Seasonal and Latitudinal Variability of Titan's Stratospheric Aerosols Composition: Cassini/CIRS and Laboratory Constraints

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1. CONTEXT

- Titan: a dense N_2-CH_4 atmosphere.
- UV radiation and energetic particles produce complex organic aerosols in the ionosphere (~ 900 km), which sediment into the stratosphere (~300 km), where they are observed by CIRS.

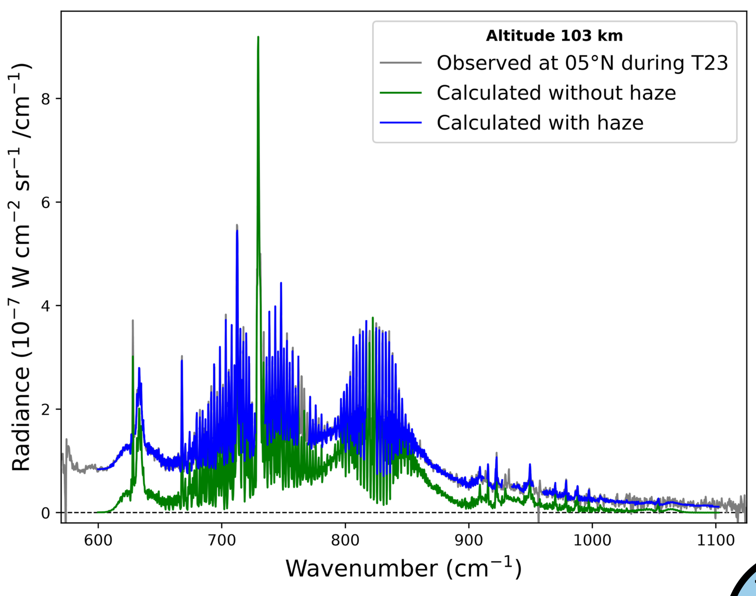
Objectives

- *Characterise aerosol composition and its variability with altitude, latitude and season.*
- *Compare CIRS spectra with laboratory-produced tholins to better understand Titan's aerosol composition.*

2. APPROACH and METHODS

Processing CIRS data

2 fields of view/spectral range:
→ FP3: 600 - 1100 cm^{-1}
→ FP4: 1100 - 1500 cm^{-1}



Limb spectra
600-1500 cm^{-1}, 0.5 cm^{-1} spectral resolution, 120-600 km altitude

↓

Radiative transfer inversion
Input: T, CH_4 abundance, aerosol vertical profile
Output: synthetic spectra + aerosol extinction profiles

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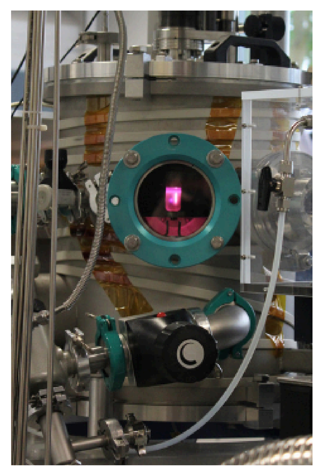
Extinction coefficient spectrum:
$k_{ext}(\nu, p) = n(p)\sigma(\nu)$

