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Twenty years of elucidating diversity and function of cloudborne microorganisms: from lab studies to biotechnological applications

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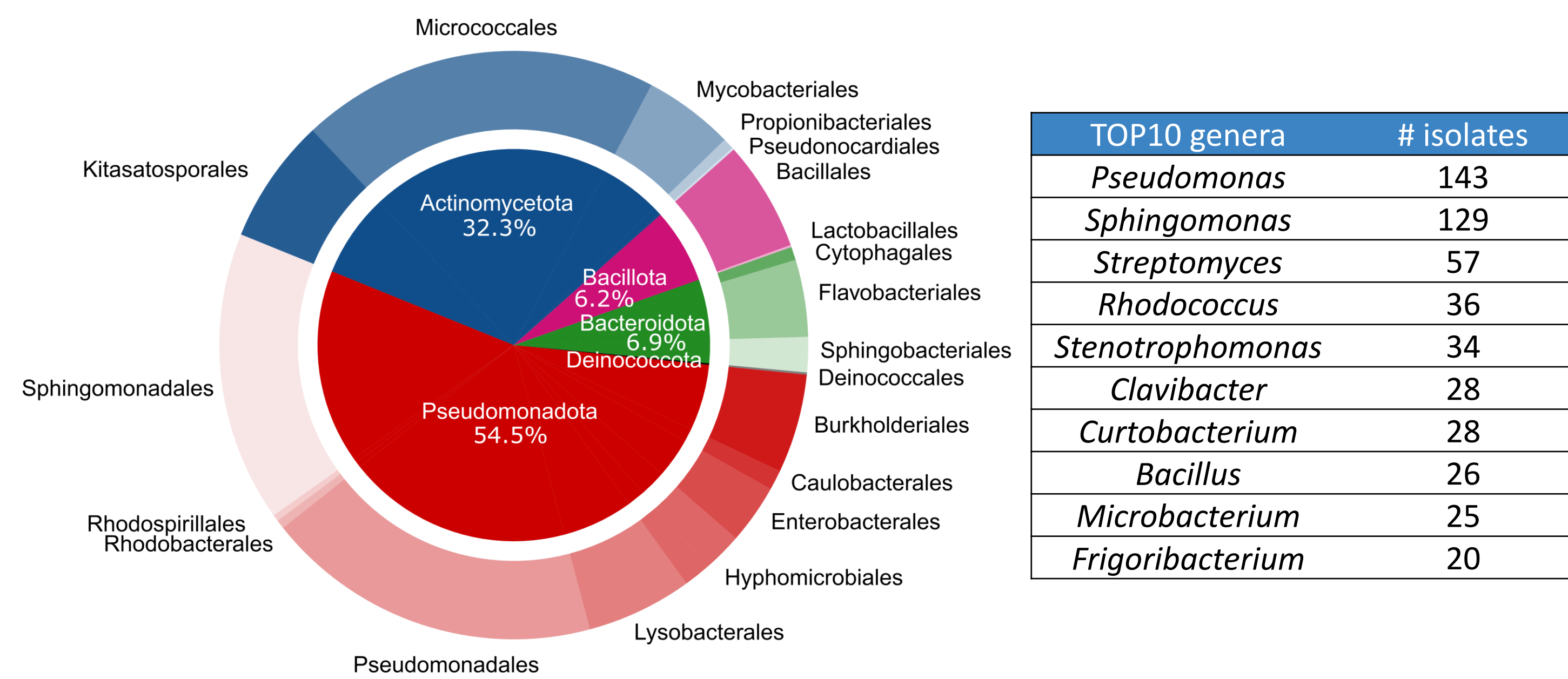
Contact: muriel.joly@uca.fr



