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RAIRS study of the dipole alignment in spontelectric solid nitrous oxide (N_2O) films: Possible astrophysical implications

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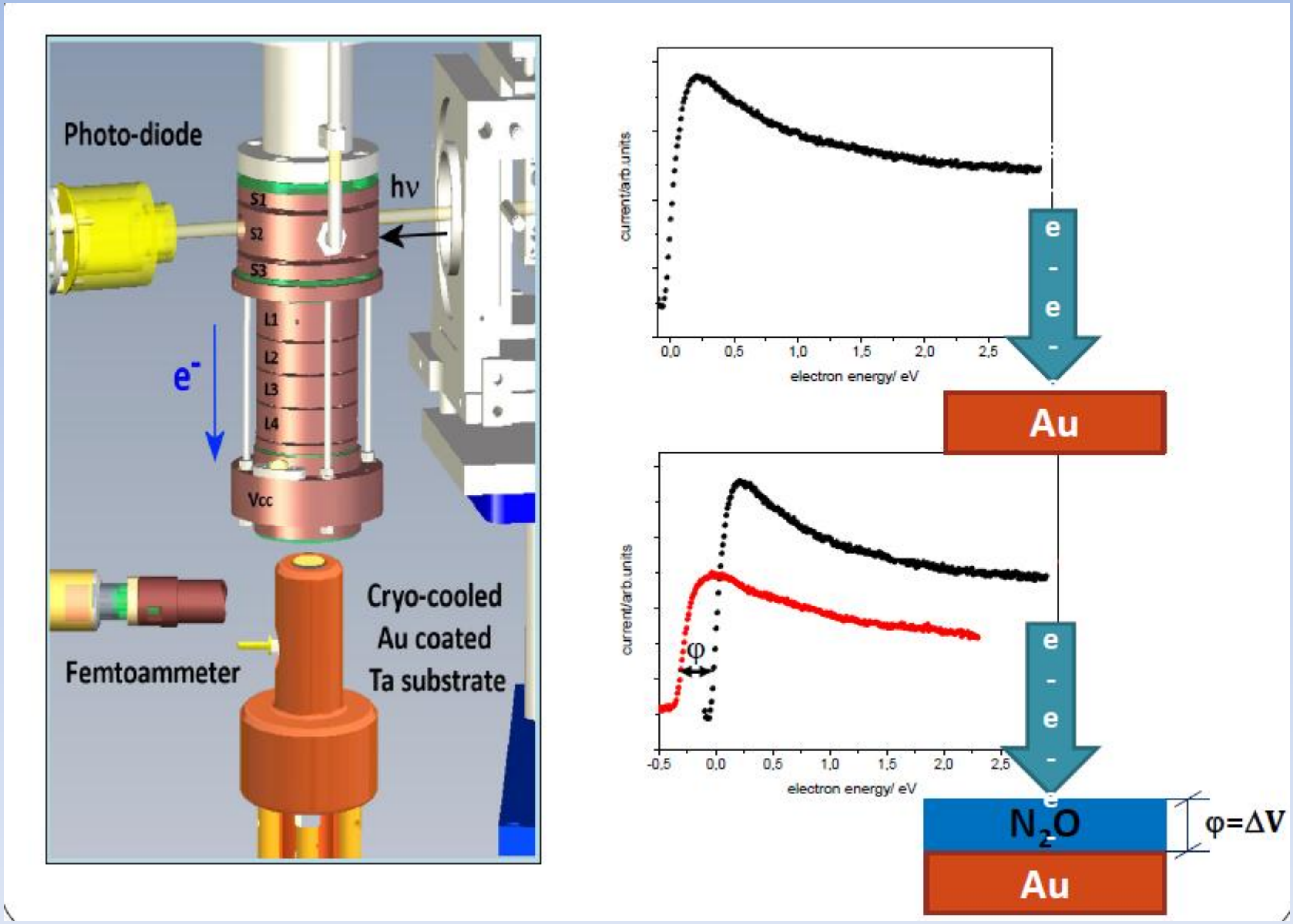
Outline

- What is the spontelectric effect and how is it measured?
- Monitoring dipole alignment with RAIRS
- Possible astrophysical implications

