

## 一株寄生蛴螬的被毛孢新种

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**摘要:**【目的】对寄生鞘翅目幼虫蛴螬的虫生真菌标本 GZUIFR-lgs-1 进行描述和鉴定。【方法】基于形态特征比较结合系统发育分析进行鉴定。【结果】该种通过形态特征产孢细胞单生,透明,多数与营养菌丝成近直角,基部具疣且明显膨大(19–27)  $\mu\text{m}\times(2.7\text{--}3.6)\ \mu\text{m}$ ,颈部长(12.0–14.5)  $\mu\text{m}$ ,顶端呈螺旋状扭曲,偶有再育;分生孢子透明、光滑,橘瓣状,单生或偶有双生,外具黏液,大小为(4.8–6.0)  $\mu\text{m}\times(2.4\text{--}3.6)\ \mu\text{m}$ ,而与被毛孢属已知种相区别。基于 ITS 位点的系统发育分析支持形态学鉴定的结果。【结论】综合形态特征比较及系统发育分析结果,该种为被毛孢属的一个新的分类单元,命名为雷公山被毛孢, *Hirsutella leigongshanensis*。

**关键词:** 虫生真菌, 被毛孢, 新种, 蛴螬

### A new *Hirsutella* species parasitic on grub larvae (*Coleoptera*)

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**Abstract:** [Objective] A new entomogenous fungi (GZUIFR-lgs-1), which was parasitic on grub larvae was identified and described. [Methods] The analysis mainly based on phenotypic characteristics and molecular phylogeny. [Results] The strain distinguished from the other *Hirsutella* species by phialides solitary, hyaline, occasionally proliferation and near right angle to hyphae, with distinctly swollen and verrucose base (19–27)  $\mu\text{m}\times(2.7\text{--}3.6)\ \mu\text{m}$ , twisting in helices at the apex, neck (12.0–14.5)  $\mu\text{m}$  long; Conidia hyaline and smooth in mucous sheath, like orange segments (4.8–6.0)  $\mu\text{m}\times(2.4\text{--}3.6)\ \mu\text{m}$ , single or occasionally in pairs. The result of phylogenetic analysis based on ITS loci supported the morphological identification. [Conclusion] The specimen GZUIFR-lgs-1 is a new species in the genus *Hirsutella*, supported by the phenotypic traits and molecular analysis, named *Hirsutella leigongshanensis*.

**Keywords:** Entomogenous fungi, *Hirsutella*, New taxonomy, Grub

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被毛孢属 *Hirsutella* Pat 是 Patouillard 于 1892 年以嗜虫被毛孢 *Hirsutella entomophila* Pat. 为模式标本建立的<sup>[1]</sup>。迄今为止, 共有 109 个被毛孢属真菌分类单元收录于 Index Fungorum (<http://www.indexfungorum.org>) 中, 被毛孢的有性阶段属于线虫草属 *Ophiocordyceps* Petch<sup>[2]</sup>。被毛孢属的主要形态特征为: 孢梗束有或无, 一般呈柱状或丝状, 单生或具分枝; 菌丝颜色呈无色、淡色乃至深褐色; 产孢细胞散生于菌丝体上或侧生于孢梗束外围菌丝上, 瓶梗表面光滑或粗糙, 颈部结构简单或再育, 颈部通常直, 部分种顶端呈波浪状弯曲或螺旋状扭曲; 分生孢子通常为单细胞, 少数为多细胞, 呈柠檬形、椭圆形、梭形或橘瓣形等形状, 部分种分生孢子表面具有无色或有色的黏液层, 单个或数个分生孢子包裹于一黏液鞘中; 少数种能产生二次分生孢子<sup>[3-4]</sup>。

被毛孢属真菌的部分种具有药用价值, 名贵中药材冬虫夏草的无性型就是中国被毛孢 *Hirsutella sinensis*<sup>[5-6]</sup>。研究发现, 从被毛孢属真菌中提取的多种活性物质具有保肾益肺<sup>[7-8]</sup>、抗癌<sup>[9-12]</sup>、镇静促眠<sup>[13]</sup>、改善心脑血管循环<sup>[14]</sup>等作用。被毛孢属真菌寄主范围包括蛛形纲、昆虫纲以及线虫纲等动物, 具有一定的生物防治价值<sup>[15-21]</sup>。文中对被毛孢这类重要虫生真菌资源中的一个种进行了菌株分离和鉴定。

