

# Observations of planetary lightning with NenuFAR

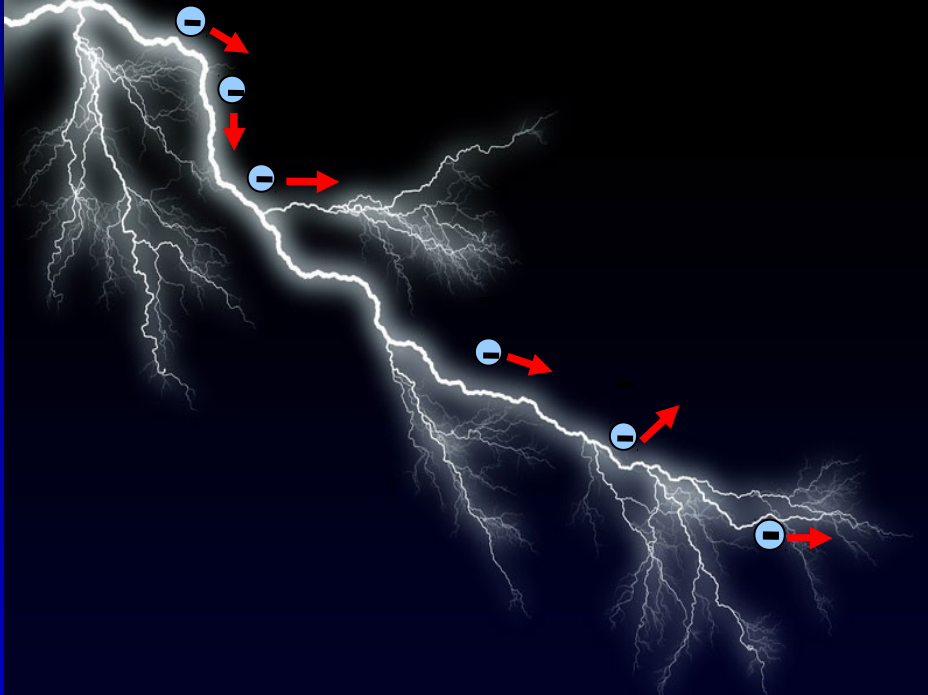


Jean-Mathias Griessmeier

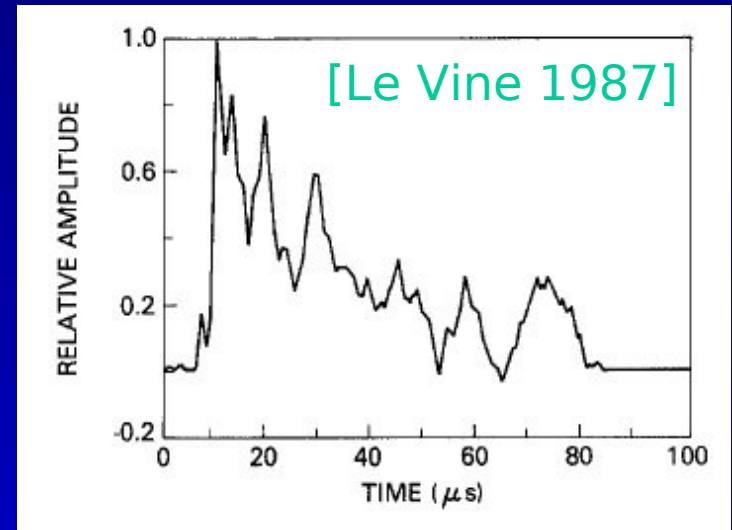
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# Radio emission from lightning



acceleration of charges  
⇒ electromagnetic radiation



Earth:

- flash duration  $\sim 10$  ms
- fine structure  $\sim 10$   $\mu$ s

# Saturn lightning observations

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## Satellite observations:

- Voyager 1 & 2: 1980 & 1981
- Cassini: 2004-now

$10^5$  km

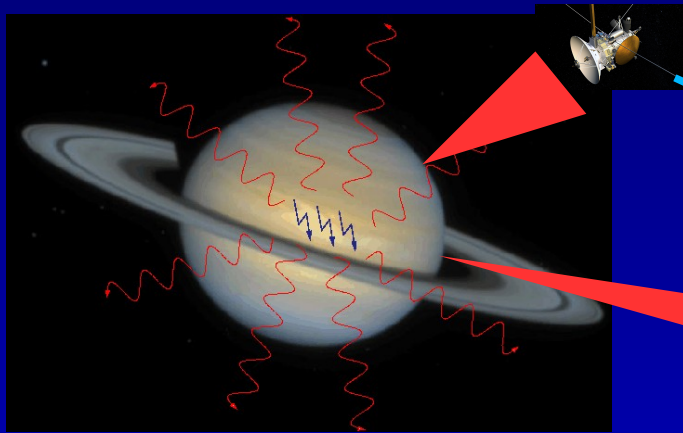
## Ground observations:

- UTR-2: 2007-now
- WSRT: under analysis
- LOFAR: comm. data

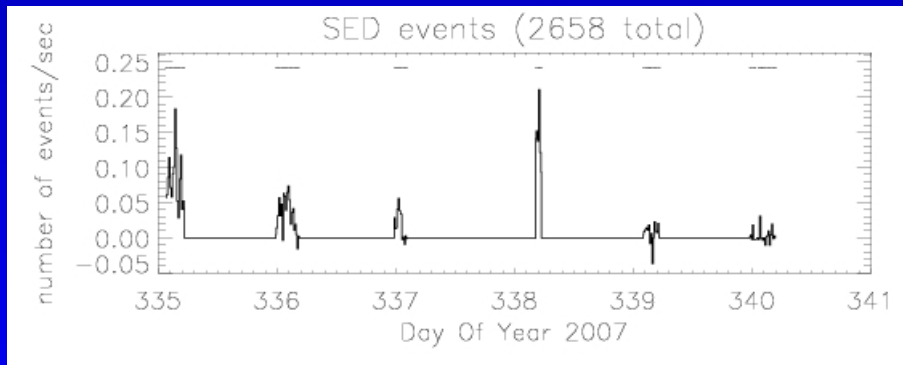
$1.5 \cdot 10^9$  km,  
i.e. signal  
 $10^8$  times  
weaker

