Implications of the TGO results on potential surface emissions of methane on Mars

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Mex PFS (June 2013) vs. TGO NOMAD and ACS (April 2018 – present)

Mars Express PFS

nature geoscience

ARTICLES

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Independent confirmation of a methane spike on Mars and a source region east of Gale Crater

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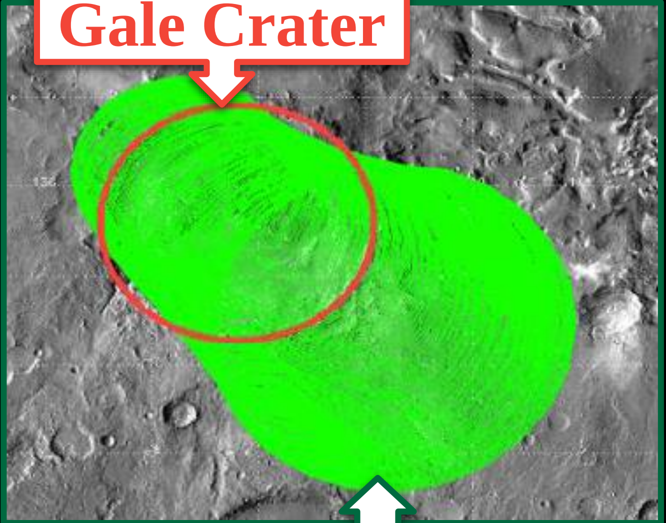
Giuranna et al., Nature Geoscience (2019)



June 16, 2013: 15.5 ppbv

~0.005 ppbv when well-mixed around the planet

TGO ACS and NOMAD

LETTER

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No detection of methane on Mars from early ExoMars Trace Gas Orbiter observations

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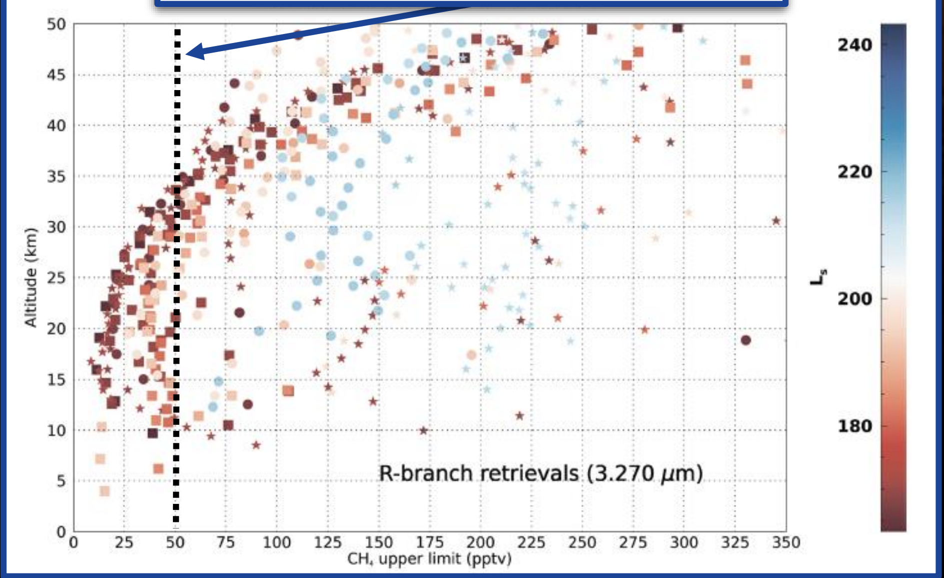
Korablev et al., Nature (2019)

