CHEMISTRY
A European Journal

A Journal of
ChemPubSoc Europe

Accepted Article

Title: Intramolecular Parallel [4 + 3] Cycloadditions of Cyclopropane 1,1-Diesters with [3]Dendralenes: Efficient Construction of [5.3.0]decane and Corresponding Polycyclic Skeletons

Authors: Zhongwen Wang, Chi Zhang, Jun Tian, and Jun Ren

To be cited as: *Chem. Eur. J.* 10.1002/chem.201605190

Link to VoR: http://dx.doi.org/10.1002/chem.201605190

Supported by
ACES

WILEY-VCH

10.1002/chem.201605190

WILEY-VCH

Intramolecular Parallel [4 + 3] Cycloadditions of Cyclopropane 1,1-Diesters with [3]Dendralenes: Efficient Construction of [5.3.0]decane and Corresponding Polycyclic Skeletons

Chi Zhang, Jun Tian, Jun Ren and Zhongwen Wang*

Abstract: Aiming to develop efficient and general strategies for construction of skeletally complex and diverse polycyclic skeletons, we have successfully developed [4+3]IMPC of cyclopropane 1,1-diesters with [3]dendralenes. With a combination of the [4+3]IMPC and subsequent [4+n] cycloadditions, *trans*-[5.3.0]decane skeleton and its corresponding structurally complex and diverse polycyclic ones could be constructed efficiently. The [4+3] cycloaddition reaction mode of D-A cyclopropanes is a novel one which is through the ring strain relief of a *trans*-[3.3.0]octane. We strongly believe that the developed methods will demonstrate their potential applications to natural products synthesis and leads discovery.

Developing efficient and general strategies to construct skeletally complex and diverse polycyclic skeletons is quite important for natural products synthesis, chemical biology research and leads discovery. Bicyclo[5.3.0]decane (hydroazulene), is a core skeleton existing in many structurally diverse and biologically important natural products (Figure 1).[1-3] Additionally, many of these natural products contain skeletally diverse polycyclic skeletons (e.g. the cyclohexane-fused ones) derived from bicyclo[5.3.0]decane. Thus, it's quite important to develop efficient and general strategies for construction of this core skeleton and corresponding polycyclic ones.

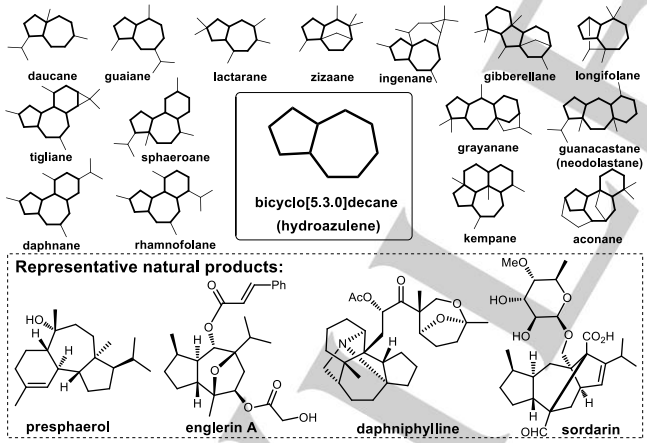


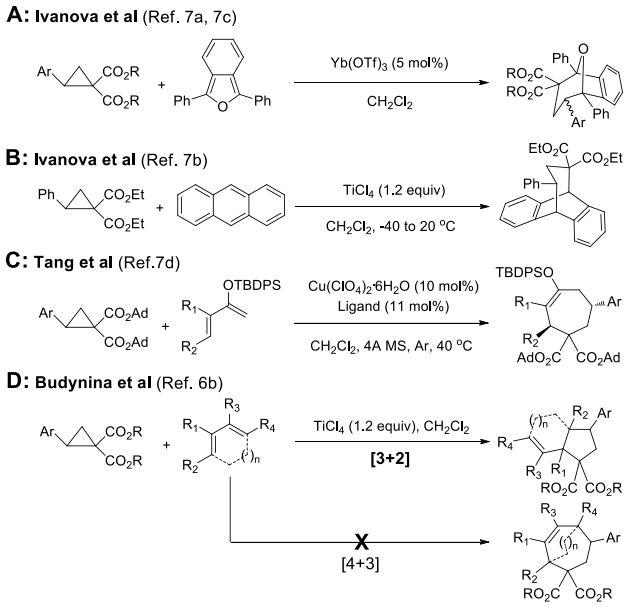
Figure 1. Some important hydroazulene-derived bicyclic/tricyclic/polycyclic core skeletons in terpenoids/alkaloids.

[*] C. Zhang. J. Tian, J. Ren, Prof. Dr. Z. Wang
State Key Laboratory of Elemento-Organic Chemistry
Institute of Elemento-Organic Chemistry, College of Chemistry, Collaborative Innovation Center of Chemical Science and Engineering, Nankai University, 94 weijin road, Tianjin 300071 (P. R. China)
E-mail: wzwrj@nankai.edu.cn
Homepage: http://wzw.nankai.edu.cn

Supporting information for this article is available on the WWW under http://www.angewandte.org or from the author.

