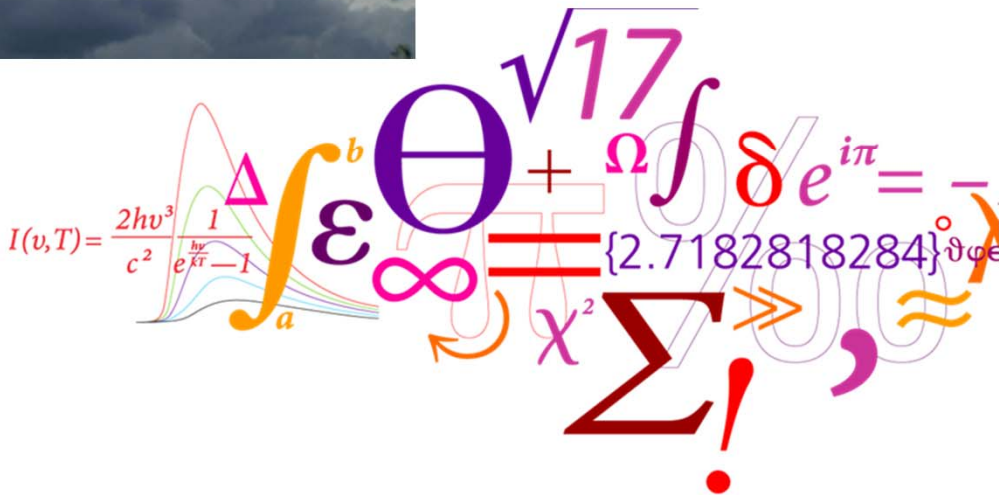
Response of Cloud Condensation Nuclei to Changes in Ion-nucleation

Jens Olaf Pepke Pedersen



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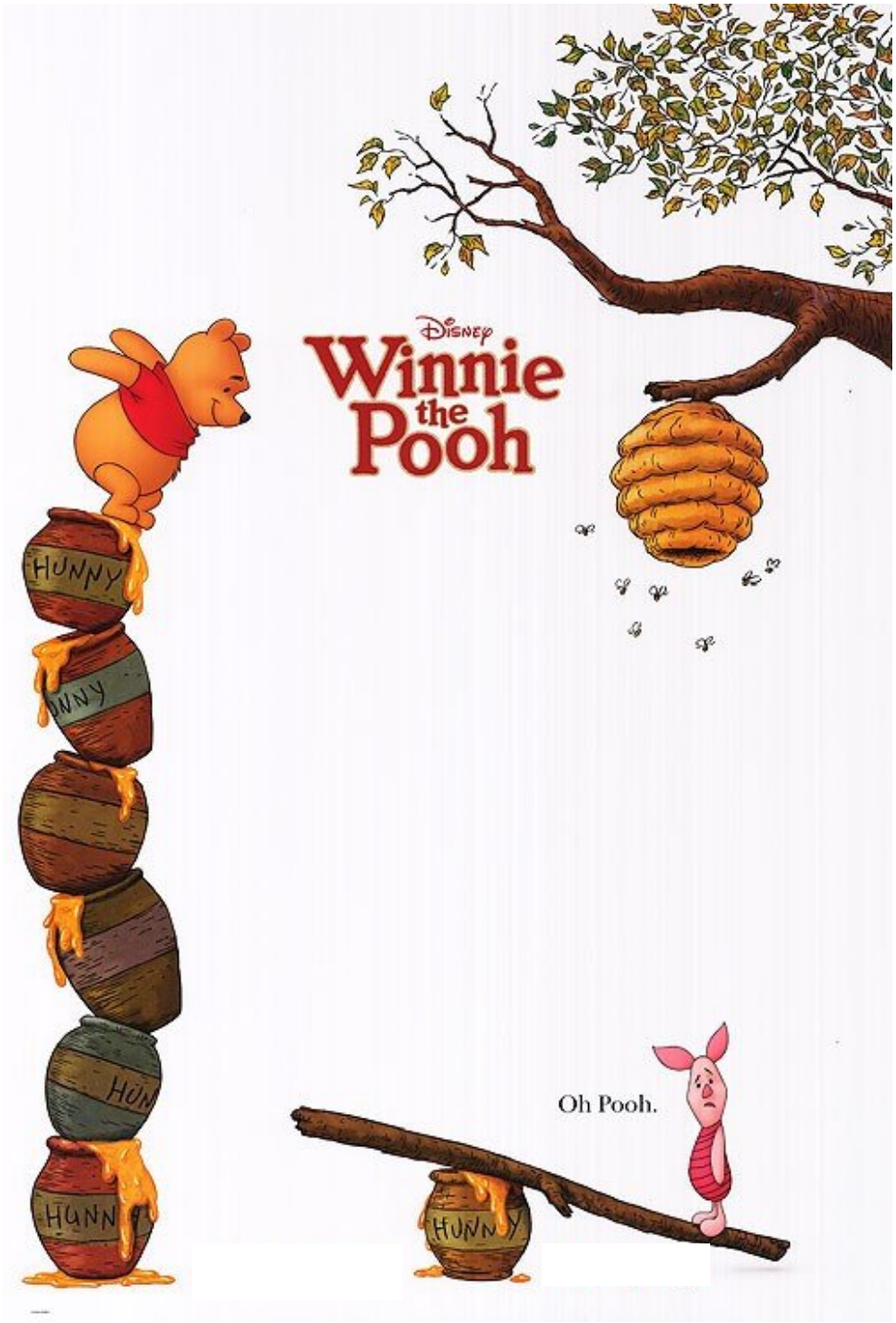
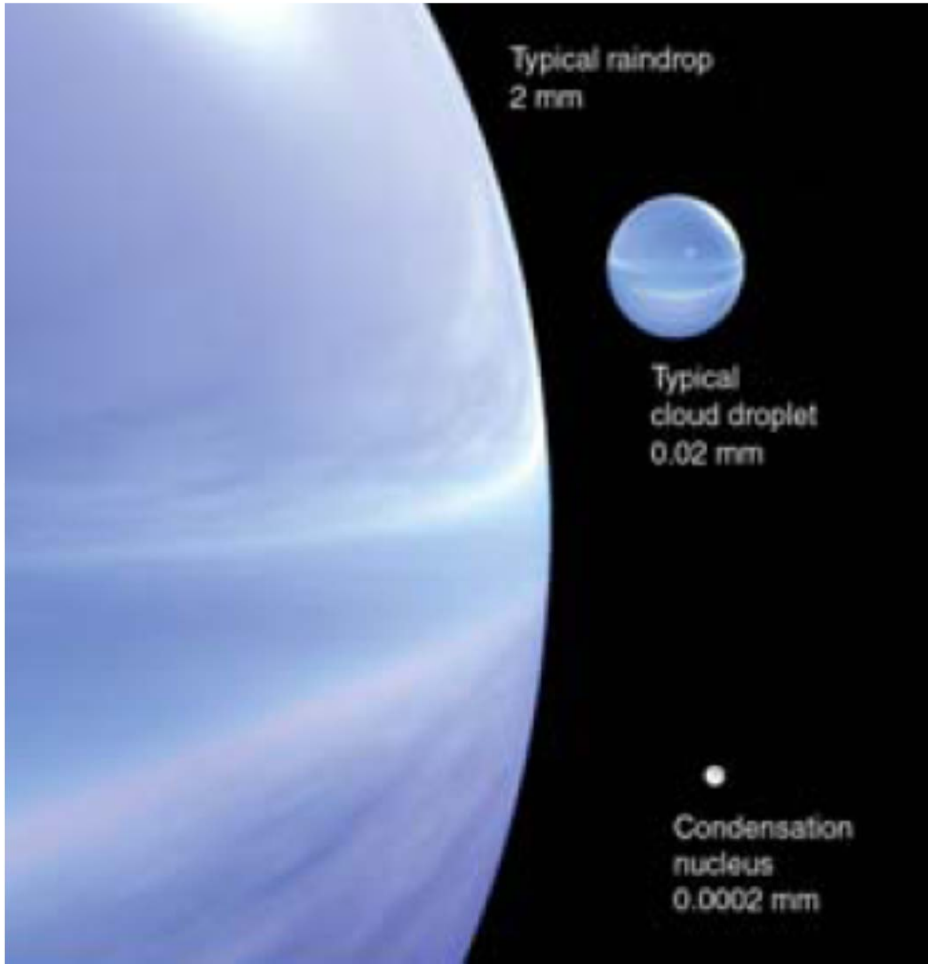


SKY experiments:

Laboratory experiment to look at the role of ions in nucleation under conditions that resemples the atmosphere

How to make a cloud?



