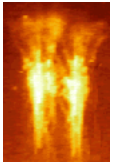




ISUAL



Global TLE observations with ISUAL

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Takahashi³, T. Adachi³, L.-C. Lee⁴

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² Physics Dept., National Cheng Kung Univ., Tainan, Taiwan

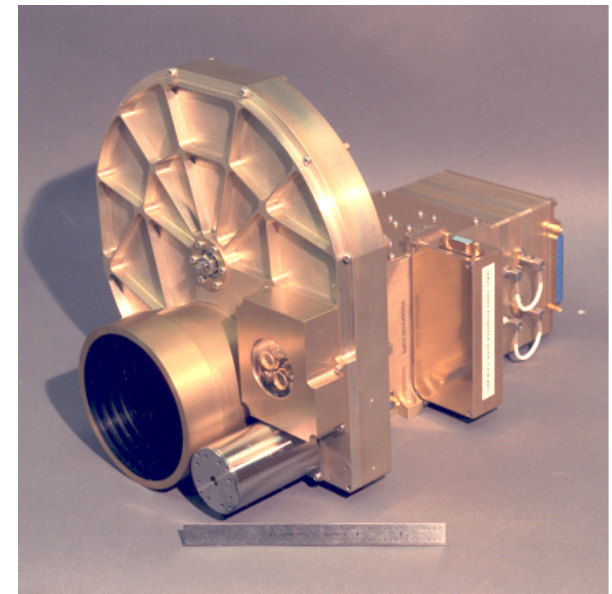
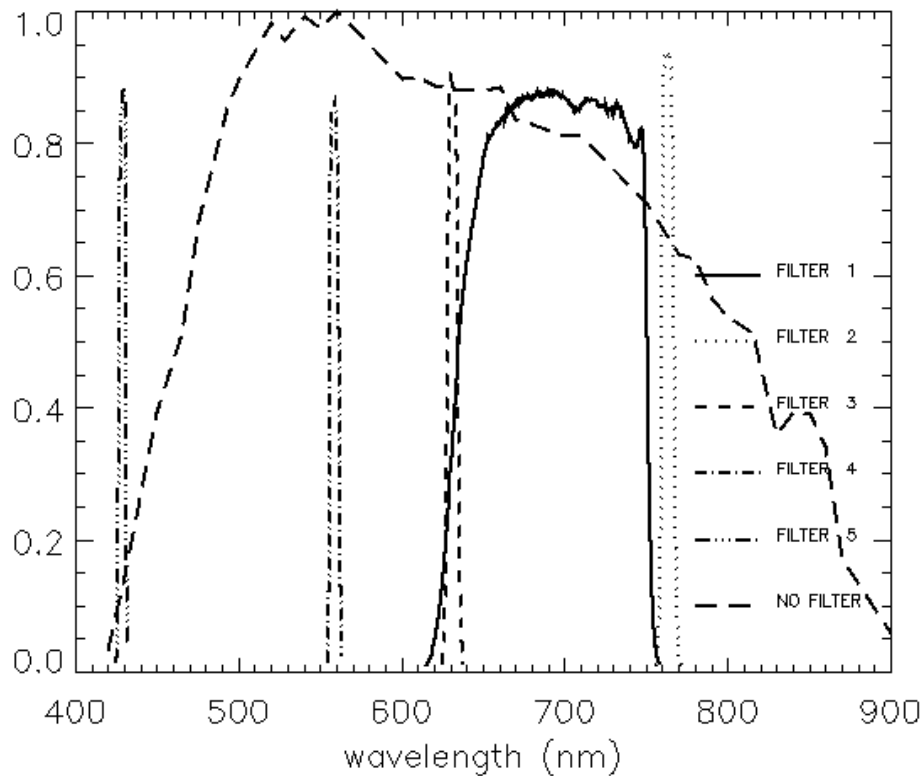
⁴ Dept. Geophysics, Tohoku Univ., Sendai, Japan

³ National Applied Research Lab., Taipei, Taiwan

Presented at Berkeley Special Seminar, Berkeley, February 15, 2005



ISUAL imager



Intensified, cooled CCD
with gating and gain
adjustment through MCP
high voltage. 1-1400
msec integration

Filter wheel: 1 - N_2 1P

2 - 762 nm $O_2(0,0)$

Filters can be
selected by moving
filter wheel. Filter
profiles are shown
above.

3 - 427.8 nm N_2^+ 1N (0,1)

4 - 630 nm OI

5 - 557.7 nm OI

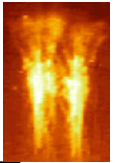
6 - open



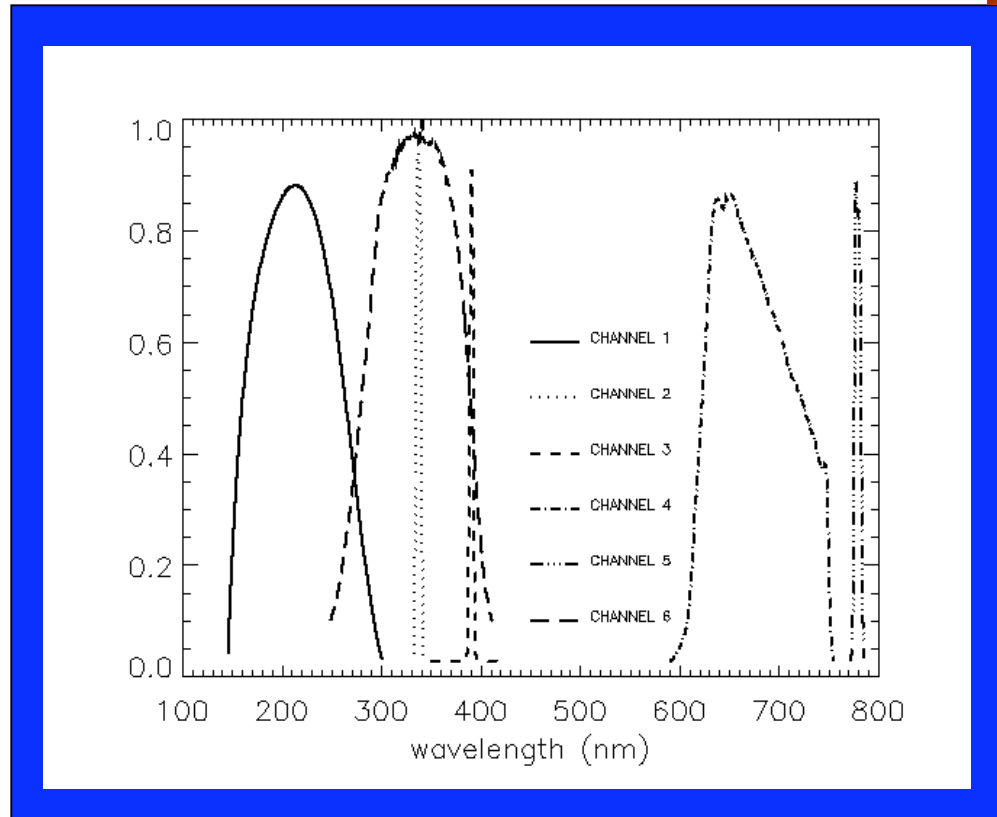
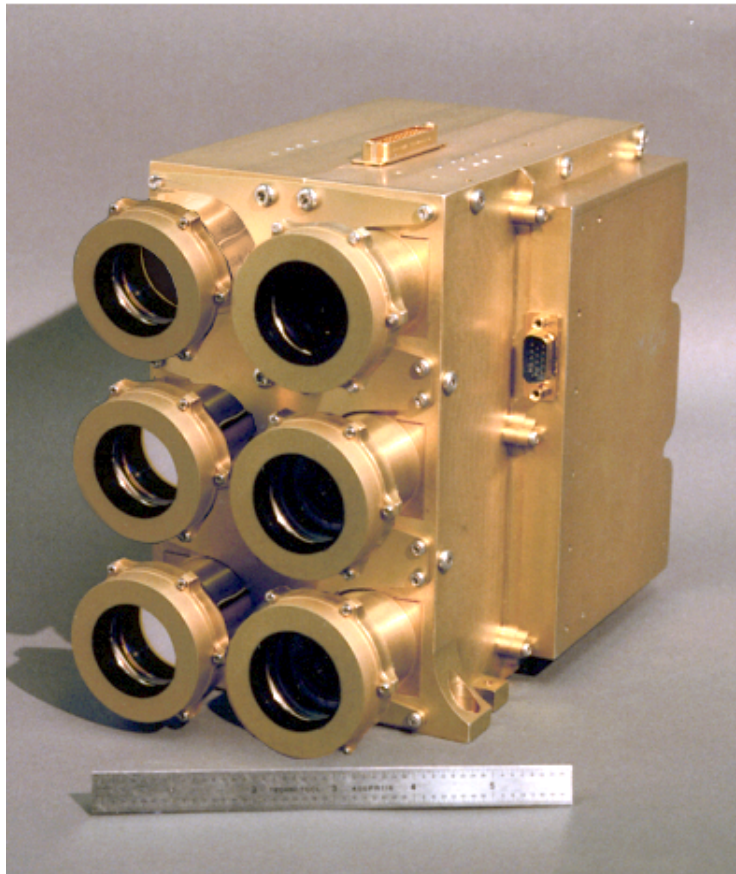
Spectrophotometer

6 parallel channels. Filter profiles more correctly the responsivities are shown below for each channel.