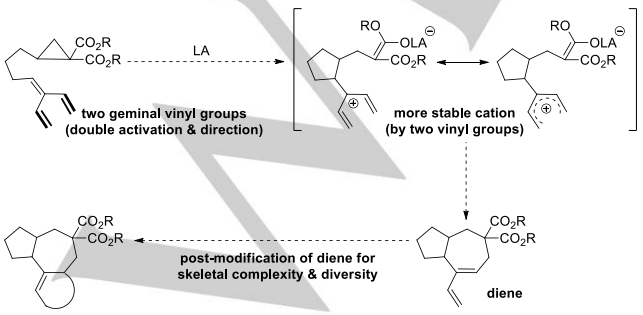
Donor–acceptor (D-A) cyclopropanes can be easily obtained and have been proved to be useful building blocks in organic synthesis,[4] and in recent years various formal cycloadditions of which have been developed for efficient construction of structurally diverse cyclic skeletons. However, compared to other mostly studied [3+2] and [3+3] cycloadditions for construction of 5- and 6-membered skeletons, [4+3] cycloadditions for construction of 7-membered skeletons via D-A cyclopropane as a 3C-synthon are quite limited. A common understanding is that due to entropic and enthalpic factors, 7-membered carbocyclic skeletons are much more difficult to assemble in high efficiency with conventional methods.[5] Thus, in the reactions of D-A cyclopropanes with dienes, [3+2] cycloaddition is considered to be the more favorable one than [4+3] cycloaddition.[6] Only three intermolecular [4+3] cycloadditions of D-A cyclopropanes with dienes were reported (Scheme 1).[7] Ivanova et al reported the first [4+3] cycloaddition with isobenzofurans[7a,7c] or anthracenes[7b] as dienes (Scheme 1 A and B), the success of which is probably ascribed to the aromatization as a driving force. Tang et al reported a [4+3] cycloaddition with siloxy-substituted dienes (Scheme 1, C),[7d] in which the steric repulsion between the bulky adamantyl esters and siloxy groups is considered as the driving force to push the reaction from the initially formed [3+2] cycloadducts to the thermodynamically stable [4+3] cycloadducts. It should be noticed that Budynina et al explored a $TiCl_4$-promoted reaction of cyclopropane 1,1-diesters with more general alkyl-substituted dienes.[6b] However, instead of the [4+3] cycloaddition, a [3+2] one took place exclusively (Scheme 1, D). And in all of these examples, aryl (or vinyl) group as a donor in the D-A cyclopropane is necessary for activation of the C-C bond in the cyclopropane ring, which may restrict the scope of the potential applications of this method. It should also be noticed that to the best of our knowledge there is no intramolecular [4+3] cycloaddition reported up to date.

Intramolecular cycloaddition is one of the most efficient and direct strategies for construction of polycyclic skeletons. We have developed several Lewis acid (LA)-catalyzed intramolecular cross (IMCC) and parallel (IMPC) [3+2], [3+3] and [4+2] cycloadditions of D-A cyclopropanes for construction of various bridged and fused polycyclic skeletons and applied them in natural products synthesis.[4h,8] In these examples, we found that besides the aryl (or vinyl) groups as donors to activate the D-A cyclopropanes, alkyl groups were also suitable in the intramolecular cycloadditions and thus make their potential applications more expansive. We decided to develop intramolecular [4+3] cycloaddition to build cycloheptane-based polycyclic skeletons.



Scheme 1. Reported intermolecular [4+3] and [3+2] cycloadditions of D-A cyclopropanes with dienes.

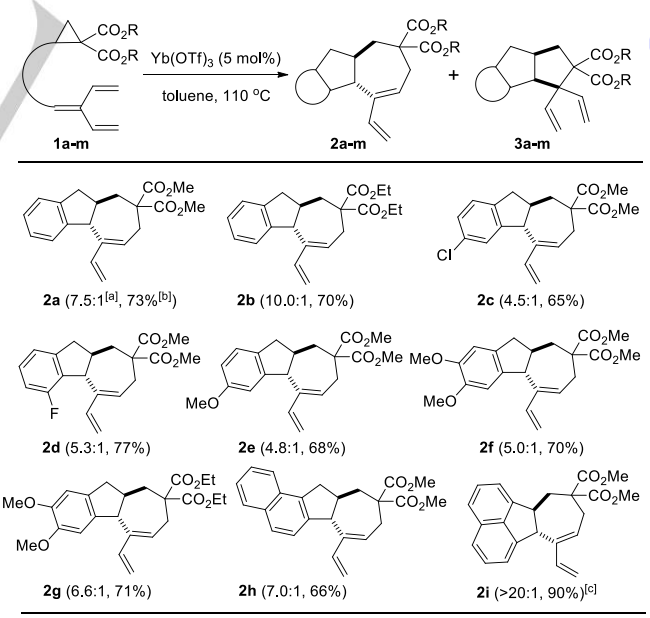
In this research, we report a LA-catalyzed [4+3]IMPC of cyclopropane 1,1-diester with [3]dendralene for construction of [5.3.0]decane skeleton (Scheme 2). [3]Dendralene was first reported in 1955[9] and can be thought as a diene with a pendent vinyl group. The most attractive feature of [3]dendralene is its double Diels-Alder [4+2] cycloadditions for efficient generation of skeletal complexity.[10] Reasons to choose [3]dendralene are mainly based on the following considerations: (1) Based on our previously developed [3+2]IMCC of cyclopropane 1,1-diester with carbon-carbon double bond for construction of bridged [n.2.1] carbocyclic skeletons,[8d] we found that a vinyl group could serve as both an activating group by stabilizing the carbenium generated in the first cyclization step and a regioselectivity-directing group. Thus in the first cyclization step of this [4+3]IMPC the geminal two vinyl groups will doubly activate and direct the reaction; (2) a diene moiety in the [4+3]IMPC cycloadducts will further proceed second [4+n] cycloadditions for construction of various carbocyclic or heterocyclic skeletons. This [4+3]IMPC/[4+n] strategy will provide a general and efficient one for construction of bicyclo[5.3.0]decane-derived polycyclic skeletons.