Clouds form when air becomes supersaturated

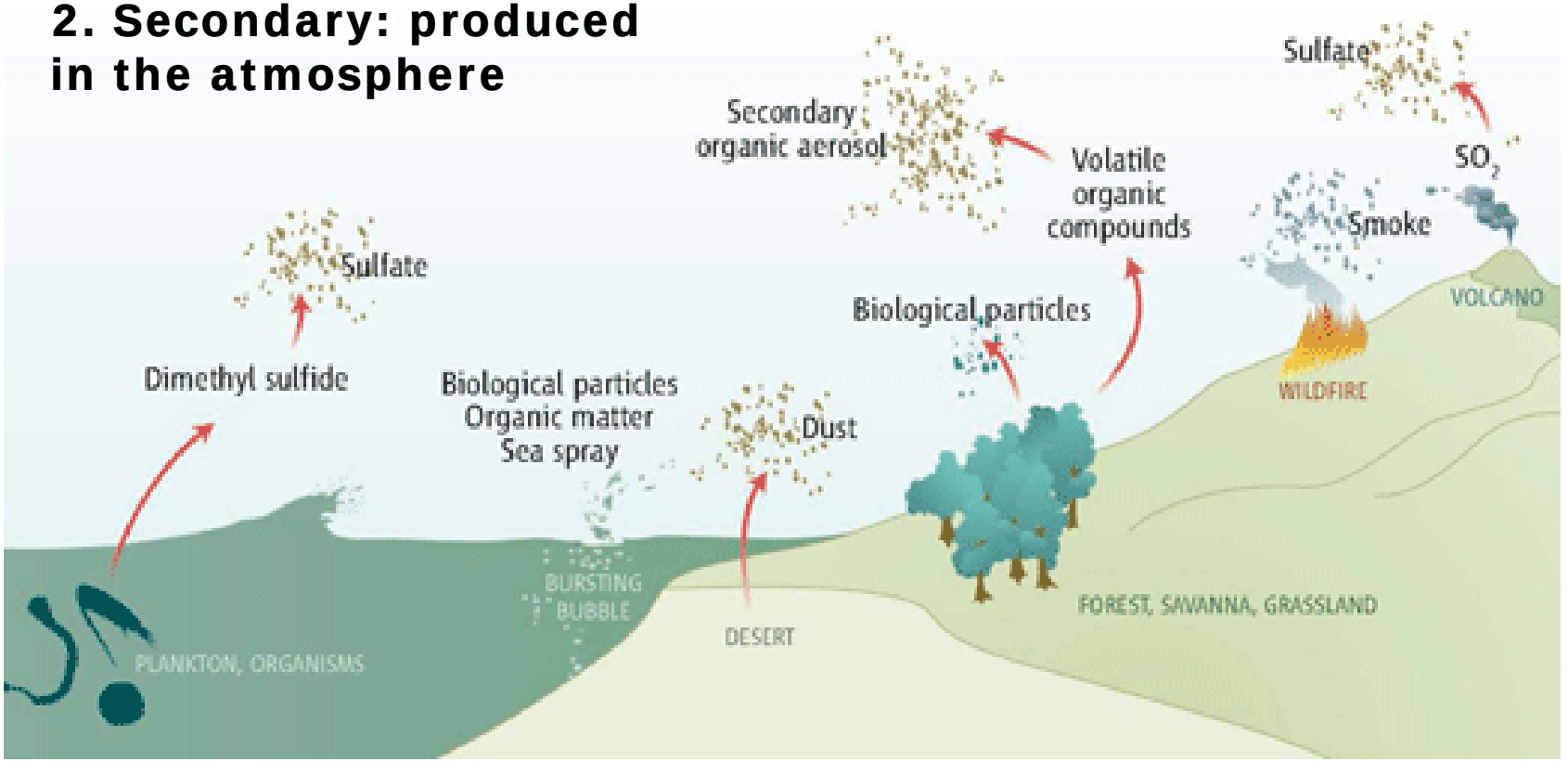
Rarely exceeds 1% (typically 0.1%)

Water vapor condenses on aerosols

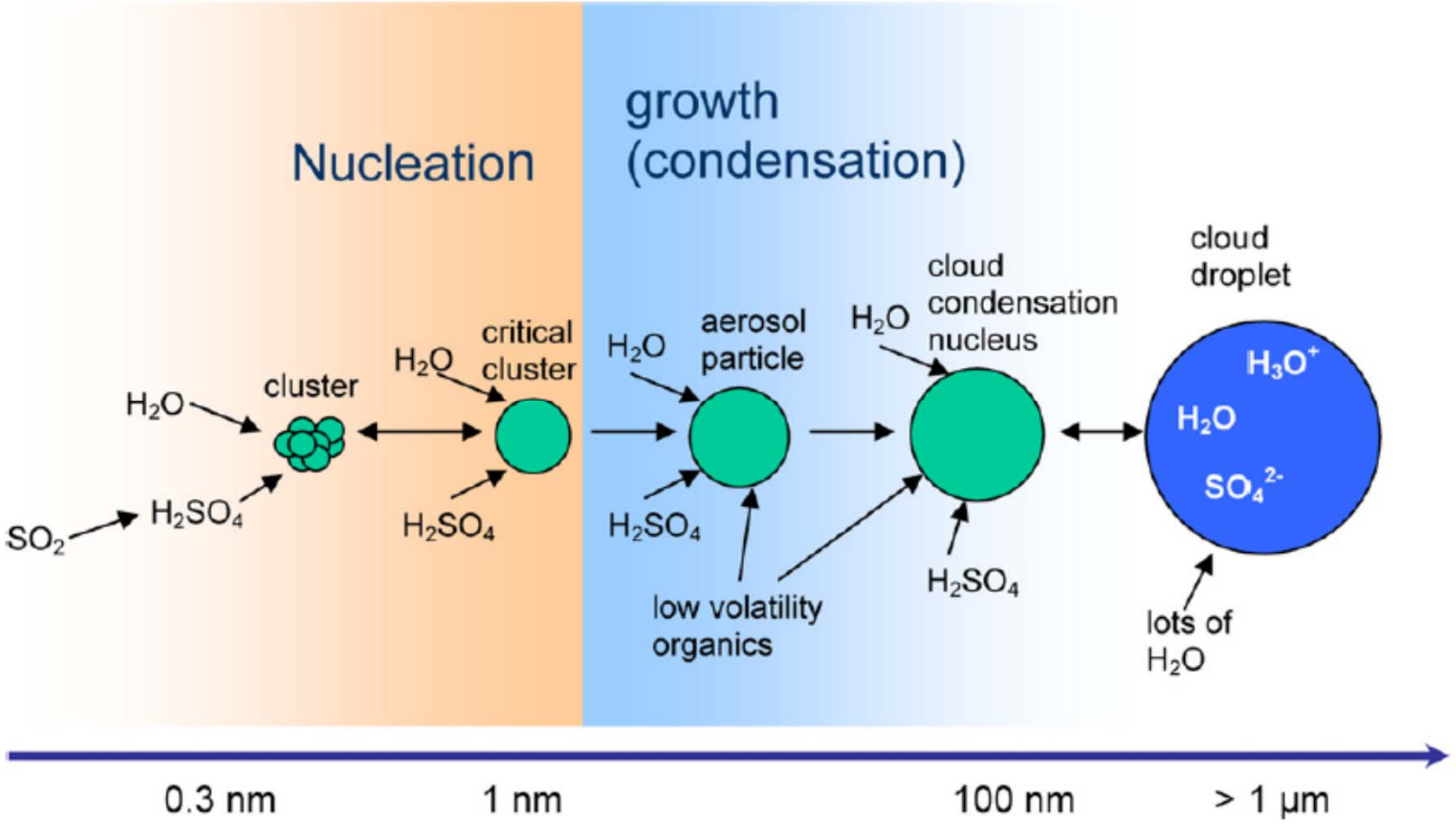
No nucleation of pure water

How to get aerosols?