## 1 材料与方法

### 1.1 材料

标本: 寄主为鞘翅目昆虫蛴螬的幼虫, 邹晓于 2010 年 06 月采自贵州省雷山县雷公山, 标本号为 GZUIFR-lgs-1。标本及其分离株均保存于贵州大学真菌资源研究所。

棉蓝染色液: 苯胺蓝(水溶) 2.5 g, 乳酸(密度 1.20 g/mL) 10.0 g, 石炭酸(结晶) 10.0 g, 甘油(密度 1.25 g/mL) 20.0 g, 蒸馏水 10 mL, 配制完后用双层擦镜纸过滤后备用<sup>[22]</sup>。

分离用马铃薯葡萄糖琼脂培养基(简称 PDA)<sup>[22]</sup>。

鉴定用察氏培养基(Czapek)<sup>[22]</sup>。

### 1.2 主要试剂和仪器

D3195-01 HP Fungal DNA 试剂盒, Omega 公司; 其余为国产分析纯。BK5000Motic 显微镜, 重庆奥特光学仪器有限公司; TC-96 PCR 仪, 杭州博日科技有限公司; MicroCL 17 高速离心机, 美国赛默飞世尔科技公司; DYY-10C 水平电泳仪, 北京六一仪器厂; Master-D Hitech-Sciencetool 超纯水机, 上海和泰仪器公司。

### 1.3 方法

菌株分离与培养: 以清水将标本表面冲洗干净, 将标本虫体表面以 75% 的乙醇消毒 3-5 s, 用无菌镊子撕开标本虫体表皮至内部组织露出, 用接种针挑取少量内菌核组织块置于灭菌的 PDA 培养基上, 22-24 °C 培养 42 d 后观察菌落形态特征并镜检其微观形态特征, 选取单菌落作为保存菌株<sup>[23]</sup>。

制片观察: 将分离所得菌株接种于 Czapek 培养基上, 22 °C 培养 42 d 后, 透明胶带粘取菌落边缘菌丝, 95% 乙醇固定 5 s, 棉兰染色液染色 30 min 以上, 在显微镜下进行微观形态观察和描述<sup>[24]</sup>。

ITS 序列扩增与分析: 提取 DNA 后<sup>[25]</sup>, 以所提 DNA 为模板, 选用通用引物 ITS5 (5'-GGTGAGA GATTCTGTG-3') 和 ITS4 (5'-TCCTCCGCTTATTG ATATGC-3') 对 ITS 区的 rDNA 片段进行 PCR 扩增, 将扩增产物送上海 Invitrogen 公司纯化测序<sup>[26]</sup>。

ITS1-5.8S-ITS2 系统发育分析: 测序结果经 BioEdit 软件分析及手工校正, 提交到 GenBank; 将测序所得序列于 NCBI 数据库进行 BLAST 比对, 导出相似度大于 85% 的序列, 结合其它与雷公山被毛孢形态相似种的序列, 采用 ClustalX 2.1 软件的 Alignment 程序进行系统发育分析, 使用 MEGA 6.0 软件设置条件为邻接法(N-J)、重复次数(Replications) 1 000 构建系统发育树。使用 SplitsTree4 (<http://www.splitstree.org>) 软件进行 Neighbor Net 发育网络分析。以球孢白僵菌 *Beauveria bassiana* 作为外群, 系统学分析所用序列及其 GenBank 登录号如表 1 所示。

表 1 构建系统发育树所用序列名称及其 GenBank 登录号

Table 1 GenBank accession numbers used for phylogenetic analysis

名称 Name	GenBank 登录号 GenBank accession No.
<i>H. subulata</i>	KJ524684
<i>H. aphidis</i>	EF194156
<i>H. tunicat</i>	JN247824
<i>H. satumaensis</i>	KJ913066
<i>H. leigongshanensis</i>	KU986637
<i>H. nodulosa</i>	KM652165
<i>H. liboensis</i>	KM652163
<i>H. vermicola</i>	DQ345592
<i>H. lecanicola</i>	KM652162
<i>H. kirchneri</i>	EF194154
<i>H. illustris</i>	KM652160
<i>H. tortricicola</i>	KT368152
<i>H. sinensis</i>	AJ309353
<i>H. rhossiliensis</i>	AB109760
<i>H. huangshanensis</i>	EF689043
<i>O. coccidiicola</i>	AB968404
<i>O. agriotidis</i>	AB968403
<i>O. rubiginosiperitheciata</i>	AB294423
<i>O. acicularis</i>	JN049820
<i>O. arborescens</i>	AB968399
<i>C. agriota</i>	AY245626
<i>C. emeiensis</i>	AJ309347
<i>B. bassiana</i>	DQ364698

