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The importance of mesopause region airglow "bright nights"

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“Bright nights” are nights with unusually bright airglow.

Of course, airglow and its “usual brightness” must be known, before the term “bright night” makes sense for us now.

This could hardly have been before 8 Nov 1929 (Lord Rayleigh IV, 1931), and probably only later...

M. Okuda (1962), literally:
At some isolated night or successive nights, intense brightness of the night sky is observed and that the intensity is not so intense at the previous and following night. Such night is called "Bright night".

“Spring transition”: Shepherd et al. (1999) and follow-up “equinox transitions” in the context of the Planetary Scale Mesopause Observing System (PSMOS):

Shiokawa & Kiyama (2000),
Manson et al. (2002),
M. Shepherd et al. (2002),
G. Shepherd et al. (2004),
Liu & Roble (2004),
Scheer et al. (2005)

End of brief “bright nights” history, 1931-2005

jump to present (2015):

The main airglow emissions in the mesopause region, the OH and O_2 bands, come from nominal altitudes of 87 and 95 km.

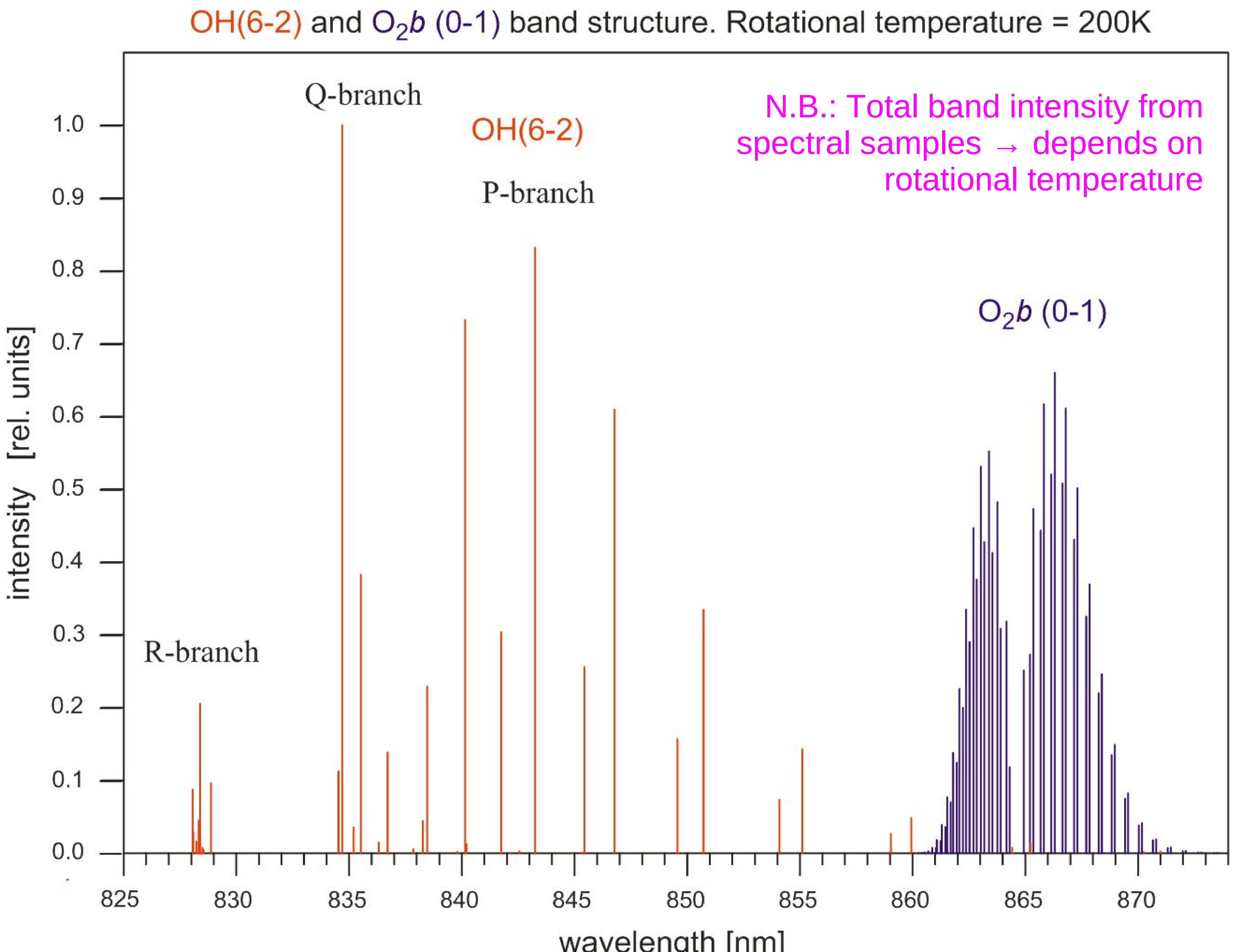
This is what the Argentine Airglow Spectrometer measures routinely from El Leoncito (31.80°S, 69.29°W).

We here use data from 2006 to 2014:

2940 nights,

94 nearly complete months

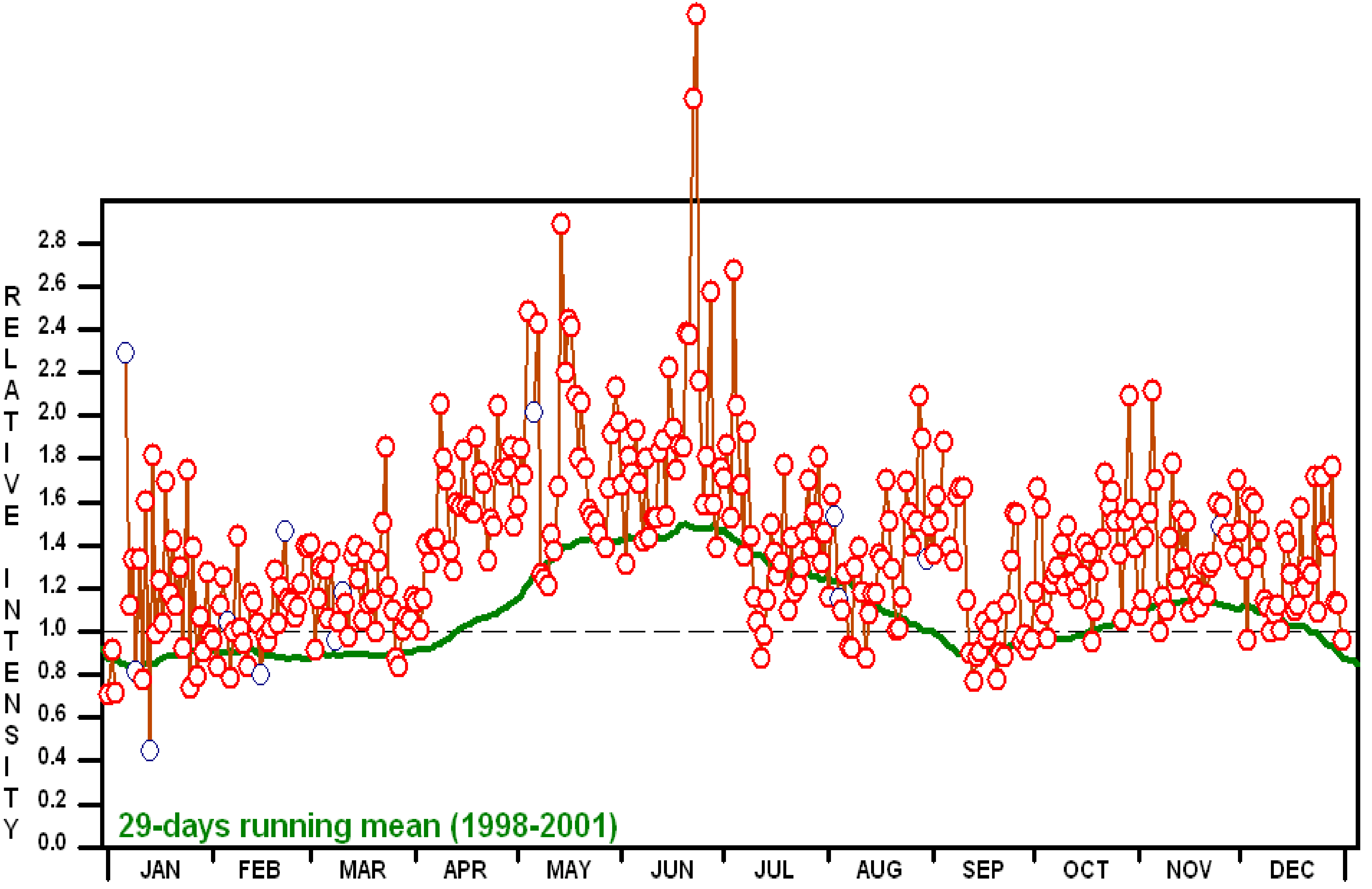
	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec	total	N
1986						5	14			6	10		**35**	10.2
1987									17				**17**	5.1
1992										16			**16**	3.6
1997								23	21	6	13	9	**72**	21.4
1998	8	1		23	17	26	18	25	9	25	26	14	**192**	64.4
1999	15	12	17	20	9	29	28	11	12	17	21	10	**201**	66.9
2000	15	17	20	20	25	15	14	23	18	26	16	17	**226**	79.5
2001	22	20	16	23	23	11		24	14	24	10	10	**197**	64.2
2002	22	10	22	19	15	27	29	31	30	28	18	29	**280**	88.3
2003	12												**12**	3.0
2006		22	27	30	31	30	25	24	29	31	23	15	**287**	90.4
2007	9	22	31	29	29	29	30	28	23	31	19	31	**311**	97.4
2008	28	29	27	30	29	29	31	30	30	31	29	30	**353**	108.0
2009	30	28	28	30	31	30	31	29	28	31	29	31	**356**	114.3
2010	29	27	31	30	30	30	29	30	27	31	28	31	**353**	113.5
2011	30	25	26	25	31	28	30	31	30	31	29	30	**346**	110.3
2012	30	29	31	30	29	30	31	31	30	31	29	31	**362**	114.8
2013	30	28	31	30	30	29	31	31	27	28	30	28	**353**	103.1
2014	30	26	2				10	30	29	31	30	31	**219**	58.0
2015	30	28	5	7	29	2							**101**	27.0
sum:	340	324	314	346	358	350	351	401	374	424	360	347	**4289**	1343.2



