The influence of dissolved organic matter properties on photodegradation efficiency

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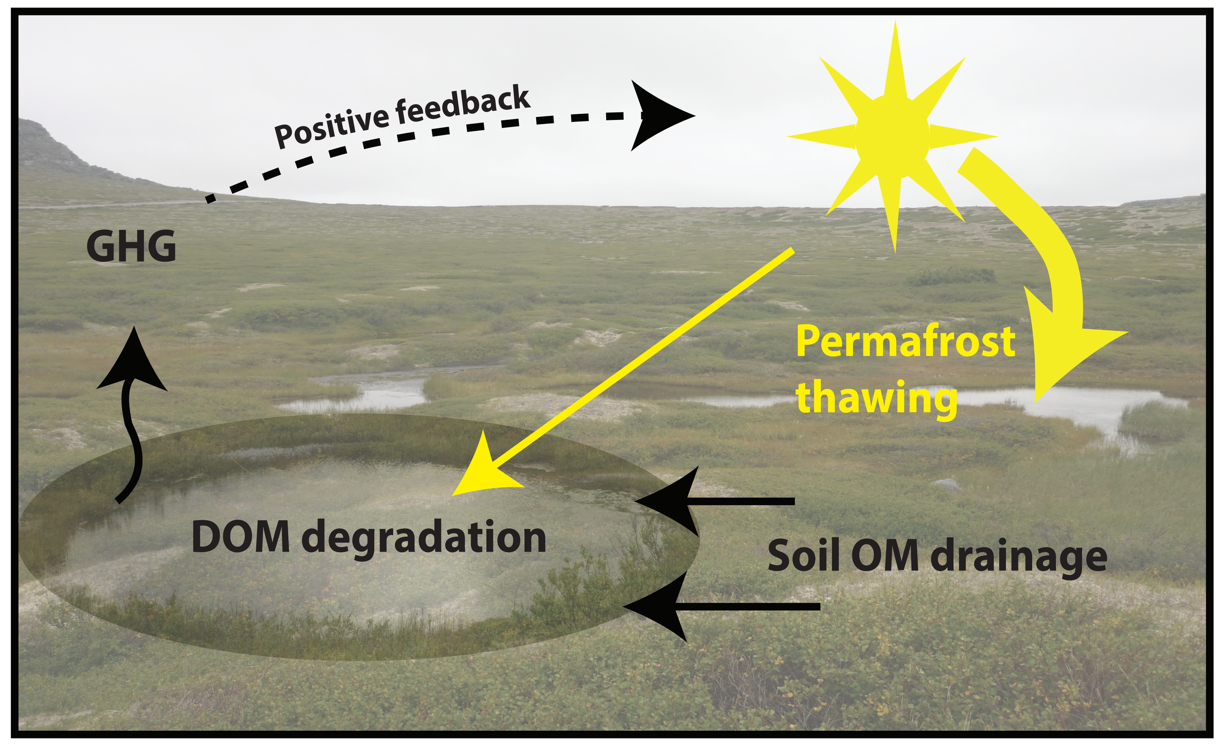
Context

• Large pools of unaltered organic matter (OM), which has accumulated for thousands of years are burried in permafrost. This stock contains up to 1850 Gt of carbon, twice of what is currently in the atmosphere[1].

• With permafrost thawing OM becomes available for degradation by bacteria and sunlight as dissolved organic matter (DOM), in the numerous thaw ponds of the landscape[2]. The resulting greenhouse gases (GHG) can be emitted into the atmosphere and act as a positive feedback on climate[3].
Photodegradation has not been considered in arctic carbon budgets, yet it could be of great importance globally[4].

PhD project objectives:
- Disentangle factors influencing DOM photodegradation efficiency in thaw ponds.
- Evaluate the contribution of photomineralisation to permafrost carbon feedback on climate.



The permafrost carbon feedback on climate

Methods

In a glance

- 2-weeks incubation experiments with two factors (bacteria and sunlight)
- 6 arctic and 1 subarctic waters tested (5 presented)
- DOM quality and quantity, CO_2 production and bacterial growth followed

• Thaw pond waters were incubated in submerged 72 mL bottles over two weeks during which these variables were followed: dissolved organic carbon, DOM absorbance spectra and excitation-emission matrices of fluorescence (PARAFAC extraction), bacterial production and abundance (tritiated leucine incorporation and flow cytometry), dissolved inorganic carbon and DOM chemistry with FT-ICR mass spectrometry. At each time step triplicate bottles were used. Light exposure dose will be estimated from satellite imagery (Hydrolight), local weather stations (SILA, CEN) and diffuse attenuation coefficients of downwelling irradiance (Kd, Satlantic). Incubation temperature was followed with thermistors.