ISUAL



**6 similar photomultiplier tubes
integrate over 6x20 degrees
10 kHz sampling
rapid increase in output is used
as trigger for imager and AP**



	N2, 1P	N2, 2P	N2, LBH	N2+, Meinel	N2+, 1N
#1, 180-310			17%		
#2, 337		27.80%			0.80%
#3, 391.4					66%
#4, 608-753	11%			4.60%	
#5, 777.4	2.60%				
#6, 228-410		84%			37%

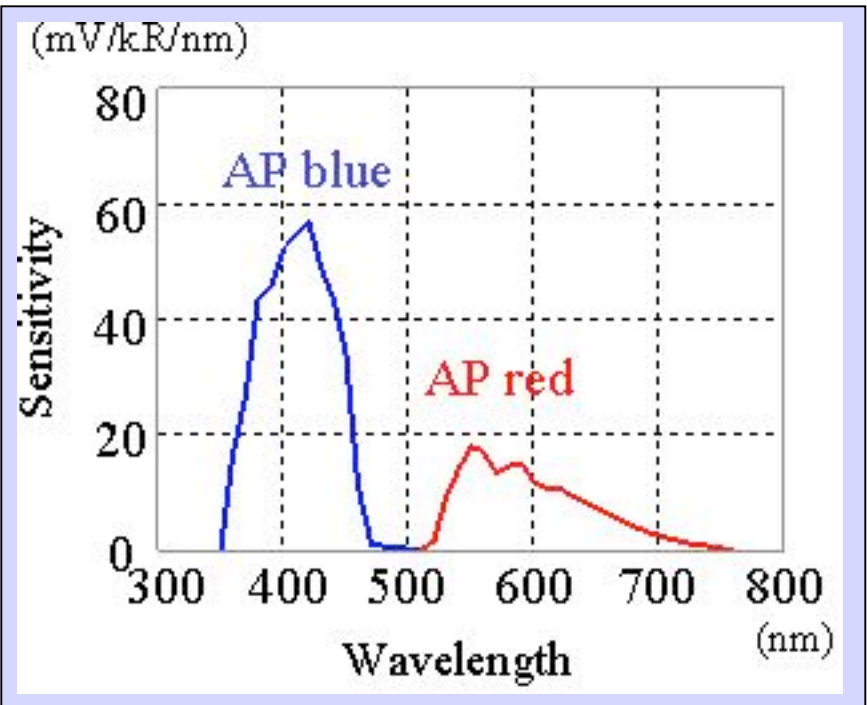
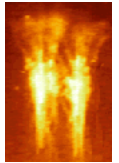
Each filter contains this many percent of the entire bands shown in the first row.



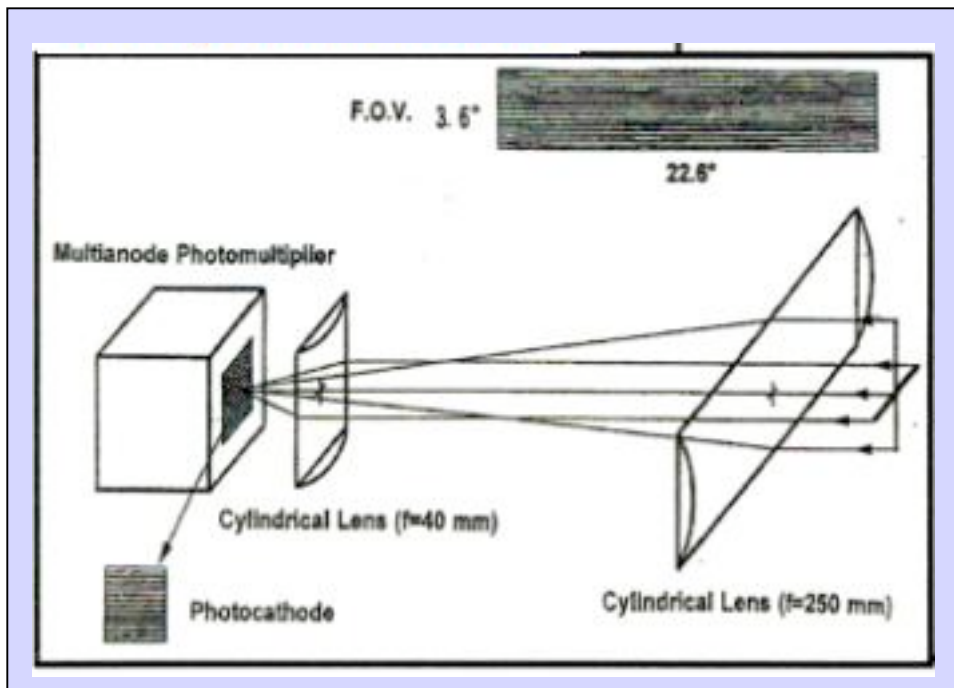
Array Photometer

Array Photometer was built by Tohoku U in Japan.

ISUAL

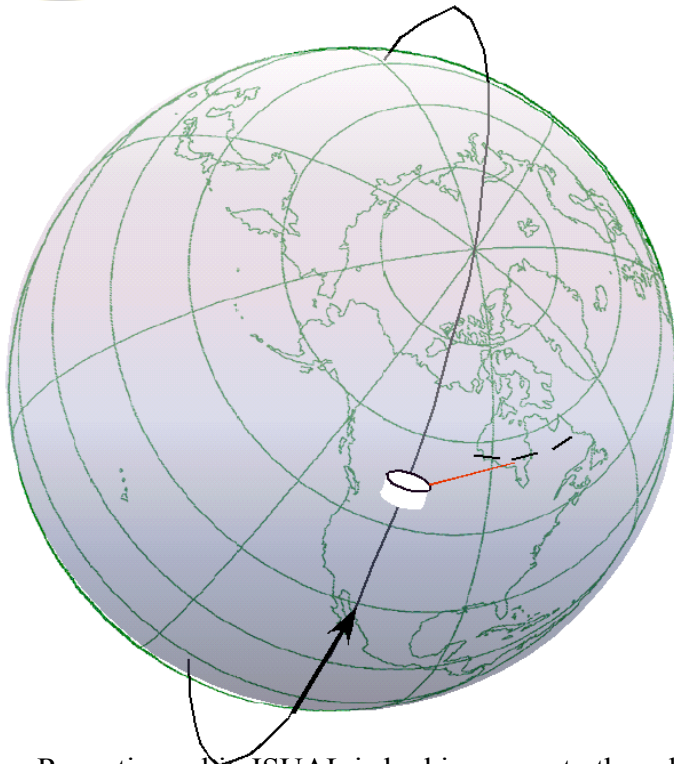


**2 photometers for N₂ 1P and N₂ 2P
integrate over 16 horizontal channels
for altitude information
2 or 20 kHz sampling**



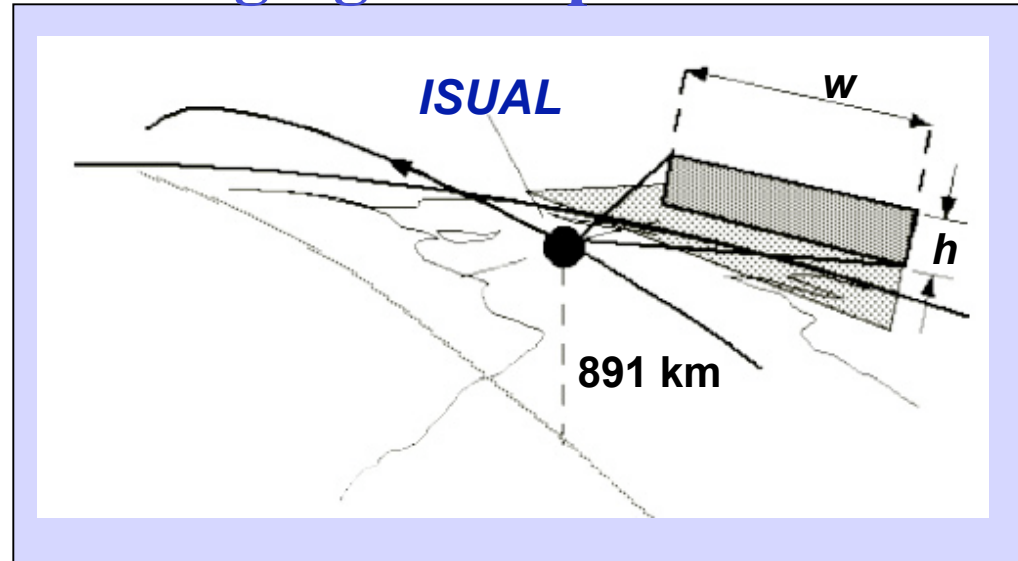


ISUAL TLE imaging concept



Repeating orbit. ISUAL is looking perp. to the orbit plane on the starboard side.