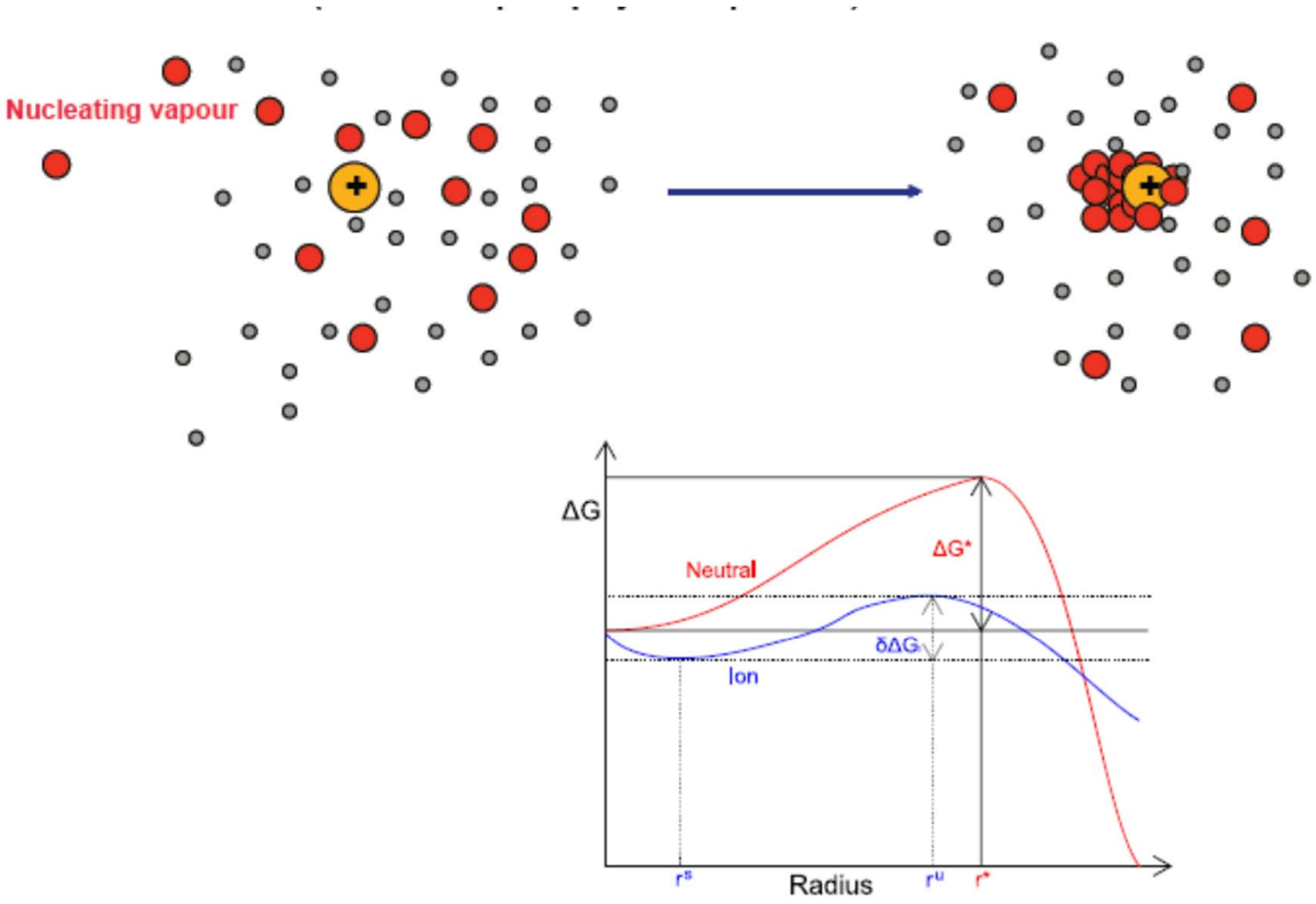
1. Primary: direct sources
2. Secondary: produced in the atmosphere

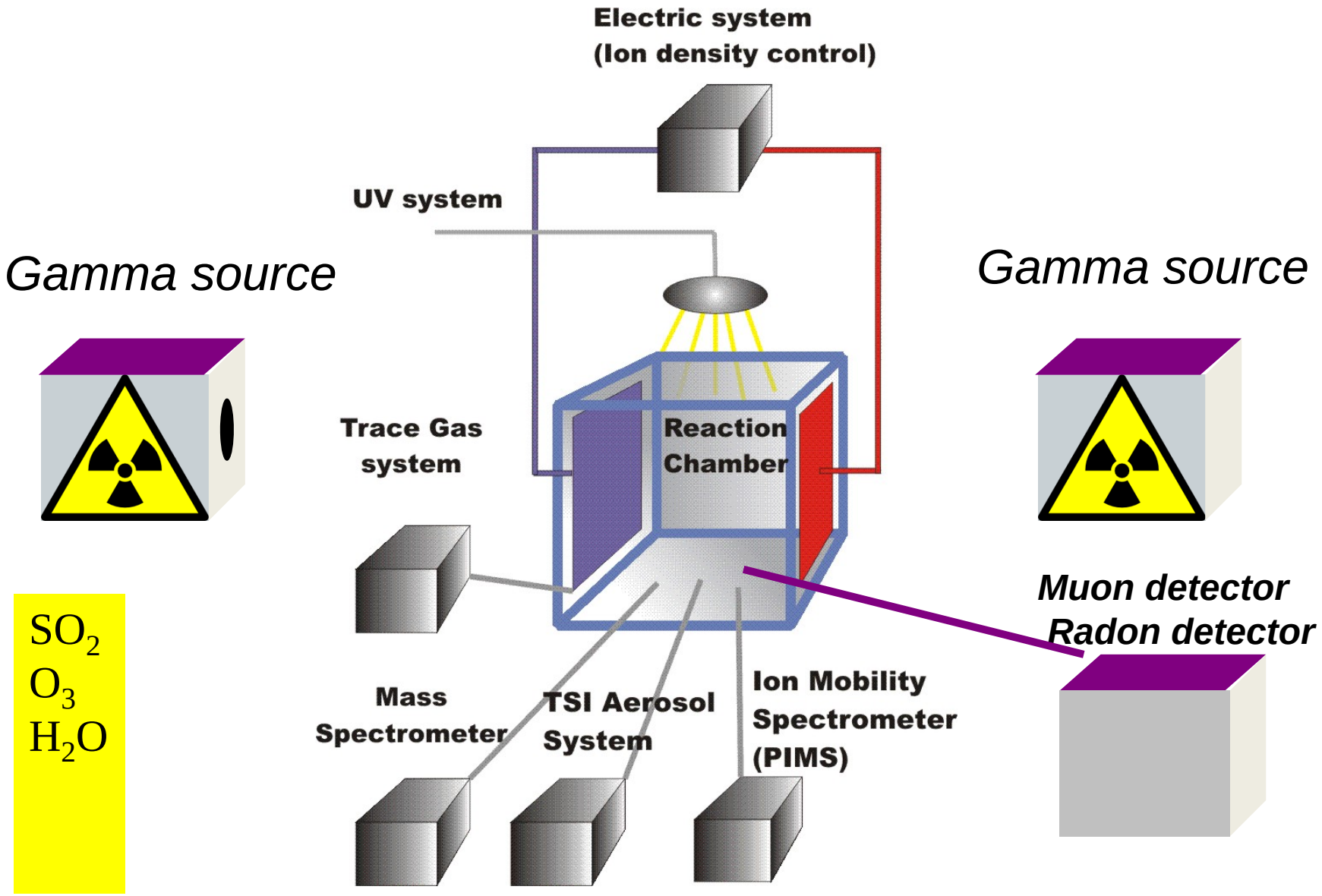


Heterogeneous nucleation (sulfuric acid + water)