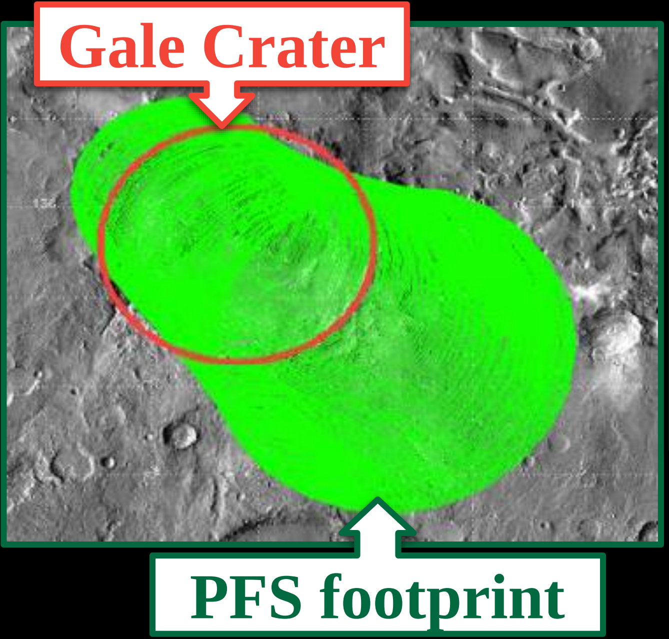
April 21 – September 4, 2018: 0.05 ppbv (upper limit)



Mex PFS (June 2013) vs. TGO NOMAD and ACS (April 2018 - present)

<u>Exercise 1:</u> What is the probability that the TGO detects an emission event similar to that recorded by PFS in June 2013?

- 15.5 ppbv over 49,000 km^2 (PFS footprint) ➔ ~50 tons CH_4
- Let the total amount released be twice larger (**100 tons**), considering that PFS did not catch the entire plume



June 16, 2013: 15.5 ppbv

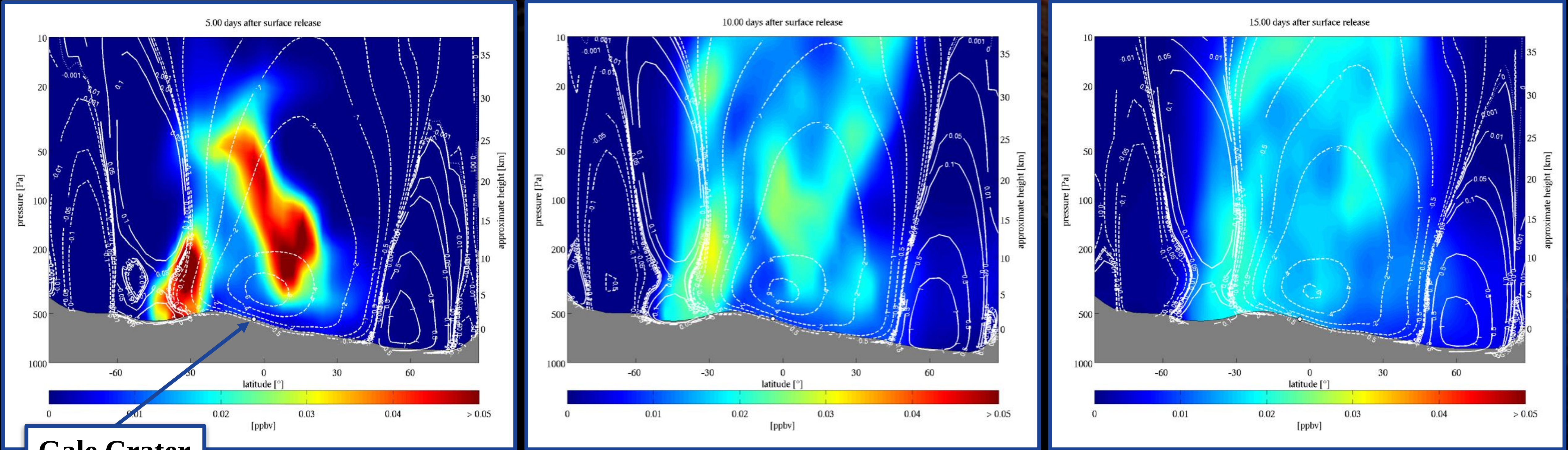
⇩

~0.005 ppbv when well-mixed around the planet

Mex PFS (June 2013) vs. TGO NOMAD and ACS (April 2018 - present)