modern  
receivers,  
Cassini as  
trigger

# Saturn lightning at UTR-2

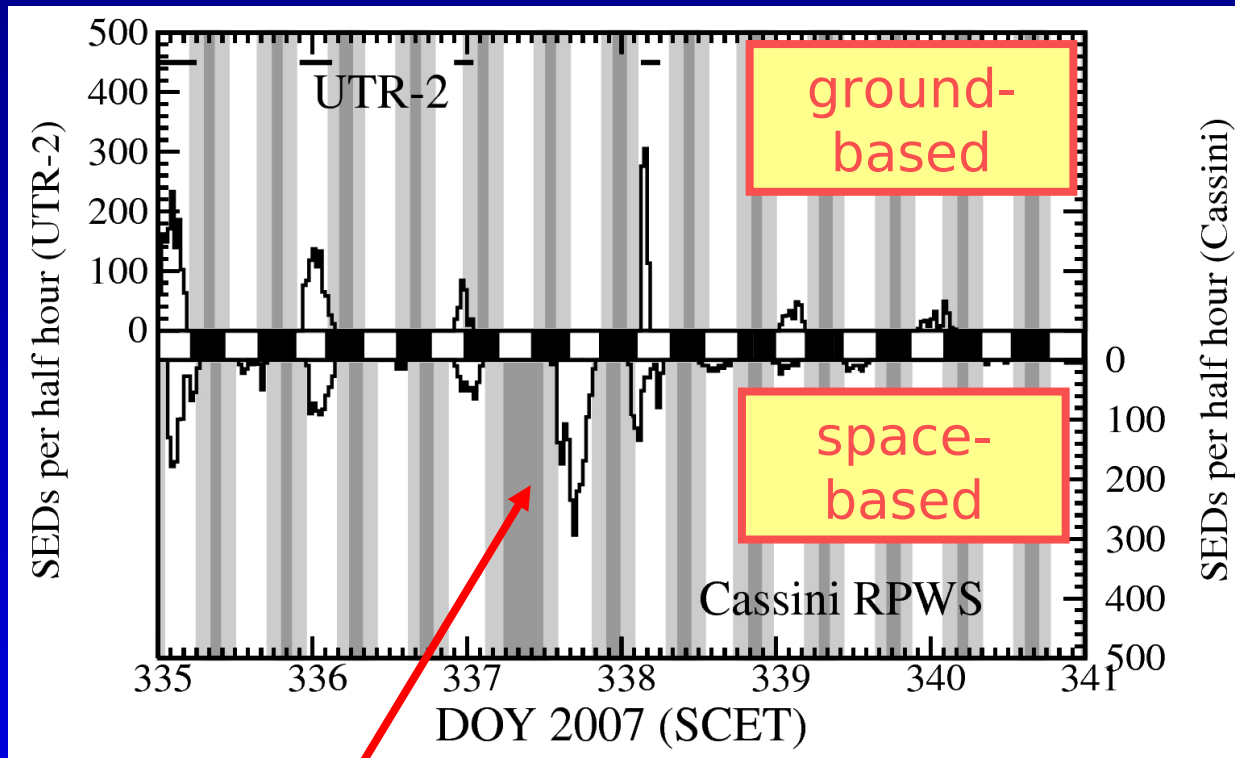


trigger



> 2000 Saturn  
lightning  
events

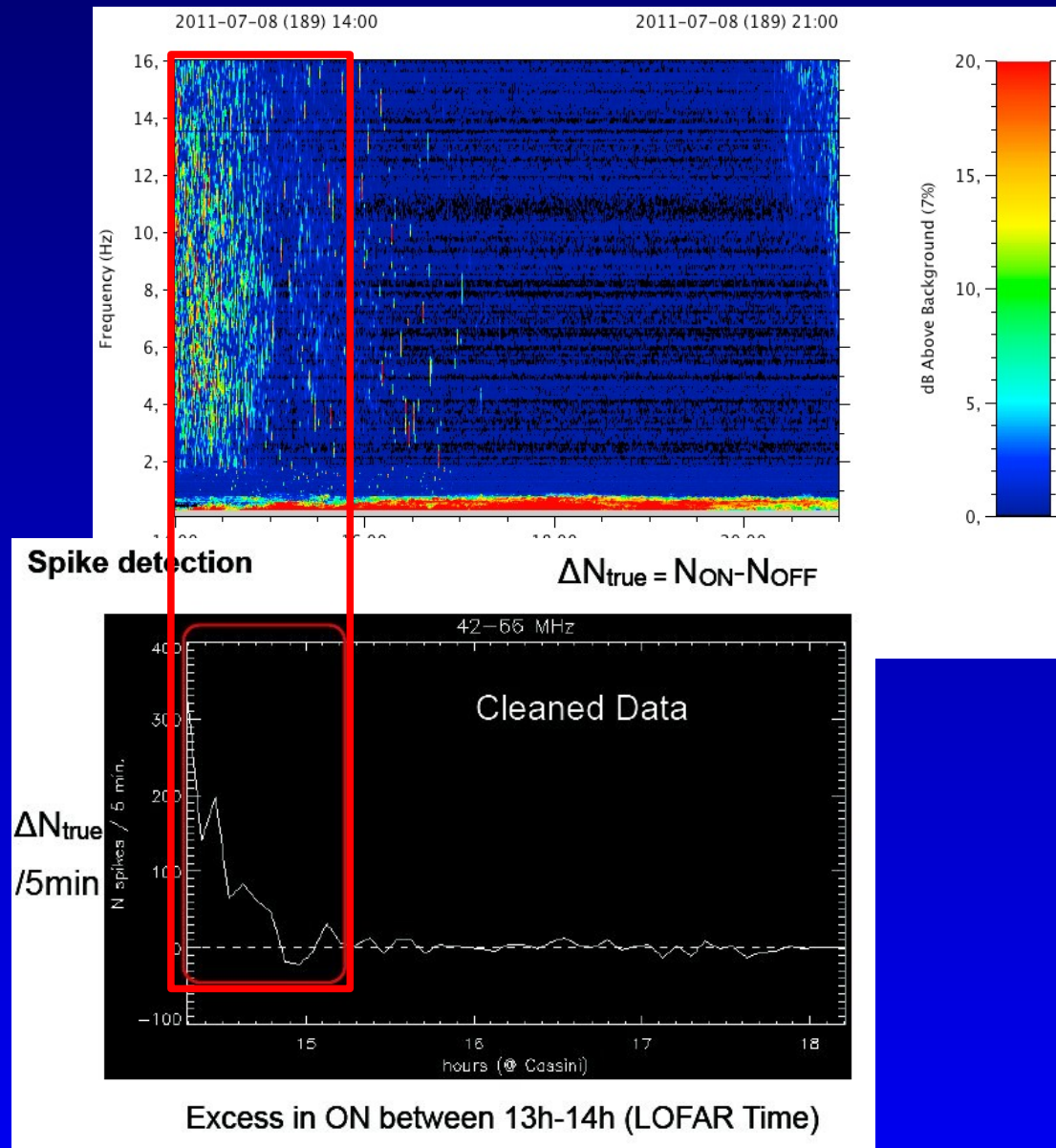
# Saturn lightning at UTR-2



normalized:

- distance
- obs. mode

# Saturn lightning with LOFAR?



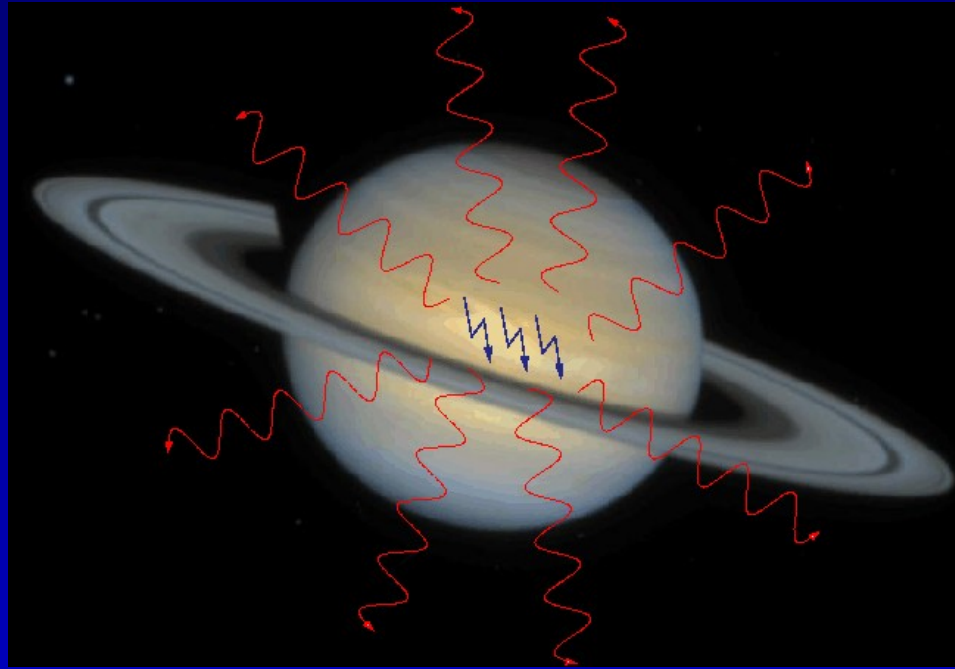
# Why to study planetary lightning?

- existence of lightning... on other planets!
- electrification processes (composition?)
- atmospheric dynamics
- geographical and seasonal variations

... but how?

# Telescope requirements

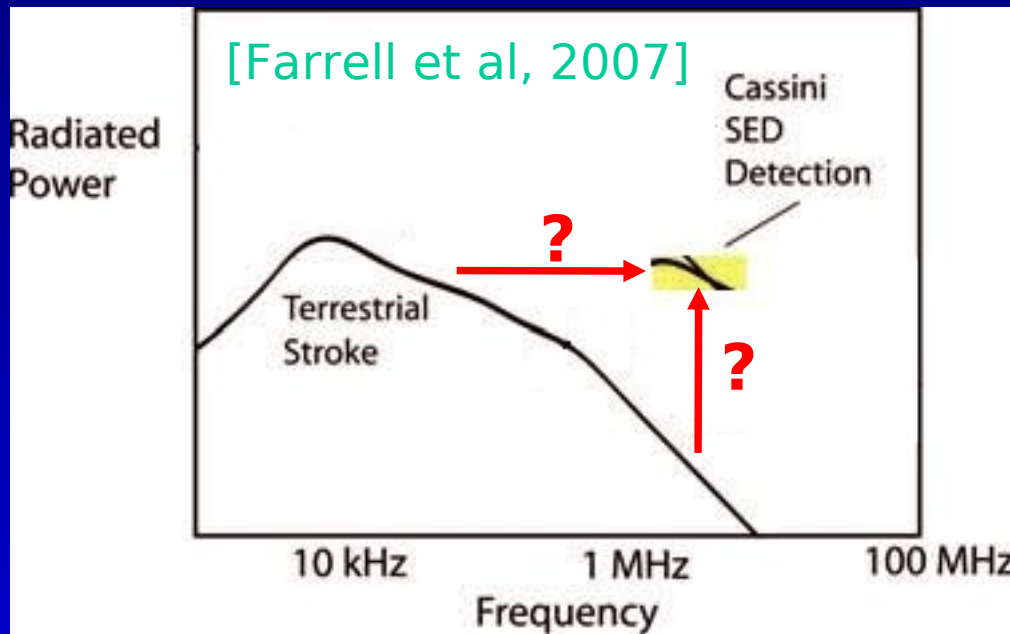
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- high sensitivity (faint signal - ground detection only 2006)
- low frequency (known at 2-40 MHz)
- wide frequency coverage ( $> 40$  MHz)
- multi-beam (discrimination against RFI)
- high time resolution (bursty signal  $\leq 2$  ms)
- good observing cadence & TOO support (sporadic emission:  $\sim 30$ d/year)



# Requirement: Spectral coverage

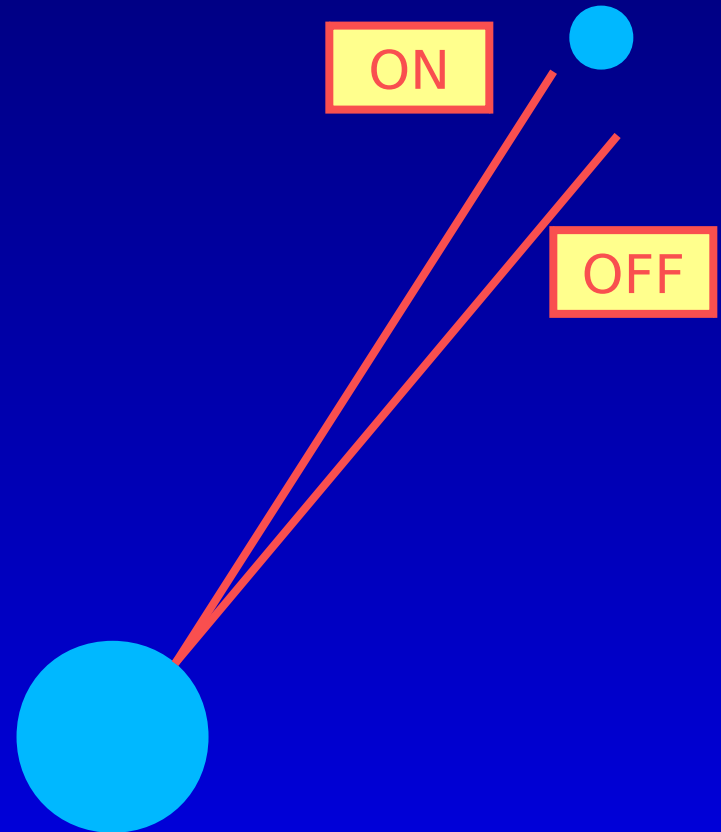


spectrum well known 2-40 MHz

# Requirement: Multiple beams

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observations at 18-28 MHz!  
⇒ strong RFI expected



- ⇒ 2 beam observations
- ⇒ planetary signal in ON only
- ⇒ signal in both ON and OFF to be discarded

# Requirement: Time resolution



- fine structure  $\leq 1$  ms are known
- time resolution larger  $\Rightarrow$   $\tau$  does **not** probe emission!

