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A new genus and species of Encyrtidae (Hymenoptera: Chalcidoidea) with a four-segmented funicle from late Eocene Baltic amber

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Abstract

Electrocerus brevifuniculatus Simutnik **gen. et sp. nov.** is described and illustrated based on a female specimen from late Eocene Baltic amber. Placement of the new genus in the subfamily Encyrtinae is supported by the presence of a filum spinosum on the linea calva and the hypopygium not reaching the metasomal apex. A key to the genera of late Eocene Encyrtinae is provided. The new taxon differs from all known extinct and most extant encyrtids by its four-segmented female funicle.

Key words: Fossil, Encyrtinae, key, European ambers, *Electrocerus brevifuniculatus*

Introduction

Chalcidoidea are an extraordinarily diverse superfamily of mostly parasitoid wasps, comprising an estimated 500,000 species worldwide with over 22,500 species described so far (Heraty 2009; Heraty *et al.* 2013; Noyes 2019). Within this superfamily, Encyrtidae stand out as one of the largest families, containing 5,100 described species (Noyes 2023). Many of the encyrtids parasitize mealybugs (Hemiptera: Pseudococcidae), but the family has a wide range of other hosts, including scale insects, beetles, cockroaches, flies, hymenopterans, heteropterans, lepidopterans, neuropterans, tick nymphs, and spider eggs (Trjapitzin 1989; Noyes 2019). The presence of Encyrtidae in Eocene ambers is well documented, with the earliest known specimens found in middle Eocene Sakhalinian amber (Simutnik 2014, 2021). To date, some 19 species in 17 extinct genera of Encyrtidae have been described from Baltic, Danish, and Rovno ambers (Simutnik *et al.* 2021a; 2022c, d; Simutnik & Perkovsky 2023).

Researchers have found that classifying Chalcidoidea families is much more difficult and complex than once thought (Cruaud *et al.* 2023). At the same time, the monophyly of Encyrtidae is much clearer and supported by all modern methods of phylogenetic reconstruction (Munro *et al.,* 2011; Heraty *et al.* 2013; Peters *et al.* 2018). Trjapitzin (1968, 1989) proposed a classification that divided the family into two subfamilies. This is the most practical division proposed to date, but there seems little doubt that while the subfamily Tetracneminae is monophyletic, the Encyrtinae present a paraphyletic assemblage (Noyes & Hayat 1994; Noyes 2004).

Because all known Eocene encyrtids are full-winged, the presence or absence of a filum spinosum (*fs*) (Figs 1, 2, 4: fs) makes it almost certain that the identified specimens can be assigned to one of two still-valid extant subfamilies. The presence of a *fs* (which is one of the main features of Encyrtinae: Trjapitzin 1968) apical to the linea calva of the forewing has been found in late Eocene ambers, but not from middle Eocene Sakhalinian amber (Simutnik 2014; Simutnik 2021; Simutnik *et al.* 2021b). To date, seven species in seven extinct genera of Encyrtidae with *fs* have been described from Baltic, Danish, and Rovno ambers: *Glaesus gibsoni* Simutnik, 2014; *Rovnosoma gracile* Simutnik, 2015; *Protocopidosoma kononovae* Simutnik, 2017; *Dencyrtus vilhelmseni* Simutnik, 2018;

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Efesus trufanovi Simutnik, 2020; *Ektopicercus punctatus* Simutnik, 2020; and *Protaphycus shuvalikovi* Simutnik, 2022. We describe another one in the present paper and provide a key to described genera of Eocene Encyrtinae from European ambers. The new taxon, like all previously described Eocene Encyrtidae, is characterized by a long marginal and stigmal vein in the forewing, a distinctly thickened parastigma, a short radicle, and a seta on the apex of the postmarginal vein not longer than any other on this vein. It differs from all known fossil and the majority of extant encyrtids, in particular, by its four-segmented funicle.

