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Narrow-band photometry of meteors

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Final year research project , under the supervision of Profs. Jaime Zamorano & Jesús Gallego

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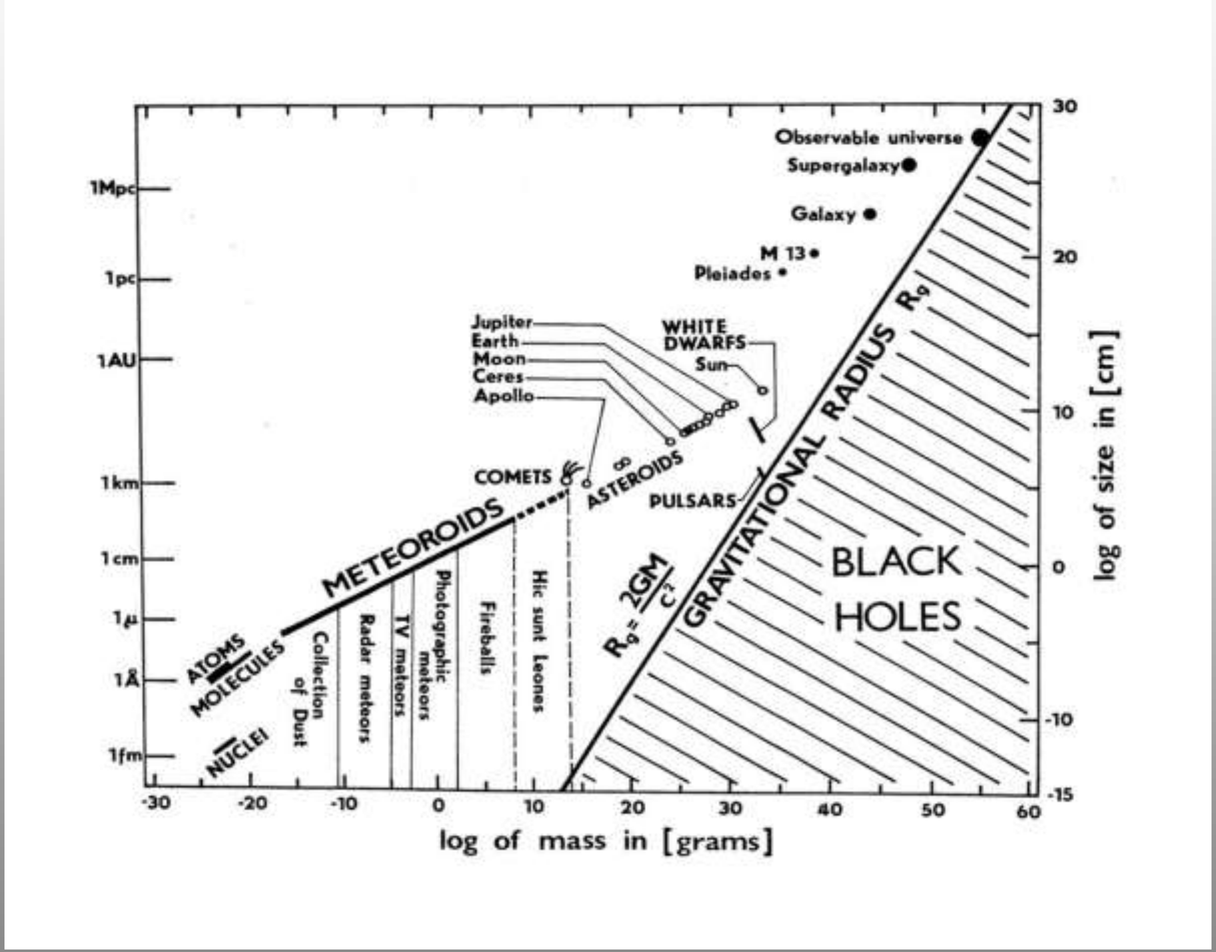
1.- Introduction

- Meteoroids, meteors and fireballs.
- UCM Fireball and Meteor Detection Station (node of the SPMN)
- Light Pollution at the UCM Observatory