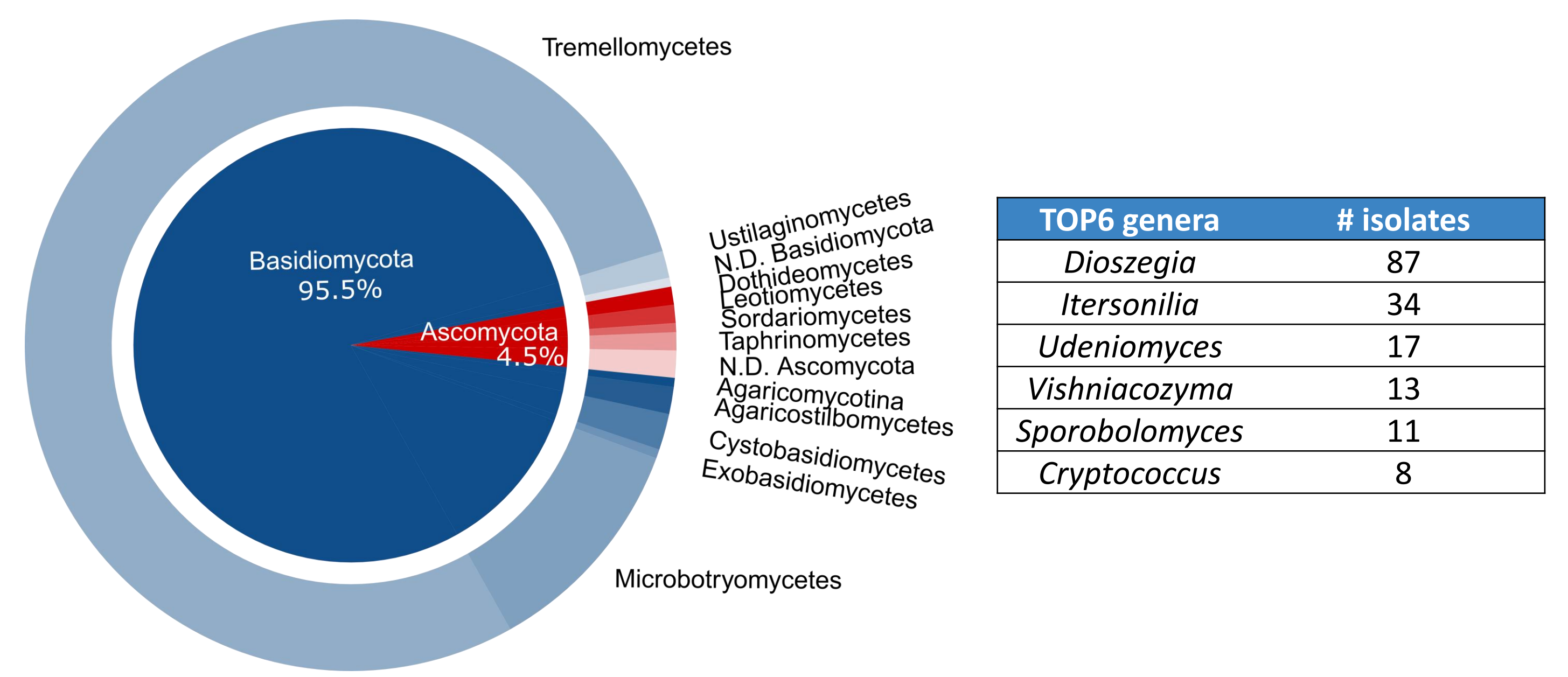
Microbial diversity in the ICCF cloudborne culture collection

- 827 bacterial strains and 223 fungal strains were isolated from cloud water sampled at the top of the puy de Dôme (Auvergne) or the Maïdo (Reunion island, Indian ocean) mountains to form a unique culture collection

