AGA5802

High resolution spectroscopy: echelle

- Echelle spectrographs
- *Applications*

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

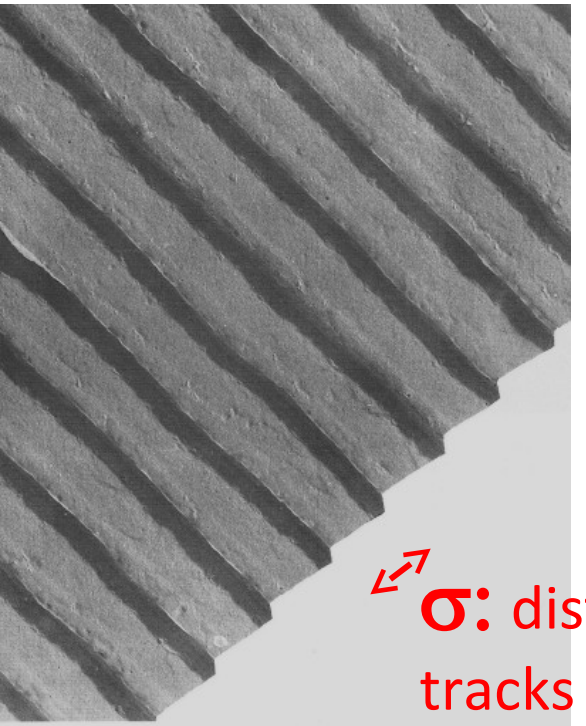
Prof. Jorge Meléndez

How to achieve a high spectral resolution (high dispersion) using a grating

$$\frac{d\theta}{d\lambda} = \frac{m}{\sigma \cos\theta}$$

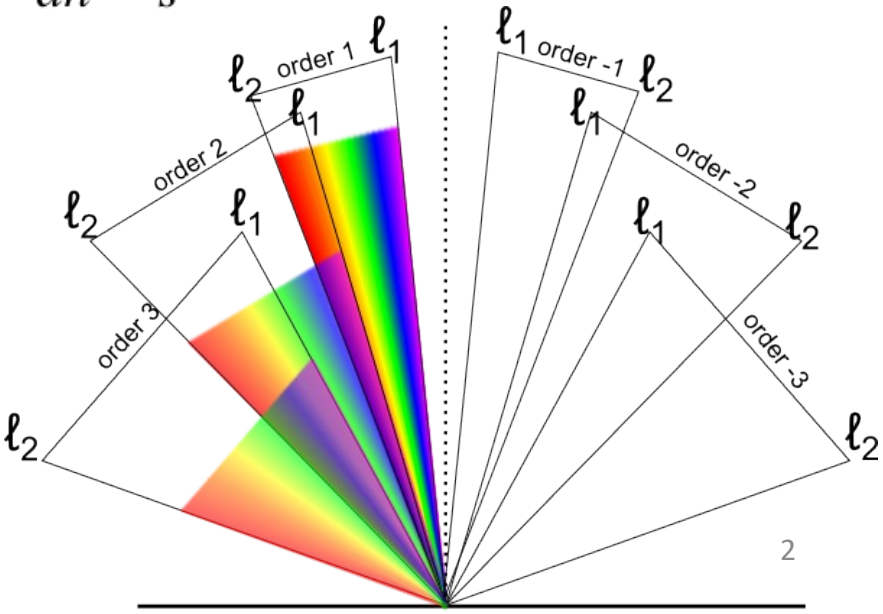
1. Use a grating of higher resolution (>> 1000 lines/mm) or increase f_{COL}
2. Work at high order m → echelle

$$R = \frac{\lambda}{d\lambda} = \frac{\lambda f_{COL}}{r_{an} w_s} \frac{d\theta}{d\lambda}$$



This microscopic picture shows the rulings on a plane reflection grating having 1180 lines/mm. (Courtesy of Jarrell-Ash.)

σ: distance between tracks of the grating



High resolution 1: grating with many lines/mm + increase f_{COL}

σ: distance between tracks of the grating

$$\frac{d\theta}{d\lambda} = \frac{m}{\sigma \cos\theta}$$

$$R = \frac{\lambda}{d\lambda} = \frac{\lambda f_{COL}}{r_{an} w_s} \frac{d\theta}{d\lambda}$$

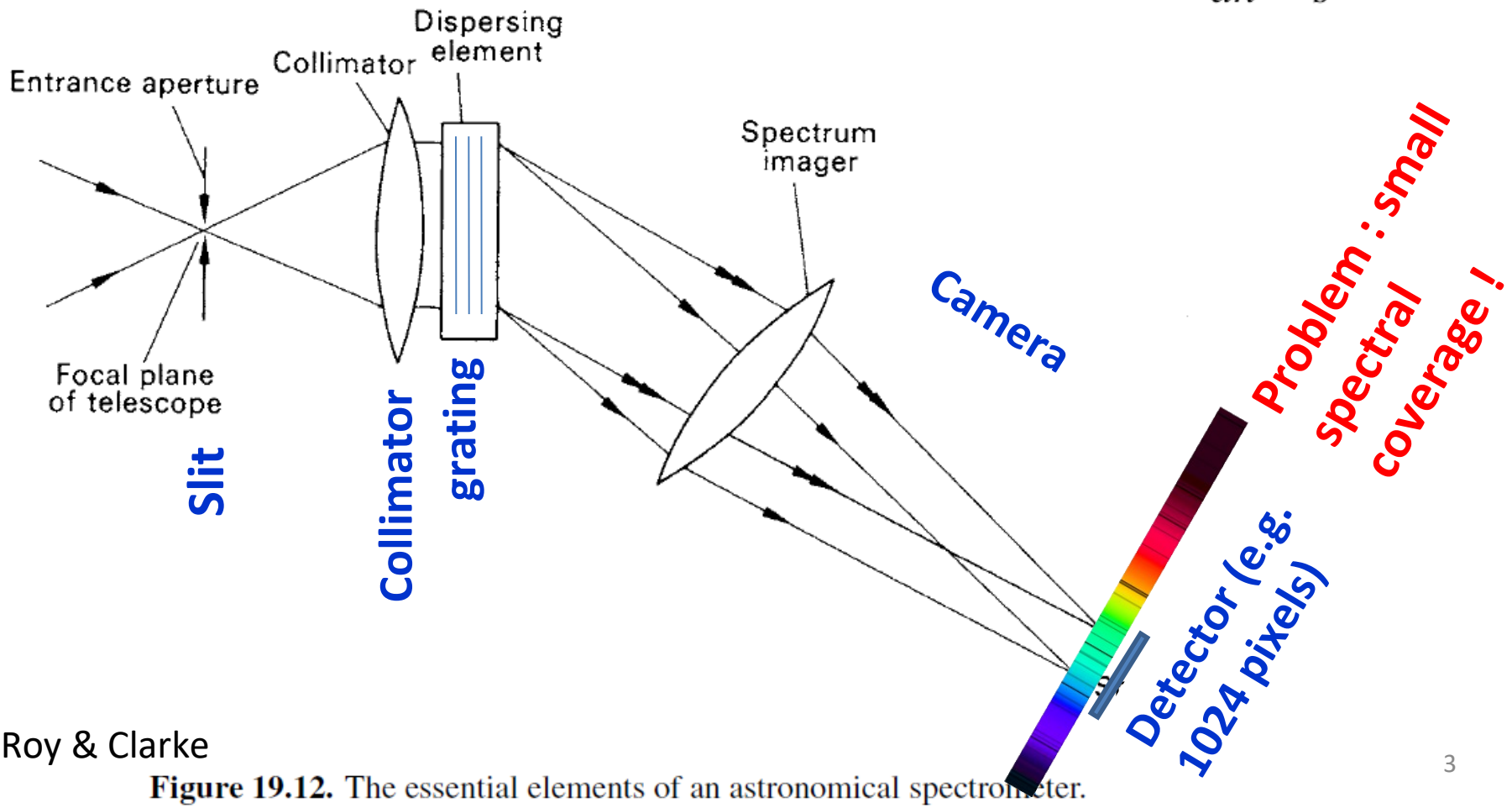


Figure 19.12. The essential elements of an astronomical spectrometer.

High resolution 1: grating with many lines/mm + increase f_{COL}

$$\frac{d\theta}{d\lambda} = \frac{m}{\sigma \cos\theta}$$

Exemplo: espectrógrafo Coudé OPD (LNA)

$$R = \frac{\lambda}{d\lambda} = \frac{\lambda f_{COL}}{r_{an} w_s} \frac{d\theta}{d\lambda}$$

	Rede 1/mm – λ_c(nm)	CCD	Cobertura (nm)	Å	Dispersão (nm/pixel)	Resolução (FWHM, Å)	R (600nm)
1ª. ORDEM DIRETA	0600 - 650	098	113,0	1130	0,025	0,50	12 000
	1800 - 650	098	35,3	353	0,008	0,20	30 000
1ª. ORDEM INVERSA	0600 - 650	098	99,7	997	0,022	0,22	27 000
	1800 - 650	098	22,1	221	0,005	0,12	50 000
2ª. ORDEM DIRETA	0600 - 650	098	56,3	563	0,012	0,24	25 000
4ª. ORDEM INVERSA	0600 - 650	098	9,1	91	0,002	0,06	120 000

Comparison : Echelle HIRES coverage 4000Å or 40 times

Many works have been published by Brazilian astronomers using the Coudé spectrograph at the 1,6 meter telescope at OPD

THE ASTROPHYSICAL JOURNAL, 482:L89–L92, 1997 June 10

HR 6060: THE CLOSEST EVER SOLAR TWIN?[1]

G. F. PORTO DE MELLO[2,3] AND L. DA SILVA[3]
Received 1996 November 22; accepted 1997 March 17

A&A 563, A52 (2014)
DOI: 10.1051/0004-6361/201322277

Astronomy & Astrophysics

A photometric and spectroscopic survey of solar twin stars within 50 parsecs of the Sun

I. Atmospheric parameters and color similarity to the Sun⋆

G. F. Porto de Mello[1], R. da Silva[1,⋆⋆], L. da Silva[2], and R. V. de Nader[1,⋆⋆⋆]

[1] Universidade Federal do Rio de Janeiro, Observatório do Valongo, Ladeira do Pedro Antonio 43, CEP: 20080-090 Rio de Janeiro,

High resolution 2: echelle spectrograph, but single order

Installation and First Results of the Coudé Echelle Spectrometer

Daniel Enard, ESO

~ anos 1980 - 2000

Introduction

The Coudé Echelle Spectrometer was installed in the 3.6-m

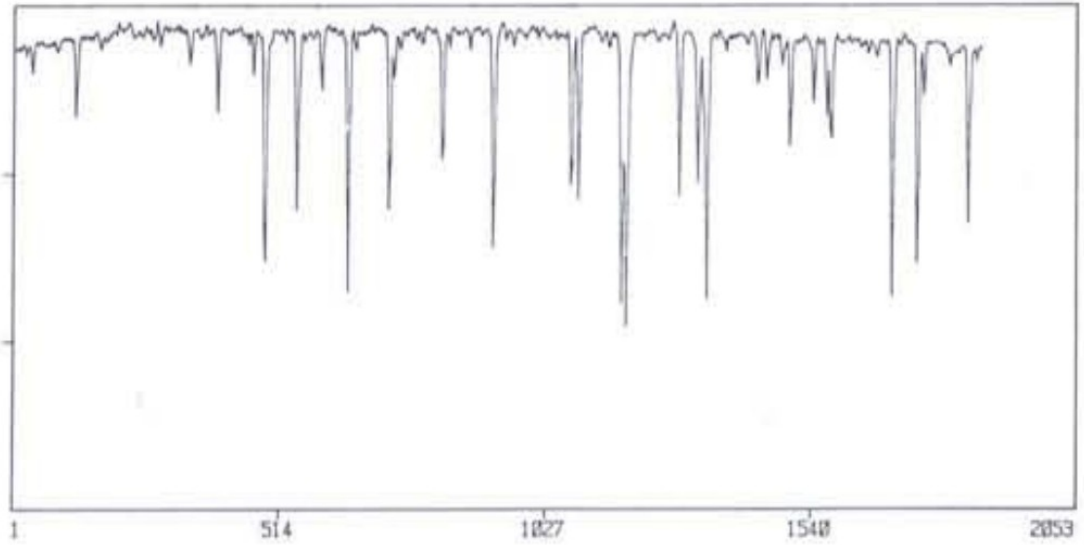


Fig. 4: *Spectrum of Nu Indus at 5135 Å. The spectrum covers 42 Å (5114–5156 Å) and a signal-to-noise ratio of 120 is obtained on this 5.2 magnitude star after 30 minutes at a resolution of 60 mÅ.*

Table 1. – CES CHARACTERISTICS

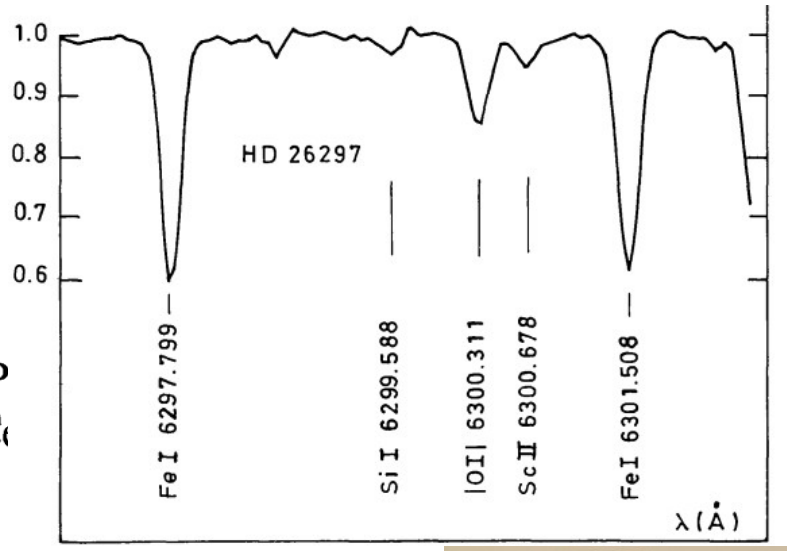
- *Resolving power: optimal 100,000 (FWHM of instru*
- *Spectral range: 3600–11000 Å*
- *2 separate optical paths optimized for:*
  - Blue $3600 < \lambda < 5500$
  - Red $5000 < \lambda < 11000$
- Detector – Reticon RL 1872 F
  - CCD or photon counting device (not yet determined)
- Dispersive element: – 200 × 400 mm echelle grating; 79 grooves/mm, blazed at 63°26'
- Order separation achieved with a prism monochromator

Astron. Astrophys. 191, 121–127 (1988)

Oxygen in 20 halo giants ⋆

B. Barbuy [1,2]

[1] Universidade de Sao Paulo, Depto de Astronomia, C.P
[2] Observatoire de Paris-Meudon, F-92195 Meudon Pl C



Summary. The |O I| λ6300.311 Å line was observed in 20 halo giants, using a CCD detector. Synthetic spectra are computed to obtain the oxygen abundance, where allowance is made for CO association.

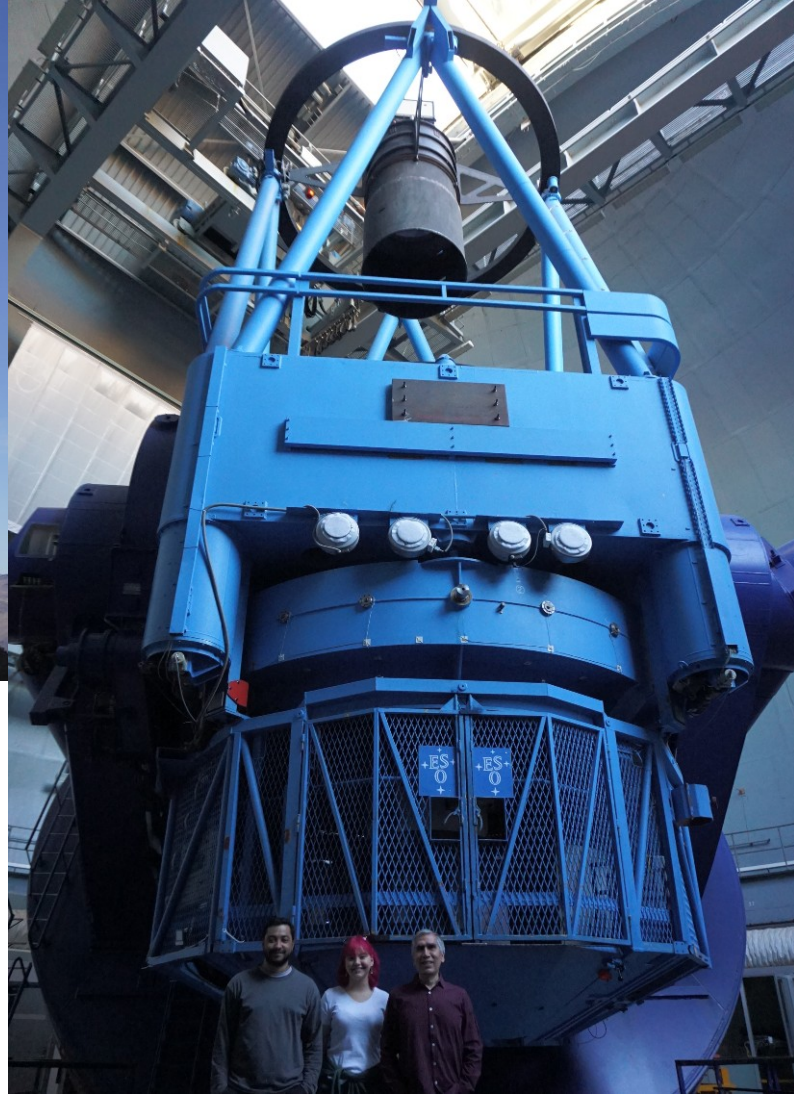
It is found that oxygen is overabundant relative to iron in the halo stars, confirming previous investigations. A mean value of $[O/Fe] \simeq +0.35 \pm 0.15$ is obtained in this work.

The data were collected at the 1.4 m Coudé Auxiliary Telescope (CAT) telescope at the European Southern Observatory (ESO) at La Silla, Chile, using the Coudé Echelle Spectrometer (CES) and a (RCA 1024 × 512 elements) CCD as detector. A resolution of 40000 to 70000 or $\Delta\lambda = 0.12$ to 0.07 Å was achieved.

Spectra obtained have a coverage of 40 Å centered at λ 6310 Å.

Beatriz Barbuy (IAG-USP). Among world most influential scientists. No. 1 "Best Physics Scientist in Brazil". IAU Symposium 395 (nov 2024, litoral norte SP) in her honor

The CES spectrograph was used both at the 3.6m and (mainly) the 1.4m (Coudé Auxiliary Telescope)



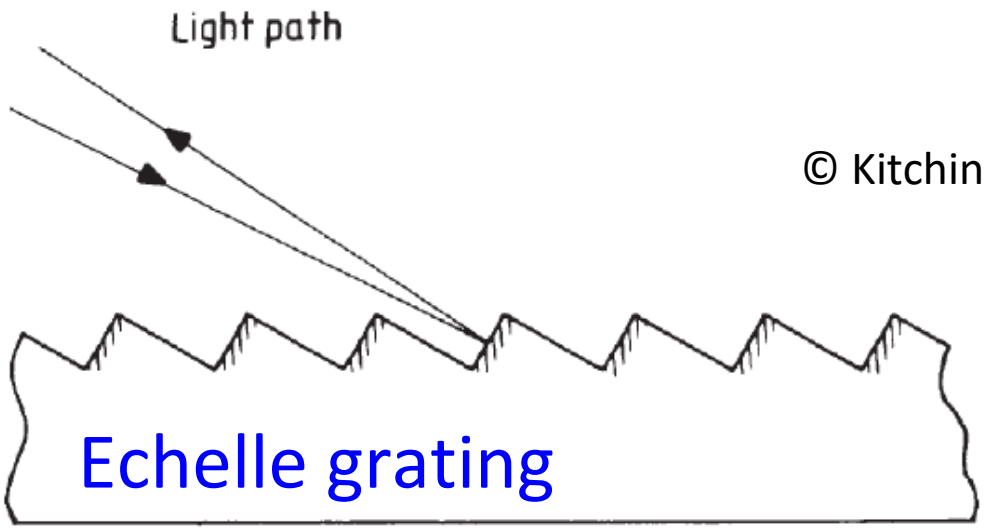
Thiago, Anne & Jorge at the 3.6m telescope at La Silla, during the May 2023 observing run to hunt exoplanets around solar twins

Since 2003, the HARPS spectrograph is used at the 3.6m

High resolution 2: echelle spectrograph with multiple orders

$$\frac{d\theta}{d\lambda} = \frac{m}{\sigma \cos\theta}$$

σ: distance between tracks of the grating

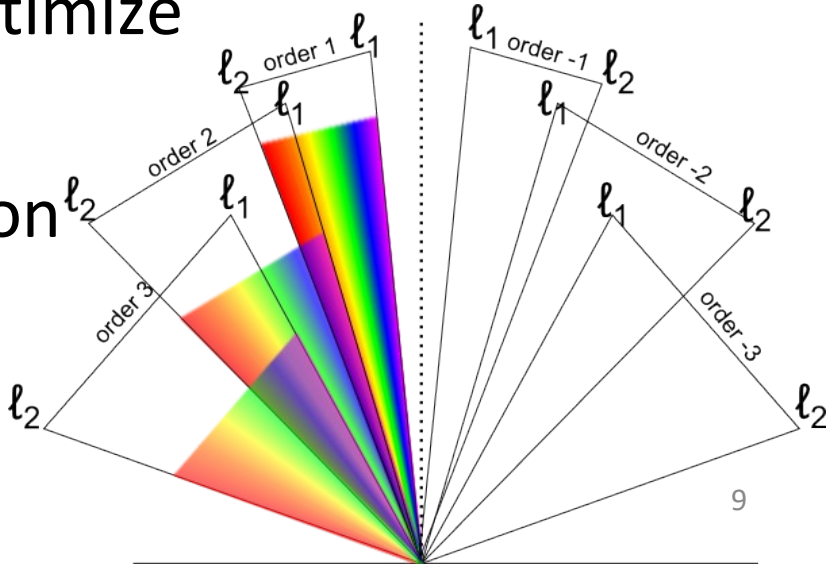


© Kitchin

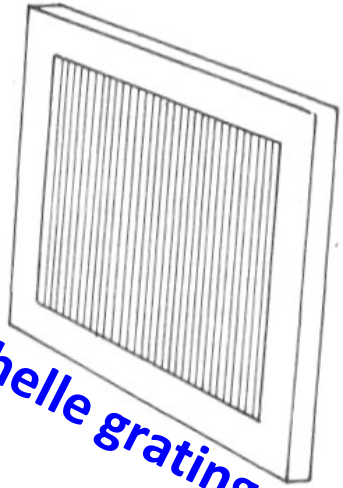
Figure 4.1.7. Enlarged view of an echelle grating.