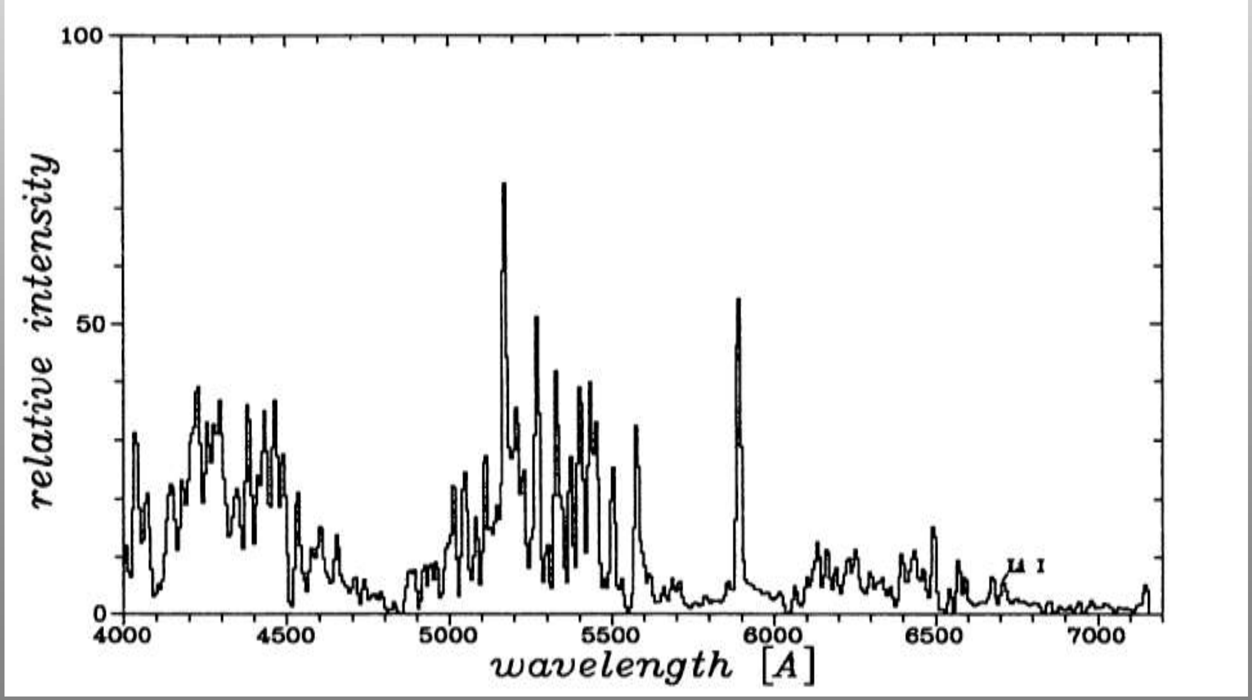
2.- Objectives of the research project

- Optimization of meteor detecion
  studying geometry and emission properties.
- Feasibility study of the narrow-band meteor photometry.
- Design a photometric system
  to maximize the scientific output.
- Prove the theoretical study
  developing an experimental setup.

3.- Theory of meteors' radiation emission

- Meteors radiation emission
  - Chemical and thermal emission
  - Optically thick

$$I_\nu = B_\nu(1 - e^{-\tau_\nu})$$



Model

(T, N, Γ parameters)

Calculation of the 3 parameters by fitting intensities I_ν

Theory of meteors' radiation emission

- Abundances and intensities determination
  - Calculating I_ν $$\Im_\lambda = P I_\lambda$$
  - Spectroscopy $$\Im_\lambda = \Im_0 e^{\frac{-(\lambda-\lambda_0)}{\Delta^2}}$$

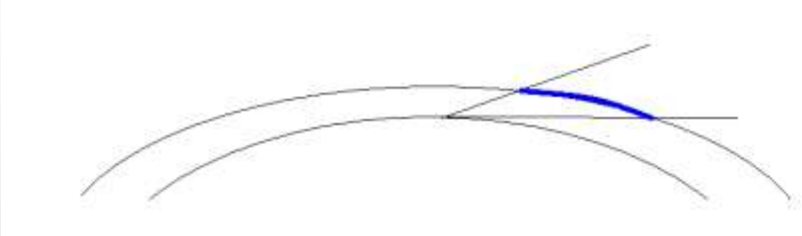
$$\Im = \int Im_\lambda \, d\lambda = \pi^{1/2} \Delta \Im_0$$

- Result
  - Main component: (4300±300)K to (7800±500)K
  - Hot component: (10000±1000)K to (14500±1000)K

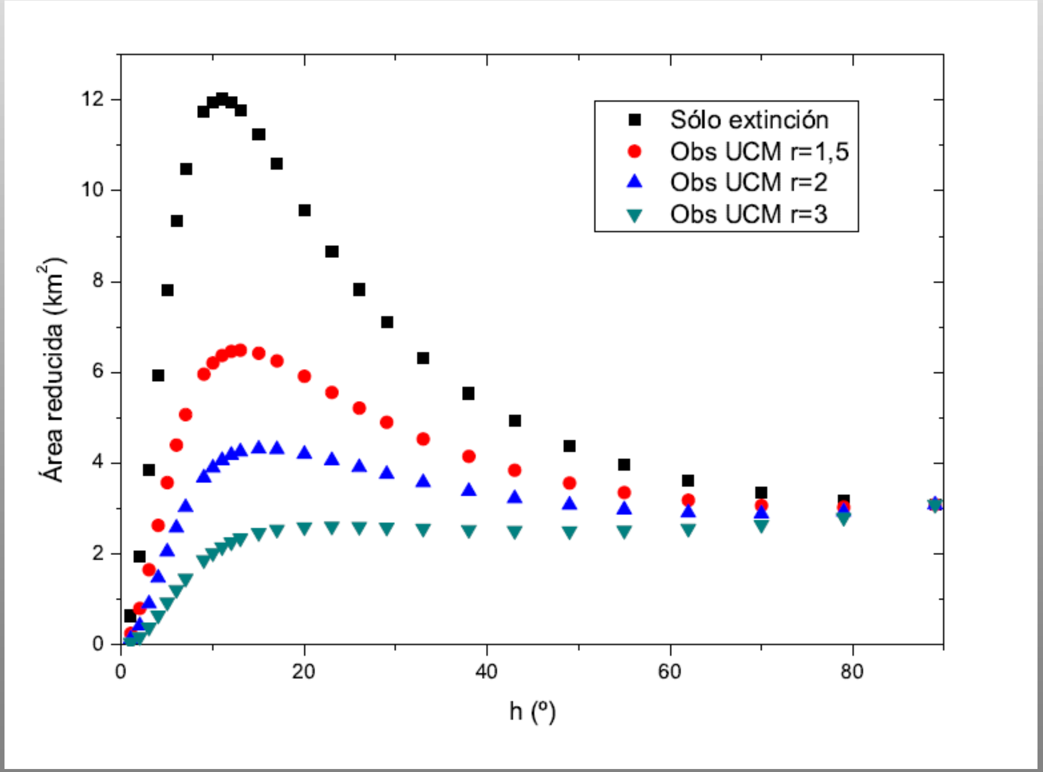
    (intensity very sensitive to speed)