This is the normal orientation of the satellite. By yawing the satellite other configurations can be used.

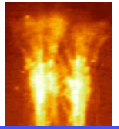


ISUAL views perpendicular to orbit
Orbit altitude 891 km. FOV
~ 20° x 5° Observes region
at about 2300 LT 1-8 image
frames

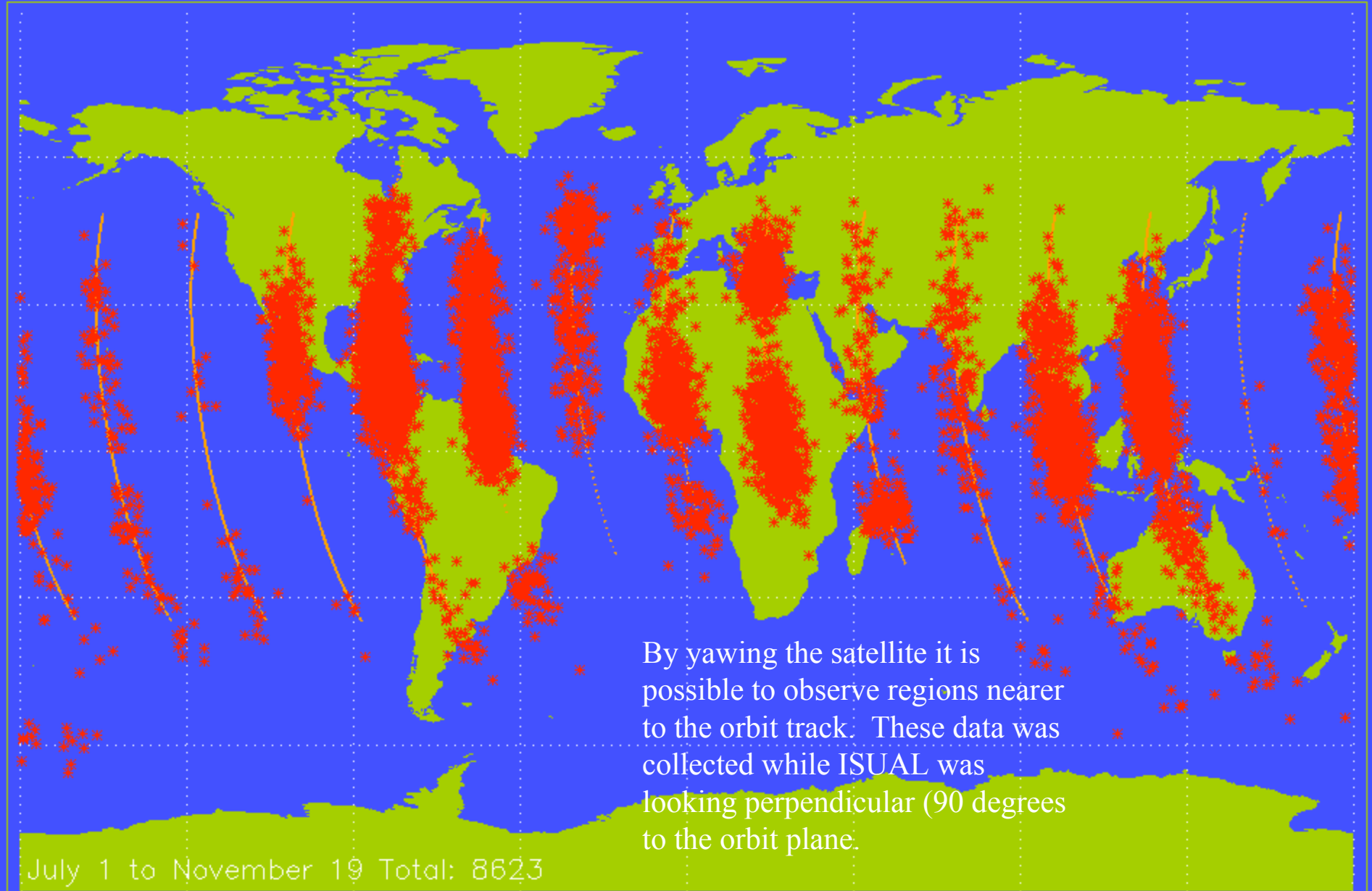
61.4° Nadir	near edge (km)	limb (km)	far edge (km)
line-of-sight	2310	3190	4130
lateral	912	1219 ($h = 223$)	1590