$\Rightarrow$  high time resolution required

# Requirement: TOO support

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• November 1980	>8 days
• August 1981	>5 days
• May 2004	~4 days
• July 2004	~8 days
• August 2004	~8 days
• September 2004	~25 days
• June 2005	~3 days
• January/February 2006	~36 days
• November/December 2007	~35 days
• January-August 2008	~240 days
• November 2008	~4 days
• December 2008	>6 days

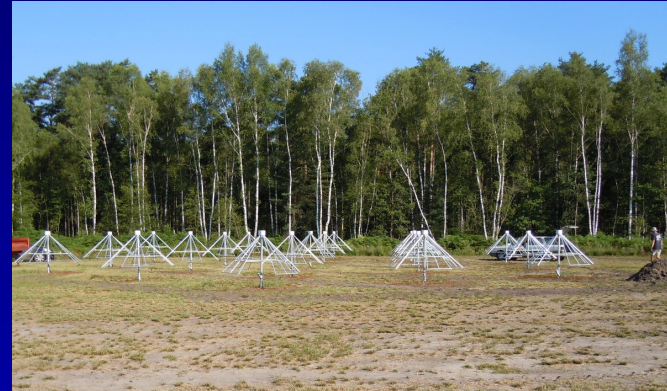
⇒ low occurrence rate

⇒ difficult to predict:

9 months with signal

20 months without signal

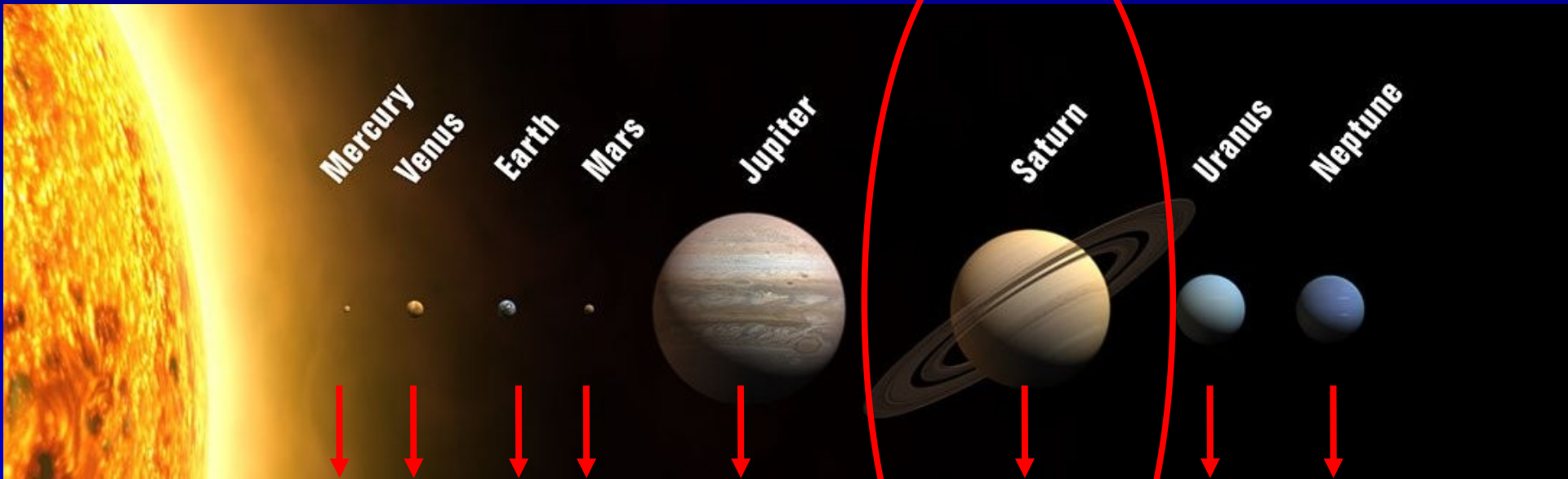
# Telescope requirements



	LOFAR core	LOFAR int-1	NenuFAR-1	NenuFAR-all
sensitivity	"1"	"0.1"	"0.3"	"1.7"
sens. 15 MHz	"0.15"	"0.015"	"0.12"	"0.7"
frequency [MHz]	10/30-90	10/30-90	10/30-85	10/30-85
bandwidth [MHz]	48 MHz	8 MHz	70 MHz	70 MHz
multi-beam	>100	4	2	2 or 4
time resolution	5.12 $\mu$ s	5.12 $\mu$ s	5,10,20 $\mu$ s?	5,10,20 $\mu$ s?
TOO support	yes	yes	yes	yes

⇒ NenuFAR-1 well suited!

# Planetary lightning



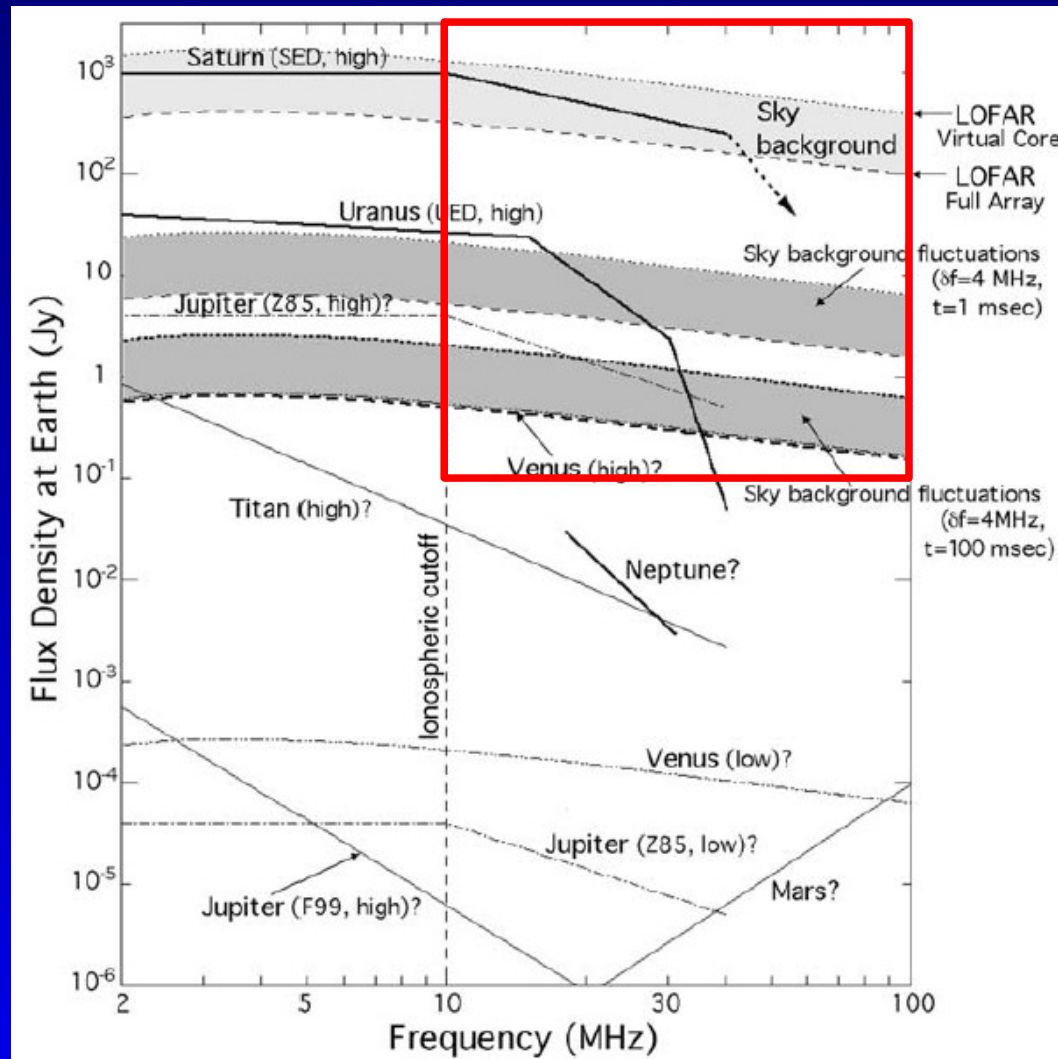
lightning

?



?