Note: *H.*: *Hirsutella*; *O.*: *Ophiocordyceps*; *C.*: *Cordyceps*; *B.*: *Beauveria*.

## 2 结果与分析

### 2.1 形态学描述

#### 雷公山被毛孢新种图 1

*Hirsutella leigongshanensis* X. Zou, L.Q. Yu, Y.F. Han & Z.Q. Liang sp. nov. Fig1

GenBank : KU986637

菌落在察氏培养基上, 22–24 °C, 生长较慢, 42 d 直径为 15 mm–18 mm, 平展絮状、浅黄, 背面

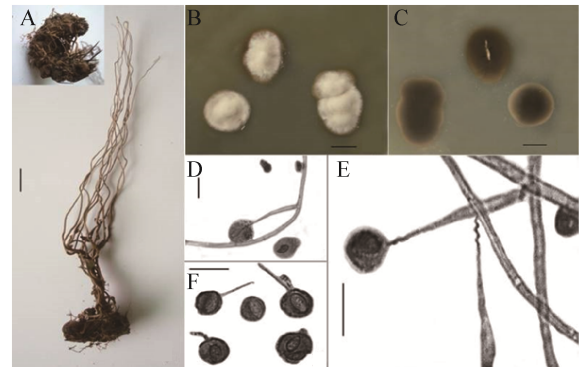


图 1 雷公山被毛孢无性阶段产孢结构和菌落特征图

Figure 1 Conidiogenous structures and colonies of the anamorph of *Hirsutella leigongshanensis*

注: A: 标本(GZUIFR-lgs-1); B–C: 菌落; D–F: 产孢结构和孢子。(标尺: A–C=10 mm, D–F=5 μm).

Note: A: Specimen (GZUIFR-lgs-1); B–C: Colonies; D–F: Conidial fructification and conidia. (Bar: A–C=10 mm, D–F=5 μm).

分泌黑色色素; 产孢细胞透明、单生, 多数与营养菌丝成近直角, 偶有再育, 基部明显膨大且具疣(19–27) μm×(2.7–3.6) μm, 颈部长 12 μm–14.5 μm、顶端突然变细呈螺旋状弯曲(8–9) μm×0.8 μm; 分生孢子透明、光滑、橘瓣状, 单生或偶有双生, 外具黏液, 大小为(4.8–6.0) μm×(2.4–3.6) μm。

有性型: 一种线型虫草

寄主: 蛴螬幼虫(鞘翅目)

语义学: 来源于标本采集地

模式标本: GZUIFR-lgs-1, 保存于贵州大学真菌资源研究所保藏中心(GZAC)。

分布: 贵州省雷山县雷公山

On Czapek-Dox agar, 22–24 °C, colonies growing slowly, diam up to 15 mm–18 mm after 42 d, colonies flat and flocculent, light yellow, black coloring secreted on the back. Phialides solitary, hyaline, occasionally proliferation and near right angle to hyphae, with distinctly swollen and verrucose base (19–27) μm×(2.7–3.6) μm, twisting in helices at the apex, neck 12 μm–14.5 μm long; Conidia hyaline and smooth in mucous sheath, like orange segments (4.8–6.0) μm×(2.4–3.6) μm, single or occasionally in pairs.

Teleomorph: A species of *Ophiocordyceps*

Host: Grub larva (*Coleoptera* sp.)

Holotype: GZUIFR-lgs-1, deposited in the Institute of Fungus Resources, Guizhou University (GZAC).

Etymology: *leigongshanensis*, referring to the collection location.

Locality: Leigongshan, Leishan County, Guizhou Province, China.

