

Novel Methylated Biosignatures: Outcomes of a General Metabolic Process as a New Class of Biosignatures

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ExoPAG 26



NASA ICAR program

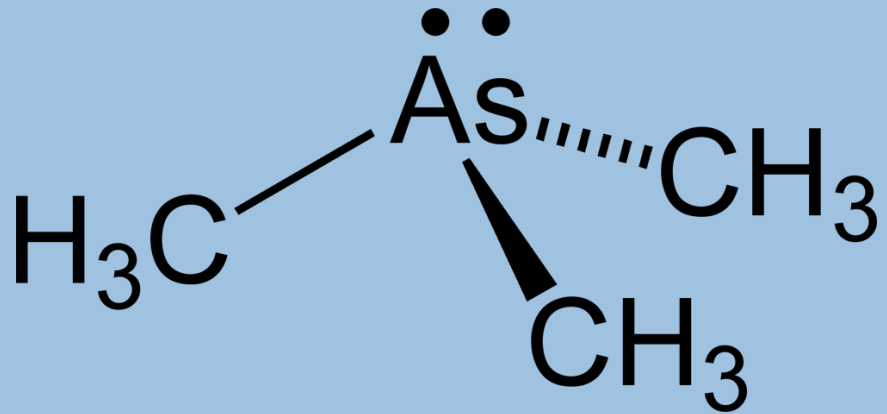
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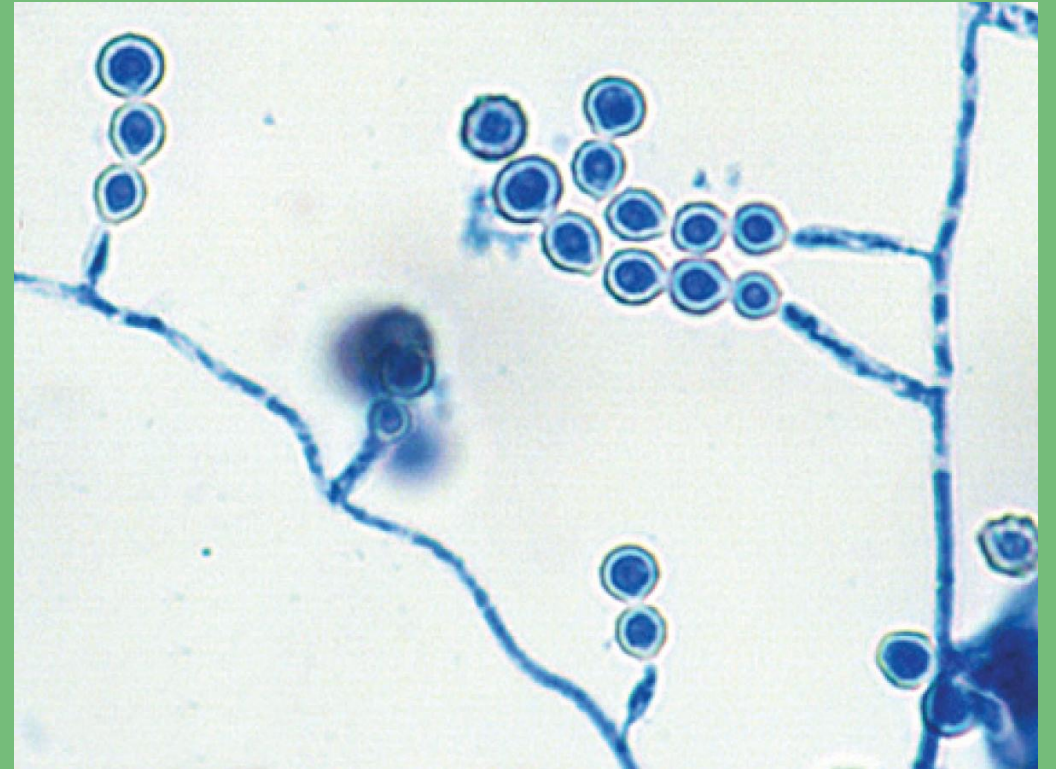
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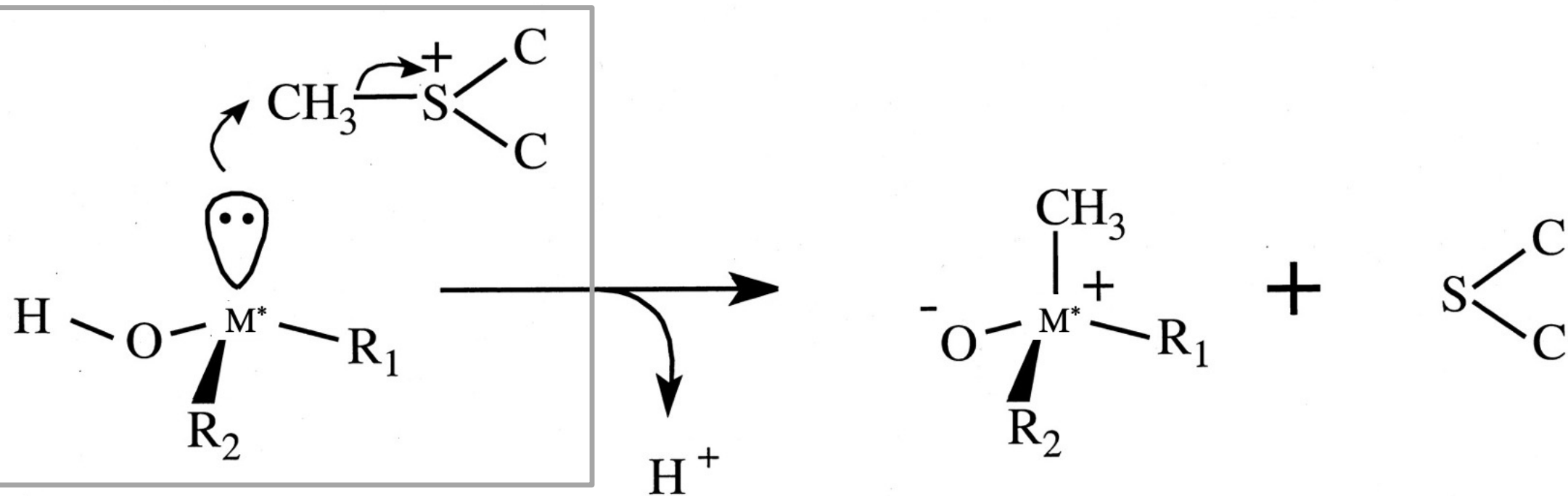
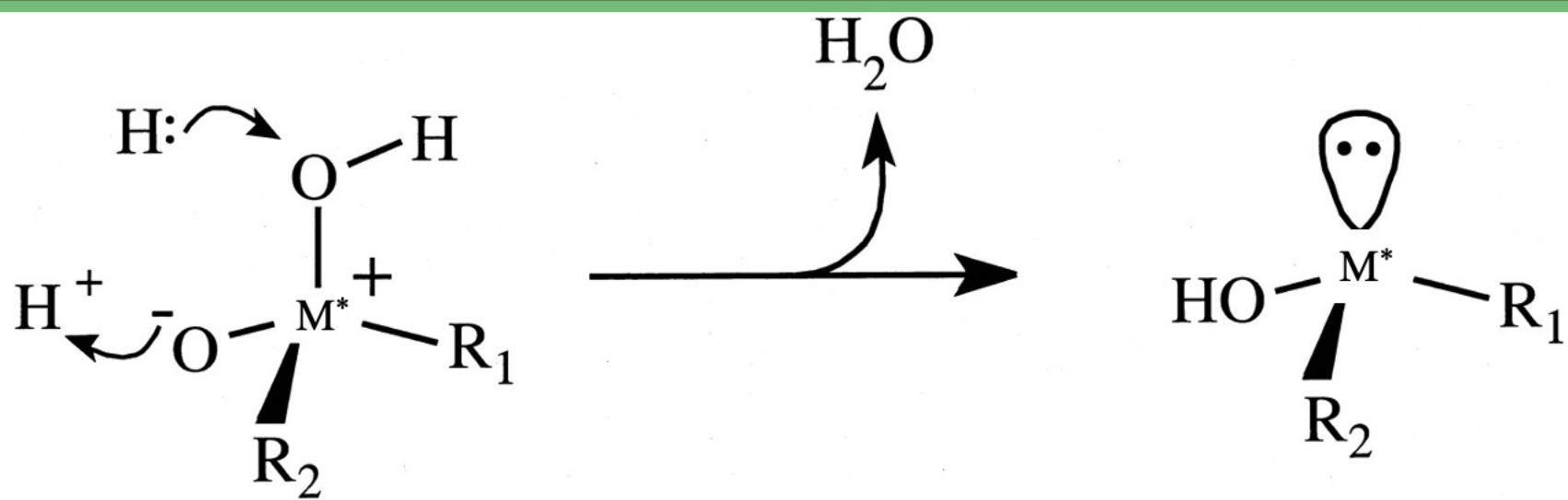