# Other planets?



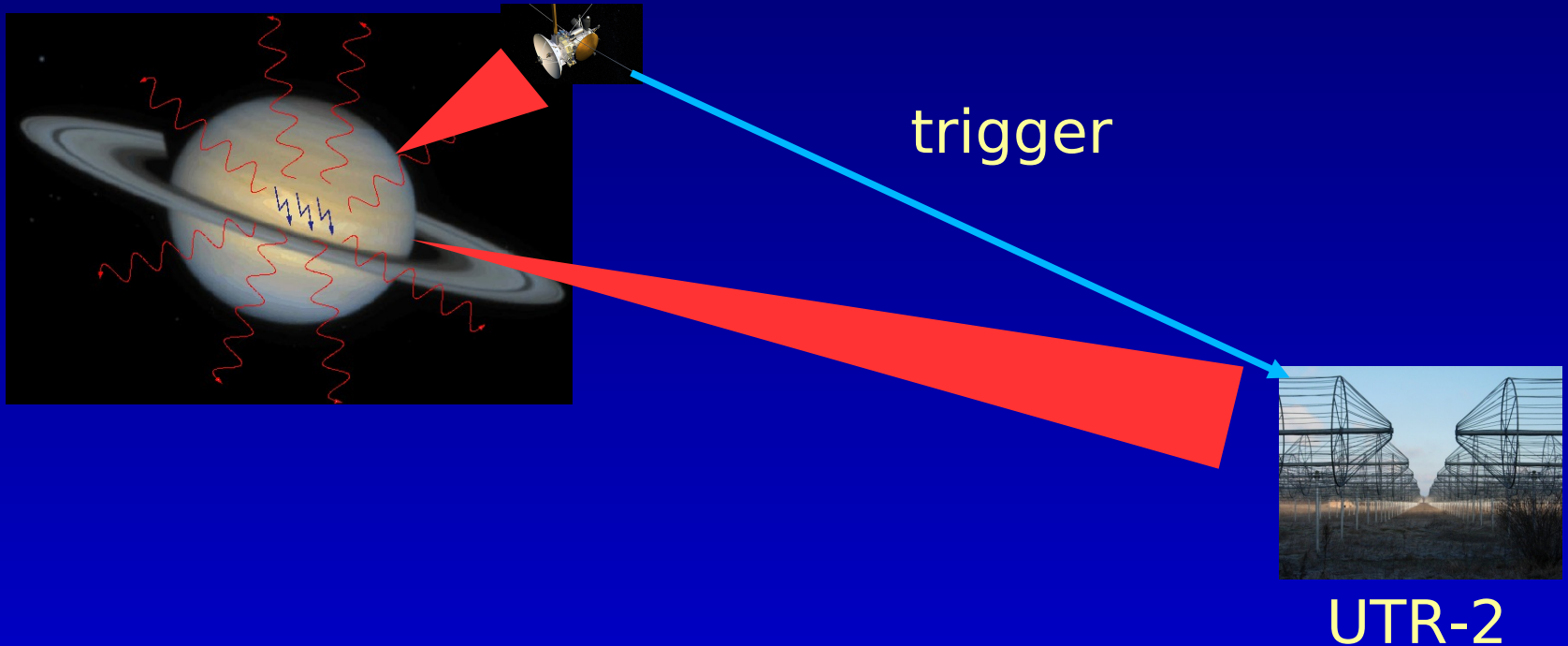
[Zarka et al, PSS, 2004]





# Saturn lightning observations

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Cassini triggers ground-based observations

# RFI test

Saturn

Saturn

RFI

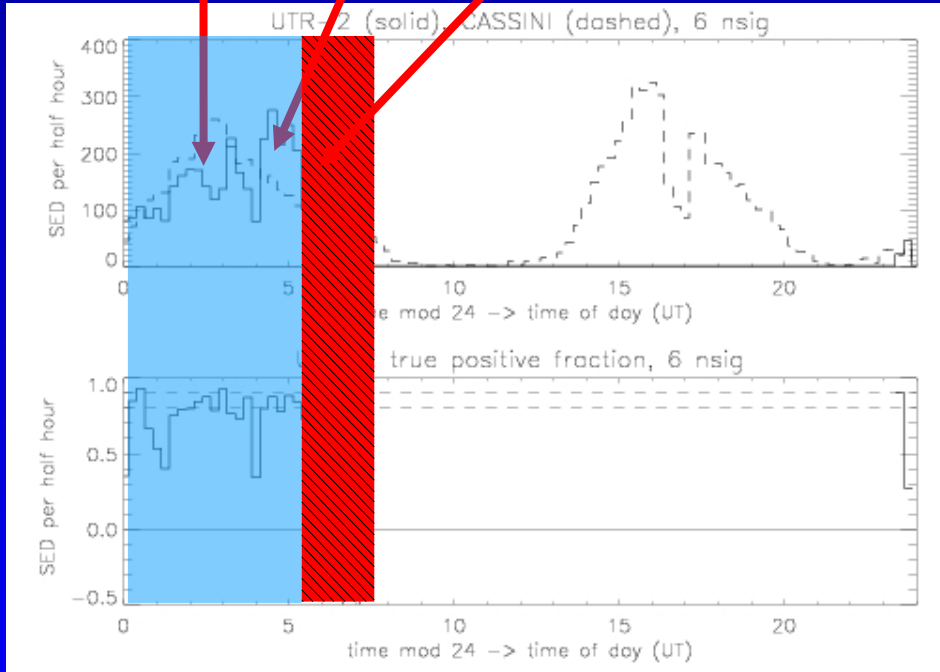
compare  
character of  
SED and RFI!

ON

&

OFF

identify &  
discard  
RFI

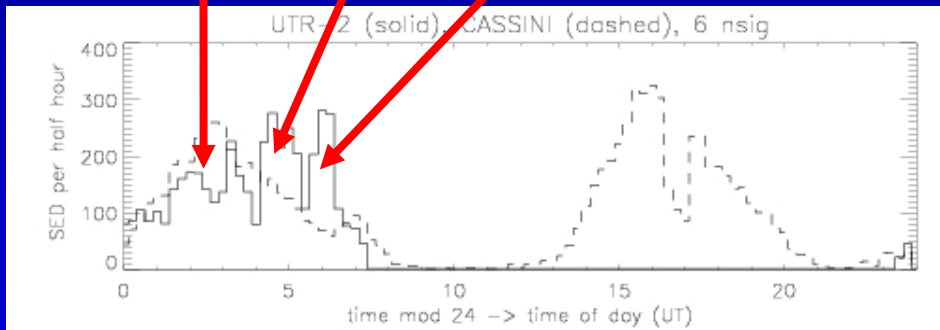


# RFI test

Saturn?

Saturn?

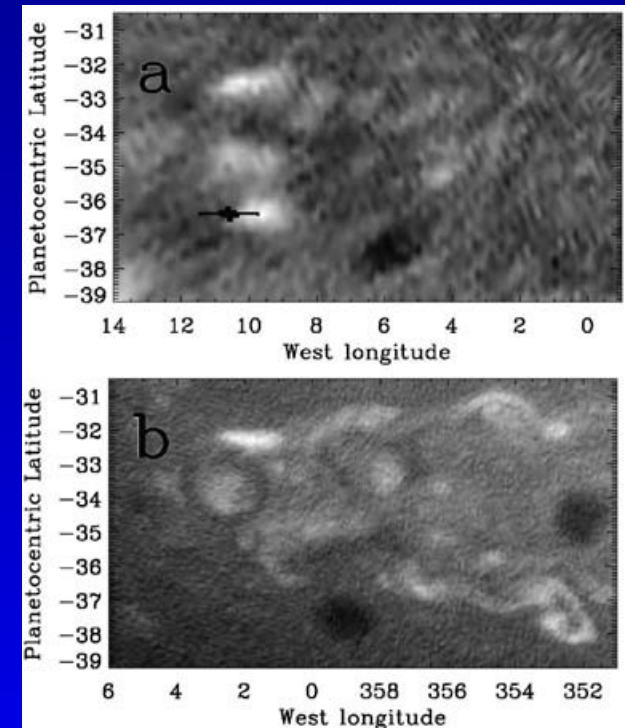
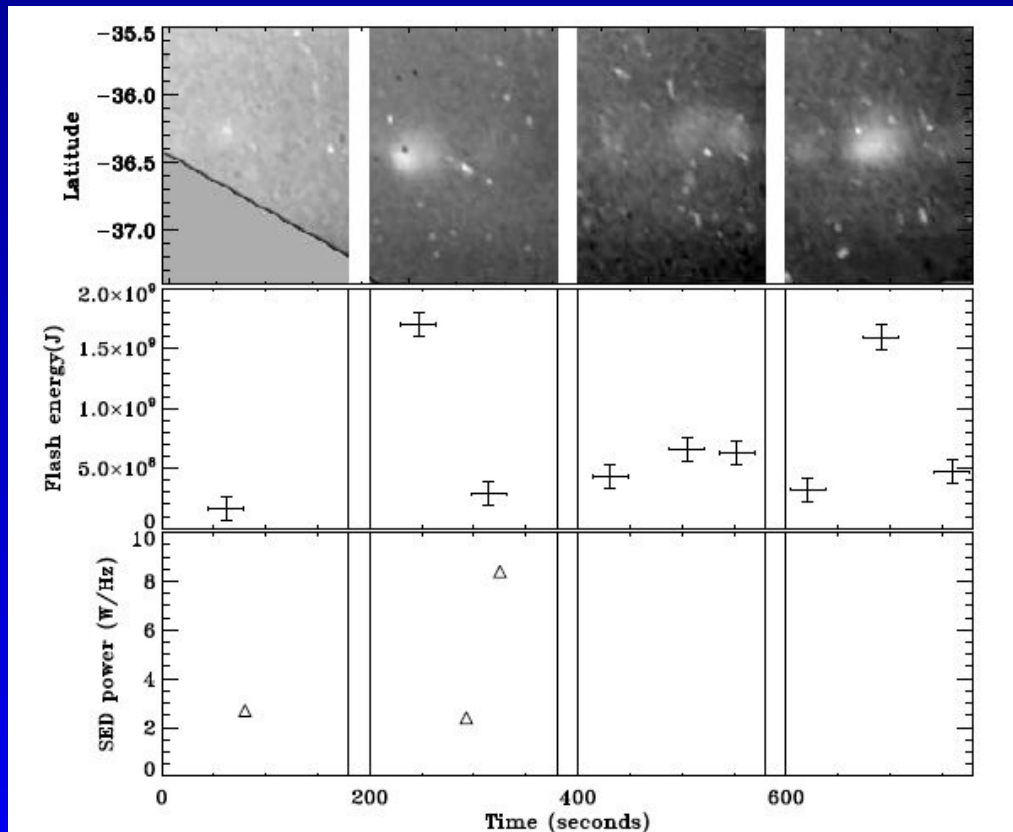
Saturn?



