Absorption diversity of bloom-forming phytoplankton species:

Toward hyperspectral remote sensing identification of red tide events?

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Red tides & Harmful algal blooms (HABs)

- Accumulation of phytoplankton at very high concentration
- Harmful due to toxins and/or subsequent hypoxia
- Frequent occurrences due to eutrophication
- Major source of concern worldwide
- Undersampled by field monitoring
- Satellite remote sensing proved useful to detect blooms, but identification of the dominant species is challenging

Potential of hyperspectral RS to detect red tide species?

269 known harmful marine microalgae

214 Toxic species

- 3 Dictyochophytes
- 5 Raphidophytes
- 8 Haptophytes
- 32 Diatoms
- 43 Cyanobacteria
- 123 Dinoflagellates

55 Non-toxigenic species

- 1 Chlorophyte
- 1 Ciliate
- 1 Cryptophyte
- 2 Pelagophytes
- 2 Dictyochophytes
- 23 Diatoms
- 25 Dinoflagellates

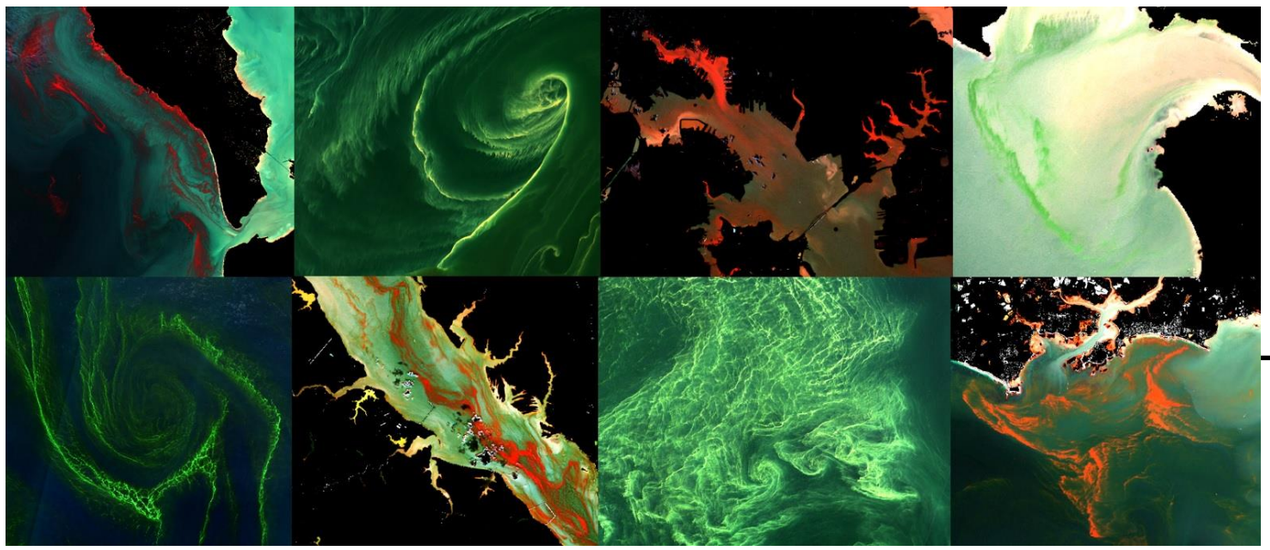
List accessed 9 Feb. 2025

Current challenges for bloom identification

Four optical bloom types can be distinguished by multispectral RS

- Blooms of cyanobacteria
- Surface accumulation of red *Noctiluca scintillans*
- Red tides of cryptophytes and/or ciliate *Mesodinium rubrum*
- Green waters dominated by dinoflagellate *Lepidodinium chlorophorum*

Other classes challenging to separate due to similarities in pigment composition : diatoms can be confused with haptophytes, raphidophytes, pelagophytes, and fucoxanthin-bearing dinoflagellates such as *Karenia brevis*.



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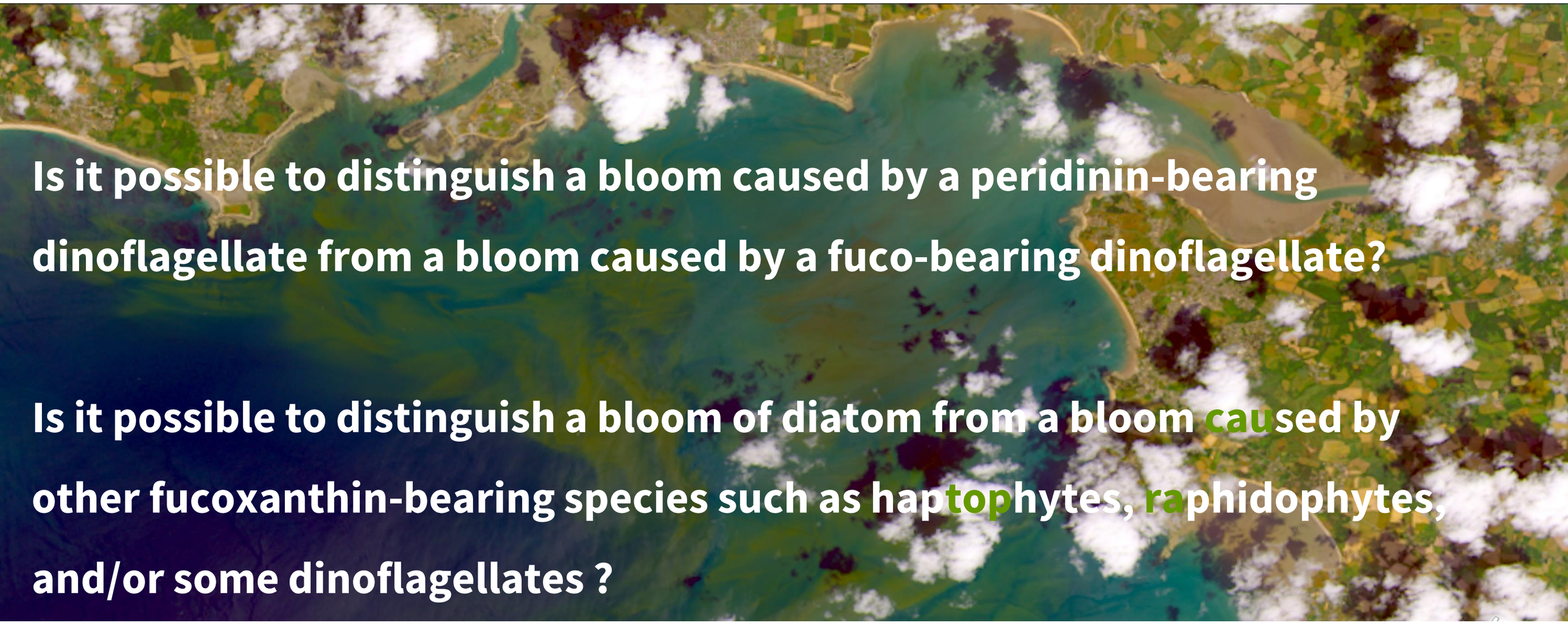
The many shades of red tides: Sentinel-2 optical types of highly-concentrated harmful algal blooms