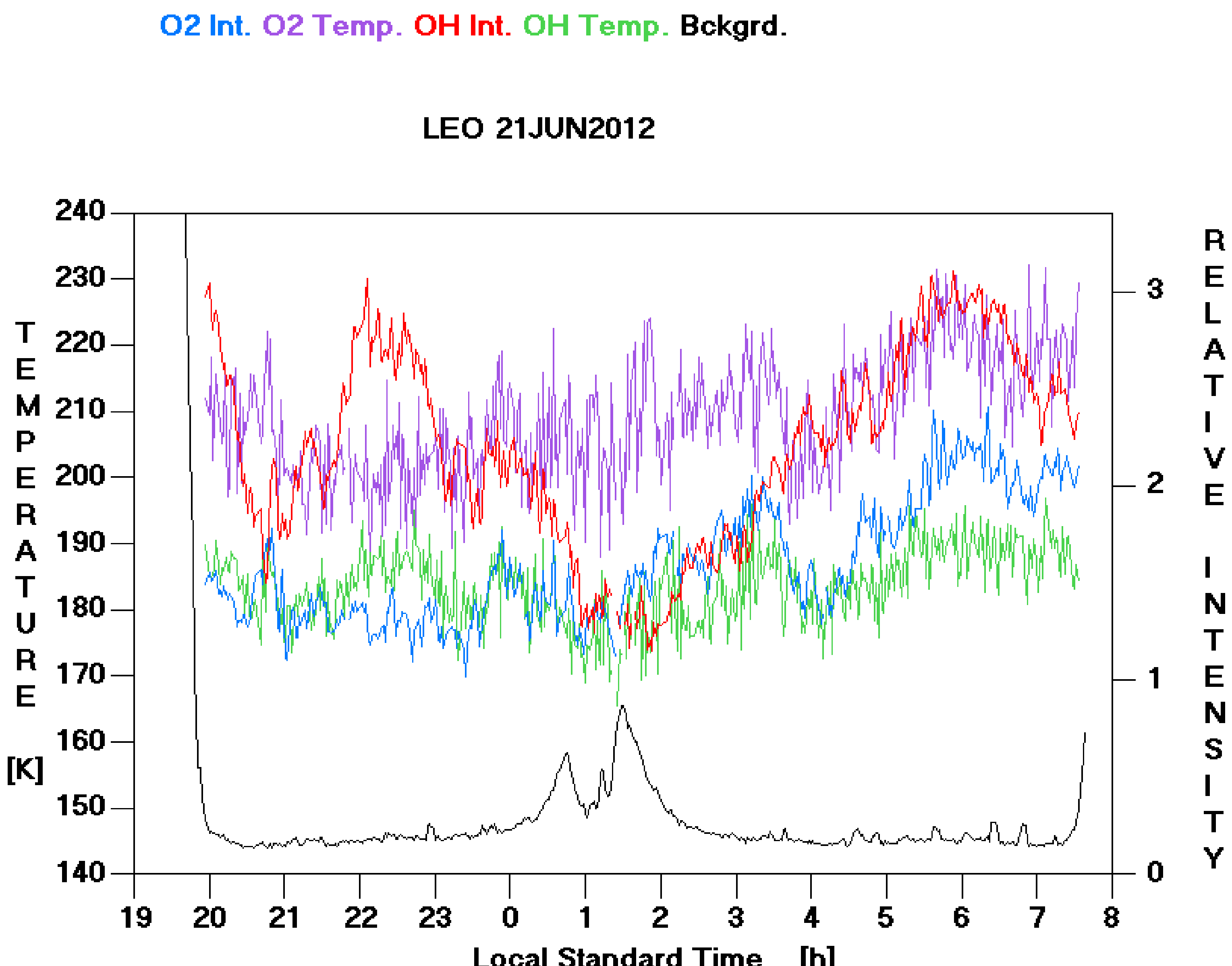
OH(6-2) and O_2b (0-1) band structure. Rotational temperature = 200K
Q-branch
OH(6-2)
P-branch
R-branch
O_2b (0-1)
N.B.: Total band intensity from spectral samples → depends on rotational temperature
intensity [rel. units]
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
825
830
835
840
845
850
855
860
865
870
wavelength [nm]

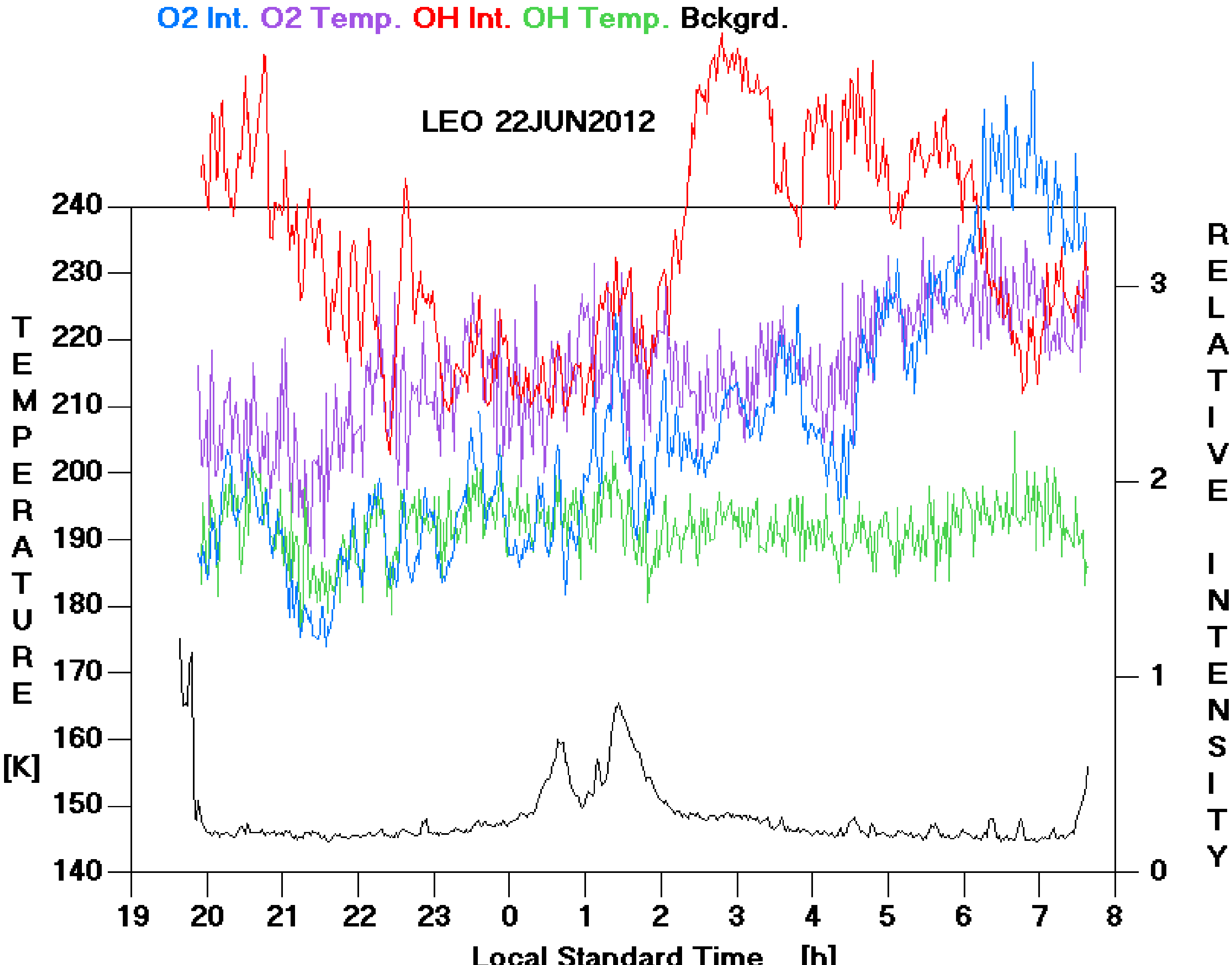
Most intense of all IOH "bursts" at El Leoncito:

23 June 2012



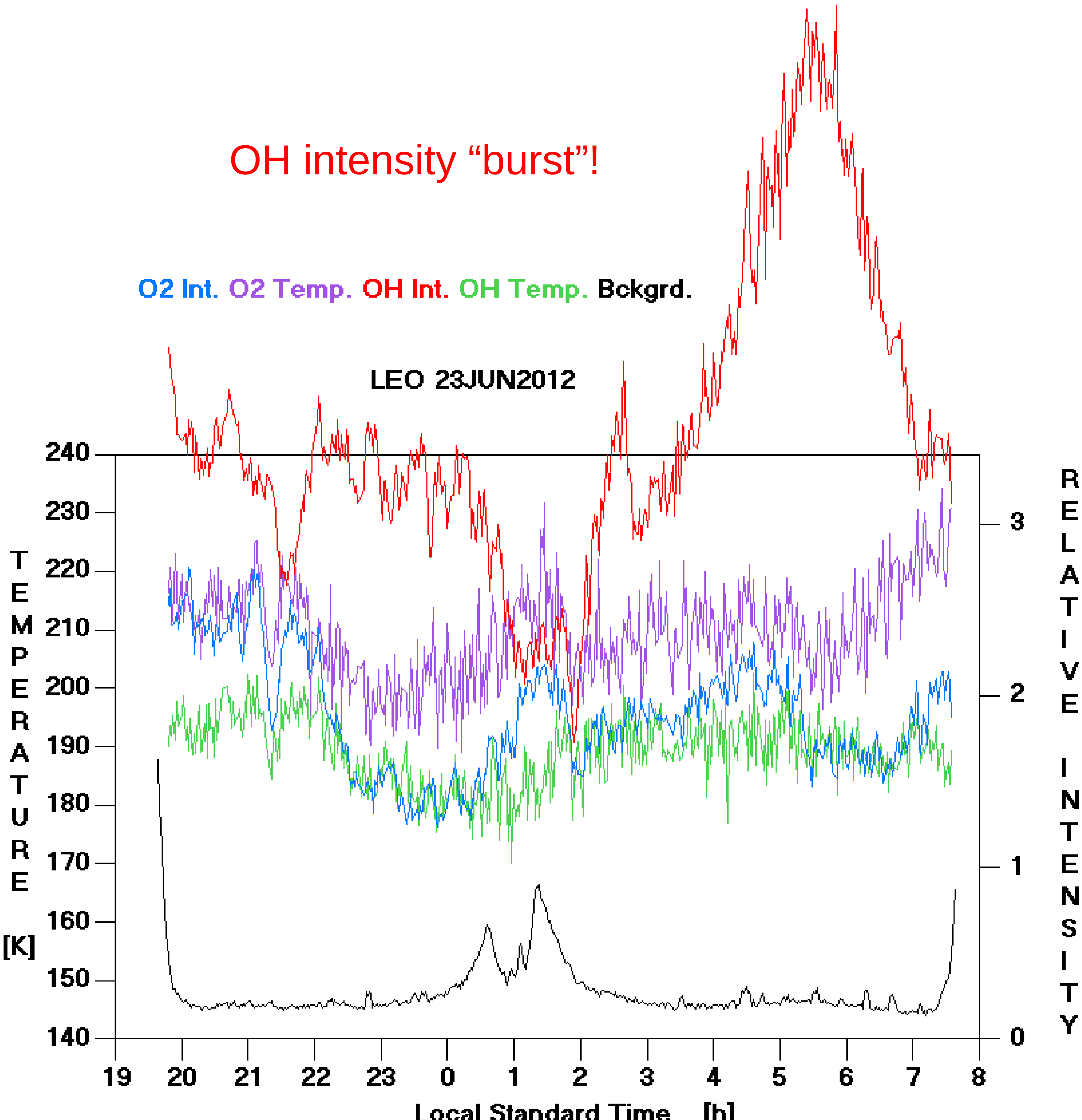
OH intensity nocturnal means, El Leoncito, 01 JAN 2012 - 31 DEC 2012