4.- Detection Optimization

Effectivity: Reduced Area



$$A_{red} = \sum_i A_i \cdot r^{5\log\frac{H}{d_i} - \varepsilon_i - \delta_i}$$

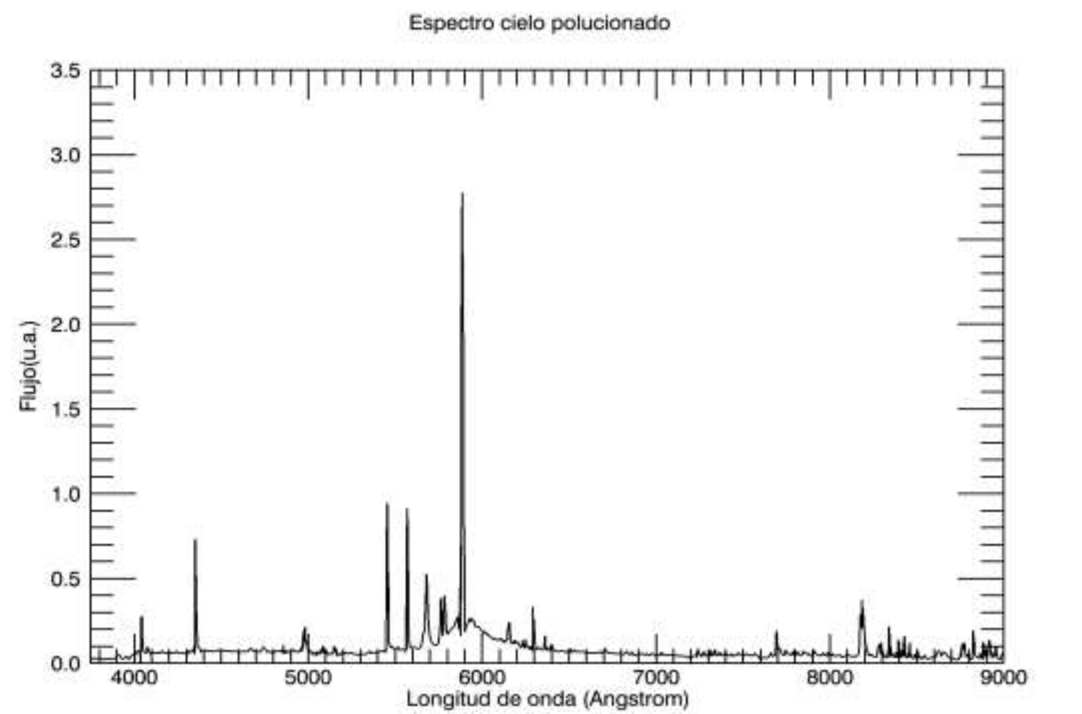


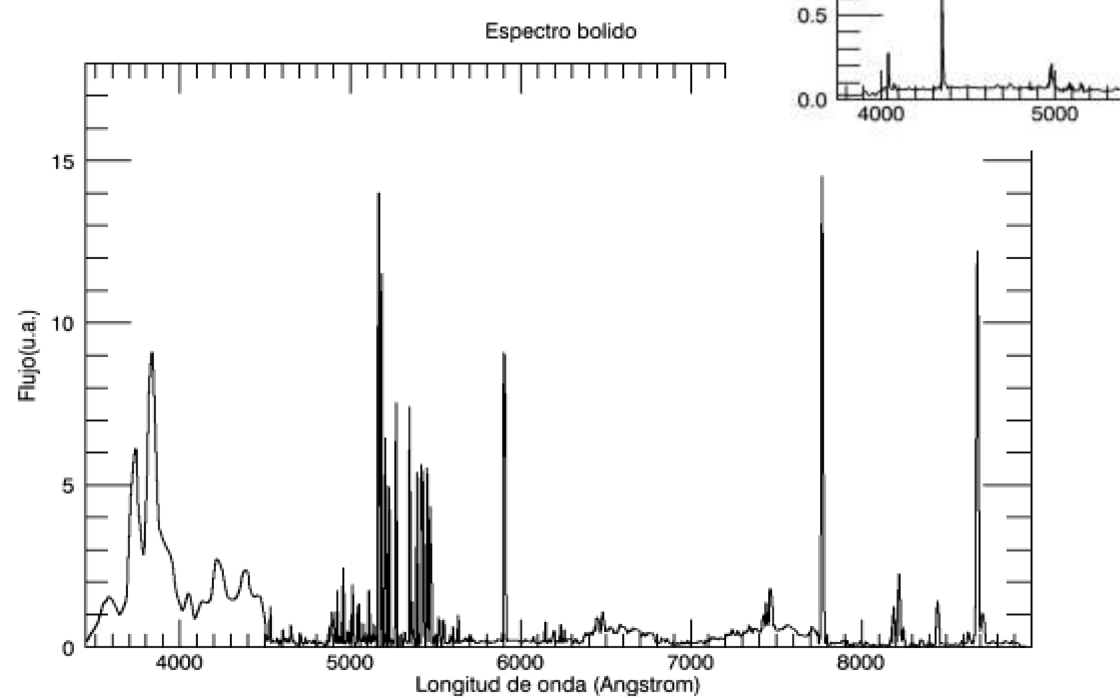
Equivalent area
is directly proportional to
the number of detections.

Light pollution
shifts the position
of the optimal pointing.