ON

# Lightning as a radiosource

Radiosource: lightning activity in corotating storm  
radio emission  $\leftrightarrow$  optical lightning flashes



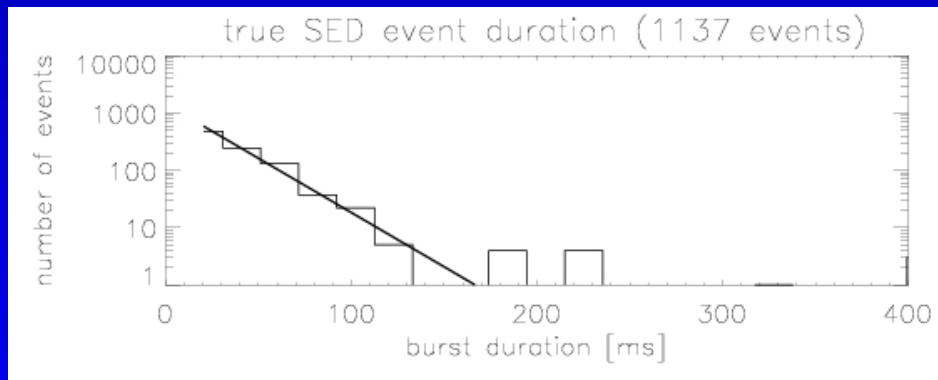
[Dyudina et al. 2010]

# Saturn lightning with WSRT?

- WRST:**
- 14 dishes, Westerbork (NL)
  - SEFD = 400 Jy
  - observations 27/02/2010
  - $f = 10$  MHz in 130-156 MHz
  - 20 kHz, 20.48 msec
  - ON/OFF beam
  - without RFI mitigation

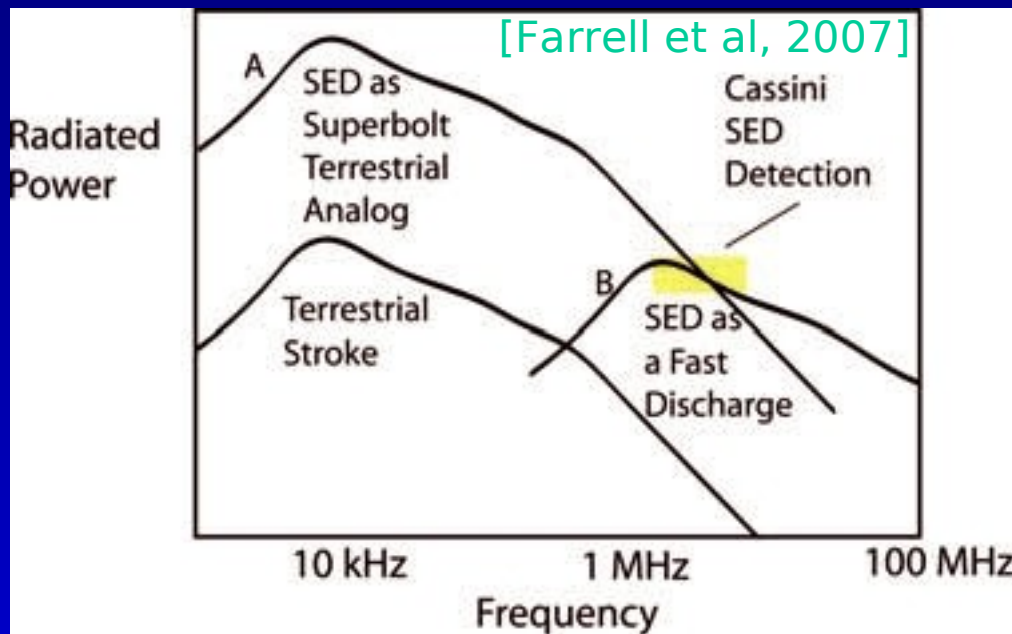


Work in progress!



$$\tau \approx 23 \text{ ms}$$

# Spectrum

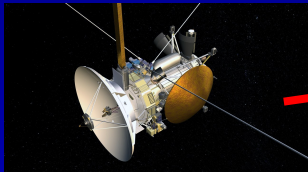


with the currently known spectrum, Saturn lightning could be

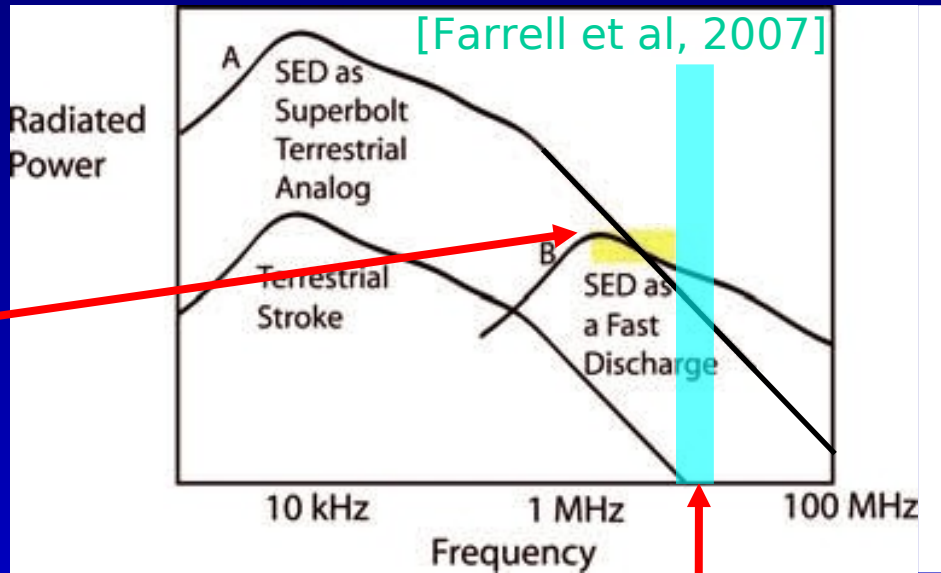
(A) 10000 times **more** energetic than on Earth