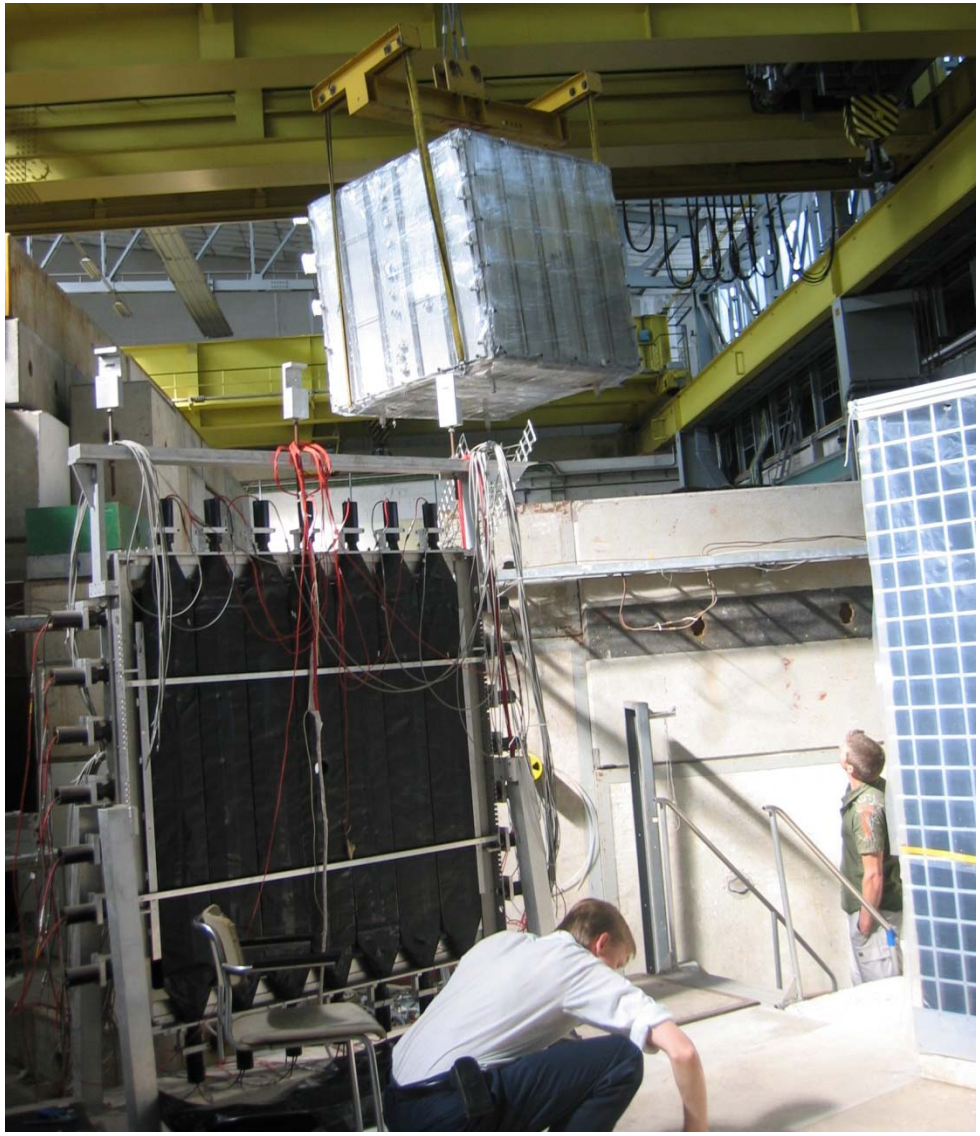
Nucleation around charges



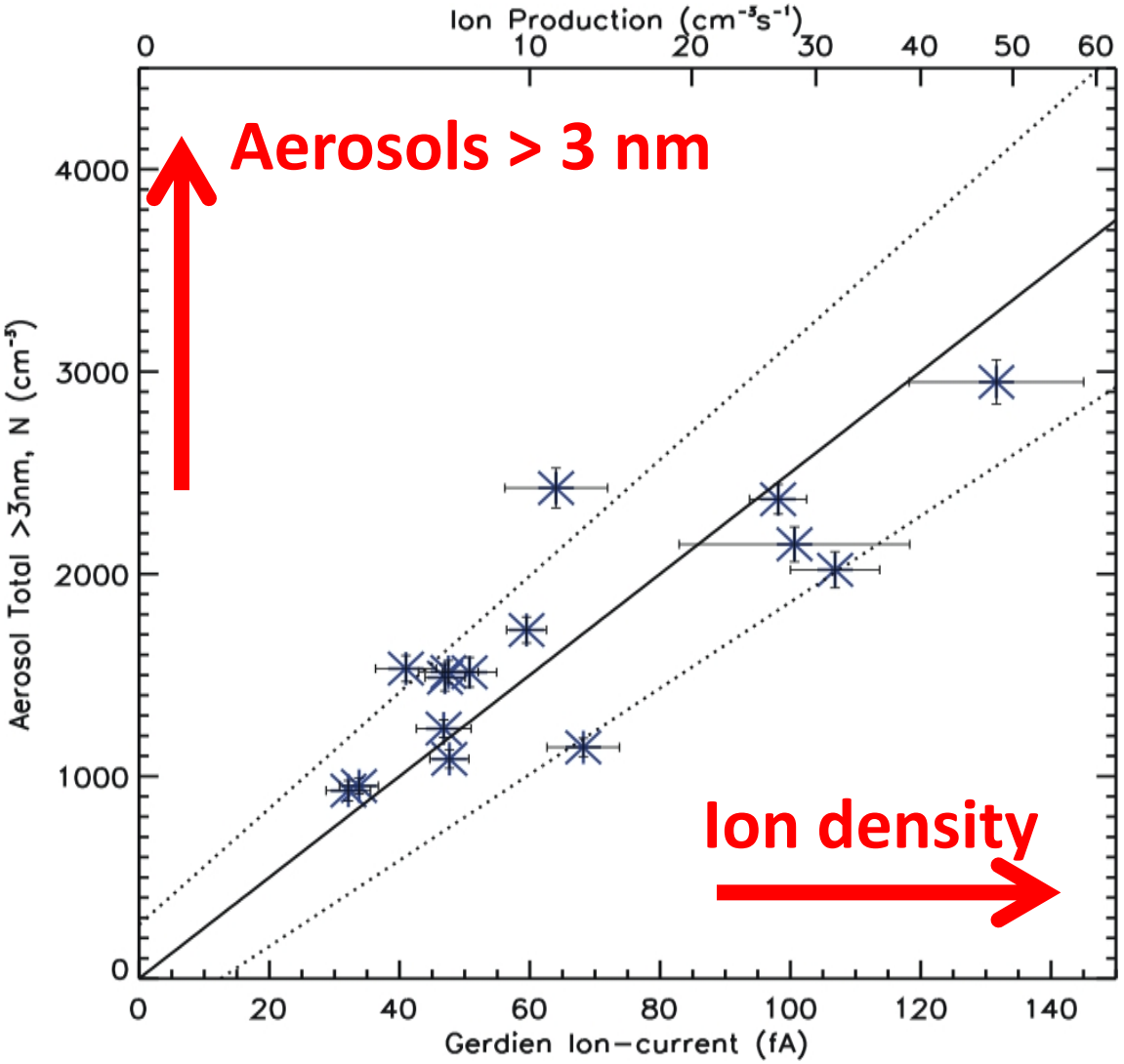

Electric system
(Ion density control)
UV system
Gamma source
Gamma source
Trace Gas
system
Reaction
Chamber
SO_2
O_3
H_2O
Muon detector
Radon detector
Mass
Spectrometer
TSI Aerosol
System
Ion Mobility
Spectrometer
(PIMS)