Contrast

The dynamic range is reduced due to the presence of light pollution



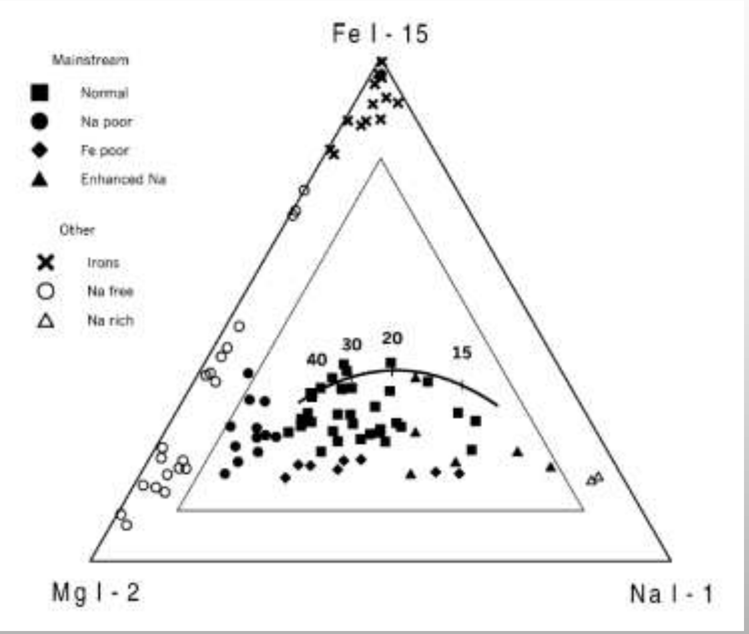


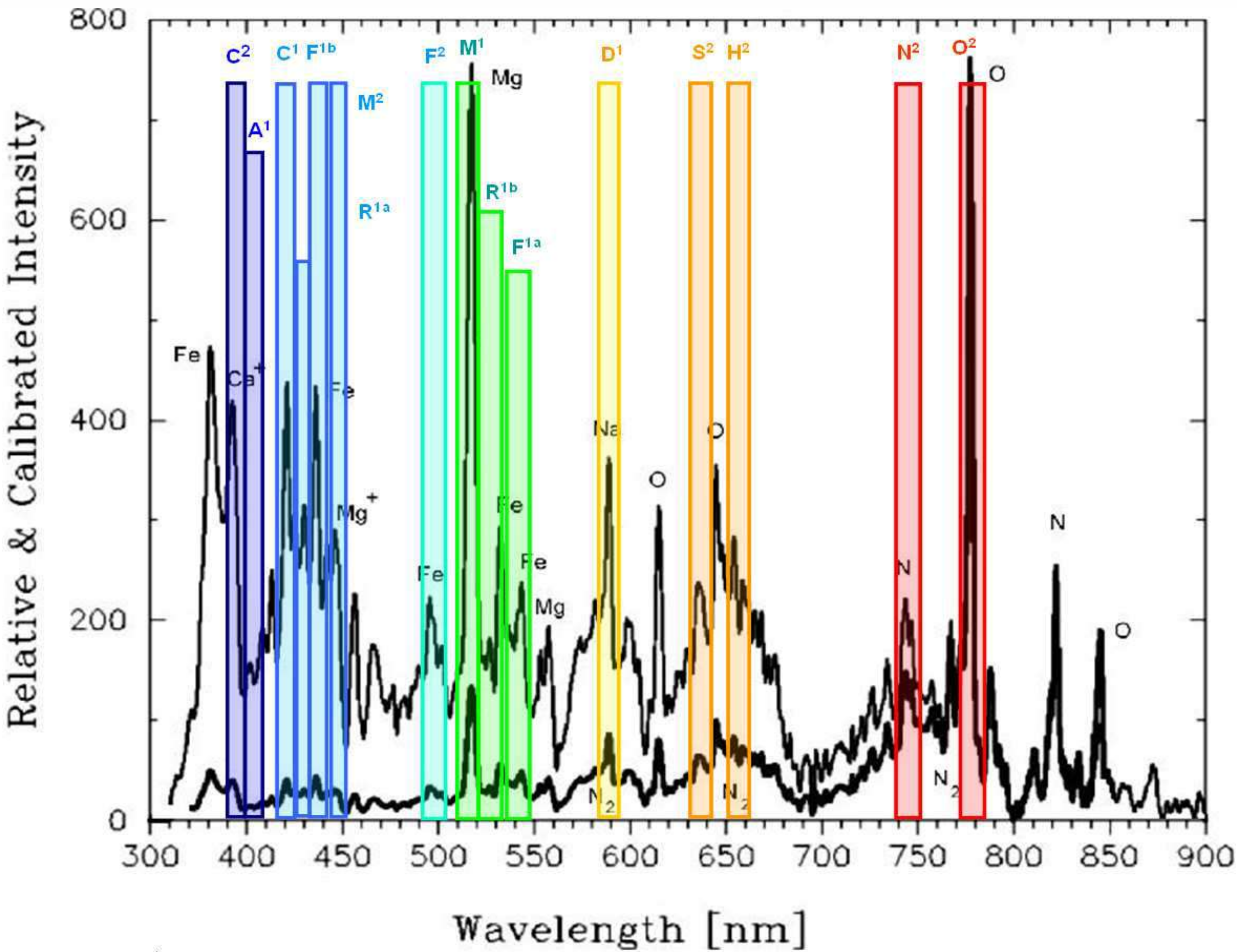
Very different emission features

Use of filters

5.- Narrow-band meteor photometry

- Emission and continuum measures
- Measuring at least
  Ca, Cr, Fe, Mg, Mn, N, Na y Si
- System reffered to N_{Fe}
- Optical range (H&K CaII – 800nm)
- Hot and main components
- Filter bandwidth~10nm → R~50
- Elements with different excitation states
- Cost of the setup is proportional to the number of bands → modular





Relative & Calibrated Intensity
Wavelength [nm]
800
600
400
200
0
300
350
400
450
500
550
600
650
700
750
800
850
900
C2
A1
C1
F1b
M2
R1a
F2
M1
Mg
R1b
F1a
D1
S2
H2
N2
O2
O
Fe
Ca+
Fe
Mg+
Fe
Fe
Fe
Mg
Na
O
O
N
N
O
N2
N2
N2