Trimethylarsenide is produced as a volatilization of environmental As



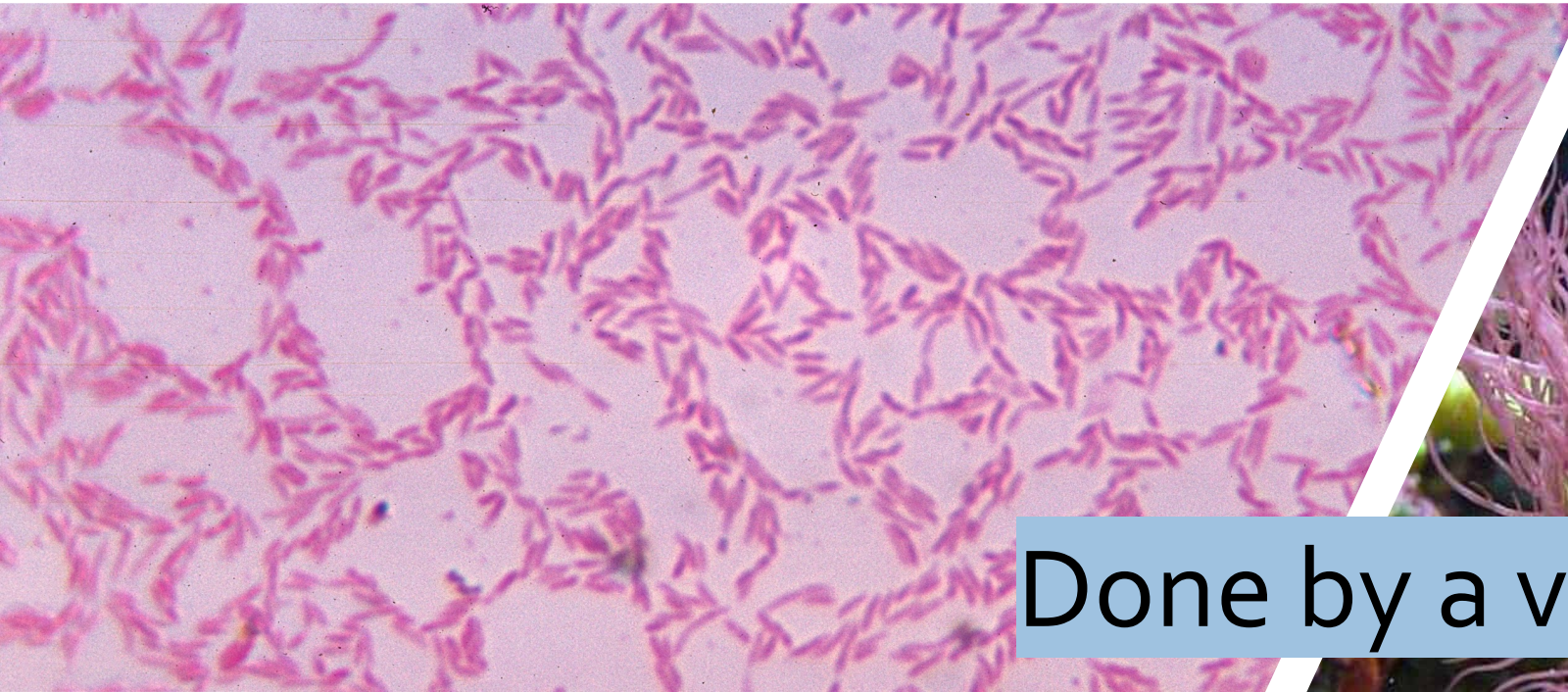
Fungi such as *Scopulariopsis* perform the methylation