• 4 treatments were applied (see below) on different pond waters in order to test the effects of DOM quality on photodegradation efficiency and associated CO_2 production, in absence and presence of bacteria.

Characteristics of the ponds, the waters and the incubation

Pond name	BYL80	BYL24	BYL121	BYL117	SAS2A
Size (m²)	212	256	99	152	196
Max. depth (cm)	80	75	60	80	280
DOC (mg.L^{-1})	6.5	6.8	9.5	9.4	18.3
a_{320} (m^{-1})	8.8	31.0	29.4	38.2	142.1
$SUVA_{254}$ (L.mg^{-1}.m^{-1})	4.1	9.9	7.2	9.8	15.6
P total (µg.L^{-1})	18	19	26	43	14
N total (µg.L^{-1})	561	409	782	917	1060
Fe (mg.L^{-1})	0.3	0.8	1.2	0.7	3.0
Kd_{380} (m^{-1})	5	24	20	30	NA
Water origin	Bylot island in East Canadian Arctic				Kuujjuarapik subarctic region (north of Québec)
Incubation date	July 2017				July-august 2016
Incubation place	A transparent pond in Bylot Island				A tray in Québec city
Incubation conditions	Arctic in situ incubations				Rooftop incubation
Sampling rate	2 times (beginning and end)				5 times

Light treatment (L)
- No bacteria (0.3 µm nominal filtration)
- Light exposure
- Evaluates light degradation alone

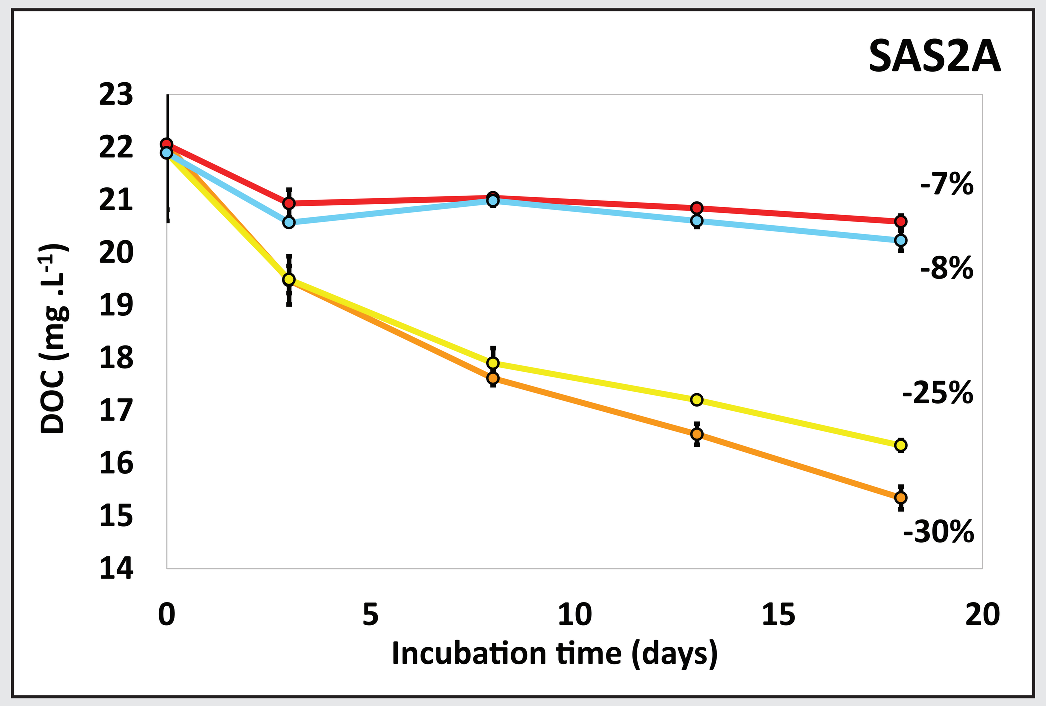
Bacteria treatment (B)
- Bacteria (2.7 µm filtration)
- No light (black covered bottle)
- Evaluates bacterial degradation alone