100 tons released from Gale crater at the same time of the year (L_s = 336°)

Zonal mean of CH_4 mixing ratio 5, 10, and 15 days after surface release
(simulation using the GEM-Mars GCM)

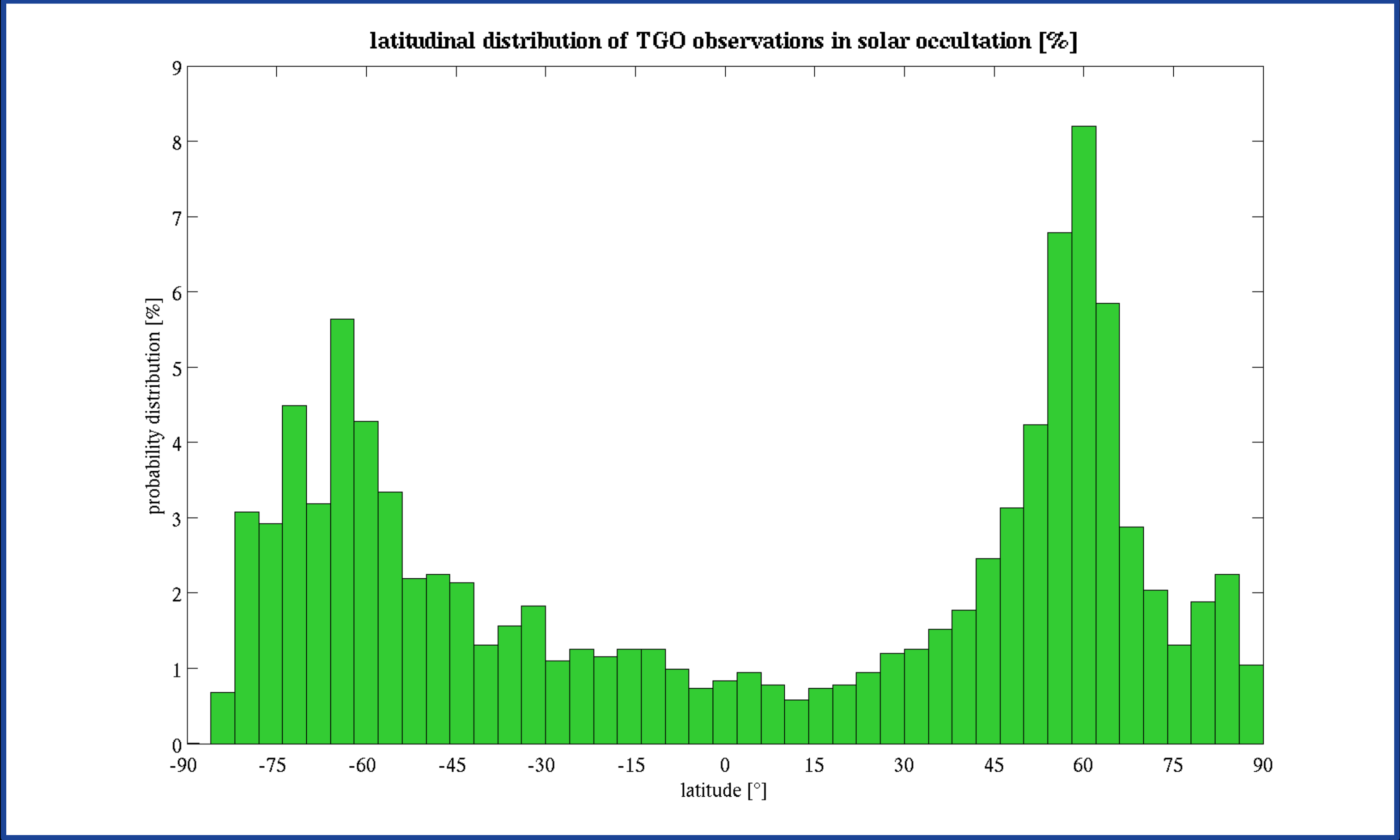


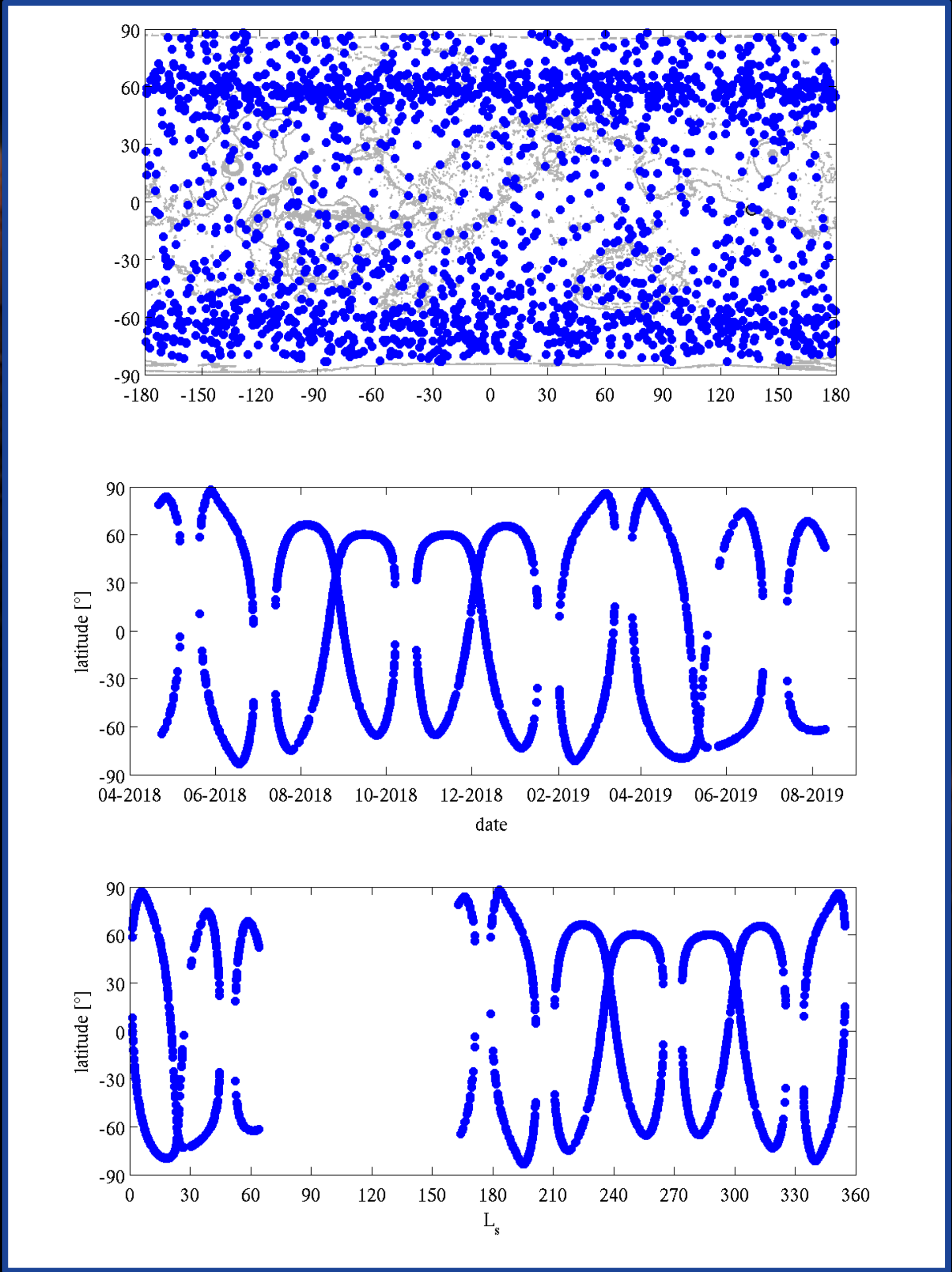
Gale Crater

Methane found above 15 km within a few days
(Viscardy et al., GRL, 2016; Giuranna et al., Nature Geoscience, 2019)

