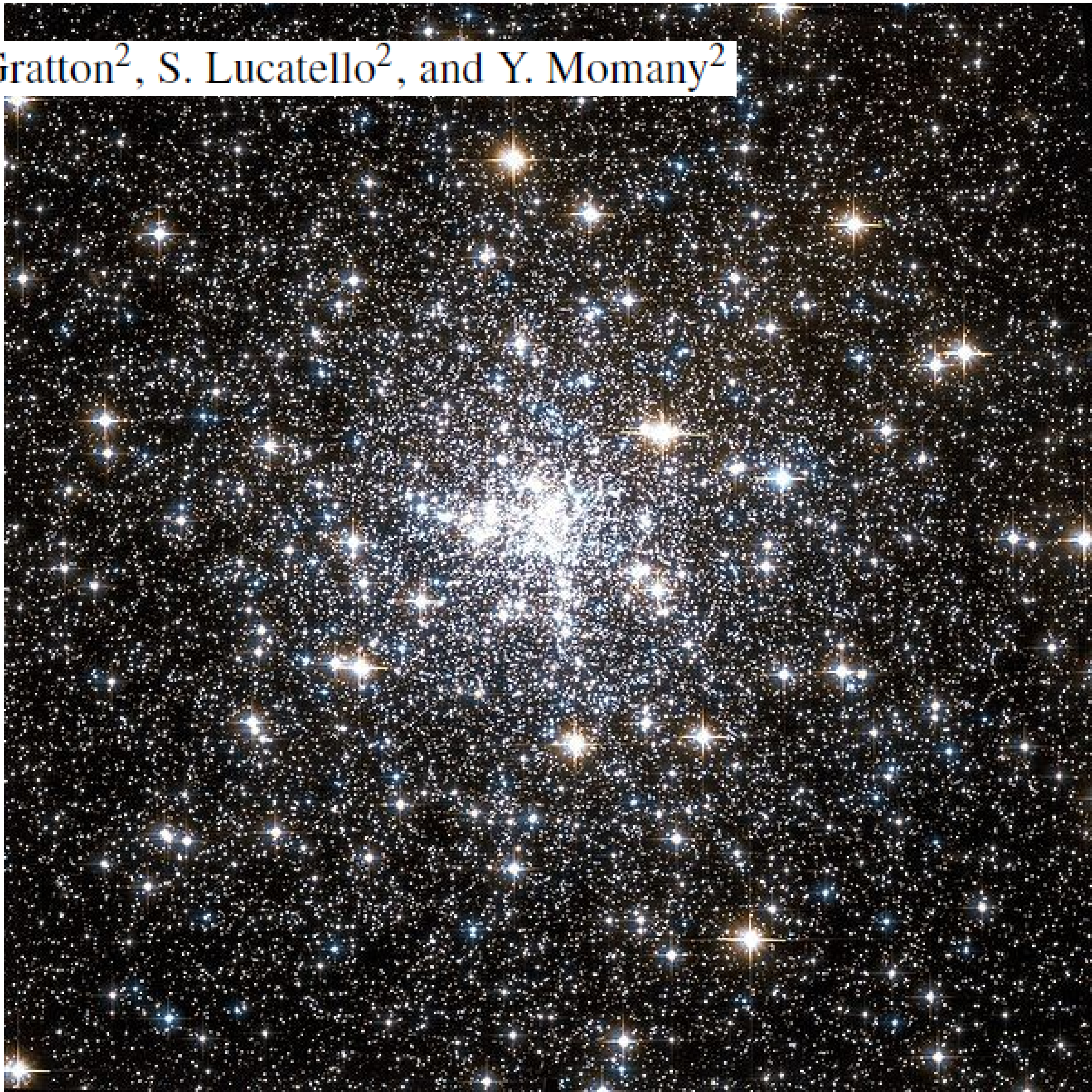
Na-O anticorrelation and horizontal branches

II. The Na-O anticorrelation in the globular cluster NGC 6752

A&A 464, 927–937 (2007)

E. Carretta[1], A. Bragaglia[1], R. G. Gratton[2], S. Lucatello[2], and Y. Momany[2]





With ESO VLT/FLAMES multi-object medium & high-resolution spectroscopy, Europeans quickly beat the Americans studying globular clusters, who were doing just one star at a time