Scheme 2. Our hypothesis for construction of bicyclo[5.3.0]decane and corresponding polycyclic skeletons.

To test our hypothesis, we synthesized substrate **1a** following the Fallis's modified Miginiac-Barbier approach.[11] We were delighted to find that when the reaction was conducted in 1,2-dichloroethane (DCE) at 50 °C under the catalysis of $Sc(OTf)_3$ (10 mol%), the expected [4+3]IMPC cycloadduct **2a** was formed, together with a [3+2]IMPC cycloadduct **3a**, both as a single diasteroisomer. Aiming at improving both the ratio of **2a**/**3a** and the yield, **1a** was used as the model substrate to optimize the condition (Supporting information). We found that the reaction was completed within 2 hours under catalysis of most of LAs and in various solvents, among which 5 mol% of $Yb(OTf)_3$ in toluene at 110 °C gave the best result (Scheme 3). Under this condition **2a** and **3a** were obtained with a ratio of 7.5:1 and 73% yield. It should be noticed that even 1 mol% of $Yb(OTf)_3$ could also efficiently promote the reaction with a longer reaction time (6 hours).

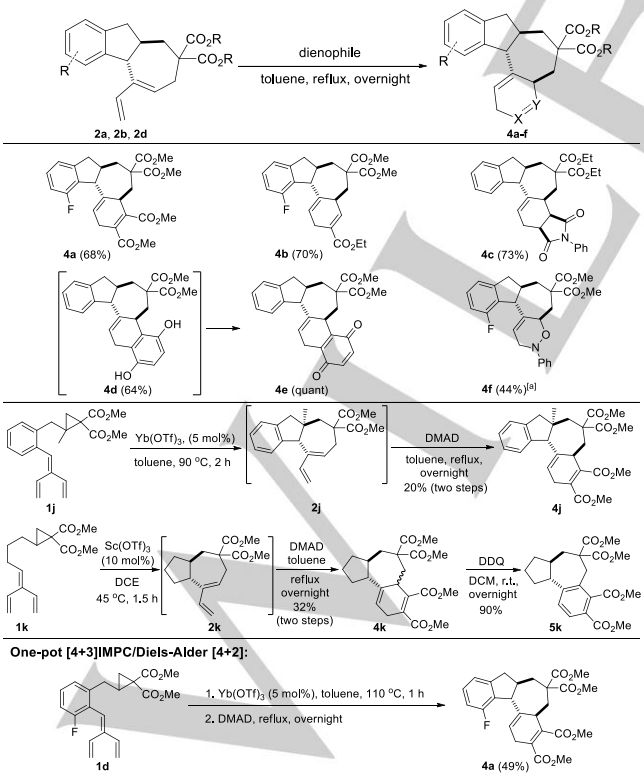
Under the optimal reaction condition, we explored the scope of substrates (Scheme 3). It was found that most of the examples with various substituents on benzene ring gave good yields and regioiselectivities. It should be pointed out that the success of methoxyl-substituted examples may guarantee their potential applications through subsequent dearomatization, e.g. Birch reduction. When cyclopropane and [3]dendralene were assembled on the 1,8-position of a naphthalene ring respectively the reaction proceeded at even lower temperature (60 °C) and with excellent regioiselectivity (**2i**:**3i** > 20:1) and yield (90%). This probably attributes to the rigidity of the naphthalene linker.



Scheme 3. [a] Ratio of **2**/**3**, determined by ^{1}H NMR spectroscopy of the crude product. [b] Combined yield. [c] Reaction temperature was 60 °C.

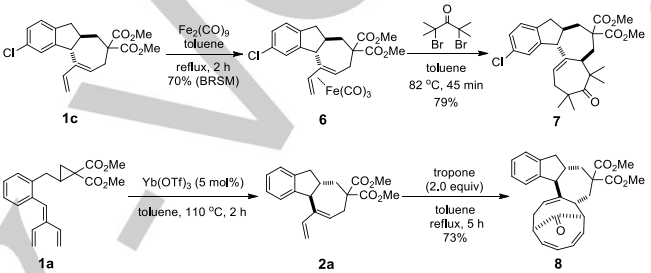
Generation of a diene motif via the [4+3]IMPC provided an excellent opportunity for post-modifications leading to natural