Mex PFS (June 2013) vs. TGO NOMAD and ACS (April 2018 - present)

TGO solar occultations:
April 21, 2018 – August 10, 2019

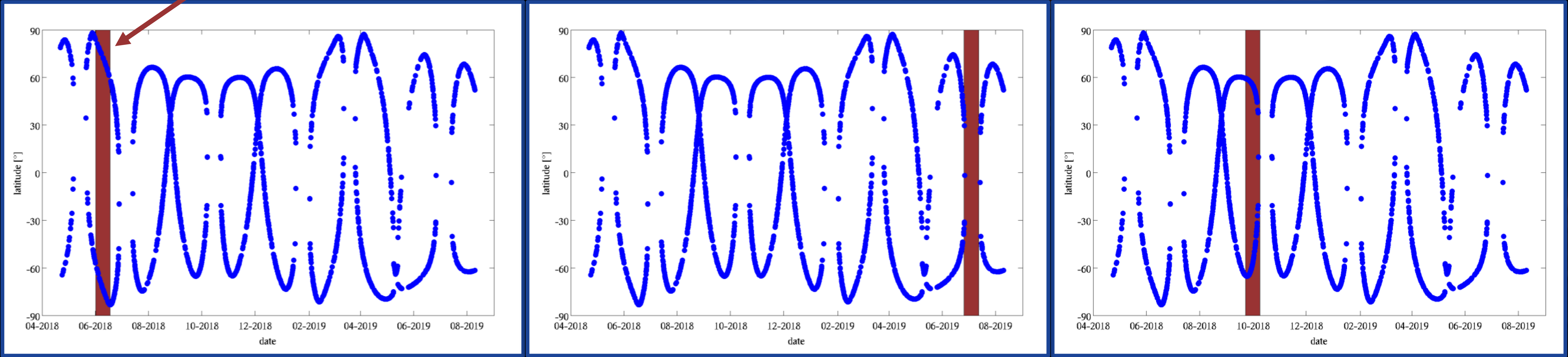




Mex PFS (June 2013) vs. TGO NOMAD and ACS (April 2018 - present)

- 100 tons of CH_4 released from Gale Crater at L_s = 336° and simulated over 17 days
- Statistical analysis of a large sample of sets of TGO solar occultations (3 examples given below)
- Size of the sample: 10,000
- Criterion: CH_4 detected if mixing ratio > 0.05 ppbv above 15 km

Time window of simulation



<u>Result</u>: probability that the TGO detects this emission event = 50.7%
A lifetime of only a few days should be required to lower significantly this probability

Mex PFS (June 2013) vs. TGO NOMAD and ACS (April 2018 - present)

Question 2: If the emission event detected by PFS takes place periodically, what is the minimum period ***T*** such that the background level remains always below the TGO detection limit?

- X : background level [ppbv]
- k : destruction rate
- τ : lifetime of CH_4 ($\tau = {}^{1}/_{k} = 300$ years)
- F : gas flux; 50 tons ($x_P = 0.005$ ppbv) released every time T
- x_T : TGO detection limit (0.05 ppbv)