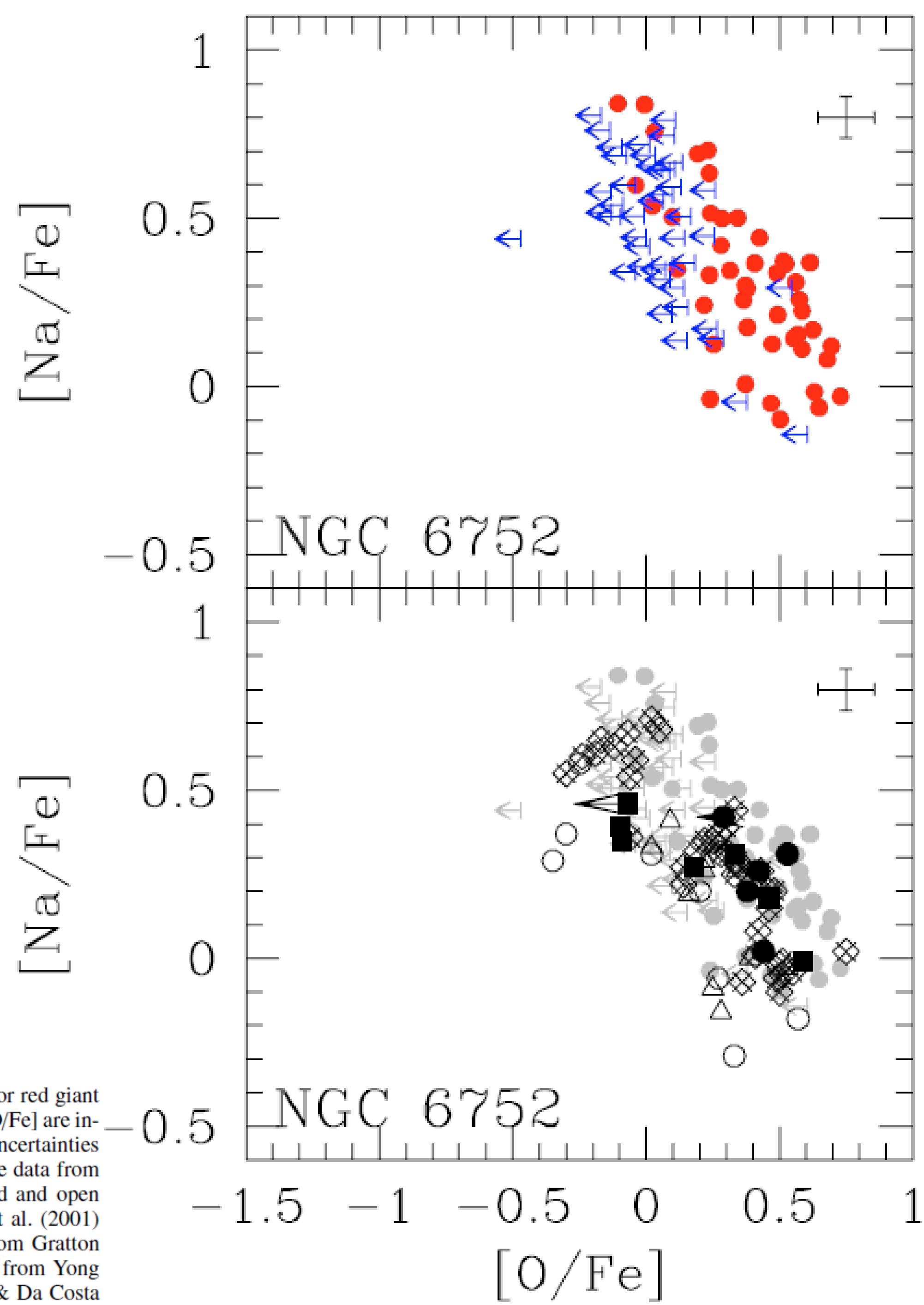
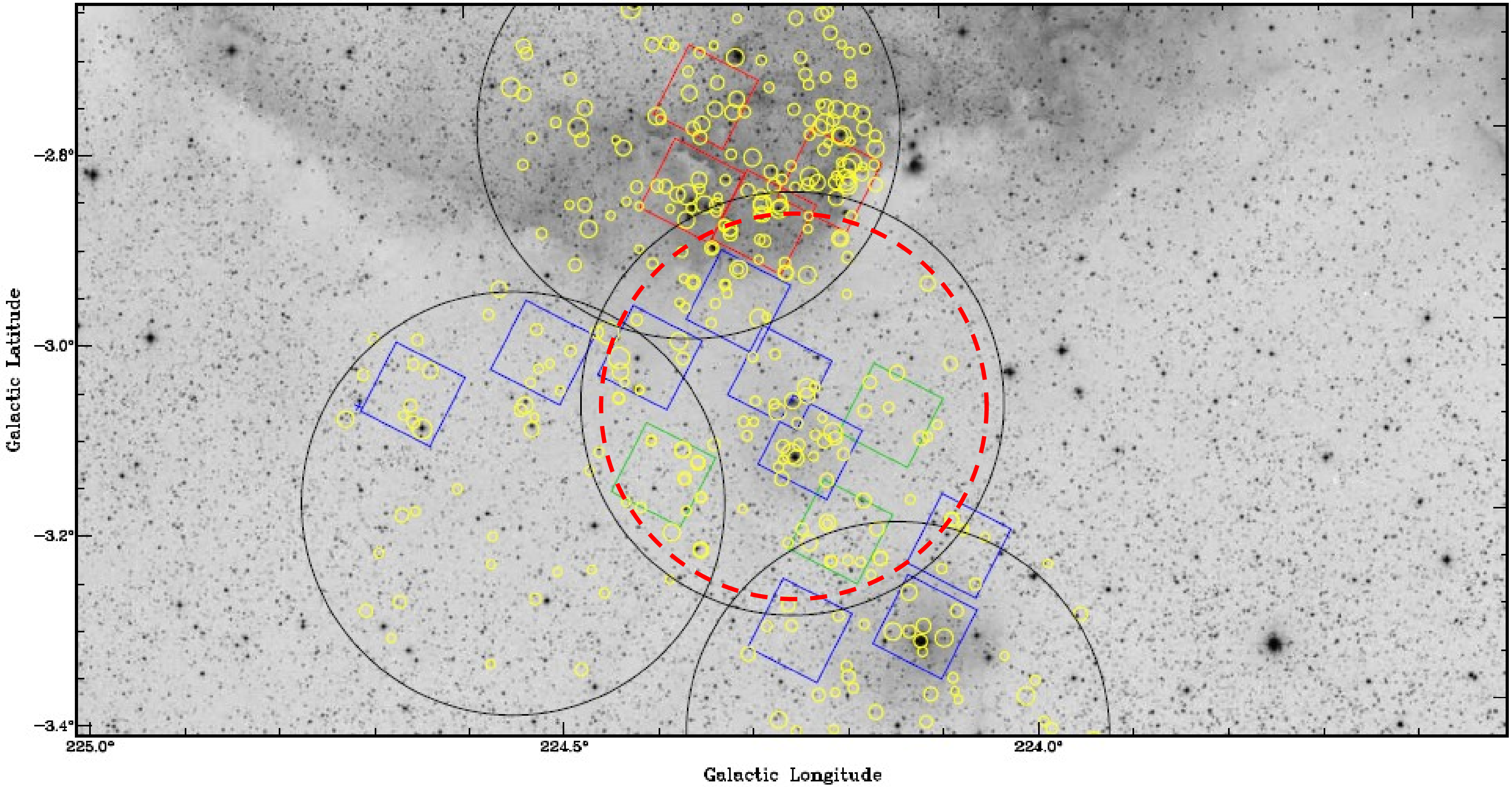