Global coverage and lightning distribution

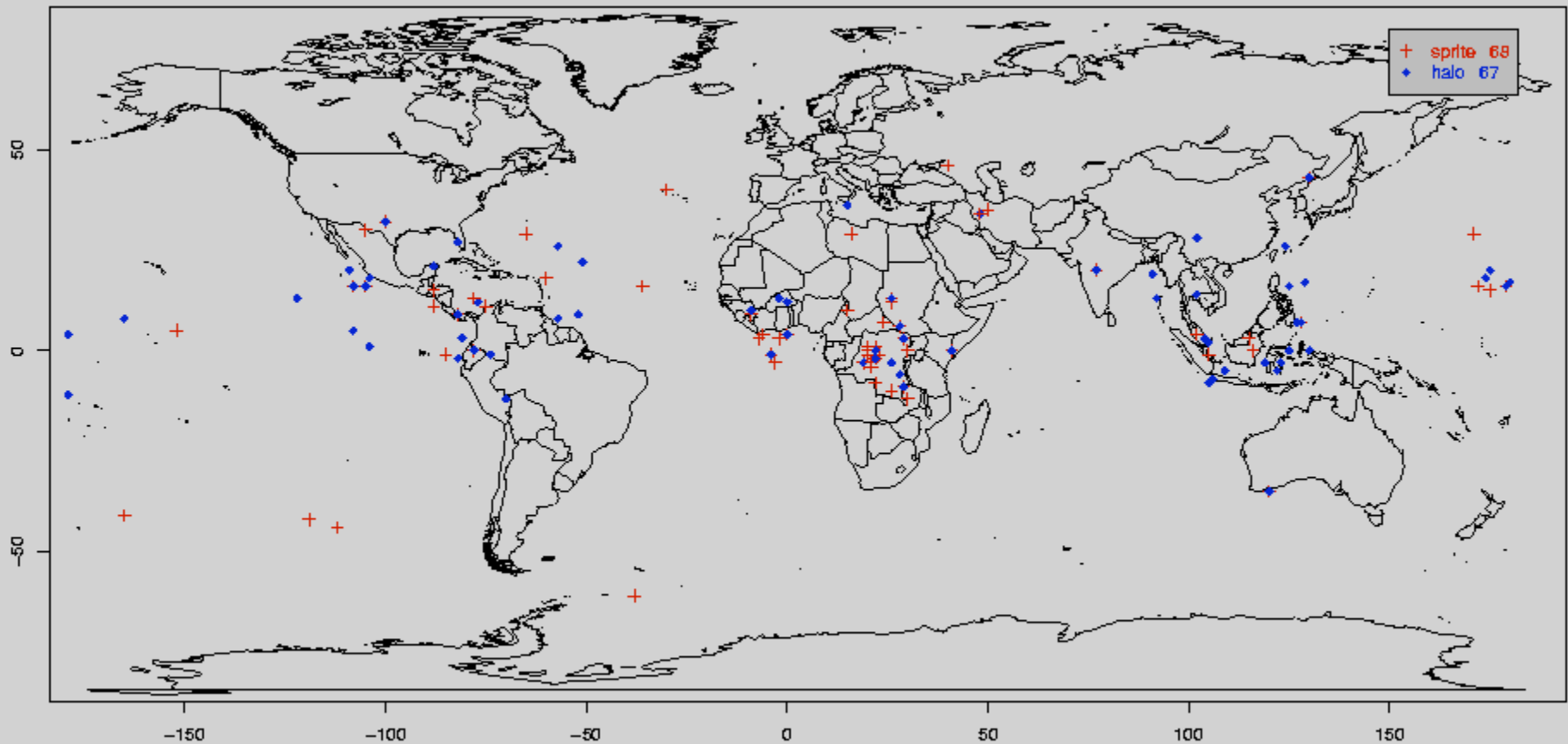


Lightning observed by ISUAL



Global distribution of sprites and halos

2004/07/16 – 2004/11/18

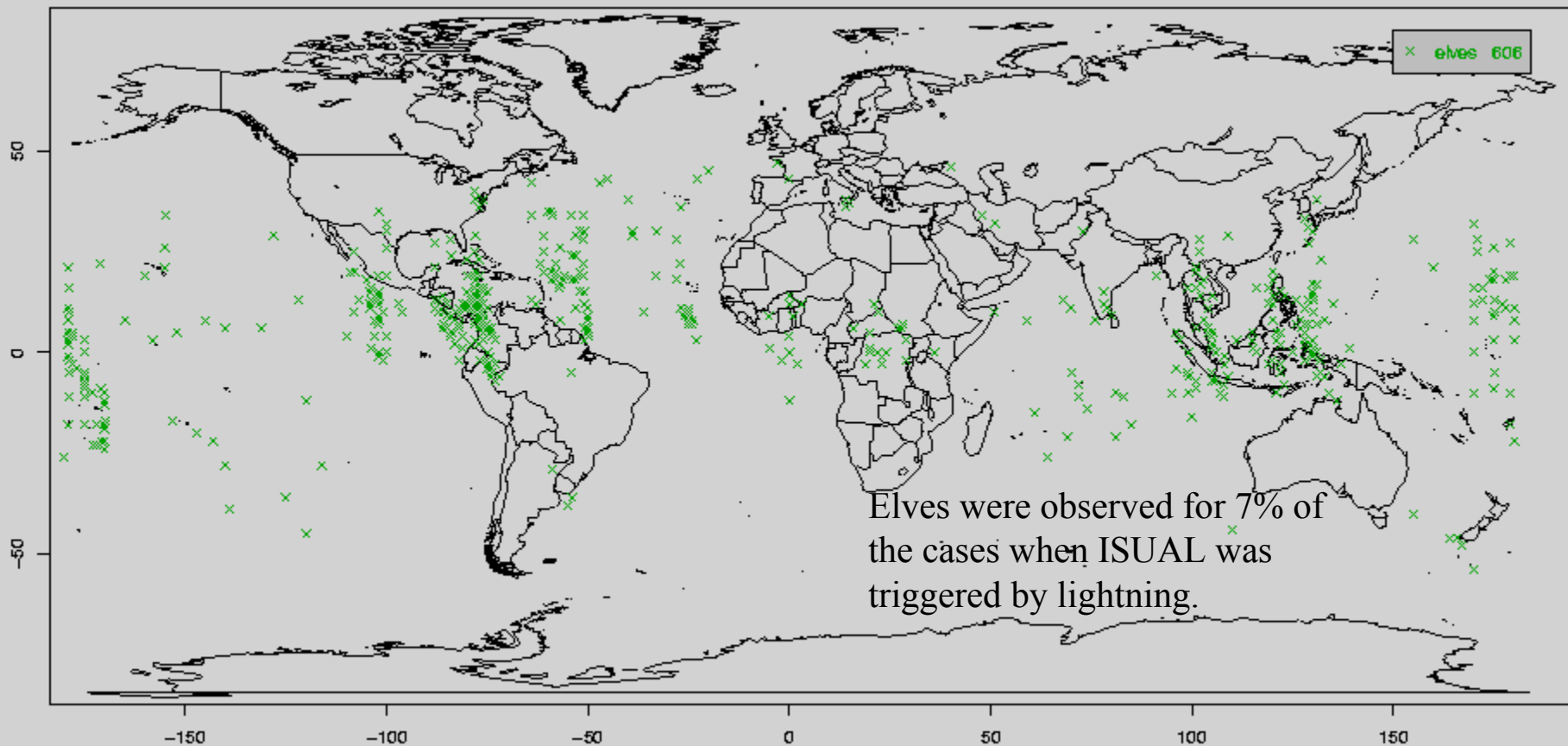
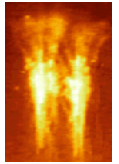




Global distribution of elves

2004/07/16 – 2004/11/18

ISUAL



“Textbook Sprite”

2004-07-18/21:30:15.267

2004-07-18/21:30:15.297

When the instrument is triggered we usually record 6 images in sequence. These were 30 msec exposures each.

2004-07-18/21:30:15.327

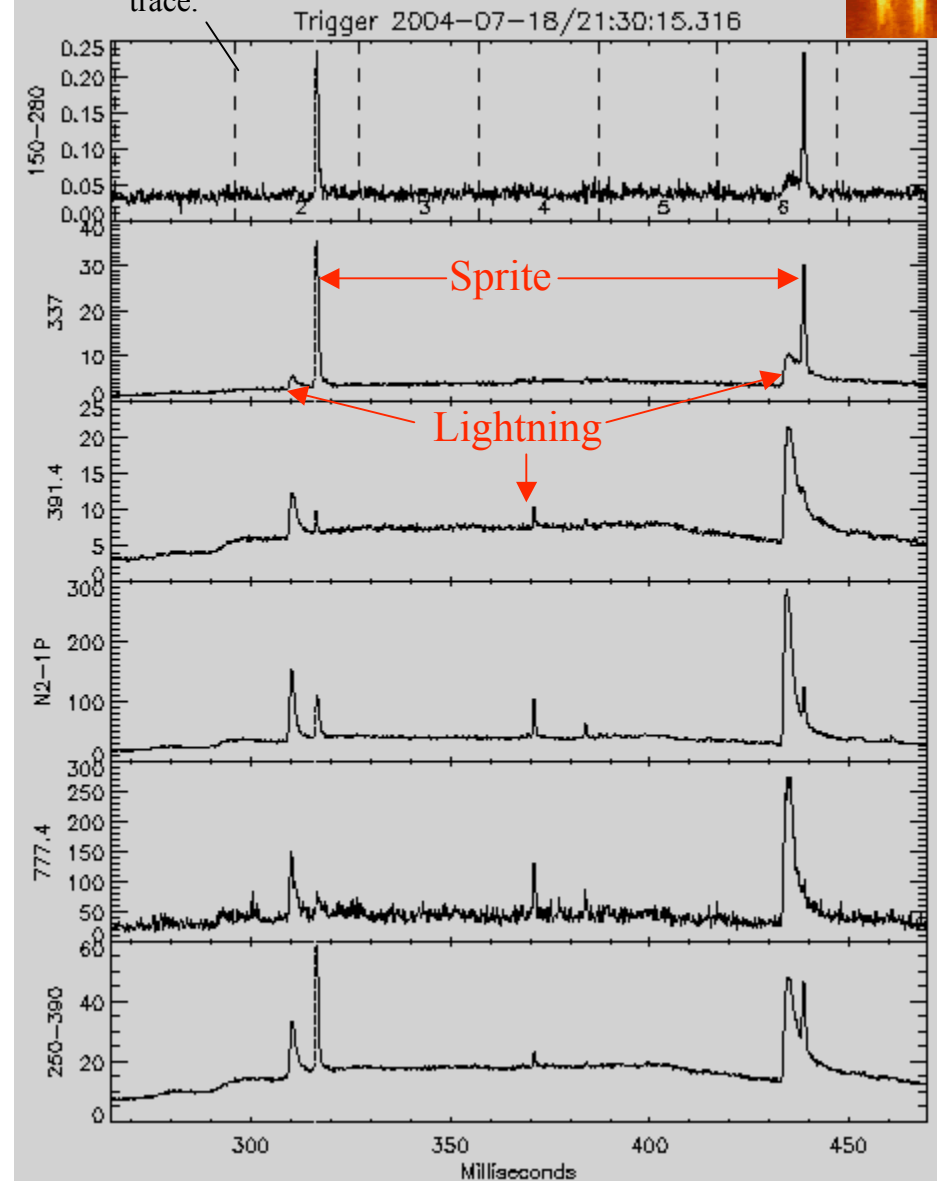
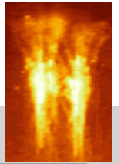
2004-07-18/21:30:15.357

2004-07-18/21:30:15.387

2004-07-18/21:30:15.417

Each exposure is separated by broken vertical line on photometer trace.