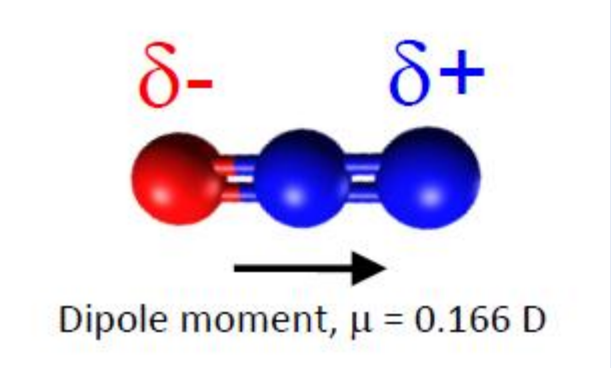
Spontelectric effect



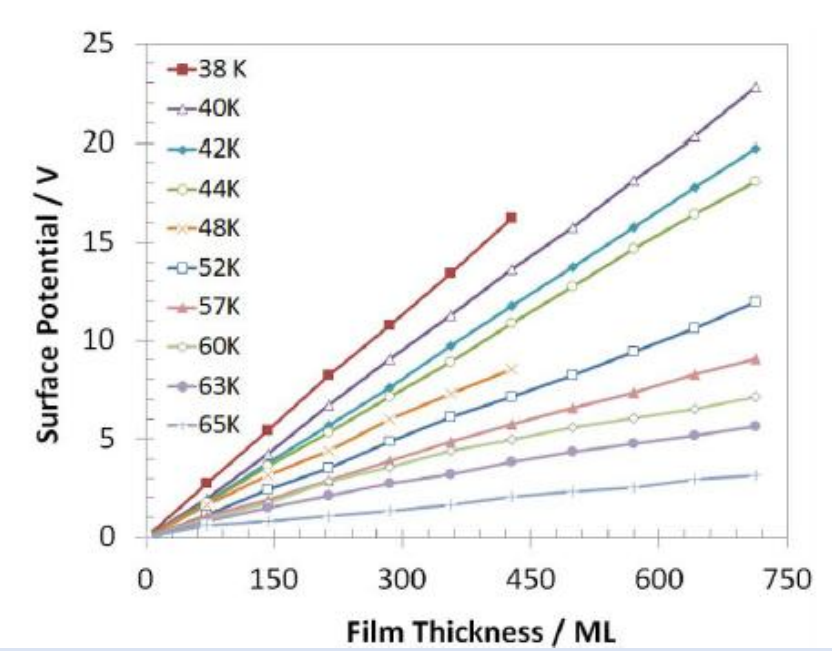
A. Cassidy *et al.*, ASTROSURF 2011, Edinburgh (UK)

Spontelectric effect

- Solid N_2O films deposited on polycrytalline Au



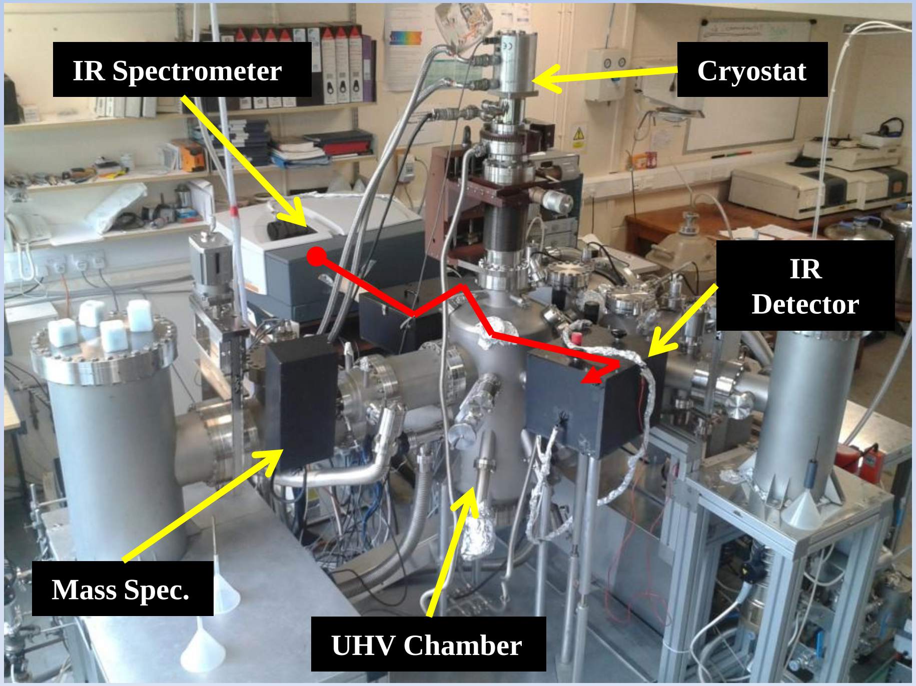
- Surface potential (V) of the films increases linearly with thickness
- Surface V depends strongly on deposition T
- Heating the films also reduces surface V