Experiment: PAMPRE



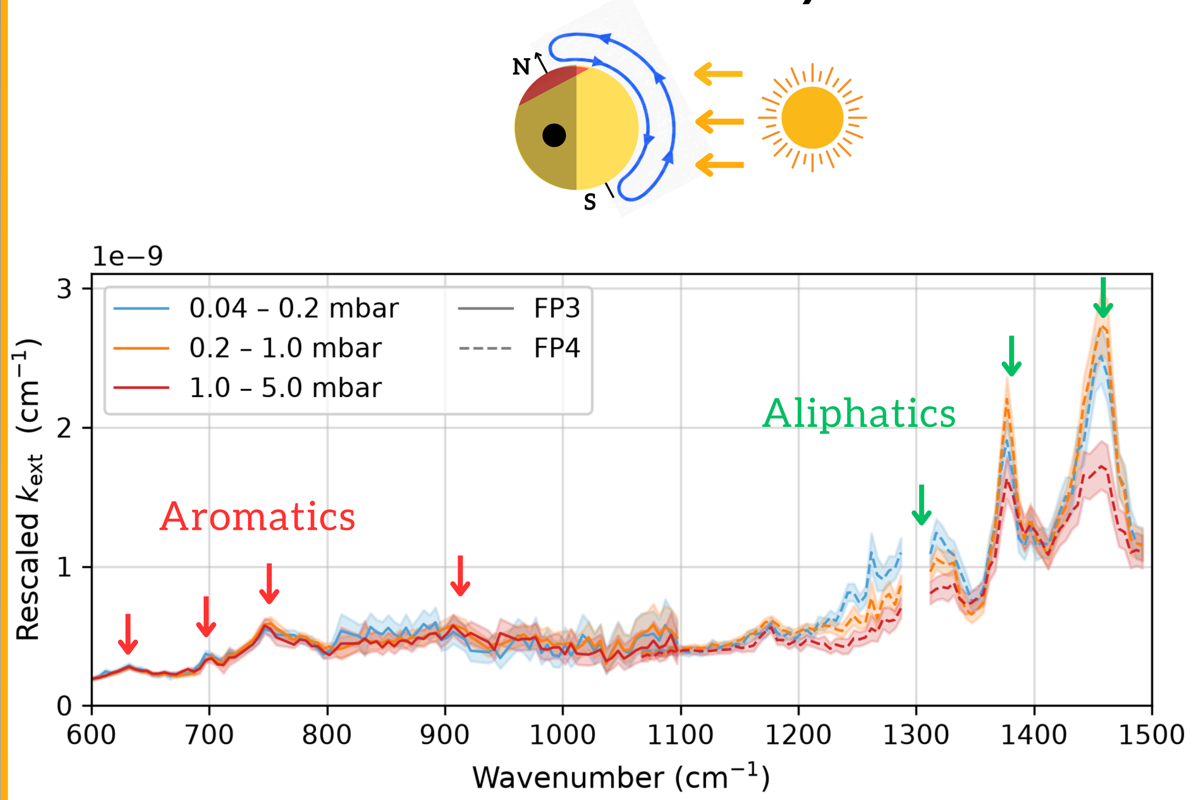
RF plasma discharge in N_2 - CH_4 mixture
- Tholins collected as films and grains [2]
- FTIR spectroscopy (600-1500 cm^{-1})

Two experimental series:
- 5% initial CH_4 → CH_4 steady state varies
- 1.5% steady-state CH_4 → flow rate varies

Gas Flow (sccm)	5.5		15		25		40		55	75	
Initial CH_4 (%)	5	15.5	5	9.2	5	7.7	5	5.8	5	5	1.4
Steady CH_4 (%)	0.4	1.5	0.5	1.5	0.7	1.5	1.2	1.5	1.5	2.2	1.5

