Preliminary studies of lightning on Venus

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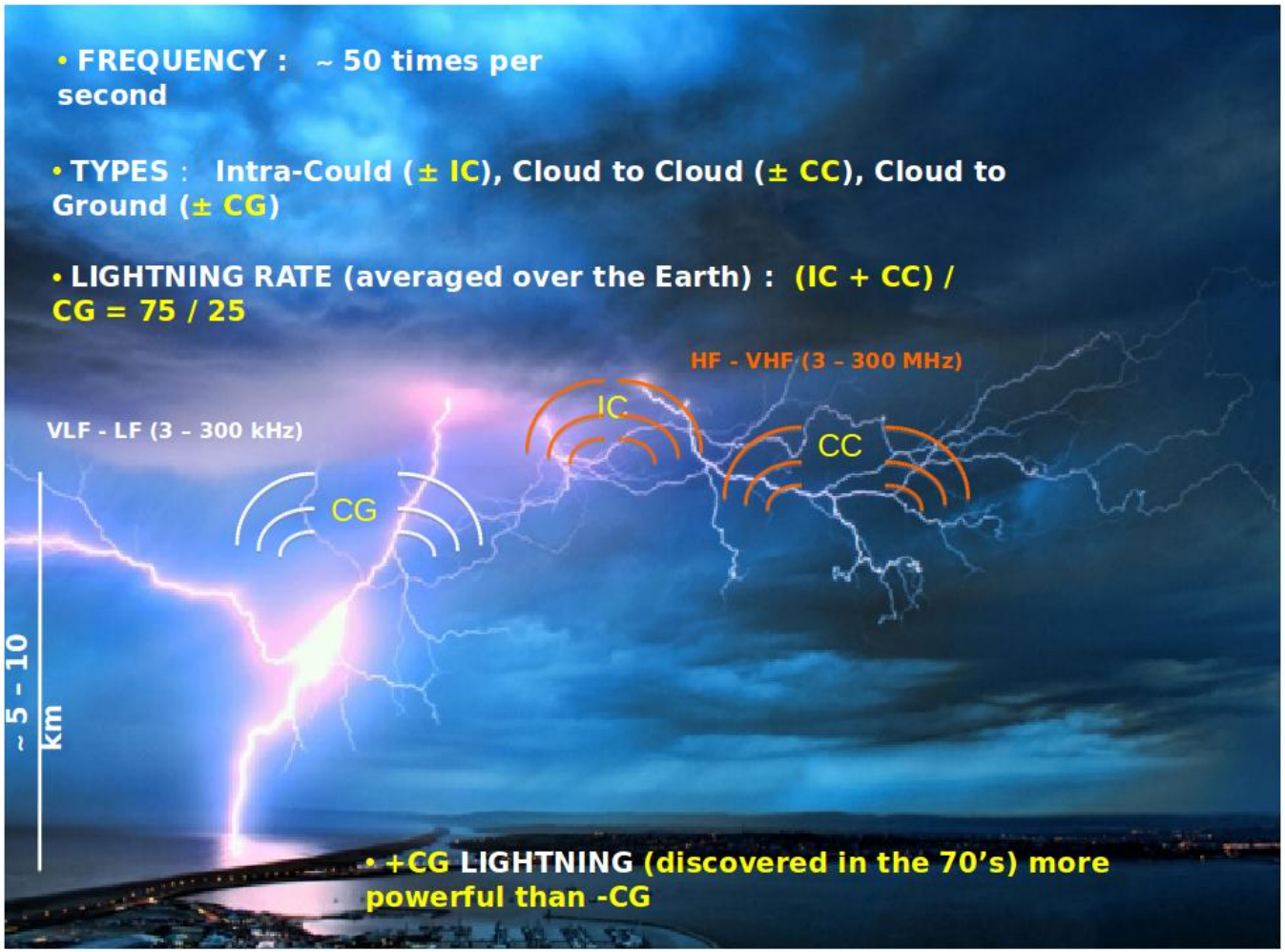
Lightning