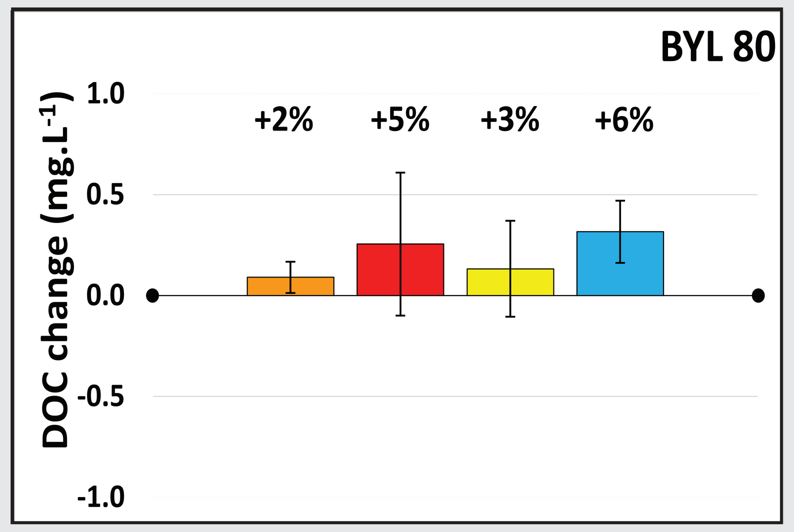
Bacteria and light treatment (B+L)
- Bacteria (2.7 µm filtration)
- Light exposure
- Evaluates conjugated degradation effects

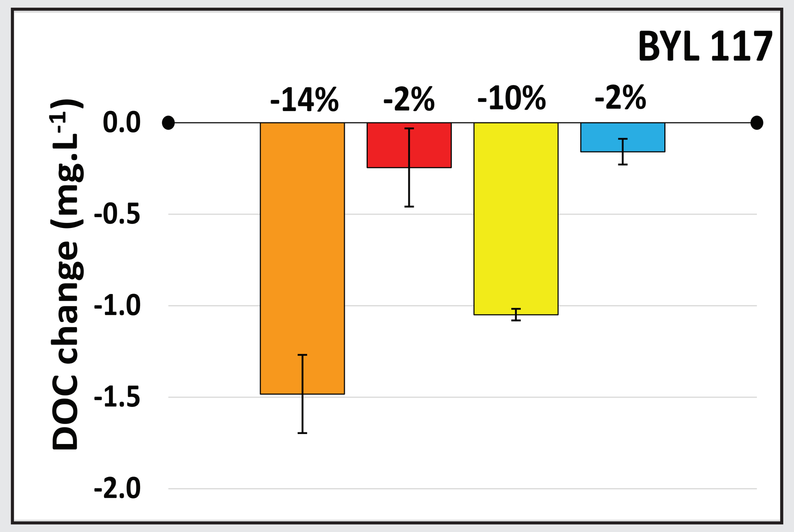
Control treatment (C)
- No bacteria (0.3 µm nominal filtration)
- No light (black covered bottle)