Pierre Gernez [a], Maria Laura Zoffoli [b], Thomas Lacour [c], Tania Hernández Fariñas [d], Gabriel Navarro [e], Isabel Caballero [e], Tristan Harmel [f]

Assessing potential of hyperspectral RS



Material & Methods

Particulate absorption coefficient $a_p(\lambda)$ measured on monospecific algal cultures using filter pads (inside sphere) or cells suspension (inside PSICAM).

Spectral library of 60 bloom-forming phytoplankton species

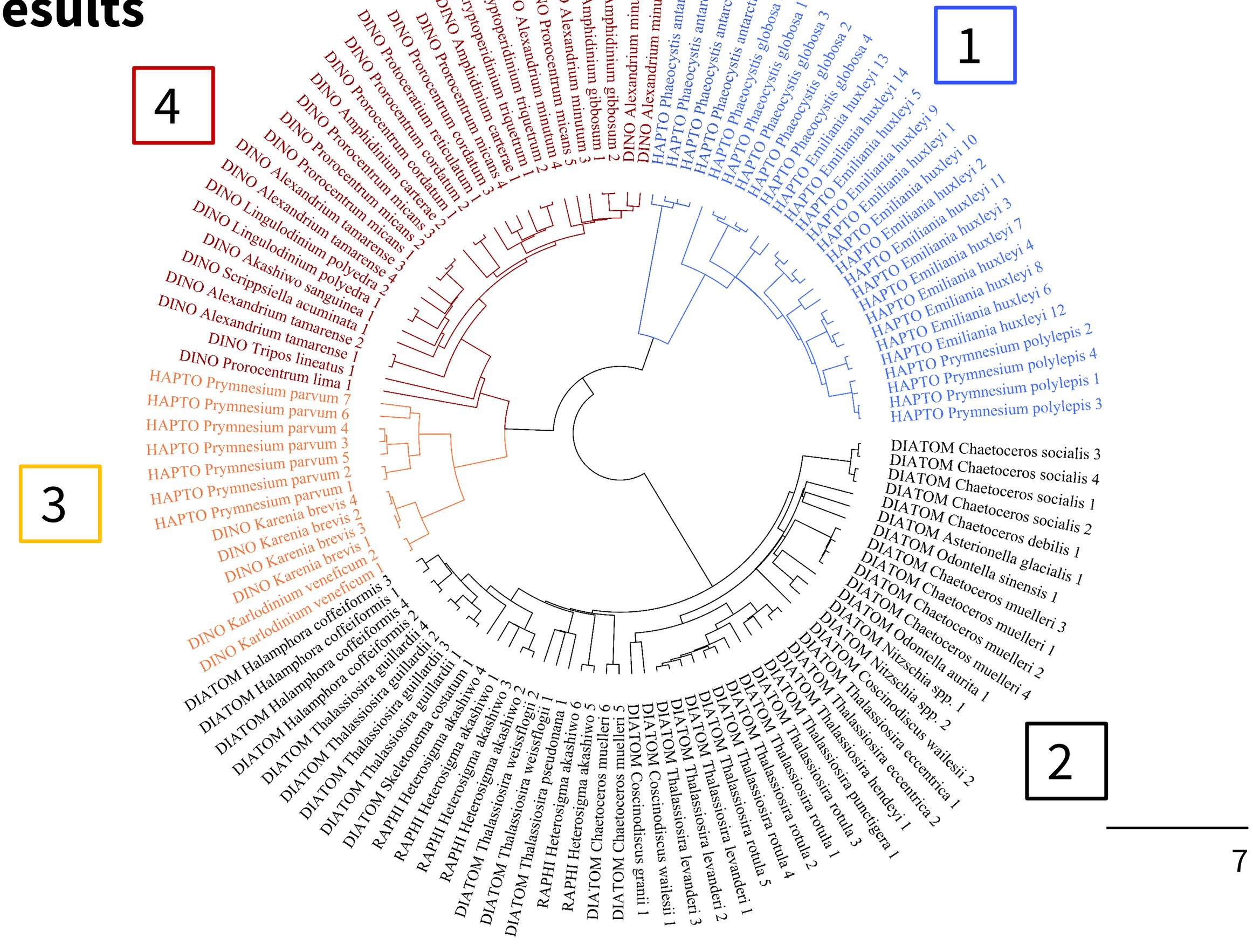
164 hyperspectral spectra covering 8 taxonomic classes compiled from Xi et al. (2015), Lomas et al. (2024), and a new IOP library of bloom-forming species.