Filtro	Características				Comentarios
	$\lambda_{central}\,(nm)$	Ancho (nm)	1ª Componente	2ª Componente	
C^2	395,0	7	CaII(1) y otras débiles	CaII(1)	
A^1	403,0	8	MnI(2)+FeI(43)		
C^1	420,5	8	CaI(2)+FeI(varios)		
R^{1a}	427,0	5	CrI(1)+FeI(152)		Banda estrecha para evitar líneas próximas
F^{1b}	437,0	11	FeI(2)+FeI(41)		
M^2	448,0	8		MgII(4)	
F^2	497,0	12	FeI(318)	FeII(42)	
M^1	515,0	9	MgI(2)+FeI(37)+CrI(7)		
R^{1b}	524,5	10	CrI(18)+FeI(varios)		
F^{1a}	541,5	10	FeI(15)		
D^1	589,5	10	NaI(1)		Línea D del NaI
S^2	636,0	12		SiII(2)	
H^2	657,0	12		HI(1)	Línea $H\alpha$
N^2	744,0	16		NI(3)	
O^2	777,0	15		OI(1)	
B^b	475,0	8			componente 'Black body' zona azul
B^{FeO}	580,0	10			máximo bandas FeO $(\nu', \nu'') = (7,3); (6,2)$
B^r	605,0	12			banda N_2^+, FeO en la zona roja
B^m	700,0	15			máximo 'Black body'

Spectroscopy vs. Narrow-band photometry

- Photometry automatization
- Larger efficiency, similar in all the bands
- No orders´ overlap
- Individual fitting for each emission line/group

6.- Theoretical development: simulation

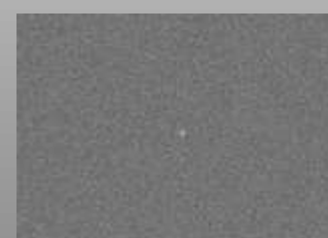
- Input: convoluted spectra using detector QE

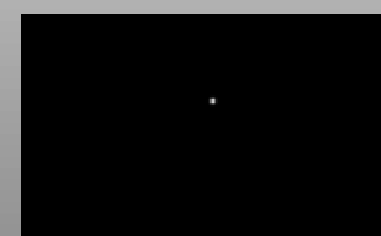
$$F_{sky} = \int_{365\,nm}^{900\,nm} F_{sky,\lambda}\, d_{\lambda} \qquad F_{obj} = \int_{365\,nm}^{900\,nm} F_{obj,\lambda}\, d_{\lambda}$$

- Filter simulation width=λ_2- λ_1

$$F_{sky} = \int_{\lambda_1}^{\lambda_2} F_{sky,\lambda}\, d_{\lambda} \qquad F_{obj} = \int_{\lambda_1}^{\lambda_2} F_{obj,\lambda}\, d_{\lambda}$$

