Integration and alignment of FLECHAS

Fibre Linked ECHelle Astronomical Spectrograph



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Purposes of our presentation

- Summary of our spectrographs
- FLECHAS specifications
- Optical design
- Integration and alignment of the instrument
- Spectra acquisition
- Brief data reduction

Spectrographs:

- Ponchado (reflecting grating) 1994
- Fiasco (reflecting grating) 1997
- Loros (prisms) 2001
- Leches (échelle) 2002
- Besos (prism) 2003
- Ingratos (Grism) 2004
- Tragos (transmission grating) 2005
- Baches (échelle) 2005
- Dados (reflecting grating) 2006
- Pucheros (échelle) in preparation with UCC
- Flechas (échelle) 2009
- Next: Flechas++ (échelle)

Spectrographs: PONCHADO INGRATOS **FIASCO** BESOS **BACHES** DADOS **TRAGOS** LECHES

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FLECHAS requirements

- Medium resolving power (R: 7000-11000)
- Wavelength range: 395 nm 750 nm
- Mechanical stability (no flexures)
- Adapted to 1.2m telescope at F/10
- Off the shell optic and mechanic components
- No moving parts
- Simple and robust mechanical design
- Low maintenance

Features

- What drives the design of the spectrograph? :
 Échelle size !!
- Fibre link to the telescope
 - Small fibre core
 - Fibre works at low F/# to reduce focal ratio degradation
 - Mini and micro lenses to match telescope and spectrograph apertures
- Full parabolic mirror working as off-axis
- Transmission grating as X-disperser
- Photo-tele-objective to image the spectrum on CCD
- Large "unexpensive" CCD size.



Optical design

To the question: why 9° between the collimator and objective beams?

This "grating" angle should be as small as possible in order to approach the Littrow configuration where the efficiency is the maximum. In the FLECHAS case, we found that 9° was the best compromise between the size of the camera objective and the optical table.

Spectrograph

- Parabola
- Collimator beam
- Pupil

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- Échelle
- X-disperser
- Objective
- CCD Atik 11000

f 444 mm, ø 75 mm, Edmund Optics F/18 25 mm 79 li/mm 63° 25 50 9, Thorlabs 200 li/mm 10° 58 58 10, Newport f 200 F/2.8, Canon 4008 2672 9 μm (24 35)

Fibre link

- Telescope
 - > 1.2 m at F/10
 - Plate scale: 58.2 µm/arcsec
 - Pinhole: 150 µm = 2.6 arcsec
- Fibre 50 µm and 20 m long, Polymicro FBP
- Input lens

- GRIN f = 450 μ m, L = 1 mm, ø 0.5 mm, GrinTech
- Conversion beam
- Output lens
- "Slit"

- Doublet f = 5 mm, ø 3 mm, Linos
- ø 308 μm at F/18

F/10 to F/3 in fibre

Beam injection

We have use the principle to project the telescope pupil on the fibre input end





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Fibre transmission (internal) in 20 m. FLECHAS uses the FBP type





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Fibre Head



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This fibre link for a 30 cm Telescope

- Best match
- Plate scale
- Sky aperture
- 100 µm pinhole =>

Increasing resolution?

F/10 telescope
14.5 µm/arcsec
10.3 arcsec ! (150 µm pinhole)
F/3 in fibre: good FRD
6.9 arcsec, but the aperture into the fibre falls to F/4.5. The FRD is at the limit of acceptance
The output spot is 308 µm.
Need of an image slicer!