Simple classification method of $a_p(\lambda)$ spectra

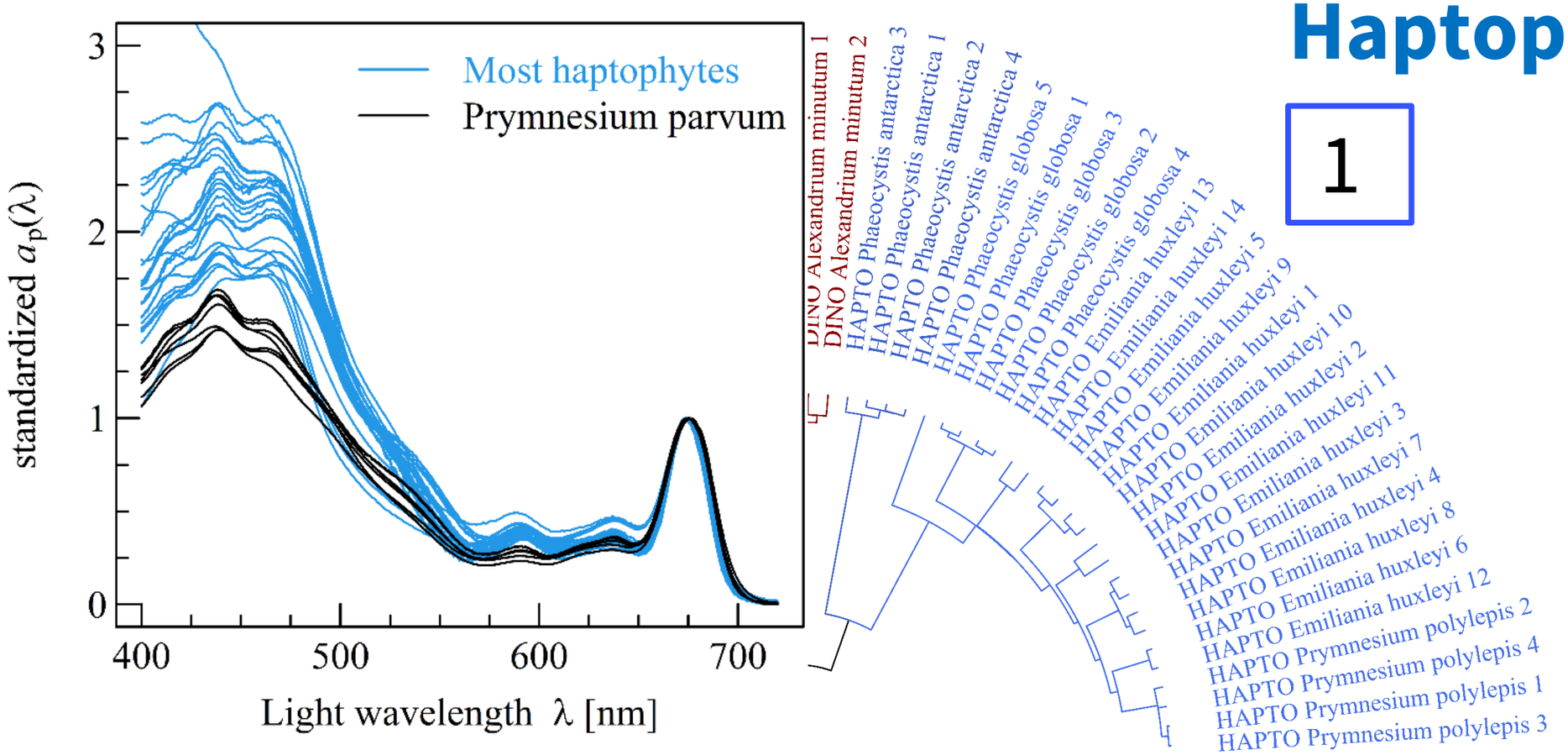
Spectra were smoothed (9nm moving average), and 2nd derivative computed.

Hierarchical cluster analysis (HCA) was performed using a similarity index distance.