$$\frac{dX(t)}{dt} = F(t) - kX(t)$$

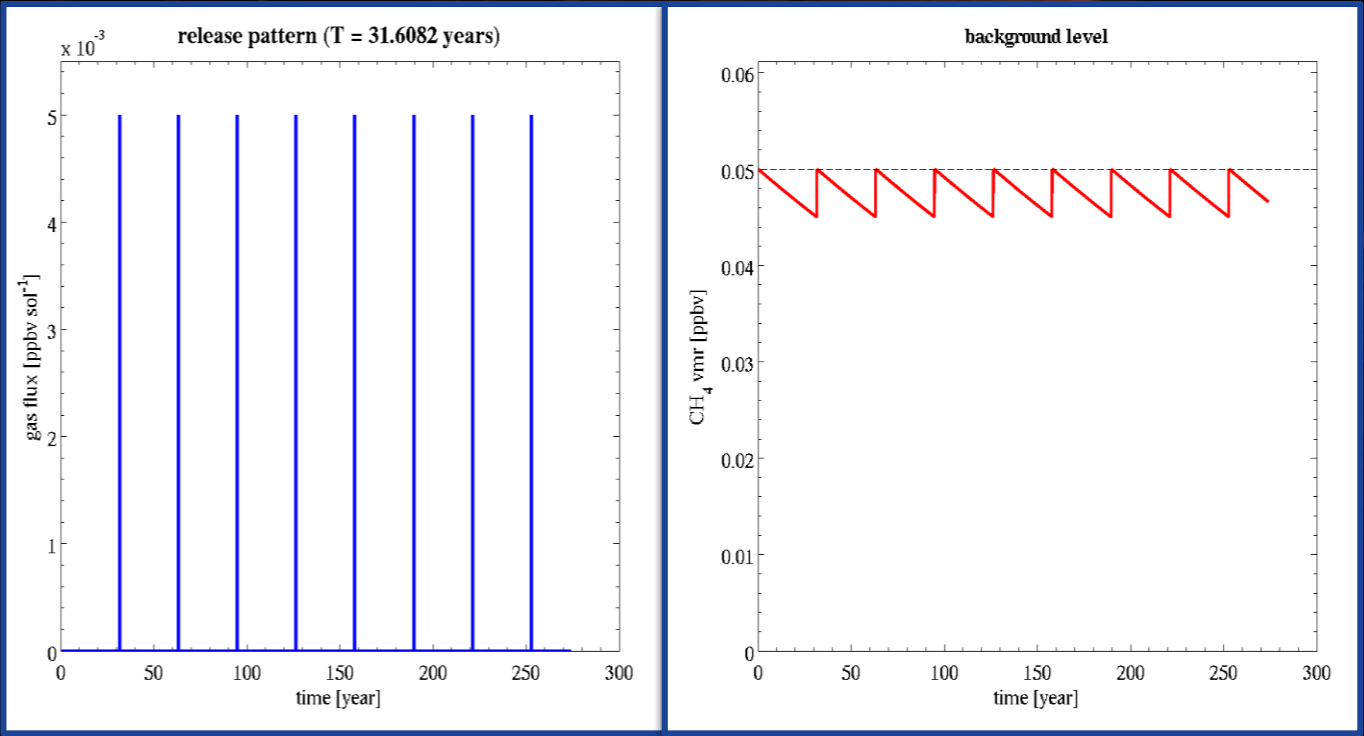
Solution between two successive emissions:

$$X(t) = X(0)\exp\left(-{}^{t}/_{\tau}\right)$$

An emission occurs when:

$$X(T) = x_T - x_P = x_T \exp\left(-{}^{T}/_{\tau}\right)$$

Result: period T = 32 years
➔ Event extremely rare



Conclusions

These two simple exercises suggest that:

- emission events similar to that detected by PFS in June 2013 could have been observed by the TGO (with a non-negligible probability) if they had taken place after April 2018

- the PFS detection is most likely inconsistent with the TGO detection limit unless:
  - PFS was at the right place at the right time, and/or
  - a fast destruction mechanism to be discovered is at work on Mars, which would lower drastically the lifetime of methane to a few days and have to be “compatible with our wide quantitative understanding of Mars photochemistry” (Korablev et al., 2019).