R. Balog *et al.*, *Phys. Rev. Lett.* **102**, 073003 (2009); D. Field *et al.*, *Int. Rev. Phys. Chem.* **32**, 345 (2013)

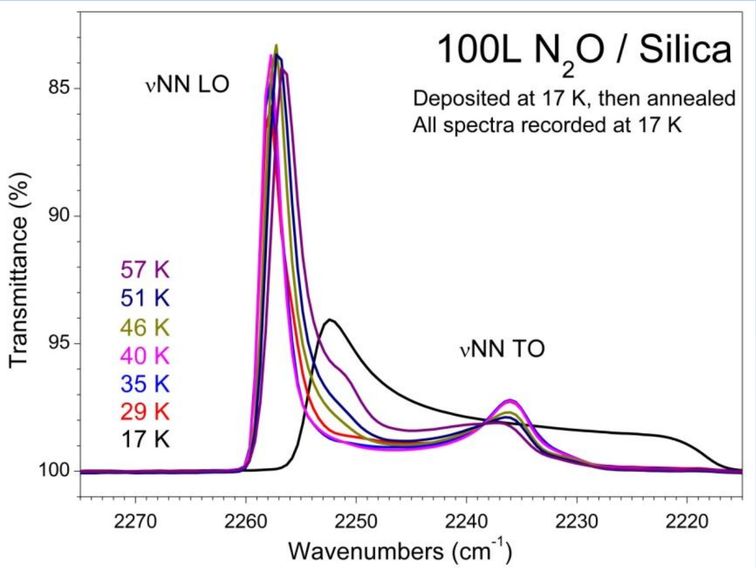
Monitoring dipole alignment with RAIRS

- IR spectroscopy in grazing incidence at HWU

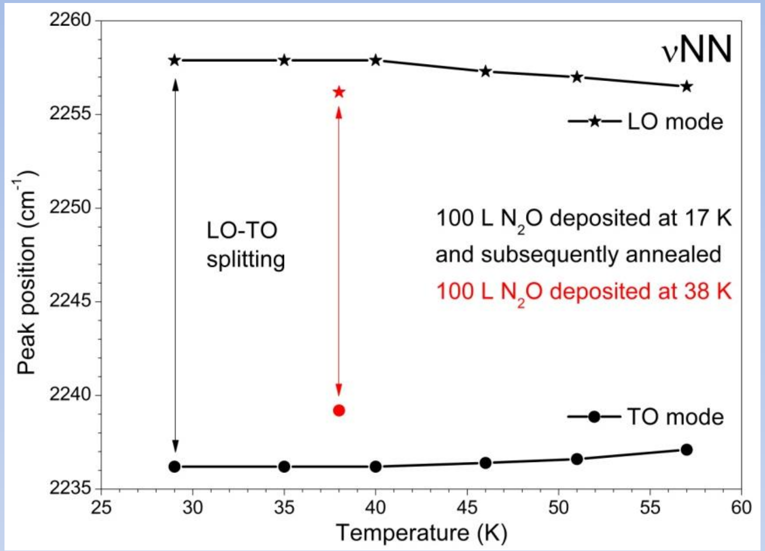


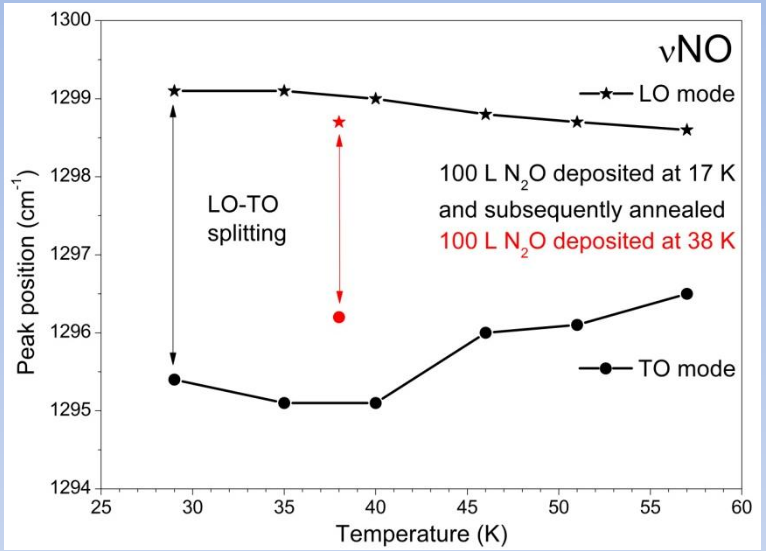
- LO-TO splitting increases with dipole coupling in solid films (*i.e.* dipole alignment)

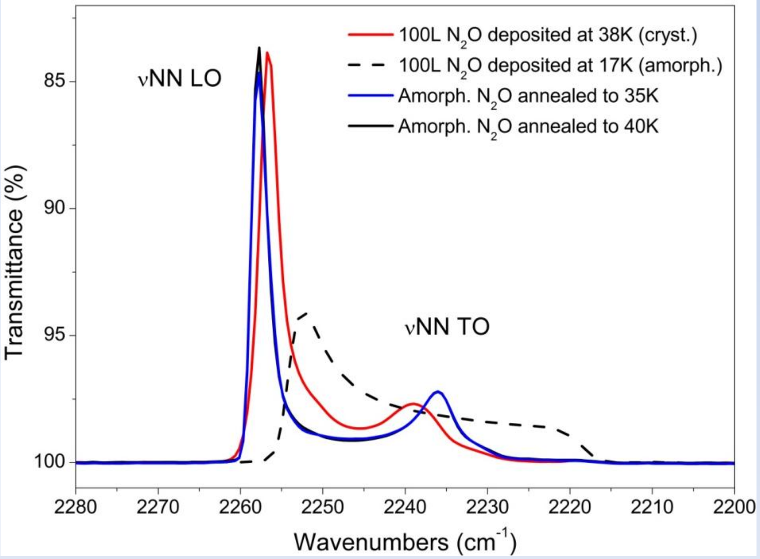
B. Rowland, N.S. Kadagathur and J.P. Devlin, *J. Chem. Phys.* **102**, 13 (1995)