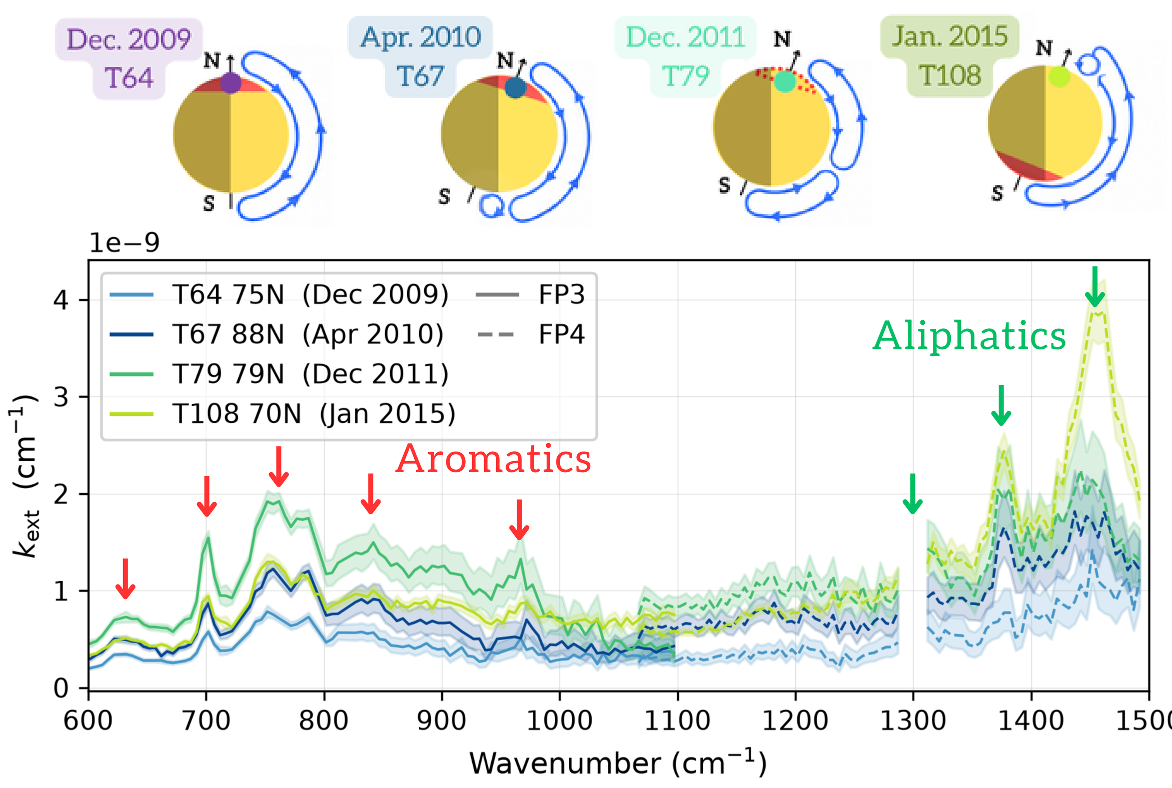
3. Aerosols spectrum from Cassini/CIRS spectra analysis