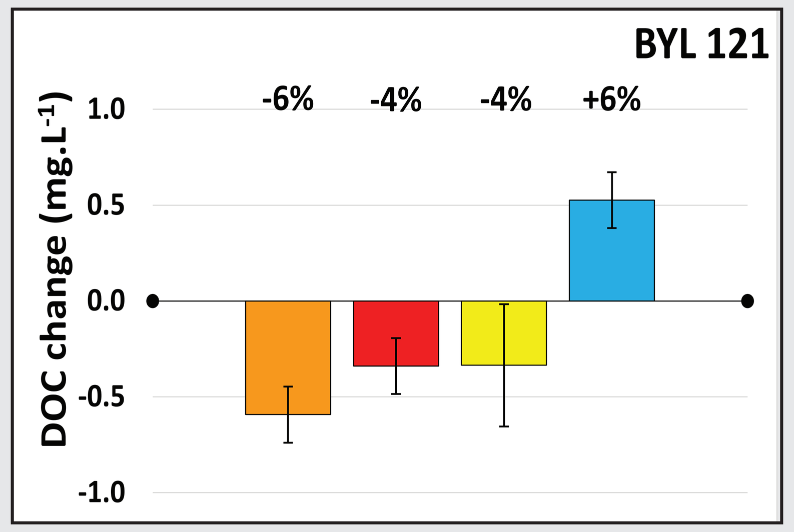
Preliminary results

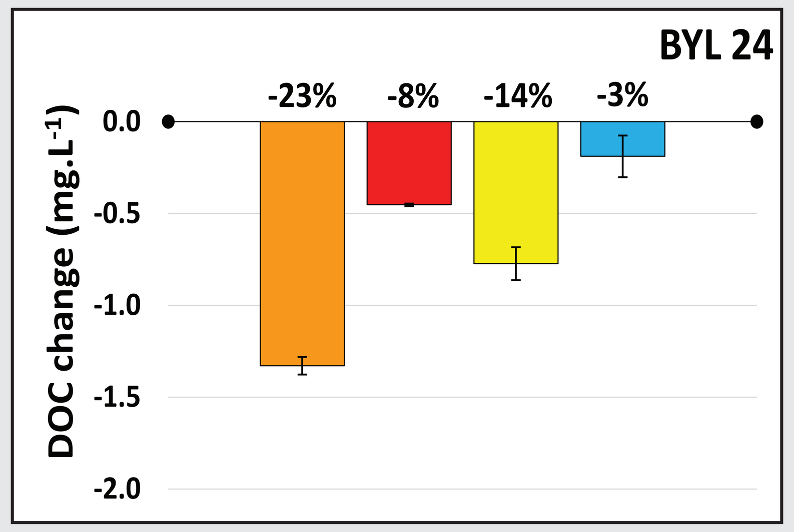
DOC change is a proxy for the synthesis or degradation of DOM