Steps to integration and alignment

- Setup of the 9° angle between collimator and Échelle
- Setup of the fibre-parabola optical axis
- Alignment of parabola with respect to the optical axis
- Installation of auto-collimator mirror
- Finding the parabola focus
- Alignment of the output fibre end
- Alignment of the Échelle
- Alignment of the objective and camera
- Alignment of the cross-disperser
- Installation of the enclosure
- Example of spectra and calibration data reduction

Set up of the optical table

300 mm





Definition of the 9° angle between collimator and Échelle





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Alignment of parabola by auto-collimation





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Definition of the parabola optical axis with a laser







adjust height of parabola with a paper mask and a hole in center

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Alignment of parabola





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Installation of auto-collimator mirror





Finding the parabola focus

inject laser in fibre. The output is projected to the parabola





The collimated beam is projected to the flat mirror, back to parabola, then

back to fibre. Focus is located where input and output coincide.

the projected laser beam will be

only reflected in these windows

Finding the parabola focus



the beam is reflected in flat mirror



test fibre is now in parabola focus



Alignment of the output fibre end

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Locate output fibre position.

set a microscope with reticule in front of test fibre

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center and focus in reticule the image of the output fibre



do not touch or move the fibre!!



Alignment of the output fibre end

the fibre support permits rotation In two axis...



to center a laser beam projected by output fibre (F/#=18.5)





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Alignment of the Échelle

install the echelle support next to fibre output.

Be careful not vignetting fibre output!!

use echelle to mark the second axis parallel to bread-board

rotate echelle until laser beam is projected against a paper screen



adjust rotation until projection is parallel to bread-board



Alignment of the objective and camera



on the objective



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Alignment of the cross-disperser



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Centring, rotation and focus of the spectrum







Focus

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Installation of the enclosure



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Handles to take it away !









Wavelength calibration

- With MIDAS (also available in Windows with Cygwin)
- Based in "SET CONTEXT/ECHELLE"
- Requires:
 - Spectrum of a halogen lamp for order identification
 - Spectrum of a thorium-argon lamp for line identification
 - An Atlas of a Thorium-Argon spectrum 400-900nm
- Provides:
 - Semi-automatic calibration: Two pair of lines are identified by hand, 1300 lines automatically
 - Resolving Power ($R = \lambda/\Delta\lambda$) calculated in 1000 lines
 - Order by order calibration and
 - it merges all orders in one continued spectrum

Orientation



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Spectrum repetition





Settings

Export

C Minimum

C Std. Dev.

Maximum

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Identifying orientation



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Identifying orientation



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Calibration data:

 Spectrum of an halogen lamp:

 Spectrum of a thoriumargon lamp:



Order identification

8,000000	
27.000000	
PE 000000	
8.000000	
5.000000	
24.000000	
3.000000	
2.000000	
1.000000	
0.000000	
9.000000	
8.000000	
7.000000	
6,000000	
5.000000	
4.000000	
5,000000 2,000000	
1.000000	
0,00000	
•000000	
1000000	
1000000	

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Th-Ar. how many lines? ~2000!



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First, manual line identification:



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Then, automatic line identification:

13 Ш . EI 2 + i i L DU П ШШ

~1300 lines identified!

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Tolerance in the identification



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Resolving Power (R= $\lambda/\Delta\lambda$)



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Spectrum of the Sun order by order



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Detailed spectrum of the Sun



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Optical efficiency

- Fibre link
- Parabola
- Échelle
- X-disperser
- Canon objective

60 % 90 % 50 % (including vignetting) 78 % 90 %

Total

49

19 %

Optical efficiency



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Optical efficiency

X-disperser Newport



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Improvements

- Image slicer to increase resolution (x1.8)
- CCD camera with higher QE (QSI?)
- Mechanical improvements
 - Échelle support with tilt
 - Fibre support with height adjustment
 - Smaller and light tightness enclosure

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Image slicer









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Image slicer









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Alignment verification after transport



when aligned, the laser should hit the parabola in its center



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when aligned, the reflected laser should always hit the same reference point.

Alignment verification after transport

fix a flat mirror in its support. It has been previously aligned for auto-collimation





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Mechanical parts



Mechanical parts



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Mechanical parts



Mechanical parts





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Mechanical parts



- Thank you for your patience and attention !
- CAOS web page:

spectroscopy.wordpress.com

• ASTELCO web page:

http://www.astelco.com/