products synthesis or leads discovery. Especially, various [4+n] cycloadditions of diene will provide efficient construction of additional carbocyclic or heterocyclic skeletons. In Scheme 4, Diels–Alder [4+2] cycloaddition of **2d** with dimethylacetylene dicarboxylate (DMAD) afforded **4a** efficiently as a single diastereoisomer. Dienophile ethyl propiolate also worked well with **1d** to afford **4b** as a single isomer, and both the diasteroselectivity and regioselectivity are excellent. When N-phenylmaleimide was used as dienophile with **1b**, **4c** was obtained as a single diastereoisomer[12] in which five new stereocenters were generated with excellent diastereoselectivity. 1,4-Benzoquinone was also used as dienophile with **1a** and **4d** was obtained as a single diastereoisomer. **4d** was not very stable and was quantitatively oxidized to the corresponding quinone **4e** when being exposed to air. A hetero Diels-Alder [4+2] cycloaddition of dienophile nitrosobenzene[13] was also conducted with combination of the [4+3]IMPC of **1d**. Cycloadduct **4f** was successfully obtained with excellent regioselectivity. [4+3]IMPC of substrate **1j** bearing a tetra-substituted cyclopropane also successfully proceed and with a subsequent Diels-Alder [4+2] with DMAD, **4j** was afforded. Under catalysis of $Sc(OTf)_3$ (10 mol%) in DCE at 45 °C, [4+3]IMPC of substrate **1k** with acyclic aliphatic linker also successfully proceed and with a subsequent Diels-Alder [4+2] with DMAD, **4k** was afforded which was further aromatized to **5k** with oxidation by DDQ. In order to make the construction of polycyclic skeletons more efficient, we tried to combine the [4+3]IMPC and the Diels-Alder [4+2] cycloaddition in one-pot. When the [4+3]IMPC of **1d** was completed, DMAD was added and we were glad to find that the reaction proceeded smoothly to give **4a** as a single diastereoisomer.



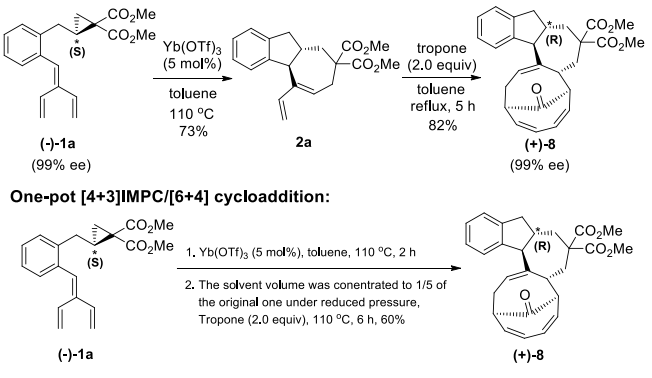
Scheme 4. [a] Solvent was dichloromethane (DCM) and the reaction was conducted at ambient temperature.

Efficient construction of an additional medium-sized ring by cycloadditions of diene is also quite important for both natural products synthesis and leads discovery. To demonstrate this, two examples were exhibited (Scheme 5). **1c** was firstly converted to an Fe-complex **6**[12] and the [4+3]IMPC of which successfully afforded an additional cycloheptane skeleton (**7**) with an excellent diasteroselectivity.[14] The other example is a [6+4] cycloaddition[15] of **2a** with tropone. Pentacylic cycloadduct **8** was obtained as a single diastereoisomer and in an excellent yield.



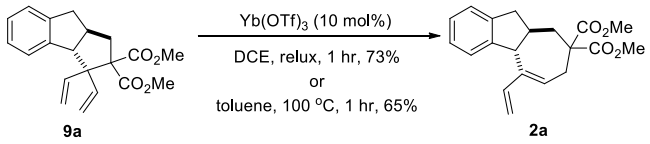
Scheme 5.

To further gain insight into the mechanism of the reaction, we prepared chiral substrate (-)-**1a**. With the combination of [4+3]IMPC of (-)-**1a** and a subsequent [6+4] with tropone, chiral cycloadduct (+)-**8** was successfully obtained (Scheme 6). (+)-**8** was obtained as a single enantiomer in which five new stereogenic centers were generated. The absolute steric configuration of (+)-**8** was unambiguously confirmed by X-ray crystal analysis.[12] This result indicates an S_N2 mechanism in the first ring-opening/cyclization step of [4+3]IMPC, which is similar to our previous reported one.[8d] A one-pot version of this was also successfully carried out and (+)-**8** was obtained in 60%

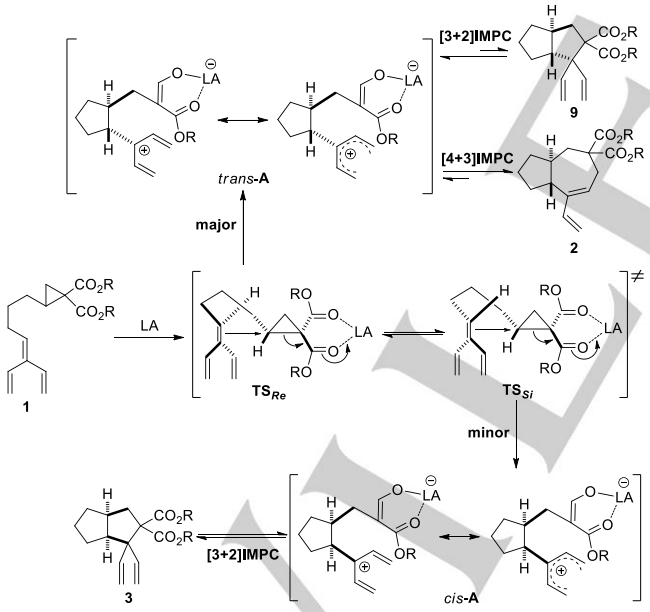


Scheme 6. Asymmetric [4+3]IMPC of **(-)-1a** and subsequent [6+4] cycloaddition.

