Supporting Information for

Structural investigations on a linear isolated depsipeptide: Importance of dispersion interactions

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a) Selection of structures and geometry parameters of MOC obtained from DFT calcutions including dispersion interactions (B3LYP-D3/TZVP)

Table S1: Complete geometry parameters obtained for six different structures of MOC (*cf.* Figure 2) calculated at the B3LYP-D3/TZVP level of theory. The bond lengths are given in Å and the bond angles in degrees.

| | $\alpha_{\rm D}\delta_{\rm D}$ | γ _D δ _D | $\alpha_L \delta_D$ | $\gamma_L \alpha_D$ | $\alpha_{\rm D}\gamma_{\rm D}$ | ε _D γ _D |
|-----------------------------|--------------------------------|-------------------------------|---------------------|---------------------|--------------------------------|-------------------------------|
| r _{N1-H1} | 1.007 | 1.008 | 1.007 | 1.012 | 1.007 | 1.012 |
| r _{N2-H2} | 1.014 | 1.011 | 1.009 | 1.011 | 1.014 | 1.013 |
| r _{C1-O1} | 1.224 | 1.222 | 1.22 | 1.223 | 1.221 | 1.223 |
| r _{C3-O2} | 1.204 | 1.203 | 1.202 | 1.202 | 1.207 | 1.209 |
| r _{C5-O3} | 1.219 | 1.220 | 1.218 | 1.217 | 1.220 | 1.218 |
| $\mathbf{r}_{\text{C2-N1}}$ | 1.445 | 1.442 | 1.445 | 1.444 | 1.448 | 1.445 |
| r _{C2-C3} | 1.529 | 1.526 | 1.529 | 1.530 | 1.527 | 1.527 |
| r _{C3-O4} | 1.345 | 1.351 | 1.348 | 1.352 | 1.345 | 1.338 |
| r _{04-C4} | 1.457 | 1.456 | 1.450 | 1.452 | 1.466 | 1.469 |
| r _{C4-C5} | 1.542 | 1.538 | 1.539 | 1.539 | 1.542 | 1.549 |
| $\mathbf{r}_{\text{C5-N2}}$ | 1.362 | 1.359 | 1.364 | 1.362 | 1.360 | 1.363 |
| r _{C1-N1} | 1.369 | 1.371 | 1.374 | 1.373 | 1.374 | 1.377 |
| r _{H2-O2} | ••• | | ••• | ••• | 2.071 | 2.116 |
| $\theta_{N1-C2-C3}$ | 115.9 | 115.9 | 115.1 | 115.9 | 112.8 | 112.4 |
| $\theta_{H1-N1-C2}$ | 117.9 | 117.6 | 117.3 | 116.6 | 116.5 | 115.7 |
| $\theta_{H2-N2-C5}$ | 117.9 | 117.0 | 115.6 | 116.6 | 117.5 | 117.4 |
| $\theta_{C4-C5-N2}$ | 113.3 | 115.2 | 114.6 | 114.5 | 115.7 | 113.4 |
| $\theta_{C2-C3-O4}$ | 112.1 | 112.5 | 111.3 | 111.6 | 112.1 | 111.5 |
| $\theta_{C5-C4-C6}$ | 112.8 | 112.1 | 111.6 | 111.4 | 113.5 | 112.3 |
| $\theta_{O1-C1-N1}$ | 120.9 | 121.8 | 121.1 | 120.0 | 121.5 | 119.5 |
| θ _{04-C3-O2} | 125.1 | 124.6 | 124.8 | 125.0 | 125.4 | 124.9 |
| $\theta_{C4-O4-C3}$ | 118.5 | 117.6 | 119.5 | 117.9 | 123.5 | 118.6 |



Figure S1: Further selected conformers of MOC and their relative energies obtained from DFT calculations (B3LYP-D3/TZVP).