Results


4
1
3
2
DINO Amphidinium gibbosum 2
DINO Alexandrium minutum 1
DINO Alexandrium minutum 2
HAPTO Phaeocystis antarctica 3
HAPTO Phaeocystis antarctica 1
HAPTO Phaeocystis antarctica 2
HAPTO Phaeocystis antarctica 4
HAPTO Phaeocystis globosa 5
HAPTO Phaeocystis globosa 1
HAPTO Phaeocystis globosa 3
HAPTO Phaeocystis globosa 2
HAPTO Phaeocystis globosa 4
HAPTO Emiliania huxleyi 13
HAPTO Emiliania huxleyi 14
HAPTO Emiliania huxleyi 5
HAPTO Emiliania huxleyi 9
HAPTO Emiliania huxleyi 1
HAPTO Emiliania huxleyi 10
HAPTO Emiliania huxleyi 2
HAPTO Emiliania huxleyi 11
HAPTO Emiliania huxleyi 3
HAPTO Emiliania huxleyi 7
HAPTO Emiliania huxleyi 4
HAPTO Emiliania huxleyi 8
HAPTO Emiliania huxleyi 6
HAPTO Emiliania huxleyi 12
HAPTO Prymnesium polylepis 2
HAPTO Prymnesium polylepis 4
HAPTO Prymnesium polylepis 1
HAPTO Prymnesium polylepis 3
DIATOM Chaetoceros socialis 3
DIATOM Chaetoceros socialis 4
DIATOM Chaetoceros socialis 1
DIATOM Chaetoceros socialis 2
DIATOM Chaetoceros debilis 1
DIATOM Asterionella glacialis 1
DIATOM Odontella sinensis 1
DIATOM Chaetoceros muelleri 3
DIATOM Chaetoceros muelleri 1
DIATOM Chaetoceros muelleri 2
DIATOM Chaetoceros muelleri 4
DIATOM Odontella aurita 1
DIATOM Nitzschia spp. 1
DIATOM Nitzschia spp. 2
DIATOM Coscinodiscus wailesii 2
DIATOM Thalassiosira eccentrica 1
DIATOM Thalassiosira eccentrica 2
DIATOM Thalassiosira hendeyi 1
DIATOM Thalassiosira punctigera 1
DIATOM Thalassiosira rotula 1
DIATOM Thalassiosira rotula 3
DIATOM Thalassiosira rotula 2
DIATOM Thalassiosira rotula 4
DIATOM Thalassiosira rotula 5
DIATOM Thalassiosira levanderi 1
DIATOM Thalassiosira levanderi 2
DIATOM Thalassiosira levanderi 3
DIATOM Coscinodiscus wailesii 1
DIATOM Chaetoceros muelleri 5
DIATOM Chaetoceros muelleri 6
RAPHI Heterosigma akashiwo 5
RAPHI Heterosigma akashiwo 6
DIATOM Thalassiosira pseudonana 1
DIATOM Thalassiosira weissflogii 2
DIATOM Thalassiosira weissflogii 1
RAPHI Heterosigma akashiwo 3
RAPHI Heterosigma akashiwo 4
RAPHI Heterosigma akashiwo 1
RAPHI Heterosigma akashiwo 2
DIATOM Skeletonema costatum 1
DIATOM Thalassiosira guillardii 2
DIATOM Thalassiosira guillardii 4
DIATOM Thalassiosira guillardii 3
DIATOM Thalassiosira guillardii 1
DIATOM Halamphora coffeiformis 2
DIATOM Halamphora coffeiformis 4
DIATOM Halamphora coffeiformis 1
DIATOM Halamphora coffeiformis 3
DINO Karlodinium veneficum 1
DINO Karlodinium veneficum 2
DINO Karenia brevis 1
DINO Karenia brevis 3
DINO Karenia brevis 2
DINO Karenia brevis 4
HAPTO Prymnesium parvum 1
HAPTO Prymnesium parvum 2
HAPTO Prymnesium parvum 5
HAPTO Prymnesium parvum 3
HAPTO Prymnesium parvum 4
HAPTO Prymnesium parvum 6
HAPTO Prymnesium parvum 7
DINO Prorocentrum lima 1
DINO Tripos lineatus 1
DINO Alexandrium tamarense 1
DINO Alexandrium tamarense 2
DINO Scrippsiella acuminata 1
DINO Akashiwo sanguinea 1
DINO Lingulodinium polyedra 1
DINO Lingulodinium polyedra 2
DINO Alexandrium tamarense 4
DINO Alexandrium tamarense 3
DINO Prorocentrum micans 1
DINO Prorocentrum micans 3
DINO Amphidinium carterae 2
DINO Prorocentrum cordatum 2
DINO Protoceratium reticulatum 1
DINO Prorocentrum cordatum 1
DINO Prorocentrum micans 4
DINO Amphidinium carterae 1
DINO Kryptoperidinium triquetrum 1
DINO Alexandrium triquetrum 2
DINO Prorocentrum micans 5
DINO Alexandrium minutum 4
DINO Amphidinium gibbosum 1
DINO Alexandrium minutum 3