- Blazing angle is increased to optimize the observation of high orders

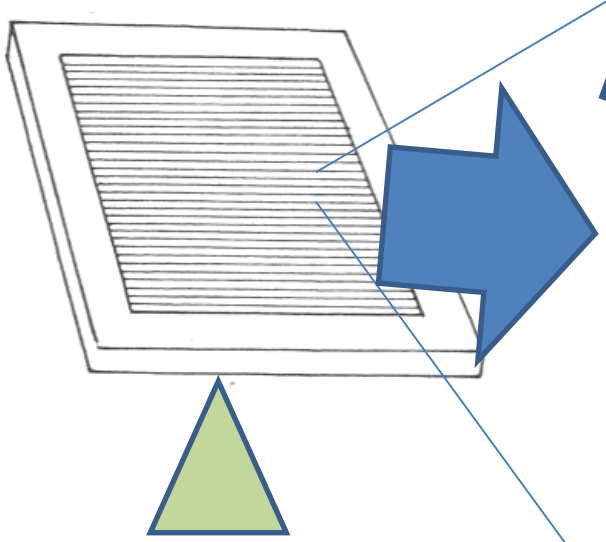
  (m ~ 30-150) → better resolution
- Typical grating 31 lines/mm
- Problem: order overlapping?



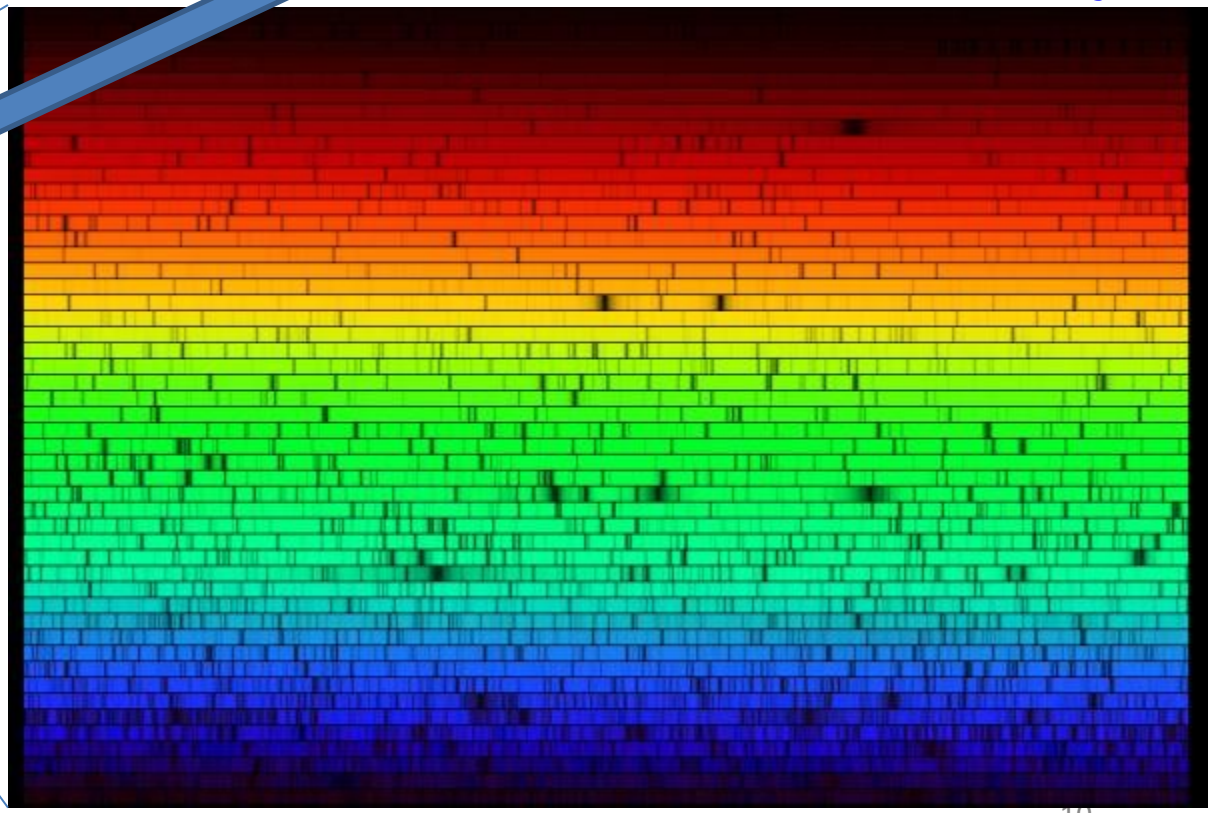
Solution for mixing of the orders: **cross disperser** (prism or grating) and use of large CCDs to fit different orders



Echelle grating



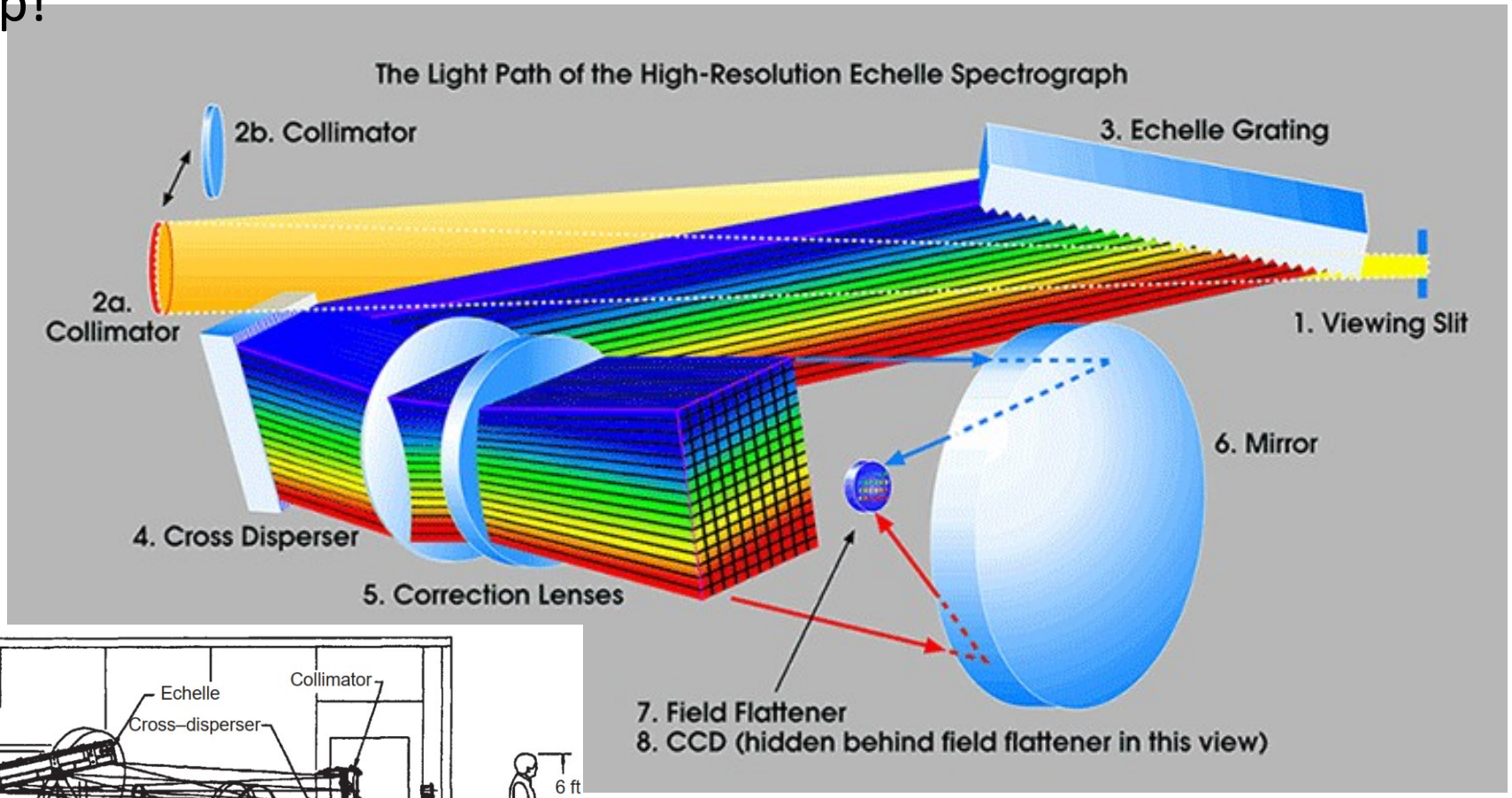
cross disperser
(grating or prism)

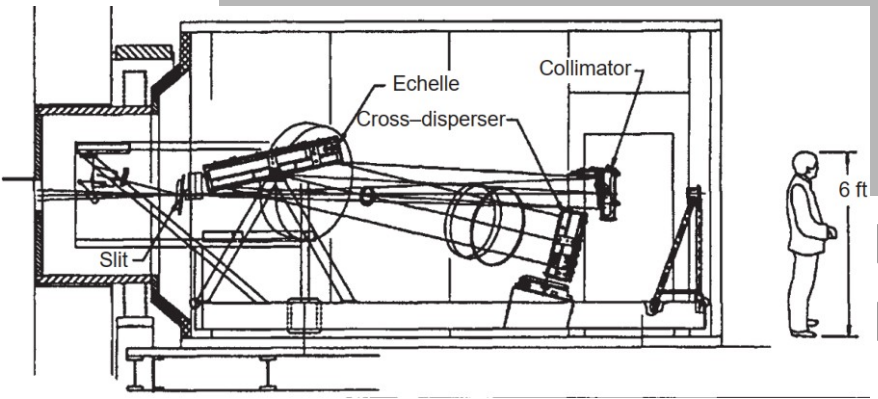


CCD

Example : HIRES spectrograph at KECK

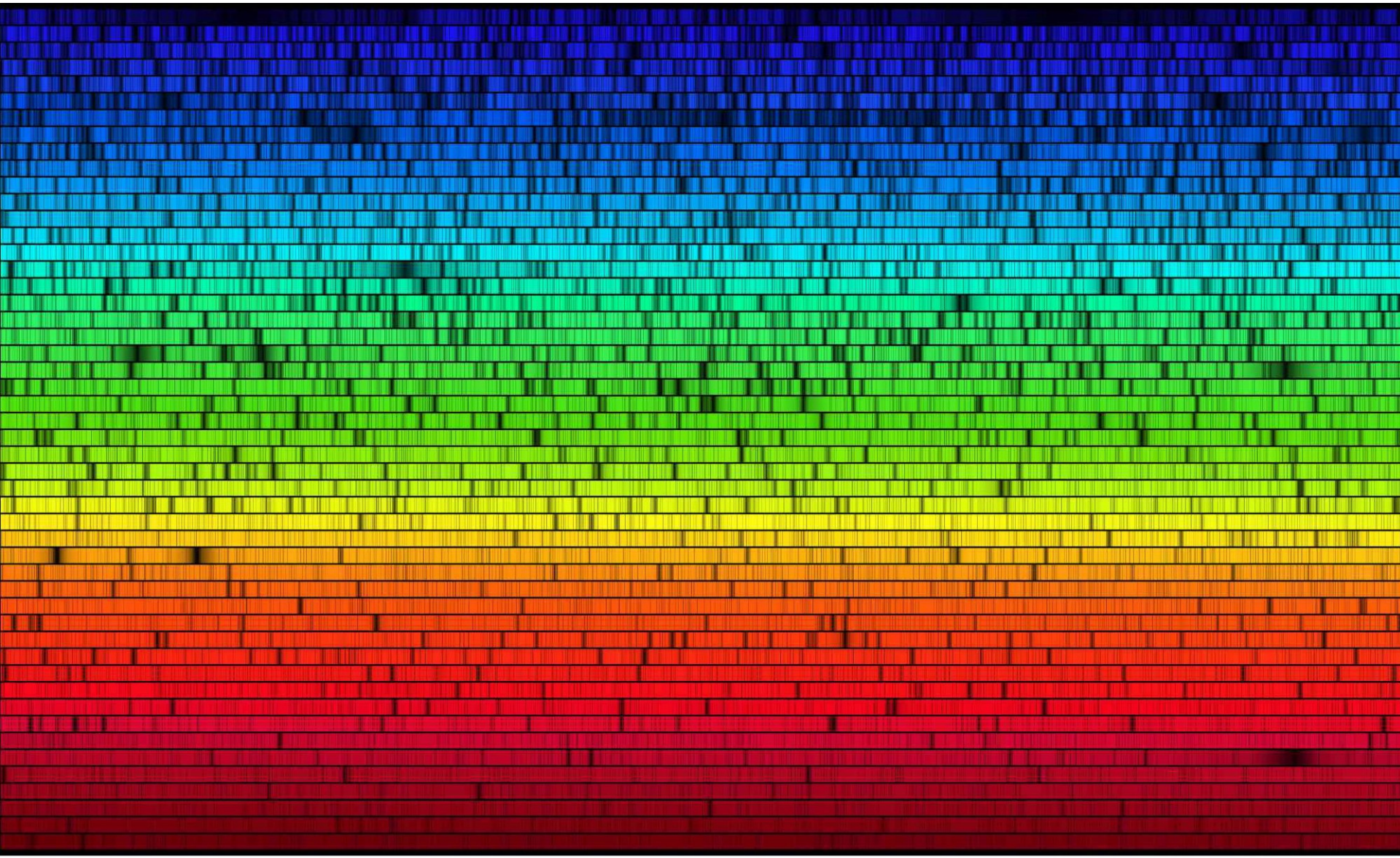
Cross dispersing is with a second grating. This disperses more than a prism, allowing better sky subtraction, but problem with order overlap!



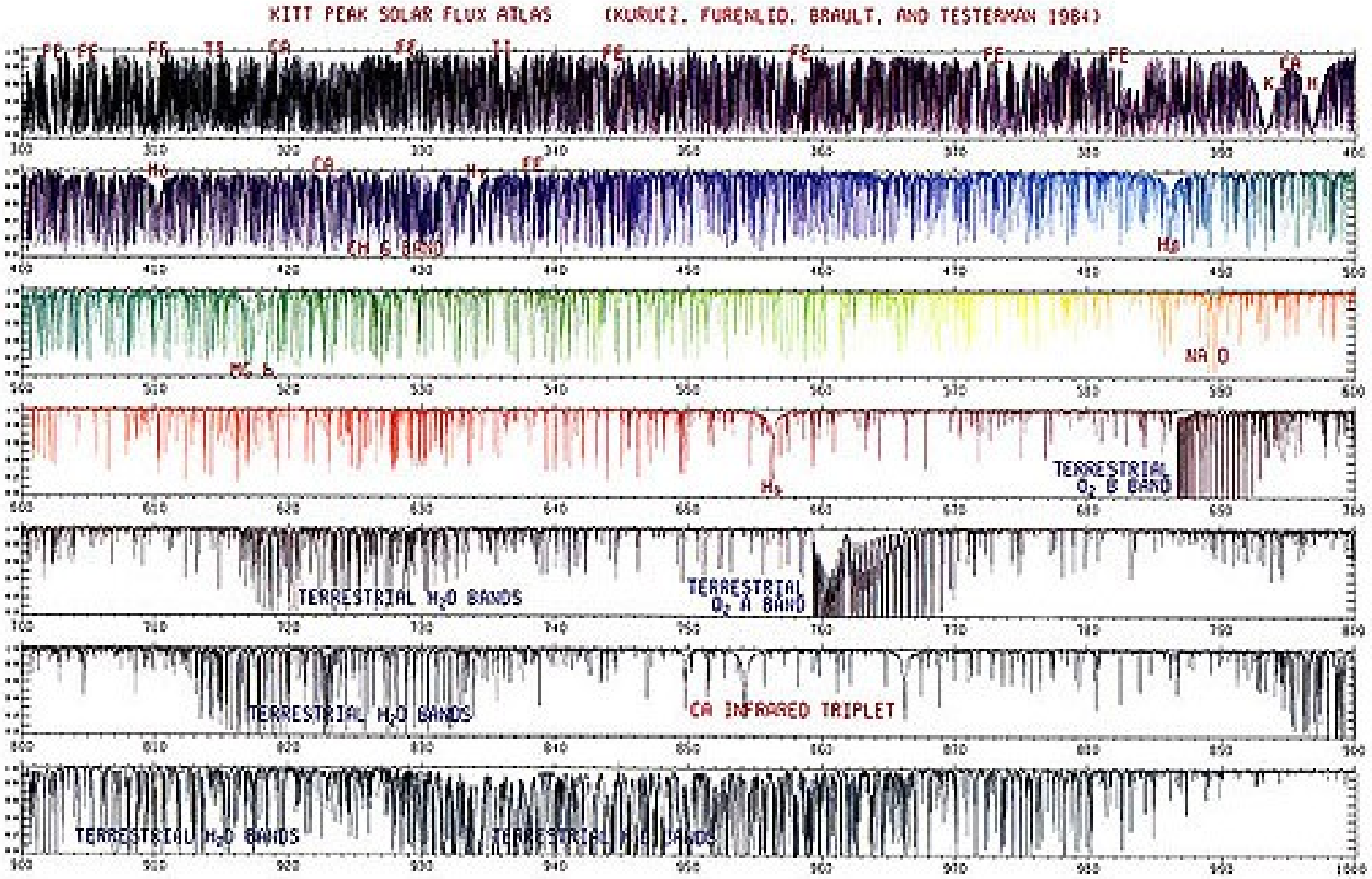


Large instrument, located at Keck's Nasmyth focus. First light 1993

Echelle orders

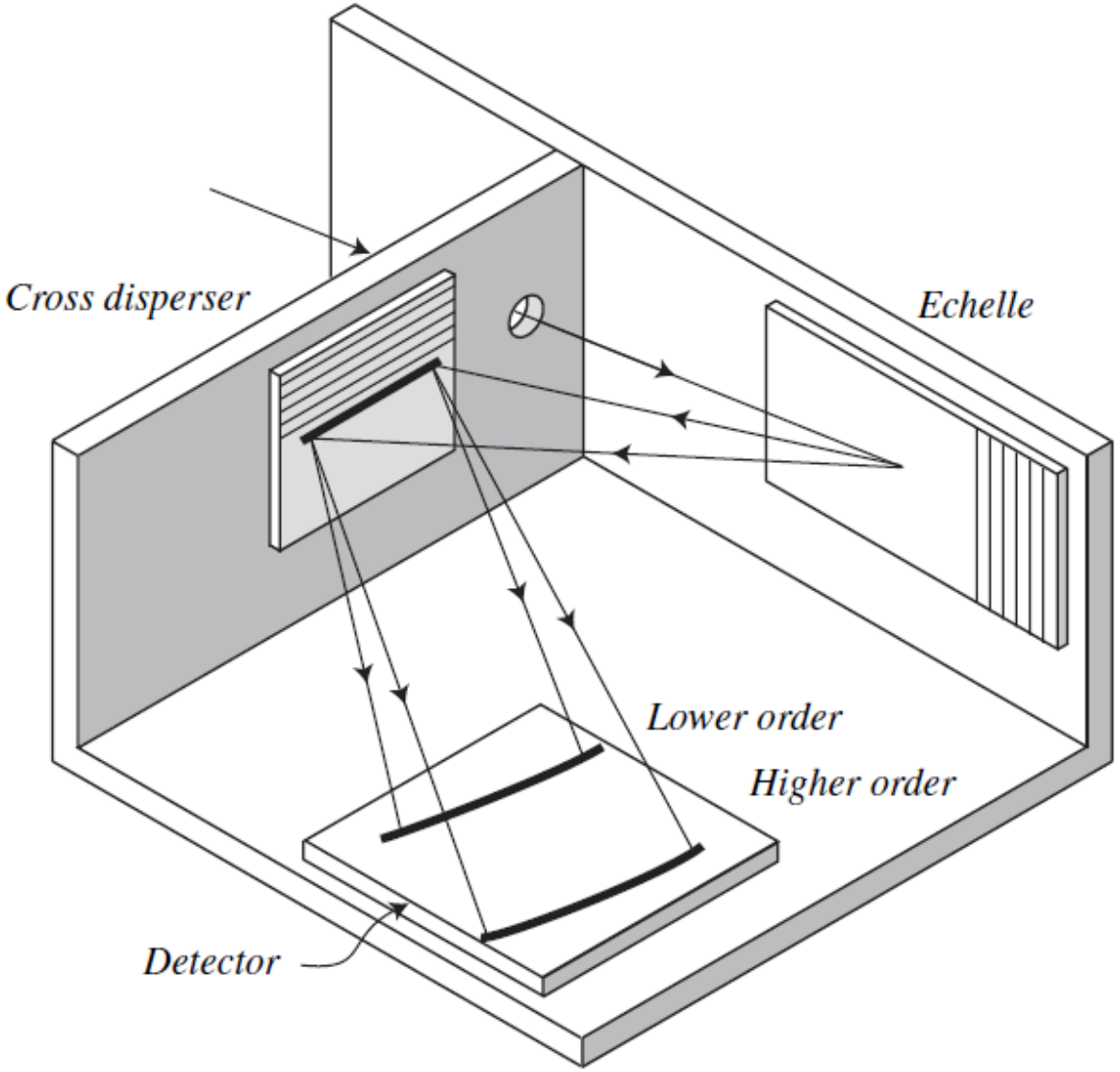


Echelle orders : extracted



Echelle spectrographs

Cross-disperser: can we use a prism instead of a grating?



Astron. Astrophys. 259, 711–719 (1992)

ASTRONOMY AND ASTROPHYSICS

MUSICOS: a fiber-fed spectrograph for multi-site observations*

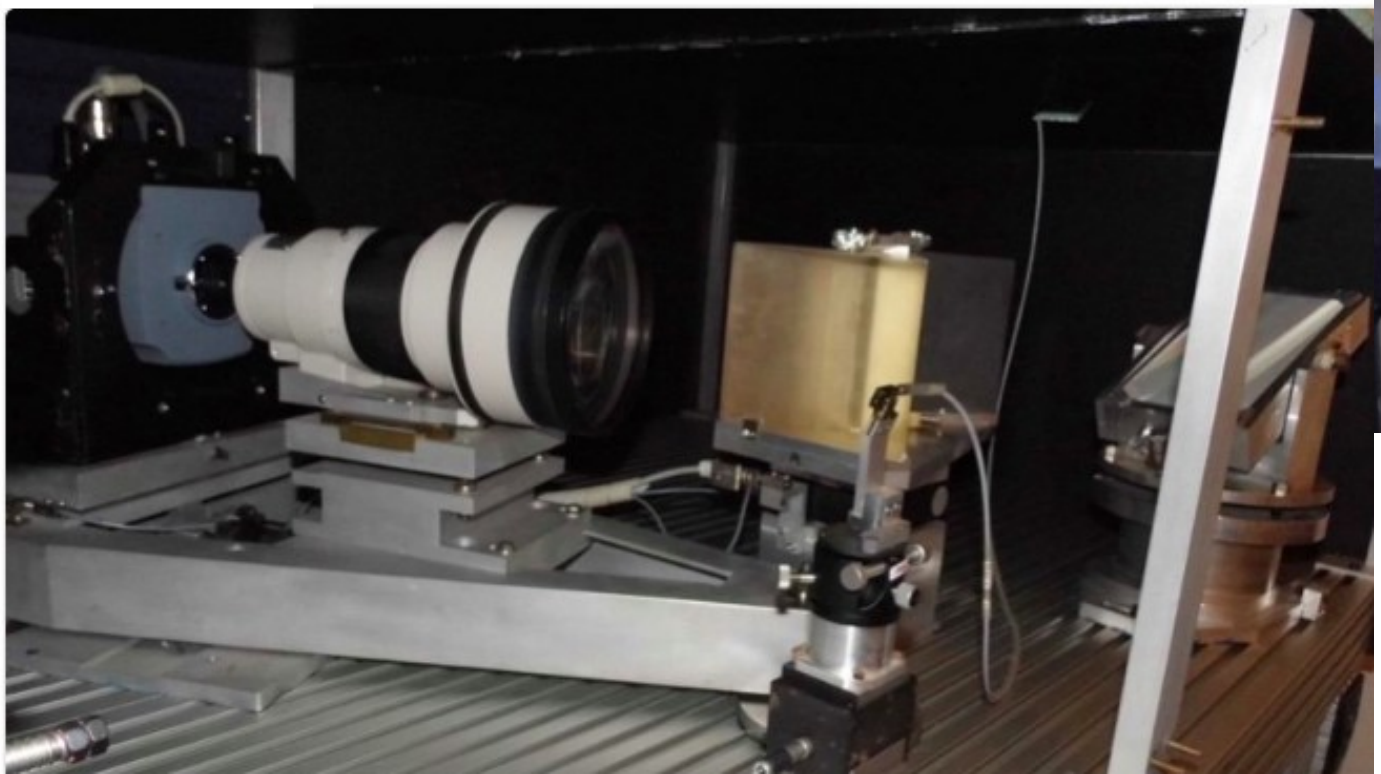
J. Baudrand and T. Böhm

Lorenzo Spina @lorenzospina · 13 h
Perkin-Elmer Telescope, happy to see you again!