Bacteria

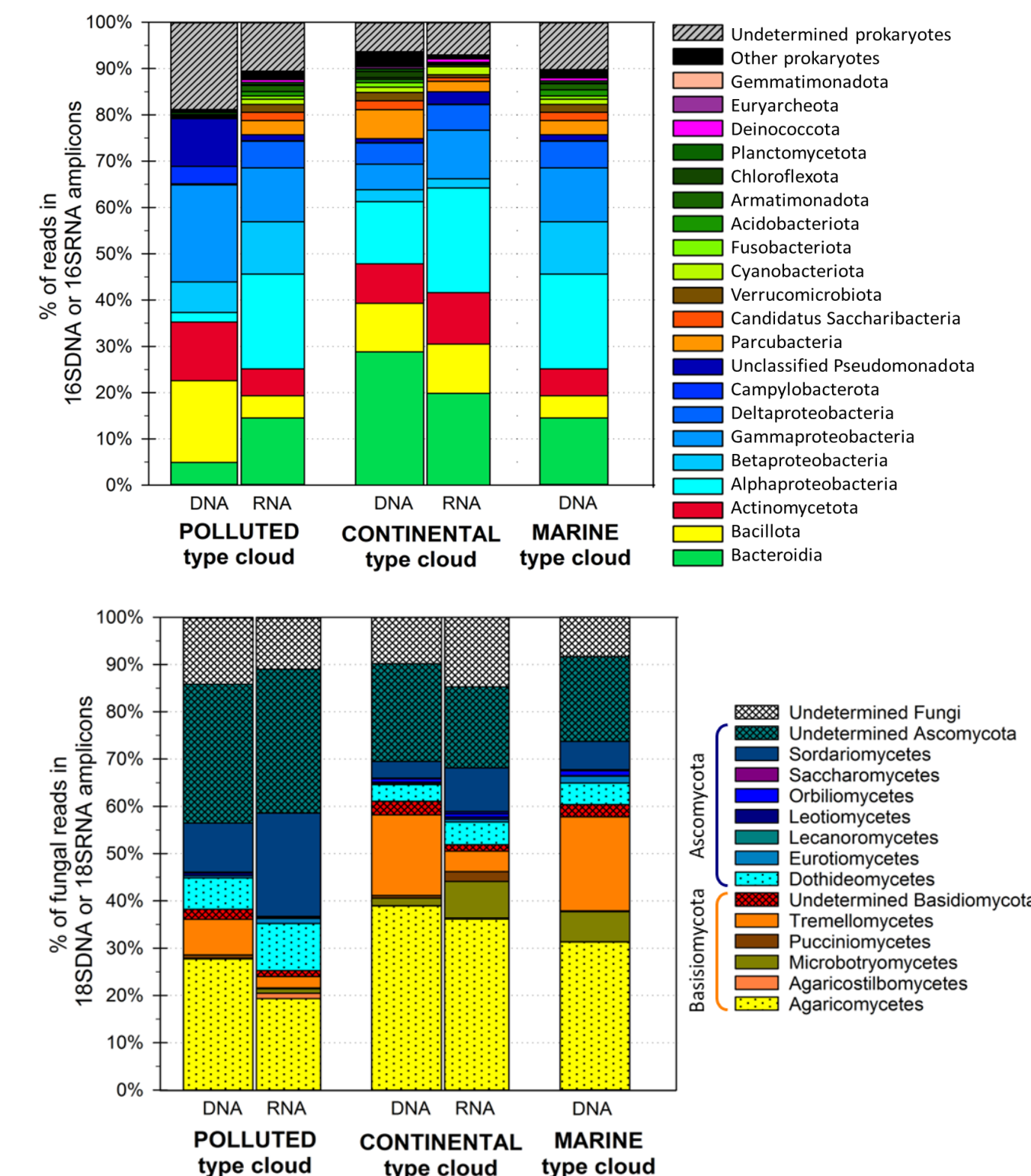


Fungi



Metabarcoding of total and active communities

- Cloud water is a rich environment with > 28 000 OTU_{97%} for bacteria and > 2600 OTU_{95%} for fungi
- Pseudomonadota and Bacteroidota phyla dominate total prokaryotic community while Ascomycota and Basidiomycota dominate fungi community
- Active orders (based on 16S or 18S rRNA) comprise Sphingomonadales, Rhodospirillales, Hyphomicrobiales, Burkholderiales and Pseudomonadales for prokaryotes