Methylation is a widespread process



Methylation is a widespread process

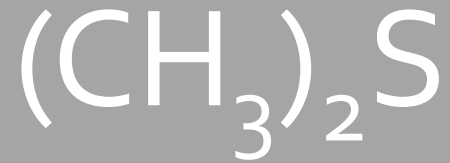


Done by a variety of organisms

Methylated
gases have
been
previously
established as
biosignatures



- Segura et al., 2005



- Domagal-Goldman et al., 2011

There are *many* potential methylated biosignatures

Methylated Halogens

- CH_2BrCl
- CHBr_2Cl
- CH_3Cl
- CH_2Cl_2
- CHCl_3
- CCl_4
- CH_3Br
- CHBr_3
- CBr_4
- CH_3I
- CH_2I_2
- CHI_3
- $(\text{CH}_3)_2\text{CHI}$
- CH_2IBr
- CHIBr_2

Methylated Chalcogens

- $(\text{CH}_3)_2\text{SeS}$
- CH_3SeH
- $(\text{CH}_3)_2\text{S}$
- $(\text{CH}_3)_2\text{S}_2$
- CH_3SH
- $(\text{CH}_3)_2\text{Se}$
- $(\text{CH}_3)_2\text{Se}_2$
- CH_3SeS
- $(\text{CH}_3)_2\text{Te}$
- $(\text{CH}_3)_2\text{Te}_2$

Methylated Metal(loids)

- $(\text{CH}_3)_3\text{As}$
- $(\text{CH}_3)_2\text{AsOH}$
- $(\text{CH}_3)_3\text{Sb}$
- $(\text{CH}_3)_3\text{Bi}$
- $(\text{CH}_3)_2\text{Hg}$

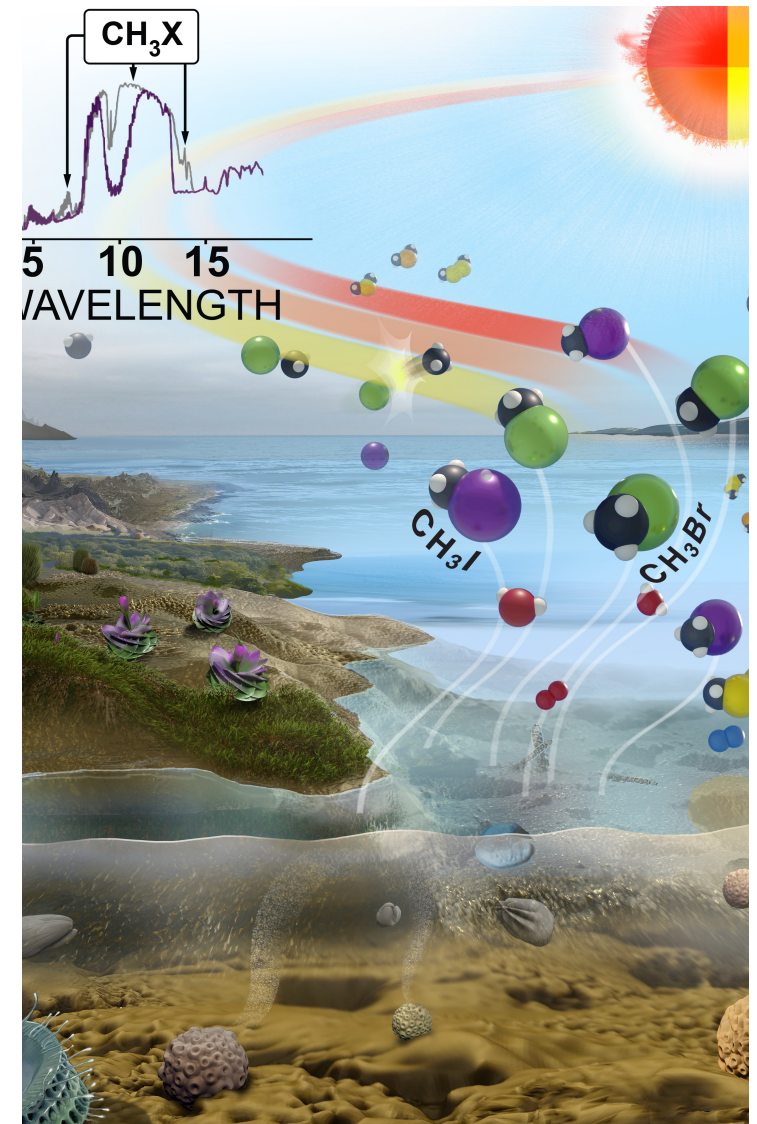
These are
potential
capstone
biosignatures