Haptophytes



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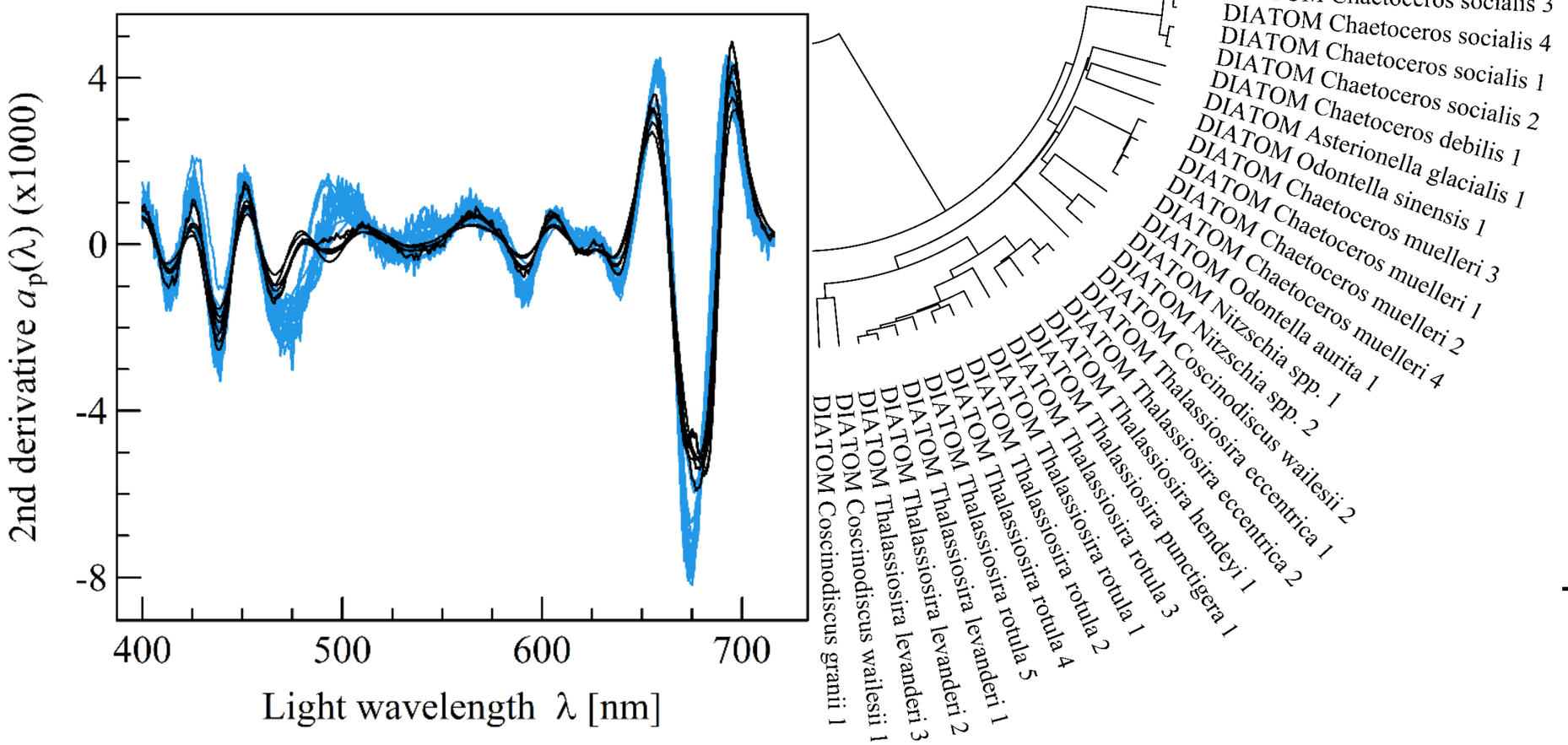