- Simulated data pipeline

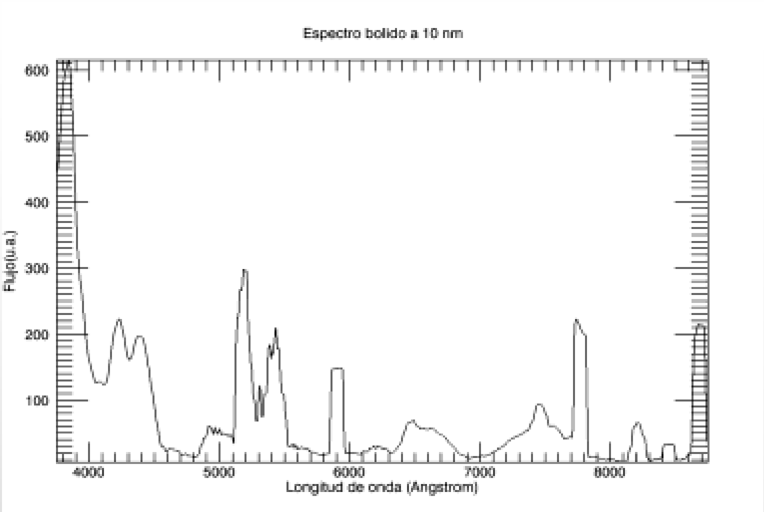


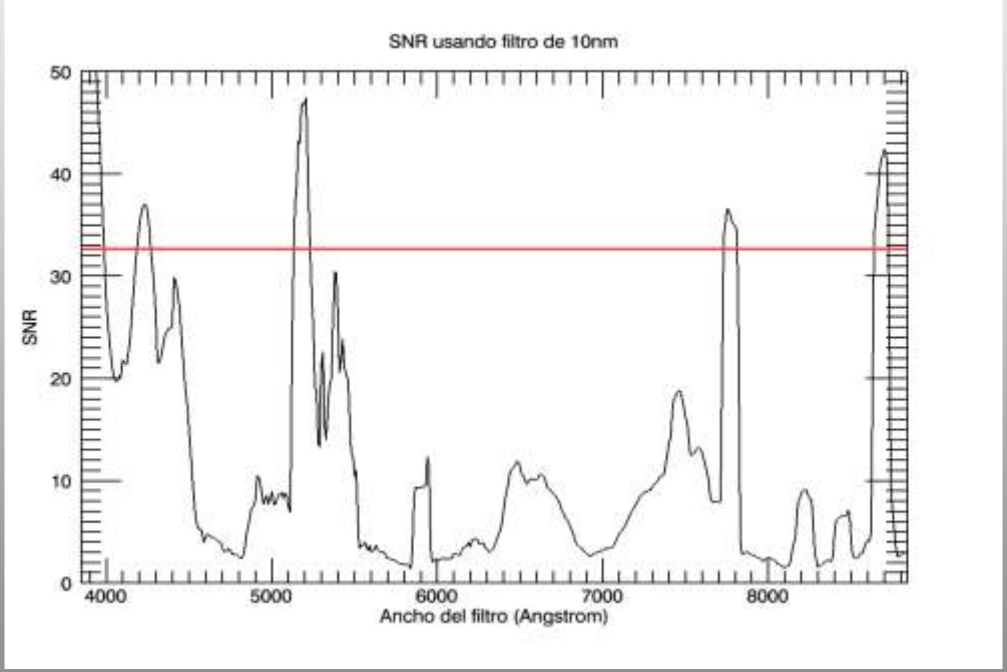


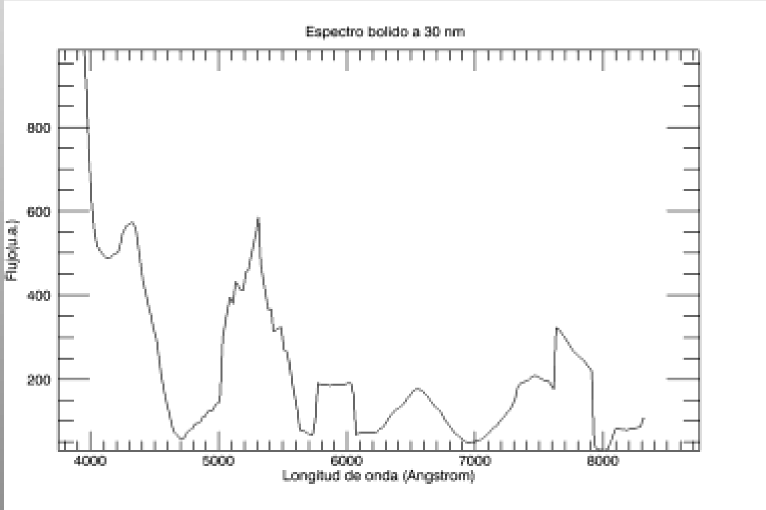
- Signal-to-noise determination

$$SNR = \frac{N_o}{\sqrt{\frac{1}{g}(N_o + A \cdot n_s) + A\frac{R^2}{g^2}}}$$

Selected Width ~10nm

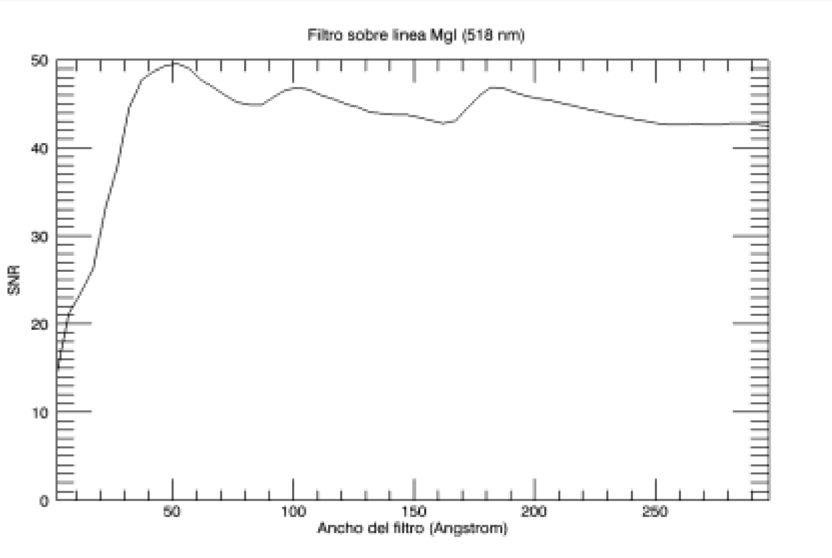


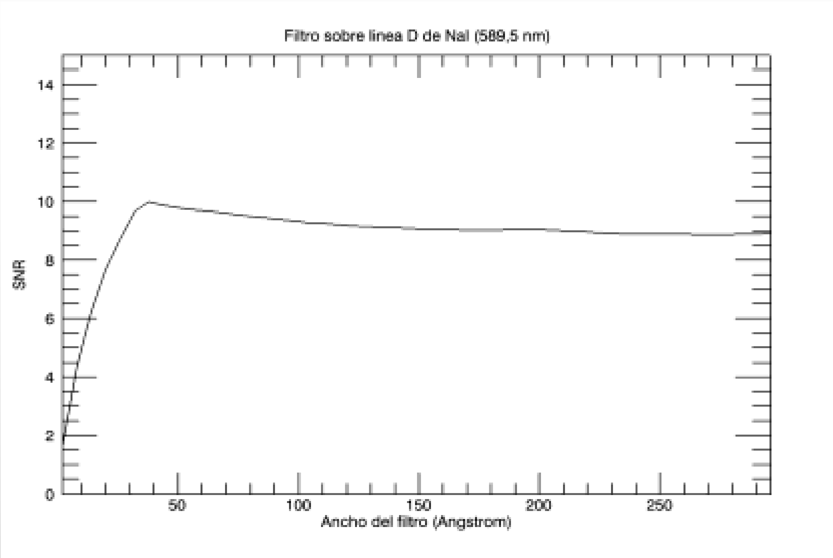




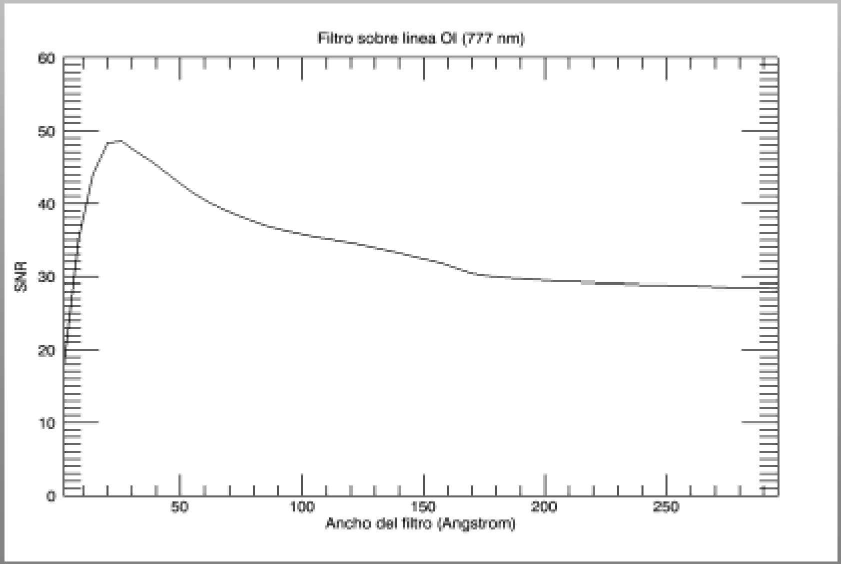
Compromise between the lines flux and resolution

- Doublets and multiplets





- Light pollution effect



7.- Experimental development

Ref.	Características			