• FREQUENCY : ~ 50 times per second
• TYPES : Intra-Could (± IC), Cloud to Cloud (± CC), Cloud to Ground (± CG)
• LIGHTNING RATE (averaged over the Earth) : (IC + CC) / CG = 75 / 25
HF - VHF (3 - 300 MHz)
IC
CC
VLF - LF (3 - 300 kHz)
CG
~ 5 - 10 km
• +CG LIGHTNING (discovered in the 70's) more powerful than -CG

TLEs and TGF

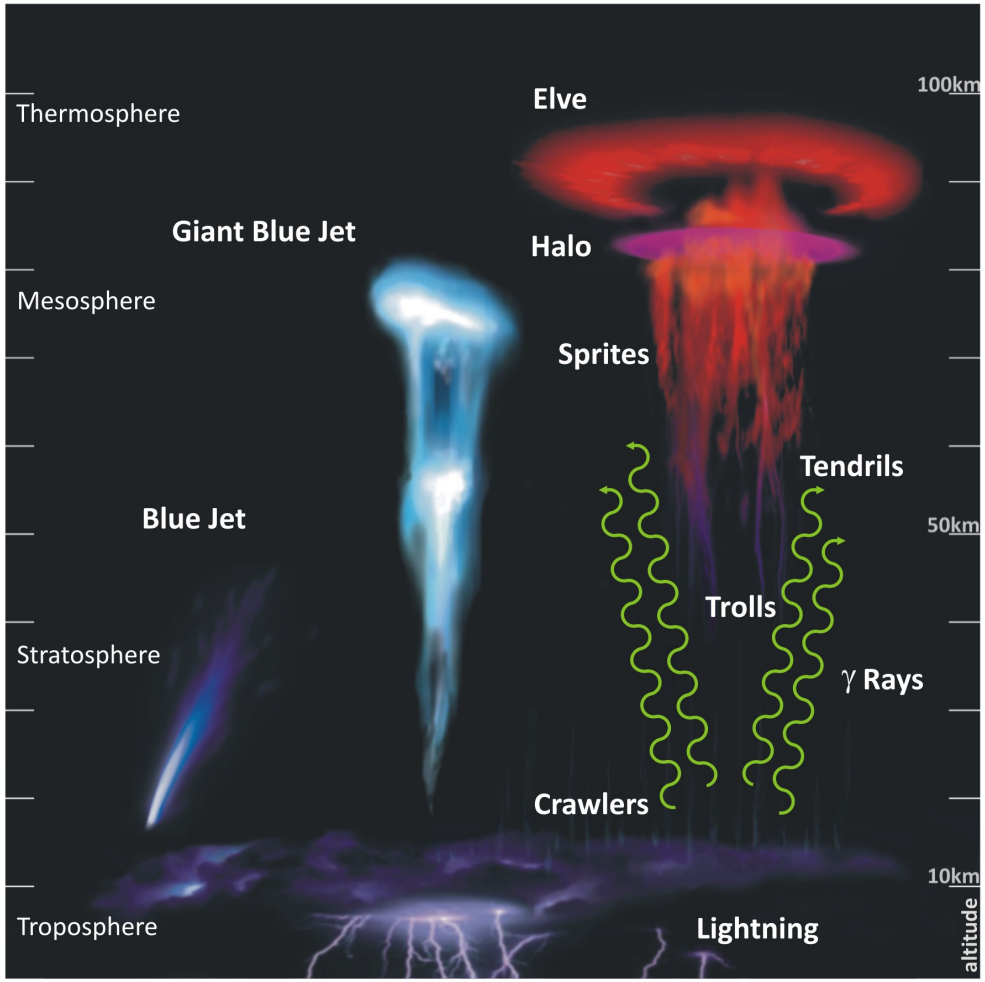


Figure : TLEs and TGF

Background I

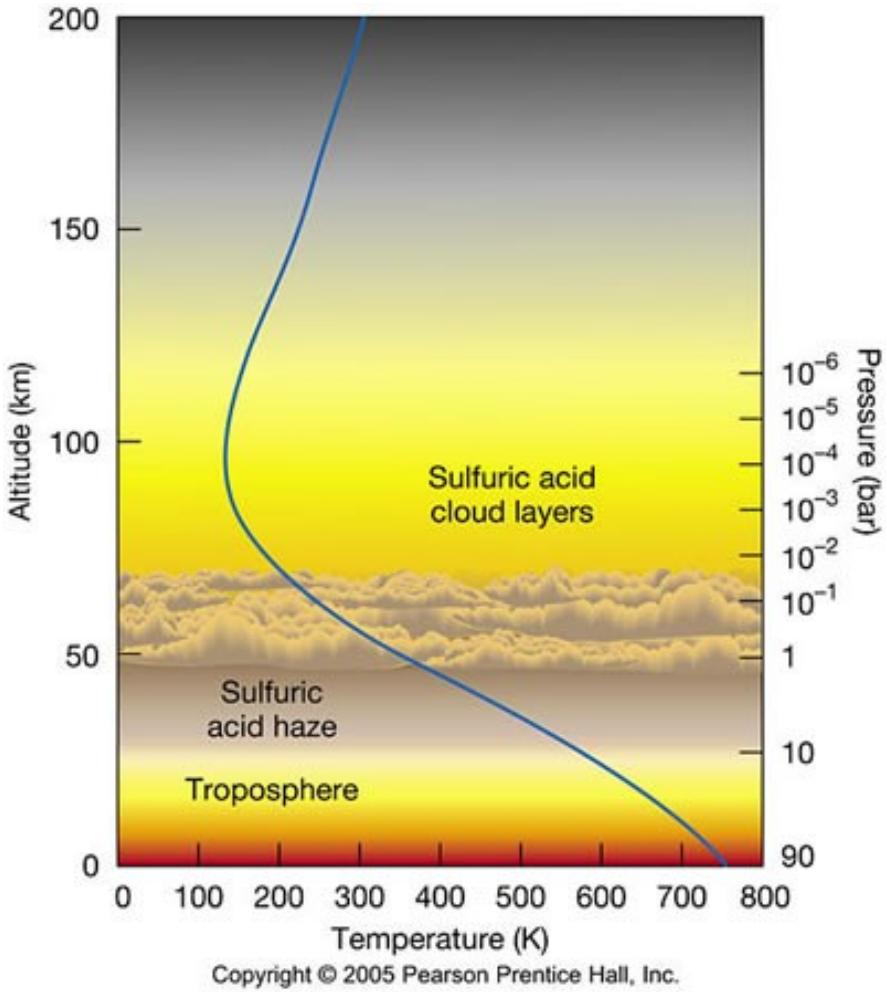


Figure : Venus atmosphere structure

Background II

- Spacecraft and balloon observations:

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- Venera 9-12: Electromagnetic and optical evidence.