Fig. 5. *Upper panel*: [Na/Fe] ratio as a function of [O/Fe] for red giant stars in NGC 6752 from the present study. Upper limits in [O/Fe] are indicated as blue arrows. The error bars take into account the uncertainties in atmospheric parameters and *EWs*. *Lower panel*: literature data from several study (see text) superimposed to our results. Filled and open large circles are subgiant and turnoff stars from Gratton et al. (2001) and Carretta et al. (2004). Filled squares are RGB stars from Gratton et al. (2005). Diamonds with crosses inside are RGB stars from Yong et al. (2003, 2005). Open triangles are giants from Norris & Da Costa (1995) and Carretta (1994).

Deciphering the star-formation scenario of the Sh2-296 nebula. Profa. Jane + Beatriz Fernandes



The Gemini GMOS fields (squares): Blue squares are used to indicate the new proposed observations, while green squares correspond to the fields for which the masks are ready. The red squares represent the fields where spectra have been previously acquired.

BLACK CIRCLES: XXM fields (X-ray). CIRCLES: VLT/FLAMES field

The future for multi-object fiber spectroscopy at ESO: 4MOST (4m VISTA/ESO telescope with FOV of 4 degrees & 2436 fibers)

Most of the 4MOST science time will be devoted to Community surveys, but PI science possible. A distinctive advantage of 4MOST lies in the capability to carry out many different science programs in parallel → small programs possible