Table S2: Most stable structures of MOC as obtained from DFT calculations (B3LYP-D3/TZVP). Relative energies (in cm⁻¹) and the dihedral angles (in degrees) Φ_{Gly} , Ψ_{Gly} , Φ_{Lat} and Ψ_{Lat} describing the backbone as well as the dihedral angles ω_1 and ω_2 describing the amide bond (*cis/trans*) of the linear depsipeptides MOC (*cf.* Figure 1) are listed. The calculated frequencies (in cm⁻¹) at the B3LYP-D3/TZVP level of theory have been scaled by 0.9563 (bonded NH vibration) and 0.9608 (free NH vibration).

| Isomer | ΔΕ | Φ_{Gly} | Ψ_{Gly} | Φ_{Lat} | Ψ_{Lat} | ω_1° | ω_2° | NH _{(NH-} | NH _(Gly) |
|----------------------------------|------|-----------------------|---------------------|---------------------|--------------|--------------------|--------------------|--------------------|---------------------|
| | | | | | | | | PhOME) | |
| $\alpha_D \gamma_D$ | 200 | 64.7 | 40.3 | 101.8 | -68.6 | -163.7 | 164.8 | 3398 | 3475 |
| $\gamma_L \delta_L$ | 326 | -102.8 | 57.5 | 156.3 | 21.4 | 169.1 | 177.2 | 3419 | 3479 |
| $\alpha_{\rm D}\delta_{\rm L}$ | 1299 | 80.5 | 2.3 | 149.8 | 15.7 | -4.4 | 179.6 | 3435 | 3460 |
| $\epsilon_L \gamma_D$ | 1300 | -86.6 | 149.9 | 91.5 | -72.3 | -21.4 | 167.1 | 3365 | 3428 |
| $\epsilon_L \alpha_L$ | 1334 | -92.7 | 137.6 | -87.5 | -75.4 | 159.5 | 175.6 | 3384 | 3461 |
| $\beta_L \gamma_D$ | 1476 | -178.0 | 178.5 | 91.9 | -72.8 | 179.5 | 176.7 | 3383 | 3470 |
| γdγd | 1559 | 68.6 | -2.3 | 92.1 | -65.3 | 14.8 | 166.7 | 3395 | 3452 |
| $\alpha_L \alpha_L$ | 1612 | -94.3 | -14.3 | -69.4 | -24.4 | 158.8 | -176.7 | 3450 | 3474 |
| $\gamma_D \delta_D$ | 2082 | 82.6 | -68.4 | 147.2 | -12.5 | 15.2 | -177.2 | 3434 | 3459 |
| $\gamma_{\rm D}\alpha_{\rm L}$ | 2159 | 96.8 | -39.0 | -63.2 | -30.5 | -168.7 | 176.6 | 3454 | 3463 |
| $\delta_L \delta_D$ | 2717 | 126.3 | 28.9 | 145.0 | -47.2 | -11.4 | 1.3 | 3415 | 3423 |
| $\alpha_{\rm D}\epsilon_{\rm D}$ | 2765 | 67.4 | 7.5 | 65.0 | -145.2 | 14.1 | -176.5 | 3453 | 3454 |

b) Detailed characterization of the strongest vibrations of the assigned isomers of MOC

Table S3: Characterization of the strongest vibrations of the most stable structure of MOC ($\alpha_D \delta_D$) as obtained from DFT calculations (B3LYP-D3/TZVP). All vibrational modes presented here are scaled by a factor of 0.9850 for the amide I/II region, 0.9608 for free NH stretching and 0.9563 for bonded NH stretching vibrations (for further explanations of the scaling factors, see paper)

| isomer | character | wavenumber / cm ⁻¹ |
|--------------------------------|---|-------------------------------|
| $\alpha_{\rm D}\delta_{\rm D}$ | NH _(Gly) stretching | 3481 |
| | NH _(NH-PhOMe) stretching | 3404 |
| | C=O _(Gly) stretching | 1771 |
| | C=O _(Lac) stretching, NH _(NH-PhOMe) bending | 1723 |
| | C=O _(CyCO) stretching, NH _(Gly) bending | 1705 |
| | NH _(NH-PhOMe) bending, CH _(PhOMe) bending | 1616 |
| | CH _(PhOMe) bending | 1610 |
| | NH _(NH-PhOMe) bending | 1549 |
| | NH _(Gly) bending | 1508 |