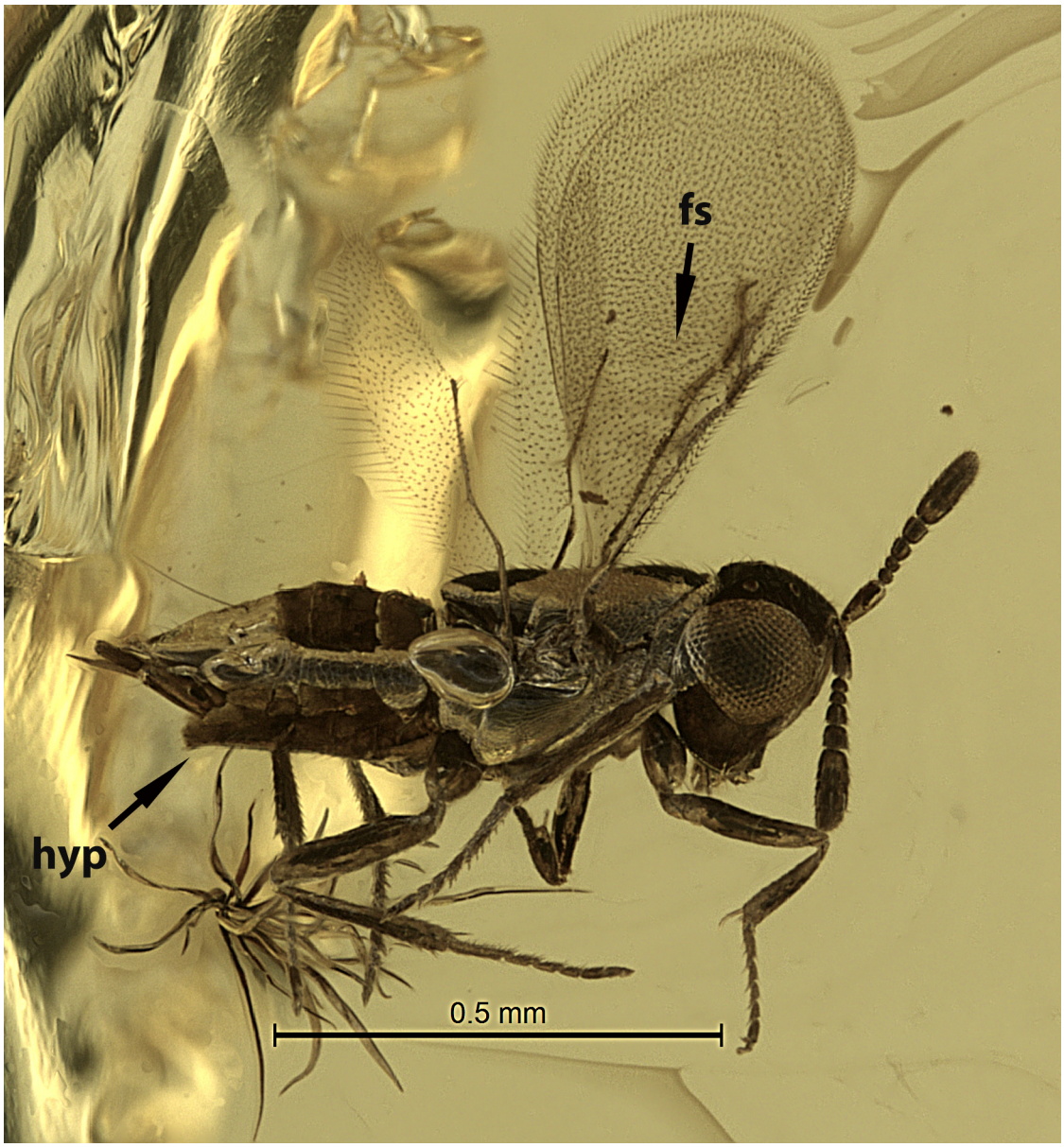

FIGURE 1. *Electrocerus brevifuniculatus* **gen. et sp. nov.**, holotype female**,** lateral view (fs—filum spinosum, hyp—hypopygium). Scale bar: 0.5 mm.