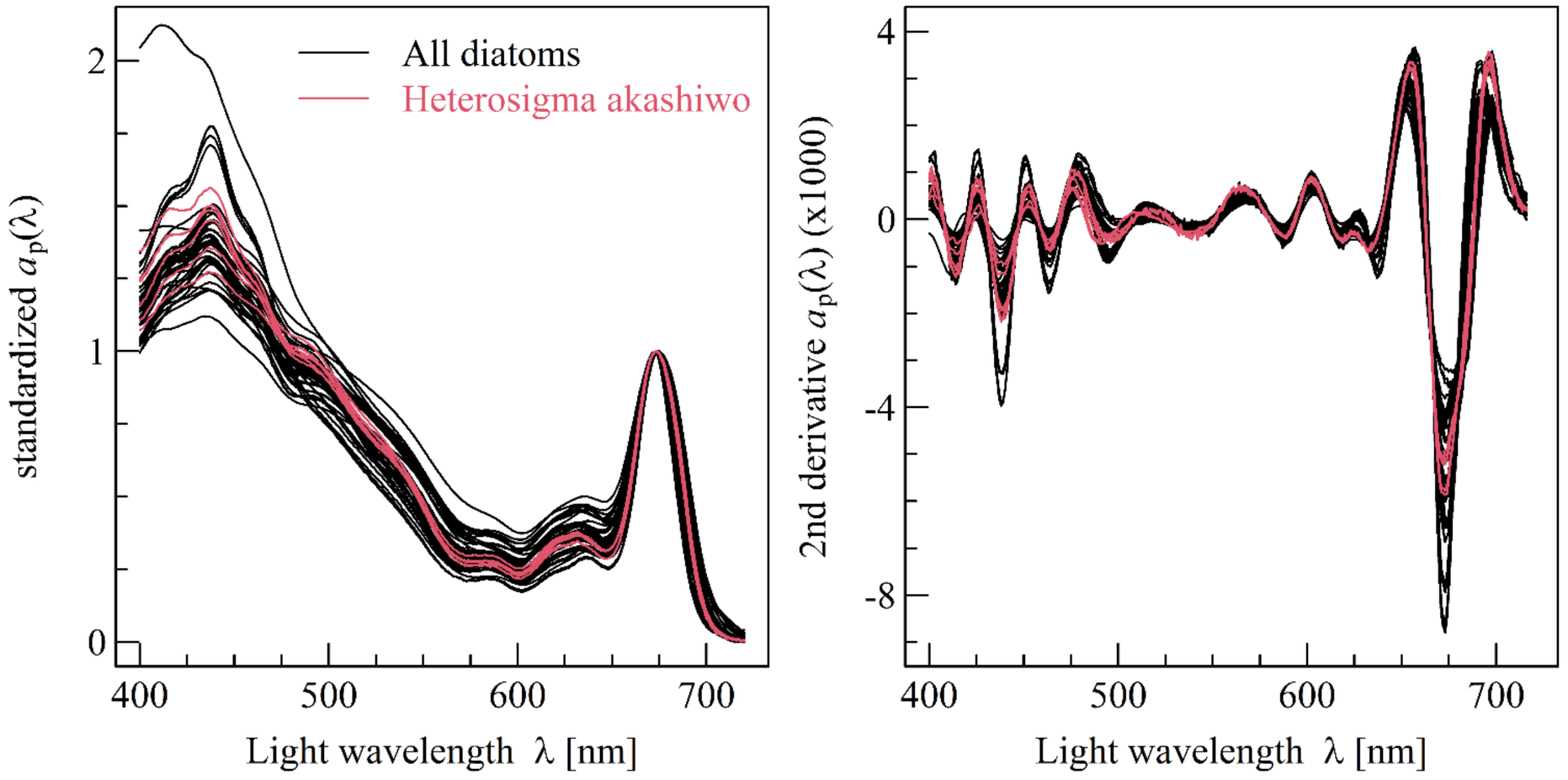
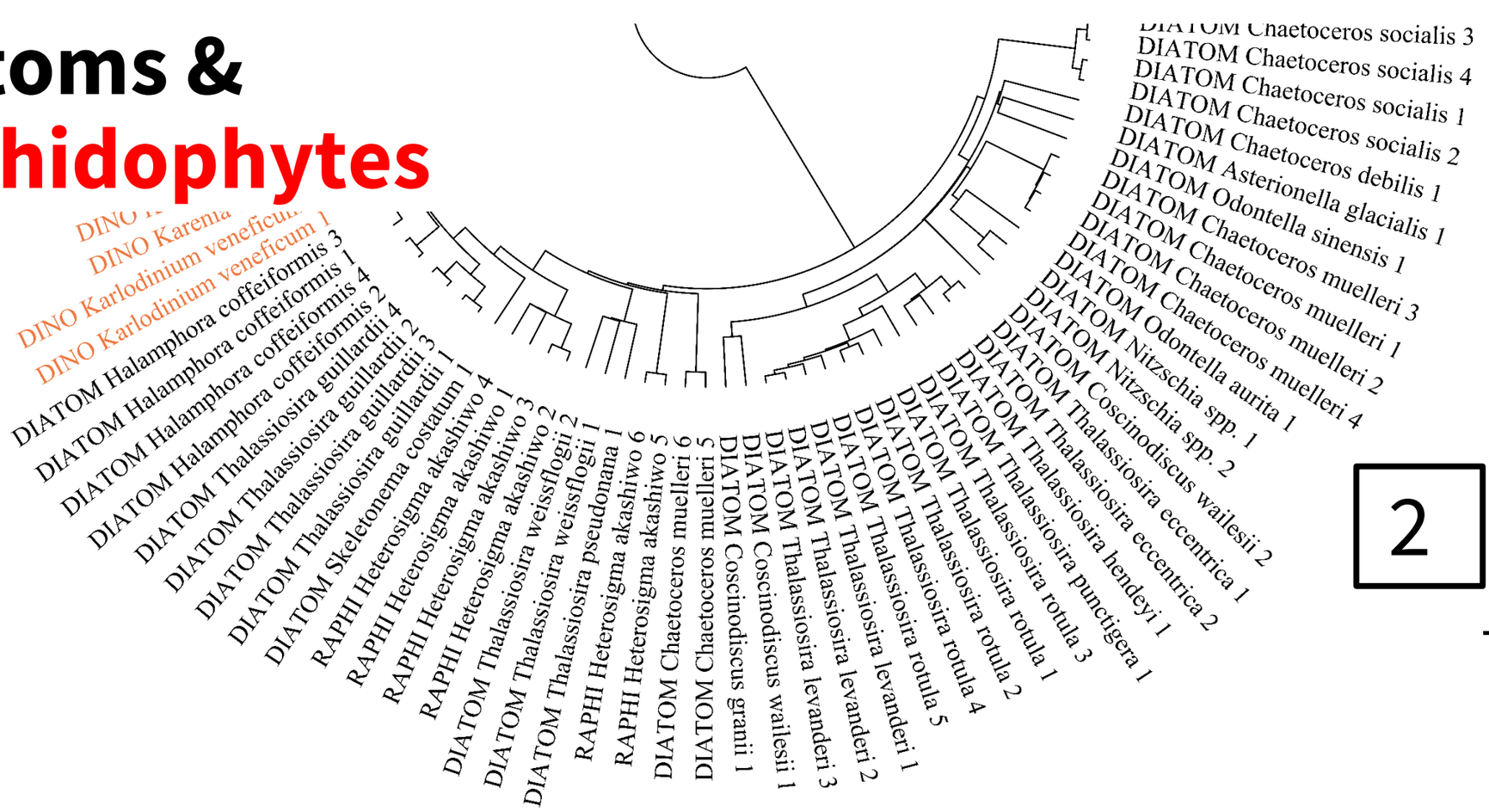