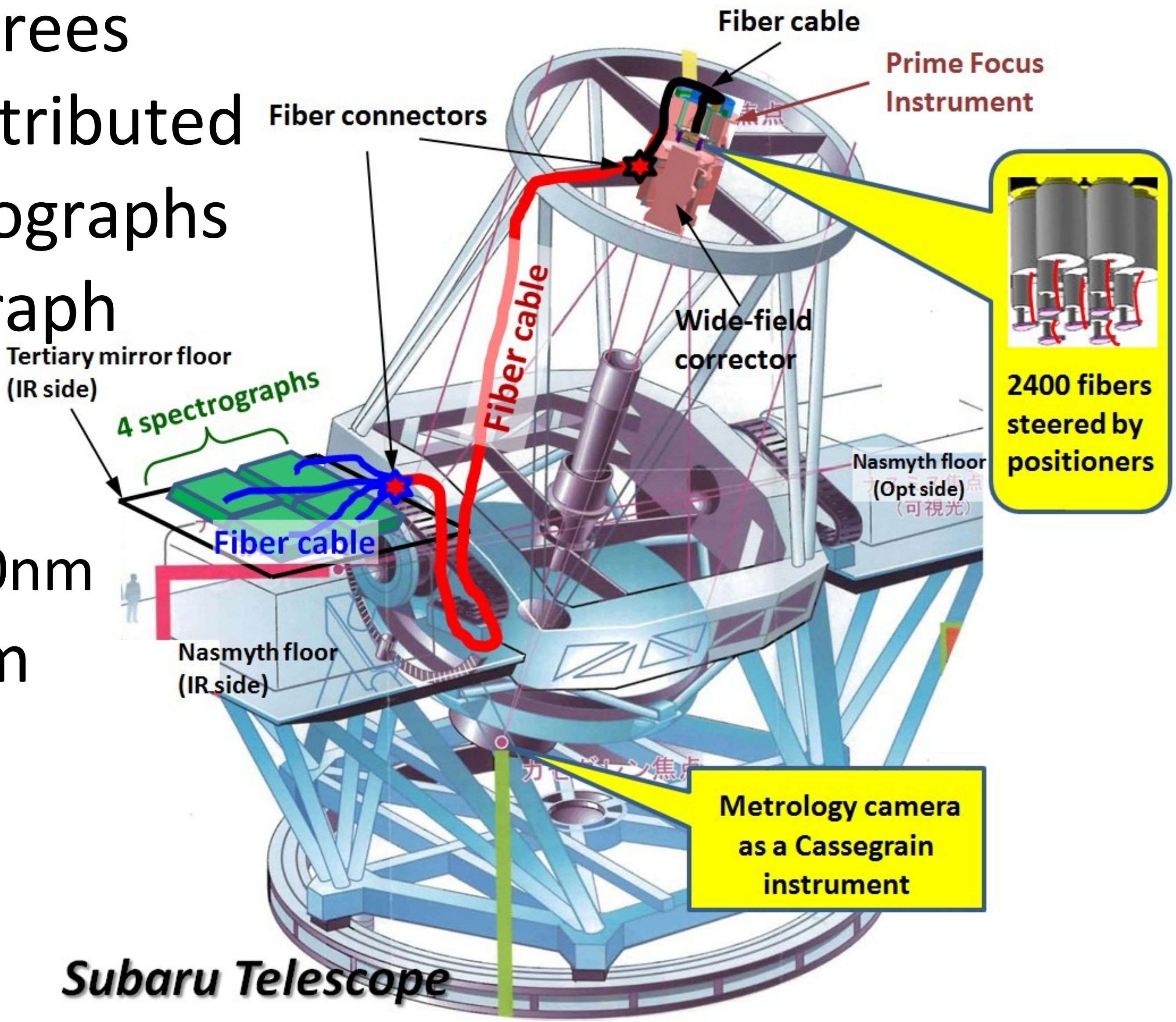
Baseline Specification

Requirement	**Baseline Specification**
Field-of-View in hexagon	4.1 $degree^2$
Fibre multiplex per pointing	2436
Smallest target separation	<17″
Low-Resolution Spectrographs (LRS)	
Fibre multiplex	1624
Spectral resolution	R>4000–7800
Wavelength coverage	370–950 nm
High-Resolution Spectrographs (HRS)	
Fibre multiplex	812
Spectral resolution	R>18,500
Wavelength coverage	392.6–435.5, 516–573 & 610–679 nm

Multi-object fiber spectroscopy in the North.