Material and methods

The studied specimen is deposited in the collection of the Schmalhausen Institute of Zoology of the National Academy of Sciences of Ukraine, Kiev (SIZK). The amber piece containing the holotype was purchased from an amber dealer, who obtained the specimen from an amber mine in Yantarny (Kaliningrad Oblast, Russia). The age of this amber was debated for many years, but the stratigraphy strongly indicates that the amberiferous part of the Prussian Formation is of Priabonian (late Eocene) age (Iakovleva *et al.* 2022).

The specimen was examined using the techniques illustrated in Simutnik *et al.* (2022a). Photographs were taken

using a Leica Z16 APO stereomicroscope equipped with a Leica DFC 450 camera and processed with LAS Core and Adobe Photoshop software (brightness and contrast only).

Some standard measurements and ratios given in the description may not be precise or could not be obtained due to the effect of light refraction in amber and the effect of perspective or the inaccessibility of the necessary viewing angles.

Terminology and abbreviations follow Gibson (1997). For the identification, comparison, and description of the new taxon, we also used the keys in Trjapitzin (1989), Noyes *et al.* (1997) and Noyes (2023). We use the following abbreviations: *fs* = filum spinosum; F1, F2, etc. = funicular segments 1, 2, etc.; LOL = minimum distance between anterior ocellus and posterior ocellus; OOL = minimum distance between eye margin and the adjacent posterior ocellus; and POL = minimum distance between posterior ocelli. Other abbreviations are explained in the figure captions.

Results

Electrocerus Simutnik, gen. nov.

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Type species. *Electrocerus brevifuniculatus* Simutnik, **sp. nov.**

Species composition. Monotypic.

Etymology. The name of the genus is a combination of the words "electrum" (Latin: *electrum* = amber) and "cerus," which comes from the Greek κερκίς, or tail, but often means "antenna" in entomological names. The antennal funicle in the holotype of *Electrocerus* consists of only four segments but otherwise may be a "teratoid," or the seasonal form of a species, with a normal, six-segmented funicle. The genus name is a masculine noun.

Diagnosis. Female. Body slightly elongated, not flattened; antenna clavate; scape much more than 3× as long as broad; funicle four-segmented; F1 broader than long; antennal toruli located close to mouth margin (Fig. 2); notauli very short, subtle, located anteriorly (Fig. 3B: arrow); forewing slightly infuscated, with small, slightly darkened areas below marginal vein and parastigma; filum spinosum and row of covering setae on basal margin of linea calva well developed; postmarginal vein shorter than marginal vein; cerci located in apical third of metasoma; apex of hypopygium not reaching apex of last gastral tergum.

Male. Unknown.

Remarks. The placement of *Electrocerus* in Encyrtinae is supported by the presence of a filum spinosum on the linea calva (Fig. 4), and the apex of the hypopygium not reaching the gastral apex (Fig. 1).

With its very long stigmal vein, the new taxon is distinctly different from known extant genera that possess a four-segmented funicle in the tribes Arrhenophagini Ashmead, 1900 and Habrolepidini Hoffer, 1955 (see Noyes 2023). Compared with the genus *Cercobelus* Walker, 1842, the new taxon differs, in particular, by its long marginal vein, the presence of a malar sulcus, and the hypopygium not reaching the apex of the gaster (see Noyes 2023).

Key to European amber genera of Encyrtinae (females)

1 (4)	Postmarginal vein shorter than marginal vein.	
2 (3)	Hypopygium extending past apex of syntergum	*Protaphycus* Simutnik, 2022
3 (2)	Hypopygium not extending apex of syntergum	*Electrocerus* Simutnik, **gen. nov.**
4 (1)	Postmarginal vein not shorter than marginal vein.	
5 (6)	Row of filum spinosum double, consisting of 9 setae	*Efesus* Simutnik, 2020
6 (5)	Row of filum spinosum single, consisting of 2–6 setae.	
7 (8)	Funicle as long as clava. All funicle segments wider than long	*Dencyrtus* Simutnik, 2018
8 (7)	Funicle longer than clava. At least some funicle segments longer than wide.	
9 (10)	Mesoscutum with large, deep, rare punctures	*Ektopicercus* Simutnik, 2020
10 (9)	Mesoscutum without large punctures.	
11 (12)	Antenna thin, filiform. Clava about 5.5× as long as wide	*Protocopidosoma* Simutnik, 2017
12 (11)	Antenna not filiform, clavate. Clava about 3× as long as wide	*Rovnosoma* Simutnik, 2015

The key does not include the genus *Glaesus* Simutnik, 2014, which is only known from a male specimen. Its postmarginal vein is longer than the marginal vein.