### 2.2 分子鉴定结果

使用 ITS 序列构建系统发育树(图 2)和 NeighborNet Splits Graph 分支网络图(图 3)。系统发育树和 NeighborNet Splits Graph 网络图中所有产孢细胞颈部有螺旋扭曲或波浪状弯曲结构的种都聚在一起,在系统发育树中新种雷公山被毛孢与 *Ophiocordyceps acicularis* 聚于同一分支,支持率为 81%。

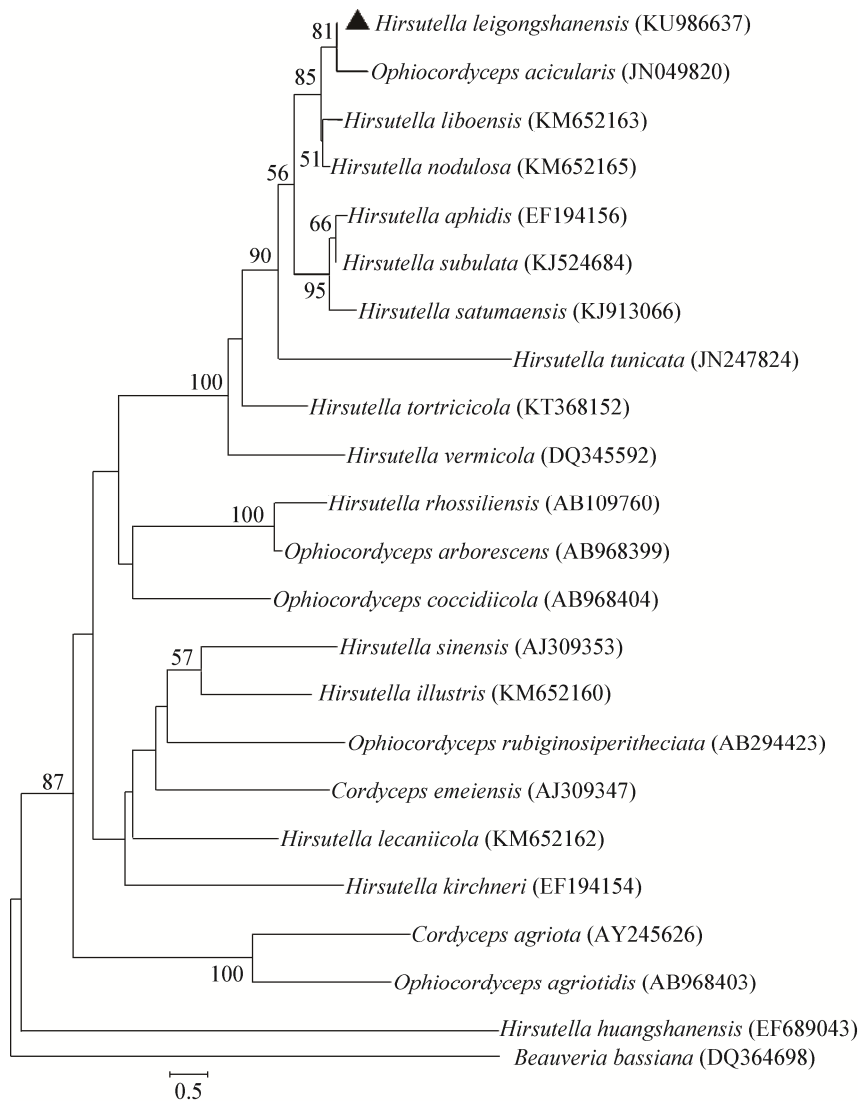


图 2 基于 rDNA ITS1-5.8S-ITS2 序列对 *Hirsutella leigongshanensis* 及一些相关种构建的进化树(NJ)

Figure 2 Phylogenetic tree based on rDNA ITS1-5.8 s-ITS2 sequences of *Hirsutella leigongshanensis* and its related species (NJ)  
注: 分支点数值是基于邻接法重复分析数据1 000次后的自律值(>50%); 括号内数值为GenBank的登录号; 标尺0.5表示序列差异的分支长度.

Note: Numbers at nodes indicate the bootstrap values (>50%) based on Neighbour-Joining analyses of 1 000 resampled datasets; Numbers in parentheses are GenBank accession numbers; Bar: 0.5 are nucleotide divergence.