(B) 10000 times **less** energetic than on Earth

# Spectrum

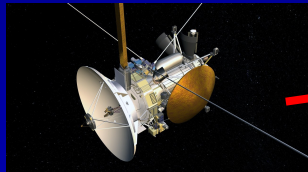


CASSINI

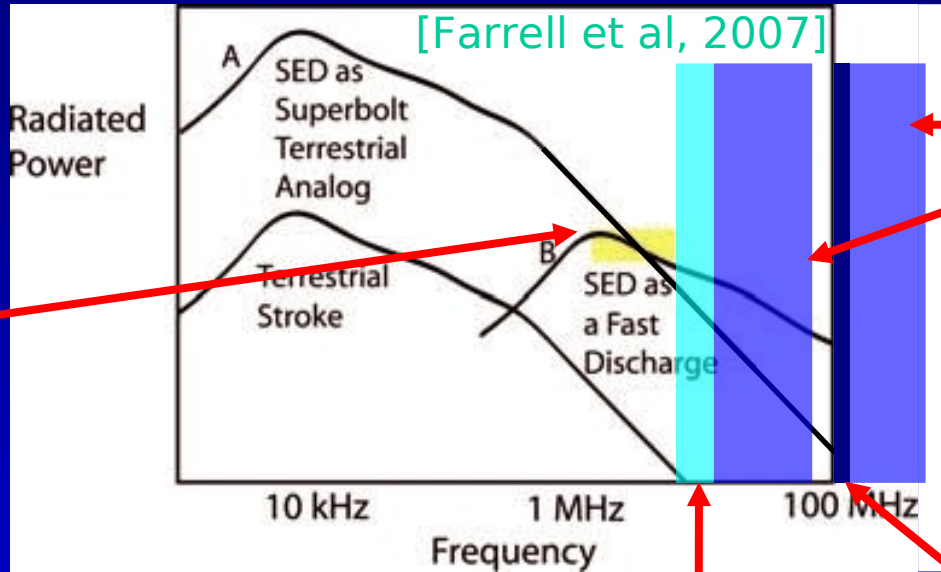


UTR-2

# Spectrum



CASSINI



LOFAR



UTR-2



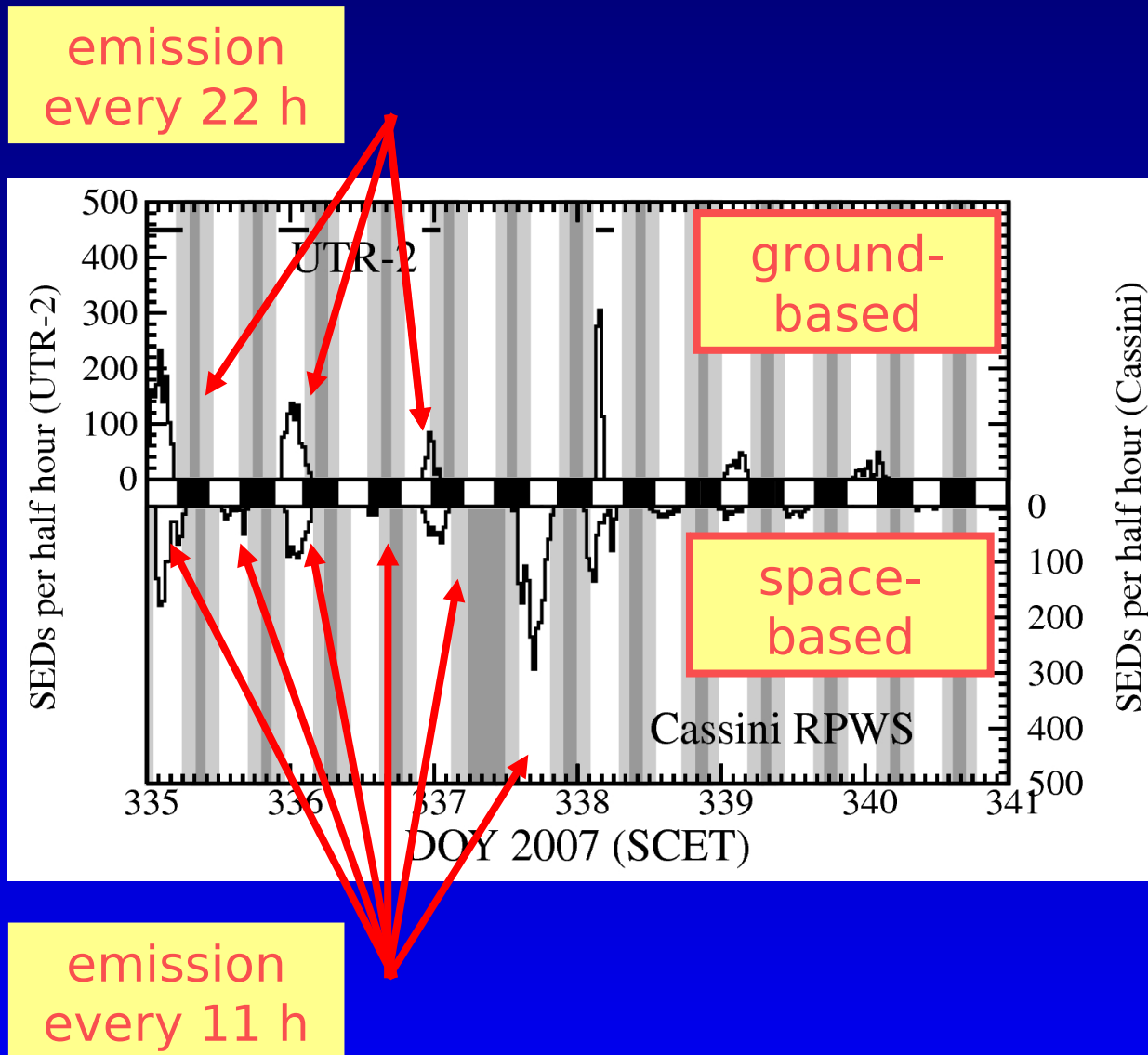
WSRT

spectrum  $\Rightarrow$  temporal profile  $\Rightarrow$  emission physics





# Ground-based vs. space-based



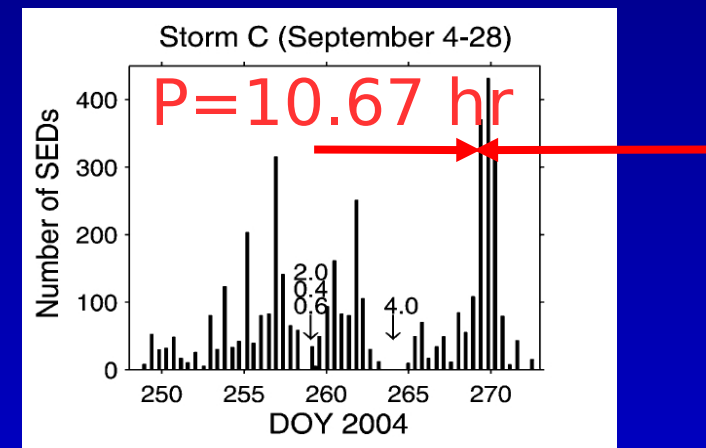
# Lightning as a radiosource

Radiosource: **lightning activity** in corotating storm system

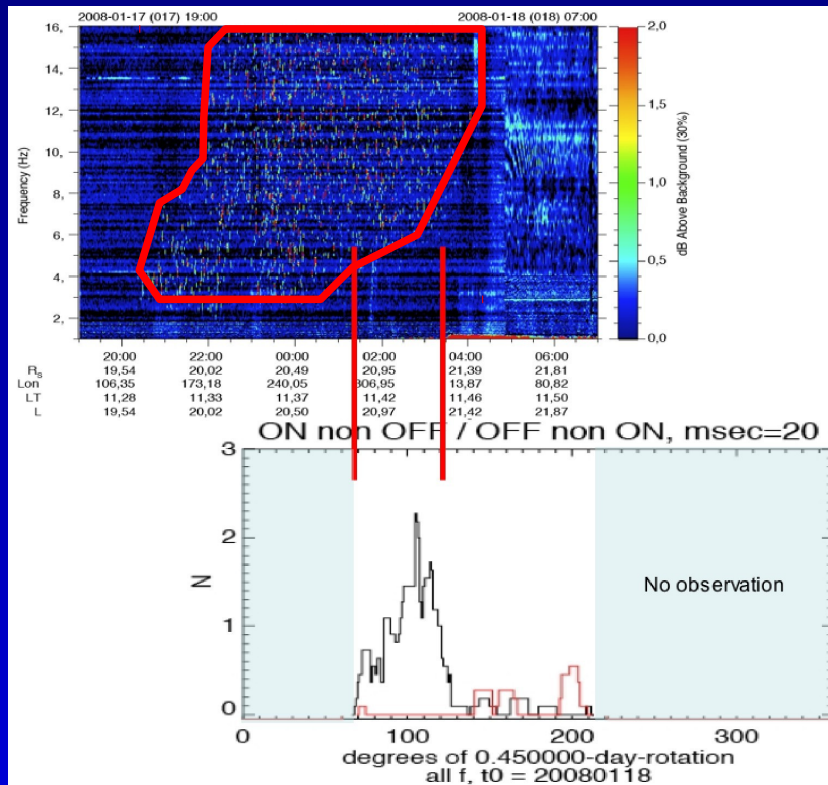
How do we know?

⇒ episodes repeat  
after one  
planetary  
rotation

⇒ we even see  
the storms in  
IR  
(e.g. “Dragon  
storm”, 2004)