Variations with altitude: T23 - 05°N January 2007



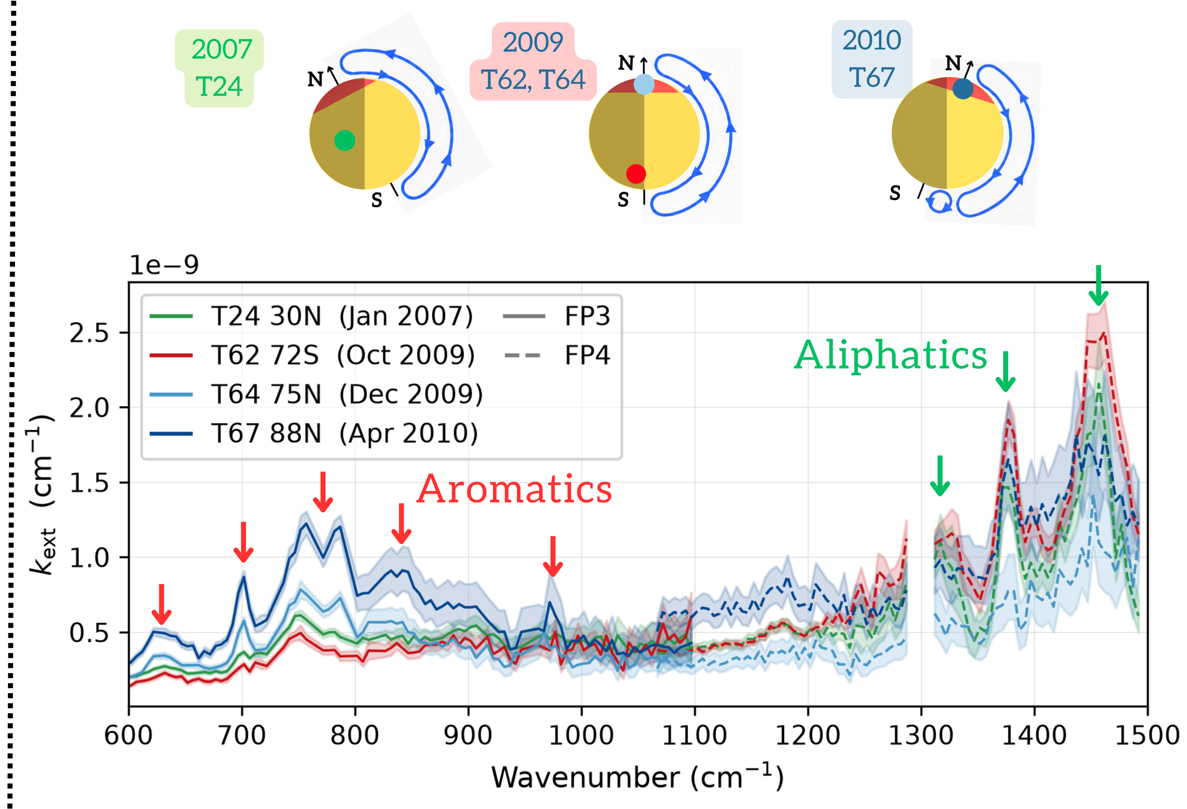
Uniform aerosol composition with altitude
Variation in the 1450 cm^{-1} band → increasing aliphatic content at higher altitudes.

Variations with seasons at high northern latitudes



Boreal spring (2009 - 2012) → increasing unsaturation
Post vortex (2015) → aliphatic signatures increase

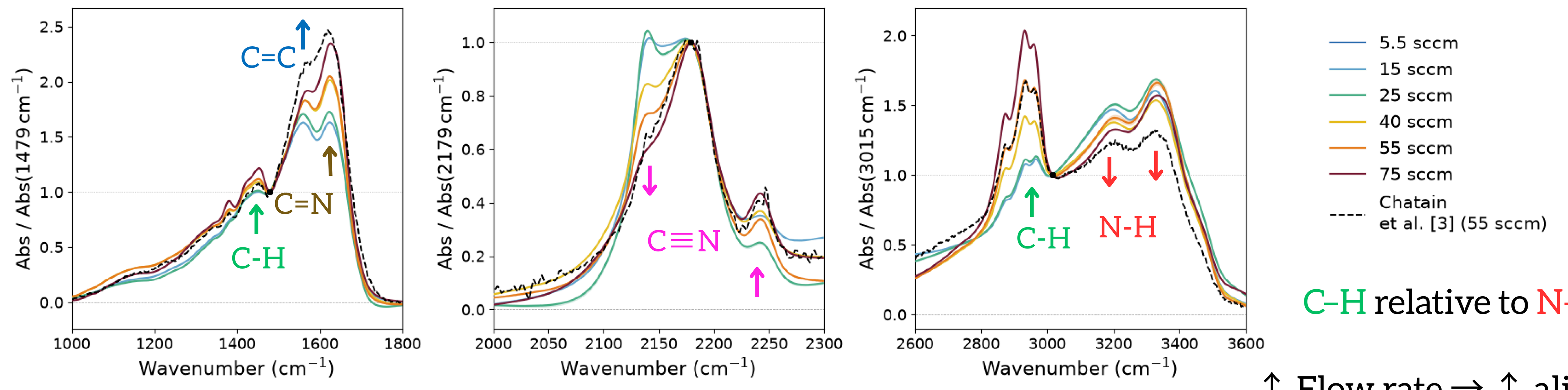
Variations with latitudes



Northern Hemisphere → higher organic content
Southern Hemisphere → lower aerosol abundance, but stronger aliphatic signatures