Updated from Amato et al., PlosOne (2017) doi.org/10.1371/journal.pone.0182869

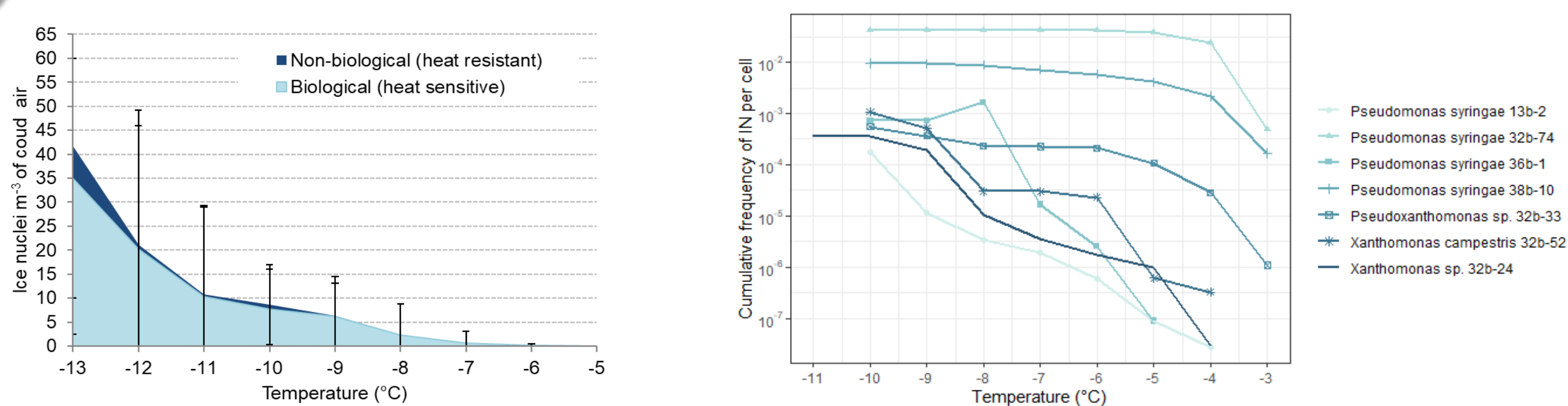
Cloud water, a source of undescribed species

- ~ 1% of bacterial isolates share < 97% of identity with the closest type strain rDNA 16S sequence
- ~ 4% of yeast isolates share < 97% of identity with the closest type strain rDNA 18S sequence and ~3% have < 95% of similarity with their closest neighbor
- Cloud water is poorly explored for its biodiversity and potentially contains new species never described before

Strain identifier	Most probable affiliation	Maximal percentage identity (16S/18S rDNA)
MAIDO-R6b-21	Micrococcaceae bacterium	96.7%
PDD-58b-27	<i>Flavobacterium</i> sp.	96.0%
PDD-23b-17	<i>Hymenobacter</i> sp.	96.6%
PDD-54b-11	Hymenobacteraceae bacterium	96.3%
PDD-69b-30	Burkholderiales bacterium	96.5%
PDD-70b-11	Burkholderiales bacterium	96.7%
PDD-26b-32	Leotiomyces yeast	96.9%
PDD-23b-2	Sordariomycota yeast	93.9%
PDD-77b-8	Agaricomycotina yeast	93.8%
PDD-33b-4	Microbotryomycetes yeast	95.6%
PDD-26b-29	Pucciniomycotina yeast	93.5%
PDD-24b-25	<i>Itersonilia</i> sp.	93.5%
PDD-26b-11	Tremellomycetes yeast	94.7%
PDD-77b-14	Tremellomycetes yeast	92.2%