In the course of optimizing reaction conditions, we found that when the reaction was conducted in DCE at temperature below reflux, besides [4+3]IMPC cycloadduct **2a** and [3+2]IMPC *cis*-cycloadduct **3a**, a third compound **9a** was also observed (Supporting information). With the increase of the reaction temperature to reflux, **9a** disappeared and the ratio of **2a**/**3a** increased which indicated a conversion of **9a** to **2a**. **9a** was isolated and the structure of which was confirmed as a [3+2]IMPC *trans*-cycloadduct. An independent experiment was carried out on **9a** (Scheme 7). It was unambiguously confirmed that **9a** was converted to **2a** either in DCE or toluene. This result implied that *trans*-[3.3.0]octane **9a** was thermodynamically less stable.[16] A synergistic action of the ring strain relief and push-pull effect of double donors (vinyl groups)/double acceptors (ester groups) of *trans*-[3.3.0]octane overcame the difficult formation of 7-membered ring, which led to a ring-opening of cyclopentane followed by a recyclization to afford a cycloheptane.



Scheme 7. Conversion of [3+2]IMPC *trans*-cycloadduct **9a** to [4+3]IMPC cycloadduct **2a**.



Scheme 8. Proposed mechanism.

Based on the above results, a stepwise mechanism was proposed (Scheme 8). The initial step is an S_N2 attack of internal C=C of [3]dendralene to open the cyclopropane ring. Two transition states were involved in this S_N2 attack: $\mathbf{TS_{Re}}$ and $\mathbf{TS_{Si}}$. These two transition states led to intermediates *trans*-**A** and *cis*-**A** respectively and the former one is preferred. The second cyclization goes through either [3+2]IMPC [17] to *trans*-[3.3.0]octane (**9**) or *cis*-[3.3.0]octane (**3**), or [4+3]IMPC to *trans*-[5.3.0]decane. From the preferred intermediate *trans*-**A**, either [3+2]IMPC to **9** or [4+3]IMPC to **2** may happen, however the unstable *trans*-[3.3.0]octane **9** [16] is converted to the thermodynamically more stable **2** through *trans*-**A** and thus the [4+3]IMPC dominates the reaction pathway. Conversion of **9** to **2** may be attributed to a synergistic action of the ring strain relief and push-pull effect of double donors (vinyl groups)/double acceptors (ester groups) of a *trans*-[3.3.0]octane. Quite different from the reported [4+3] cycloaddition reaction modes of D-A cyclopropanes, this is a novel one.

In conclusion, we have successfully developed LA-catalyzed [4+3]IMPC cyclopropane 1,1-diesters with [3]dendralenes. To the best of our knowledge, this is the first intramolecular [4+3] cycloaddition of D-A cyclopropanes in which the donors can be either aromatic or aliphatic functional groups. The [4+3]IMPC reaction mode is also a novel one. By the [4+3]IMPC, a *trans*-[5.3.0]decane skeleton was efficiently constructed. With a combination of the [4+3]IMPC and subsequent [4+n] cycloadditions through either stepwise or one-pot process, *trans*-[5.3.0]decane-derived structurally complex and diverse polycyclic ones could be constructed efficiently. We strongly believe that the developed methods will demonstrate their potential applications to natural products synthesis and leads discovery.

Acknowledgements

We thank NSFC (Nos 21372126, 21572103 and 21421062) for financial support.

Keywords: cyclopropane • cycloaddition • medium-sized ring • polycyclic skeleton • natural products

[1] E. Breitmaier, *Terpenes: Flavors, Fragrances, Pharmaca, Pheromones*, WILEY-VCH, Weinheim, **2006**.