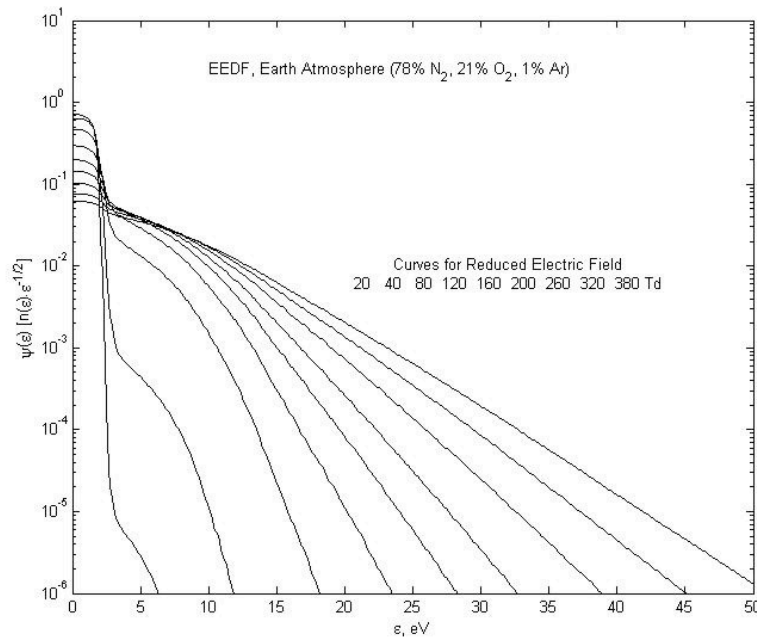
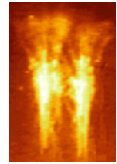
ISUAL



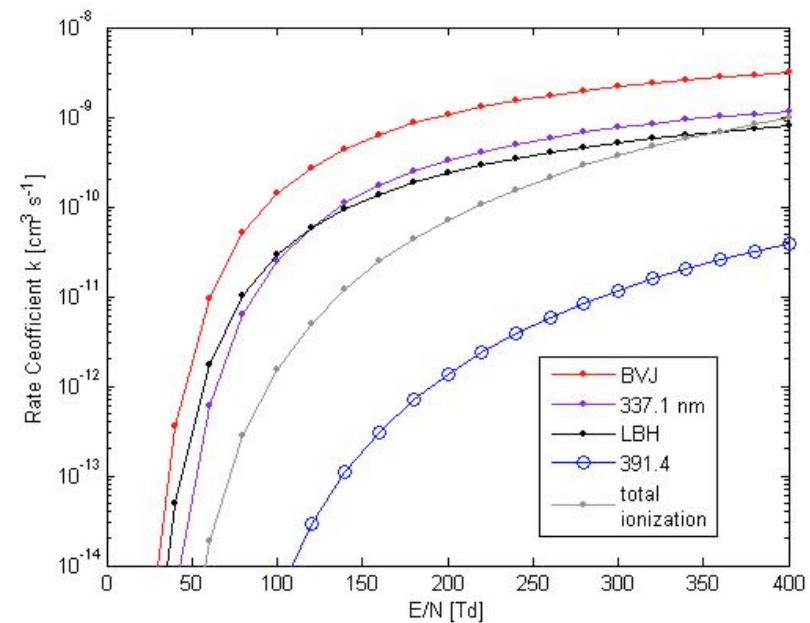


Theoretical calculations of Dave Sentman. 1) Solving the Boltzmann equation for the electron distribution function in the Earth atmosphere. 2) Rate coefficient generating N₂ 1st pos (BVJ), N₂ 2nd pos (0,0) 337.1, LBH, N₂⁺ 1st negative (0,0) (391.4) and total ionization including that of O₂

ISUAL



Rate coefficient for the production of N₂ 1st pos, N₂ 2nd pos (0,0), N₂ LBH, N₂⁺ 391.4 and total ionization. (Sentman, 2004)

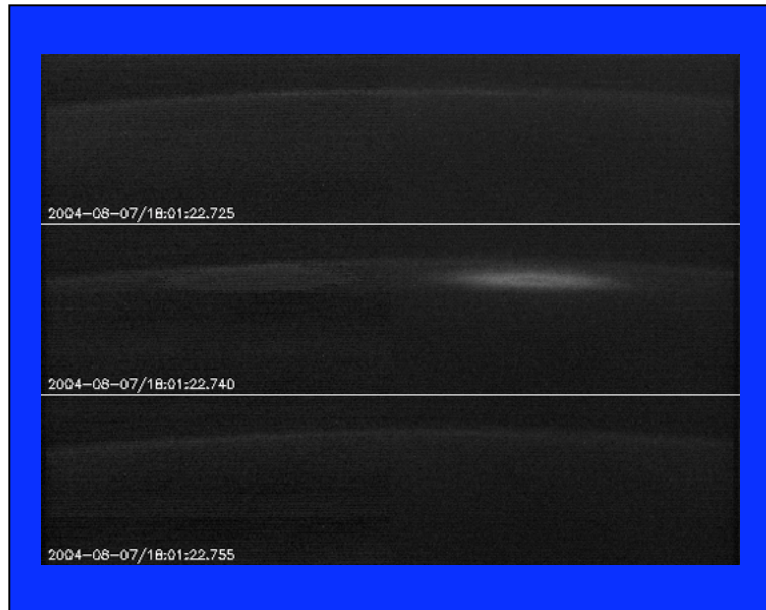


Electron Energy Distribution Function for different Reduced Electric Fields (Sentman, 2004).

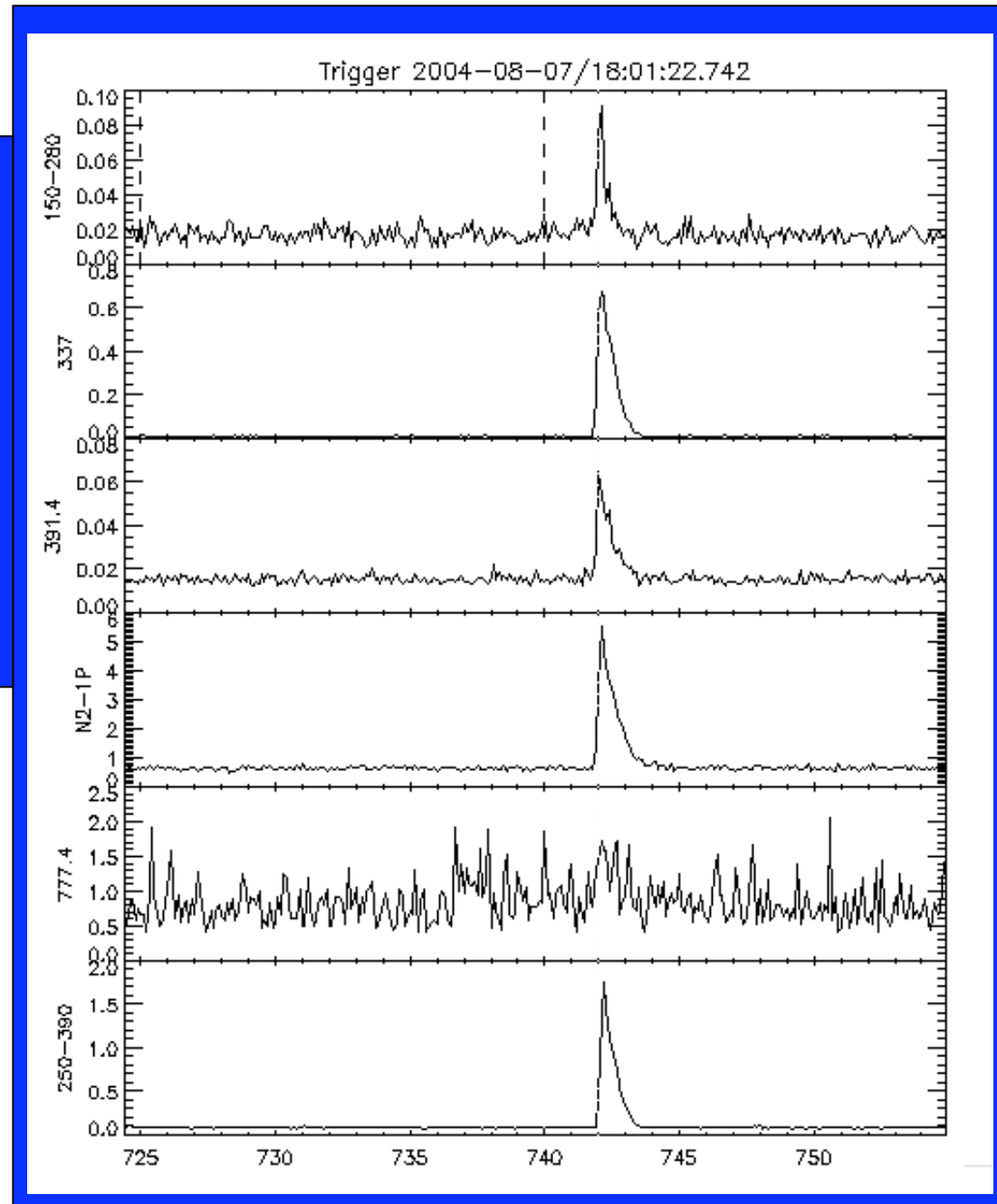
$$(1 \text{ Td} = 10^{-21} \text{ V m}^2 = 10^{-17} \text{ V cm}^2)$$



Case of an elves where the parent lightning is behind the earth limb.