# Ground-based observation

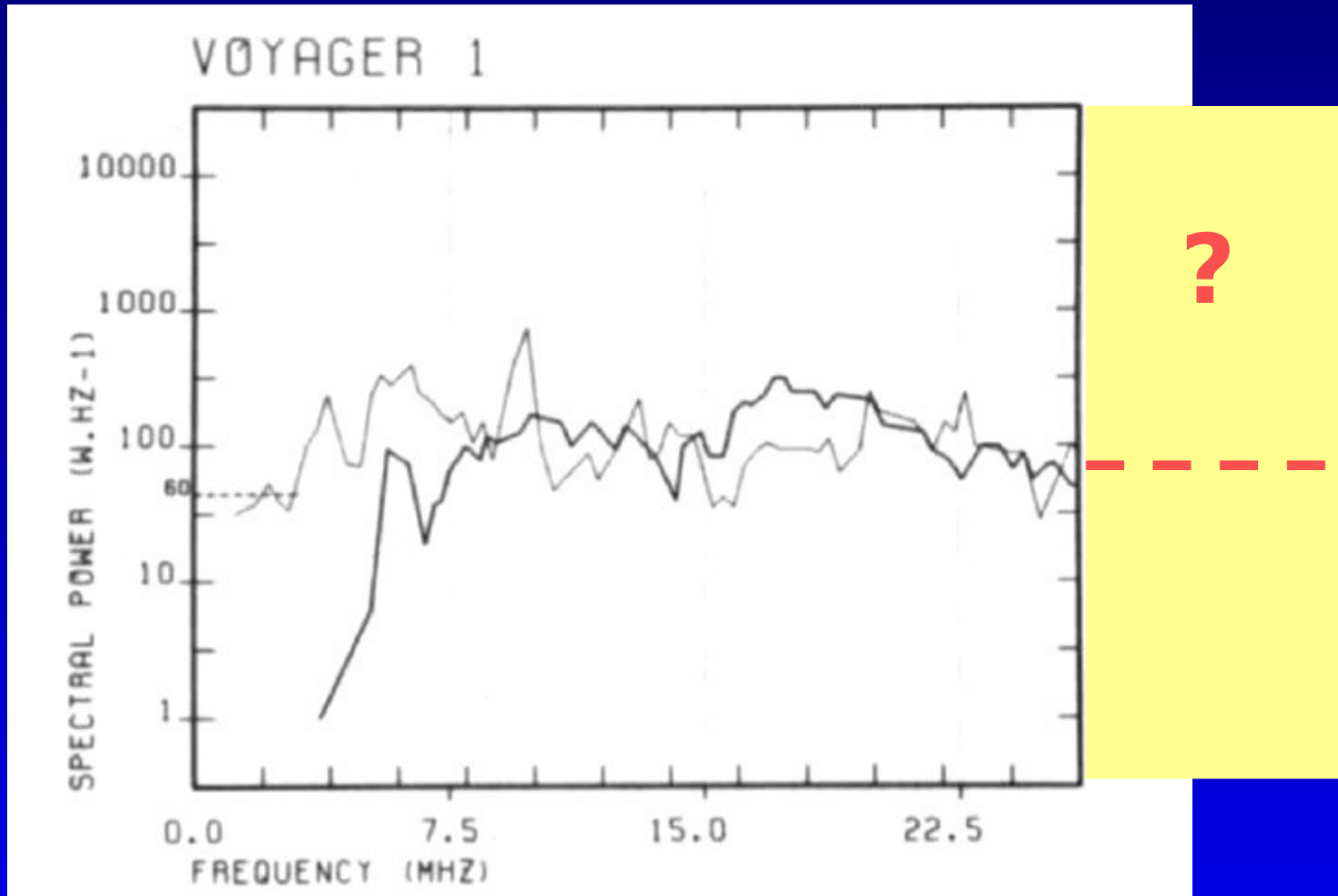


Cassini

UTR-2

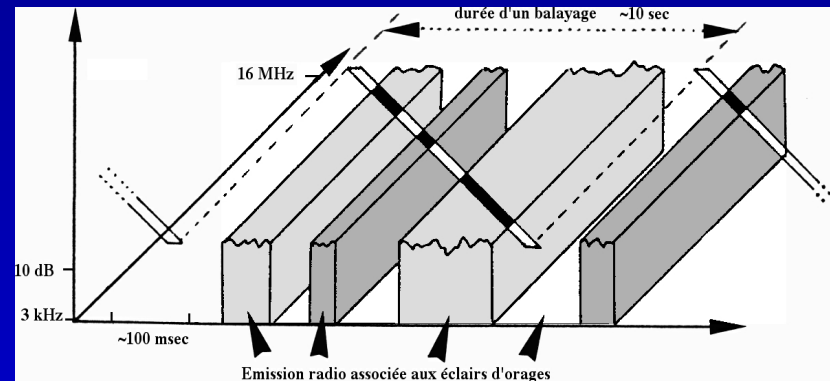
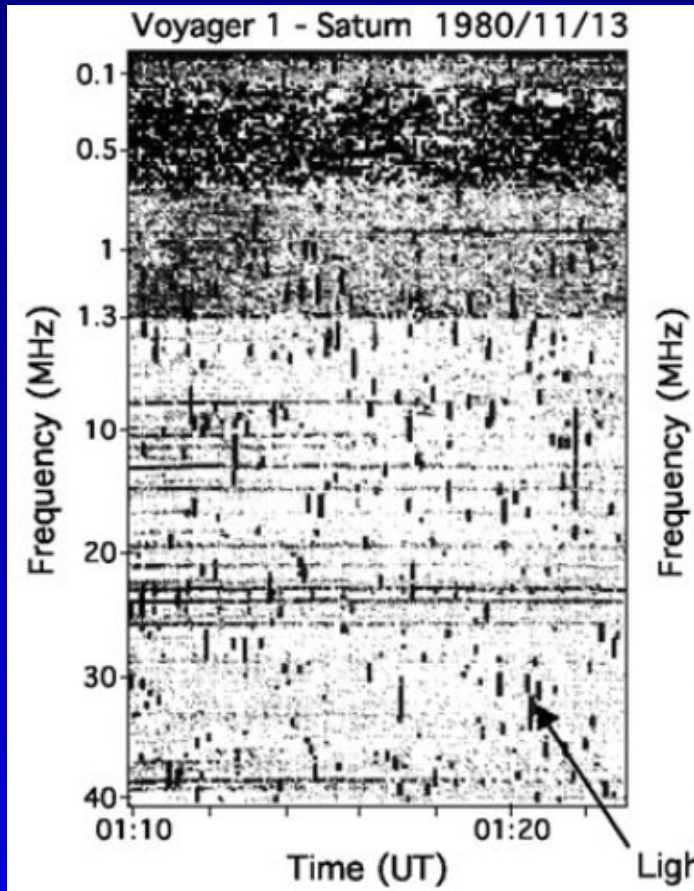
- now: Cassini triggers ground-based observations
- after Cassini (>2010)?

# Spectrum



average spectrum

# Observation by Voyager

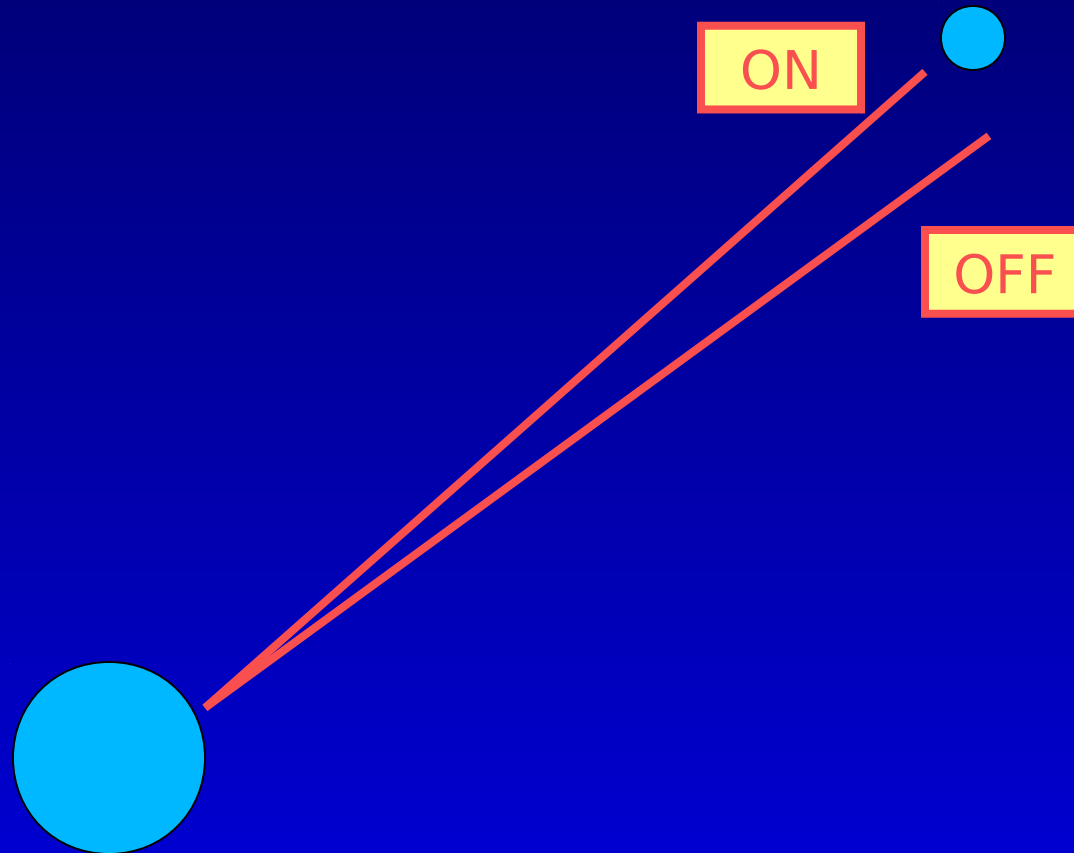


⇒ measured: **average** spectrum

⇒ spectra of **individual** events unknown!

# Simultaneous ON/OFF mode

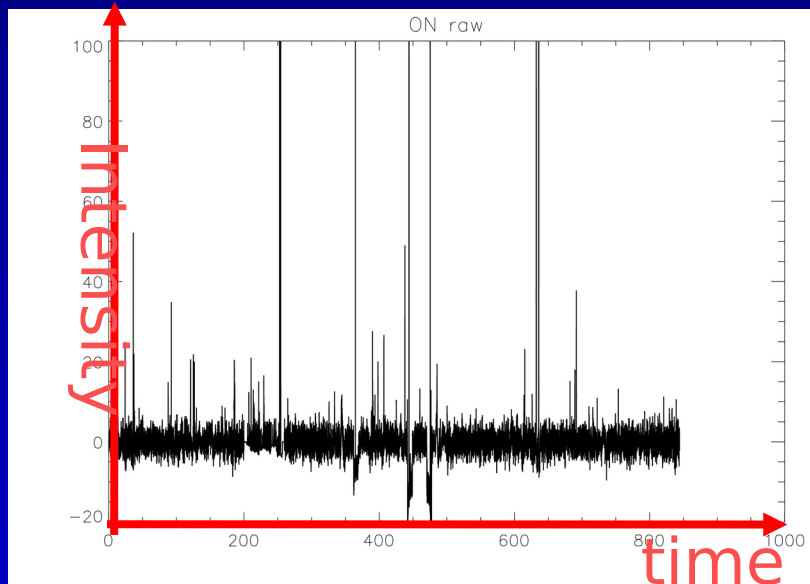
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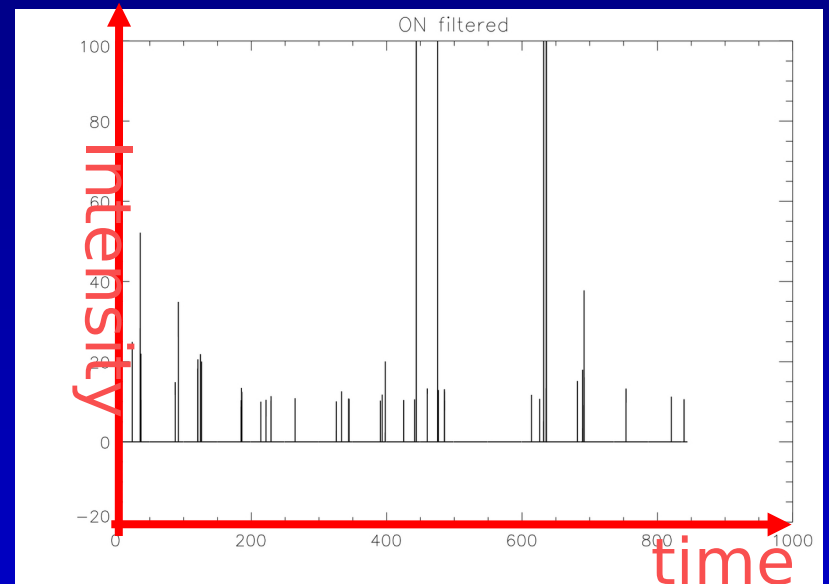
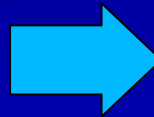
⇒ planetary signal in ON only