4. PAMPRE experiment: CaF_2 films

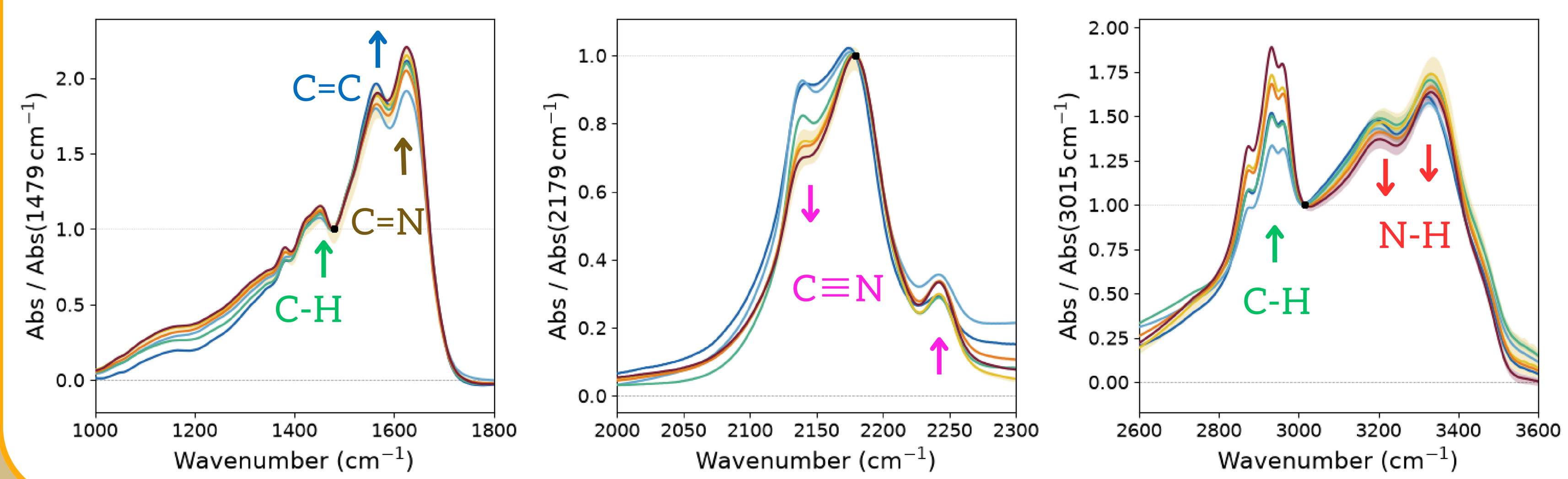
- *Initial CH_4 is fixed at 5% — the steady-state fraction varies with flow rate*