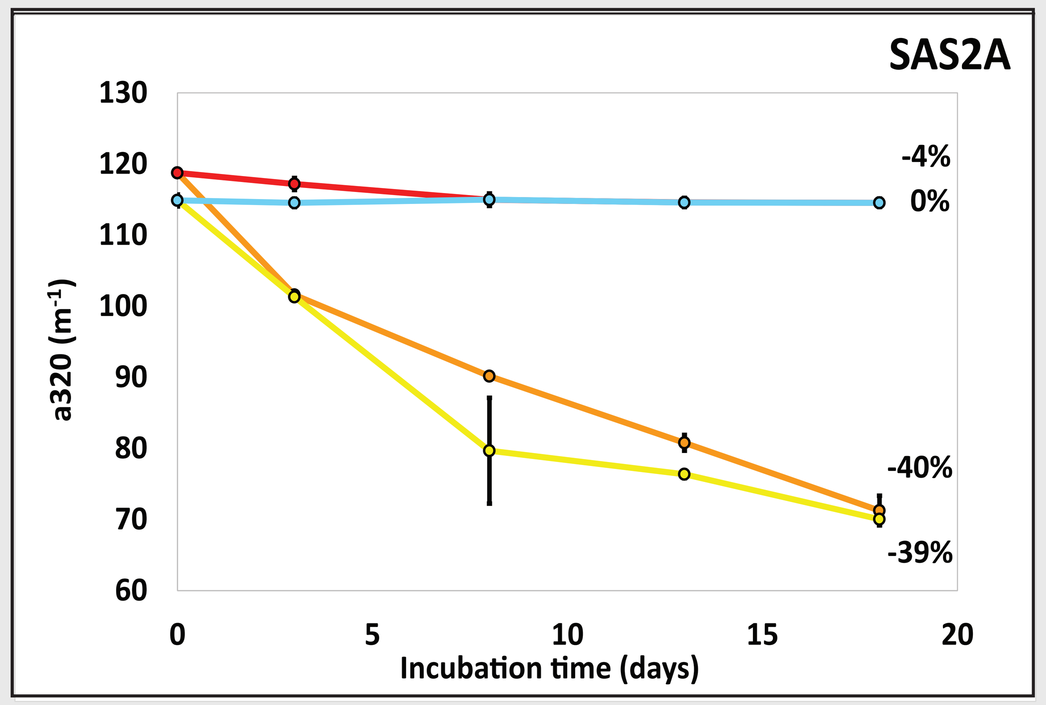


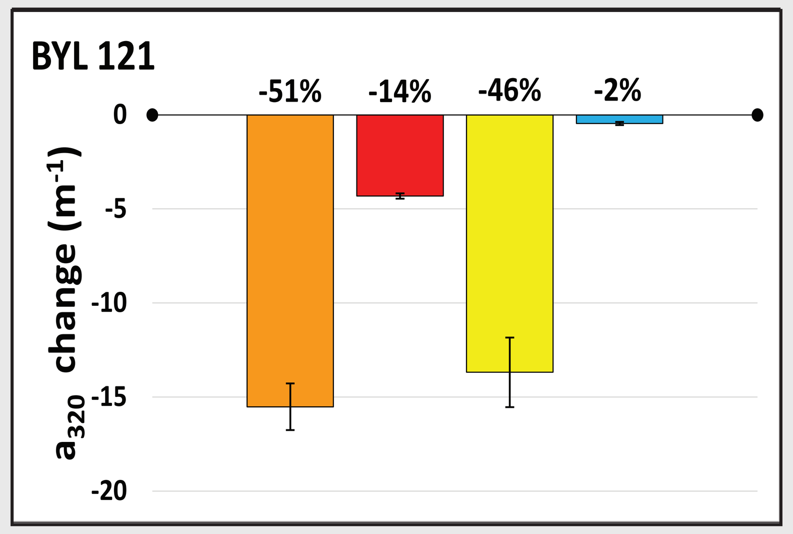




- When significant DOC change is observed, sunlight has a stronger degradation effect than bacteria. The extent of DOC degradation depends on the water.
- A DOC loss together with a limited CDOM loss suggest the bacterial use of non chromophoric DOM.
- DOC loss in L suggests direct photomineralisation.

Change in absorption coefficient at 320 nm (a_{320}) is a proxy for the synthesis or degradation of chromophoric DOM (CDOM)