⇒ signal in both ON and OFF to be discarded

# What do we see?



noise+RFI+data



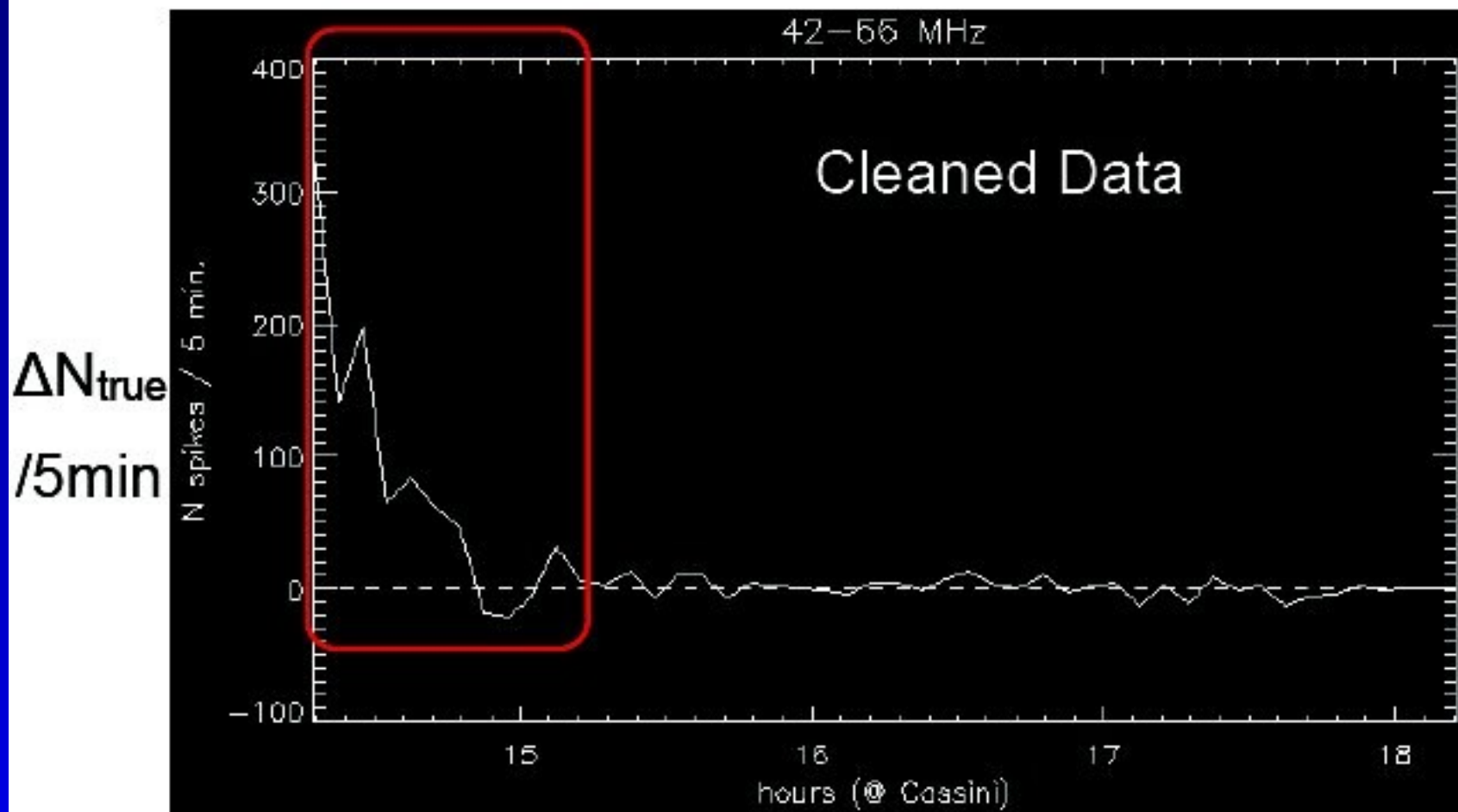
data



# Saturn lightning with LOFAR?

## Spike detection

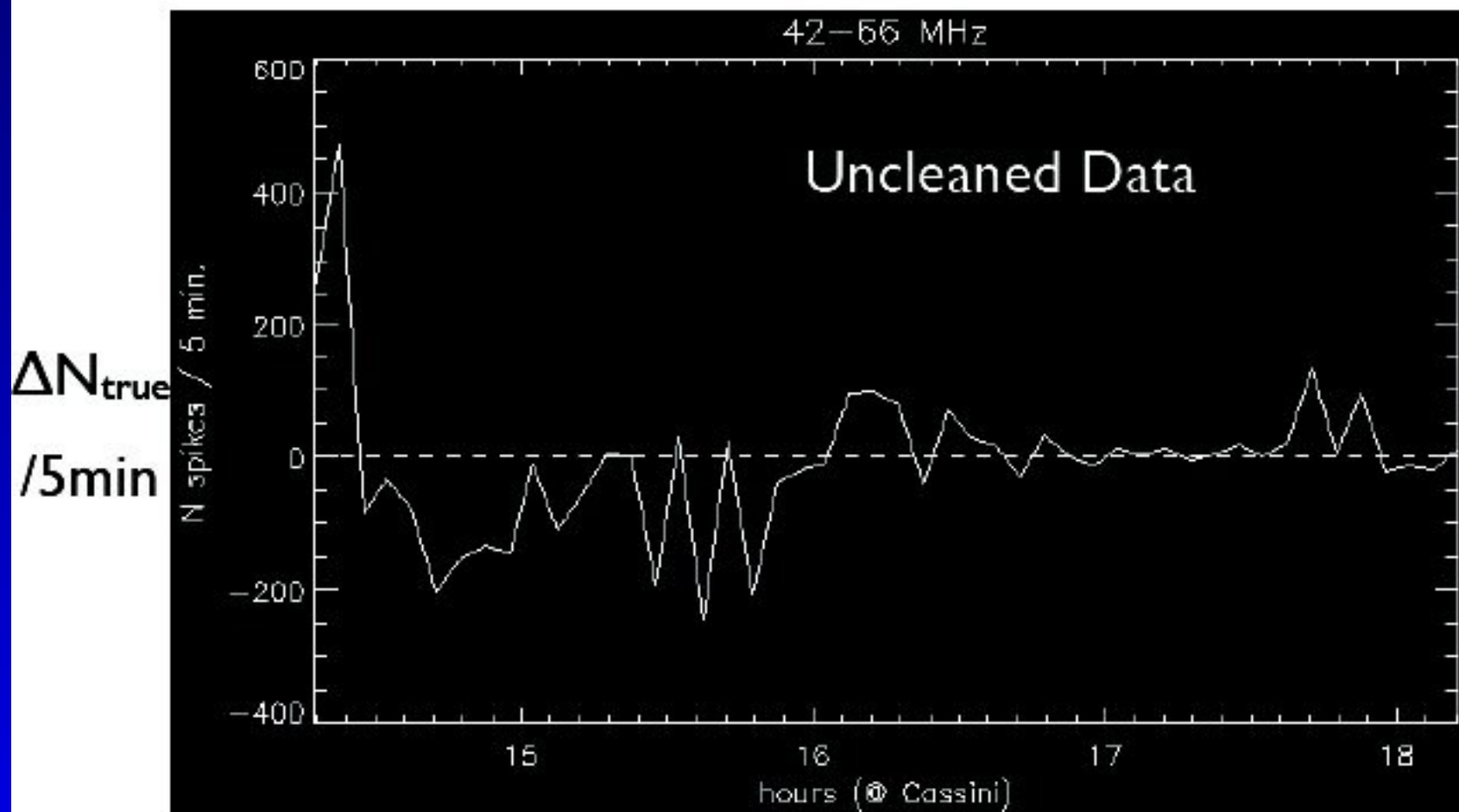
$$\Delta N_{\text{true}} = N_{\text{ON}} - N_{\text{OFF}}$$



Excess in ON between 13h-14h (LOFAR Time)

# Saturn lightning with LOFAR?

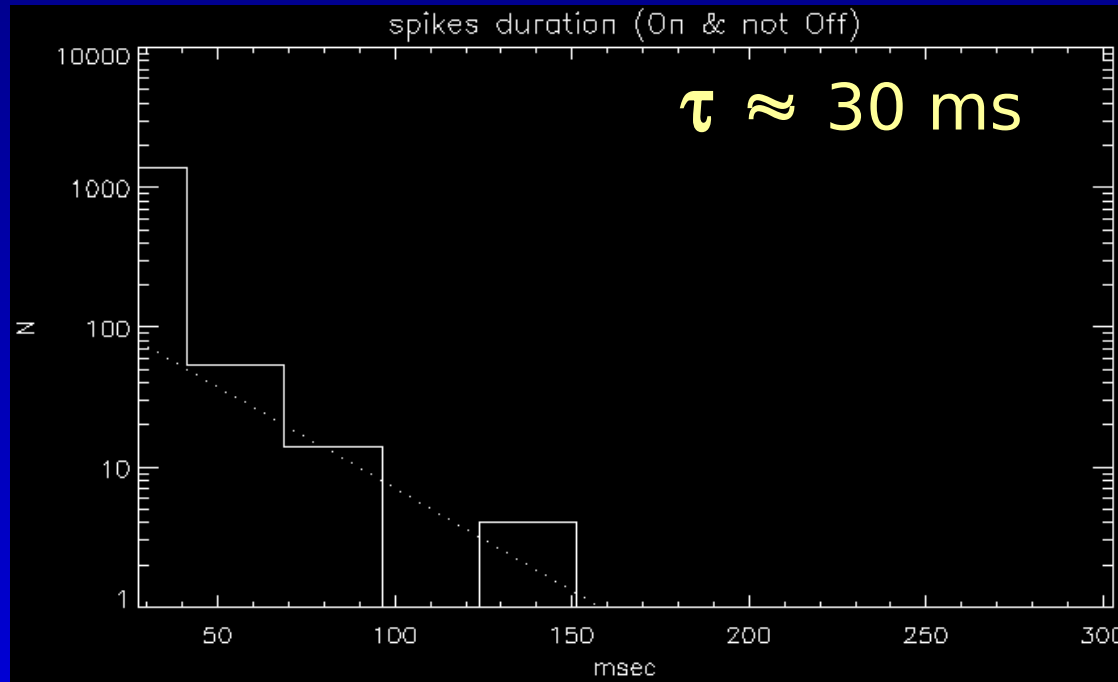
Same procedure on uncleaned data



- Higher fluctuations
- No unambiguous detection

# Saturn lightning with LOFAR?

‘Clean’ data (after RFI elimination)



[J. Girard]

Work in progress!

# Planetary lightning

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## Observations:

- Earth 1956-now
- Saturn (Voyager 1 & 2): 1980-1981
- Uranus (Voyager 2): 1986
- Saturn (Cassini): 2004-now
- Saturn (Nancay & UTR-2): 2006-now

## Tentative detections:

- Neptune (Voyager 2): 1990/91
- Venus (Galileo, but not Cassini): 1991?

## Non-detections:

- Mars (but dust discharges expected)
- Jupiter (but optical flashes observed!)
- (Titan)

# Observation plans with LOFAR

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## Observations:

- Earth: spectrum  
imaging
- Saturn: geographical variation  
seasonal variation  
correlation to optical surveys
- Uranus: spectrum  
discharge timescale

## Tentative detections:

- Neptune: follow-up tentative detections
- Venus: follow-up tentative detections
- Mars: discharges in dust clouds?