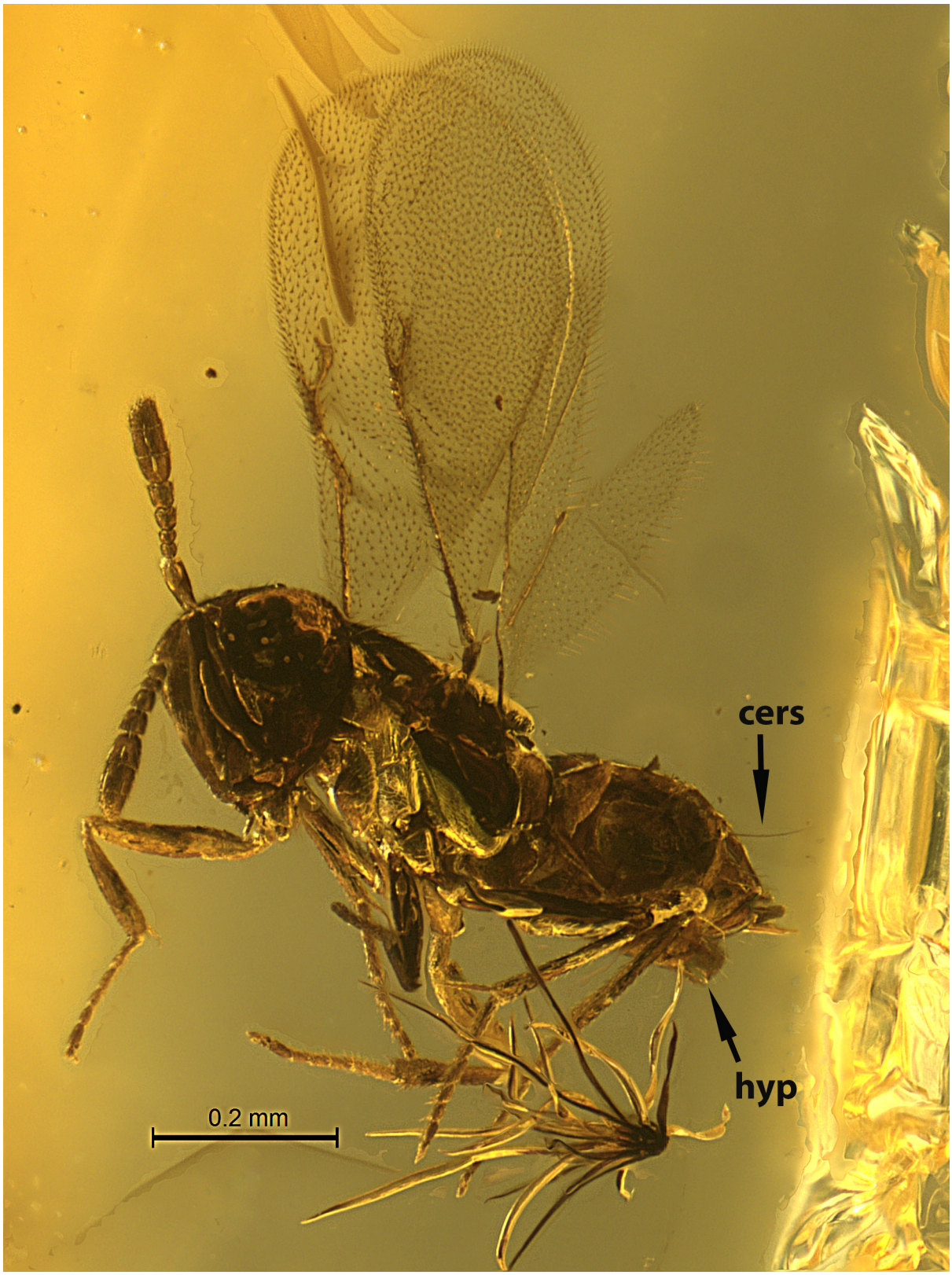

FIGURE 2. *Electrocerus brevifuniculatus* **gen. et sp. nov.**, holotype female. **A** body, anteroventrolateral view (cers—cercal seta, hyp—hypopygium). Scale bar: 0.2 mm.

***Electrocerus brevifuniculatus* Simutnik, sp. nov.**
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Figs 1–6, 7C

Material. Holotype, SIZK B-130, 1 ♀, Yantarnyi, Kaliningrad Oblast, Russia; Baltic amber; late Eocene. The inclusion is in a yellow, clear piece of amber (ca. 16 × 13 × 5 mm).

Syninclusions: absent.

Etymology. The specific name also refers to the female antenna with a four-segmented funicle.

Description. Female. Habitus as in Figs 1–3. Body length 0.84 mm, not including the ovipositor.

Coloration. Head, antenna, thorax, tegula black; gaster and legs dark brown; forewing slightly infuscate, with small darkened areas below marginal vein and parastigma (Fig. 2); wing venation, mesotibial spur, and tarsi brown; some parts of surface of mesosoma, gaster, and legs shiny due to presence of a thin layer of air but without metallic shine.

Sculpture. Head, mesosoma, and gaster relatively rough reticulate; genae and mesopleuron with elongated cells (Fig. 3B); frontovertex, mesoscutum, and scutellum with short, dark setae.

Head. Hypognathous, not flattened, slightly wider than mesosoma in dorsal view, about 1.3× as high as long in lateral view; occipital margin sharp (Fig. 3); eyes bare, without visible setae; ocelli forming about equilateral triangle (POL about equal to LOL) (Fig. 3A), posterior ocelli slightly closer to eye than occipital margin (Fig. 3A); OOL about equal to posterior ocellar diameter; eye reaching occipital margin (Figs 3A, B); antennal scrobes as in Figs. 2 and 3B, v- or