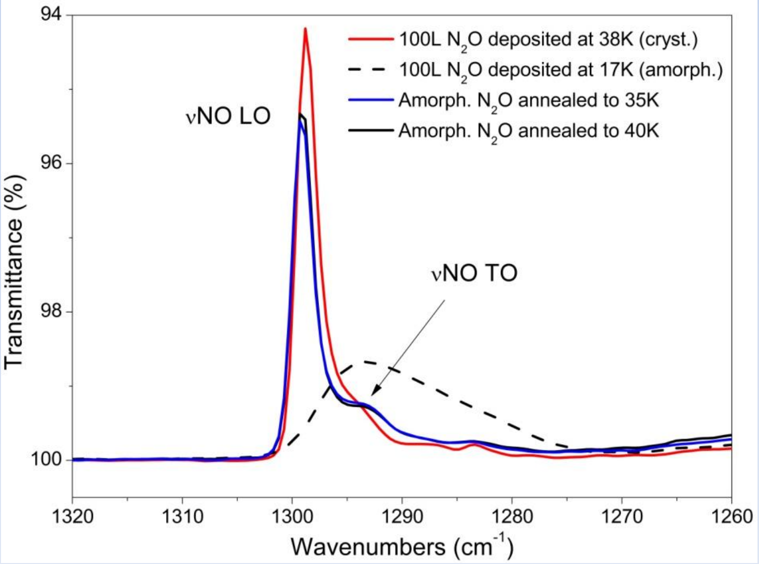


Monitoring dipole alignment with RAIRS









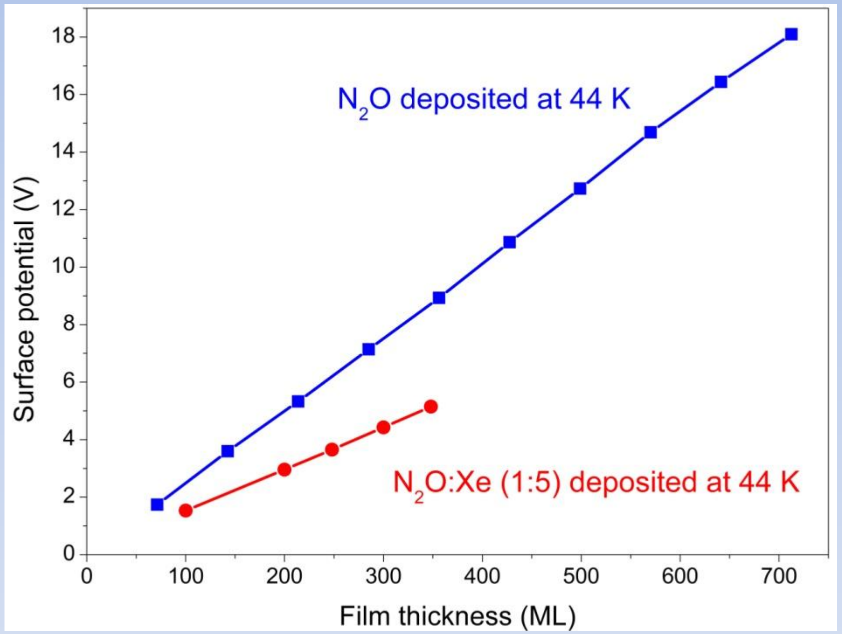
Monitoring dipole alignment with RAIRS

- LO-TO splitting, and therefore dipole coupling decreases in N_2O films with increasing T and more noticeably with deposition T