Not as detectable as
'primary' biosignature
such as O₂

Could be detected
alongside primary
biosignature features
or in follow up
observations

Has very limited
abiotic pathways which
results in low false
positive potential

Case study of methylated gases: CH_3Cl and CH_3Br



Methods

01

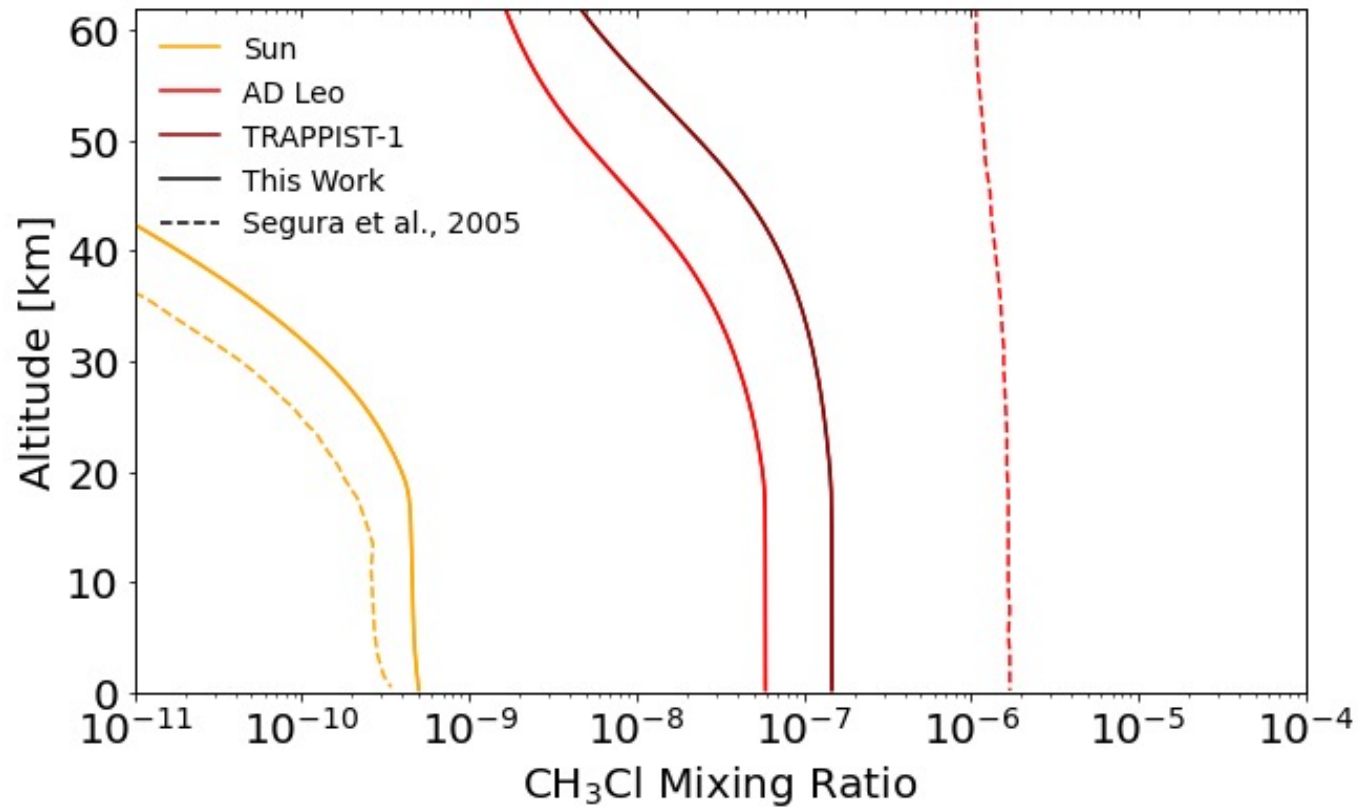
Atmos – 1D
photochemistry
(Arney et al.,
2016)

02

SMART –
transmission
and emission
spectra
(Meadows &
Crisp 1996)