u-shaped and meeting dorsally, not extended to anterior ocellus, in dorsal view anterior ocellus closer to upper margin of scrobal depression than occipital margin (Fig. 3A); interantennal prominence not high, as in Fig. 2; distance between antennal torulus and mouth margin less than diameter of torulus (Fig. 2); malar space with complete malar sulcus, slightly shorter than high of eye; mandible probably 3-dentate. Some standard measurements and ratios of the head cannot be given due to the unavailability of the necessary viewing angles.

***Antenna*.** Geniculate, 9-segmented, without visible anelli, with four funicular segments and 3-segmented clava; radicle short (Fig. 2), remainder of scape long, its accurate ratios not visible, widest at middle (Fig. 2); pedicel long, 2.3× as long as wide, conical, a little longer than first 3 funicular segments combined, longer than any funicular; F1 and F2 broader than long, conspicuously smaller than F3 and F4, which are as long as broad; multiporous plate sensilla (mps) visible on F3, F4, and each claval segment, on F3 and F4 mps the longest; clava a little longer than funicle, slightly wider than F4, with rounded apex and small oblique truncation at apical segment only (Figs 2–3); flagellum and clava covered by very short setae.

***Mesosoma*.** Pronotum short, almost vertical (in lateral view); mesoscutum as broad as long or nearly to (in dorsal view), notauli as in Fig. 3B: not; mesothoracic spiracle open, not concealed beneath pronotum (Fig. 3B); axillae meeting; scutellum flat, apically rounded, as long as mesoscutum (Fig. 3A); mesopleuron enlarged posteriorly; metapleuron triangular, narrow, without visible setation (Fig. 1A); propodeum bare, touching metacoxa (Fig. 3B).