→ Independent confirmation of the results of surface potential measurements

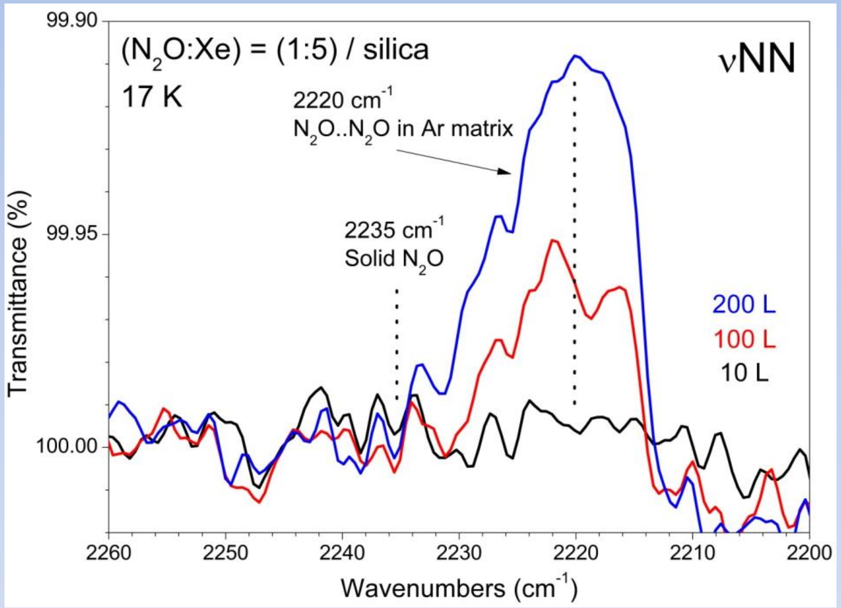
A long-range effect

- Spontelectric effect is retained for N_2O diluted in Xe



- Segregation of N_2O from Xe? → IR spectroscopy

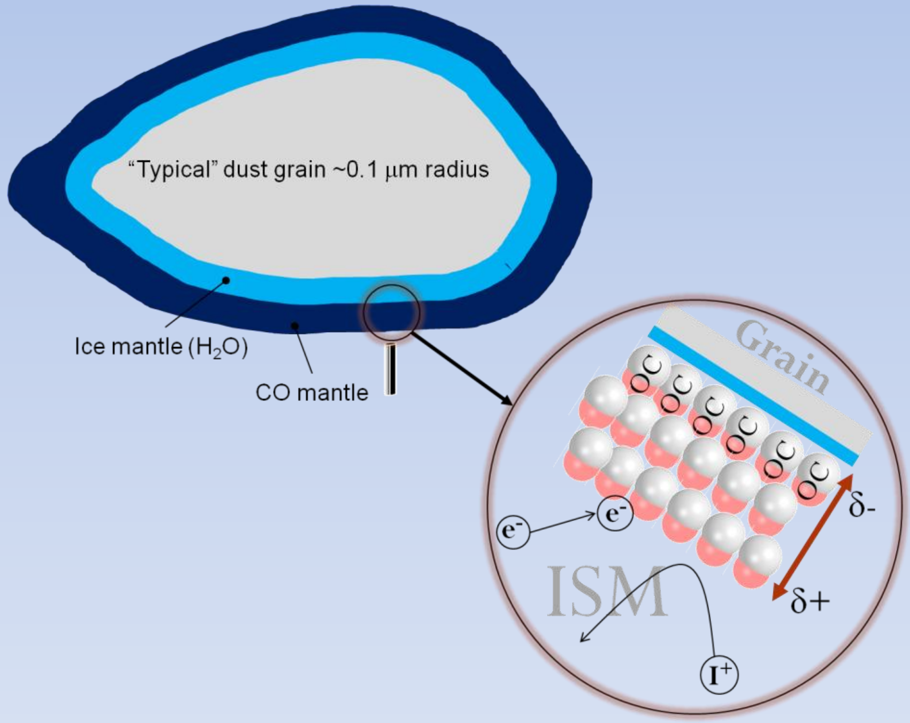
- (N_2O:Xe) = (1:5) mixture: N_2O dimers



- No segregation, spontelectric effect is due to a long-range interaction (dipole-dipole) and ambient electric field interactions with dipoles

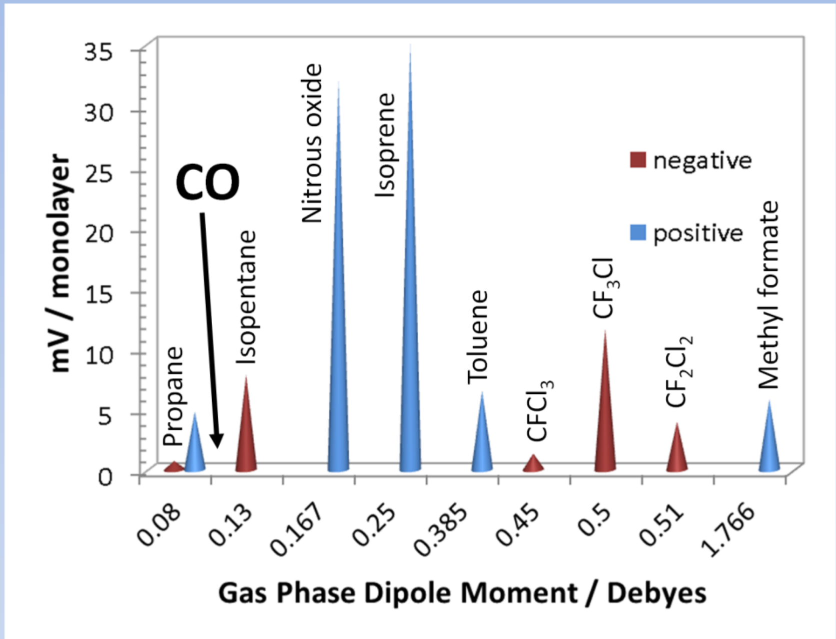
Possible astrophysical implications

- In dense and cold regions of the ISM, CO condenses on top of H_2O ice
- Layered CO-H_2O system with approx. 67 ML of CO (L1544, starless core)
- CO adsorbed with positive end (O atom) pointing towards the vacuum → positively charged surface



A. Cassidy *et al.*, ASTROSURF 2011, Edinburgh (UK)

Possible astrophysical implications



A. Cassidy *et al.*, ASTROSURF 2011, Edinburgh (UK)

- Prediction based on exp.: surf. polarisation ≥ 10^{-4} C.m^{-2} for CO ice (surf. V ≈ +2 V)

→ equivalent to roughly 100 surf. “charges” per grain (or per m^3)

- These positive “charges” are neutralised by e^- impacting the ice during its deposition

→ Spontelectric character of CO ice would attract 100 e^-/grain. e^- available on the grains’ surface to recombine with molecules/radicals and form anions (e.g. C_4H^-/C_6H^- observed in dense clouds*)

*M.A. Cordiner *et al.*, *Astrophys. J.* (2013)