Prime Focus Spectrograph at 8m Subaru:

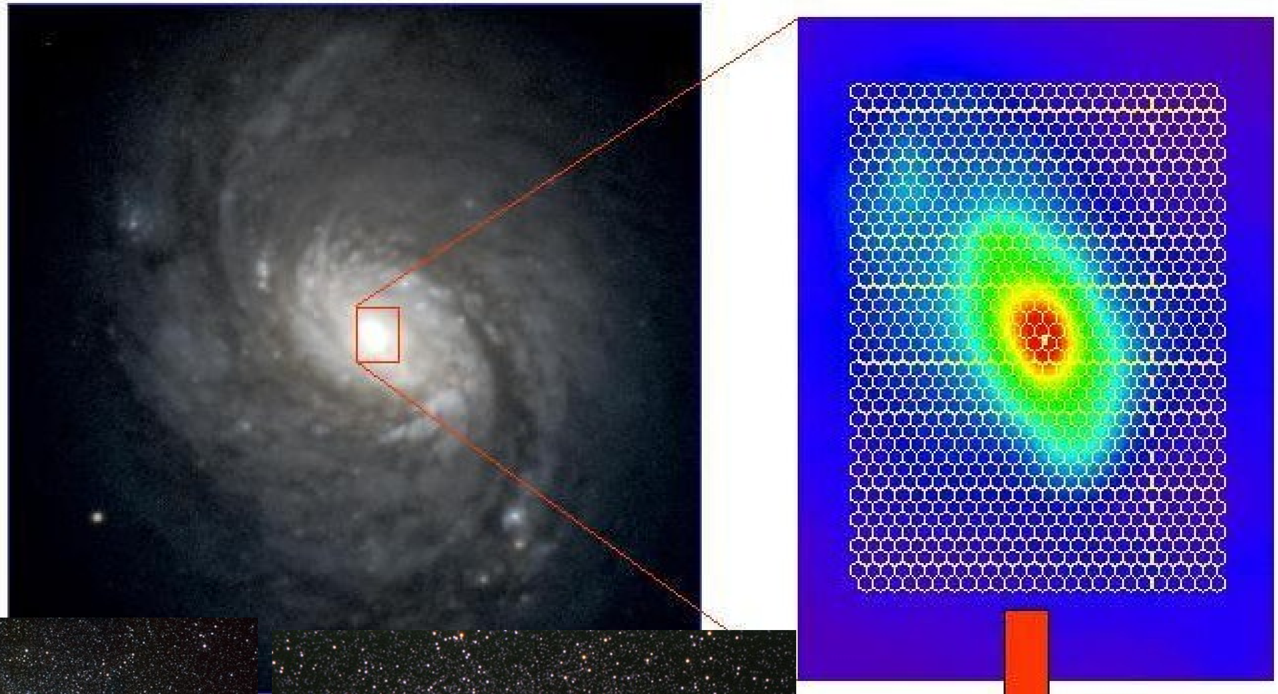
- FOV of 1.3 degrees
- 2400 fibers distributed among 4 spectrographs
- Each spectrograph has 3 channels (blue, red, NIR) covering 380-1260nm
- Low or medium resolution



Multi-object spectroscopy : which one?

IFU ? Longslit ? Multislit? Multifiber?

Image taken by GMOS without using the IFU



The GMOS IFU records a spectrum for each pixel

GMOS IFU Field of view 5"x7"

Aglomerados Omega Cen (left) e 47 Tuc (right) são aprox. do tamanho angular da Lua cheia