***Wings*.** Fully developed, about 2× as long as broad; linea calva not interrupted but closed on posterior margin of forewing, with filum spinosum consisting of a row of 5 setae, with a well-developed line of long setae alongside basal margin of dorsal surface (Fig. 4); parastigma thickened, about 2× as long as marginal vein; hyaline break (unpigmented area) present; marginal vein ~3× as long as broad, as long as stigmal vein, ~1.7× as long as postmarginal vein; stigmal vein with long narrow uncus consisting of a row of 3 uncal sensilla (Fig. 4C); enlarged seta marking apex of postmarginal vein of forewing absent (as long as others on this vein); fringe setae short. Hind wing about 4.5× as long as broad; costal cell very narrow, without line of long setae (Fig. 4); spur vein originating from marginal venation visible as very small hyaline process; apex of marginal vein with 3 hamuli; longest setae of marginal fringe ~ 0.2 as long as wing width.

***Legs*.** Protibia with long, curved, bifurcate calcar; strigil and basitarsal comb absent (Figs 1B, 2A); midtibial spur long and straight but slightly shorter than a very long midtarsal segment, tarsi 5-segmented.

***Metasoma*.** Slightly shorter than head and mesosoma together; cerci in apical third of metasoma, with long setae (Figs 1, 2; 3A); syntergum (Mt8 + Mt9) v-shaped, not longer than 1/3 of metasoma; hypopygium not reaching apex of syntergum (Fig. 1); lateral margin of hypopygium bare, without row of setae; ovipositor extended beyond apex of gaster, ovipositor sheaths shorter than mesobasitarsus (Fig. 3A).

Measurements (μm) of the holotype. Mesosoma 322; gaster 378; mesotibia 238. Antenna: pedicel 56; flagellum 182; clava 98. Forewing 686:322, hind wing 504:112.

Male. Unknown.