2017-05-03

Lorenzo Spina @lorenzospina · 13 h
The prisms of the MUSICOS spectrograph at the OPD/LNA

2017-05-03



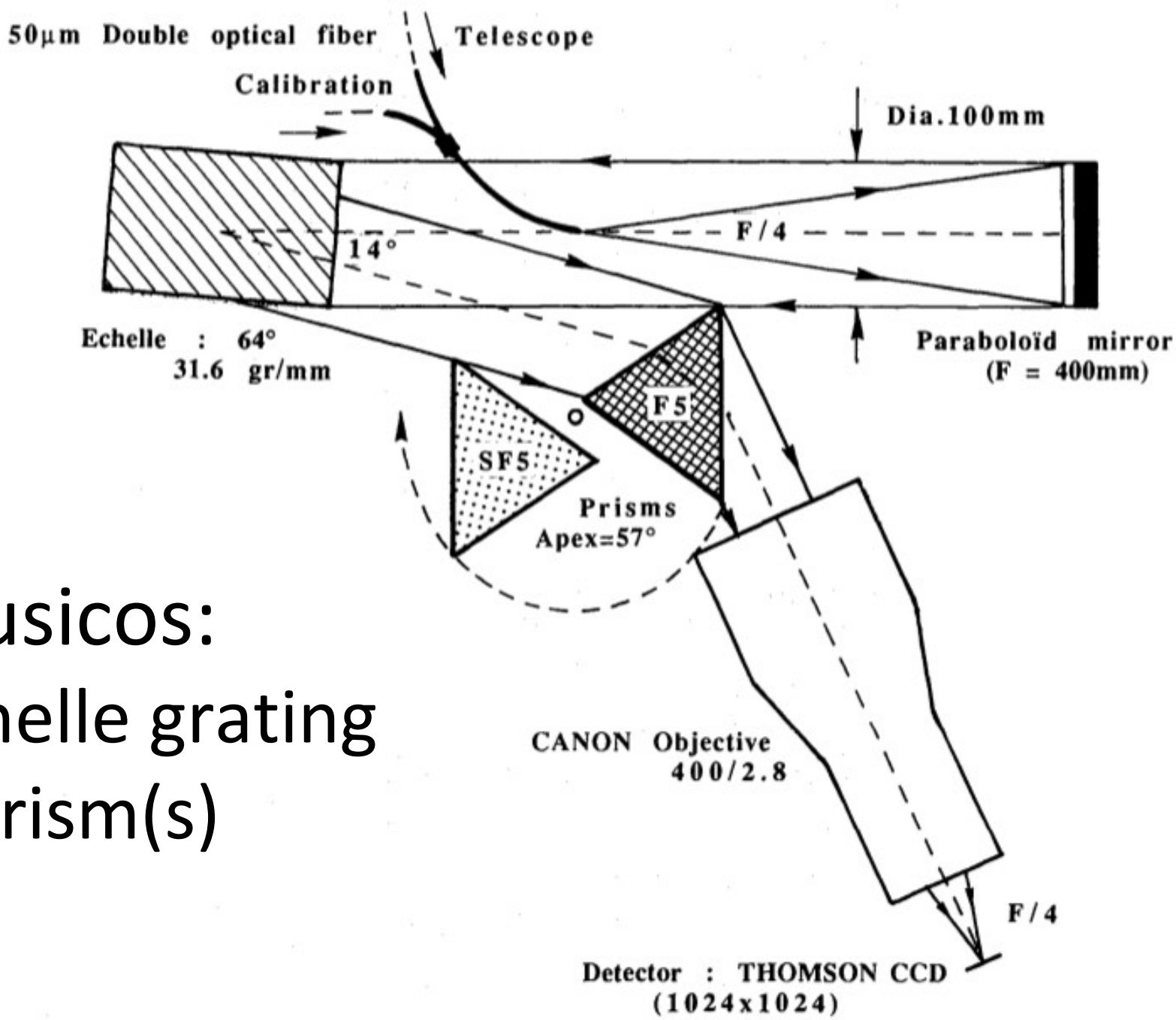


Fig. 1. Optical layout

Musicos:
echelle grating
+ prism(s)

MUSICOS at Pic de Château-Renard

http://www.astrosurf.com/thizy/musicos/musicos.htm

MUSICOS: blue setup

MUSICOS: red setup

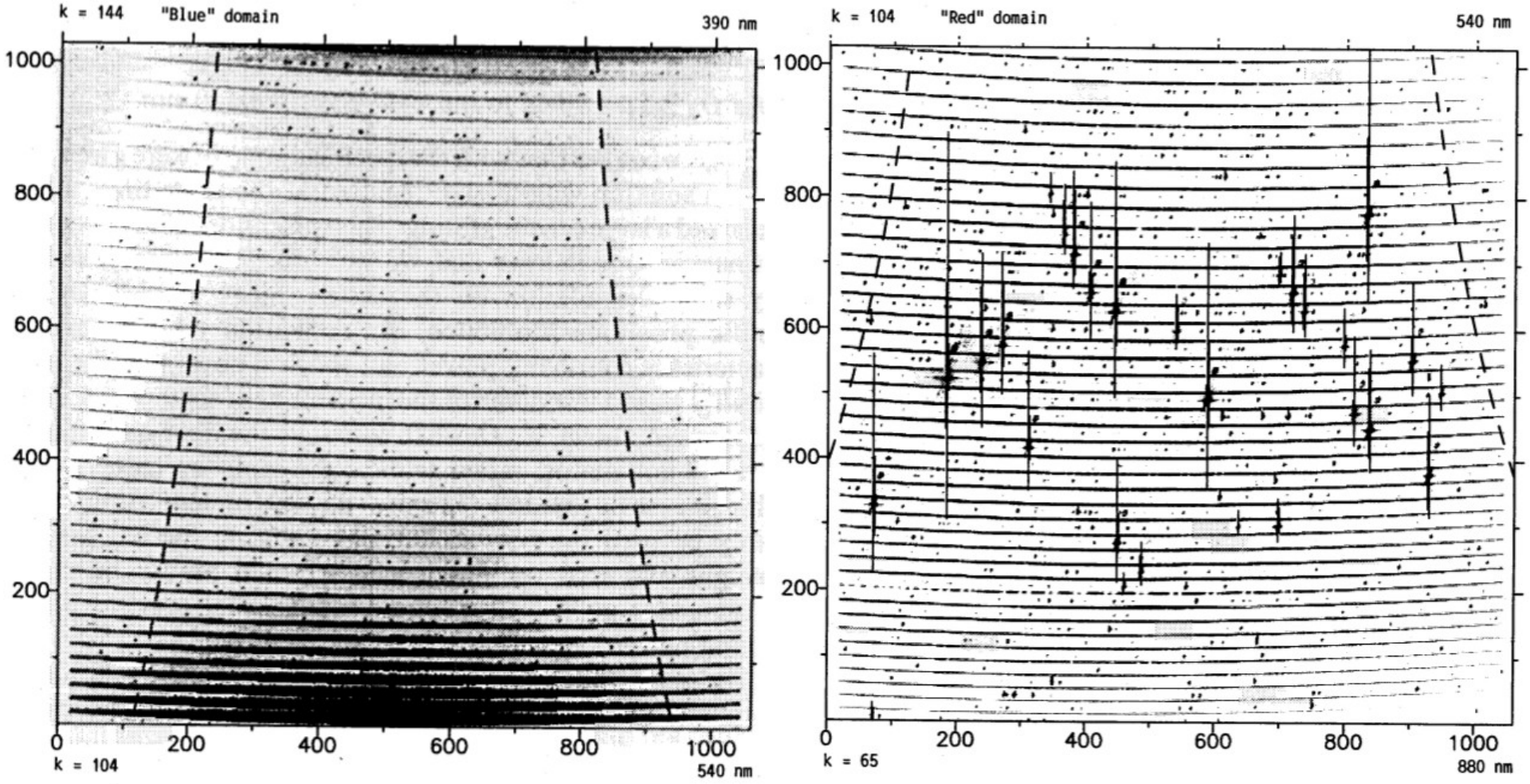


Fig. 3. Echellograms. Typical "blue" and "red" exposures on a THOMSON CCD 1024 × 1024, with two interleaved spectra: a continuum from a tungsten lamp and a wavelength calibration spectrum from a Th/Ne lamp (the free spectral range is represented by the dashed lines)

Espectrógrafo MUSICOS

http://www.lna.br/opd/instrum/musicos.html

O MUSICOS é um espectrógrafo Echelle alimentado por fibra óptica e resolução R=35.000. Está em operação no telescópio P&E de 1,60m do Observatório do Pico dos Dias e foi doado pelo Observatoire du Pic du Midi.

O espectrógrafo foi oferecido pela primeira vez para o período 2012A, ainda no modo de risco compartilhado pois seu comissionamento científico ainda não se encontrava completo.

Abaixo algumas informações para orientar o usuário em sua proposta de tempo e observações. Mais informações podem ser obtidas junto a equipe técnica do OPD (rodrigo-at-lna.br).

O MUSICOS é alimentado por uma fibra óptica no foco Cassegrain do telescópio P&E de 1.60m, que corresponde a 2" arco no plano focal, o espectrógrafo cobre uma região espectral compreendida entre 3800 e 8800 Å em duas exposições: uma exposição no "azul" de 3800 a 5400 Å;, e outra no "vermelho", de 5400 a 8800 Å, em aproximadamente 100 ordens. A resolução média (R) é de 35.000. A dispersão média é de 0,05 A/pixel por volta de 6000 Å e 0,034 Å/pixel por volta de 4300 Å.

O espectrógrafo é utilizado com detector Andor iKon-L de 2k x 2k pixels de 13,5 micra.

Blue: 3800 - 5400 Å

Red: 5400 a 8800 Å

R ~ 35.000

Modern iKon-L CCD

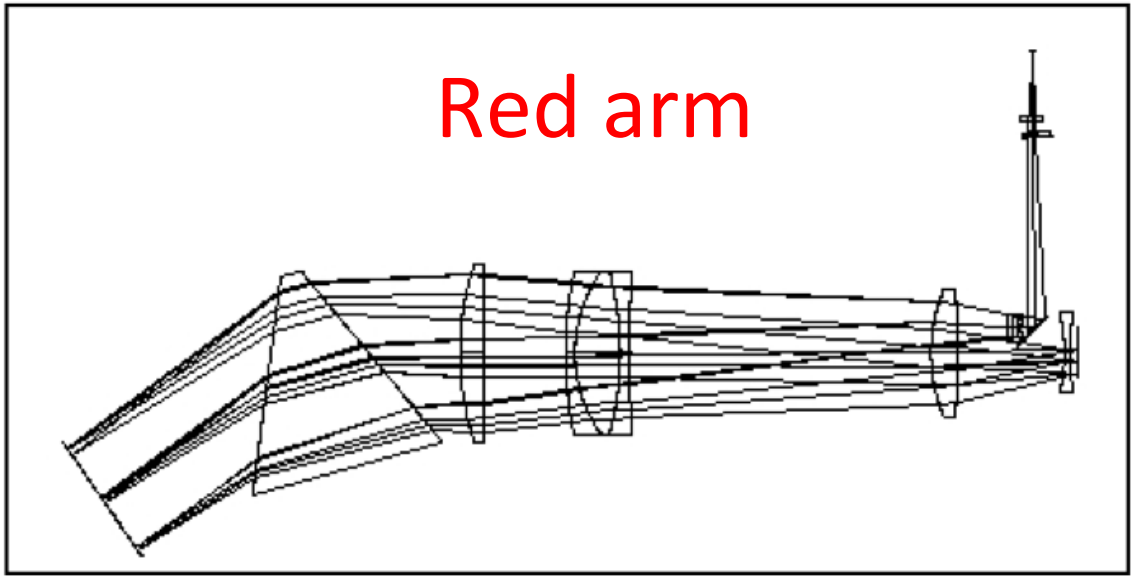
(better than the original CCD)

First original CCD

λ (nm)	S/N	CCD Q.E (%)
400	125	12
500	320	30
600	405	45
700	380	40
800	300	30

MIKE: A Double Echelle Spectrograph for the Magellan Telescopes at Las Campanas Observatory.

Rebecca A. Bernstein[a,b], Stephen A. Shectman[b], Steve Gunnels[c], Stefan Mochnacki[d], Alex Athey[a]
[a]Astronomy Department, 830 Dennison Bldg, University of Michigan, Ann Arbor, MI, 48109-1090
[b]Carnegie Observatories, 813 Santa Barbara St., Pasadena, CA, 91101



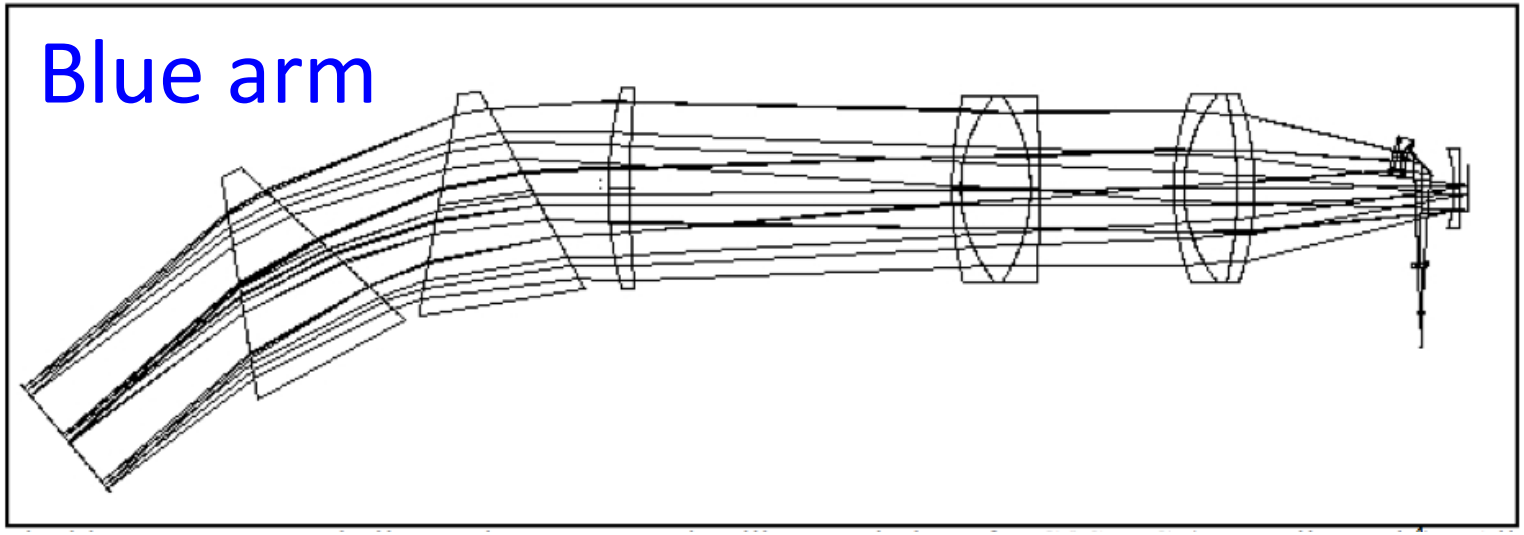


Figure 1: (top) Red optical path. Elements are as follows (from the slit): dichroic slide, field lens, flat mirror, injection triplet, camera (R5, R4/3/2, R1), prism, grating (drawn as a mirror). **(bottom) Blue optical path.** Elements are as follows (from the slit): field lens, flat mirror, injection triplet, camera (B7/6/5, B4/3/2, B1), 2 prisms, grating. The dichroic reflection is omitted from the diagram of the blue side for simplicity.

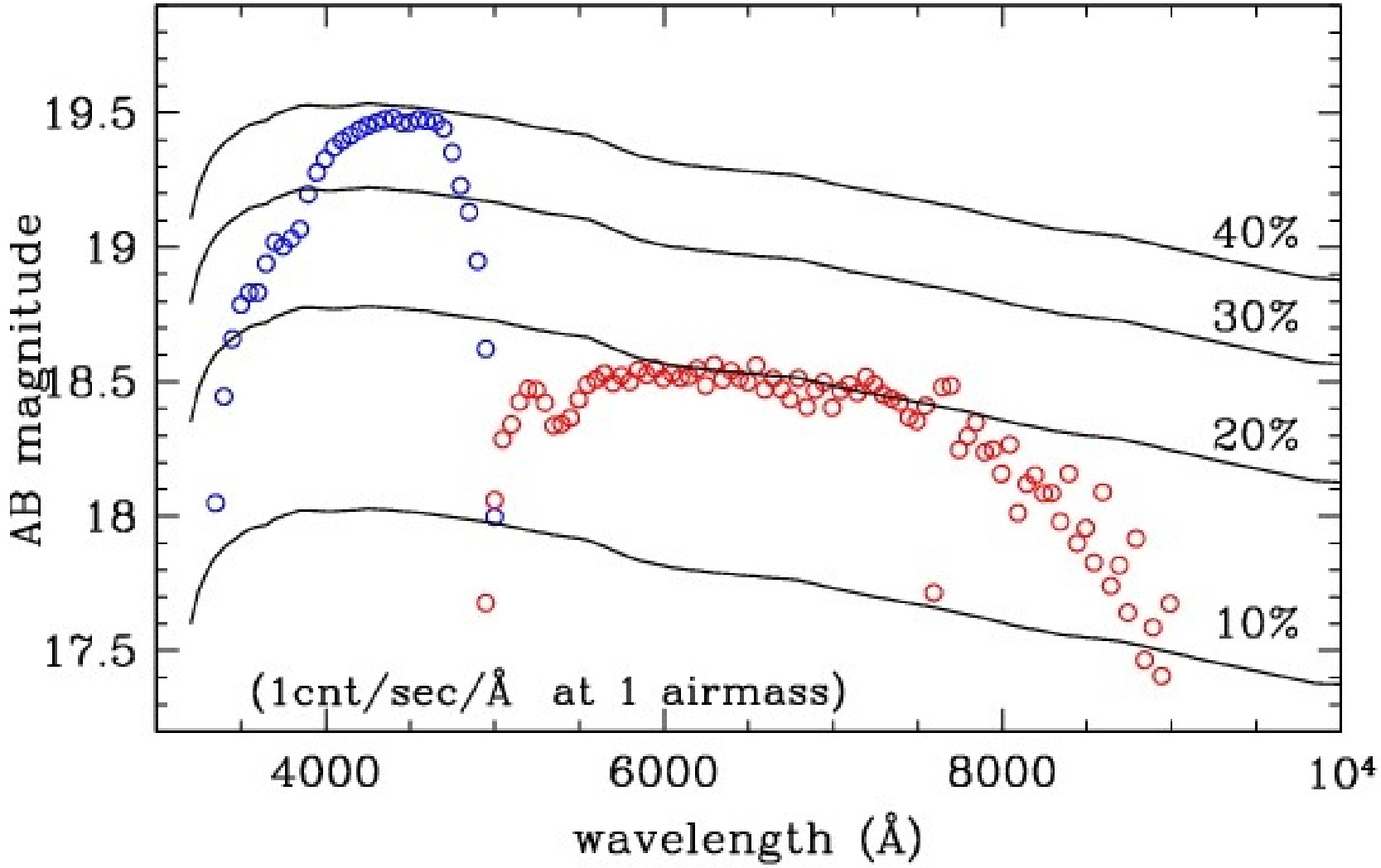
Mike Spectrograph at 6,5m Magellan (Las Campanas)

	BLUE	RED
effective focal ratio	f/3.9	f/3.6
scale at CCD	8.2 pix/" (0.12"/pix)	7.5 pix/sec (0.13"/pix)
Å/pixel (unbinned)	~0.02	~0.05
detector	2048x4096 (15µm pix)	2048x4096 (15µm pix)
gain	~0.47 e-/DN	~1.0 e-/DN
Readnoise	~2 e-/pix	~3.5e-/pix
Dark current	~5 DN/pix/hr	~2 DN/pix/hr
Wavelength range*	3200 – 5000 Å	4900 – 10000Å
Resolution (0.35"slit)	83,000	65,000
Resolution (1.0" slit)	28,000	22,000