Table S4: Characterization of the strongest vibrations of the second most stable structure of MOC ($\gamma_D \delta_D$) as obtained from DFT calculations (B3LYP-D3/TZVP). All vibrational modes presented here are scaled by a factor of 0.9850 for the amide I/II region, 0.9608 for free NH stretching and 0.9563 for bonded NH stretching vibrations.

| isomer | character | wavenumber / cm ⁻¹ |
|---------------------|---|-------------------------------|
| $\gamma_D \delta_D$ | NH _(Gly) stretching | 3479 |
| | NH _(NH-PhOMe) stretching | 3437 |
| | C=O _(Gly) stretching | 1773 |
| | C=O _(Lac) stretching, NH _(NH-PhOMe) bending | 1716 |
| | C=O _(CyCO) stretching, NH _(Gly) bending | 1715 |
| | NH _(NH-PhOMe) bending, CH _(PhOMe) bending | 1614 |
| | CH _(PhOMe) bending | 1611 |
| | NH _(NH-PhOMe) bending | 1545 |
| | NH _(Gly) bending | 1516 |

Table S5: Characterization of the strongest vibrations of the $\alpha_D\gamma_D$ isomer of MOC as obtained from DFT calculations (B3LYP-D3/TZVP). All vibrational modes presented here are scaled by a factor of 0.9850 for the amide I/II region, 0.9608 for free NH stretching and 0.9563 for bonded NH stretching vibrations.

| isomer | character | wavenumber / cm ⁻¹ |
|--------------------------------|---|-------------------------------|
| $\alpha_{\rm D}\gamma_{\rm D}$ | NH _(Gly) stretching | 3491 |
| | NH _(NH-PhOMe) stretching | 3367 |
| | C=O _(Gly) stretching | 1760 |
| | C=O _(Lac) stretching, NH _(NH-PhOMe) bending | 1715 |
| | C=O _(CyCO) stretching, NH _(Gly) bending | 1710 |
| | NH _(NH-PhOMe) bending | 1619 |
| | CH _(PhOMe) bending | 1610 |
| | NH _(NH-PhOMe) bending | 1555 |
| | NH _(Gly) bending | 1515 |



c) Comparision between the experimental IR/R2PI spectrum of MOC and calculated frequencies obtained from DFT calculations (B3LYP-D3/TZVP)

Figure S2: Comparison between the experimental IR/R2PI spectrum of MOC *via* the R2PI resonance at 35071 cm⁻¹ (upper trace) and calculated frequencies obtained from DFT calculations (B3LYP-D3/TZVP) of selected isomers of MOC. (The frequencies were scaled for the free NH stretching region with 0.9608, for hydrogen-bonded NH stretching vibrations with 0.9563 and for the carbonyl stretching and NH bending region with 0.9850. For a better illustration the calculated intensities in the amide A region were tripled.)



Figure S3: Comparison between the experimental IR/R2PI spectrum of MOC *via* the R2PI resonance at 35149 cm⁻¹ (upper trace) and calculated frequencies obtained from DFT calculations (B3LYP-D3/TZVP) of selected isomers of MOC. (The frequencies were scaled for the free NH stretching region with 0.9608, for hydrogen-bonded NH stretching vibrations with 0.9563 and for the carbonyl stretching and NH bending region with 0.9850. For a better illustration the calculated intensities in the amide A region were tripled.)



d) Selection of structures and geometry parameters of MOC obtained from DFT calculations (B3LYP/TZVP)

Figure S4: Selected conformers of MOC and their relative energies obtained from DFT calculations without dispersion interactions (B3LYP/TZVP).