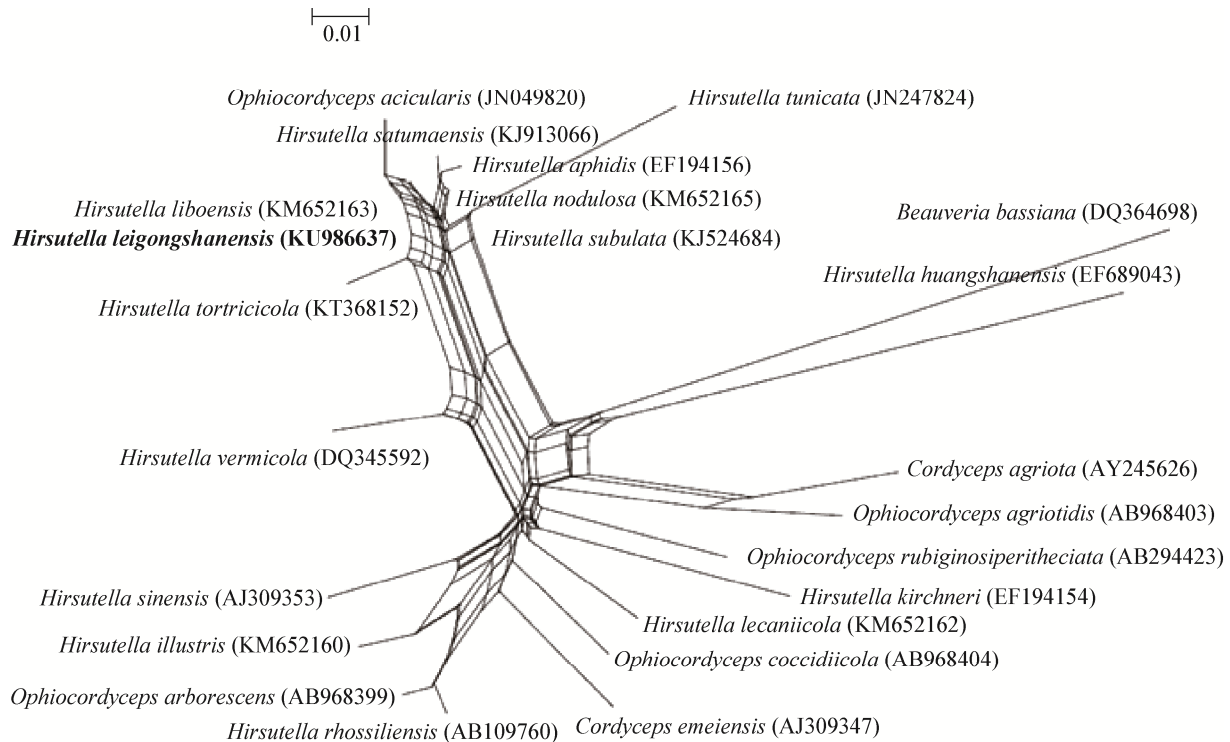


图3 基于表1序列构建的NeighborNet Splits Graph分支网络图

Figure 3 Reconstructure of the NeighborNet Splits Graph from Table 1

注：括号内数字表示序列 GenBank 登录号；标尺为进化距离。

Note: The GenBank accession numbers of aligned sequences are shown in the brackets; Bar: Nucleotide divergence.

### 3 讨论

已发表的产孢细胞颈部有螺旋扭曲或波浪状弯曲结构特征的被毛孢迄今为止共有10个：*H. liboensis* X. Zou, A.Y. Liu & Z.Q. Liang<sup>[15]</sup>, *H. leizhouensis* H.M. Fang & S.M. Tan<sup>[17]</sup>, *H. vermicola* M.C. Xiang & Xing Z. Liu<sup>[27]</sup>, *H. brownorum* Minter & B.L. Brady<sup>[28]</sup>, *H. satumaensis* Aoki<sup>[23,29]</sup>, *H. aphidis* Petch<sup>[30-31]</sup>, *H. dendritica* Samson & H.C. Evans<sup>[32]</sup>, *H. parasitica* Samson & H.C. Evans<sup>[32]</sup>, *H. nodulosa* Petch<sup>[33]</sup>, *H. tortricicola* Zou<sup>[24]</sup>。在系统发育树和NeighborNet Splits Graph分支网络图中雷公山被毛孢都与颈部具有螺旋或扭曲结构的被毛孢*H. liboensis*, *H. vermicola*, *H. satumaensis*, *H. aphidis*, *H. nodulosa*, *H. tortricicola*聚在一起,说明这些种之间不仅在形态上具有瓶梗颈部螺旋或扭曲的共同特征,在分子系统发育中也具有较近