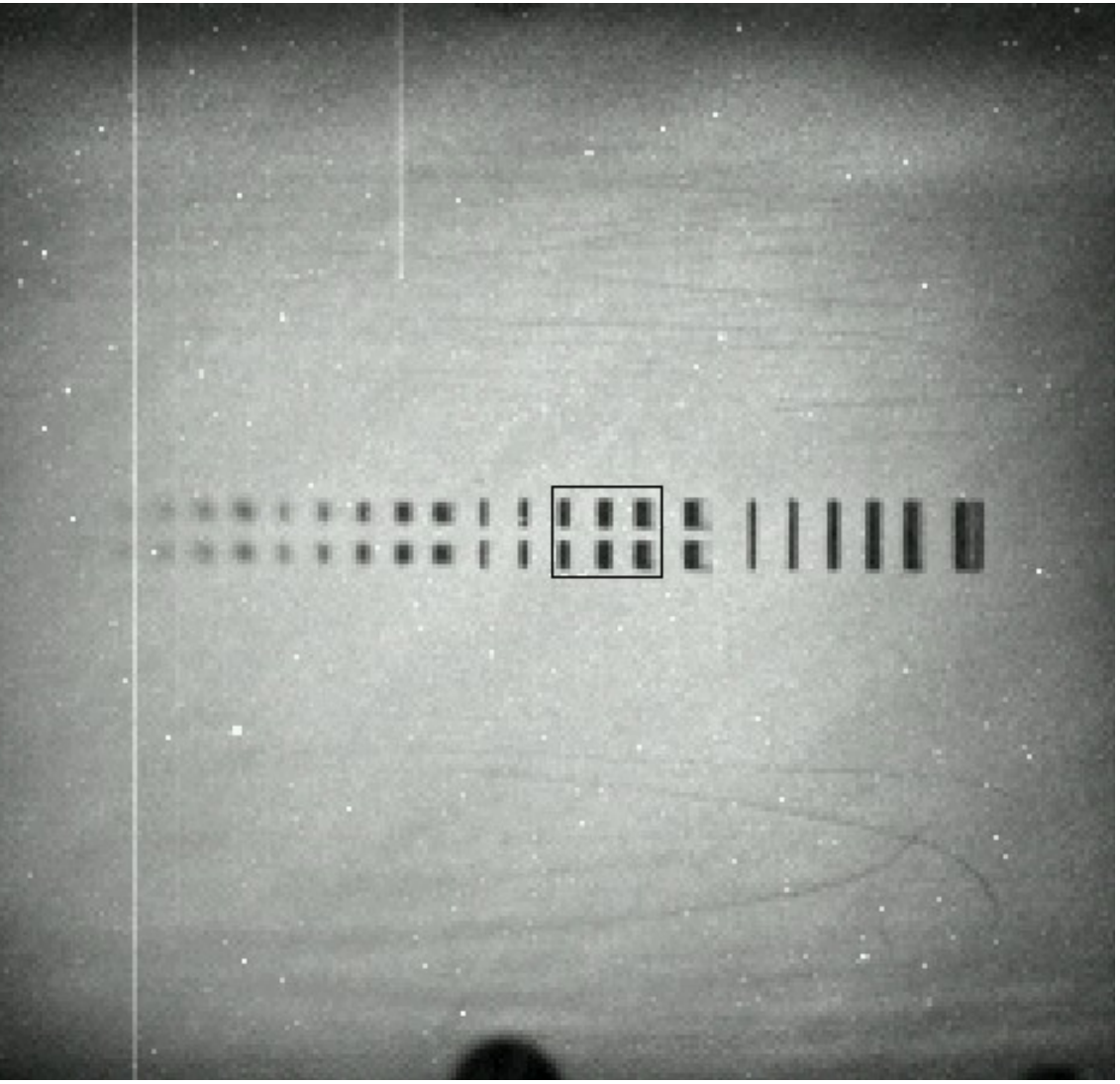
The tangent of the blazing angle = R#. Thus blazing angle for the R4 grating is 76 ^{o}

Echelle grating	R2.4	R2
Prism (cross-disperser)	Fused Silica (2 prisms)	PBM2 (1 prism)

MIKE: a double spectrograph. Sensitivity in the blue and red arms



Slits available at MIKE

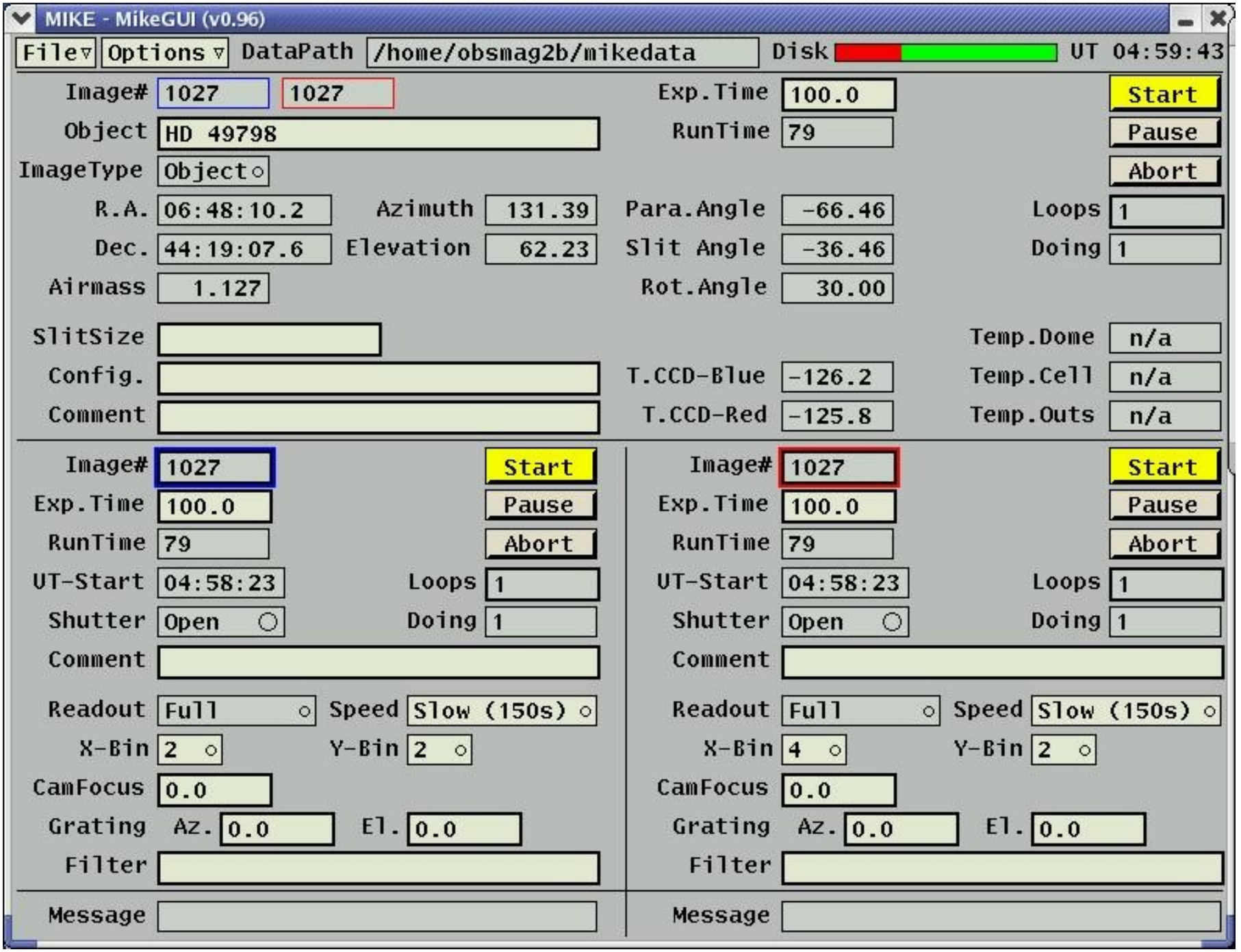


Aperture Pairs (separation 3"):

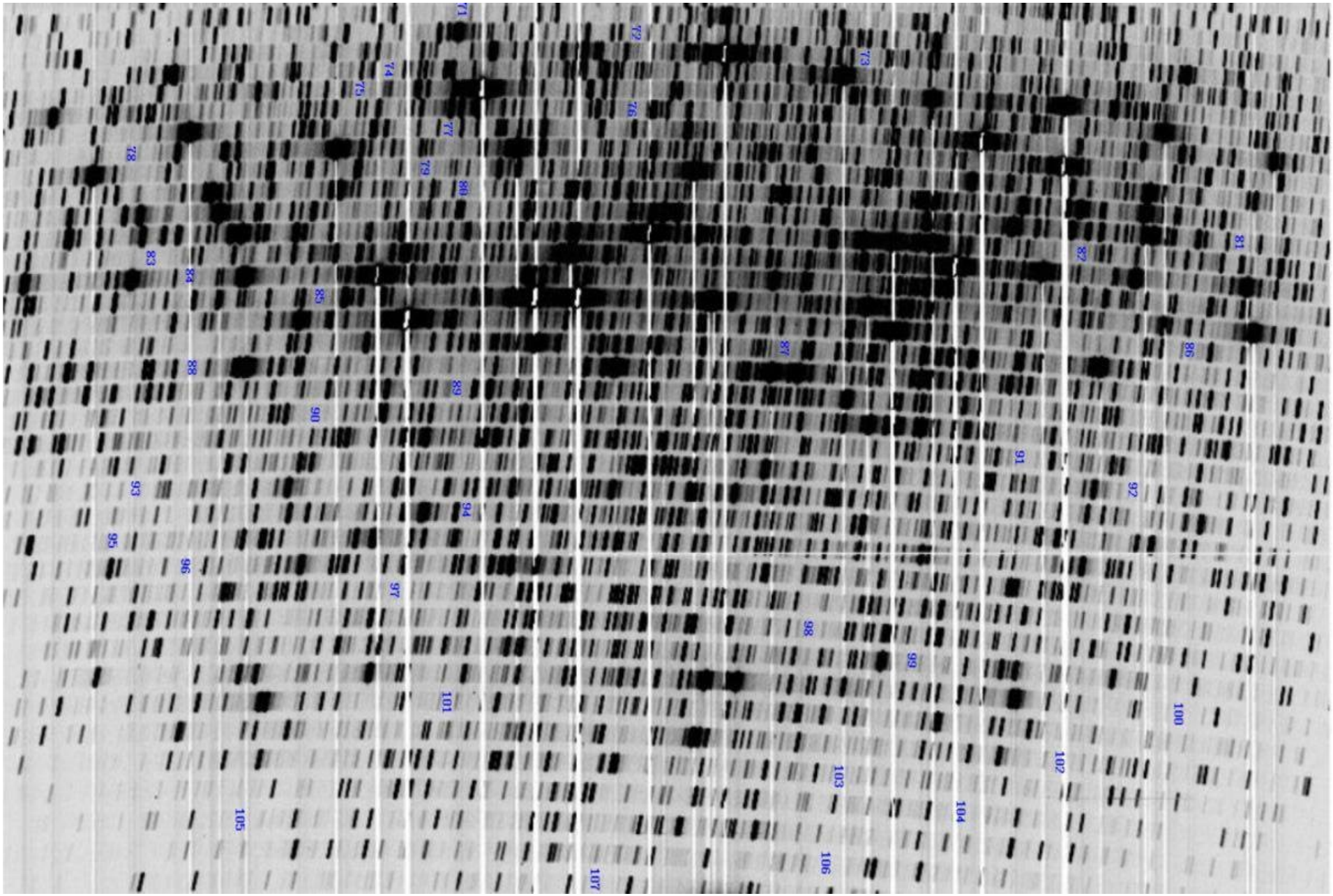
1 0.35 x 0.35 (for focusing)
2 1.00 x 0.35
3 1.00 x 0.50
4 1.00 x 0.70
5 1.00 x 1.00
6 1.50 x 0.35
7 1.50 x 0.50
8 1.50 x 0.70
9 1.50 x 1.00
10 1.50 x 1.50
11 2.00 x 0.35
12 2.00 x 0.50
13 2.00 x 0.70
14 2.00 x 1.00
15 2.00 x 1.50
16 2.00 x 2.00

Single Slits:

17 0.35 x 5.00
18 0.50 x 5.00
19 0.70 x 5.00
20 1.00 x 5.00
21 1.50 x 5.00
22 2.00 x 5.00


MIKE - MikeGUI (v0.96)
File
Options
DataPath
/home/obsmag2b/mikedata
Disk
UT 04:59:43
Image# 1027 1027
Exp.Time 100.0
Start
Object HD 49798
RunTime 79
Pause
ImageType Object
Abort
R.A. 06:48:10.2
Azimuth 131.39
Para.Angle -66.46
Loops 1
Dec. 44:19:07.6
Elevation 62.23
Slit Angle -36.46
Doing 1
Airmass 1.127
Rot.Angle 30.00
SlitSize
Temp.Dome n/a
Config.
T.CCD-Blue -126.2
Temp.Cell n/a
Comment
T.CCD-Red -125.8
Temp.Outs n/a
Image# 1027
Start
Exp.Time 100.0
Pause
RunTime 79
Abort
UT-Start 04:58:23
Loops 1
Shutter Open
Doing 1
Comment
Readout Full
Speed Slow (150s)
X-Bin 2
Y-Bin 2
CamFocus 0.0
Grating Az. 0.0
El. 0.0
Filter
Message
Image# 1027
Start
Exp.Time 100.0
Pause
RunTime 79
Abort
UT-Start 04:58:23
Loops 1
Shutter Open
Doing 1
Comment
Readout Full
Speed Slow (150s)
X-Bin 4
Y-Bin 2
CamFocus 0.0
Grating Az. 0.0
El. 0.0
Filter
Message

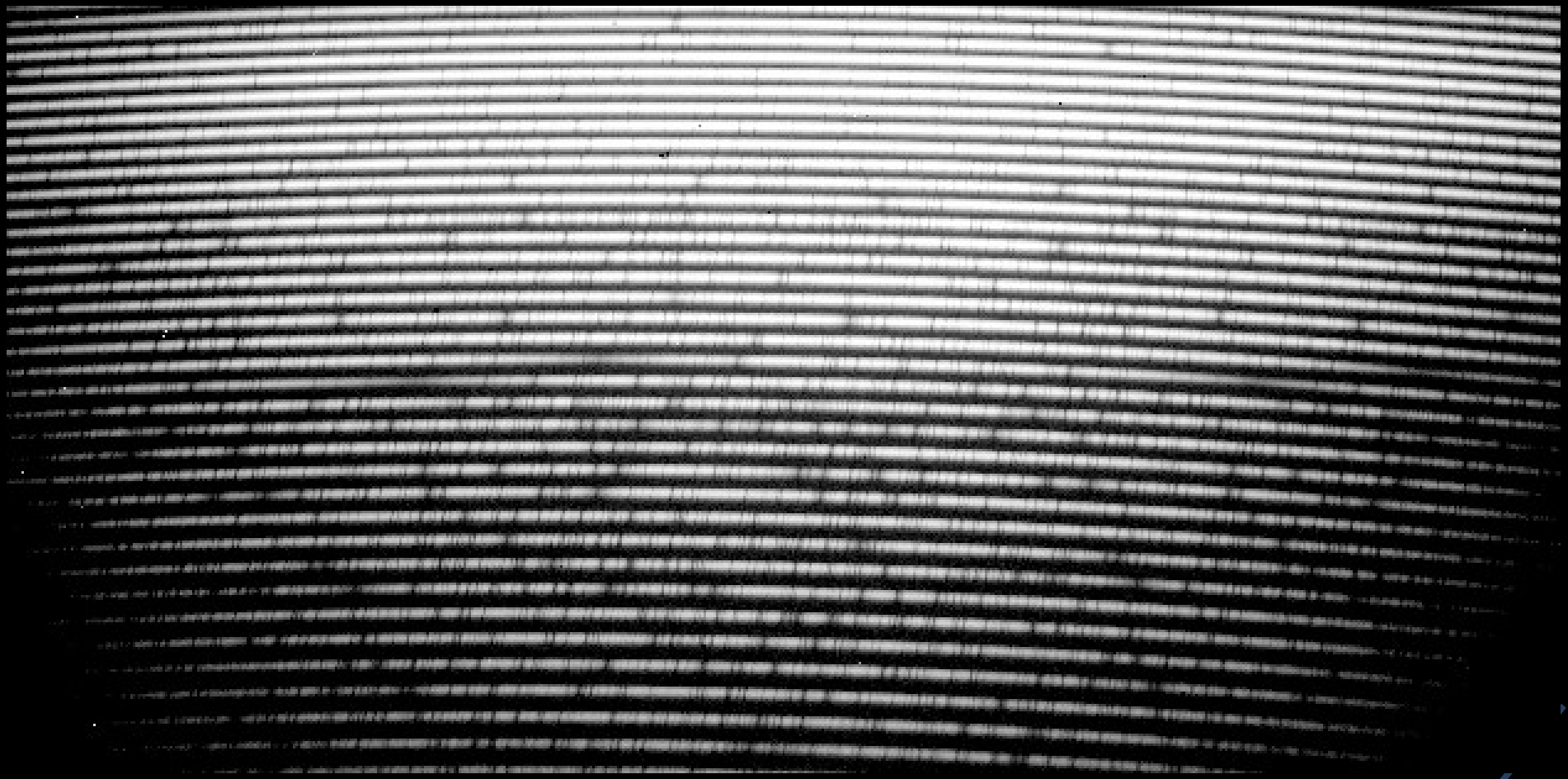
MIKE Blue ThAr calibration arc



Magellan/MIKE

Observations of the solar twin 18 Sco

BLUE frame



Magellan/MIKE

Observations of the solar twin 18 Sco

RED frame

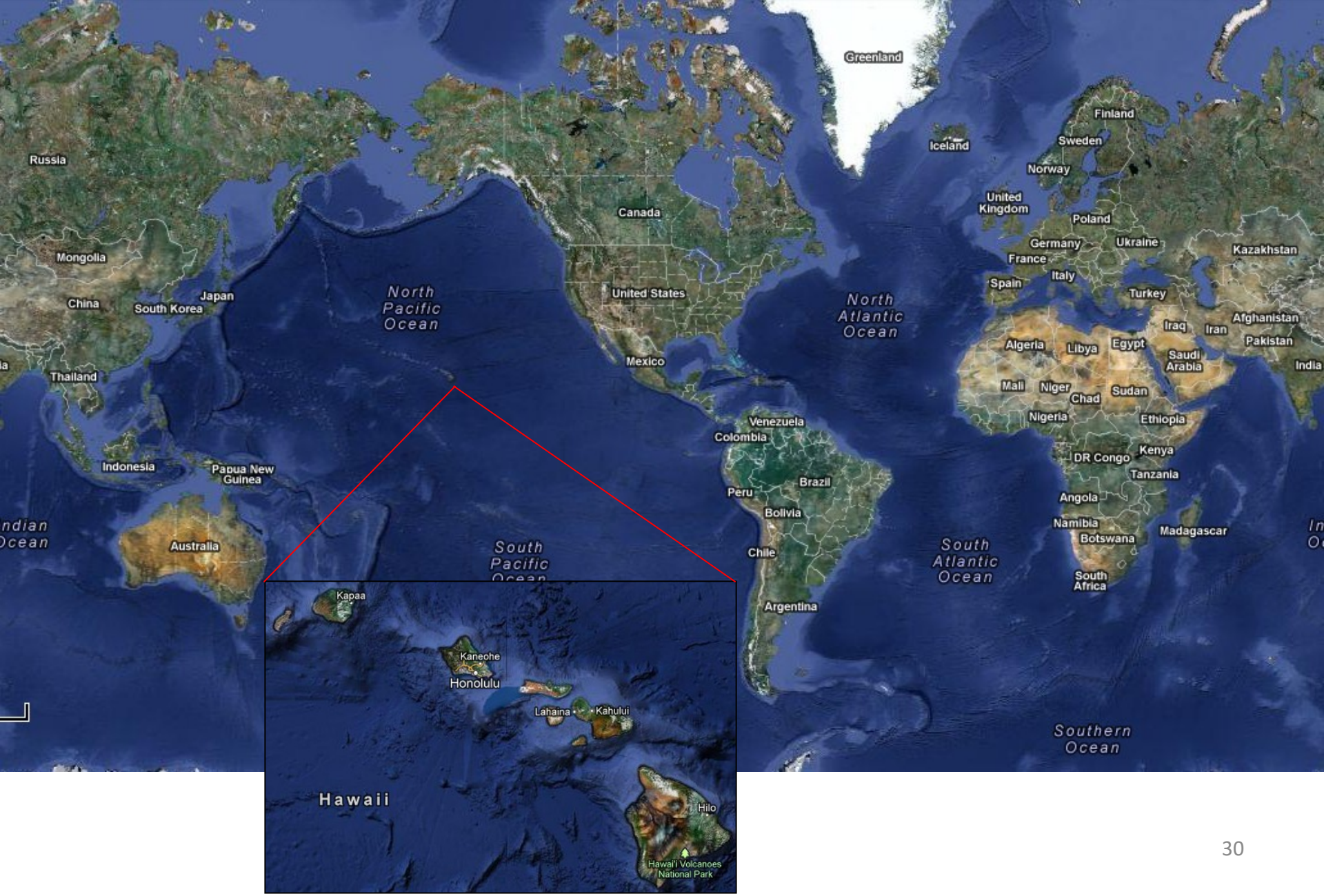
Planning observations with echelle spectrographs

1. Spectral coverage: which are the most important spectral features? 1 or 2 arms?

1. Resolving power: enough to resolve your spectral features?

1. S/N: adequate telescope + instrument?

Example: high resolution echelle spectroscopy of a solar twin with HIRES at the Keck telescope (very small exploratory project during classical [visitor] observing run with the Keck telescope)