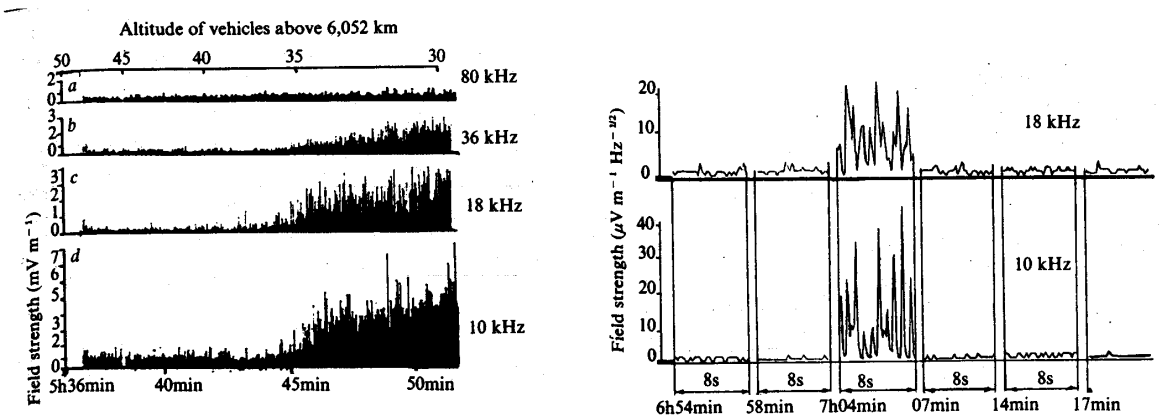

Figure : Venera 11 and 12 observations. Ksanfomaliti et al. (1980)

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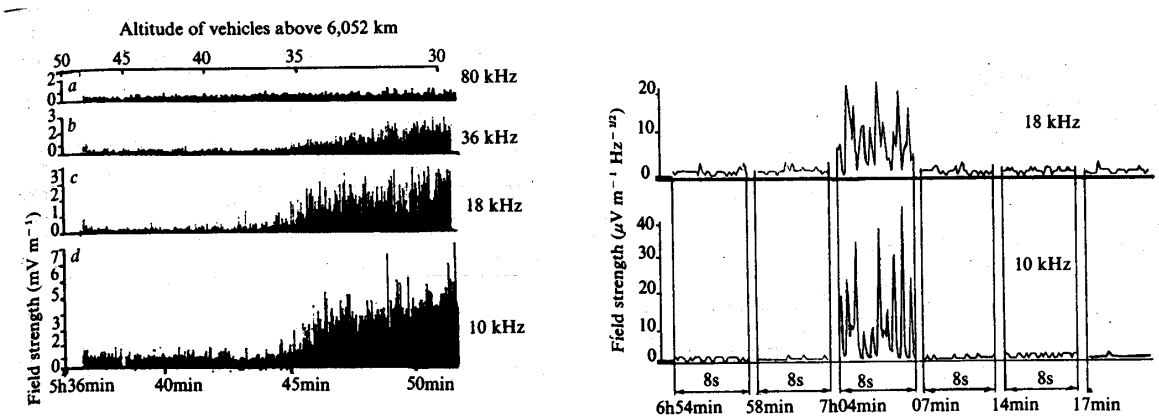

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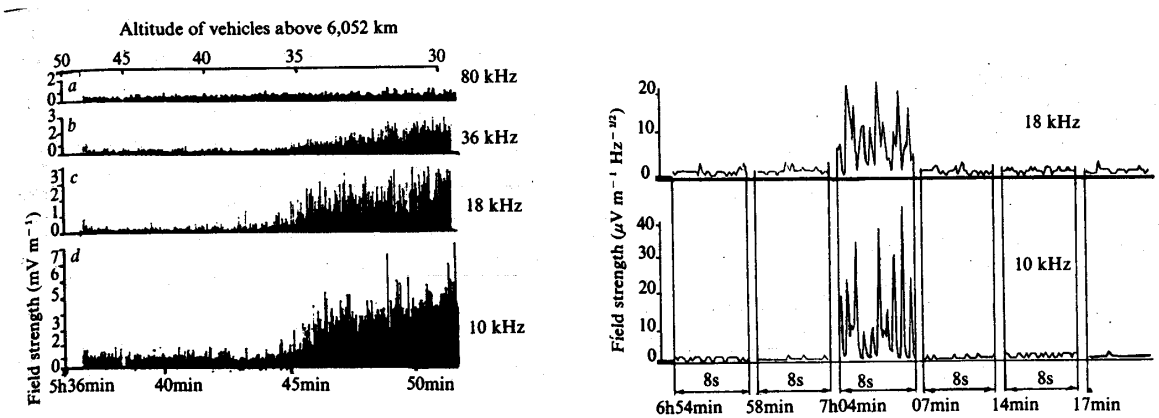

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- Vega 1-2: No evidence.
- Galileo, PVO, Cassini: No evidence.