SKY

SKY II



Main result from SKY



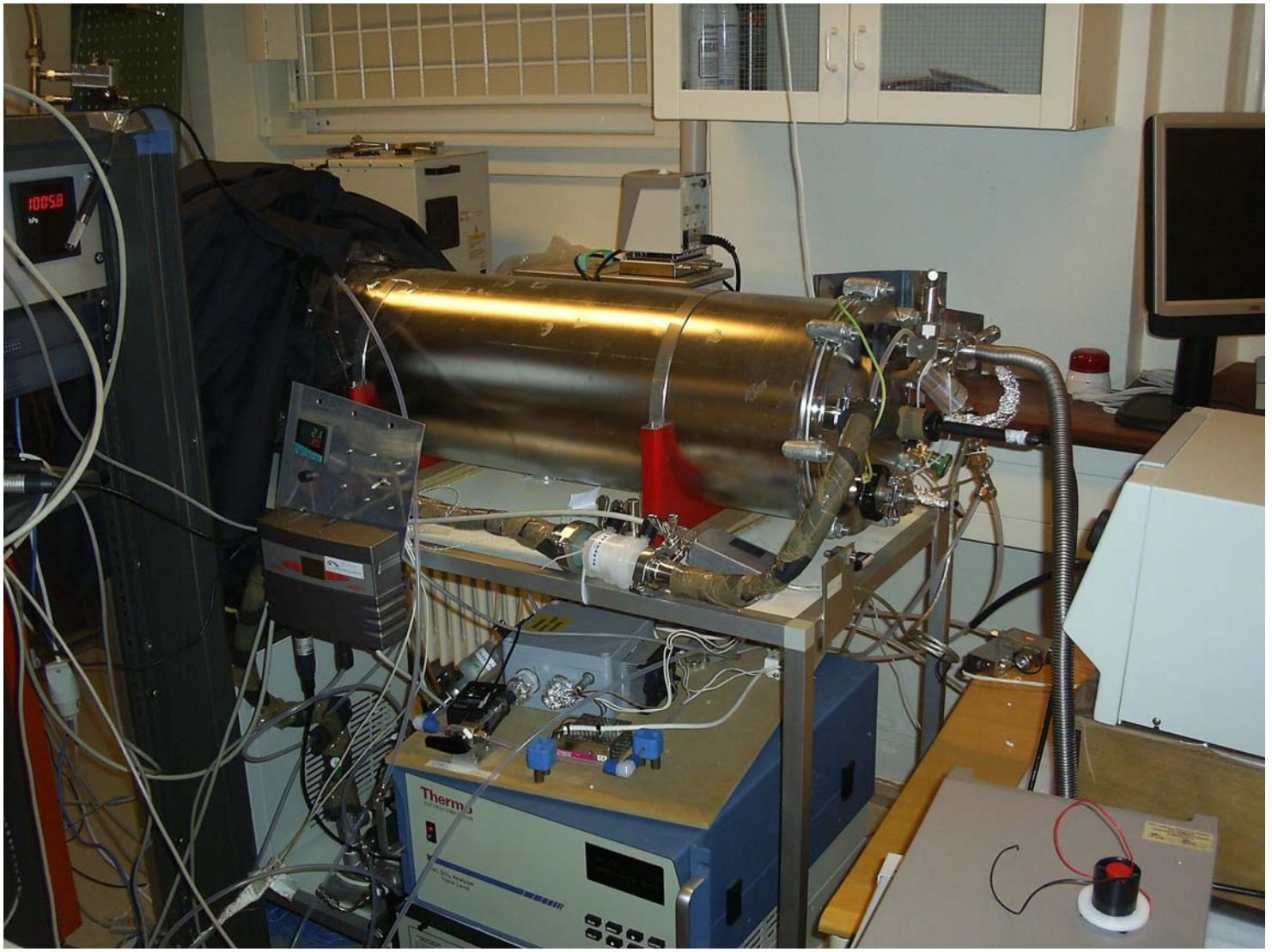
Correlation between ions and aerosols produced at 3 nm.

p = 1 atm

T = 25 °C

Svensmark et al. (2007) Proc.Roy.Soc. A

Little SKY



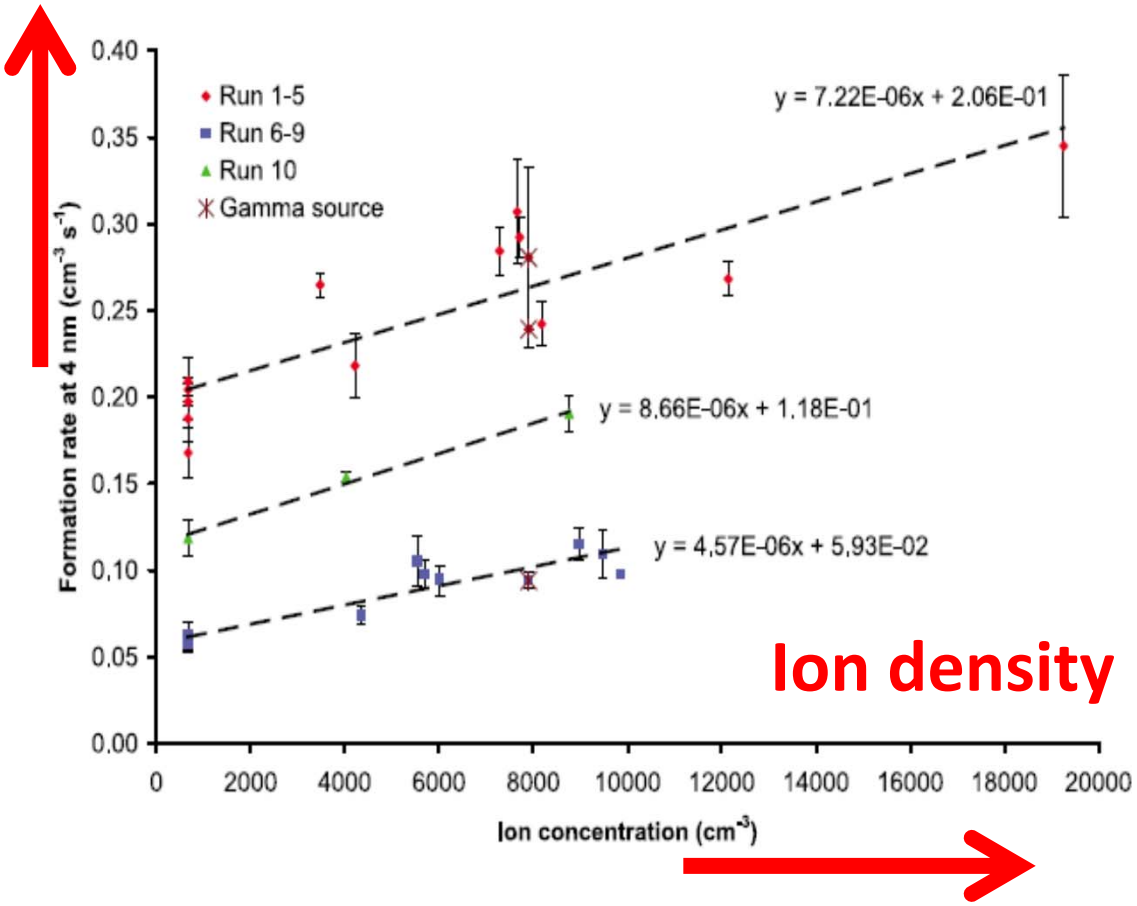
The chamber was cleaned carefully with nitric acid to remove surface contaminants

Me

Martin Enghoff

580 MeV electrons

Main result from SKY in Aarhus



Correlation between ions and aerosols produced at 4 nm (as with SKY).