Unpublished data - BlastN against nr/nt nucleotide collection - 2021

Ice nucleating bacteria, possible rainmakers

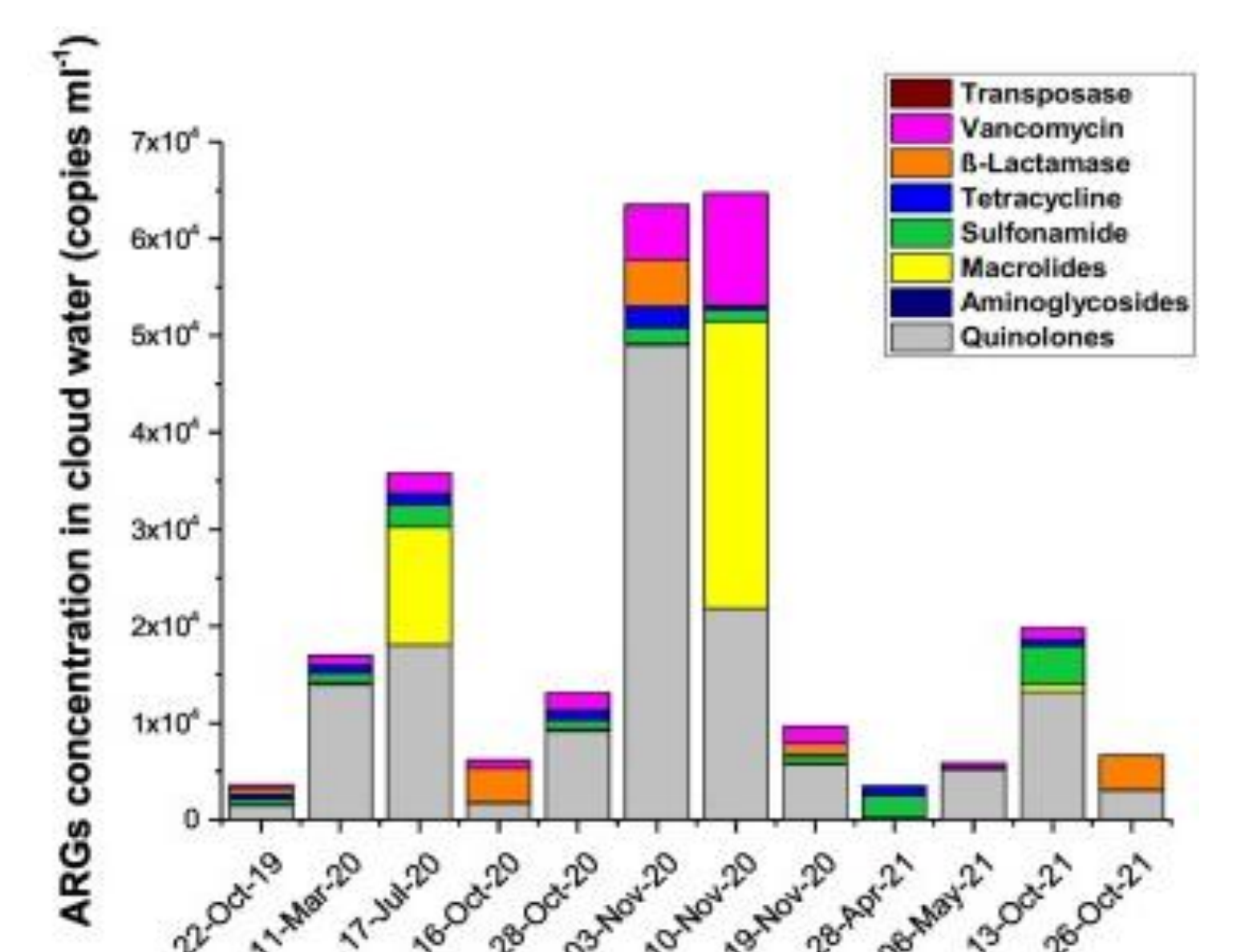


- Biological particles participate in ice nucleation at high temperature in cloud water sampled at the puy de Dôme mountain
- 7 bacterial strains of our cloud collection belonging to *Pseudomonas* and *Xanthomonas* genera were identified as ice nucleation active at near 0°C temperatures. They are among the most active identified to date
- Bacteria could contribute to cloud evolution by triggering precipitation at temperatures close to 0°C