Greenland
Finland
Sweden
Iceland
Norway
Russia
United Kingdom
Canada
Poland
Germany
Ukraine
Kazakhstan
Mongolia
France
Spain
Italy
China
Japan
South Korea
North Pacific Ocean
United States
North Atlantic Ocean
Turkey
Iraq
Iran
Afghanistan
Pakistan
Algeria
Libya
Egypt
Saudi Arabia
India
Mexico
Thailand
Mali
Niger
Chad
Sudan
Nigeria
Ethiopia
Venezuela
Colombia
Kenya
DR Congo
Tanzania
Indonesia
Papua New Guinea
Brazil
Peru
Angola
Bolivia
Namibia
Botswana
Madagascar
Australia
South Pacific Ocean
Chile
South Atlantic Ocean
South Africa
Argentina
Kapaa
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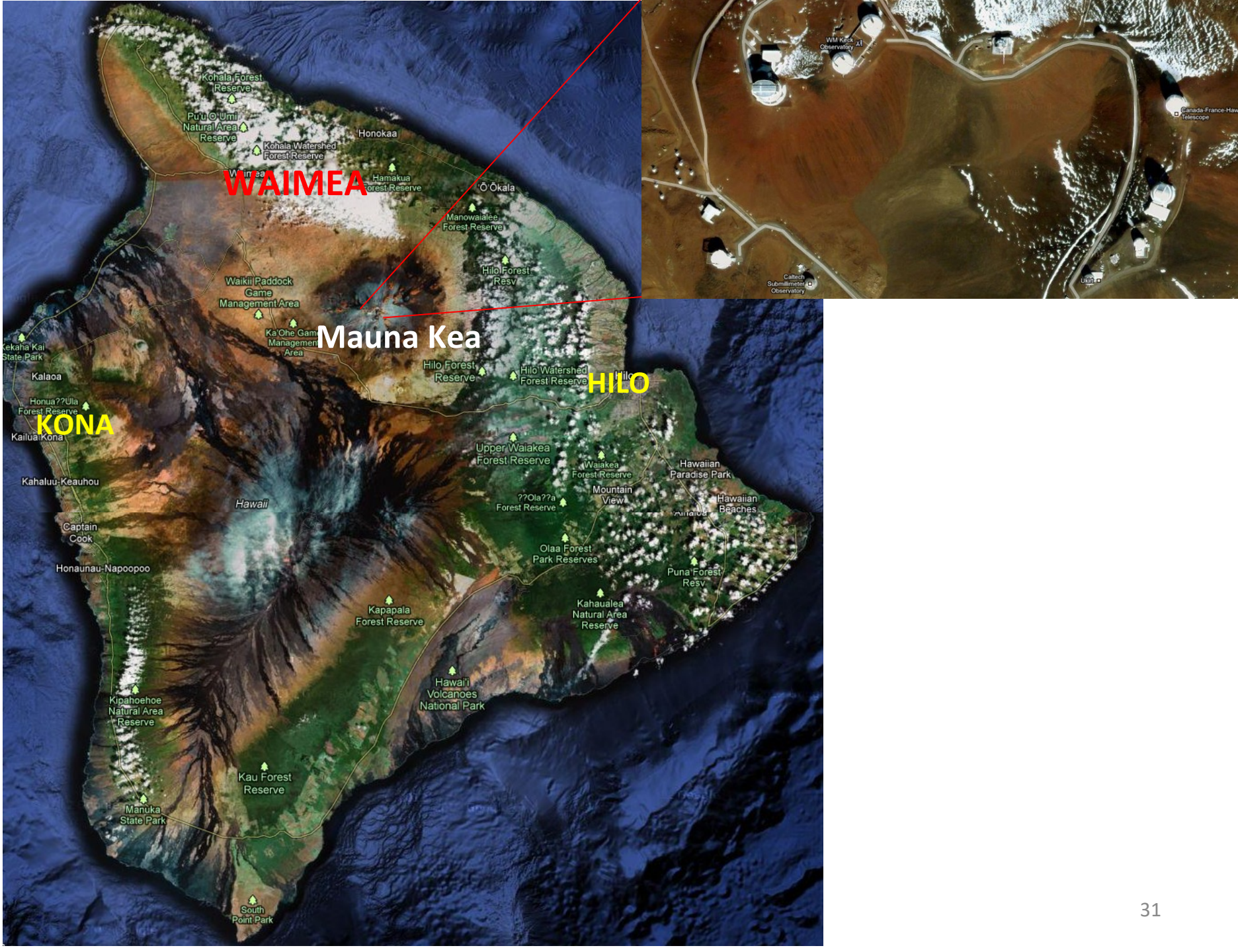
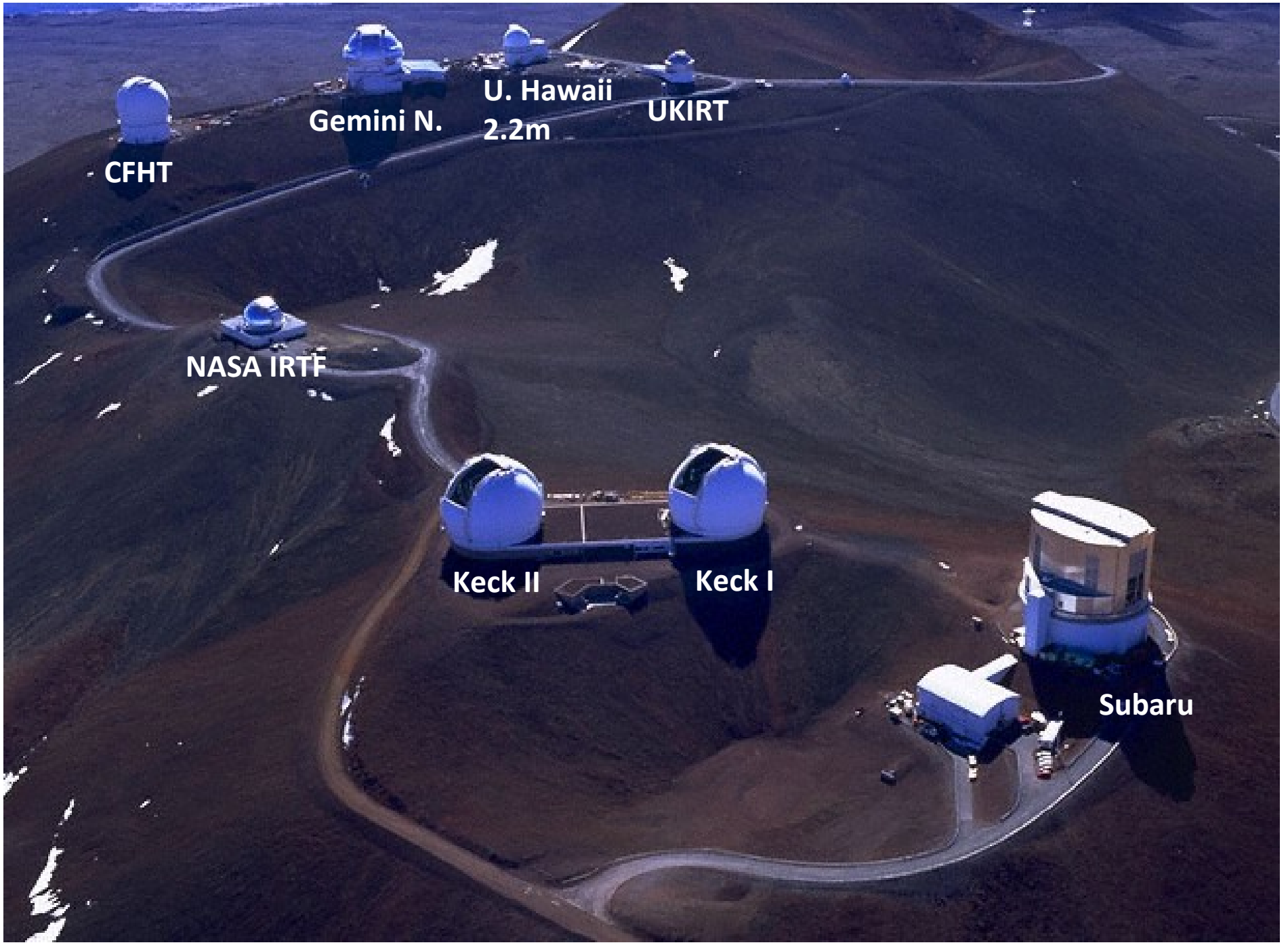
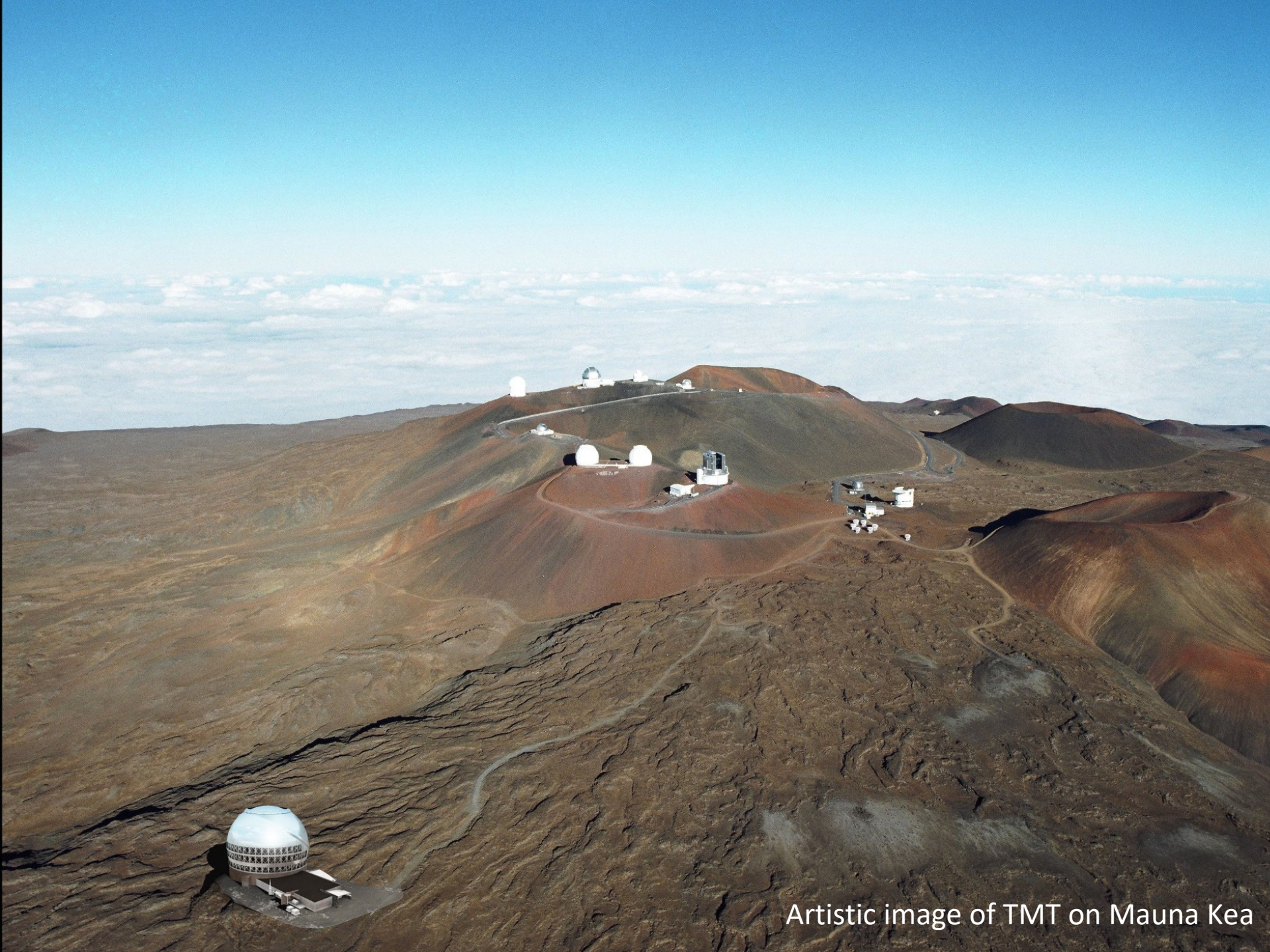
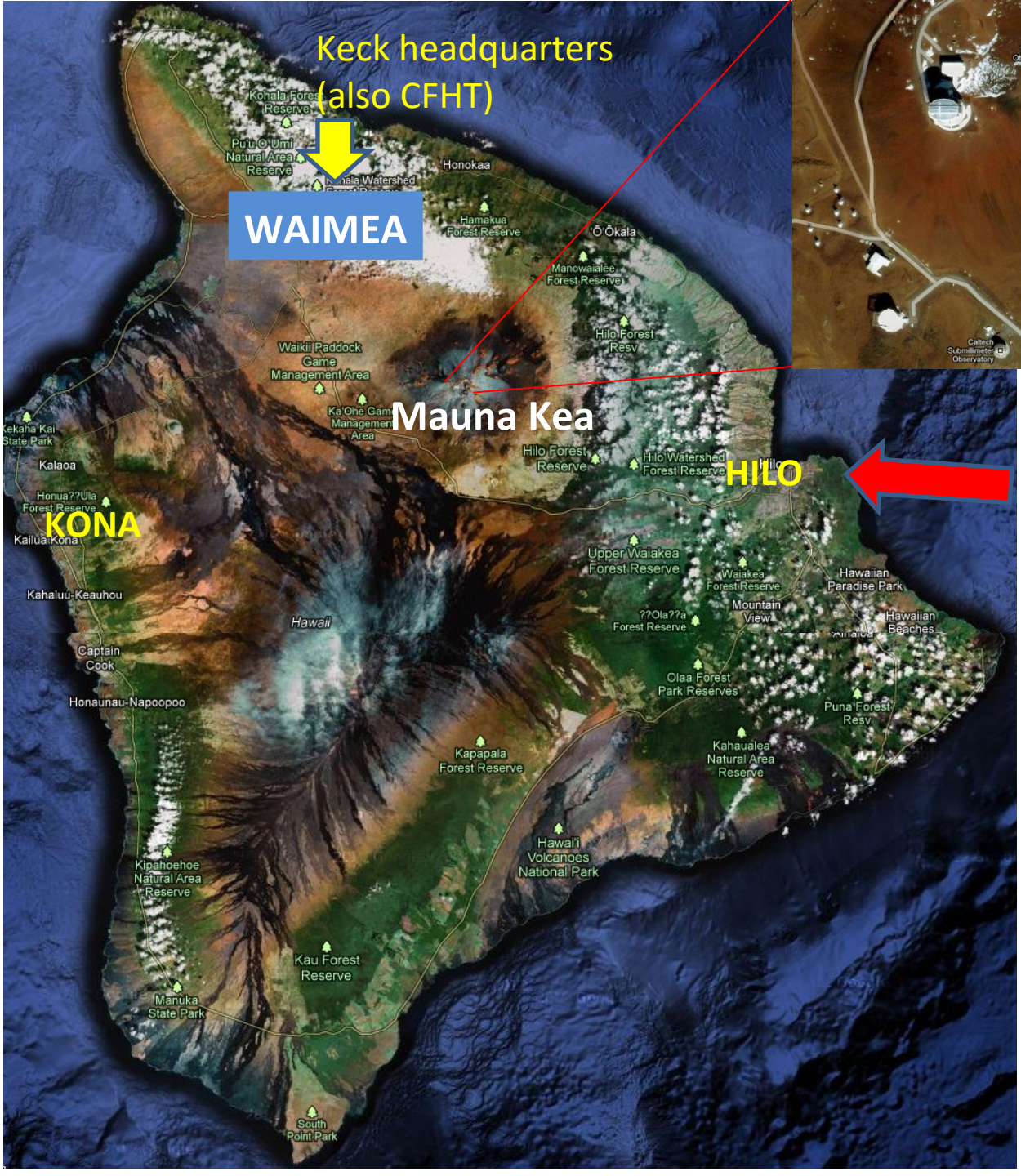
Lahaina
Kahului
Hawaii
Hilo
Hawai'i Volcanoes National Park
Southern Ocean


WAIMEA
Mauna Kea
HILO
KONA
Kohala Forest Reserve
Puu O Umi Natural Area Reserve
Honokaa
Kohala Watershed Forest Reserve
Hamakua Forest Reserve
Ō Ōkala
Manowaialee Forest Reserve
Hilo Forest Resv
Waikii Paddock Game Management Area
Hilo Forest Reserve
Hilo Watershed Forest Reserve
Kalaoa
Honua??Ula Forest Reserve
Kailua-Kona
Upper Waiakea Forest Reserve
Waiakea Forest Reserve
Hawaiian Paradise Park
Mountain View
??Ola??a Forest Reserve
Hawaiian Beaches
Kahaluu-Keauhou
Hawaii
Captain Cook
Honaunau-Napoopoo
Olaa Forest Park Reserves
Puna Forest Resv
Kapapala Forest Reserve
Kahaualea Natural Area Reserve
Hawai'i Volcanoes National Park
Kipahoehoe Natural Area Reserve
Kau Forest Reserve
Manuka State Park
South Point Park
WM Keck Observatory
Canada-France-Haw Telescope
Caltech Submillimeter Observatory
UKIRT

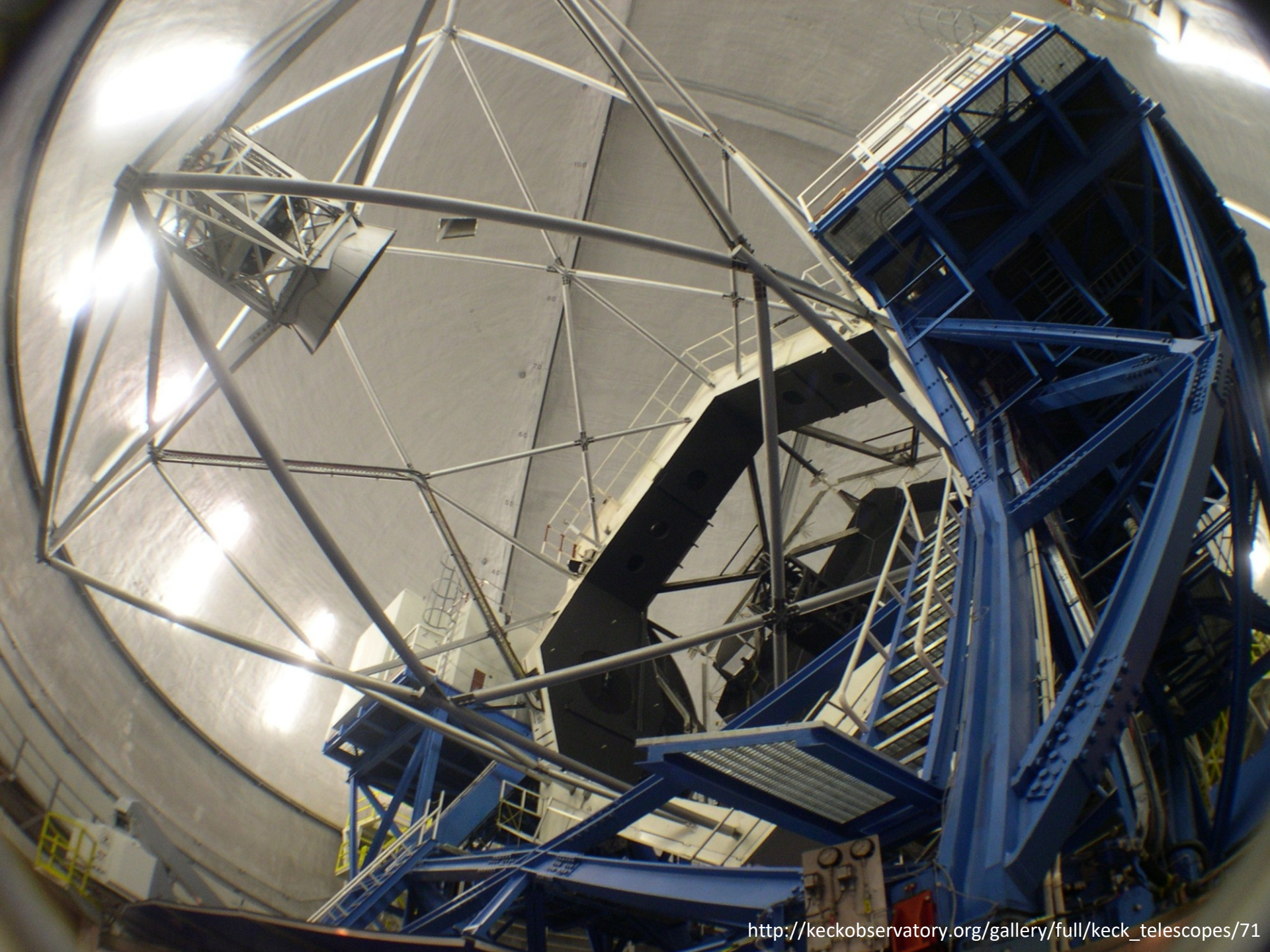

CFHT
Gemini N.
U. Hawaii
2.2m
UKIRT
NASA IRTF
Keck II
Keck I
Subaru



Artistic image of TMT on Mauna Kea

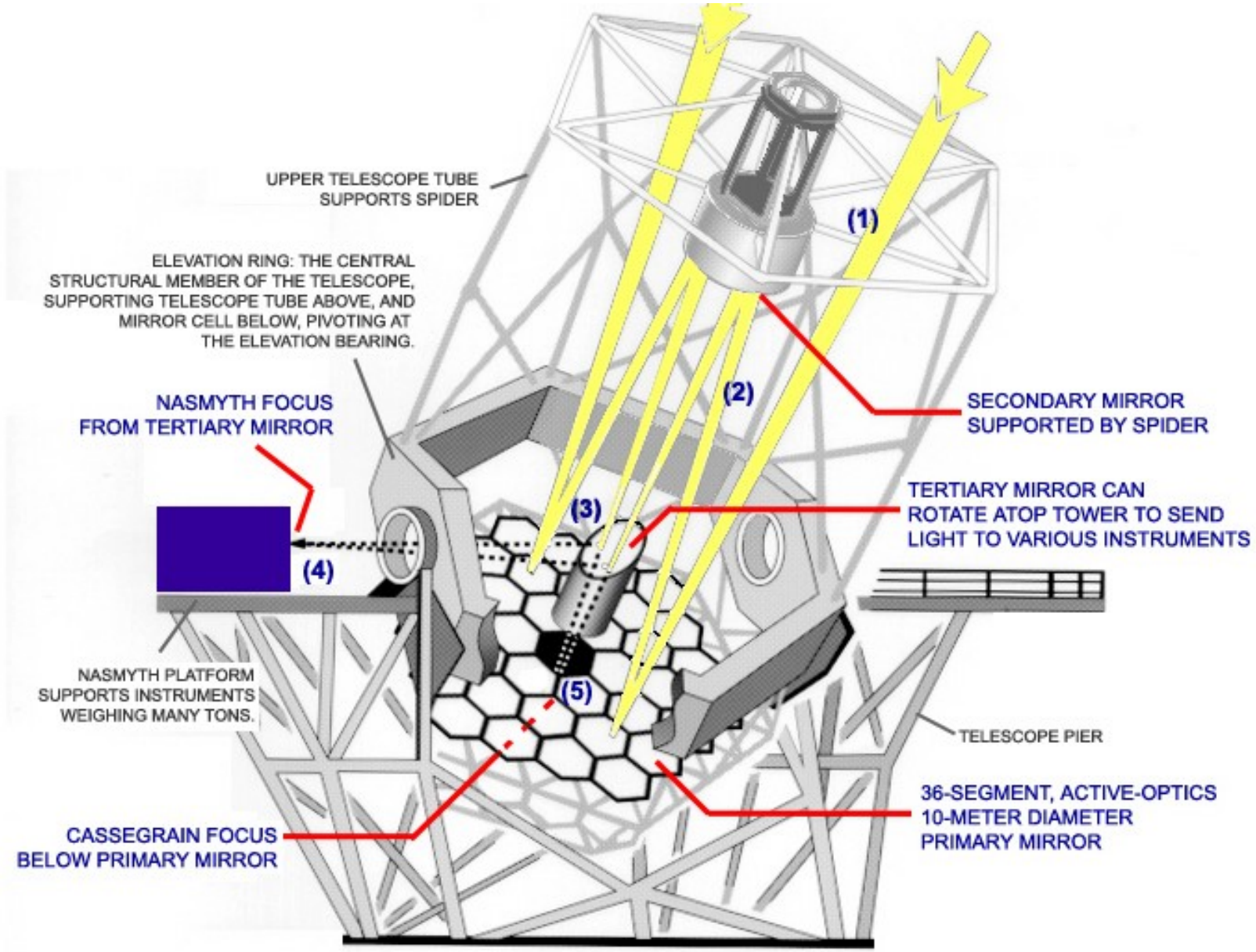


Gemini & Subaru headquarters (*rainy side*)



http://keckobservatory.org/gallery/full/keck_telescopes/71

Keck telescope



Jorge (right) & student Damian Fabbian (left)
at the Keck prime focus cage


2006.05.06 20:45


2006.05.08 12:35

Sunset from Waikiki

January 2006

(Sometimes you flight to Honolulu rather than directly to the Big Island [Kona or Hilo])

Keck/HIRES run when the 2nd solar twin was found

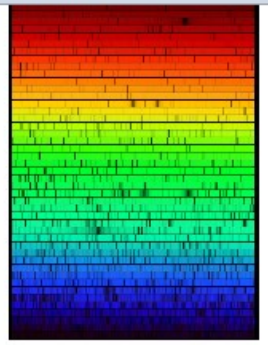
HIRES no Keck I

www2.keck.hawaii.edu/inst/hires/

HIRES Contents

- Introduction
- News
- Pre-Observing
- Observing
- Post-Observing
- Technical Pages
- Keck Obs. Archive

- Keck Home Page
- Instruments Home Page



High Resolution Echelle Spectrometer

http://www2.keck.hawaii.edu/inst/hires/

HIRES is a grating cross-dispersed, echelle spectrograph capable of operating between 0.3 and 1.0 microns. Although adjustable slits are available by special request, almost all observers choose from a number of slit plates which provide resolutions between roughly 25,000 and 85,000. These slits are available in a variety of lengths since order separation varies between 6 and 43 arcseconds. HIRES does not currently have multi-slit capability.

Observers can request one of two configurations. HIRESb and HIRESr use different cross-dispersers and collimators, which are optimized for short and long wavelength observations respectively. The efficiency of the two is equal at approximately 4200 Angstroms. Switching between the two is not possible during the night.