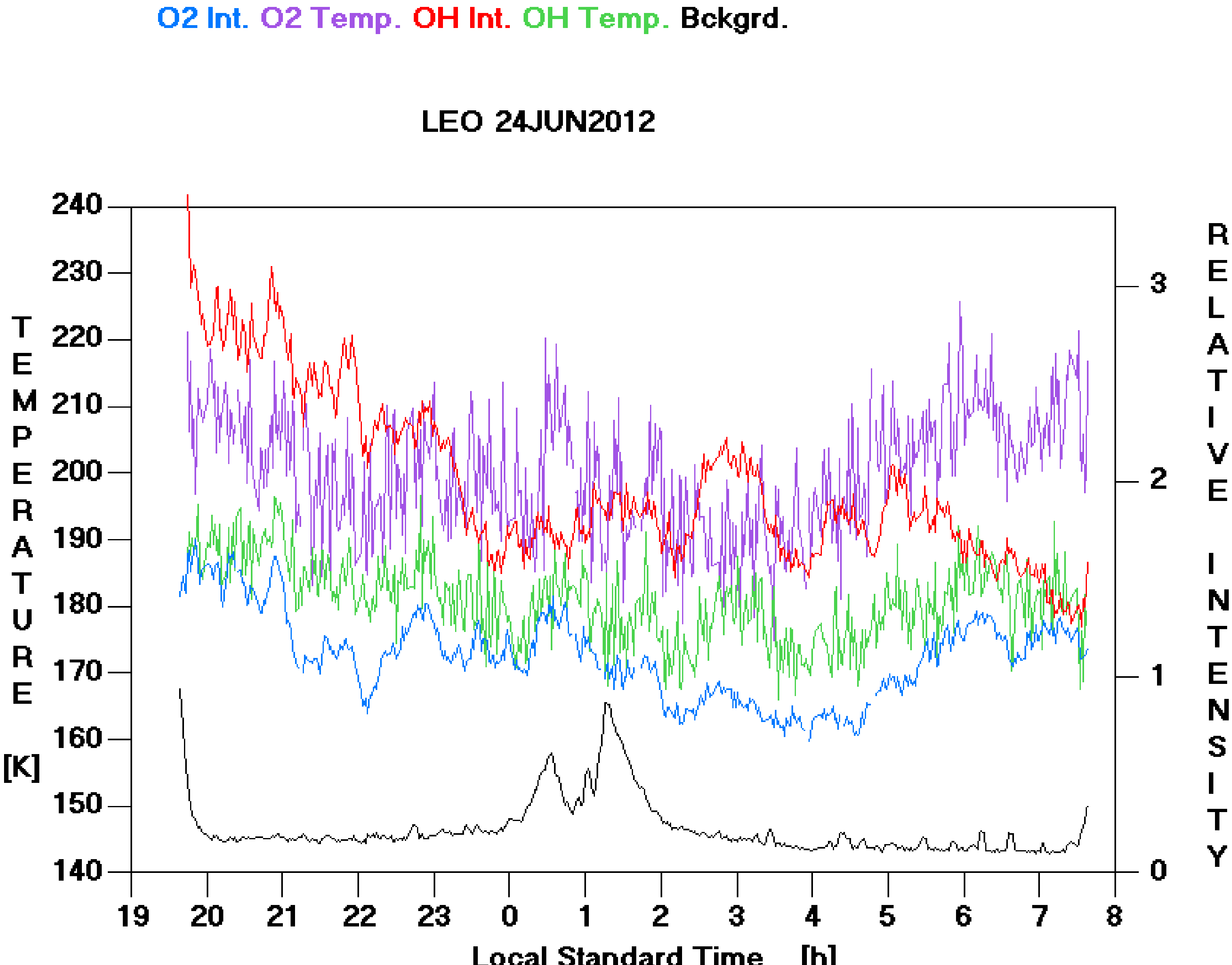

O2 Int. O2 Temp. OH Int. OH Temp. Bckgrd.
LEO 21JUN2012
TEMPERATURE [K]
RELATIVE INTENSITY
240
230
220
210
200
190
180
170
160
150
140
3
2
1
0
19 20 21 22 23 0 1 2 3 4 5 6 7 8
Local Standard Time [h]

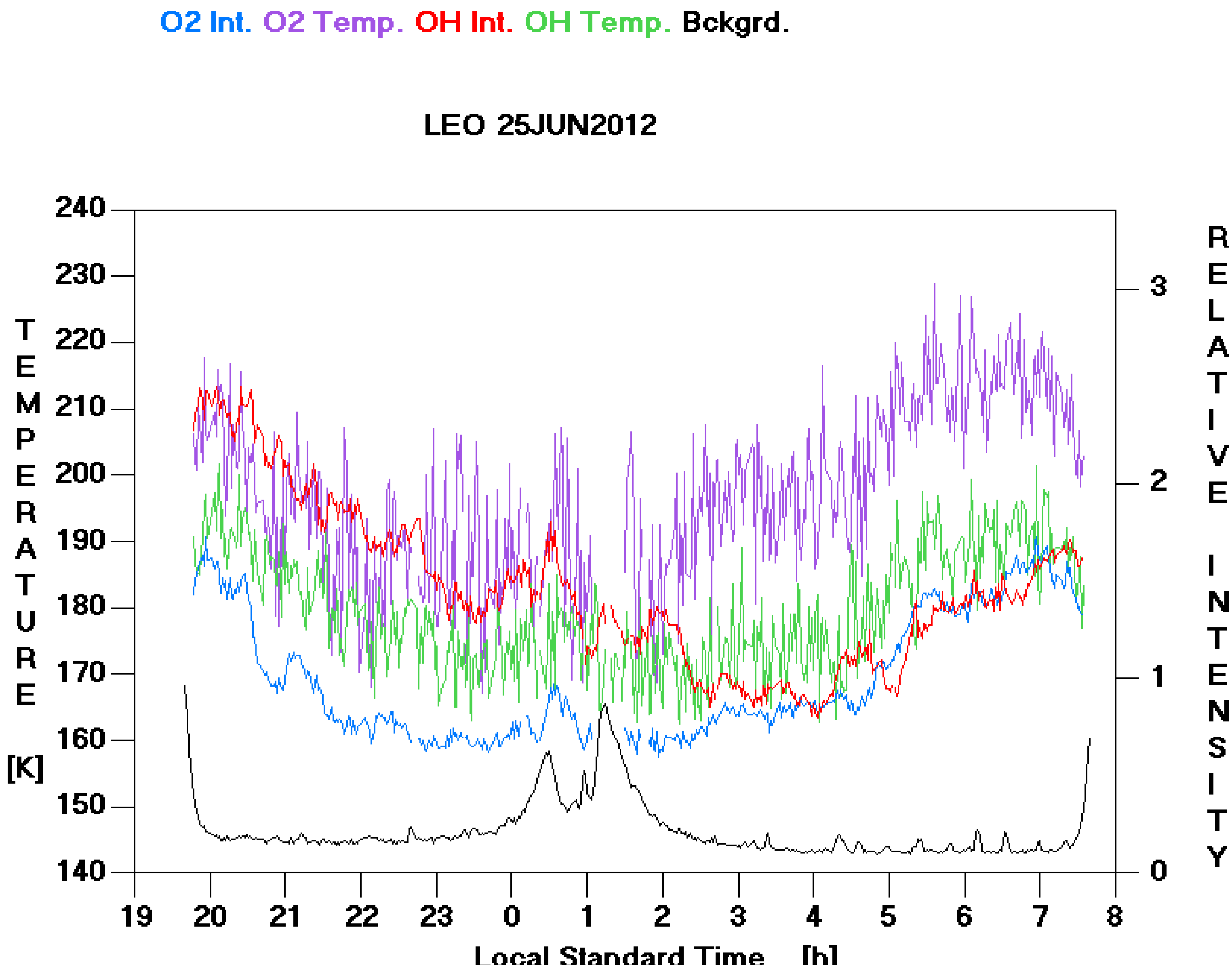


O2 Int. O2 Temp. OH Int. OH Temp. Bckgrd.
LEO 22JUN2012
TEMPERATURE [K]
240
230
220
210
200
190
180
170
160
150
140
RELATIVE INTENSITY
3
2
1
0
19
20
21
22
23
0
1
2
3
4
5
6
7
8
Local Standard Time [h]

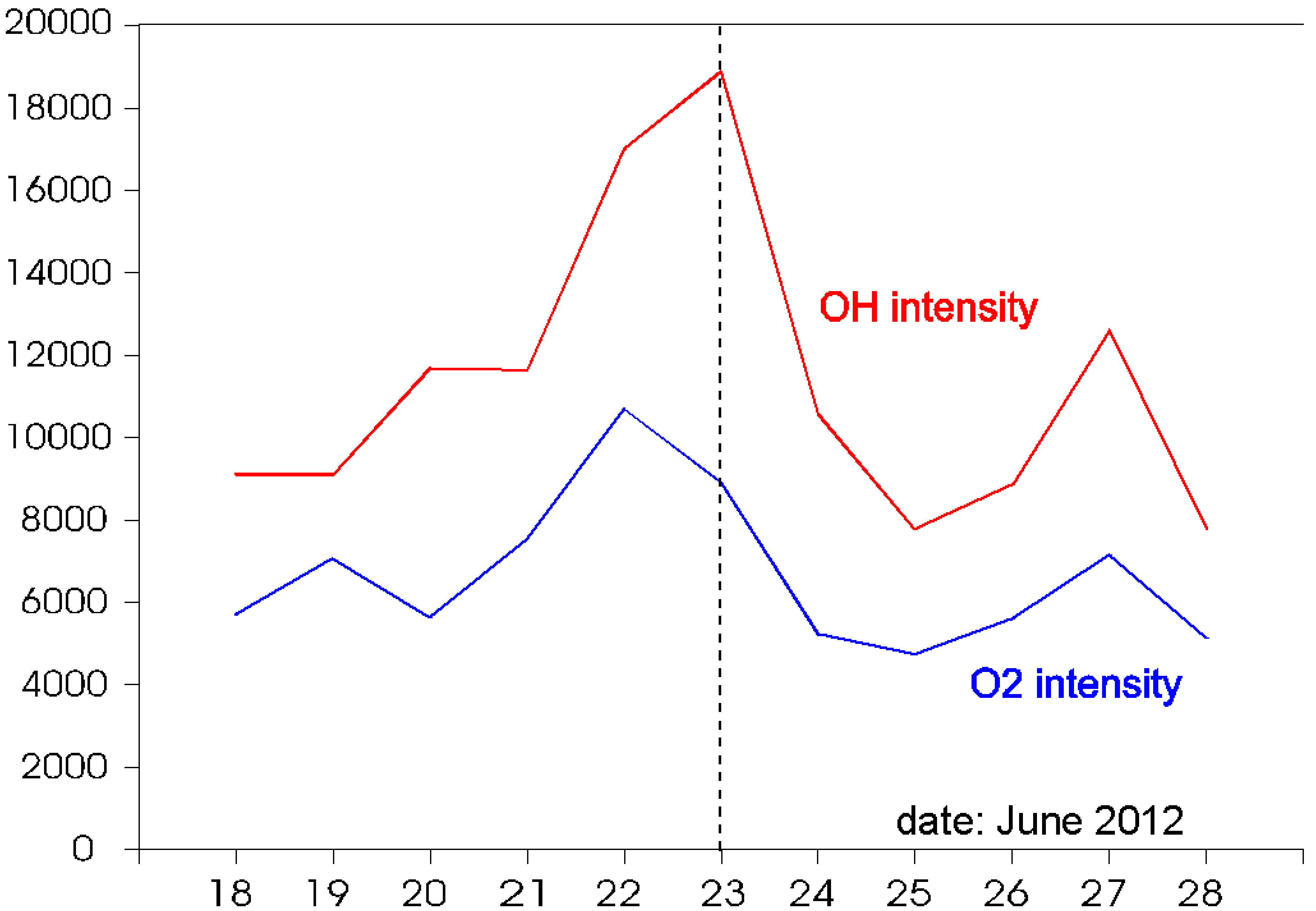
OH intensity “burst”!