Table S6: Most stable structures of MOC as obtained from DFT calculations (B3LYP/TZVP). Relative energies (in cm⁻¹) and the dihedral angles (in degrees) Φ_{Gly} , Ψ_{Gly} , Φ_{Lat} and Ψ_{Lat} describing the backbone as well as the dihedral angles ω_1 and ω_2 describing the amide bond (*cis/trans*) of the linear depsipeptides MOC (*cf.* Figure 1) are listed. The calculated frequencies (in cm⁻¹) at the B3LYP/TZVP level of theory have been scaled by 0.9567 (bonded NH vibration) and 0.9613 (free NH vibration).

| Isomer | ΔΕ | $\Phi_{ m Gly}$ | Ψ_{Gly} | Φ_{Lat} | Ψ_{Lat} | ω_1° | ω_2° | NH _(NH-PhOME) | NH _(Gly) |
|-------------------------------|------|-----------------|--------------|---------------------|---------------------|--------------------|--------------------|--------------------------|---------------------|
| $\beta_L \delta_L$ | 0 | -171.1 | 178.1 | 145.0 | 0.1 | 177.9 | -178.8 | 3449 | 3468 |
| $\gamma_D \delta_D$ | 641 | 117.2 | -29.9 | 138.0 | -8.5 | -179.0 | -175.8 | 3438 | 3493 |
| $\alpha_L \delta_D$ | 1250 | -96.2 | -2.5 | 144.7 | -7.2 | 170.8 | -175.7 | 3473 | 3483 |
| $\gamma_L \alpha_L$ | 1922 | -105.3 | 7.1 | -67.9 | -26.5 | 174.8 | 179.2 | 3446 | 3493 |
| ε _D γ _D | 2757 | 70.8 | 145.5 | 92.6 | -64.6 | 24.4 | 175.8 | 3370 | 3429 |
| $\alpha_D \gamma_D$ | 3446 | 118.1 | 16.3 | 79.3 | -58.6 | -174.2 | 178.6 | 3334 | 3498 |

| | $\beta_L \delta_L$ | $\gamma_D \delta_D$ | $\alpha_L \delta_D$ | γιαι | ε _D γ _D | $\alpha_{\rm D}\gamma_{\rm D}$ |
|----------------------------|--------------------|---------------------|---------------------|-------|-------------------------------|--------------------------------|
| r _{N1-H1} | 1.009 | 1.007 | 1.007 | 1.007 | 1.012 | 1.007 |
| r _{N2-H2} | 1.011 | 1.011 | 1.009 | 1.011 | 1.014 | 1.017 |
| r _{C1-O1} | 1.224 | 1.223 | 1.220 | 1.224 | 1.222 | 1.222 |
| r _{C3-O2} | 1.206 | 1.204 | 1.202 | 1.202 | 1.208 | 1.209 |
| r _{C5-O3} | 1.220 | 1.220 | 1.219 | 1.218 | 1.218 | 1.222 |
| r _{C2-N1} | 1.443 | 1.444 | 1.443 | 1.443 | 1.445 | 1.442 |
| r _{C2-C3} | 1.513 | 1.524 | 1.527 | 1.527 | 1.529 | 1.522 |
| r _{C3-O4} | 1.346 | 1.351 | 1.352 | 1.351 | 1.340 | 1.340 |
| r _{04-C4} | 1.458 | 1.457 | 1.455 | 1.463 | 1.469 | 1.469 |
| r _{C4-C5} | 1.537 | 1.537 | 1.538 | 1.545 | 1.550 | 1.546 |
| r _{C5-N2} | 1.359 | 1.358 | 1.363 | 1.360 | 1.364 | 1.359 |
| r _{C1-N1} | 1.362 | 1.367 | 1.374 | 1.367 | 1.380 | 1.373 |
| r _{H2-O2} | ••• | ••• | ••• | ••• | 2.144 | 2.022 |
| $\theta_{N1-C2-C3}$ | 110.0 | 115.9 | 116.7 | 117.0 | 112.8 | 116.1 |
| $\theta_{\text{H1-N1-C2}}$ | 117.1 | 118.6 | 118.4 | 118.5 | 115.4 | 118.3 |
| $\theta_{\text{H2-N2-C5}}$ | 116.5 | 116.8 | 115.8 | 117.5 | 117.4 | 117.4 |
| $\theta_{C4-C5-N2}$ | 115.6 | 115.7 | 115.2 | 114.4 | 113.7 | 117.1 |
| $\theta_{C2-C3-O4}$ | 110.4 | 112.7 | 112.6 | 112.8 | 111.6 | 112.6 |
| $\theta_{C5-C4-C6}$ | 111.7 | 111.9 | 111.9 | 113.1 | 112.3 | 113.6 |
| $\theta_{01-C1-N1}$ | 121.4 | 122.1 | 121.9 | 122.1 | 119.2 | 121.6 |
| θ _{04-C3-O2} | 124.8 | 124.6 | 124.5 | 125.0 | 124.6 | 125.2 |
| $\theta_{C4-O4-C3}$ | 118.4 | 117.8 | 118.3 | 119.4 | 118.3 | 122.8 |