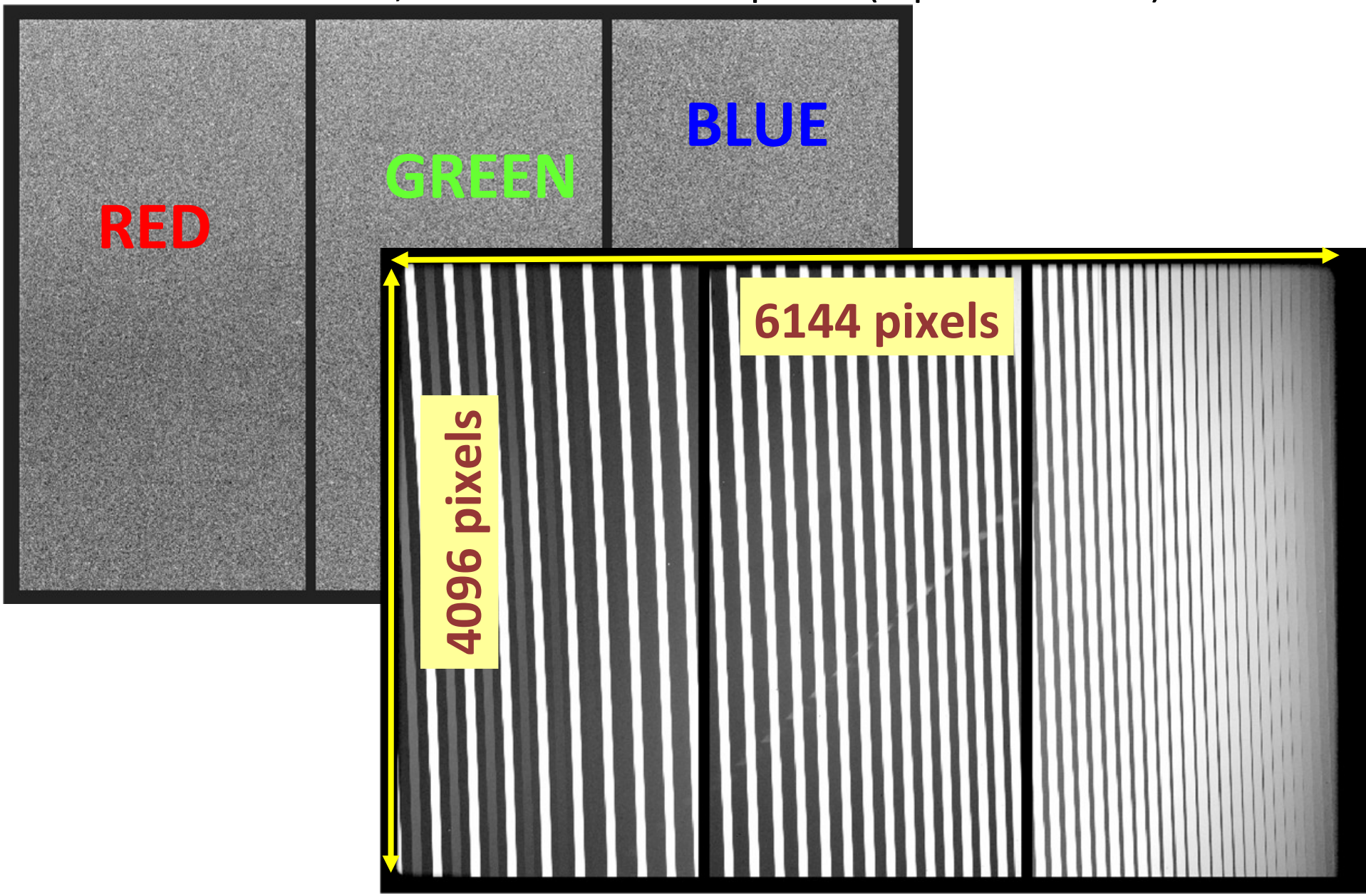
only 1 arm: choose HIRESb or HIRESr

Spectral coverage is complete shortward of 6200 Angstroms. Longward of this, two different echelle settings are necessary to achieve complete coverage. Aside from the possible gaps in coverage at long wavelengths, the spectral span per exposure ranges from about 3000 Angstroms for short wavelength settings, to about 4500 Angstroms at long wavelength settings.

Since HIRES is mounted at a nasymth platform, fields will rotate during an exposure. If desired though, an image rotator can be introduced into the light path which will maintain the slit orientation at a particular PA or at the parallactic angle. This rotator is always available and can be moved into or out of the beam remotely. Other devices which observers can select at will are an exposure meter for accurate control of signal levels and an iodine cell for precise radial velocity work.

HIRES CCD data format

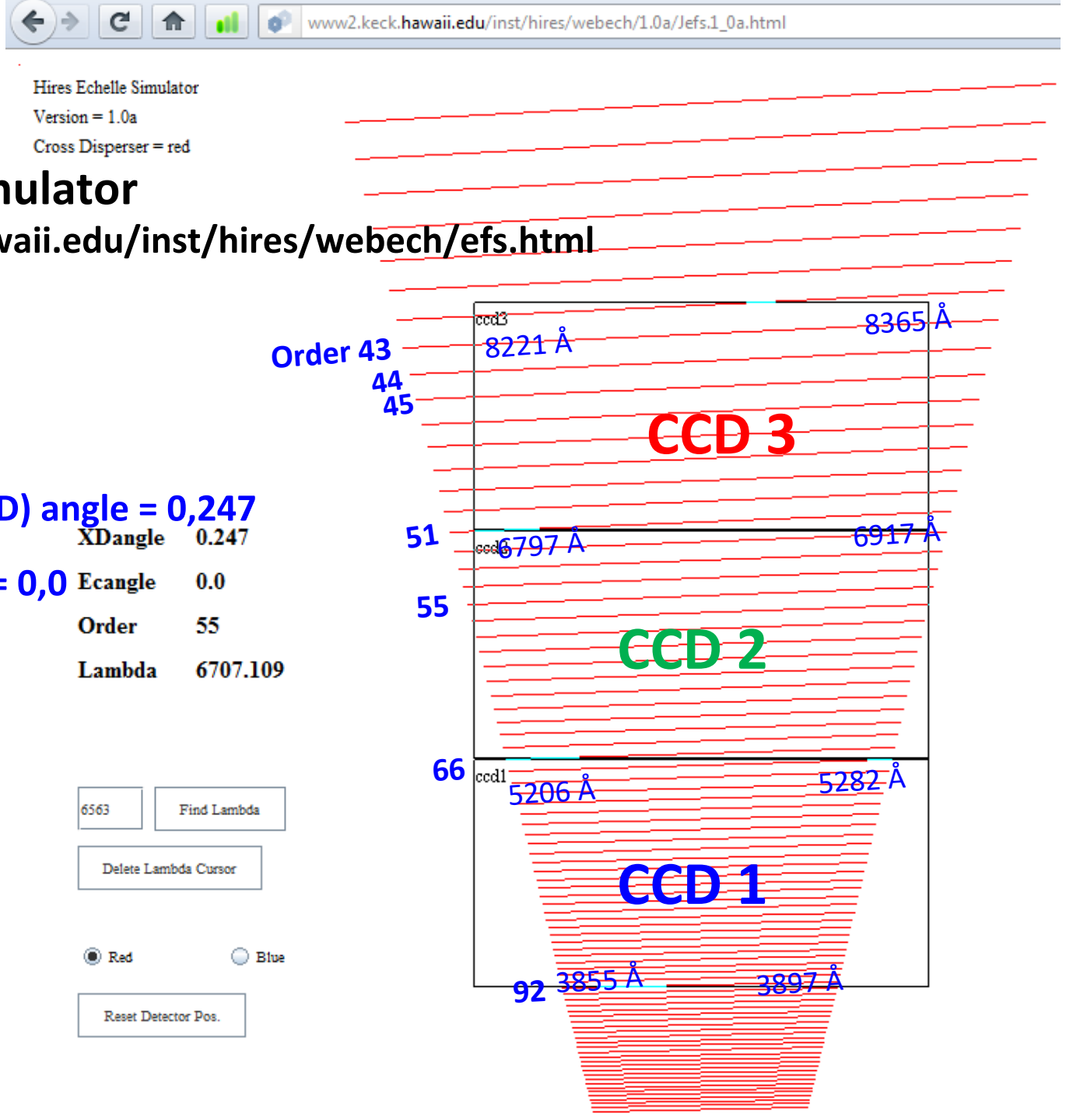
Mosaic of 3 CCDs, each 2048 x 4096 pixels (1 pixel = 15um)

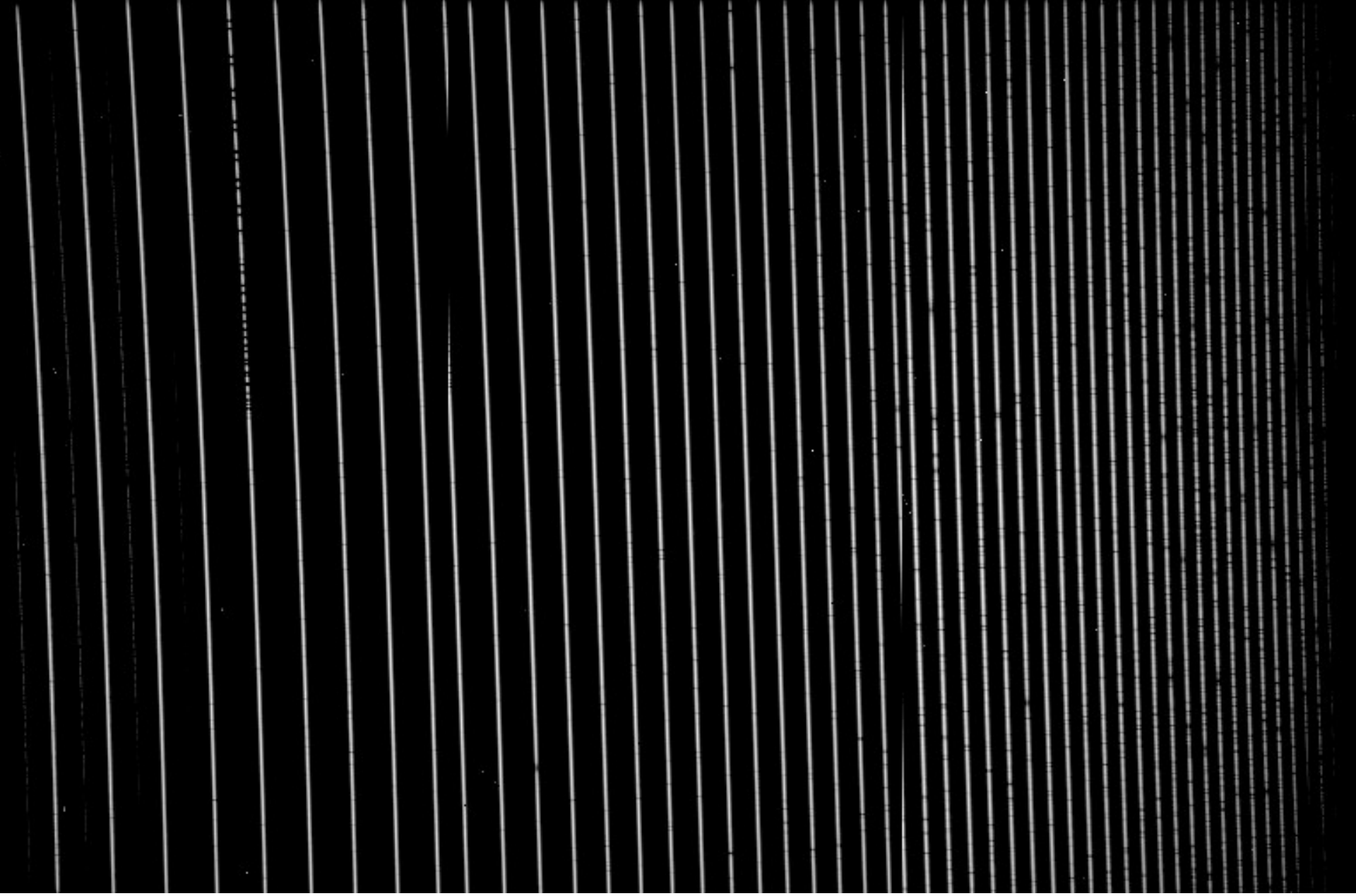


HIRES

Echelle Format Simulator

http://www2.keck.hawaii.edu/inst/hires/webech/efs.html





HD 98618 : my first solar twin

Header of image hires1851.fits

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- HA = '+22:37:54.36'
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- ST = '09:59:45.87'
- AIRMASS = '1.33 '
- MJD = '53755.515760'
- TARGNAME= 'HD 98618'
- TELESCOP= 'Keck I '
- CCDGAIN = 'low '

- UTC-END = '12:25:11.39'
- DATE-END= '2006-01-20'
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- OUTFILE = 'hires '
- FRAMENO = 1851
- **EXPTIME = 150 seconds**
- OBSERVER= 'J. Melendez'
- OBJECT = 'hd 98618'
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- DATE_END= '2006-01-20T12:25:09'
- **DECKNAME= 'E4 ' (slit 0,40 x 7,0 ” defines the resolving power)**
- ECHANGL = 0.00004228
- **FIL1NAME= 'kv389 '**

Resolving power vs. slit width ϕ_s

HIRES spectrograph on the 10m Keck I telescope

$$R = \frac{\lambda}{\delta\lambda_0} = \frac{\lambda}{r_{an}\phi_s}\frac{D_{COL}}{D_{TEL}}\frac{d\theta}{d\lambda}$$

Decker name	Length (")	Width (")	Resolution R (calculated)	Resolution R (measured*)	Resolution R (measured+)
B1	3.5	0.574	72,000	67,000	66,400
B2	7.0	0.574	72,000	67,000	66,400
B3	14.0	0.574	72,000	67,000	66,400
B4	28.0	0.574	72,000	67,000	66,400
B5	3.5	0.861	48,000	49,000	50,000
C1	7.0	0.861	48,000	49,000	50,000
C2	14.0	0.861	48,000	49,000	50,000
C3	28.0	0.861	48,000	49,000	50,000
C4	3.5	1.148	36,000	37,000	37,500
C5	7.0	1.148	36,000	37,000	37,500
D1	14.0	1.148	36,000	37,000	37,500
D2	28.0	1.148	36,000	37,000	37,500
D3	7.0	1.722	24,000	24,000	24,700
D4	14.0	1.722	24,000	24,000	24,700
D5	0.119	0.179	pinhole		
E1	1.0	0.400	103,000	84,000	86,600
E2	3.0	0.400	103,000	84,000	86,600
E3	5.0	0.400	103,000	84,000	86,600
E4	**7.0**	**0.400**	**103 000**	**84 000**	**86 600**
E5	1.0	0.800	51,000	52,000	52,000

DECKER: length & width of slits

* Using UV cross-disperser. Average of 5 Th/Ar lines near 4100 A.
+ Using Red cross-disperser. Average of 4 Th/Ar lines near 5240 A.

According to my measurements
R ~ 85 - 95000

THE ASTROPHYSICAL JOURNAL, 752:5 (13pp), 2012 June 10

THE $UBV(RI)_C$ COLORS OF THE SUN

I. RAMÍREZ[1], R. MICHEL[2], R. SEFAKO[3], M. TUCCI MAIA[4,5], W. J. SCHUSTER[2], F. VAN WYK[3], J. MELÉNDEZ[5], L. CASAGRANDE[6], AND B. V. CASTILHO[7]

HIP	$T_{\rm eff}$ (K)	log g	[Fe/H]	V	$(B-V)$	$(U-B)$	$(V-R)$	$(V-I)$
55459	5838 ± 21	4.42 ± 0.03	0.038 ± 0.012	7.646 ± 0.004	0.644 ± 0.004	0.147 ± 0.010	0.338 ± 0.006	0.692 ± 0.006

simbad.u-strasbg.fr/simbad/sim-id?Ident=HD+98618&NbIdent=1&Radius=2&Radius.unit=arcmin&submit=submit+id

Basic data :

HD 98618 -- Star

query around with radius 2 arcmin

Other object types: * (HD,AG,BD,GEN#,GSC,HIC,HIP,PPM,SAO,SKY#,SPOCS,TYC,UBV,uvby98,YZ), IR (2MASS)

ICRS coord. (ep=J2000) : 11 21 29.07012 +58 29 03.7016 (Optical) [3.96 3.87 90] A 2007A&A...474..653V

FK5 coord. (ep=J2000 eq=2000) : 11 21 29.070 +58 29 03.70 (Optical) [3.96 3.87 90] A 2007A&A...474..653V

FK4 coord. (ep=B1950 eq=1950) : 11 18 36.06 +58 45 29.0 (Optical) [22.85 22.34 89] A 2007A&A...474..653V

Gal coord. (ep=J2000) : 143.3023 +54.9422 (Optical) [3.96 3.87 90] A 2007A&A...474..653V

Proper motions *mas/yr* [error ellipse]: 41.57 28.89 [0.44 0.45 0] A 2007A&A...474..653V

Radial velocity / Redshift / cz : V(km/s) 16 [6.8] / z(~) 0.000053 [0.000023] / cz 16.00 [6.80] (~) D 1995A&AS..110..177D

Parallaxes *mas*: 24.96 [0.66] A 2007A&A...474..653V

Spectral type: G5V D ~

Fluxes (5) :

B 8.265 [~] C ~

V 7.659 [~] C ~

J 6.448 [0.029] C 2003yCat.2246....0C

H 6.142 [0.046] C 2003yCat.2246....0C

K 6.061 [0.020] C 2003yCat.2246....0C

Identifiers (16):

HD 98618

HIP 55459

http://www2.keck.hawaii.edu/inst/hires/etc.html

HIRES Signal-to-Noise Estimator

Plot Type	Binning	Parameters		
◉ S/N	◉ 1×1	AB Magnitude	7.646	
○ Efficiency	○ 2×1	Exposure time	150	sec
○ Noise	○ 3×1	Slit width	0.4	arcsec
○ Data Table	○ 2×2	Seeing FWHM	0.6	arcsec
		Airmass	1.3	
		Moon phase	7	days
		Min wavelength	3850	Å
		Max wavelength	8350	Å
		Increment	200	Å

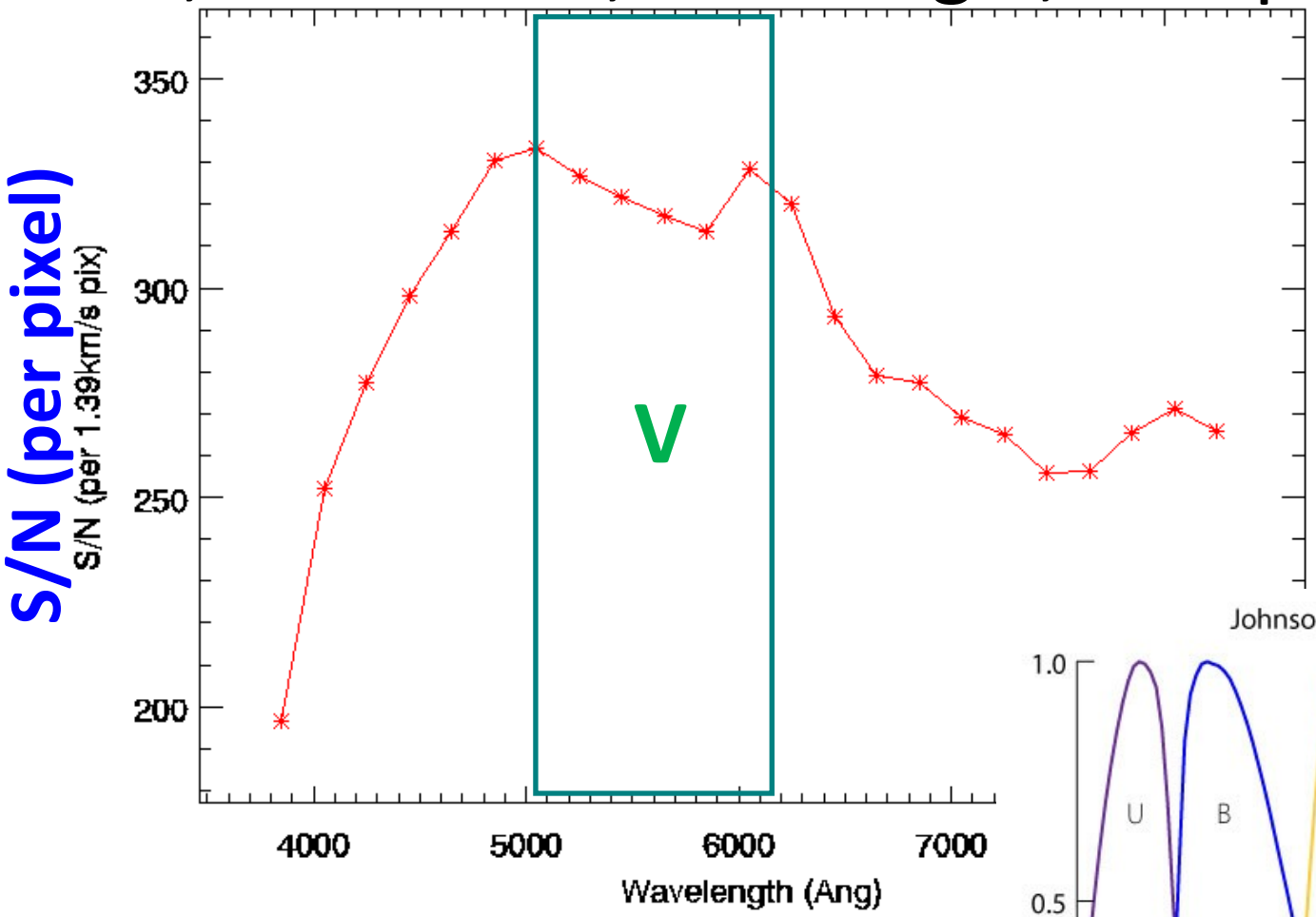
We are adopting V = 7,646, but this is in the Johnson system. Be careful. What we need are "AB" magnitudes, i.e., U_{AB},B_{AB},V_{AB}, R_{AB} , etc

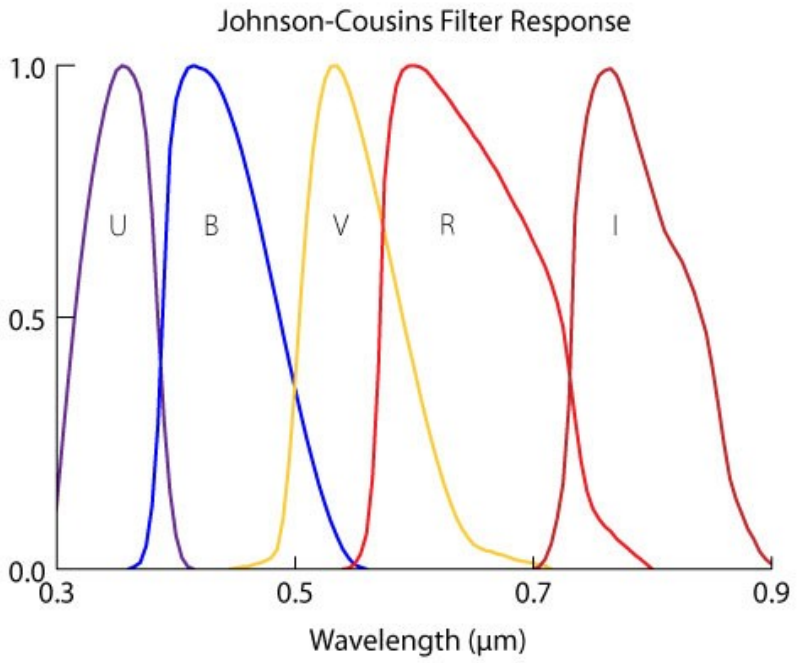
$$V_{AB} = V - 0.044$$

The exact definition is stated relative to the cgs units of erg s^{-1} cm^{-2} Hz^{-1}:

$$m_{\rm AB} = -2.5 \log_{10} f_\nu - 48.60.$$

V = 7,646 slit = 0,4” seeing 0,6” exptime = 150 s





Header of the image hires1851.fits

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- ST = '09:59:45.87'
- AIRMASS = '1.33 '
- MJD = '53755.515760'
- TARGNAME= 'HD 98618'
- TELESCOP= 'Keck I '
- CCDGAIN = 'low '