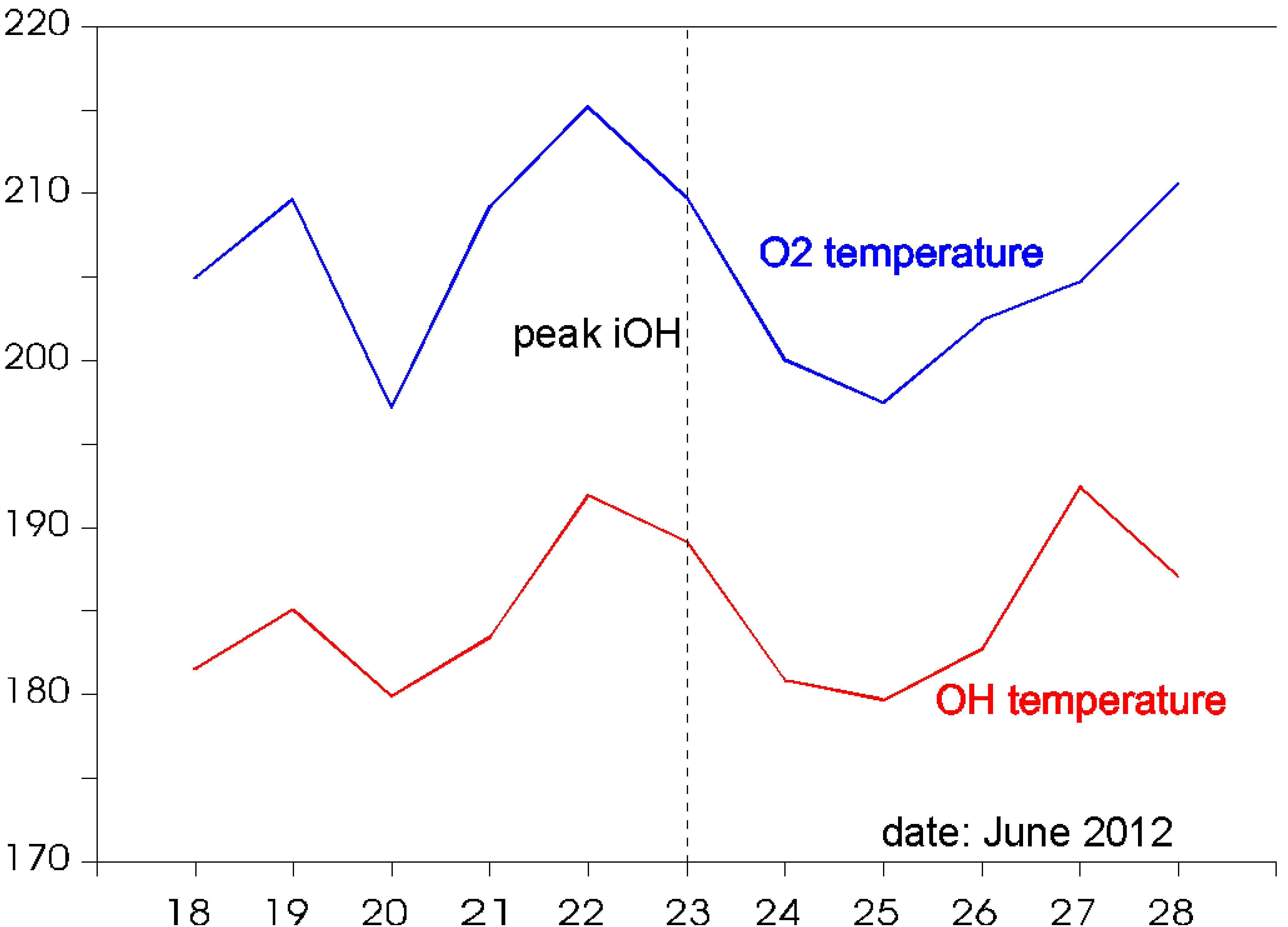



O2 Int. O2 Temp. OH Int. OH Temp. Bckgrd.
LEO 24JUN2012
TEMPERATURE [K]
240
230
220
210
200
190
180
170
160
150
140
RELATIVE INTENSITY
3
2
1
0
19 20 21 22 23 0 1 2 3 4 5 6 7 8
Local Standard Time [h]

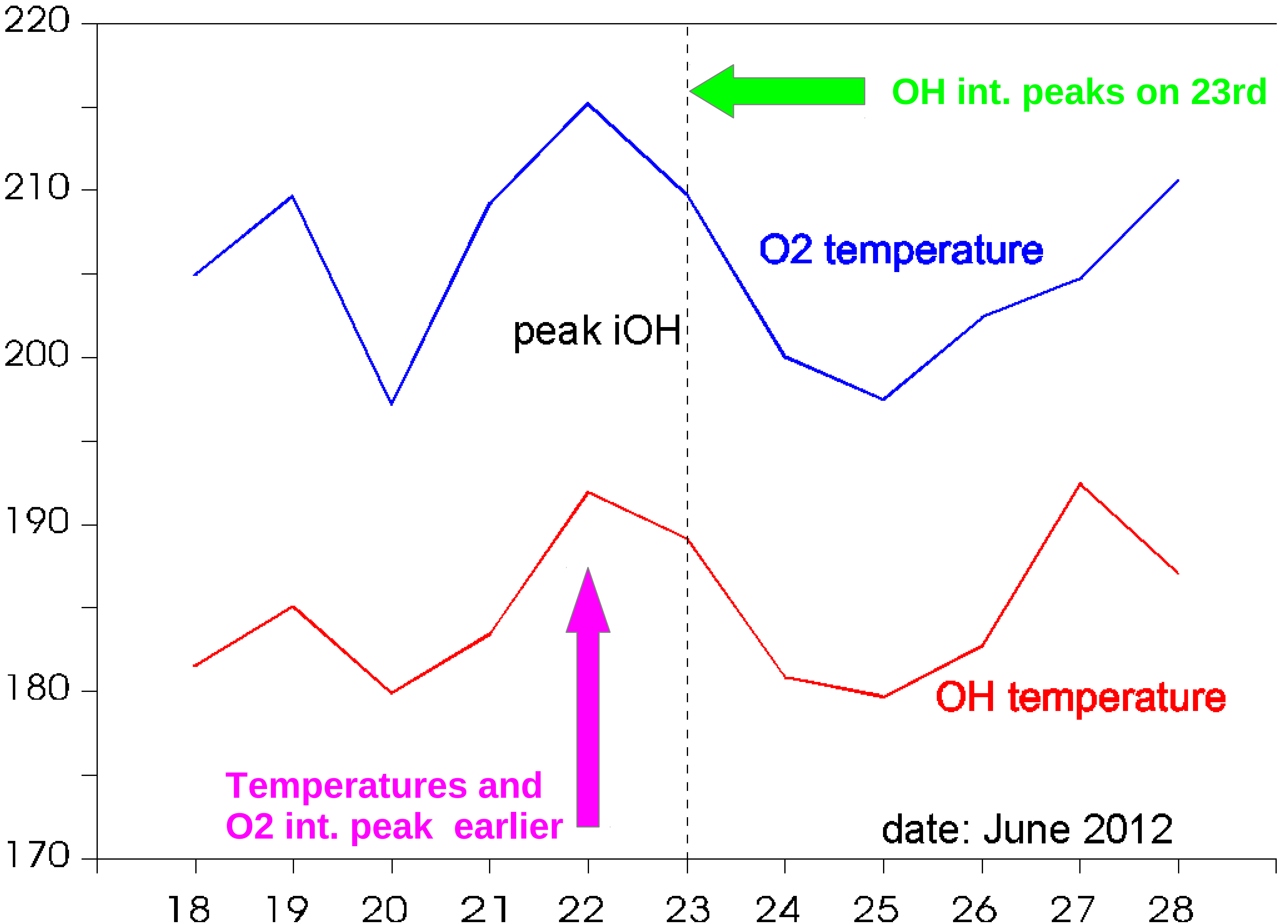

O2 Int. O2 Temp. OH Int. OH Temp. Bckgrd.
LEO 25JUN2012
TEMPERATURE [K]
240
230
220
210
200
190
180
170
160
150
140
RELATIVE INTENSITY
3
2
1
0
19
20
21
22
23
0
1
2
3
4
5
6
7
8
Local Standard Time [h]

Nocturnal means around this burst:


20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
18
19
20
21
22
23
24
25
26
27
28
OH intensity
O2 intensity
date: June 2012



220
210
200
190
180
170
18
19
20
21
22
23
24
25
26
27
28
O2 temperature
peak iOH
OH temperature
date: June 2012



220
210
200
190
180
170
OH int. peaks on 23rd
O2 temperature
peak iOH
OH temperature
Temperatures and
O2 int. peak earlier
date: June 2012
18
19
20
21
22
23
24
25
26
27
28

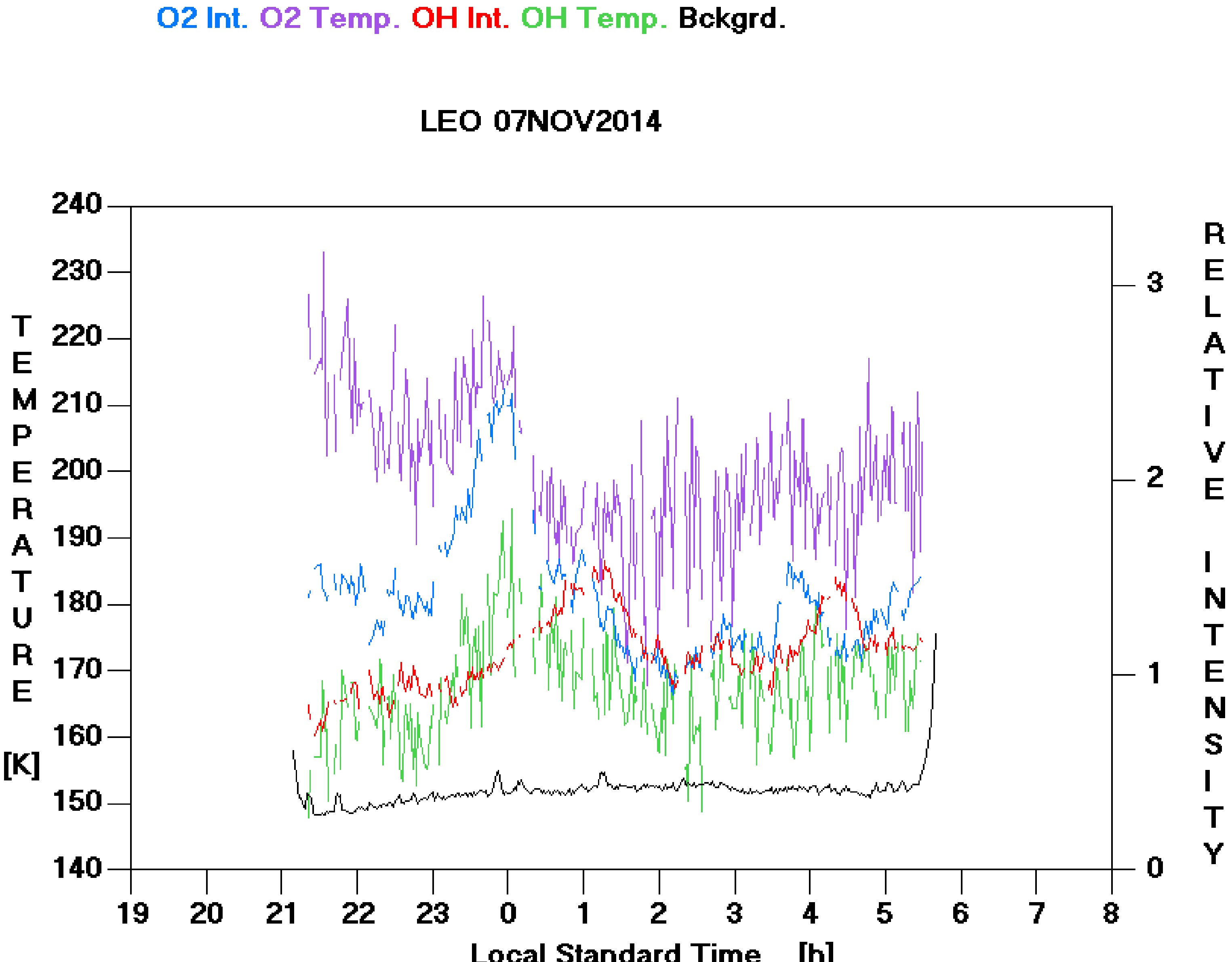
Such a phase progression is not always seen in our data.