Background III

- Ground-based telescope observations:

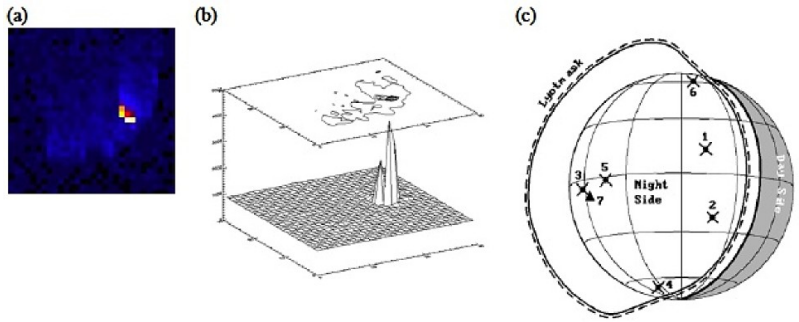

Figure : Example of the CCD image (a) and its response (b) for a flash detected at 777.4 nm. (c) Locations of all 7 flash events. Hansell et al. (1995)

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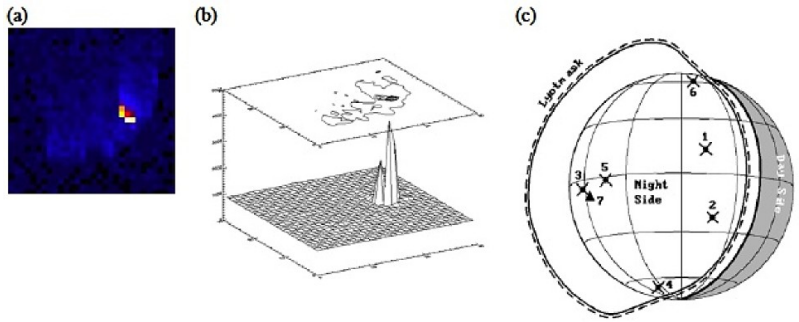

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- TEXES spectograph at NASA IRTF: Chemical evidence. Three NO lines. (Krasnopolsky (2005))

Background IV

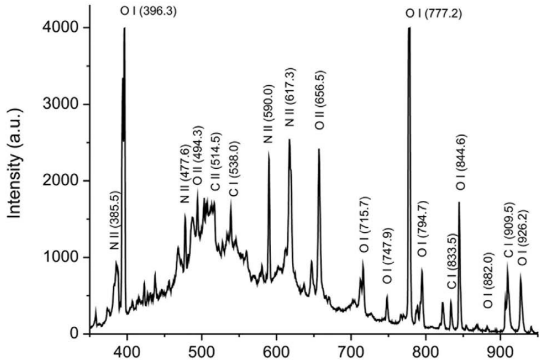

Figure : Time-integrated emission spectrum obtained at a 1 atm preassure in laboratory simulated lightning on Venus. Robledo et al. (2010)

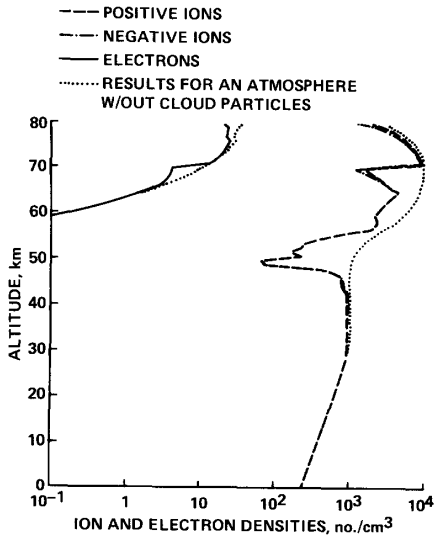

Figure : Calculated values of the ion and electron densities. Borucki et al. (1982)