[2] One general review: a) D. A. Foley, A. R. Maguire, *Tetrahedron* **2010**, *66*, 1131. Some other related reviews: b) R. Dorel, A. M. Echavarren, *J. Org. Chem.* **2015**, *80*, 7321; c) N. Nishiwaki, *Methods and Applications of Cycloaddition Reactions in Organic Syntheses*, John Wiley & Sons, Inc., Hoboken, New Jersey, **2014**； d) A. Brandi, S. Cicchi, F. M. Cordero, A. Goti, *Chem. Rev.* **2014** , *114*, 7317; e) L. Jiao, Z. Yu, *J. Org Chem.* **2013**, *78*, 6842; f) P. A. Wender, *Tetrahedron* **2013**, *69*, 7529; g) I. Fernandez, J. L. Mascarenas, *Org. Biomol. Chem.* **2012**, *10*, 699; h) A. Padwa, *Tetrahedron* **2011**, *67*, 8057; i) F. Lopez, J. L. Mascarenas, *Chem. Eur. J.* **2011**, *17*, 418; j) H. Pellissier, *Adv. Syn. Catal.* **2011**, *353* 189; k) A. G. Lohse, R. P. Hsung, *Chem. Eur. J.* **2011**, *17*, 3812; l) W. Zhao, *Chem. Rev.* **2010**, *110*, 1706; m) M. Harmata, *Chem. Commun.* **2010**, *46*, 8904; n) M. Harmata, *Chem. Commun.* **2010**, *46*, 8886; o) H. Butenschon, *Angew. Chem.* **2008**, *120*, 5367; *Angew. Chem. Int. Ed.* **2008**, *47*, 5287; p) V. Nair, T. D. Suja, *Tetrahedron* **2007**, *63*, 12247; q) M. Rubin, M. Rubina, V. Gevorgyan, *Chem. Rev.* **2007**, *107*, 3117; r) M. A. Battiste, P. M. Pelphrey, D. L. Wright, *Chem. Eur. J.* **2006**, *12*, 3438; s) M. Harmata, *Adv. Synth. Catal.* **2006**, *348*, 2297; t) I. Coldham, R. Hufton, *Chem. Rev.* **2005**, *105*, 2765; u) G. Mehta, S. Muthusamy, *Tetrahedron* **2002**, *58*, 9477; v) M. Harmata, *Acc. Chem. Res.* **2001**, *34*, 595; w) L. Yet, *Chem. Rev.* **2000**, *100*, 2963; x) E. J. Kantorowski, M. J.

Kurth, *Tetrahedron* **2000**, *56*, 4317; y) M. Filippini, J. Rodriguez, *Chem. Rev.* **1999**, *99*, 27; z) L. Yet, *Tetrahedron* **1999**, *55*, 9349; aa) G. A. Molander, *Acc. Chem. Res.* **1998**, *31*, 603; ab) M. Harmata, *Tetrahedron* **1997**, *53*, 6235; ac) M. Ramaiah, *Synthesis* **1984**, 529.

[3] Representative natural products: **Presphaerol**: a) J. Lee, J. Hong, *J. Org. Chem.* **2004**, *69*, 6433; b) F. Cafieri, E. Fattorusso, B. di Blasio, C. Redone, *Tetrahedron Lett.* **1981**, *22*, 4123; c) F. Cafieri, L. de Napoli, E. Fattorusso, M. Piattelli, S. Sciuto, *Tetrahedron Lett.* **1979**, *20*, 963; **Englerins**: d) G. Yue, Q. Huang, P. Zou, *Chin. Prog. Chem.* **2012**, *24*, 1742; e) Y. Lu, H. Yao, B. Sun, *Chin. J. Org. Chem.* **2012**, *32*, 1; f) R. H. Pouwer, J.-A. Richard, C.-C. Tseng, D. Y.-K. Chen, *Chem. Asian J.* **2012**, *7*, 22; g) W. J. Chain, *Synlett* **2011**, 2605; **Daphniphyllum alkaloids**: h) J. Kobayashi, T. Kubota, *Nat. Prod. Rep.* **2009**, *26*, 936; i) Z. Li, Y. Guo, *Chin. J. Org. Chem.* **2007**, *27*, 565; j) C. H. Heathcock, *Angew. Chem.* **1992**, *104*, 675; *Angew. Chem. Int. Ed.* **1992**, *31*, 665; **Sordarin**: k) H. Liang, M. Ciufolini, *Org. Prep. Proced. Int.* **2010**, *42*, 111; l) H, Liang, *Beilstein J. Org. Chem.* **2008**, *4*, 1.