Table S7: Geometry parameters obtained for the six different structures of MOC calculated at the B3LYP/TZVP level of theory. The bond lengths are given in Å and the bond angles in degrees.

e) Band analysis of the IR/R2PI spectrum *via* the third resonance of the R2PI spectrum at 35149 cm⁻¹



Figure S5: Band analysis (using gauss fits) of the IR/R2PI spectrum *via* the third resonance of the R2PI spectrum at 35149 cm⁻¹.

The spectrum can be described as overlap between the transitions at 3386, 3408, 3440, 3466 and 3470 cm^{-1} (3520 cm⁻¹).

f) IR/IR/R2PI spectrum of MOC by using IR burn laser frequency at 3386 cm⁻¹

IR/R2PI and IR/IR/R2PI spectrum *via* 35149 cm⁻¹ with the IR burn laser fixed at 3386 cm⁻¹ drawn separately for a better comparison. In Figure 8 the spectra are superimposed and the IR induced "new" bands might be less obvious.



Figure S6: IR/IR/R2PI spectrum of MOC *via* the excitation at 35149 cm⁻¹ by using a frequency-fixed IR burn laser at 3386 cm⁻¹. The IR/IR/R2PI spectrum is given in red and the corresponding IR/R2PI spectrum is given in black.

g) Possible combination bands (CH deformation bands)



Figure S7: Representative illustration of the out-of-plane CH deformation fundamentals which could lead to combination bands above 1800 cm⁻¹.

h) Thermodynamic data from DFT calculations at 50, 100, 200 and 298 K

Table S8: Thermodynamic data from B3LYP-D3/TZVP calculations at 50 K, free energies *G* are given in Hartree, relative energies in cm⁻¹, entropies *S* and relative entropies in cal·mol⁻¹·K⁻¹. Relative energies and entropies always refer to the $\alpha_D \delta_D$ isomer. Assigned isomers are given in bold letters.

| isomer | G | ΔG | S | ΔS |
|-----------------------|--------------|------------|--------|------------|
| $\alpha_D \delta_D$ | -1224,696989 | 0 | 79,633 | 0,000 |
| $\gamma_D \delta_D$ | -1224,696919 | 15 | 82,783 | 3,150 |
| $\alpha_L \delta_D$ | -1224,694006 | 655 | 83,381 | 3,748 |
| $\gamma_L \alpha_D$ | -1224,690129 | 1506 | 83,311 | 3,678 |
| $\alpha_D \gamma_D$ | -1224,689094 | 1733 | 78,186 | -1,447 |
| $\epsilon_D \gamma_D$ | -1224,686569 | 2287 | 82,827 | 3,194 |