Adapted from Joly et al., Atm Env (2013), doi.org/10.1016/j.atmosenv.2013.01.027 and Joly et al., ACP (2014), doi:10.5194/acp-14-8185-2014

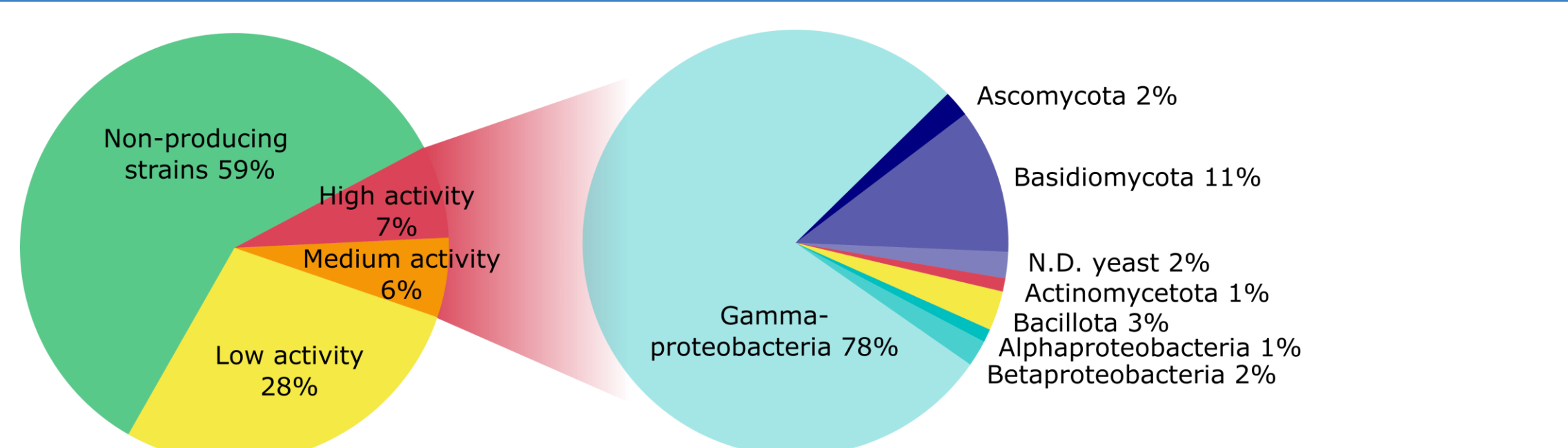
Antibiotic resistance genes (ARGs) dissemination via clouds

- 29 different ARGs subtypes were detected by qPCR on cloud water sampled at the puy de Dôme
- ~10³ to 10⁴ copies of ARGs per m³ were quantified
- Air mass origin influenced the prevalence of ARGs subtypes
- Cloudborne microorganisms participate in ARGs dissemination at large scales



Rossi et al., STOTEN (2023), doi.org/10.1016/j.scitotenv.2022.161264

Surfactant-producing microorganisms to facilitate droplet formation



- Surfactants in the atmosphere may facilitate the formation of cloud droplets by reducing water surface tension
- ~41% of strains isolated from cloud water are active producers of biosurfactants, 7 % are extremely active

Adapted from Renard et al. ACP (2016), doi:10.5194/acp-16-12347-2016

Towards biotechnological applications

Biocontrol agents for vegetal cultures?
Promotion of plant growth?

Production of therapeutic molecules?

Production of enzymes to recycle and reuse industrial wastes?

Production of food or cosmetic additives?

New species from cloud water may also represent a source of new activities for emerging biotechnological purposes



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