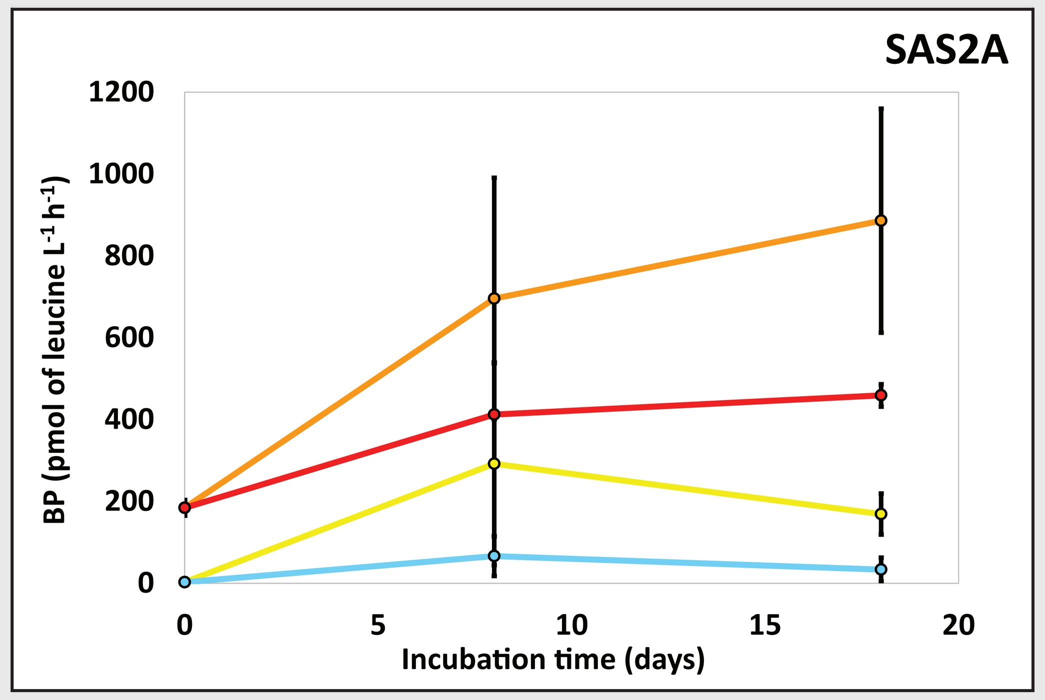


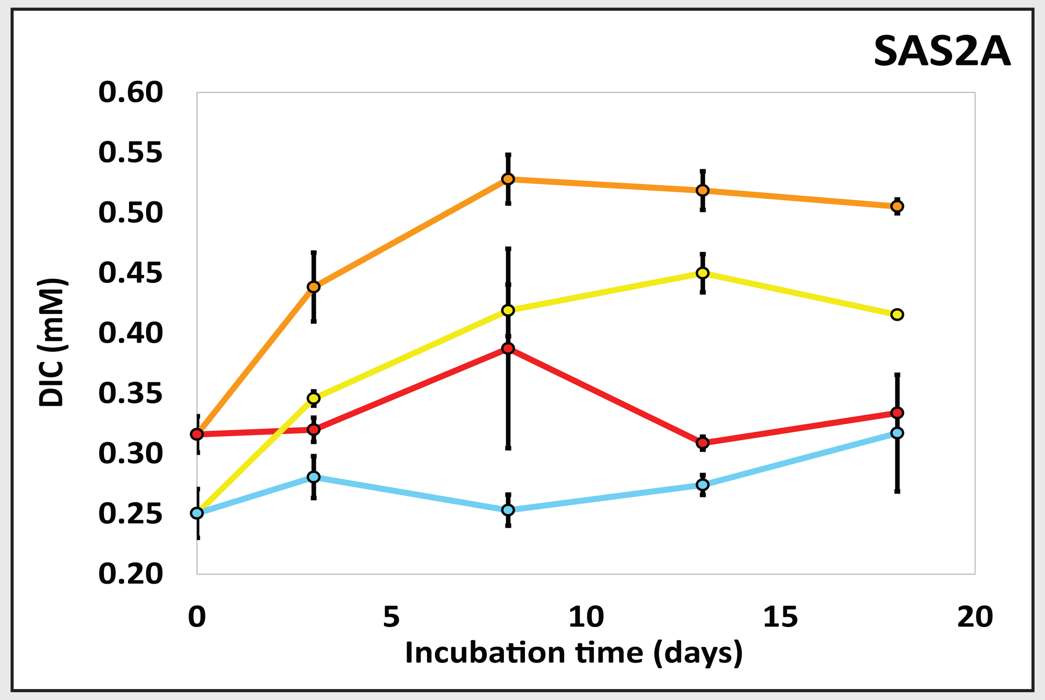
	B + L	B	L	C
BYL80	-40%	-11%	-36%	-3%
BYL24	-43%	-7%	-41%	-2%
BYL117	-43%	-9%	-36%	-2%

- All BYL ponds graphs are similar to the one of BYL121 (see percentages above).

- In all ponds, light is the most efficient CDOM degradation factor.
Bacteria also have an effect, but it is limited (see SAS2A).

Leucine incorporation is a proxy for bacterial production (BP) while dissolved inorganic carbon (DIC) is a proxy for CO_2 concentration





- Results indicate that BP is photostimulated (B+L > B).

- BP for filtered treatments (L and C) indicates a bacterial regrowth, but also again a stimulation by sunlight.

- DIC production is highest in the presence of sunlight indicating the importance of direct photomineralization, consistent with DOC loss.

Concluding remarks

• CDOM loss is stinkingly similar among ponds but DOC loss varies. This suggests the importance to consider DOM intrinsic properties, and particularly the non chromophoric photoproducts.

• Direct photomineralisation can be significant, but apparently depends on DOM intrinsic properties. Sunlight can also stimulate bacterial production. This will be better documented by subsequent analysis on DOM properties.

• Sunlight carbon degradation is definitely an important factor to consider in arctic carbon cycling.

Results to come
- Fluorescent compounds extraction with PARAFAC
- Other optic index (SUVAs, spectral slopes)
- Bacterial abundance with flow cytometry
- DIC
- Compounds identification with FT-ICR-MS

References: [1] McGuire A. D. et al. (2009). *Ecological Monographs*. 79(4):523-555; [2] Vonk J. E. et al. (2015). *Biogeosciences*. 12(23): 7129-7167; [3] Schuur E. A. G. et al. (2015). *Nature*. 520: 171-179; [4] Cory R. M. et al. (2014). *Science*. 345(6199): 925-928

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