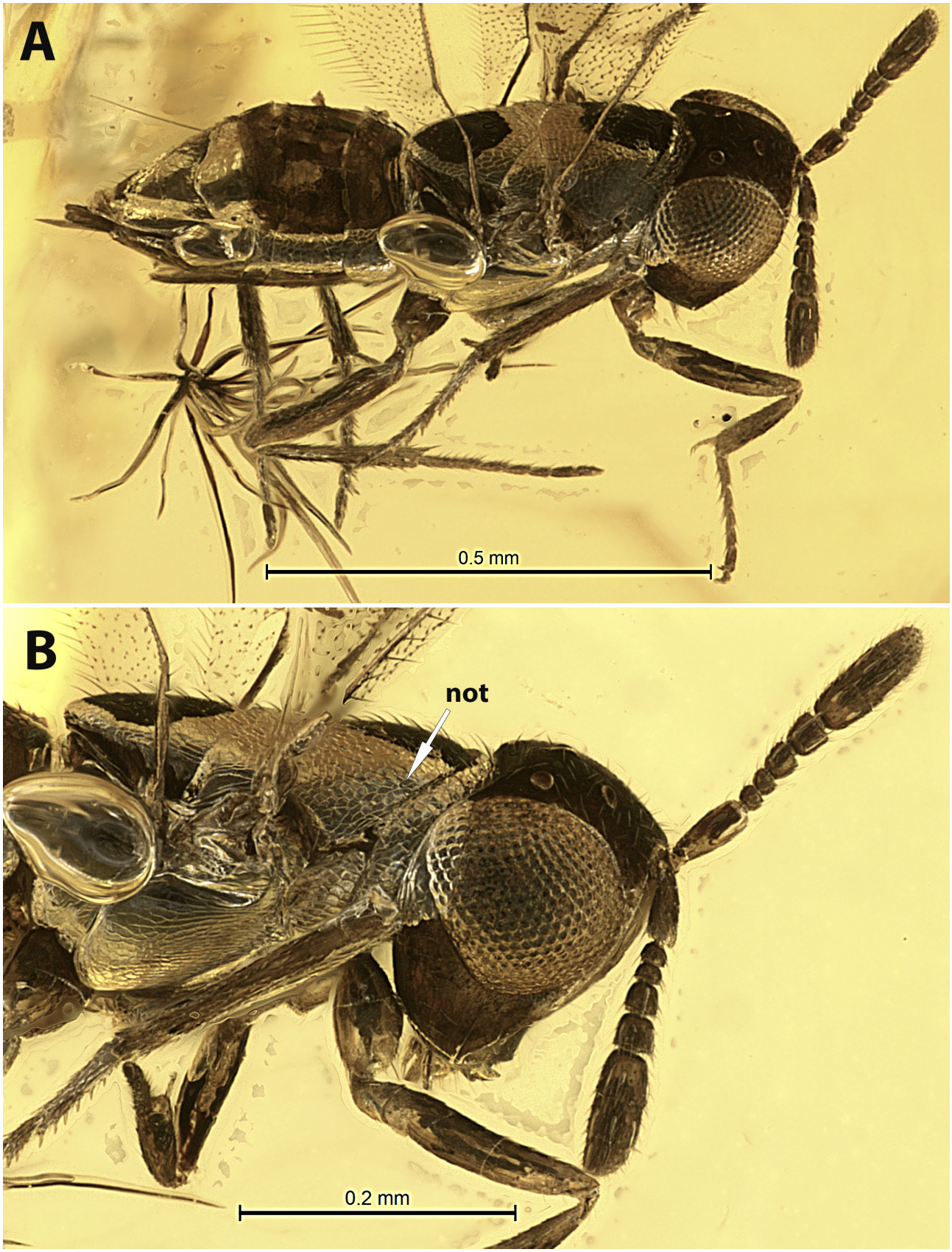

FIGURE 3. *Electrocerus brevifuniculatus* **gen. et sp. nov.**, holotype female. **A** body, dorsolateral view; **B** head, antennae, mandible, mesosoma, lateral view (not—notaulus). Scale bars: 0.5 mm (**A**); 0.2 mm (**B**).