Of 100 nights with OH intensity bursts,
34 are also IO2 bursts, and
17 are preceded by IO2 bursts one or two days earlier.

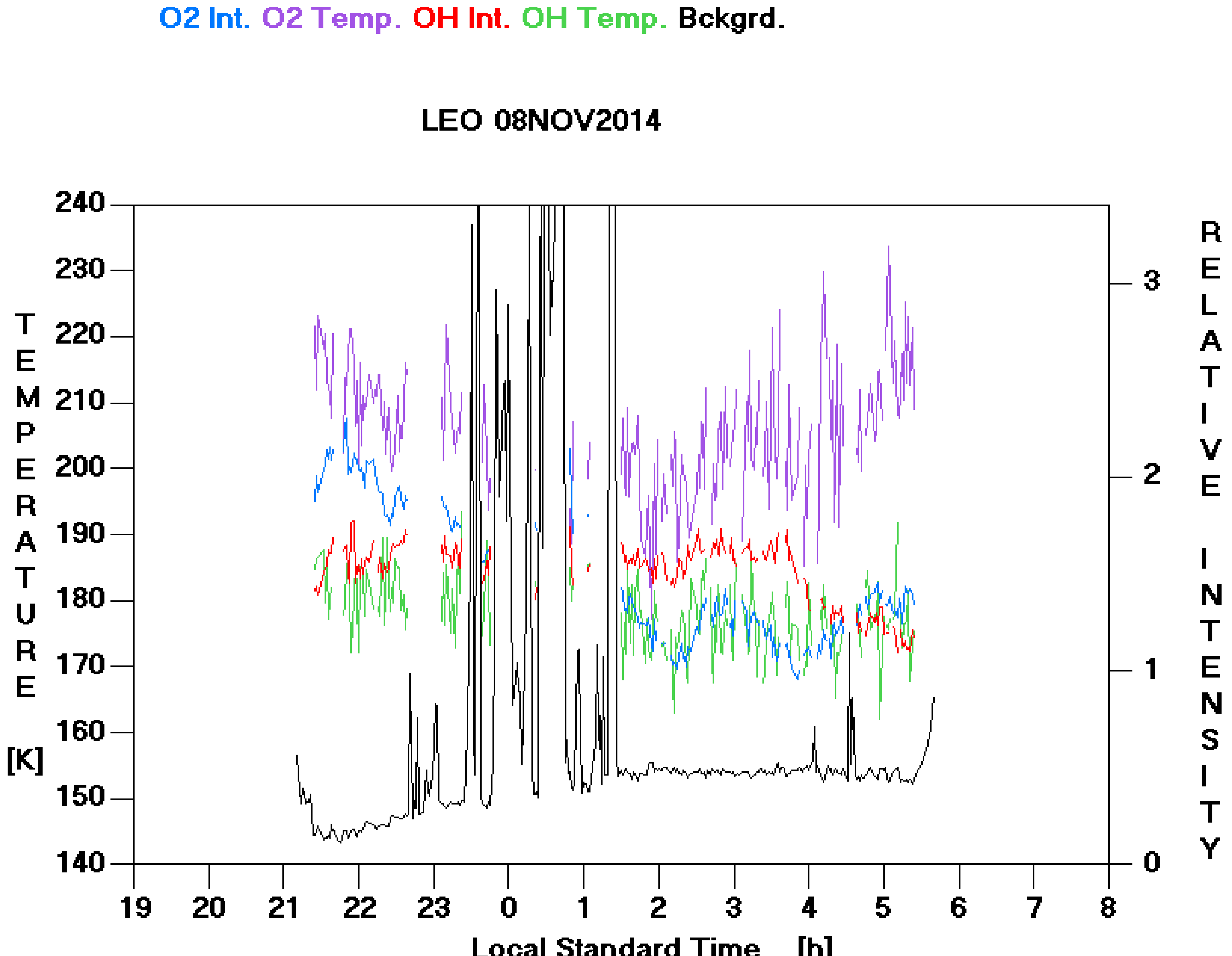
Nearly all the rest (49) is without IO2 signature.
There are no convincing counterexamples (upward phase pr.).

A recent example of O2 intensity burst:

9 Nov 2014 (*clear full moon night*)

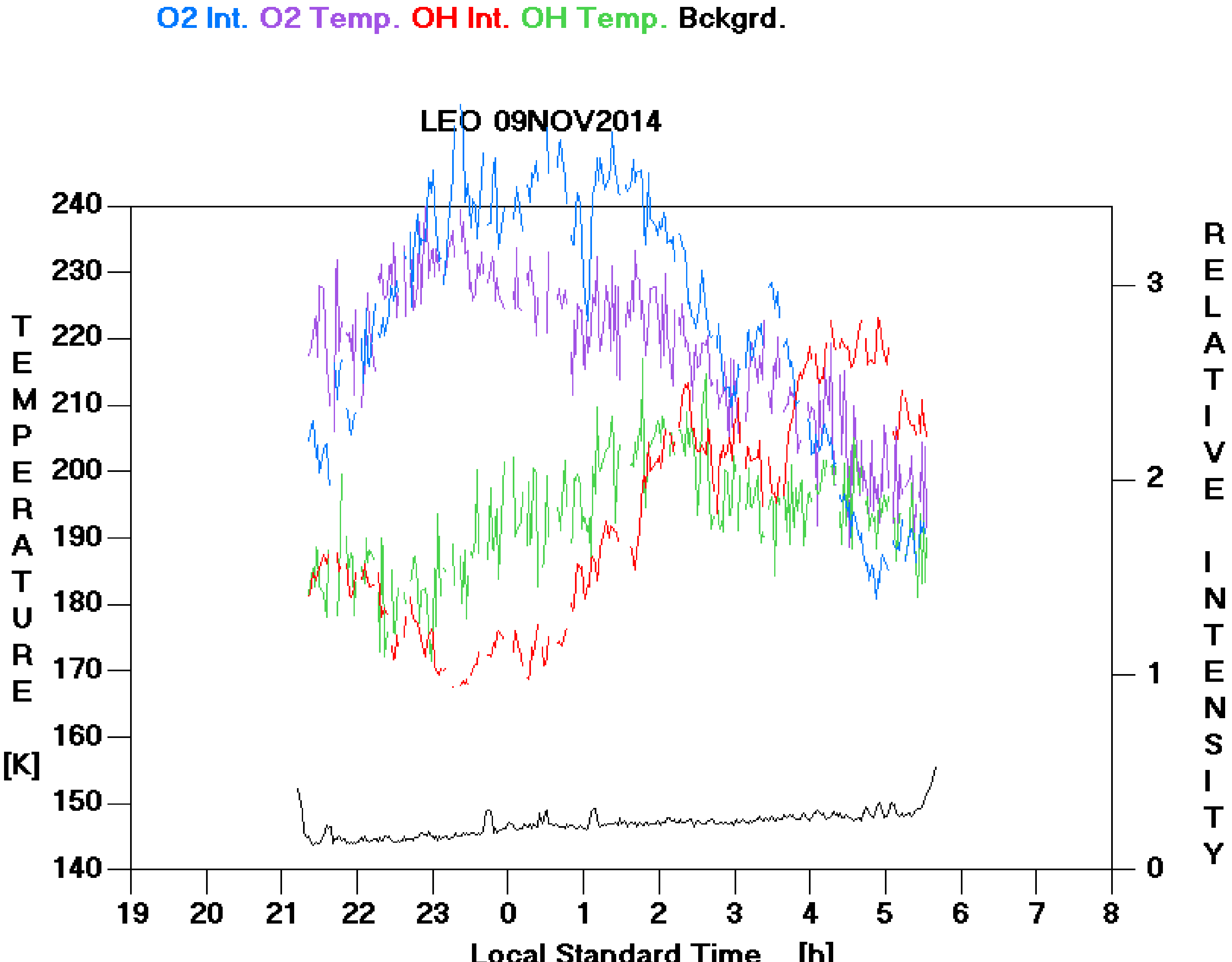


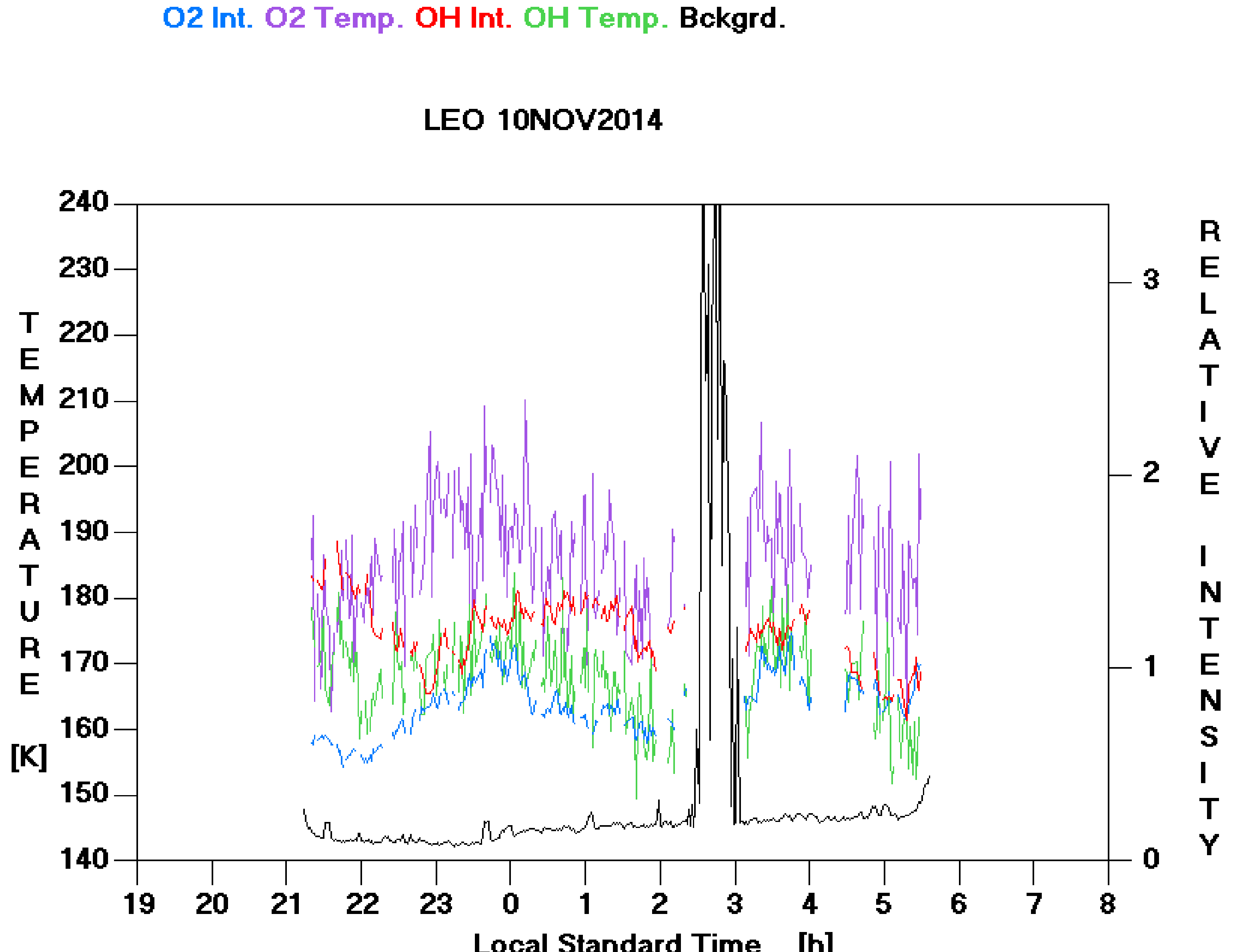
O2 Int. O2 Temp. OH Int. OH Temp. Bckgrd.
LEO 07NOV2014
TEMPERATURE [K]
240
230
220
210
200
190
180
170
160
150
140
RELATIVE INTENSITY
3
2
1
0
19 20 21 22 23 0 1 2 3 4 5 6 7 8
Local Standard Time [h]