Diatoms & Raphidophytes



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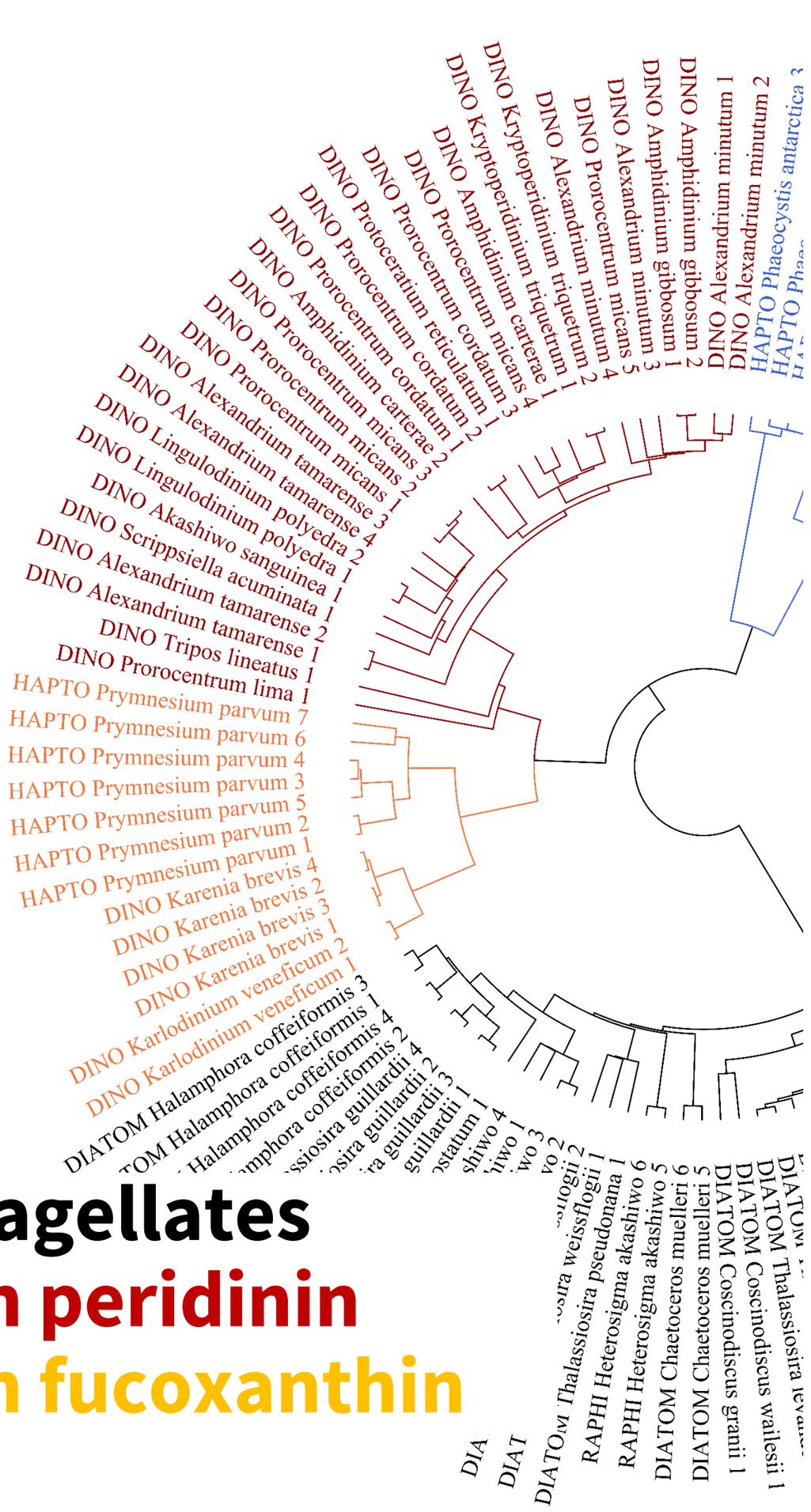
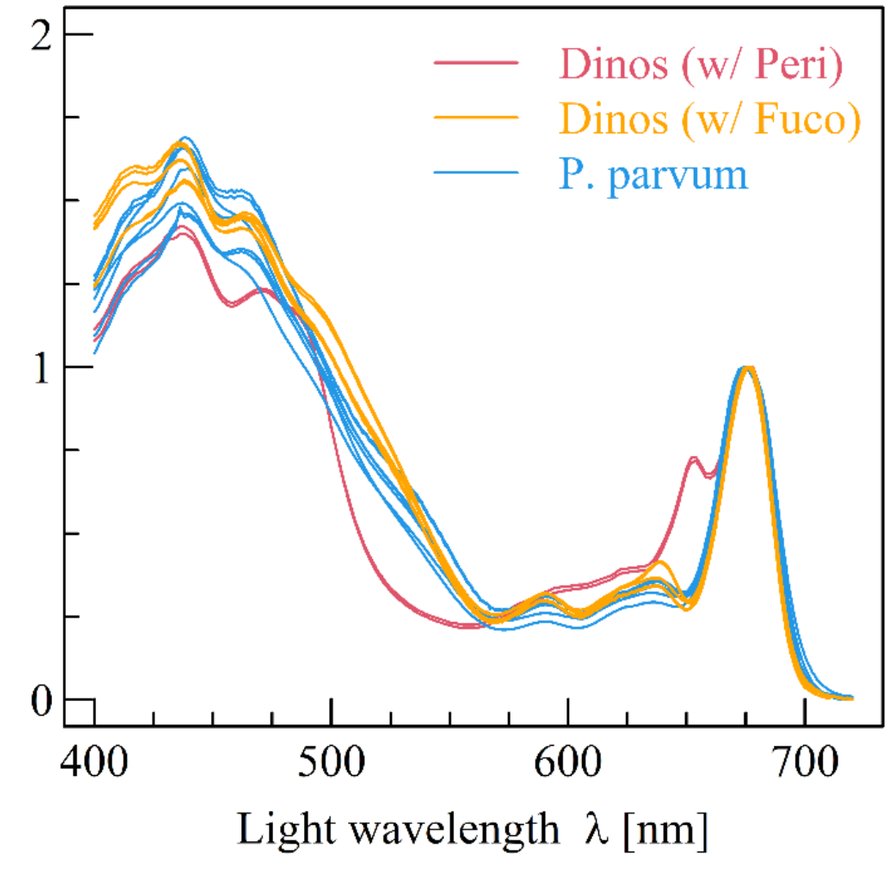
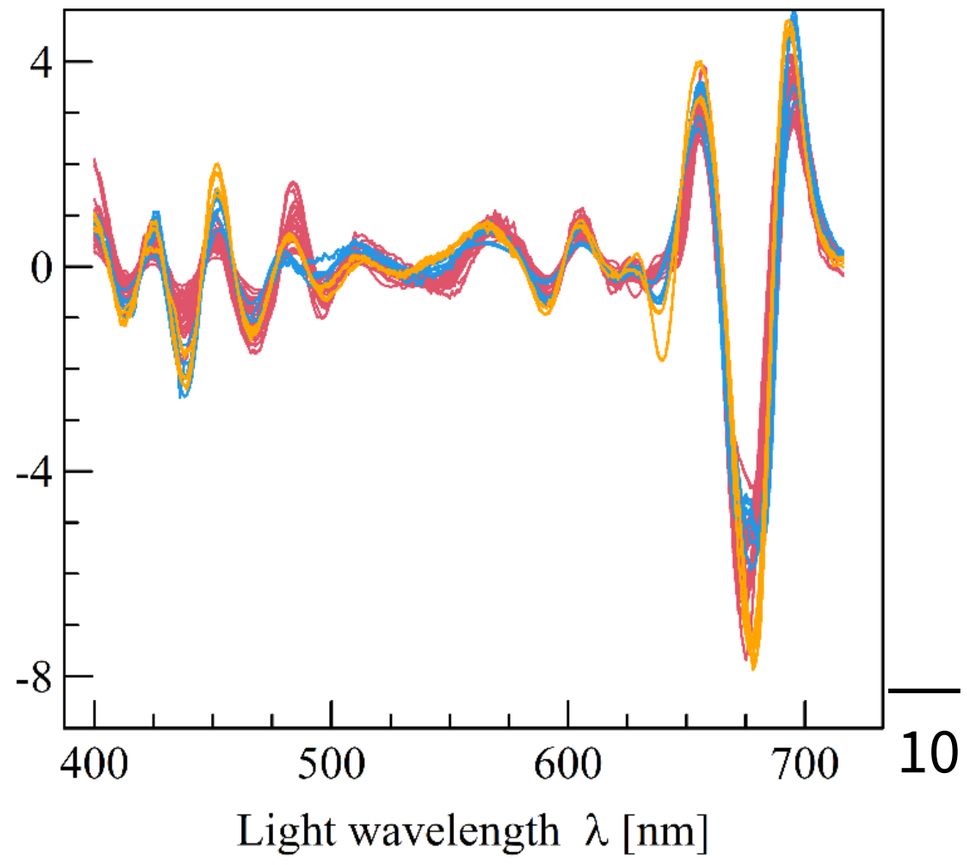