Conclusions

- Independent confirmation of the decrease of dipole coupling when increasing (deposition) temperature of the films
- Spontelectric effect is caused by a long-range interaction (dipole-dipole coupling) and the interaction of the ambient electric field with dipoles, and is retained in dilute mixtures
- Possible spontelectric character of CO ice would lead e^- to charge the grains' surface. These e^- are available to recombine with atoms/molecules and form the anions observed in dense clouds (C_4H^-/C_6H^-)

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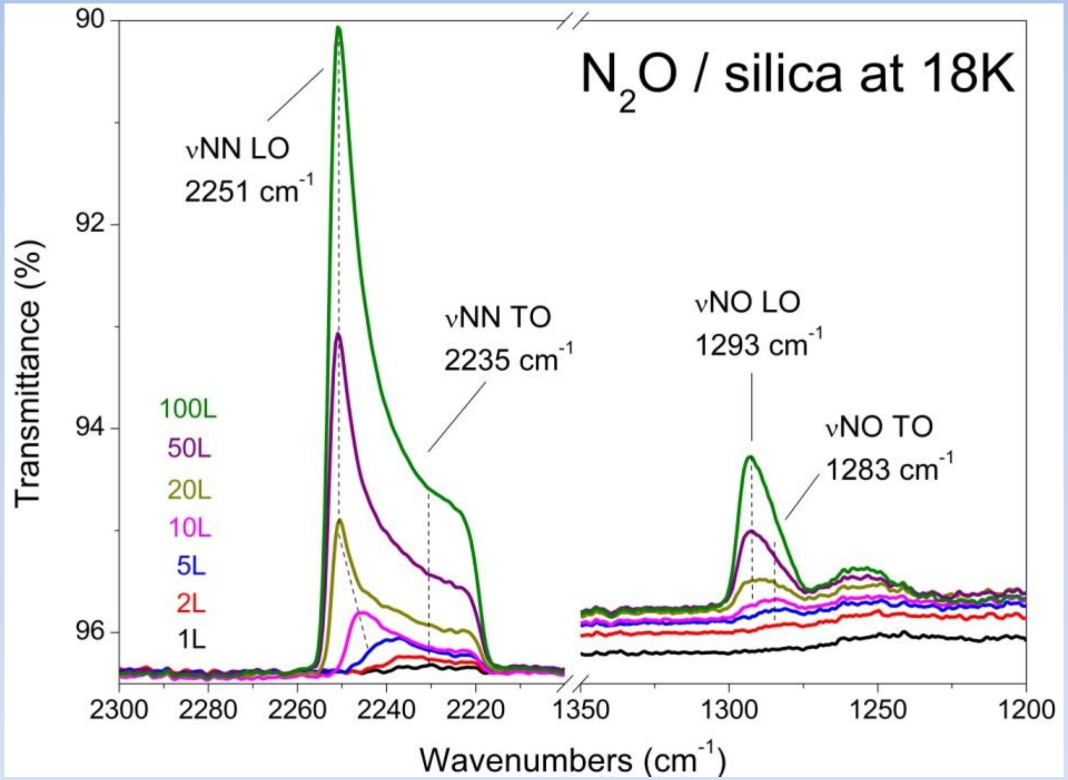
Monitoring dipole alignment with RAIRS



Possible astrophysical implications

- Dust grain *r* = 0.1 μm → surface area = 1.3 x 10^{-13} m^2
- 1 ML = 10^{19} molecules.m^{-2} → 1.3 x 10^6 CO molecules.ML^{-1} on this grain

- Number of dust grains [K. Acharyya, G.E. Hassel and E. Herbst, *Astrophys. J.* **732**, 73 (2011)] = 1.33 x 10^{-12} x n_H cm^{-3}

- For L1544 (starless core, [A.B. Ford and Y.L. Shirley., *Astrophys. J.* **728**, 144 (2011)]) n_H = 8 x 10^5 cm^{-3} *i.e.* number of dust grains = 1.065 x 10^{-6} cm^{-3} = 1.065 m^{-3}

- Number of CO ML = number of CO per m^3 all frozen divided by the number to make one ML divided by number of dust grains :

  9 x 10^7 /(1.257 x 10^6 x 1.065) = 67 ML of CO

- CO: μ = 0.122 D
- N_2O: μ = 0.167 D