的亲缘关系,此前已有研究将颈部螺旋或扭曲的结构作为被毛孢形态分类的鉴别特征<sup>[3,24,28,34]</sup>,由于产孢细胞颈部不具螺旋的种与雷公山被毛孢产孢细胞颈部具螺旋的形态特征不符,因此本文首先将产孢细胞颈部无螺旋的种予以排除,再与产孢细胞颈部具有螺旋结构的种进行详细对比加以区分鉴定。雷公山被毛孢及其近似种形态对比如表2所示。

通过与近似种进行形态特征比较发现雷公山被毛孢与*H. satumaensis*的产孢结构较为相似,主要差别在于雷公山被毛孢瓶梗基部明显膨大,而*H. satumaensis*瓶梗为柱状膨大,且在分子系统发育树中雷公山被毛孢与*H. satumaensis*分别聚于不同的独立分支,从而可以将两者区分开来;在分子系统发育树中雷公山被毛孢与针孢虫草*Ophiocordyceps acicularis*聚于同一分支,亲缘关系较近,但支持率仅为81%,依据分子系统学原则可将两者判定为不同的种。

表 2 *Hirsutella leigongshannensis* 与近似种的形态比较  
Table 2 Morphological comparison between *Hirsutella leigongshannensis* and its similar species

种名 Name	瓶梗 Phialide	分生孢子 Conidia	寄主 Host	参考文献 Reference
<i>H. liboensis</i>	单生, 光滑, 颈部有螺旋扭曲	长梭形, 外具黏液, (6-10) μm×(1.5-4) μm	鳞翅目	[15]
<i>H. leizhouensis</i>	两型瓶梗	近卵形偶有桔瓣状, (3.5-4.5) μm×(2-3) μm	蔗褐蠹蛾	[17]
<i>H. vermicola</i>	单生或对立	椭圆形或橘瓣形, (7-8) μm×(1.5-3) μm	线虫	[27]
<i>H. brownorum</i>	非聚生, 颈部有螺旋扭曲	柠檬形, (5-6) μm×(4-5) μm	螨	[23,28]
<i>H. satumaensis</i>	颈部有螺旋扭曲, 基部具疣瘤并柱状膨大	单生, 船形或橘瓣状, (6-7) μm×(2.7-3) μm	家蚕	[23,29]
<i>H. aphidis</i>	两型瓶梗	两型分生孢子	同翅目蚜科	[30-31]
<i>H. nodulosa</i>	颈部有螺旋扭曲, 具疣瘤	柠檬形或橘瓣状, 具黏液, (4-7) μm×(3-4) μm	螨	[33]
<i>H. parasitica</i>	颈部波浪状弯曲	圆筒状, 无黏液, (14-25) μm×(2.5-4) μm	蚜虫	[32]
<i>H. dendritica</i>	颈部修长, 有波浪状弯曲	梭形, 无黏液, (6-8) μm×(2-3) μm	鳞翅目蛹	[32]
<i>H. tortricicola</i>	单生, 基部球形膨大, 颈部末端具1-2个螺旋	椭圆形或橘瓣状, 具黏液, (2.7-3.6) μm×(1.4-1.8) μm	鳞翅目, 卷叶蛾幼虫	[24]
<i>H. leigongshannensis</i>	单生, 基部具疣并明显膨大, 颈部有螺旋扭曲	单生或双生, 橘瓣形, 外具黏液, (4.8-6) μm×(2.4-3.6) μm	鞘翅目蛴螬幼虫	本文

结合形态特征比较以及系统分析结果, 将雷公山被毛孢鉴定为一个新的分类单元, 命名为 *Hirsutella leigongshanensis* X. Zou, L.Q. Yu, Y.F. Han & Z.Q. Liang sp. nov.

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