	λ	ancho	líneas	transmitancia
#65616	$394\,nm$	$10\,nm$	H&K CaII	>0.3
#65623	$436\,nm$	$10\,nm$	FeI(varios)	>0.4
#65638	$515\,nm$	$10\,nm$	MgI(2)+ FeI(37)+ CrI(7)	>0.45
#65647	$589\,nm$	$10\,nm$	D NaI	>0.45

- Interference filters: angle of incidence

$$\lambda_{eff} = \lambda_0 \cdot \left(1 - \frac{\beta^2}{4n^2}\right)$$

$$sin\beta \sim \frac{1}{2N_0}$$

- New magnitude limit of the system

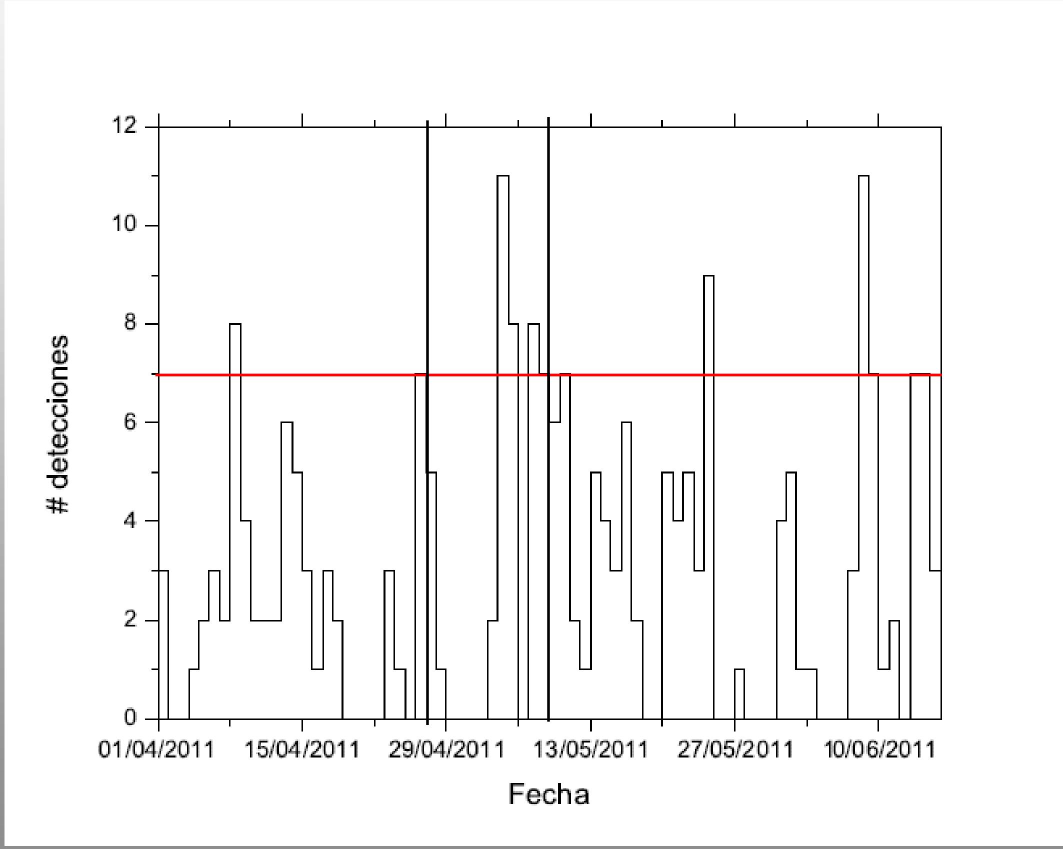
$$\alpha = \frac{\int_{365\,nm}^{900\,nm} F_{obj,\lambda}\, d_\lambda}{\int_{\lambda_1}^{\lambda_2} F_{obj,\lambda}\, d_\lambda}$$