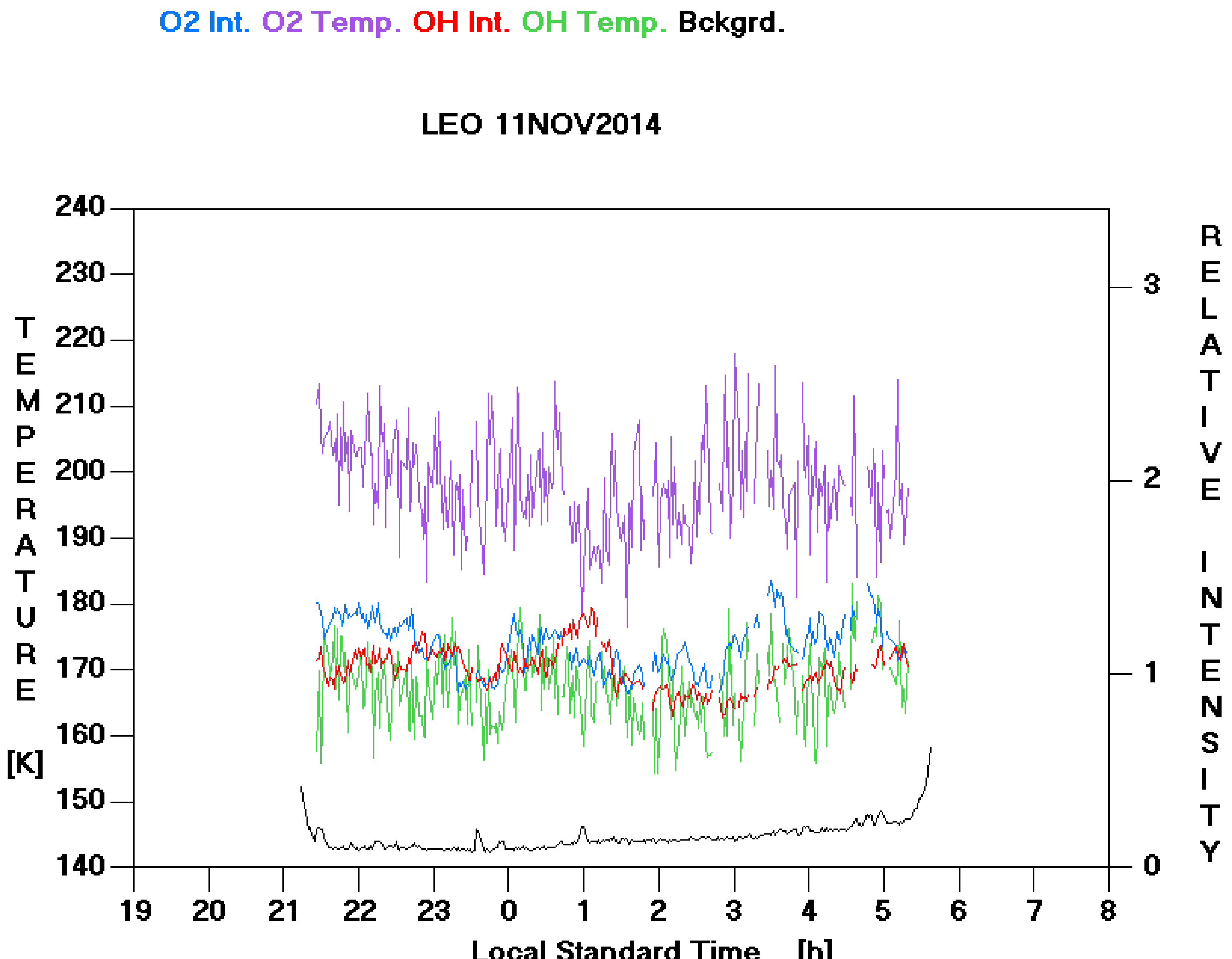


O2 Int. O2 Temp. OH Int. OH Temp. Bckgrd.
LEO 08NOV2014
TEMPERATURE [K]
240
230
220
210
200
190
180
170
160
150
140
RELATIVE INTENSITY
3
2
1
0
19 20 21 22 23 0 1 2 3 4 5 6 7 8
Local Standard Time [h]

O2 intensity “burst”!




O2 Int. O2 Temp. OH Int. OH Temp. Bckgrd.
LEO 10NOV2014
240
230
220
210
200
190
180
170
160
150
140
TEMPERATURE
[K]
3
2
1
0
RELATIVE INTENSITY
19
20
21
22
23
0
1
2
3
4
5
6
7
8
Local Standard Time [h]



O2 Int. O2 Temp. OH Int. OH Temp. Bckgrd.
LEO 11NOV2014
TEMPERATURE [K]
240
230
220
210
200
190
180
170
160
150
140
RELATIVE INTENSITY
3
2
1
0
19
20
21
22
23
0
1
2
3
4
5
6
7
8
Local Standard Time [h]

Intensity scales for OH and O_2 are different, and mean intensity varies

with season, but also quite strongly from year to year.

Therefore, statistical analysis not done directly on “photon counts”.

For objective ranking of OH and O_2 bright nights (airglow ”bursts”), we...

For objective ranking of OH and O_2 bright nights (airglow ”bursts”), we

1. take the difference between “burst” and weighted average over
   5 previous and 5 following nights

2. we then normalize by the weighted average of the neighbours

   “burst strength” = “burst” / <neighbours> - 1

   (not needed for temperature: difference in kelvins
   is clear enough: “temp. burst strength” = “burst”- <neighbours>)