Table S9: Thermodynamic data from B3LYP-D3/TZVP calculations at 100 K; free energies G are given in Hartree, relative energies in cm⁻¹, entropies S and relative entropies in cal·mol⁻¹·K⁻¹. Relative energies and entropies always refer to the $\alpha_D \delta_D$ isomer. Assigned isomers are given in bold letters.

| isomer | G | ΔG | S | ΔS |
|-------------------------------|--------------|------------|---------|------------|
| $\alpha_D \delta_D$ | -1224,704316 | 0 | 103,353 | 0,000 |
| γ _D δ _D | -1224,704505 | -41 | 106,593 | 3,240 |
| $\alpha_L \delta_D$ | -1224,701634 | 589 | 107,082 | 3,729 |
| $\gamma_L \alpha_D$ | -1224,697758 | 1439 | 107,132 | 3,779 |
| $\alpha_D \gamma_D$ | -1224,696282 | 1763 | 101,362 | -1,991 |
| $\epsilon_D\gamma_D$ | -1224,694148 | 2232 | 106,446 | 3,093 |

Table S10: Thermodynamic data from B3LYP-D3/TZVP calculations at 200 K, free energies *G* are given in Hartree, relative energies in cm⁻¹, entropies *S* and relative entropies in cal·mol⁻¹·K⁻¹. Relative energies and entropies always refer to the $\alpha_D \delta_D$ isomer. Assigned isomers are given in bold letters.

| isomer | G | ΔG | S | ΔS |
|--------------------------------|--------------|------------|---------|------------|
| $\alpha_{\rm D}\delta_{\rm D}$ | -1224,723934 | 0 | 141,649 | 0,000 |
| $\gamma_D \delta_D$ | -1224,724620 | -151 | 144,667 | 3,018 |
| $\alpha_L \delta_D$ | -1224,721818 | 464 | 145,061 | 3,412 |
| $\gamma_L \alpha_D$ | -1224,717947 | 1314 | 145,052 | 3,403 |
| $\alpha_D \gamma_D$ | -1224,715525 | 1846 | 139,006 | -2,643 |
| $\epsilon_D \gamma_D$ | -1224,714231 | 2130 | 144,417 | 2,768 |

Table S11: Thermodynamic data from B3LYP-D3/TZVP calculations at 298 K, free energies *G* are given in Hartree, relative energies in cm⁻¹, entropies *S* and relative entropies in cal·mol⁻¹·K⁻¹. Relative energies and entropies always refer to the $\alpha_D \delta_D$ isomer. Assigned isomers are given in bold letters.

| isomer | G | ΔG | S | ΔS |
|-----------------------|--------------|------------|---------|------------|
| $\alpha_D \delta_D$ | -1224,748733 | 0 | 175,081 | 0,000 |
| $\gamma_D \delta_D$ | -1224,749881 | -252 | 178,010 | 2,929 |
| $\alpha_L \delta_D$ | -1224,747138 | 350 | 178,385 | 3,304 |
| $\gamma_L \alpha_D$ | -1224,743261 | 1201 | 178,306 | 3,225 |
| $\alpha_D \gamma_D$ | -1224,739889 | 1941 | 172,181 | -2,900 |
| $\epsilon_D \gamma_D$ | -1224,739446 | 2038 | 177,689 | 2,608 |

i) Time-correlated single-photon counting

The excited state lifetime measurements of MOC and AcPheOMe were determined using the time-correlated single-photon counting technique (by applying a DeltaFlex spectrometer from Horiba Jobin-Yvon). The samples are dissolved in CH_2Cl_2 at a concentration of $5 \cdot 10^{-5}$ mol/L and are excited using short light pulses of a NanoLED (273 nm for MOC and 256 nm for AcPheOMe). The emission monochromator was set to 300 nm since both substances have a maximum in their fluorescence spectra at this wavelength. The precision photon counting is carried out using a PPD (picosecond photon counting detection module) detection, including a fast-rise photomultiplier tube (PMT) with an integral GHz timing preamplifier, a constant fraction discriminator and a regulated high voltage supply. The instrumental response function (IRF) was collected by use of LUDOX[®].