$$M_{det,515\,nm} = M_{det,clear} - 2,5 \cdot log\alpha$$

Observations

- 2 all-sky cameras (28/04 - 08/05)
  - No filter
  - MgI 518 nm

- 3 cameras 60º x 40º (09/05 -)
  - No filter
  - MgI 518 nm
  - FeI 436 nm



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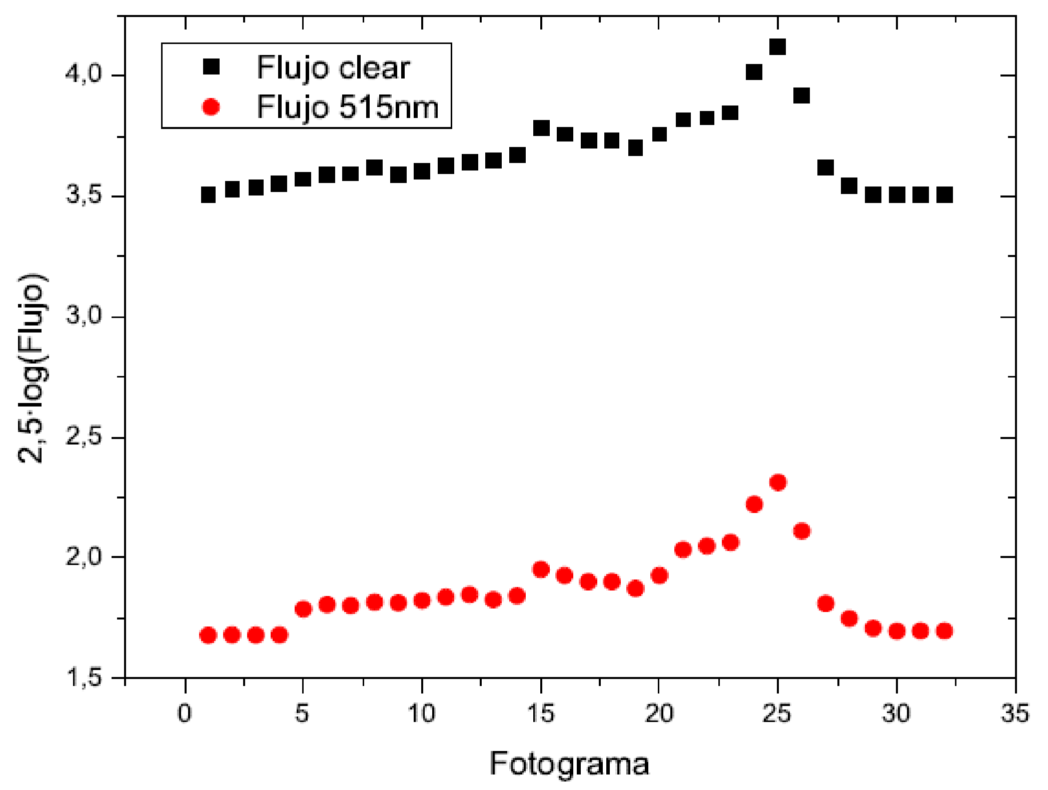

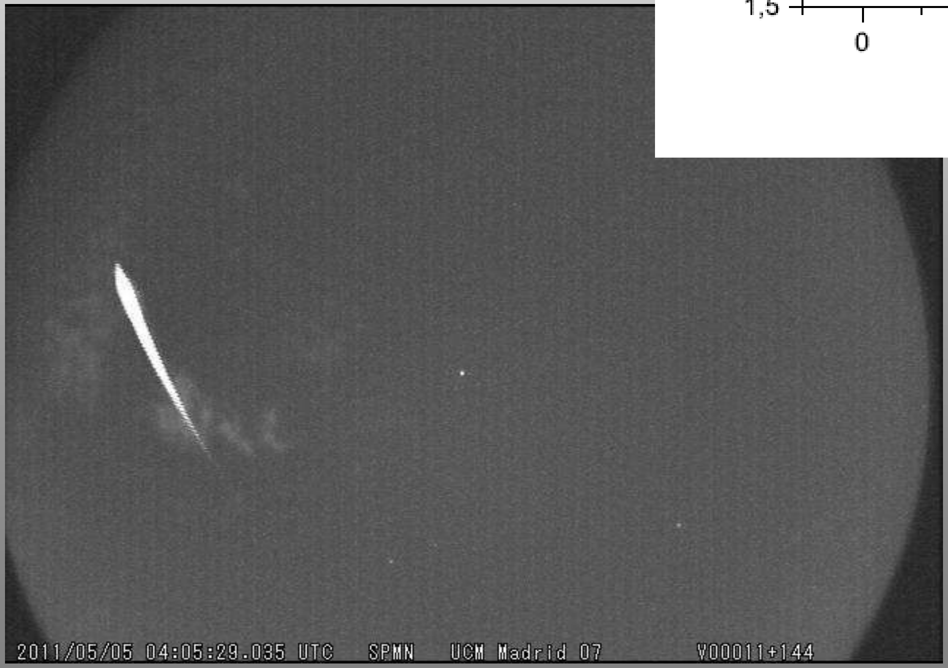

04:05:29 TU

Eta-Acuarid -7

Detected by several SPMN stations

8.- Results and conclusions

- Light pollution modifies the optimal pointing, and reduces the detecion capability of the system.
- The use of photometric filters improves the detection of fireballs in certain bands (better SNR than without filters).
- We propose the use of a narrow-band photometric system, R~50, suitable for many scientific cases.
- The experimental setup, based on the system here proposed and the theoretical simulation, is working at Observatorio UCM, and has detected several events.
- Future improvements: to increase the dynamic range to cover the whole lightcurve of the fireballs and the use of professional filters.

10 Sept 2011 – 04:46 TU AllSky Camera (Nikon D60 + Peleng 8mm)

AllSky video camera
No filter


Video 72 x 54 deg
518nm MgII
2011/09/10 04:46:09.0 1010
V00010+061 UFOCaptureV2


Video 72 x 54 deg
436nm FeI
2011/09/10 04:46:09.3 0561
V00002+042 UFOCaptureV2