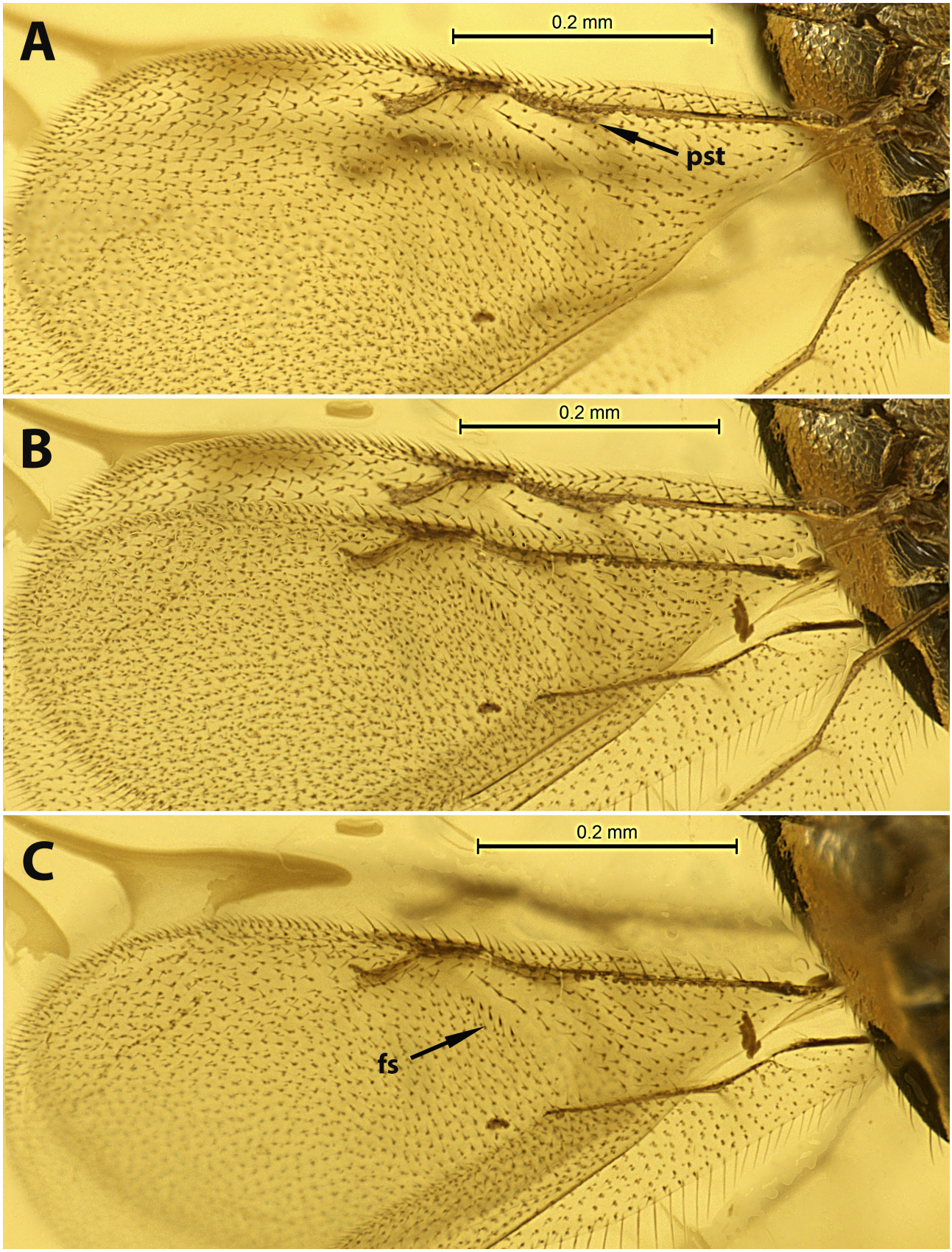

FIGURE 4. *Electrocerus brevifuniculatus* **gen. et sp. nov.**, holotype female. Wings **A** right forewing in focus (pst—parastigma); **B** all wings in focus; **C** left forewing and hind wing in focus (fs—filum spinosum). Scale bars: 0.2 mm.

Discussion

The new genus is not related to any known extant genera with a four-segmented funicle, *Arrhenophagus* Aurivillius, 1888 (Arrhenophagini); *Plagiomerus* Crawford, 1910; *Caenohomalopoda* Tachikawa, 1979; *Homalopoda* Howard, 1894; *Pseudhomalopoda* Girault, 1915; *Spaniopterus* Gahan, 1927 (Habrolepidini); and *Cercobelus* (Cercobelini Hoffer, 1953) (see remarks below on the generic diagnosis and Noyes 2023), although the antennae of some of them are very similar.

Microterys anomalus (Erdös & Novicky, 1955) (Microteryini Hoffer, 1955) was described from a teratoid female from Hungary (Erdös & Novicky 1955: 196 as *Birous*; Erdös 1957: 43–44 as *Birous*). The funicle of both antennae of the holotype consists of only three segments. According to Bouček & Graham (1978: 230), this specimen is possibly a seasonal form of *M. chalcostomus* (Dalman, 1820) (Trjapitzin 1989). The holotype of *Electrocerus brevifuniculatus* may also be a teratoid with a normal, six-segmented female funicle. Finding more specimens of the new species would help confirm or refute this. However, even if the holotype does turn out to be a teratoid, it would still represent a new genus based on its other distinctive features. The new fossil differs from all known Eocene Encyrtidae by its antennal toruli located very close to the mouth margin. Furthermore, the postmarginal vein of the forewing of the new genus is almost 0.5× as long as the marginal vein (Fig. 4). In contrast, all described genera (listed above in the introduction and key) and all studied specimens with a *fs* from European ambers are characterized by the postmarginal vein longer than the marginal vein, except in *Protaphycus*. This latter genus differs from *Electrocerus* in possessing a hypopygium reaching far past the apex of the last gastral tergum, as well as by the presence of a bare strip resembling a speculum running alongside the linea calva, basal to the row of covering setae and below the parastigma (Simutnik *et al.* 2022b). The taxonomic position of the new genus remains uncertain (*incertae sedis*) within Encyrtinae.

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