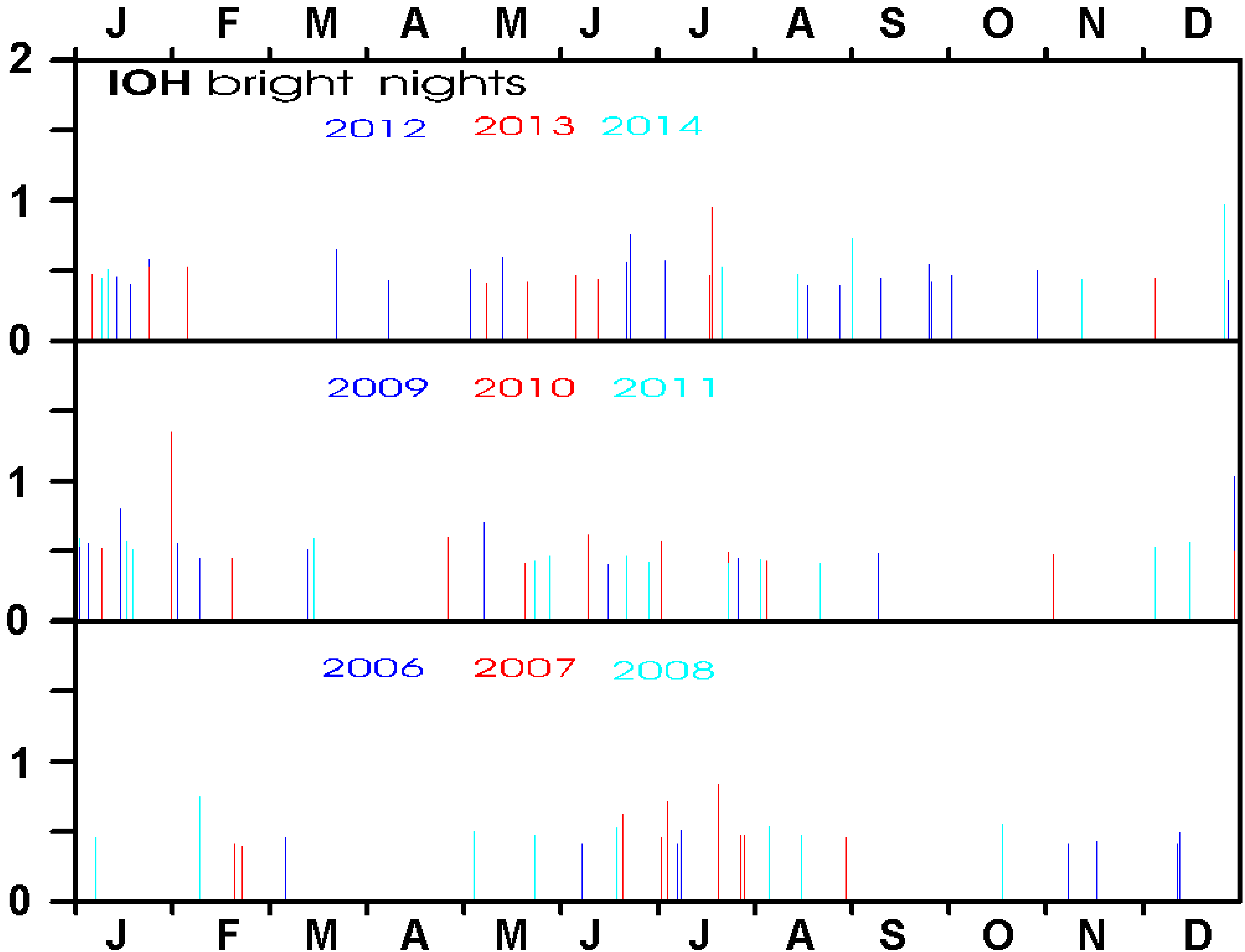
ca. 3:30 h

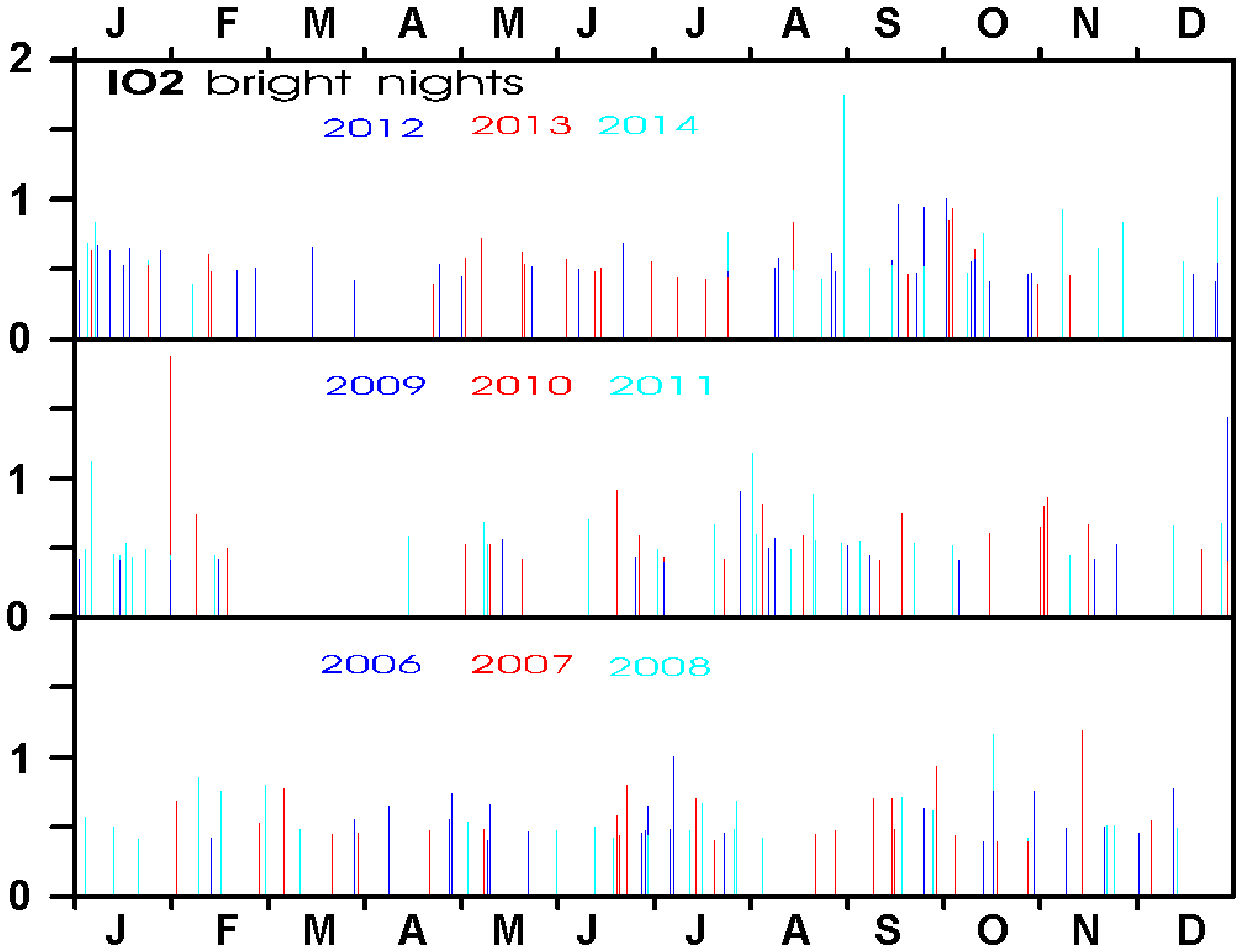
The center night -burst candidate- must have at least 150 data points.
Still 87% of our data comply with this requirement.

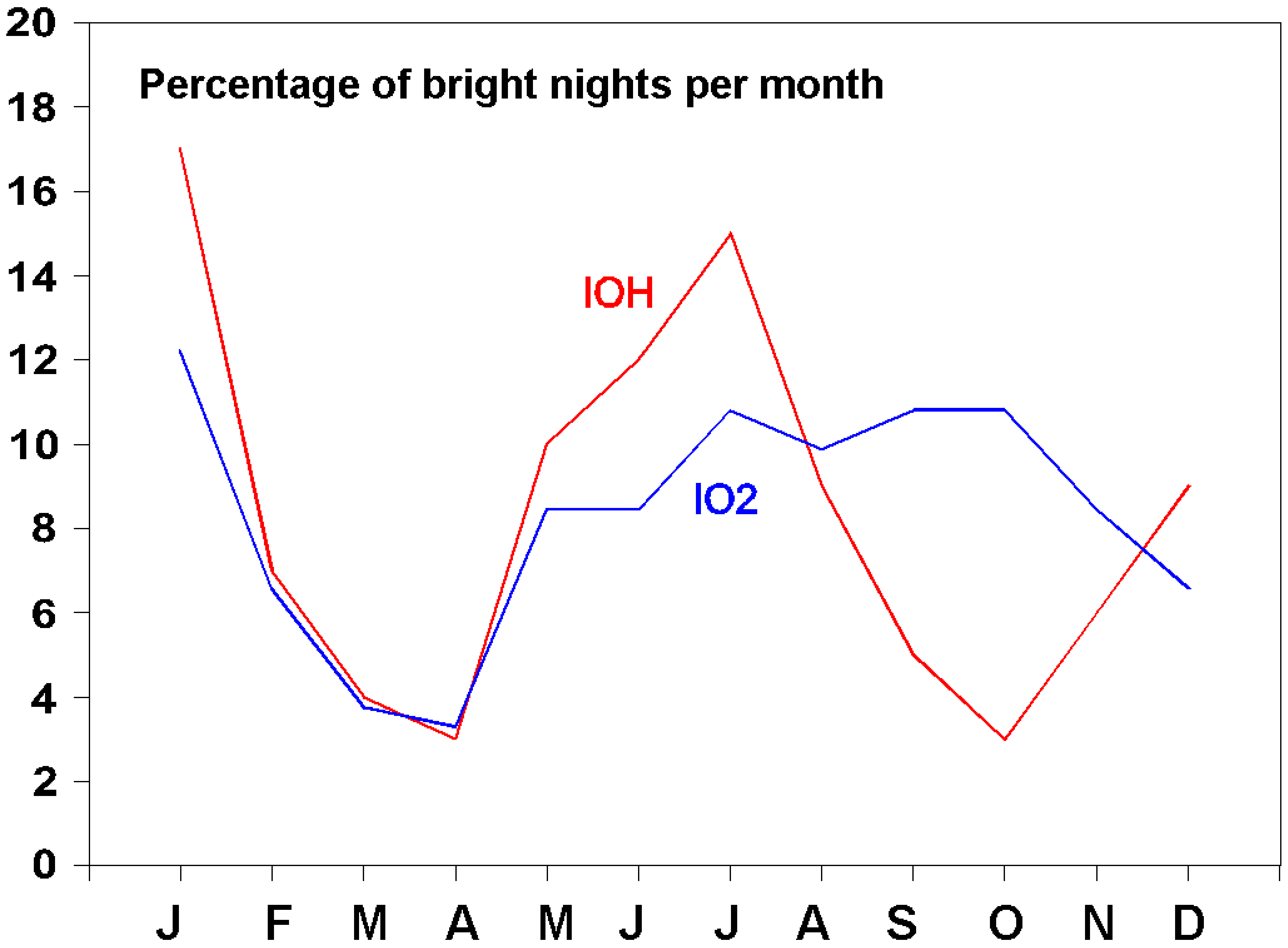
After some experimentation, we define a cutoff of 0.393 “burst strength”.
This means the “burst” is about 40% above local “normal”.

This defines the top 100 for OH intensity, and the top 213 for O_2 intensity.

This greater number of O_2 bursts may reflect the stronger [O] dependence.


J F M A M J J A S O N D
2
IOH bright nights
2012 2013 2014
1
0
2009 2010 2011
1
0
2006 2007 2008
1
0
J F M A M J J A S O N D


J F M A M J J A S O N D
2
1
0
IO2 bright nights
2012 2013 2014
2009 2010 2011
1
0
2006 2007 2008
1
0
J F M A M J J A S O N D



Percentage of bright nights per month
IOH
IO2
20
18
16
14
12
10
8
6
4
2
0
J
F
M
A
M
J
J
A
S
O
N
D

May-July maximum in OH burst occurrence (similar: Scheer et al. 2005)

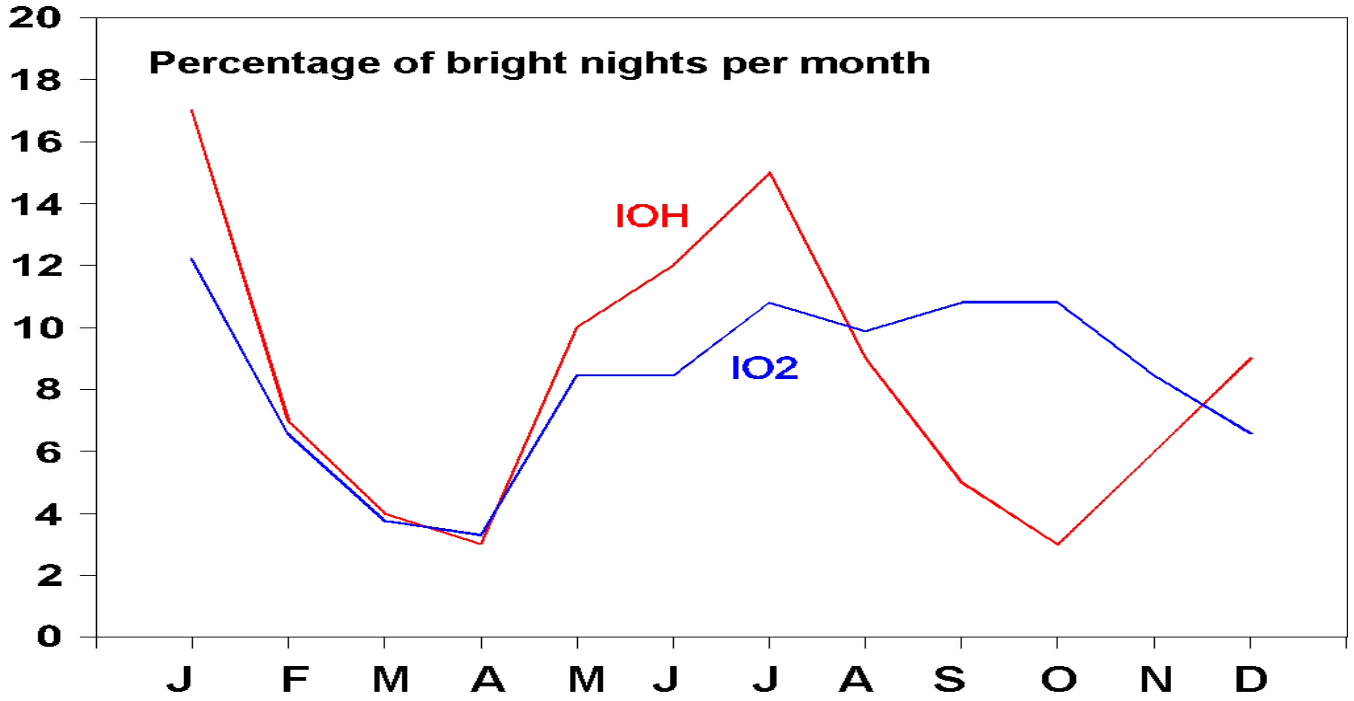
OH burst minimum in April, also for O2

Another OH minimum in October

O2 intensity bursts now frequent in July-October

A possible contribution from the southern spring transition (Sep, Oct)

January maximum is also unexpected (and probably not an artifact from Q2D planetary wave, or is it?).