- UTC-END = '12:25:11.39'
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- **EXPTIME = 150 seconds**
- OBSERVER= 'J. Melendez'
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- DATE_BEG= '2006-01-20T12:22:39'
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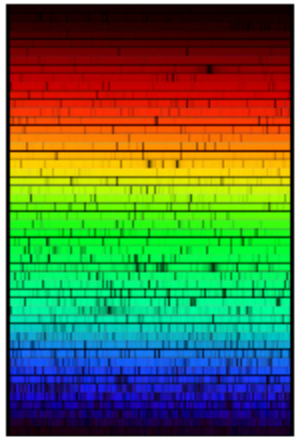
- **DECKNAME= 'E4 ' (slits 0,40 x 7,0 ” defines the resolving power)**
- ECHANGL = 0.00004228
- **FIL1NAME= 'kv389 '**



http://www2.keck.hawaii.edu/inst/hires/filter_choices.html

High Resolution Echelle Spectrometer

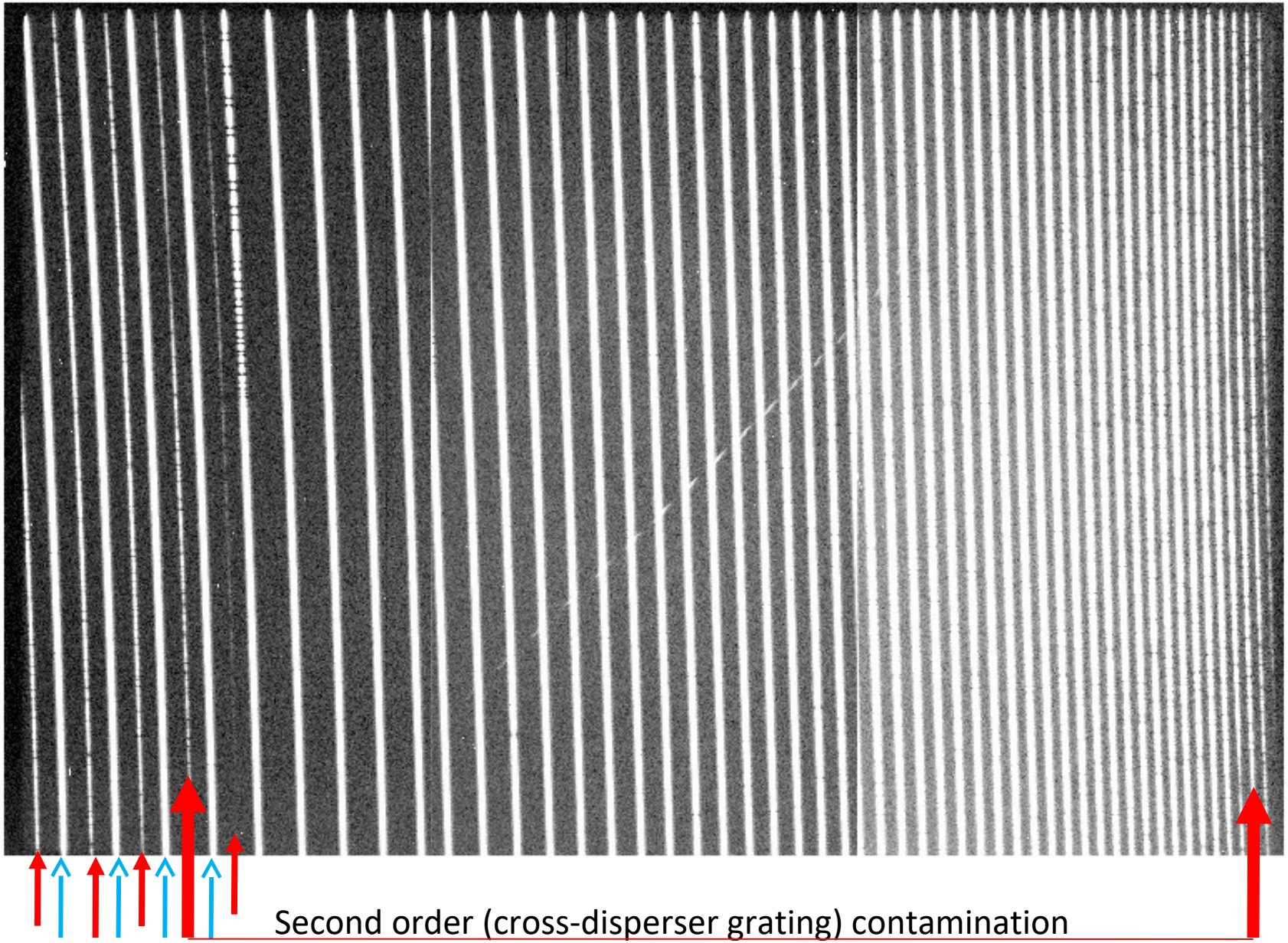
Filter Choices

Is it possible to observe the H & K (394 nm) lines and at the same time the oxygen triplet (777 nm) & the Al doublet (784 nm)?

HIRES has two 12 position filter wheels that reside immediately behind the decker plate. Their primary function is to block unwanted orders from the cross-disperser. Each filter wheel has a "clear" position that is empty. Proper choice of blocking filters is critical for isolating particular regions of interest. The Table below gives some useful combinations of filter choice for given spectral regions. Note that each combination of filters requires refocusing of the collimator which is handled automatically if installed from the XHIRES GUI.

Cross-disperser Order	Wavelength (microns)	Filter Wheel 1	Filter Wheel 2
1	0.69 - 1.1	2 (OG610)	1 (clear)
1	0.63 - 0.95	3 (OG530)	1 (clear)
1	0.58 - 0.90	3 (OG530)	1 (clear)
1	0.53 - 0.85	4 (GG475)	1 (clear)
1	0.48 - 0.80	5 (KV418)	1 (clear)
1	0.44 - 0.75	6 (KV408)	1 (clear)
1	0.39 - 0.70	8 (KV380)	1 (clear)
1	0.35 - 0.65	9 (KV370)	1 (clear)
1	0.30 - 0.60	11 (WG335)	1 (clear)

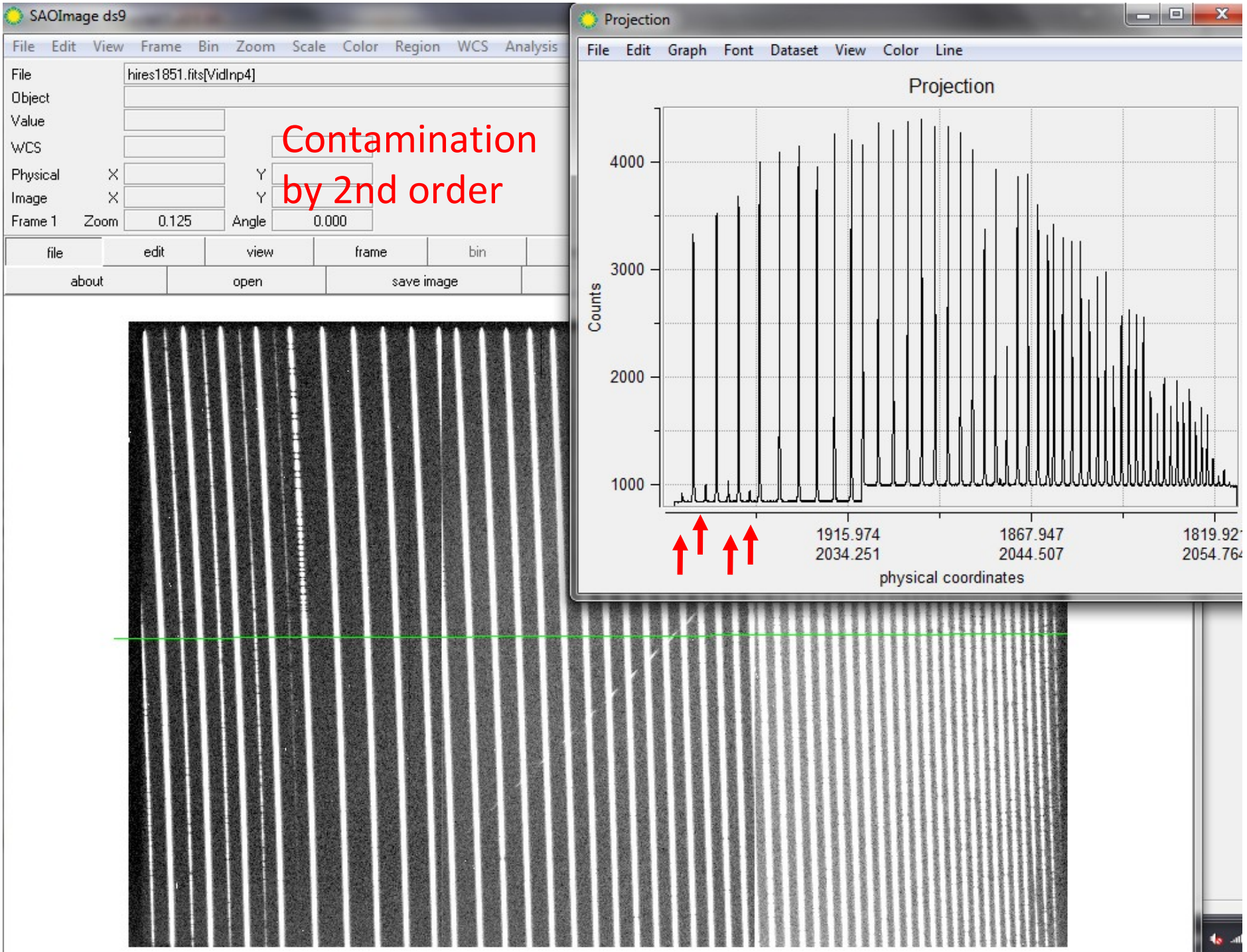
HIRES mosaic for solar twin HD 98618



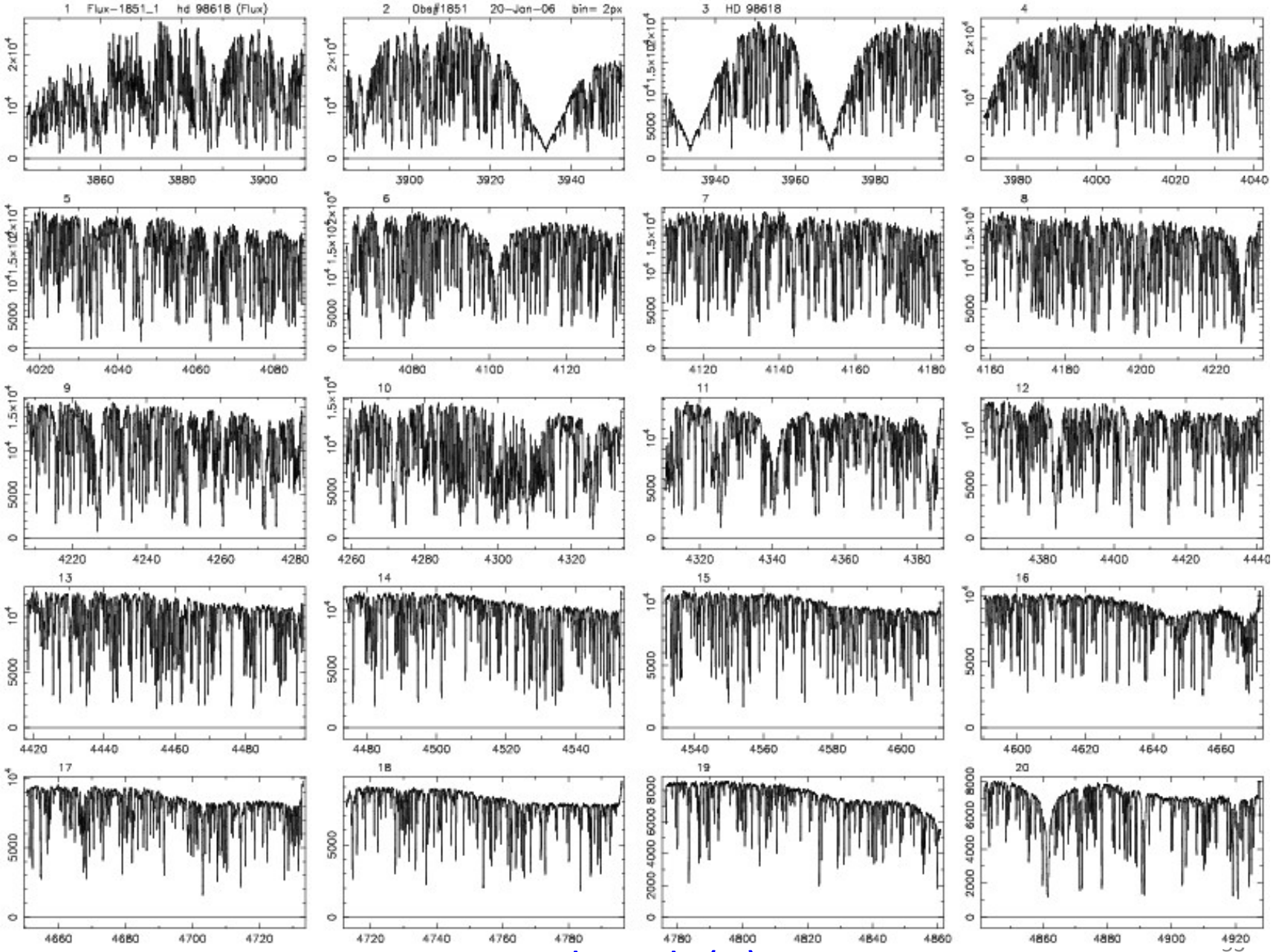
Red arrows: Easily identified 2nd order contamin.

Blue arrows: 1st orders contamin. by other 2nd orders

Large red arrow right: 1st order in the UV. Left: in the red CCD we see the 2nd order of the 1st order from the UV


SAOImage ds9
File Edit View Frame Bin Zoom Scale Color Region WCS Analysis
File hires1851.fits[VidInp4]
Object
Value
WCS
Physical X Y
Image X Y
Frame 1 Zoom 0.125 Angle 0.000
file edit view frame bin
about open save image
Contamination by 2nd order
Projection
File Edit Graph Font Dataset View Color Line
Projection
Counts
4000
3000
2000
1000
1915.974
2034.251
1867.947
2044.507
physical coordinates

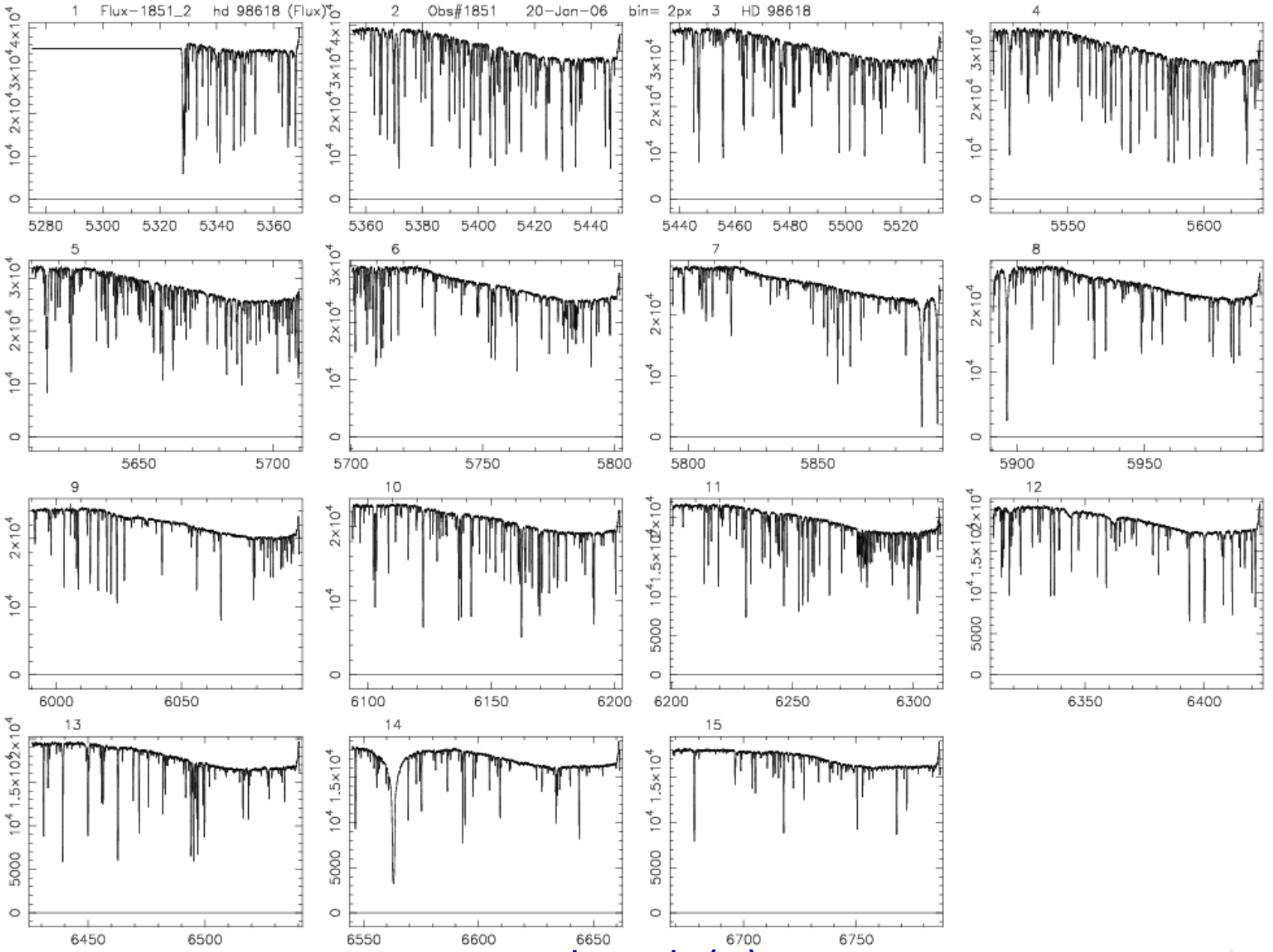
MAKEE hires pipeline (automatic reduction)



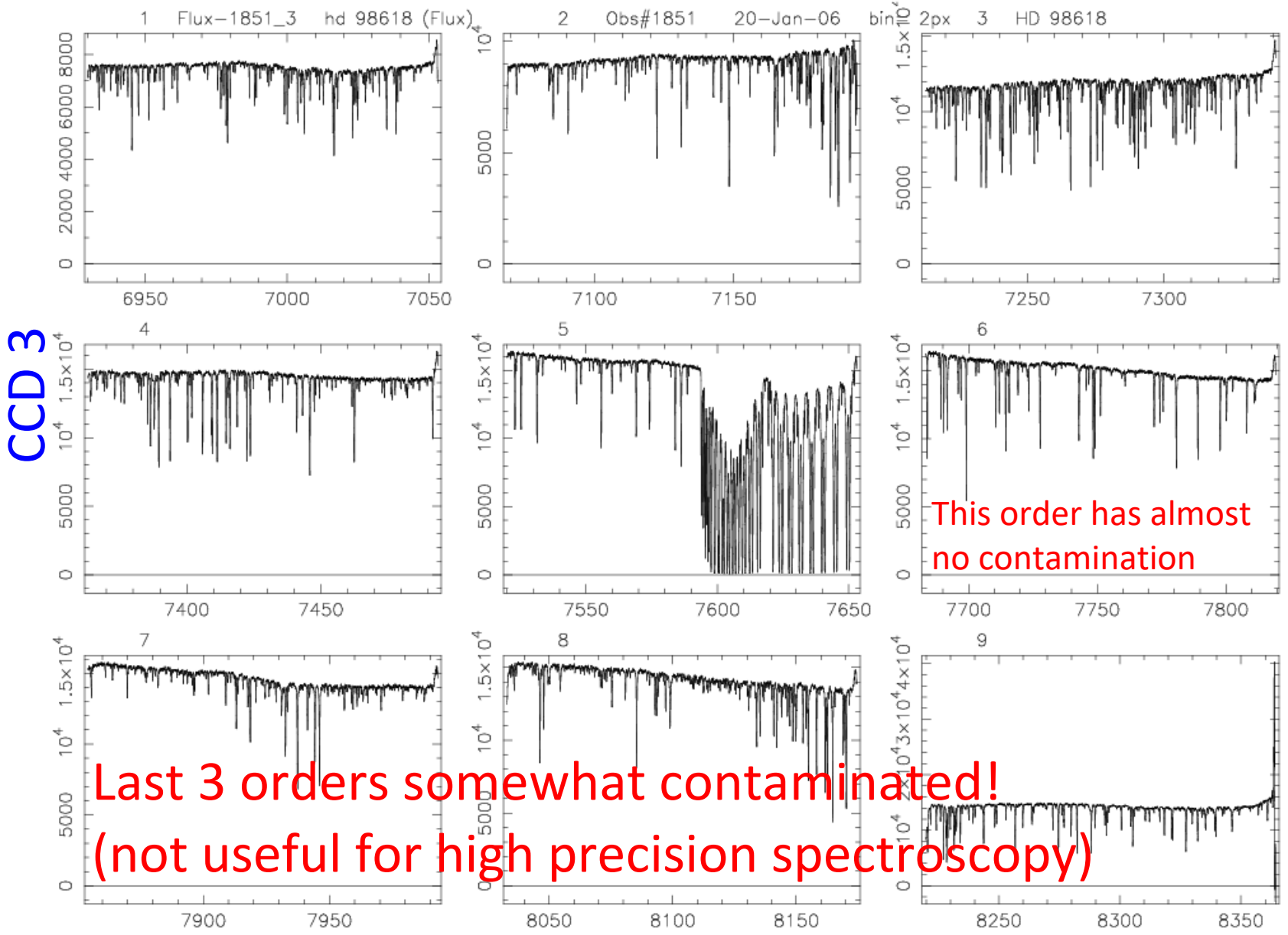
CCD 1 (some orders missing)

Wavelength (A)

MAKEE hires pipeline (automatic reduction)



MAKEE hires pipeline (automatic reduction)



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- **FIL1NAME= 'kv389 '**

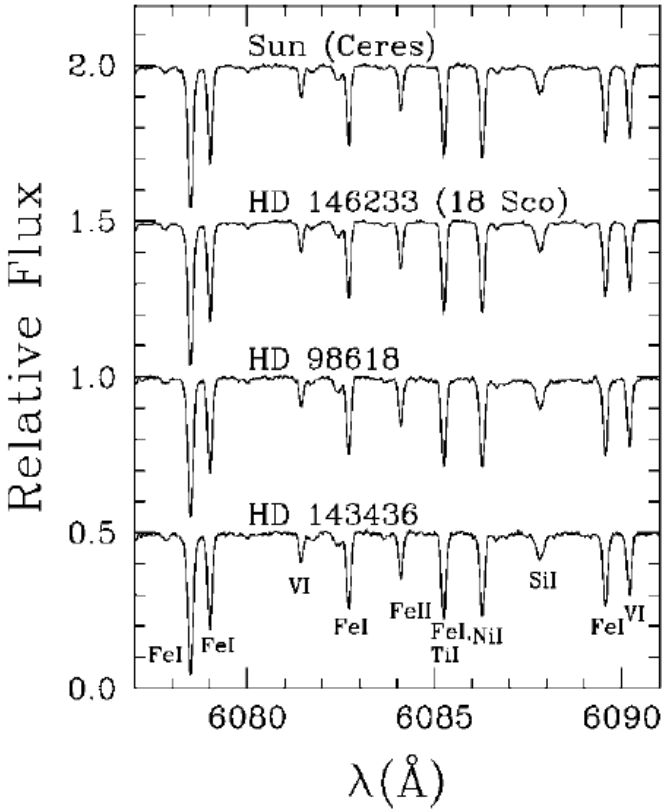
Finding solar twins: project of Summer Scholar at Stromlo Observatory (Australian National University), 12/2015 – 2/2016

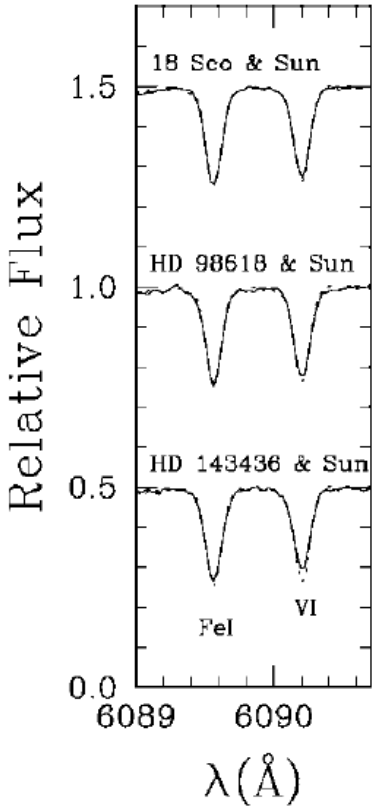
Katie Dodds Eden (Summer Scholar, Iniciação Científica durante o verão)

THE ASTROPHYSICAL JOURNAL, 641:L133–L136, 2006 April 20

HD 98618: A STAR CLOSELY RESEMBLING OUR SUN[1]

JORGE MELÉNDEZ,[2] KATIE DODDS-EDEN, AND JOSÉ A. ROBLES
Research School of Astronomy and Astrophysics, Mount Stromlo Observatory, Cotter Road, Weston Creek, ACT 2611, Australia; jorge@mso.anu.edu.au, katie@mso.anu.edu.au, josan@mso.anu.edu.au
Received 2006 February 13; accepted 2006 March 6; published 2006 March 30





- Observations done on 20/1/2006
- Letter submitted on 13/2/2006
- Accepted 6/3/2006

HD 98618: Highlights in the media

A Solar Twin in th

By Ken Croswell

March 10, 2006

A yellow star in the Big Dipper's bo
scientists search the star for signs of

Solar twins are stars with the same
more light than the typical star in th
extraterrestrial intelligence.