Dinoflagellates

4) with peridinin

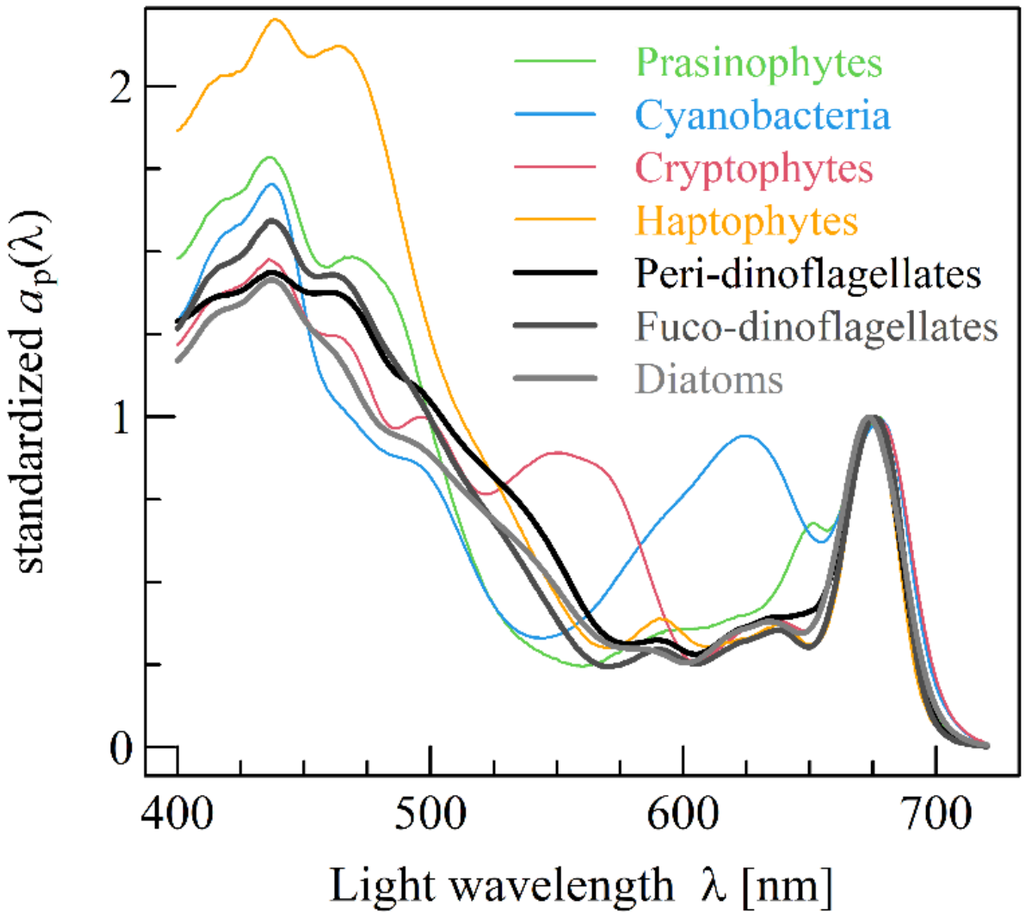
3) with fucoxanthin

Conclusion

Previous studies shown that cyanobacteria, cryptophytes, and prasinophytes could be distinguished due to their unique pigments and absorption signature.

Here, we confirmed it and further demonstrated that **4 additional types of blooms could be distinguished at taxonomic class level using hyperspectral absorption measurements**:

1) Haptophytes
2) Peridinin-bearing dinoflagellates
3) Fucoxanthin-bearing dinoflagellates
4) Diatoms and/or raphidophytes



Next steps

Analyze library of hyperspectral Remote-sensing reflectance $R_{rs}(\lambda)$. Such library could be obtained from:

1) In situ $R_{rs}(\lambda)$ acquired during highly concentrated “monospecific” blooms

2) Satellite $R_{rs}(\lambda)$ extracted from bloom images

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Poster on Thursday:

«Exploring the potential of hyperspectral data from space supporting harmful algal bloom studies»

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2) Satellite $R_{rs}(\lambda)$ extracted from bloom images

3) Synthetic $R_{rs}(\lambda)$ obtained from IOPs using radiative-transfer simulations

See you soon at…

THANK YOU!

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TOSCA LASHA

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