Background V

COMPARISON OF TERRESTRIAL AND VENUSIAN LIGHTNING

	Earth	Venus
Peak optical power (W)	1.1×10^{10} Ref. 1	2.8×10^{8}, derived from Ref. 2
Total energy per flash (J)	5×10^{7} Ref. 3	10^{10}, Ref. 2
	7×10^{8} Ref. 1	
Stroke duration (sec)	0.3×10^{-3} Ref. 4	0.25, Ref. 2
	1×10^{-3} Ref. 5	
Planetary flash rate (flashes km^{-2} $year^{-1}$	2, Ref. 6	0.08; lower limit
	7, Ref. 7	45, Ref. 9
Energy-dissipation rate (W m^{-2})	0.0016 Ref. 8	0.014, derived from Ref. 2 0.039, upper limit derived from the PVO star sensor data for a pulse duration of 0.25 sec.

Note. References: (1) Krider *et al.* (1968); (2) Krasnopolsky (1980); (3) Hill (1979); (4) Uman (1969); (5) Brook and Ogawa (1977); (6) Turman (1978); (7) Kolokolov (1971); (8) Chameides *et al.* (1977); (9) Krasnopolsky (personal communication, 1982).

Figure : Comparison of Terrestrial and Venusian lightning. Borucki. (1982)

Elves

- 3-D Finite-Difference time-domain algorithm:

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  - Shape depending on the IC inclination.

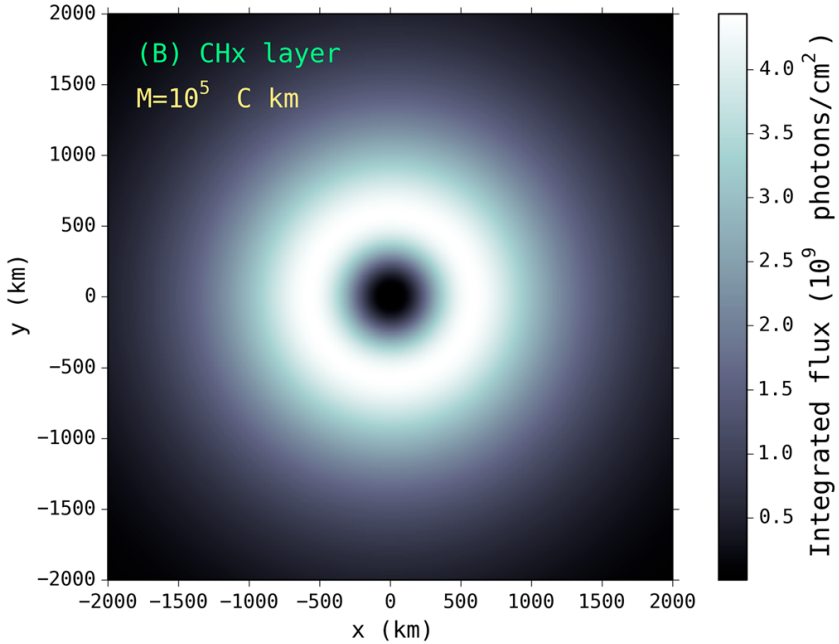

Figure : Simulated elve in Saturn. Luque et al. (2014)

Halos and sprites

- Impact of lightning in the atmosphere of Venus.

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- Modified Scharfetter-Gummel Algorithm of electron transport coupled with a chemical model.

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- Modified Scharfetter-Gummel Algorithm of electron transport coupled with a chemical model.
- Breakdown field.
- Electron and ions density (CO_2^+, N_2^+, O^-, CO_3^-...)

Lightning model

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- High temperature chemistry associated with lightning (production of NO_x).
- Optical emissions ($N\,II - 617.3\,nm$, $O\,I - 777.4\,nm$ ... lines).

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- Impact of IC in the atmosphere of Earth.

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- Impact of IC in the atmosphere of Earth.
- Elves in Saturn and Jupiter.

Future observations

- ASIM: This mission will give information to improve the current knowledge on TLEs and TGFs on Earth.

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- Akatsuki probe designed by JAXA:
  - It includes a lightning detector (LAC, Lightning and Airglow Camera).
  - The lightning measurements will be made in the strong 777.4 nm atomic oxygen line.