C-H relative to N-H

↑ Flow rate → ↑ aliphatic C + ↓ N incorporation

- *CH_4 remains steady at 1.5% — only the flow rate varies*

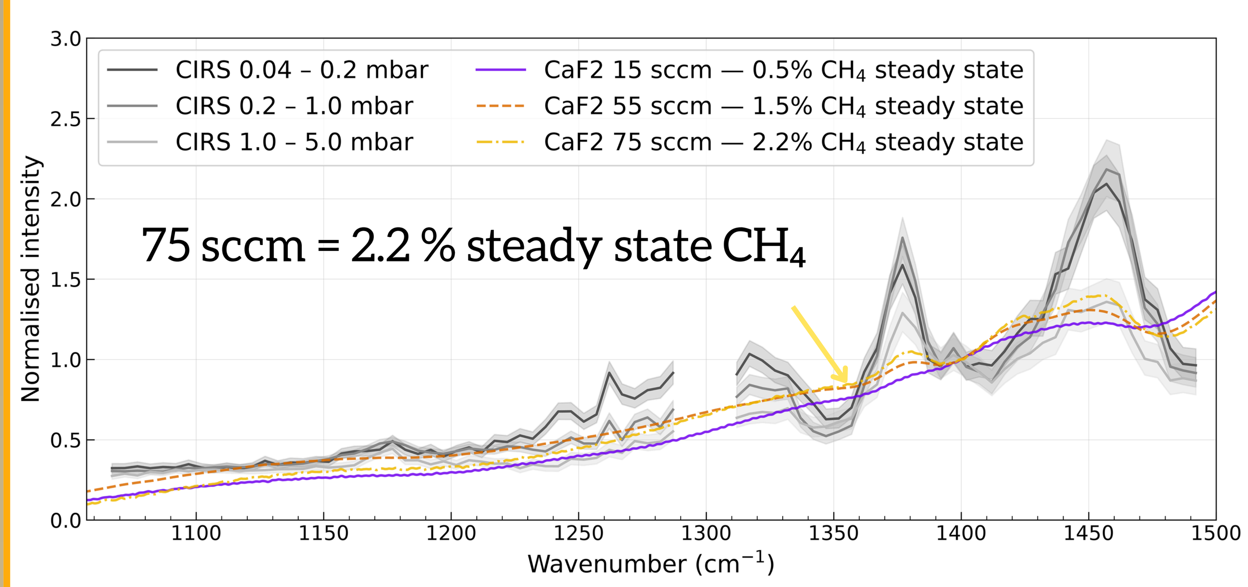


Fixed steady-state CH_4 → variation nearly negligible

⇒ Composition controlled by steady-state CH_4

Note: similar trends on KBRr pellets; caution when comparing experimental setups.

5. CIRS vs PAMPRE

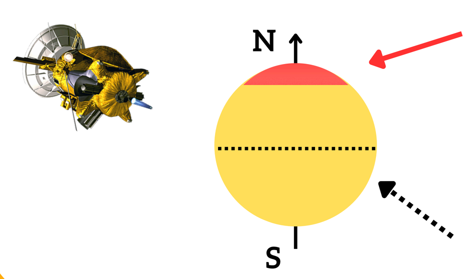


CIRS spectra are qualitatively more similar with PAMPRE tholins at higher steady-state CH_4 (5–10%)
→ Consistent with CH_4 conditions in Titan's ionosphere which can reach up to 35 % CH_4 [4].

See the poster of O. Rering (EPSC2026-329) for the effect of CH_4 [5]

CIRS (particles) vs PAMPRE (film) = qualitative

CONCLUSION



Unsaturated signatures in northern spring are probably linked to the enriched air confined by the polar vortex

Relative homogeneous composition in altitude

The steady-state CH_4 abundance primarily controls tholin composition.

The gas flow rate mainly influences particle size (5.5 sccm ~ 1 μm to 75 sccm ~ 0.5 μm)

PERSPECTIVES

- Expand CIRS observations across latitudes and seasons.
- Investigate higher CH_4 fractions in PAMPRE to better match laboratory and observations.

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[3] A. Chatain, N. Carrasco, N. Ruscassier, T. Gautier, L. Vettier et O. Guaitella. « Interaction dust–plasma in Titan's ionosphere : An experimental simulation of aerosols erosion ». In : Icarus 345 (2020), p. 113741.
[4] M. Coutelier, T. Gautier, K. Das, J. Serigano, J. Westlake, S. M Hörst et M. G Trainer. « Seasonal variation of the main gases in Titan's ionosphere from Cassini INMS data ». In : Astronomy & Astrophysics 708 (2026), A229.
[5] Rering, O., Maurice, C., Chatain, A., and Vinatier, S.: New constraints on Titan's stratospheric methane variability from Cassini/CIRS and its influence on laboratory tholins composition, Europlanet Science Congress 2026, The Hague, The Netherlands, 7–11 Sep 2026, EPSC2026-329