Jorge Meléndez, Katie Dodds-E
high-resolution spectra of HD 9
126 light-years from Earth, almo

http://www.20minutos.es/noticia/107450/0/sol/estrella/astronomos/

Astrónomos australianos descubren una estrella idéntica al Sol

Se llama HD98618 y es prácticamente idéntica al Sol: tiene su misma edad, su mismo tamaño, su misma temperatura y su misma composición, según los científicos de la Escuela de Astronomía australiana.

Los expertos esperan que este hallazgo ayude a

El mellizo del
(Imagen: Web

WEEKLY | NEWS IDEAS INNOVATION

NewScientis

8 April 2006 No2546 Australia $6.50 (Inc.GST) New Zealand NZ$6.95 (Inc.GST) Print Post Approved 230009/00015

SUN'S TWIN IS STRONG CANDIDATE FOR LIFE

Astronomers have found a twin of the sun, the first such star to be spotted in a decade and only the second ever. They say that these stars are our best bets for finding Earth-like planets with life on them.

Jorge Meléndez, Katie Dodds-Eden and José Robles of Mount Stromlo Observatory near Canberra, Australia,

have roughly the same concentratio of heavy elements as the sun. These elements are crucial to the formation Earth-like planets and the emergence of life (www.arxiv.org/astro-ph/060321

Another cause for optimism is the absence of "hot Jupiters", massive gas giants orbiting close to each star whose gravity could destabilise the orbits of

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News Update

with Dave Reneke

New solar twin sheds light on twin Earth

Astronomers at the Australian National University (ANU) have discovered a nearby solar twin which may shed light on the search for Earth-like planets capable of supporting life.

and to the other closest Sun twin, a star known as 18 Scorpii, which was discovered a decade ago.

The spin-offs of this discovery are tantalising. Solar twins are ideal for the absolute calibration of astronomical measuring instruments. They can provide data useful in modelling the solar phenomena that may affect climate change and will help settle the argument about the uniqueness or otherwise of our Sun and Solar System.

With a number of sample stars to study, HD 98618 was one of the last on the list to be analysed. Team members were quite surprised when they discovered how it stood out from the other candidates along with 18 Scorpii. "It was very exciting – I had to blink twice to be sure I wasn't imagining it," Ms Dodds-Eden said.

The researchers made the discovery using the largest telescope in the world, the 10metre Keck I telescope on the summit of Hawaii's dormant Mauna Kea volcano. A paper detailing this amazing discovery is expected to be published shortly.

Source: ANU

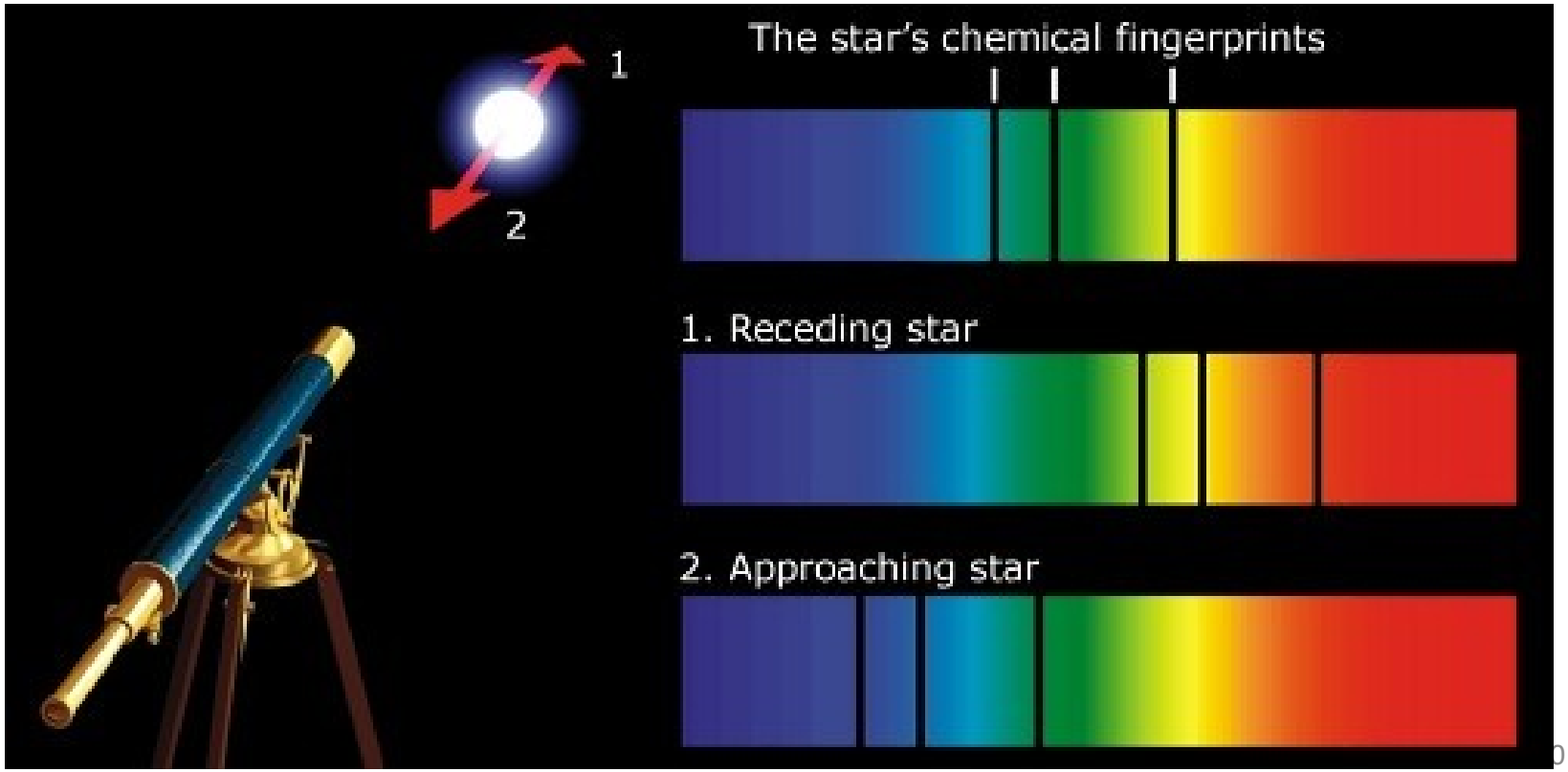
A colour-enhanced close-up around the newly discovered HD 98618, one of the most Sun-like stars

New 'earthly' planet found in our galaxy

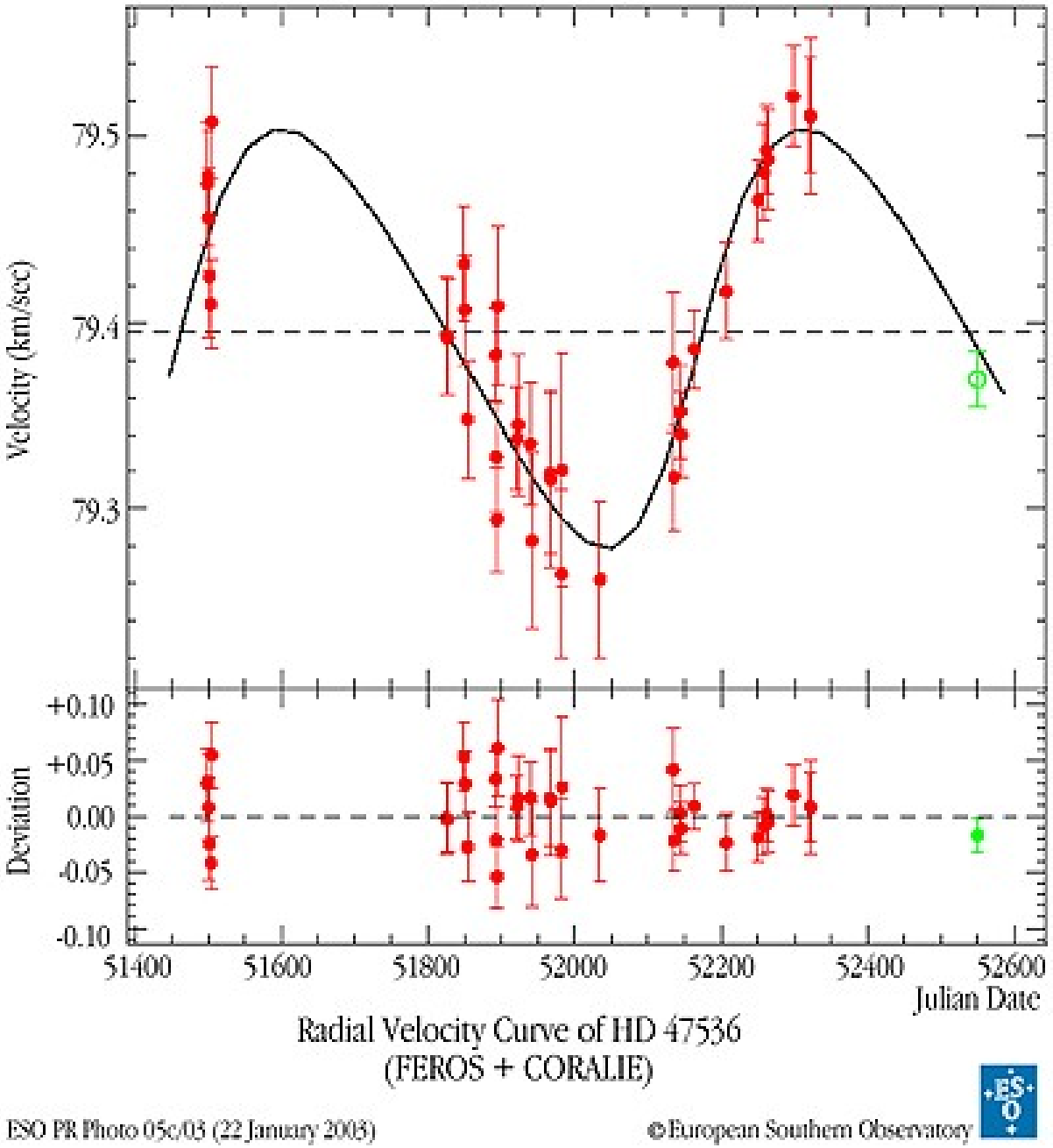
A ground-breaking discovery in the search for planets that may support life in our galaxy has been made by an international team of astronomers, with much critical data provided by

Radial velocity and planets

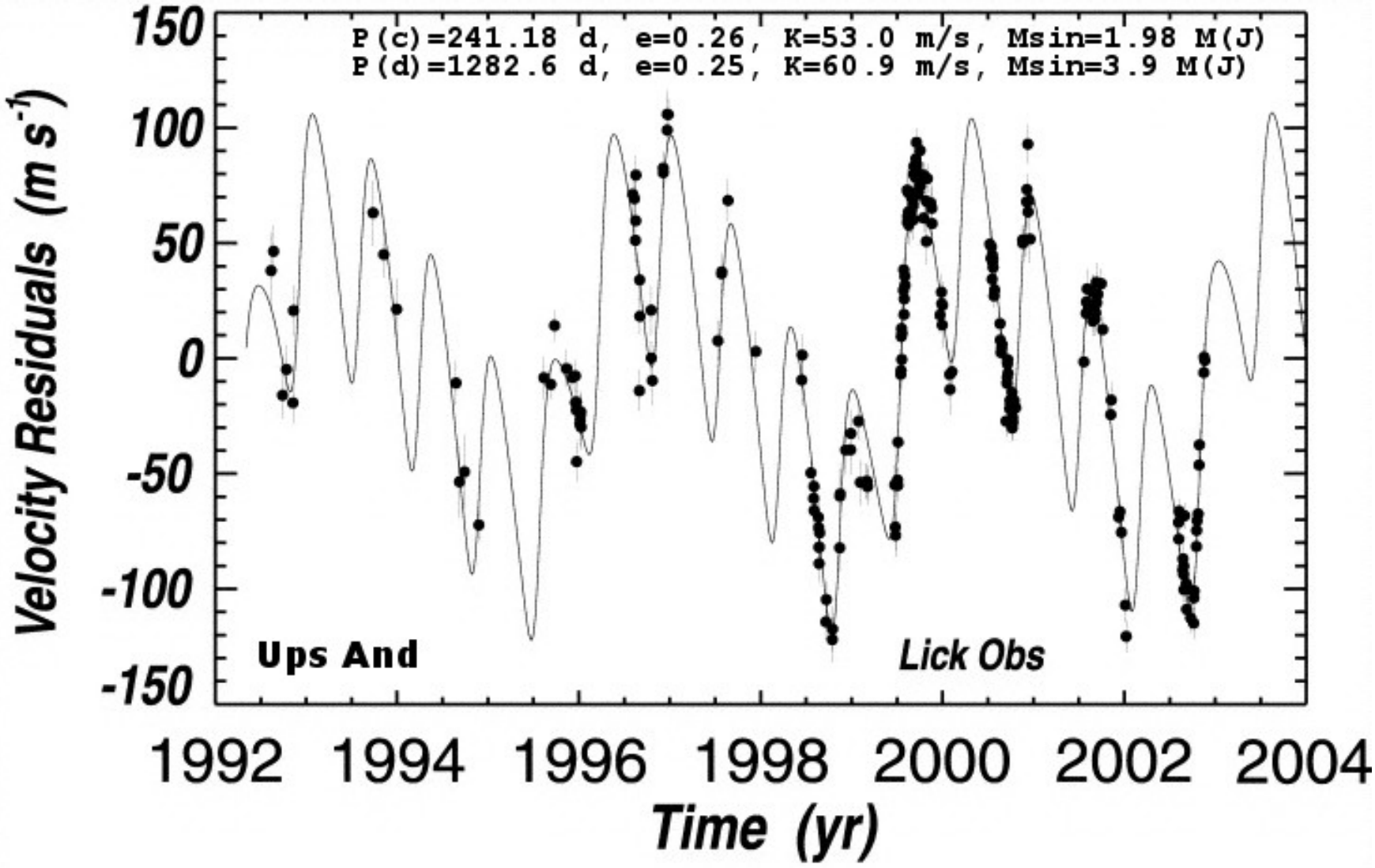
$$\frac{\lambda - \lambda_0}{\lambda_0} = \frac{\Delta\lambda}{\lambda_0} = \frac{v_R}{c}$$



Planet around HD 47536



Two planets around Ups And



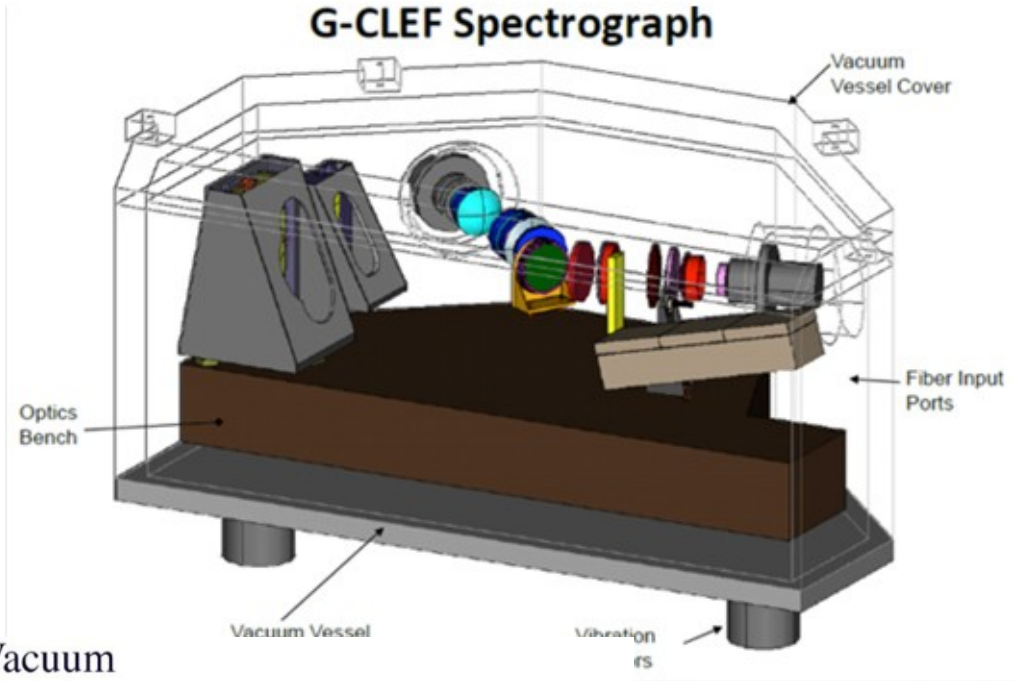
HARPS: High Accuracy Radial velocity Planet Searcher
at the 3,6m telescope at ESO La Silla

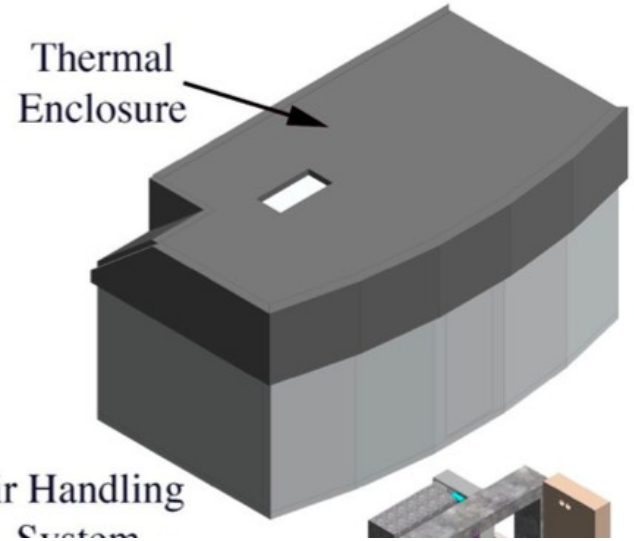
R = 115 000, coverage 378 – 691 nm
(68 orders using 2x4k CCDs)
Cross disperser: a grism
2 fibers: 1 for simultaneous ThAr arc
RV precision ~ 1 m/s
Vacuum and thermal enclosure (0.01K)

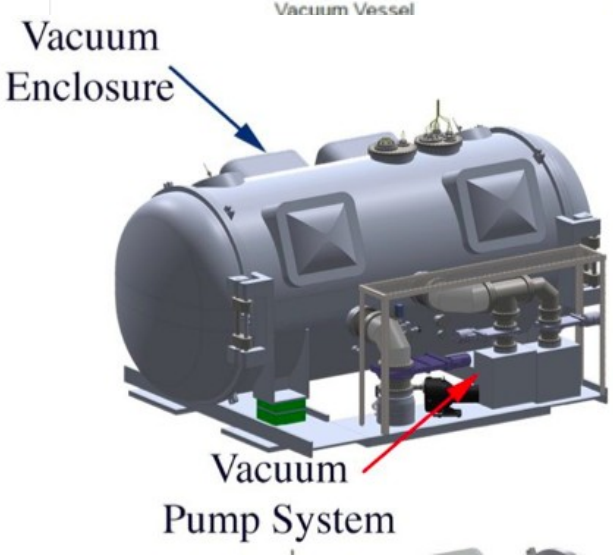
The GMT-Consortium Large Earth Finder (G-CLEF): An optical echelle spectrograph for the Giant Magellan Telescope (GMT)

Andrew Szentgyorgyi[a], Daniel Baldwin[a], Stuart Barnes[a], Jacob Bean[e], Sagi Ben-Ami[a], Patricia

Goal: 10 cm/s







HW #7: Musicos. Deadline June 8

Write 1,5 page (minimum) to 2 pages (maximum) overview of **musicos** in a "journalistic" style, meaning address the 6 most important questions or journalism. If on computer, use TimesRoman (or similar) font #12.

Portuguese or English is OK.

Who, What, Why, When, Where & How

Astron. Astrophys. 259, 711–719 (1992)

MUSICOS: a fiber-fed spectrograph for multi-site observations*

J. Baudrand and T. Böhm