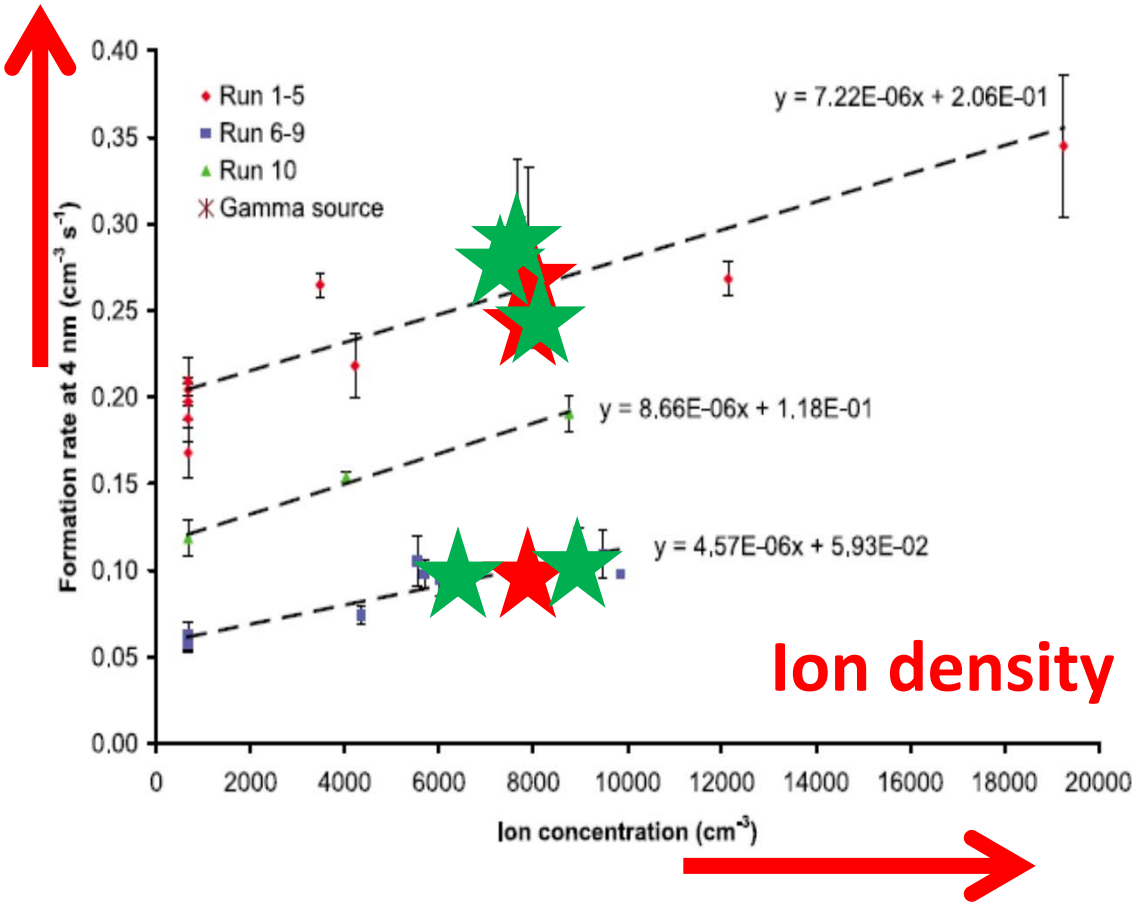
p = 1 atm

T = 25 ^{o}C

Enghoff et al. (2011) Geophys.Res.Lett.

Main result from SKY in Aarhus

Aerosols > 4 nm



Ion density

Gamma rays

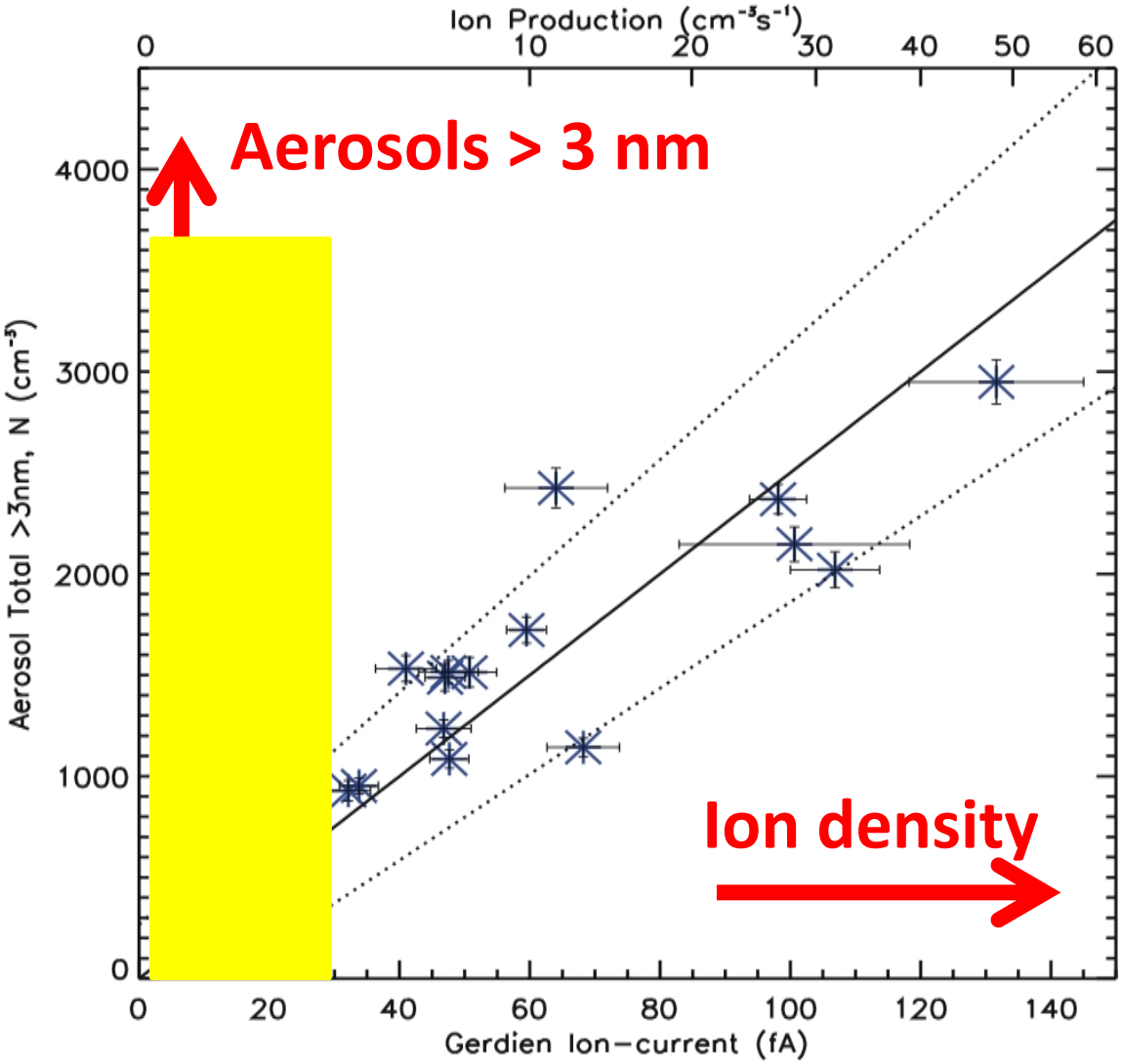
and **Electrons**

give same result

(i.e. a beam in not needed)

Enghoff et al. (2011) Geophys.Res.Lett.

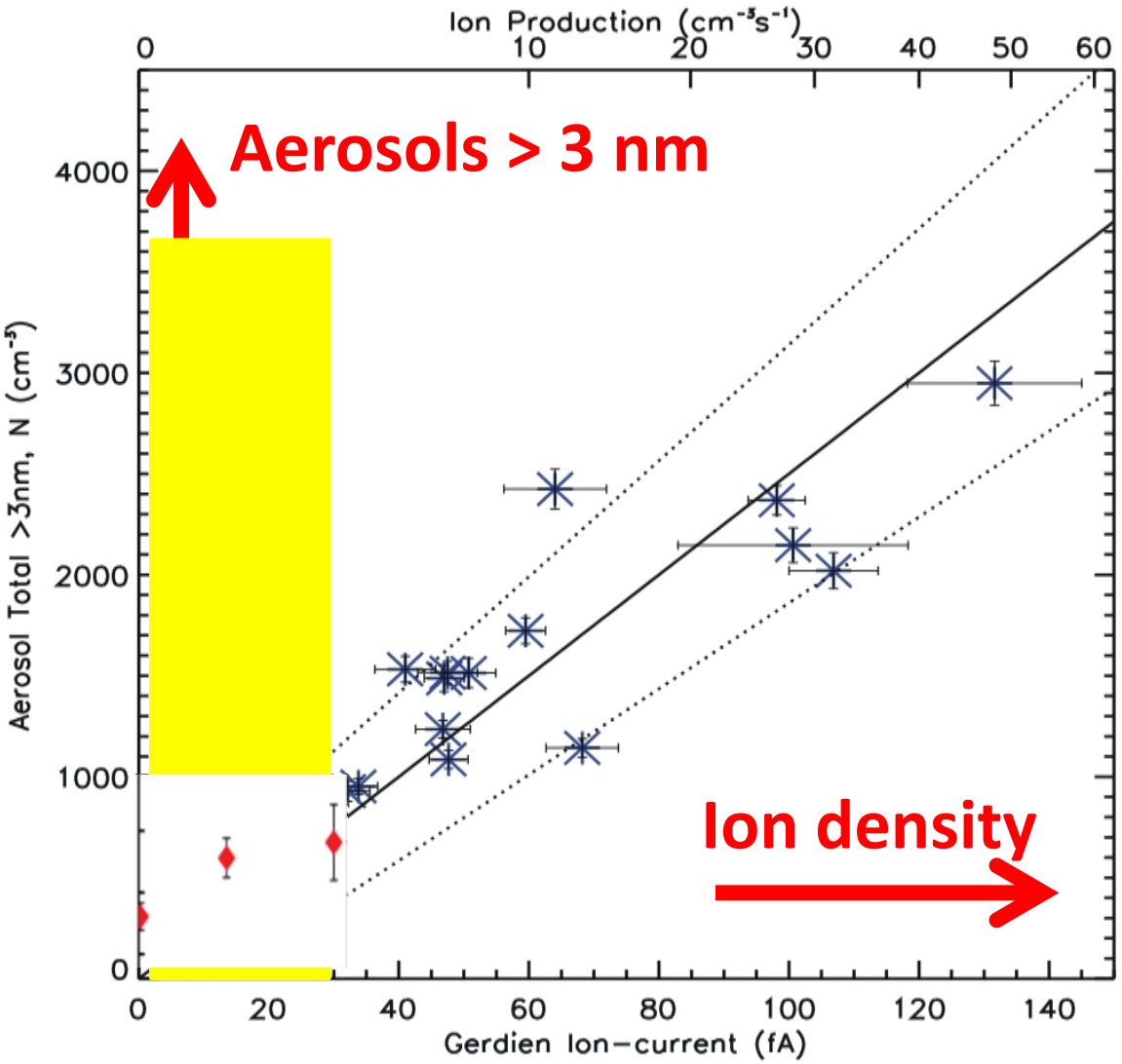
Main results so far:



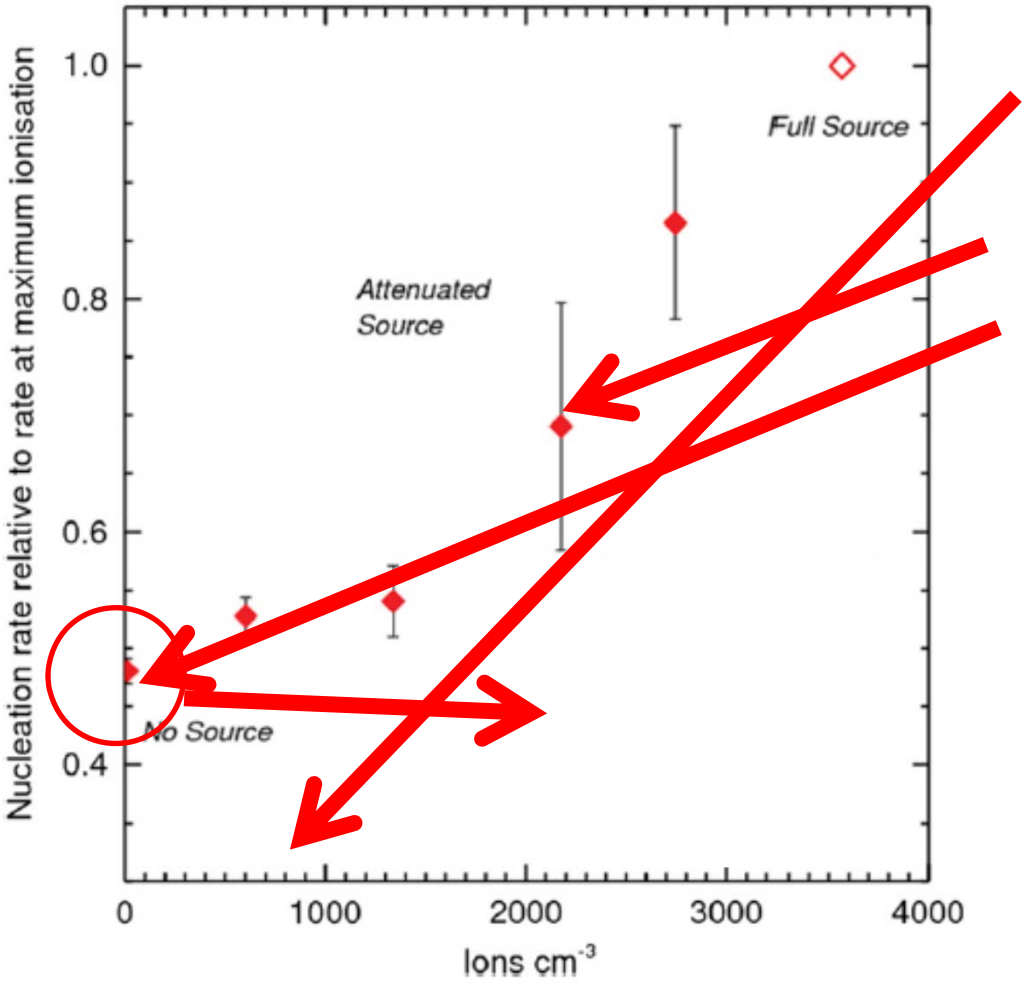
SKY@Boulby

SKY@Boulby


DARK
MATTER


Ion Production (cm⁻³s⁻¹)
0
10
20
30
40
50
60
Aerosols > 3 nm
4000
3000
2000
1000
0
Aerosol Total >3nm, N (cm⁻³)
Ion density
0
20
40
60
80
100
120
140
Gerdien Ion−current (fA)

Aerosol nucleation vs. ion density:



Surface ionization is here

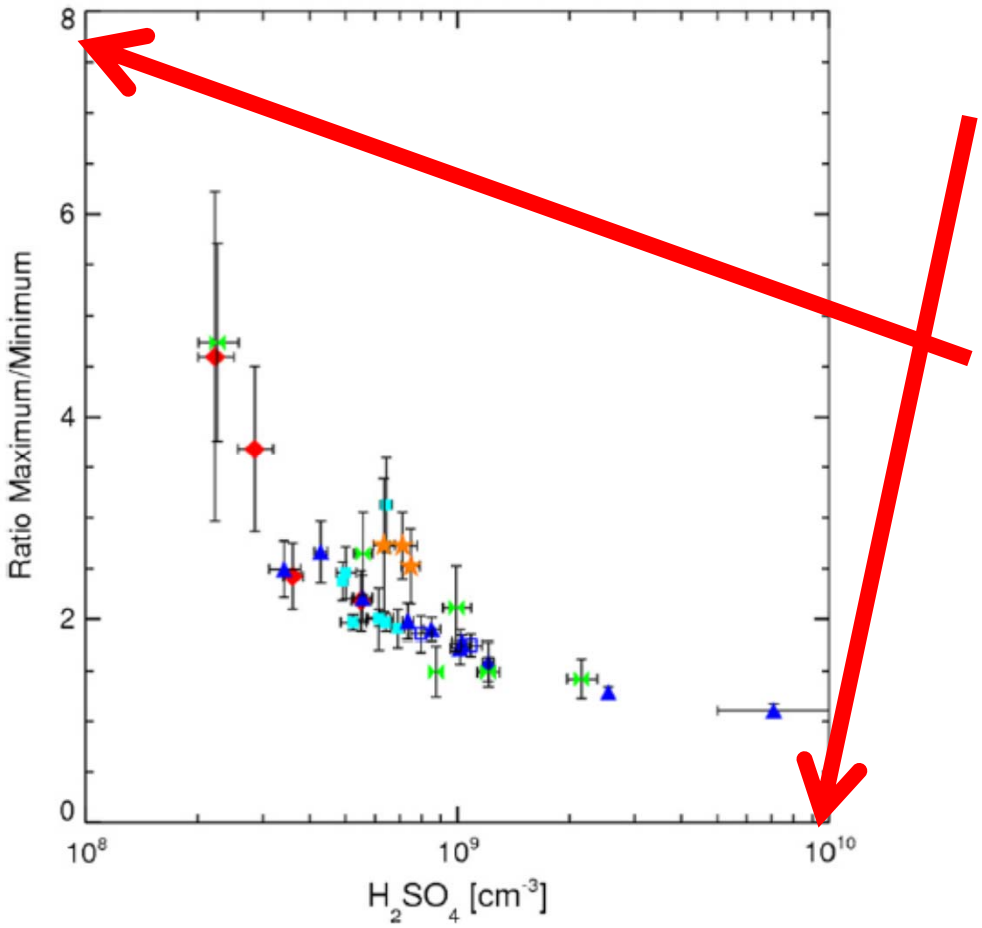
Ions have again an effect

But still significant nucleation at zero ion density

(Sulfuric acid conc. about 5 x 10^8 cm^{-3})

Pedersen et al (2012) J. Aerosol Sci.