Some more statistics:

66 nights are bright only in OH intensity

179 bright nights only in O2 intensity

34 nights with “bursts” in both emissions

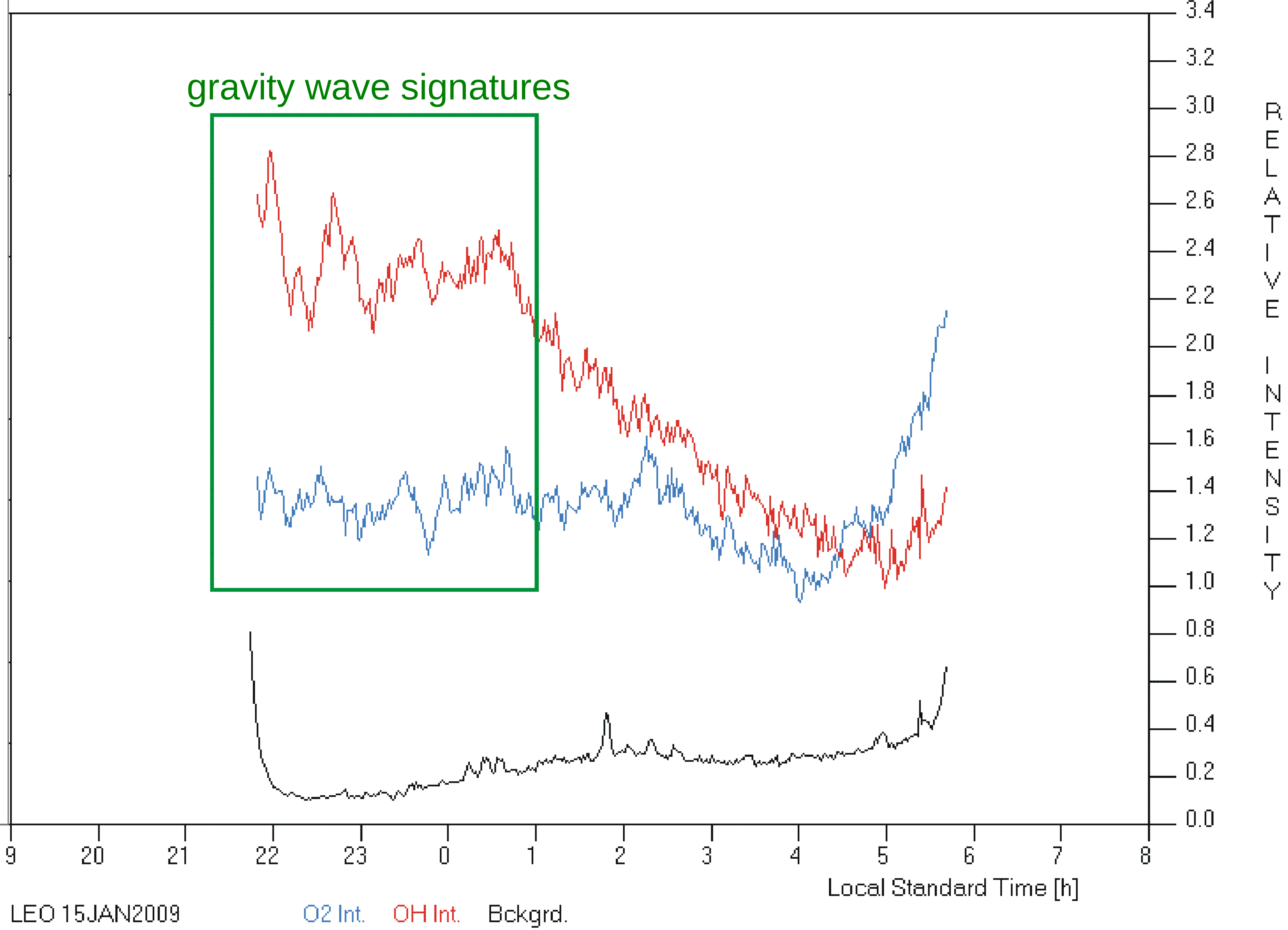
Please, believe me even if I only show part of the “both emissions” list!

#IOH	ddmmyy	bsIO2	DTO2[K]	bsIOH	DTOH[K]
1	310110	1.88	30.1	1.37	22.5
2	311209	1.45	18.8	1.04	17.6
3	281214	1.02	13.9	0.98	22.7
5	220707	0.41	-1.4	0.85	7.4
6	150109	0.43	2.6	0.81	6.3
8	090208	0.86	11.4	0.76	13.7
13	220607	0.45	12.5	0.63	11.1
22	170111	0.55	10.1	0.58	7.2
23	220612	0.70	11.2	0.58	9.3
28	250912	0.95	6.2	0.55	9.1
32	020109	0.43	4.6	0.54	7.2
33	240113	0.53	7.1	0.54	5.8
34	190608	0.43	6.8	0.53	3.5
41	190111	0.44	5.8	0.52	4.1
43	311210	0.41	0.9	0.51	3.3
44	291012	0.49	9.1	0.51	10.0
45	141206	0.78	8.3	0.50	10.5
46	250710	0.43	7.9	0.50	6.8
49	041110	0.87	9.5	0.49	11.7
51	160814	0.51	6.8	0.49	8.7
53	060113	0.65	13.6	0.49	15.6
57	190713	0.44	4.4	0.48	5.4

etc.etc.

#IOH	ddmmyy	bsIO2	DTO2[K]	bsIOH	DTOH[K]
1	310110	1.88	30.1	1.37	22.5
2	311209	1.45	18.8	1.04	17.6
3	281214	1.02	13.9	0.98	22.7
5	220707	0.41	-1.4	0.85	7.4
6	150109	0.43	2.6	0.81	6.3
8	090208	0.86	11.4	0.76	13.7
13	220607	0.45	12.5	0.63	11.1
22	170111	0.55	10.1	0.58	7.2
23	220612	0.70	11.2	0.58	9.3
28	250912	0.95	6.2	0.55	9.1
32	020109	0.43	4.6	0.54	7.2
33	240113	0.53	7.1	0.54	5.8
34	190608	0.43	6.8	0.53	3.5
41	190111	0.44	5.8	0.52	4.1
43	311210	0.41	0.9	0.51	3.3
44	291012	0.49	9.1	0.51	10.0
45	141206	0.78	8.3	0.50	10.5
46	250710	0.43	7.9	0.50	6.8
49	041110	0.87	9.5	0.49	11.7
51	160814	0.51	6.8	0.49	8.7
53	060113	0.65	13.6	0.49	15.6
57	190713	0.44	4.4	0.48	5.4

etc.etc.


gravity wave signatures
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
RELATIVE INTENSITY
19
20
21
22
23
0
1
2
3
4
5
6
7
8
Local Standard Time [h]
LEO 15JAN2009
O2 Int.
OH Int.
Bckgrd.

coincident bursts among top 12

ddmmyy	rank	with GW?
310110	1 IOH, 1 IO2	no
311209	2 IOH, 3 IO2	GW, both?
281214	3 IOH, 8 IO2	GW IO2
220707	5 IOH, 198 IO2	GW both
150109	6 IOH, 192 IO2	GW both
090208	8 IOH, 20 IO2	GW both
090706	9 IO2, 83 IOH	no
021012	10 IO2, 58 IOH	GW both
250912	12 IO2, 28 IOH	GW both

-> assoc with GW in 10 of 12 cases

may be consistent with earlier result:
50% GW assoc; while normal is 5% of all nights
(Scheer et al. 2005)

Summary:

Objective ranking of nights with enhanced airglow brightness defined

Top 100 in OH intensity, top 213 in O_2 intensity above same threshold

Seasonal occurrence probability peaks in May to July, for OH

Unexpected April minimum, for both emissions

High September, October occurrence for O2 emission
– the southern spring transition?

Very strong association with GW signatures in top dozen airglow bursts

Some evidence of downward phase propagation
(without good counterexamples) suggests link to dynamics

Open questions:

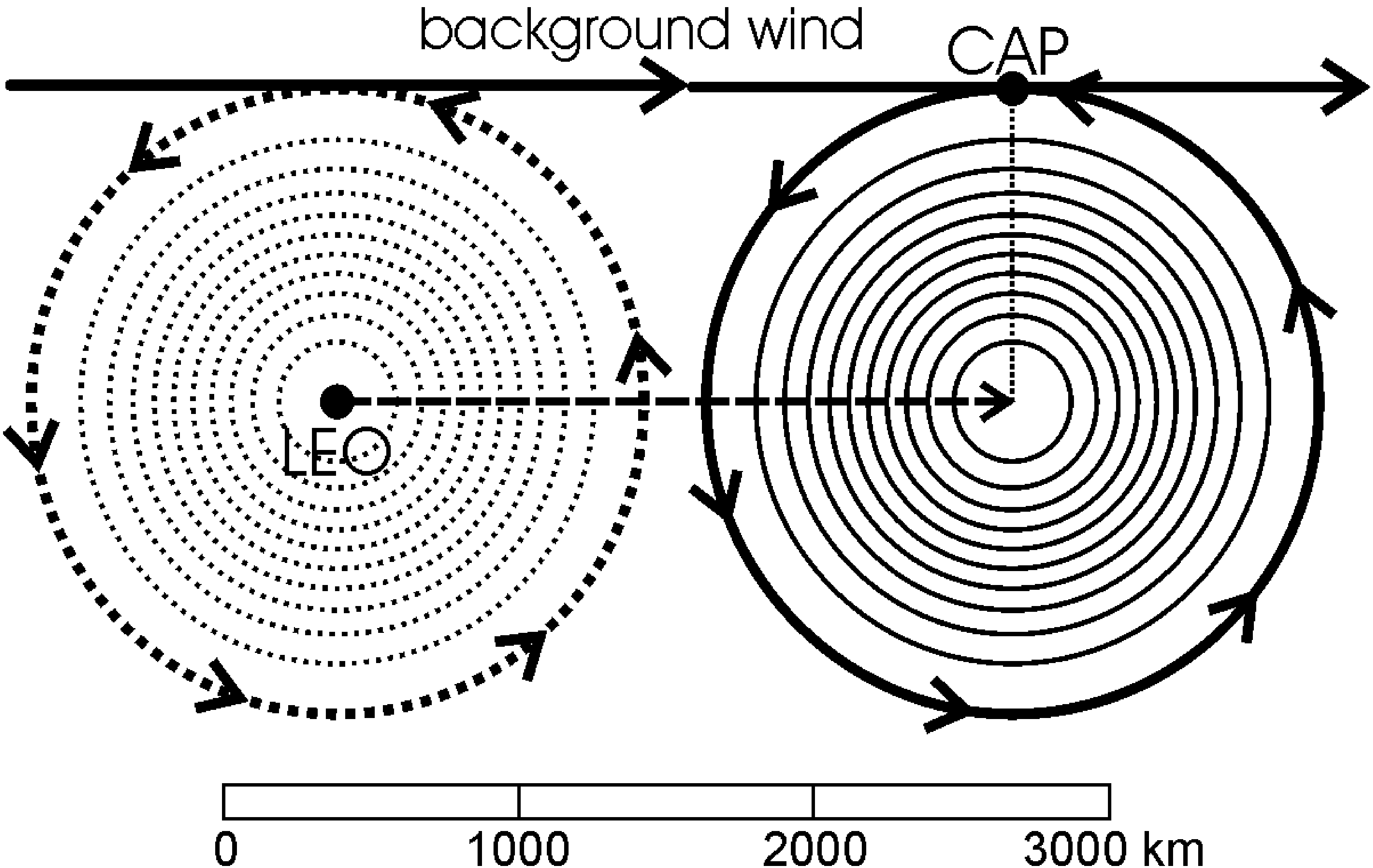
What is the dominant dynamical mechanism for producing bright nights?

What is the reason for the strong association with gravity waves?

Are there different types of airglow burst?

Is the thermal wind vortex mechanism (Scheer et al. 2005) valid?

Can satellite data (SABER, TIDI?) help resolve some of these questions?


background wind
CAP
LEO
0
1000
2000
3000 km

Thank you for your attention!

http://www.iafe.uba.ar/aeronomia/

Some references...

Strutt (Lord Rayleigh IV), R.J., On a night sky of exceptional brightness, and on the distinction between the polar aurora and the night sky, Proc. Roy. Soc. (London) A131, 376-381, 1931. (obs on 8 Nov 1929, @52°N, not due to 558 nm)

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