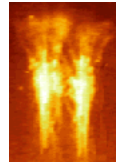
Elves without lightning. In calibrating the intensities (MR) we assumed that the spatial extent was as depicted by the image.



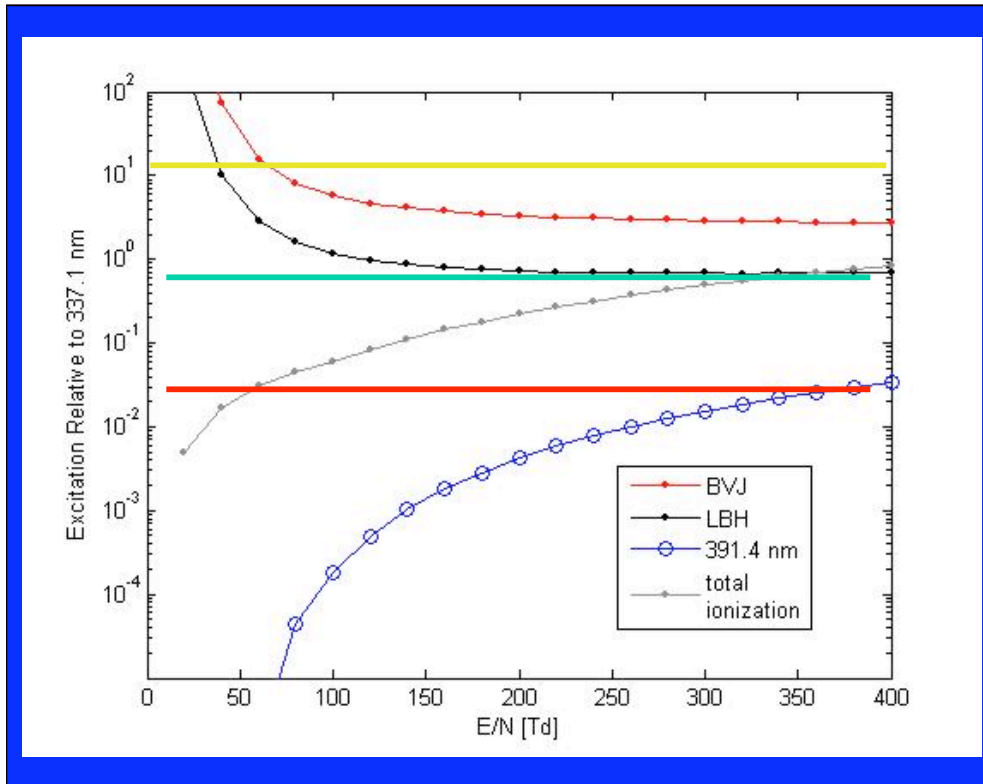


Comparison of the measured ratios (last column in Table) to the theoretically obtained ones from the calculations.

ISUAL



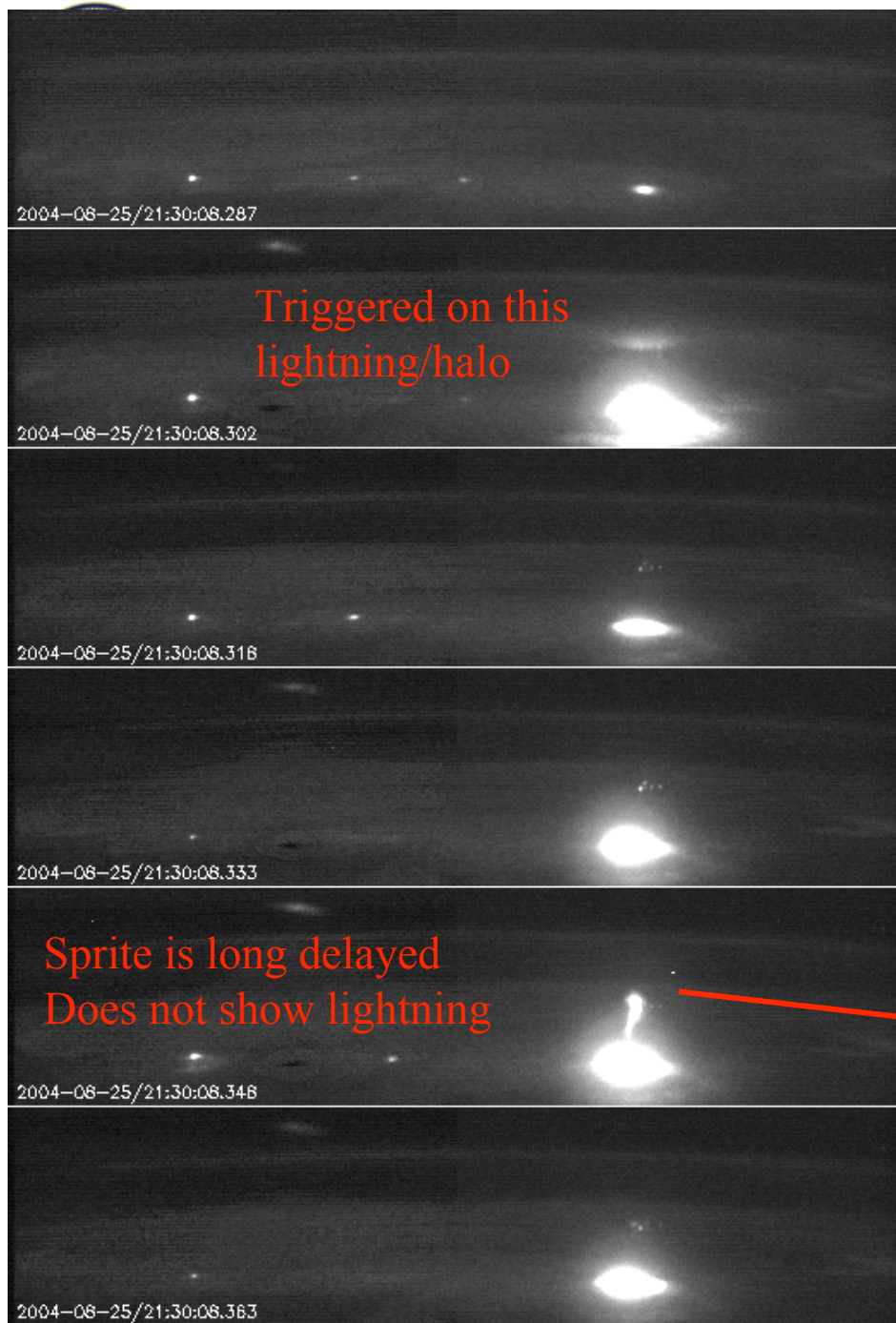
Ratio of the various measured emissions to the N₂
2nd positive band measurement