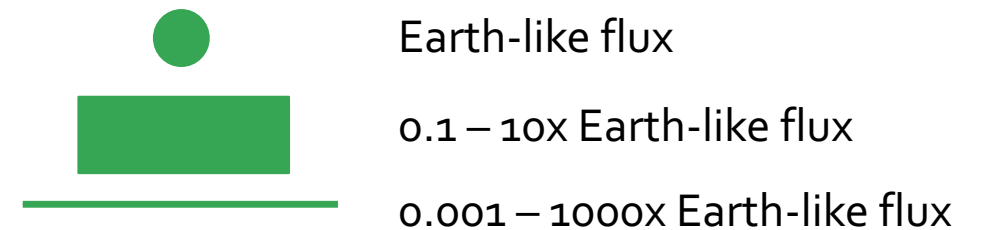
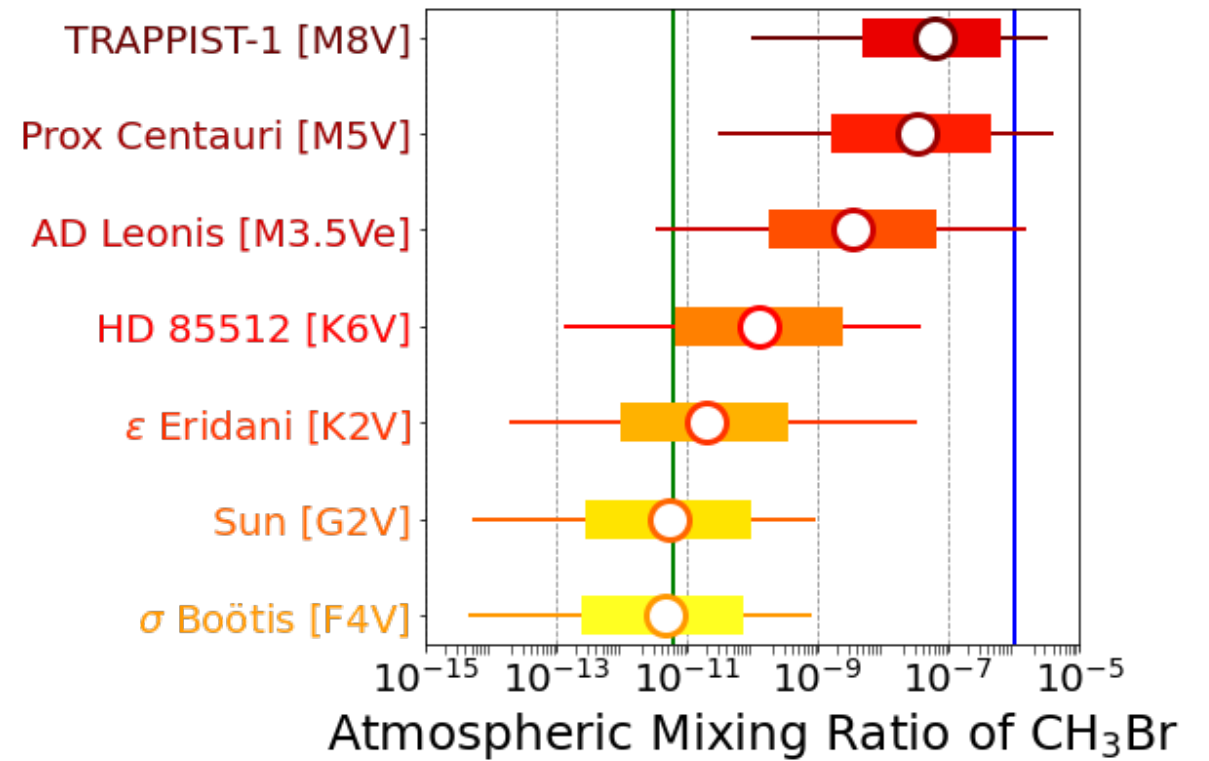
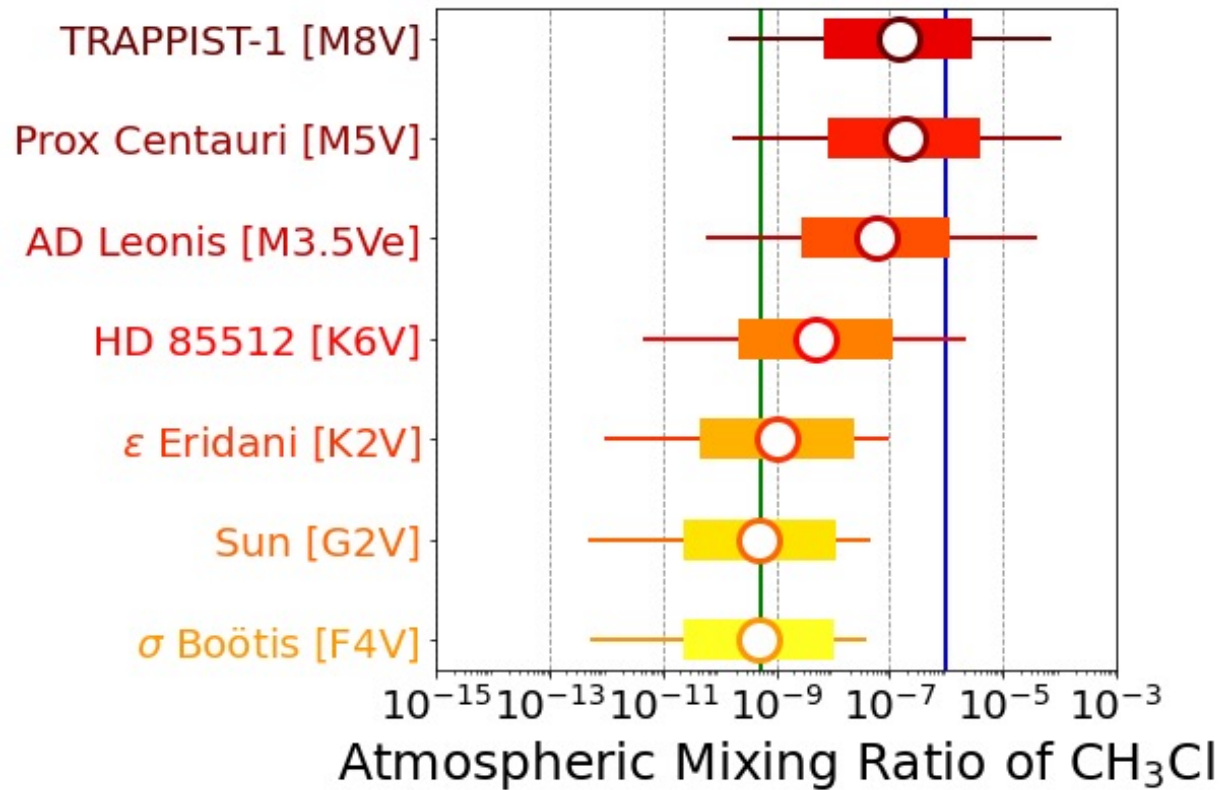
03