The effect of ions increases with low sulfuric acid concentration

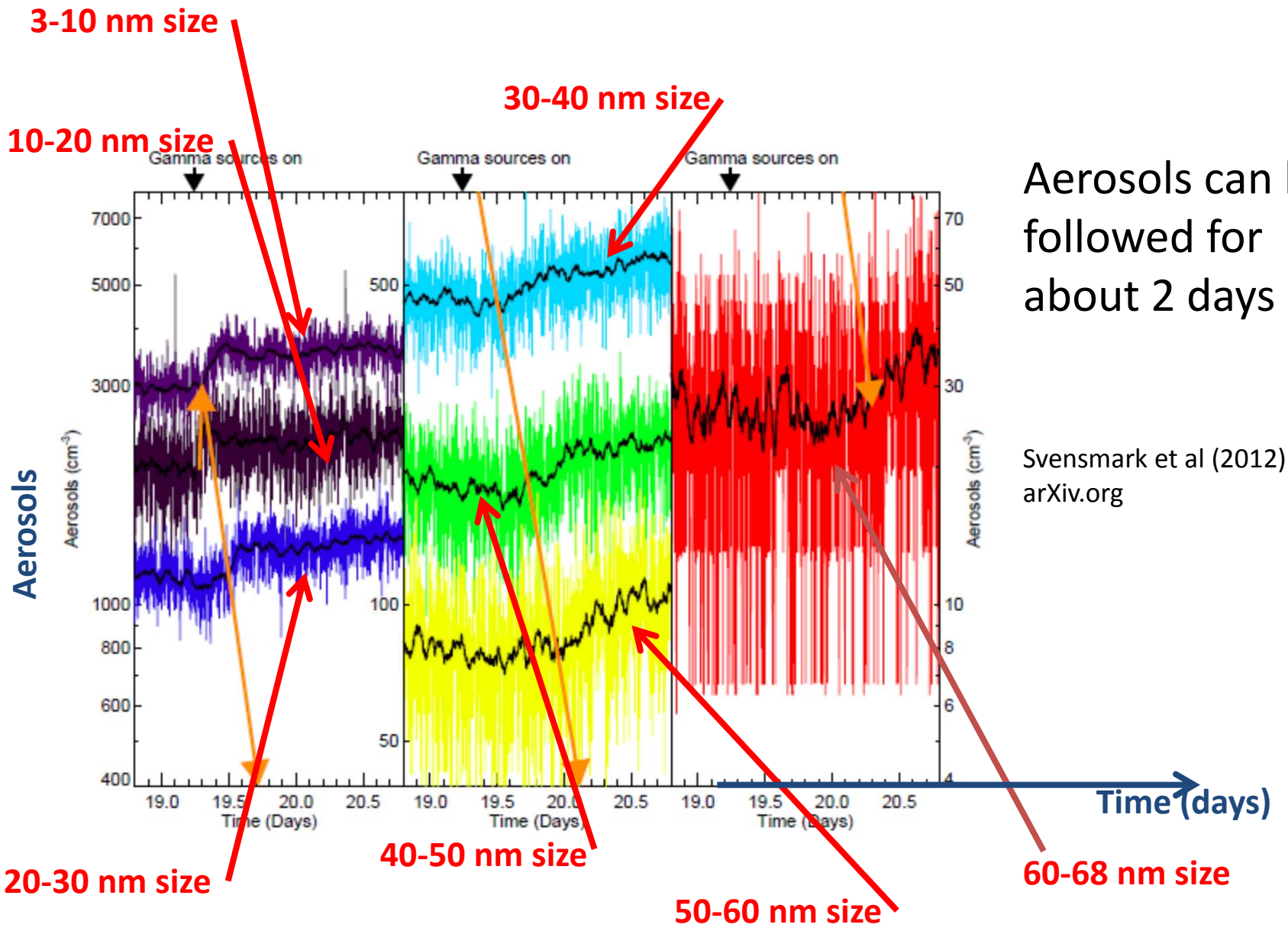


Sulfuric acid concentration

Relative increase in nucleation rate due to ions (compared to zero ion density)

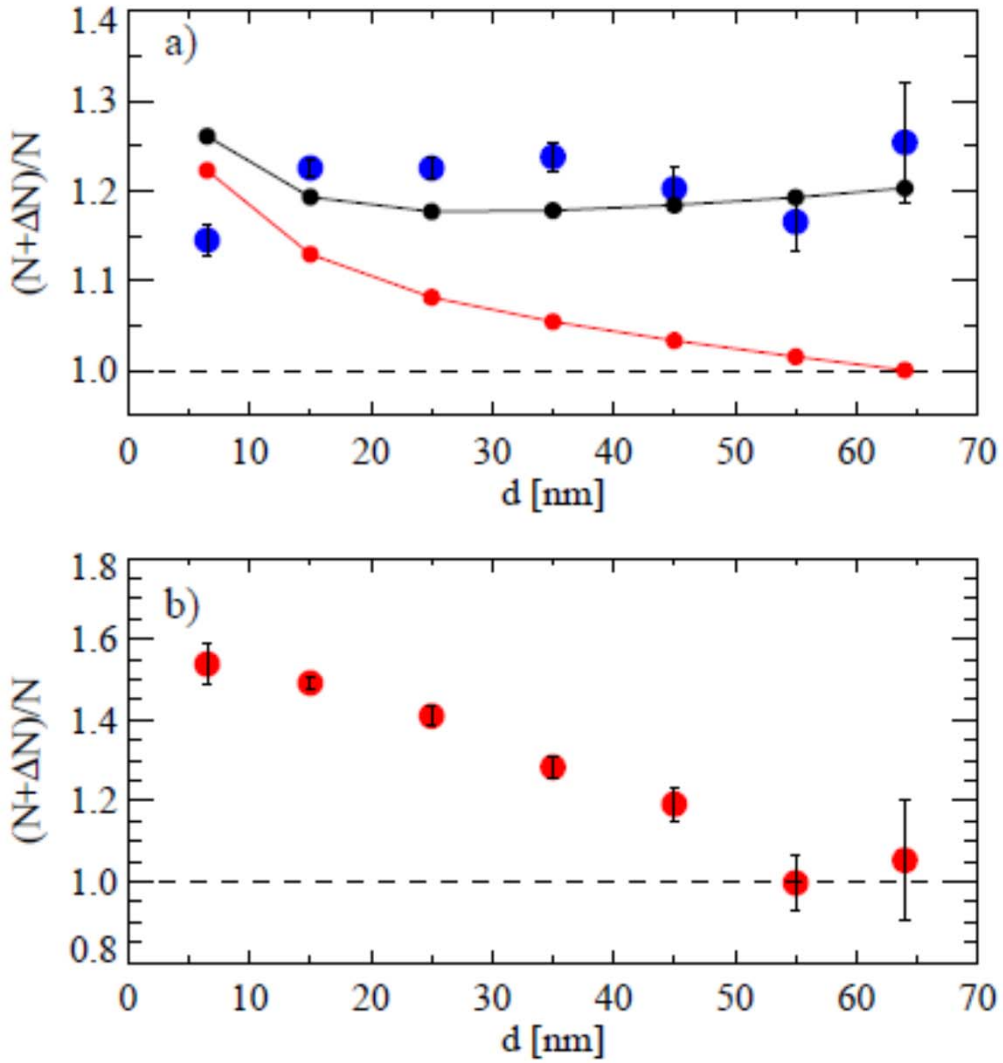
(i.e. ions becomes more important when the sulfuric acid concentration is low)

Pedersen et al (2012) J. Aerosol Sci.



Aerosols can be followed for about 2 days

Svensmark et al (2012) arXiv.org

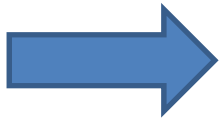

a)
b)
(N+ΔN)/N
d [nm]
1.4
1.3
1.2
1.1
1.0
1.8
1.6
0.8
0
10
20
30
40
50
60
70

Conclusions

- Ions do play a role in 3-4 nm nucleation in all experiments
- How the ion is produced is not important
- Underground experiments allows ions to be separated from ”neutral” nucleation mechanisms
- Both neutral and ion-induced nucleation takes place in the experiment
- Undetected impurities and organic vapors may also participate
- Model simulations show that ions increase nucleation at 4 nm due to increase in nucleation rate and faster growth during initial stage
- The model also indicates that the critical clusters contain 1-2 sulfuric acid molecules
- Ion effect also visible on larger aerosols (65 nm)

Atmospheric implications?

- SO_2 and chamber pressure & temperature all above atmospheric conditions, so extrapolations are difficult
- If we still extrapolate, ion-induced nucleation may dominate nucleation at 3-4 nm in clean air regions of the atmosphere
- An open question is how many of the 3-4 nm aerosols will grow to become activated



climate effect still unknown

Future work:
New (1,000 L) chamber constructed (U.K.)

Kurt J. Lesker Company