Integrated emission in the elves

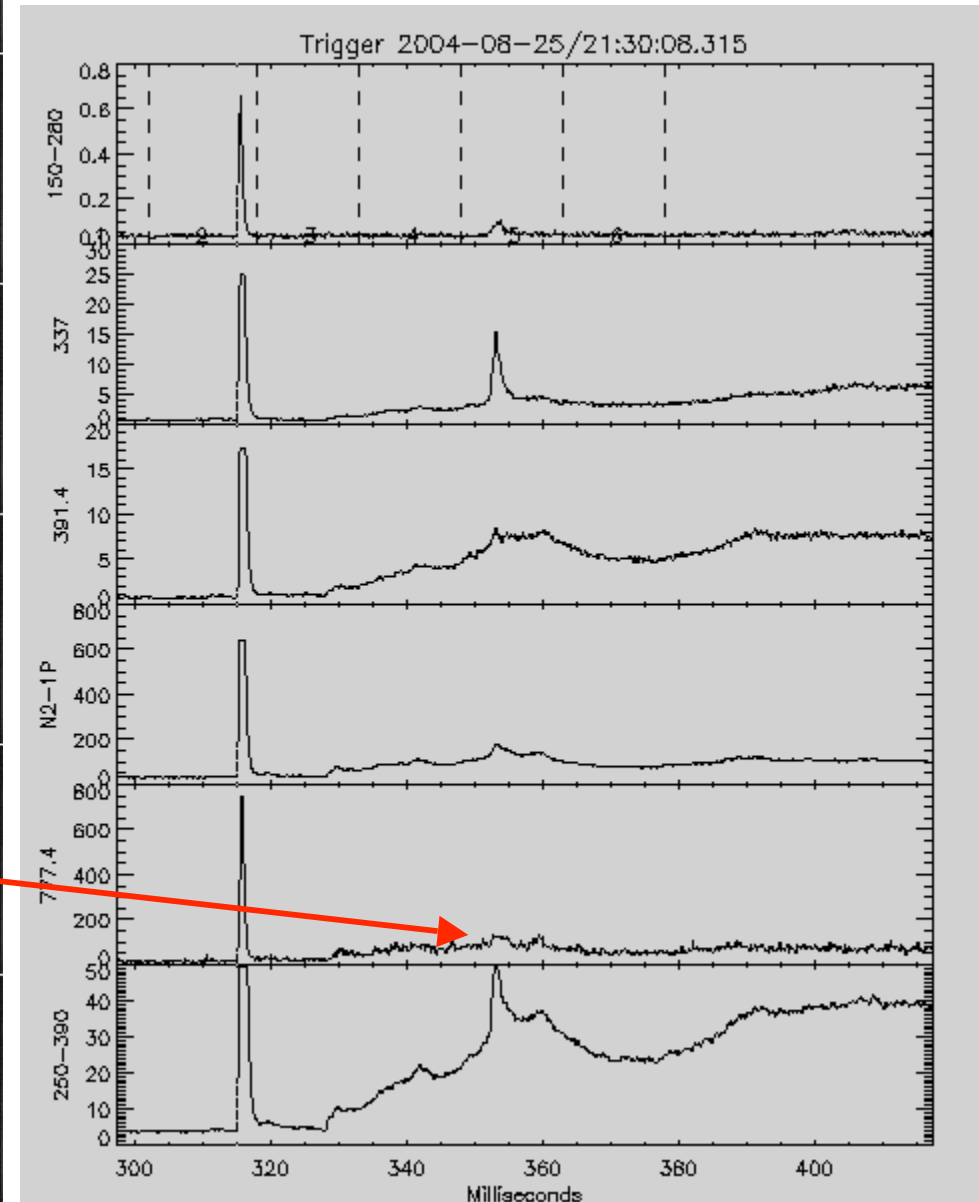
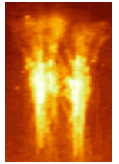
Photometer channels	Rayleigh sec During counting interval	Total band int Rayleigh sec	Ratio to N ₂ 2 nd positive
filter 1	28	1,157	0.70
filter 2	456	1,639	1
filter 3	29	44	0.026
filter 4	3,328	30,251	18.4
filter 5	0	0	0.0000
filter 6	951	1,133	0.69

The ratio of filter 1 to filter 2 and filter 3 to filter 2 is consistent with high reduced fields of 300 Td. Filter 4 to filter 2 is consistent with low reduced fields but not all the excitation modes the N₂ 1st pos (filter 4) have been included. Net result is that the elves produced ionization of about 40 electron cm⁻³ over several hundred square km region.

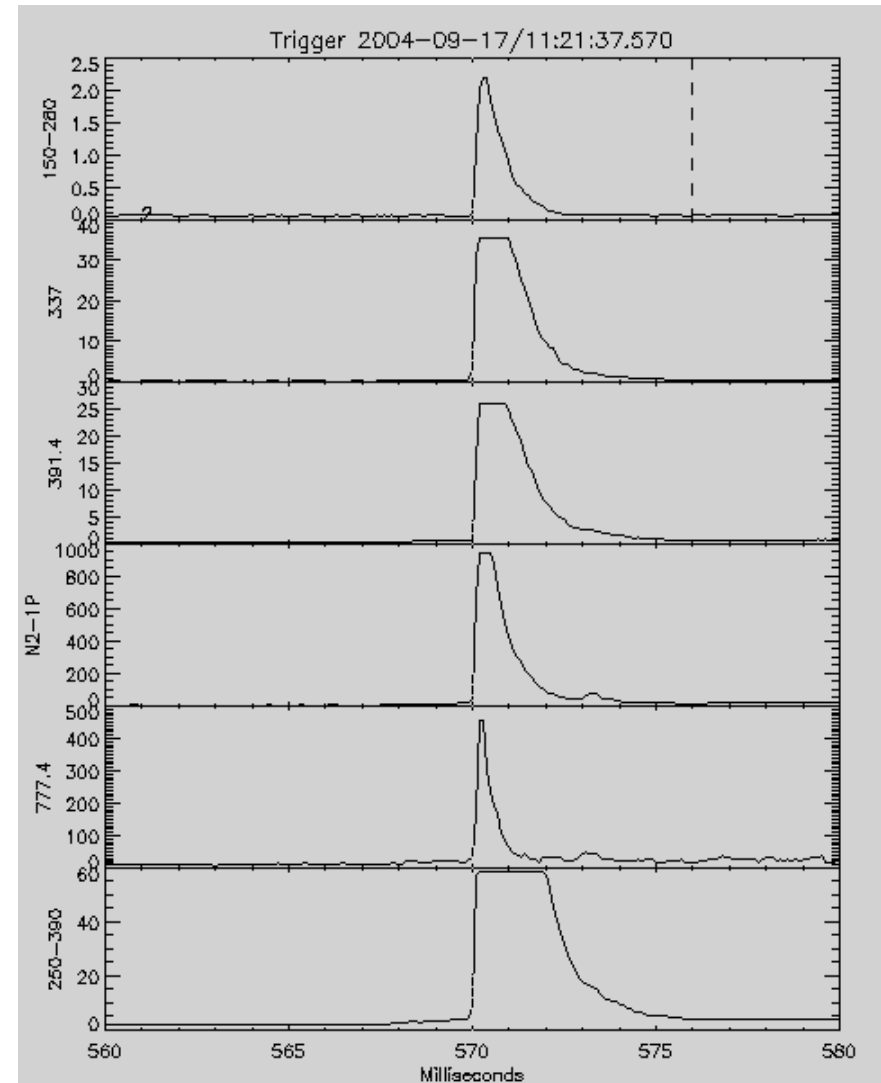
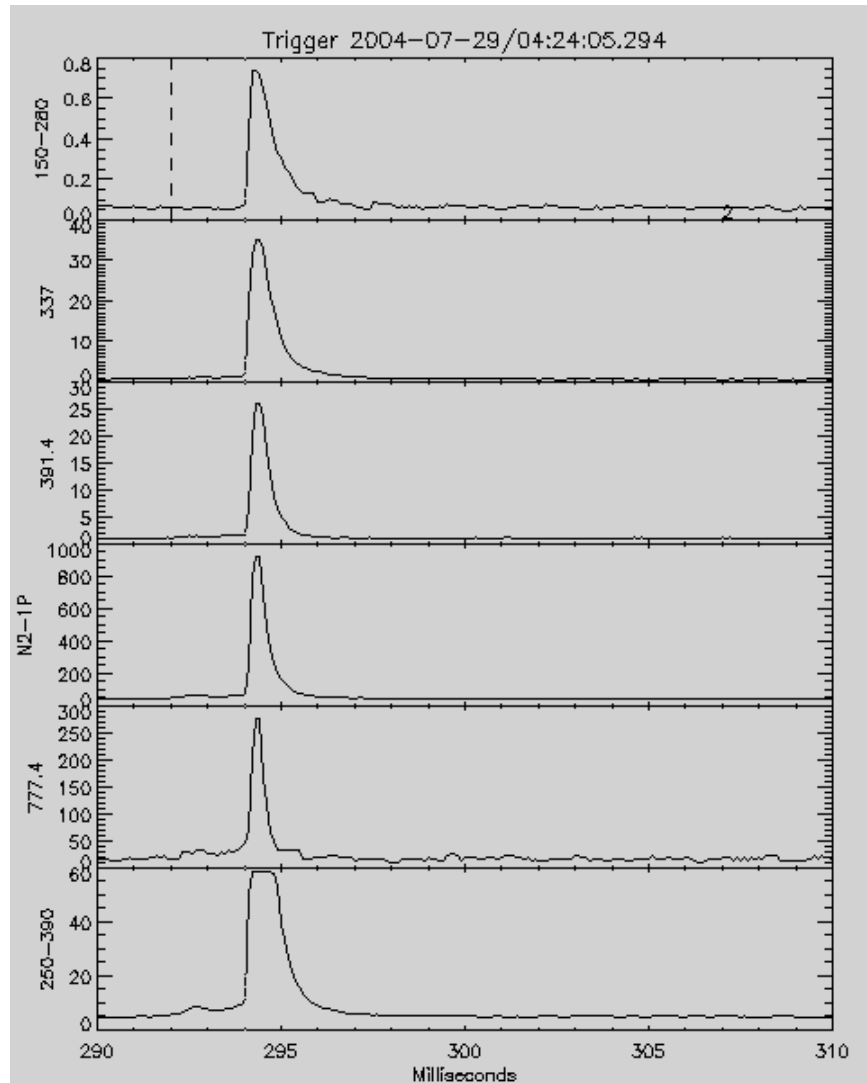
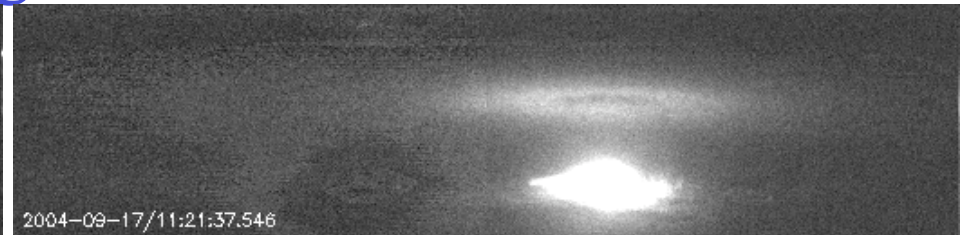