PSG - spectral &
instrumental
modeling
(Villanueva et
al., 2018, 2022)

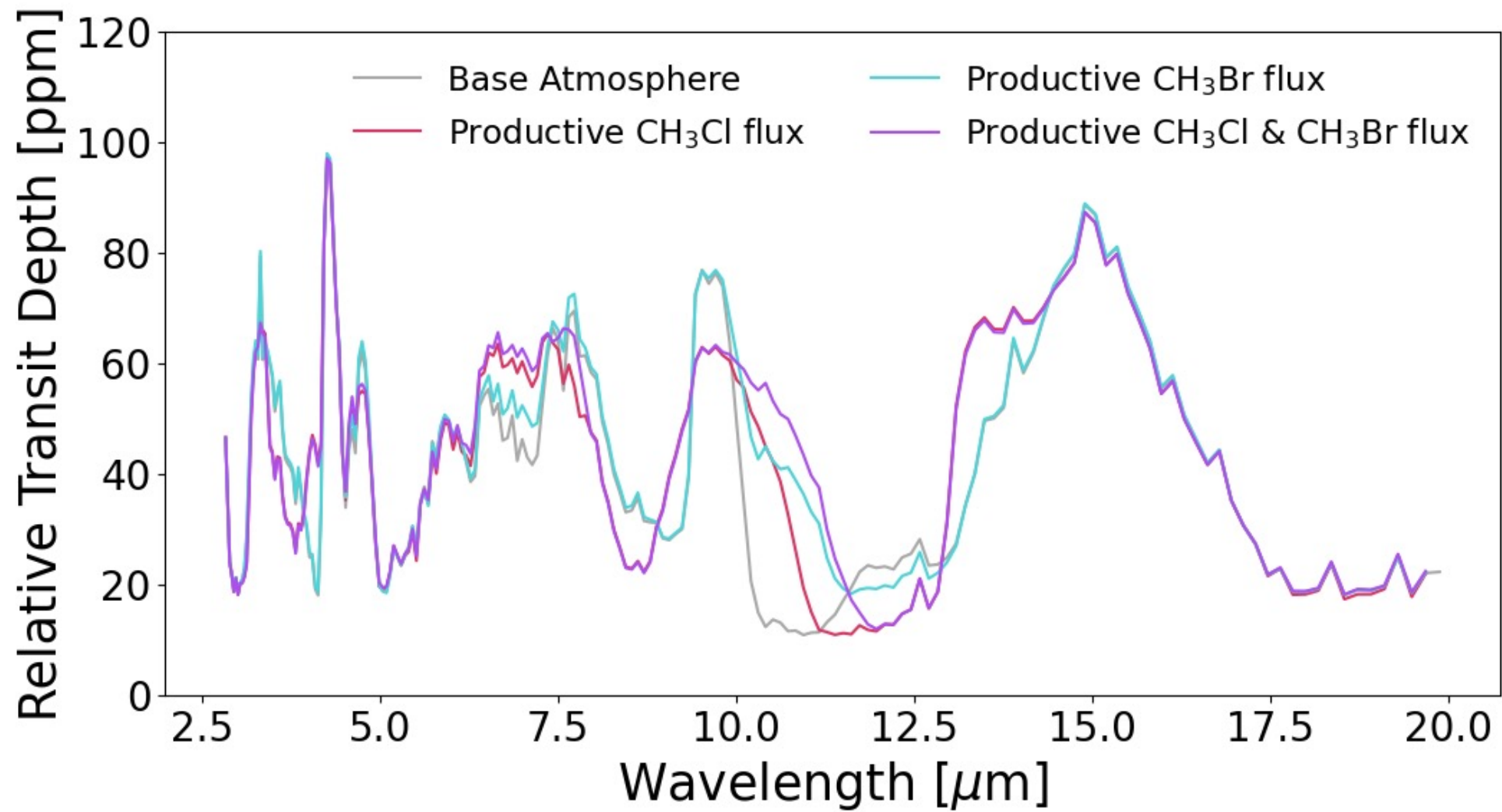


CH₃Cl: Revisited

- Significant changes have been made to atmos since Segura et al., (2005) including updating all reaction rates
- Our version of the code does not exactly replicate previous results with CH₃Cl but maintains the same overall conclusions