[4] Selected reviews: a) V. A. Rassadin, Y. Six, *Tetrahedron* **2016**, *72*, 4701; b) H. K. Grover, M. R. Emmett, M. A. Kerr, *Org. Biomol. Chem.* **2015**, *13*, 655; c) R. A. Novikov, Y. V. Tomilov, *Mendeleev Commun.* **2015**, *25*, 1; d) F. de Nanteuil, F. De Simone, R. Frei, F. Benfatti, E. Serrano, J. Waser, *Chem. Commun.* **2014**, *50*, 10912; e) M. A. Cavitt, L. H. Phun, S. France, *Chem. Soc. Rev.* **2014**, *43*, 804; f) T. F. Schneider, J. Kaschel, D. B. Werz, *Angew. Chem.* **2014**, *126*, 5608; *Angew. Chem. Int. Ed.* **2014**, *53*, 5504; g) Y. Wang, J. J. Yin, *Chem. Reagents* **2013**, *35*, 318; h) Z. Wang, *Synlett* **2012**, *23*, 2311; i) P. Tang, Y. Qin, *Synthesis* **2012**, *44*, 2969; j) M. Y. Mel'nikov, E. M. Budynina, O. A. Ivanova, I. V. Trushkov, *Mendeleev Commun.* **2011**, *21*, 293; k) T. P. Lebold, M. A. Kerr, *Pure Appl. Chem.* **2010**, *82*, 1797; l) M. J. Campbell, J. S. Johnson, A. T. Parsons, P. D. Pohlhaus, S. D. Sanders, *J. Org. Chem.* **2010**, *75*, 6317; m) C. A. Carson, M. A. Kerr, *Chem. Soc. Rev.* **2009**, *38*, 3051; n) F. De Simone, J. Waser, *Synthesis* **2009**, 3353; o) D. Agrawal, V. K. Yadav, *Chem. Commun.* **2008**, 6471; p) M. Yu, B. L. Pagenkopf, *Tetrahedron* **2005**, *61*, 321; q) H.-U. Reissig, R. Zimmer, *Chem. Rev.* **2003**, *103*, 1151; r) H. N. C. Wong, M.-Y. Hon, C.-W. Tse, Y.-C. Yip, J. Tanko, T. Hudlicky, *Chem. Rev.* **1989**, *89*, 165; s) E. Wenkert, *Acc. Chem. Res.* **1980**, *13*, 27; t) S. Danishefsky, *Acc. Chem. Res.* **1979**, *12*, 66. A special issue on D-A cyclopropanes (edited by H.-U. Reissig and D. B. Werz): u) I. V. Trushkov, *Israel J. Chem.* **2016**, *56*, 369; v) A. A. Tabolin, S. L. Ioffe, *Israel J. Chem.* **2016**, *56*, 385; w) Y. Deng, M. P. Doyle, *Israel J. Chem.* **2016**, *56*, 399; x) C. Lin, B. Plietker, *Israel J. Chem.* **2016**, *56*, 409; y) V. Ganesh, P. Sridhar, S. Chandrasekaran, *Israel J. Chem.* **2016**, *56*, 417; z) N. R. O'Connor, J. L. Wood, B. M. Stoltz, *Israel J. Chem.* **2016**, *56*, 431; aa) R. Talukdar, A. Saha, M. K. Ghorai, *Israel J. Chem.* **2016**, *56*, 445; ab) T. Selvi, K. Srinivasan, *Israel J. Chem.* **2016**, *56*, 454; ac) L. Wang, Y. Tang, *Israel J. Chem.* **2016**, *56*, 463; ad) M. A. Kerr, *Israel J. Chem.* **2016**, *56*, 476; ae) M. C. Martin, R. Shenje, S. France, *Israel J. Chem.* **2016**, *56*, 499; af) A. K. Pandey, A. Ghosh, P. Banerjee, *Israel J. Chem.* **2016**, *56*, 512; ag) O. Reiser, *Israel J. Chem.* **2016**, *56*, 531; ah) T. Hudlicky, *Israel J. Chem.* **2016**, *56*, 540.

[5] a) C. Galli, L. Mandolini, *Eur. J. Org. Chem.* **2000**, *2000*, 3117; b) G. Illuminati, L. Mandolini, *Acc. Chem. Res.* **1981**, *14*, 95; c) M. A. Winnik, *Chem. Rev.* **1981**, *81*, 491.

[6] [3+2] cycloadditions of D-A cyclopropanes with dienes under various conditions: a) A. G. Amador, E. M. Sherbrook, T. P. Yoon, *J. Am. Chem. Soc.* **2016**, *138*, 4722; b) E. M. Budynina, O. A. Ivanova, A. O. Chagarovskiy, Y. K. Grishin, I. V. Trushkov, M. Ya. Melnikov, *J. Org. Chem.* **2015**, *80*, 12212; c) C. Wang, X. Ren, H. Xie, Z. Lu, *Chem. Eur. J.* **2015**, *21*, 9676; d) S. Racine, F. de Nanteuil, E. Serrano, J. Waser, *Angew. Chem.* **2014**, *126*, 8624; *Angew. Chem. Int. Ed.* **2014**, *53*, 8484; e) J. Fang, J. Ren, Z. Wang, *Tetrahedron Lett.* **2008**, *49*, 6659; f) P. G. Gassman, R. J. Riehle, *J. Am. Chem. Soc.* **1989**, *111*, 2319.

[7] a) O. A. Ivanova, E. M. Budynina, Y. K. Grishin, I. V. Trushkov, P. V. Verteletskii, *Angew. Chem.* **2008**, *120*, 1123; *Angew. Chem. Int. Ed.* **2008**, *47*, 1107; b) O. A. Ivanova, E. M. Budynina, Y. K. Grishin, I. V. Trushkov, P. V. Verteletskii, *Eur. J. Org. Chem.* **2008**, 5329; c) A. O. Chagarovskiy, O. A .Ivanova, E. M. Budynina, E. L. Kolychev, M. S. Nechaev, I. V. Trushkov, M. Ya. Mel'nikov, *Russ. Chem. Bull.* **2013**, *62*, 2407; d) H. Xu, J. Hu, L. Wang, S. Liao, Y. Tang, *J. Am. Chem. Soc.* **2015**, *137*, 8006. A hetero-[4+3] cycloaddition: e) L. K. B. Garve, M. Pawliczek, J. Wallbaum, P. G. Jones, D. B. Werz, *Chem. Eur. J.* **2016**, *22*, 521. A Palladium-catalyzed example: f) R. Shintani, M. Murakami, T. Tsuji, H. Tanno, T. Hayashi, *Org. Lett.* **2009**, *11*, 5642.