Another example of TLE-s
observed by ISUAL

ISUAL

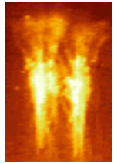


Spectral/temporal signature of Elves





ISUAL

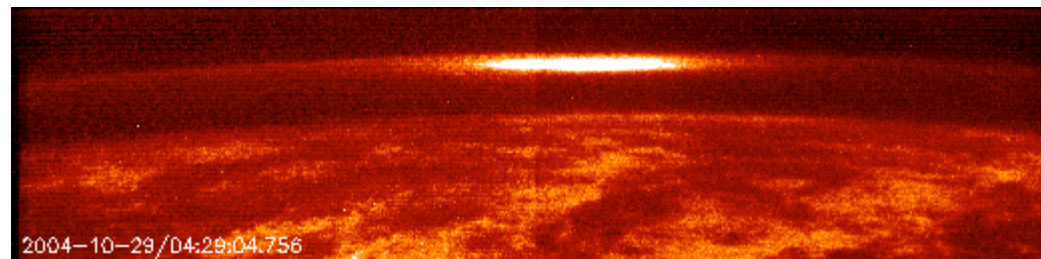


Peak brightness of spectral bands (Mega-Rayleigh)

	N2 LBH	337	391	N2-1P	7774	N2-2P
Lightning w/o TLE	<0.01	1.7	1.2	250	17	2.7
Lightning w Sprite	0.05	4.8	3.5	620	33	6.2
Lightning w Halo	0.03	7.2	4.4	940	65	8.9
Lightning w Elve	0.09	4.8	2.2	440	13	5.6
Sprite	0.03	2.8	0.21	29	<0.5	1.3
Elve	0.05	2.9	0.05	47	<0.9	1.4

N2+ 1N?
Absorp.?

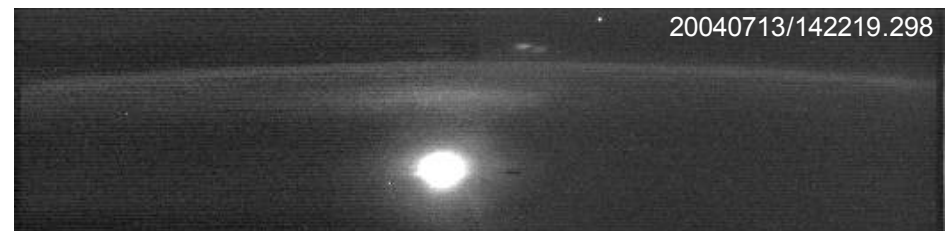
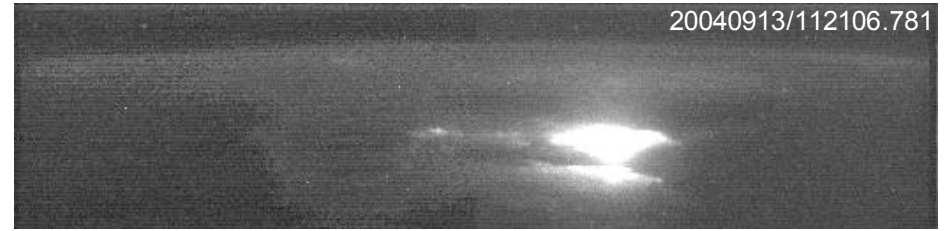
Corrected for high voltage and relative contribution of bands in SP channels.
Not corrected for atmospheric absorption.



Two types of elves

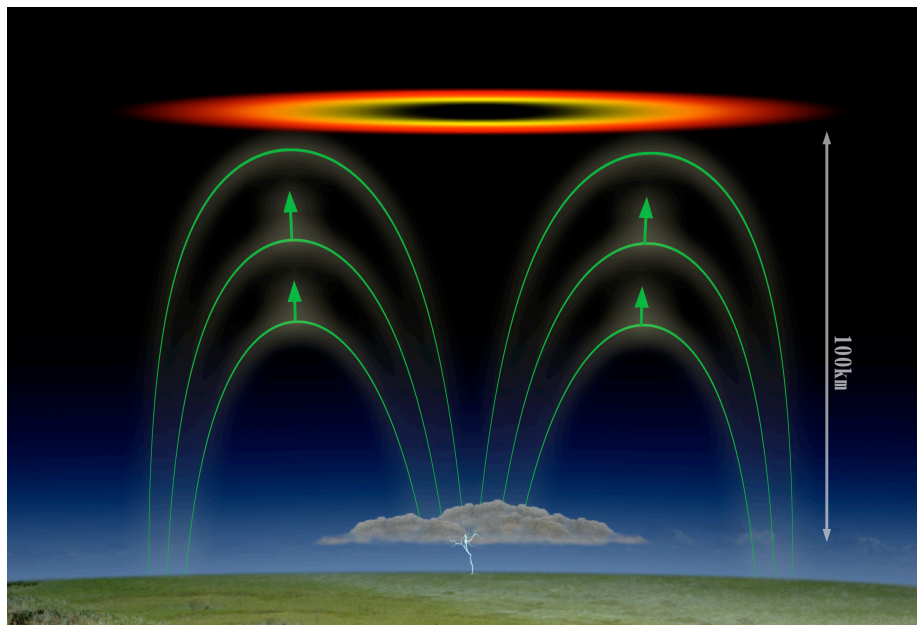
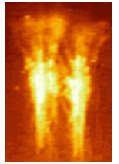
Ring elves

Disk elves

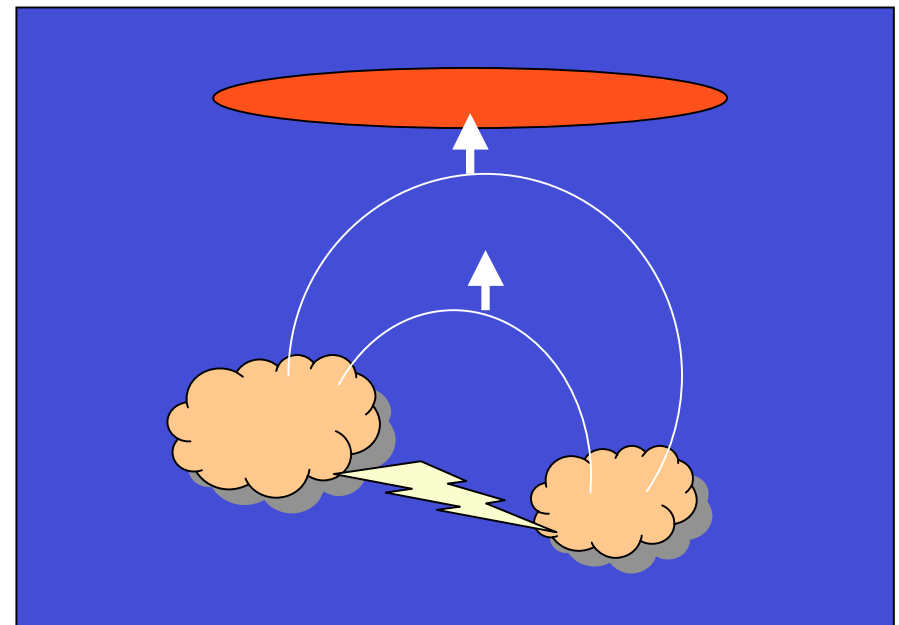


Two types of elves-producing lightning

ISUAL



Ring-shaped elves are induced by
CG strokes



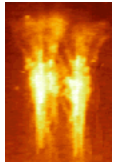
Disk-shaped elves are induced by
IC strokes

See observations in Israelevich et al., GRL 31, L06124, 10.1029/2003GL019110, 2004



Summary

ISUAL



- ISUAL fulfills design goal of observing TLE-s
- UV channels unique for TLE observations from space
- observe on average 7.6 TLE/day
- global distribution of TLE roughly as lightning
- 53 immediate sprites ($\Delta T < 10$ msec)
- 16 long delayed sprites (ΔT 10-120 msec)
- Time delay between lightning stroke and sprite allows for separation of spectral signal.
- Many pure elves spectra found because lightning was blocked by solid Earth. Shows significant ionization in elves.