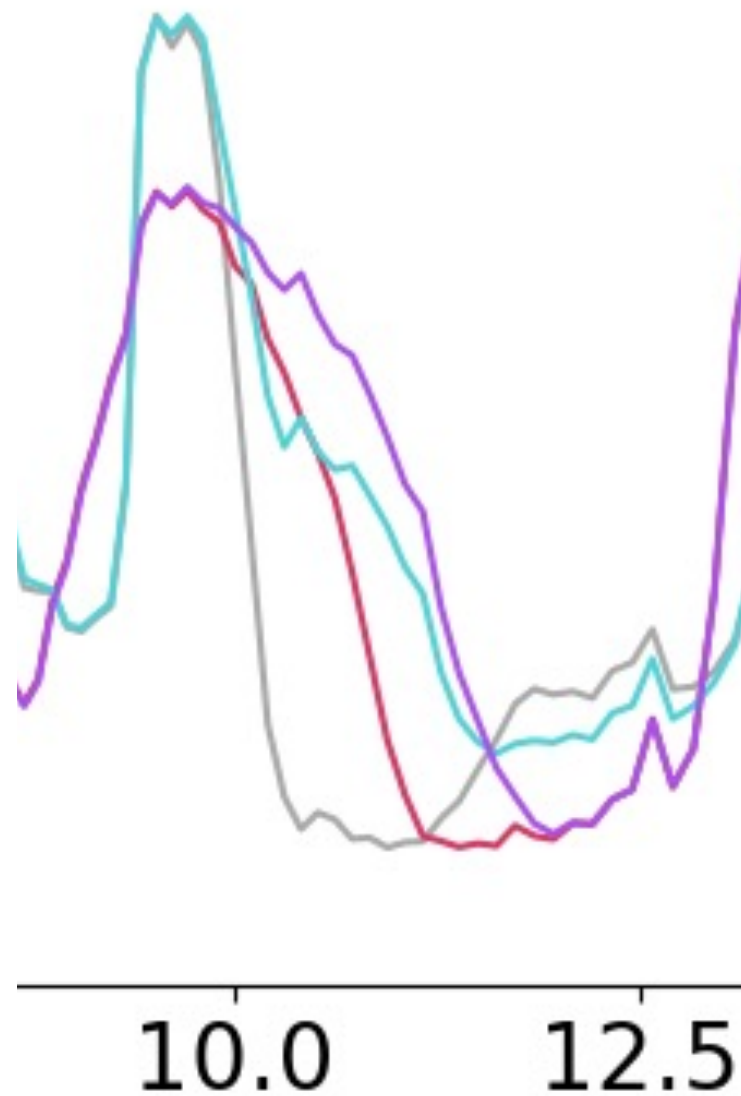


Photochemical Results – CH_3Br has even higher build up around M dwarfs



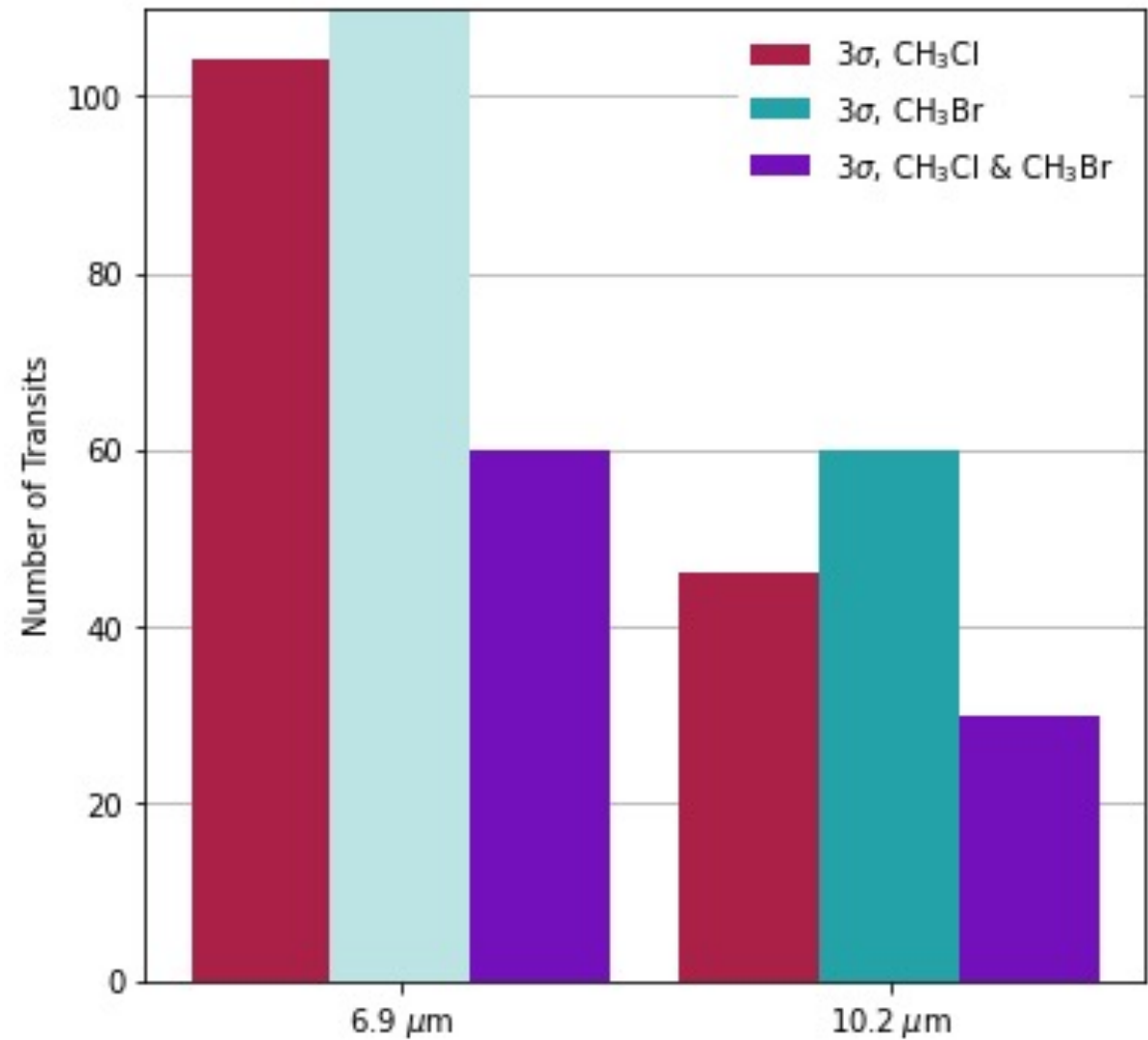
Simulated observations

Multiple
methylated
gas features
near 10 μm

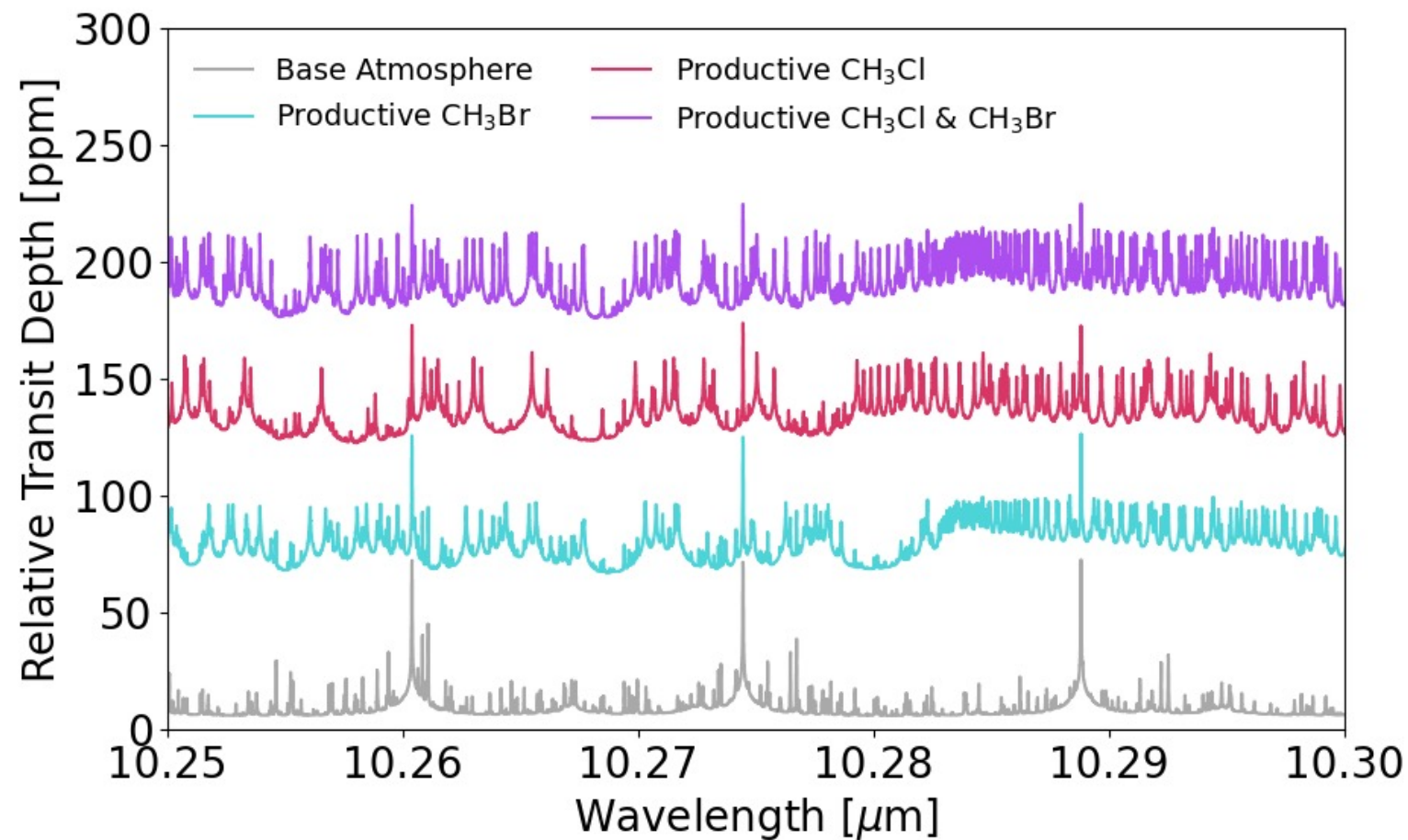


- Adjacent features generated from C-halogen bond which varies in specific methylated compounds and generates adjacent features
- We expect this advantage to continue for additional methylated gases

Multiple
methylated
gases make
detection
much easier



High resolution spectral simulations



Future Work

Exploring additional methylated species through photochemical and spectral modelling

Laboratory and field measurements of fluxes of methylated gases to inform model input

Iodine species (CH_3I)

Polyhalomethanes e.g. CH_2BrCl

Methylated chalcogens e.g. $(\text{CH}_3)_2\text{Se}$



Alternative Methylated Biosignatures I: Methyl Bromide, A Capstone Biosignature

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Takeaways

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Methylated gases present
an exciting new class of
biosignatures

CH_3X gases are likely
detectable with next
generation MIR capable
telescopes, confirming
status as capstone
biosignatures

Co-additive spectral effect
for atmospheres with
multiple methylated
gases; motivates further
work on large range of
add'l gases