[8] a) Z. Wang, S. Chen, J. Ren, Z. Wang, *Org. Lett.* **2015**, *17*, 4184; b) W. Ma, J. Fang, J. Ren, Z. Wang, *Org. Lett.* **2015**, *17*, 4180; c) J. Zhang, S. Xing, J. Ren, S. Jiang, Z. Wang, *Org. Lett.* **2015**, *17*, 218; d) W. Zhu, J. Ren, Z. Wang, *Eur. J. Org. Chem.* **2014**, *2014*, 3561; e) J. Ren, J. Bao, W. Ma, Z. Wang, *Synlett* **2014**, *25*, 2260; f) W. Zhu, J. Fang, Y. Liu, J. Ren, Z. Wang, *Angew. Chem.* **2013**, *125*, 2086; *Angew. Chem. Int. Ed.* **2013**, *52*, 2032; g) Z. Wang, J. Ren, Z. Wang, Org. Lett. **2013**, *15*, 5682 h) Y. Bai, W. Tao, J. Ren, Z. Wang, *Angew. Chem.* **2012**, *124*, 4188; *Angew. Chem. Int. Ed.* **2012**, *51*, 4112 ; i) S. Xing, Y. Li, Z. Li, C. Liu, J. Ren, Z. Wang, *Angew. Chem.* **2011**, *123*, 12813; *Angew. Chem. Int. Ed* **2011**, *50*, 12605 ; j) S. Xing, W. Pan, C. Liu, J. Ren, Z. Wang, *Angew. Chem.* **2010**, *122*, 3283; *Angew. Chem. Int. Ed.* **2010**, *49*, 3215 ; k) B. Hu, S. Xing, J. Ren, Z. Wang, *Tetrahedron* **2010**, *66*, 5671.

[9] a) W. J. Bailey, J. Economy, *J. Am. Chem. Soc.* **1955**, *77*, 1133; b) W. J. Bailey, C. H. Cunov, L. Nicholas, *J. Am. Chem. Soc.* **1955**, *77*, 2787.

[10] Reviews on dendralenes: a) M. S. Sherburn, *Acc. Chem. Res.* **2015**, *48* 1961; b) H. Hopf, M. S. Sherburn, *Angew. Chem.* **2012**, *124*, 2346; *Angew. Chem. Int. Ed.* **2012**, *51*, 2298; c) H. Hopf, *Angew. Chem.* **2001** *113*, 727; *Angew. Chem. Int. Ed.* **2001**, *40*, 705; d) J. D. Winkler, *Chem. Rev.* **1996**, *96*, 167; e) H. Hopf, *Angew. Chem.* **1984**, *96*, 947; *Angew. Chem. Int. Ed.* **1984**, *23*, 948.

[11] S. Woo, N. Squires, A. G. Fallis, *Org. Lett.* **1999**, *1*, 573.

[12] CCDC 1499504 ((+)-**8**), 1499506 (**4c**) and 1499505 (**6**) contain the supplementary crystallographic data for this paper. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/data_request/cif.

[13] A. Anand, G. Bhargava, P. Singh, M. P. Mahajan, *Heterocycles* **2009**, *77*, 547.

[14] H. Takaya, S. Makino, Y. Hayakawa, R. Noyori, *J. Am. Chem. Soc.* **1978**, *100*, 1765.

[15] J. H. Rigby, *Org. React.* **1997**, *49*, 331.

[16] H. L. Gordon, S. Freeman, T. Hudlicky, *Synlett* **2005**, *19*, 2911.

[17] A $EtAlCl_2$-promoted [3+2]IMPC with 1,1-dimethyl alkene was reported: R B. Beal, M. A. Dombroski, B. B. Snider, *J. Org. Chem. 1986*, **51**, 4391.

10.1002/chem.201605190

WILEY-VCH

Entry for the Table of Contents (Please choose one layout)

Layout 1:

COMMUNICATION

Text for Table of Contents

((Insert TOC Graphic here))

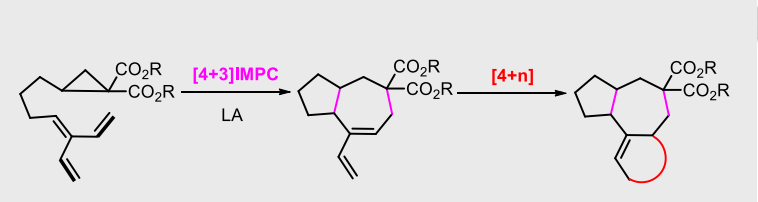
*Author(s), Corresponding Author(s)**

Page No. – Page No.

Title

Layout 2:

COMMUNICATION



*Author(s), Corresponding Author(s)**

Page No. – Page No.

Intramolecular Parallel [4 + 3] Cycloadditions of Cyclopropane 1,1-Diesters with [3]Dendralenes: Efficient Construction of [5.3.0]decane and Corresponding Polycyclic Skeletons

[4+3]IMPC of cyclopropane 1,1-diesters with [3]dendralenes have been successfully developed. With a combination of the [4+3]IMPC and subsequent [4+n] cycloadditions, *trans*-[5.3.0]decane skeleton and its corresponding structurally complex and diverse polycyclic ones could be constructed efficiently.