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Fluorescence in jumping spiders of the genus *Tutelina* (Araneae: Salticidae: Dendryphantini)

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Abstract. Fluorescence during the near ultraviolet (NUV, 395 nm peak) illumination of *Tutelina elegans* and two related but undescribed species of *Tutelina* is documented and described.

Keywords. *Cosmophasis*, fluorophore, *Maevia*, myrmecophagy, near ultraviolet

Tutelina Simon 1901 is a small dendryphantine genus, with four described species that are mostly endemic to the eastern deciduous forest of North America (Richman, Cutler & Hill 2012). These spiders are often observed feeding on ants (*myrmecophagy*; Kaston 1948; Wing 1983; Cushing 2012; Figure 1:1), but they also take other insect prey (Figure 1:2). Here (Figures 2-5) we document fluorescence in three species, one the well-known type species for the genus, *T. elegans* (Hentz 1846), and the other two undescribed (*Tutelina* sp. A and *Tutelina* sp. B, respectively).

Figure 1. Female *Tutelina elegans* with prey. **1,** Feeding on a large ant (*Formica*), Occoquan Bay National Wildlife Refuge, Woodbridge, Virginia, 4 SEP 2016. **2,** Feeding on midge (*Chironomus*), Bear Creek Lake State Park, Cumberland, Virginia, 4 OCT 2020. Photographs by Judy Gallagher, used under a Creative Commons Attribution 2.0 Generic (CC BY 2.0) license.

Figure 2. Adult male *Tutelina elegans*. **1-4,** Flash photographs of male from Massachusetts. **5,** Male from Greenville county, South Carolina. **6-12,** Blacklight (NUV, peak 395 nm) photos of male from Greenville County, South Carolina. The brighter, cyan structures are fluorescent.

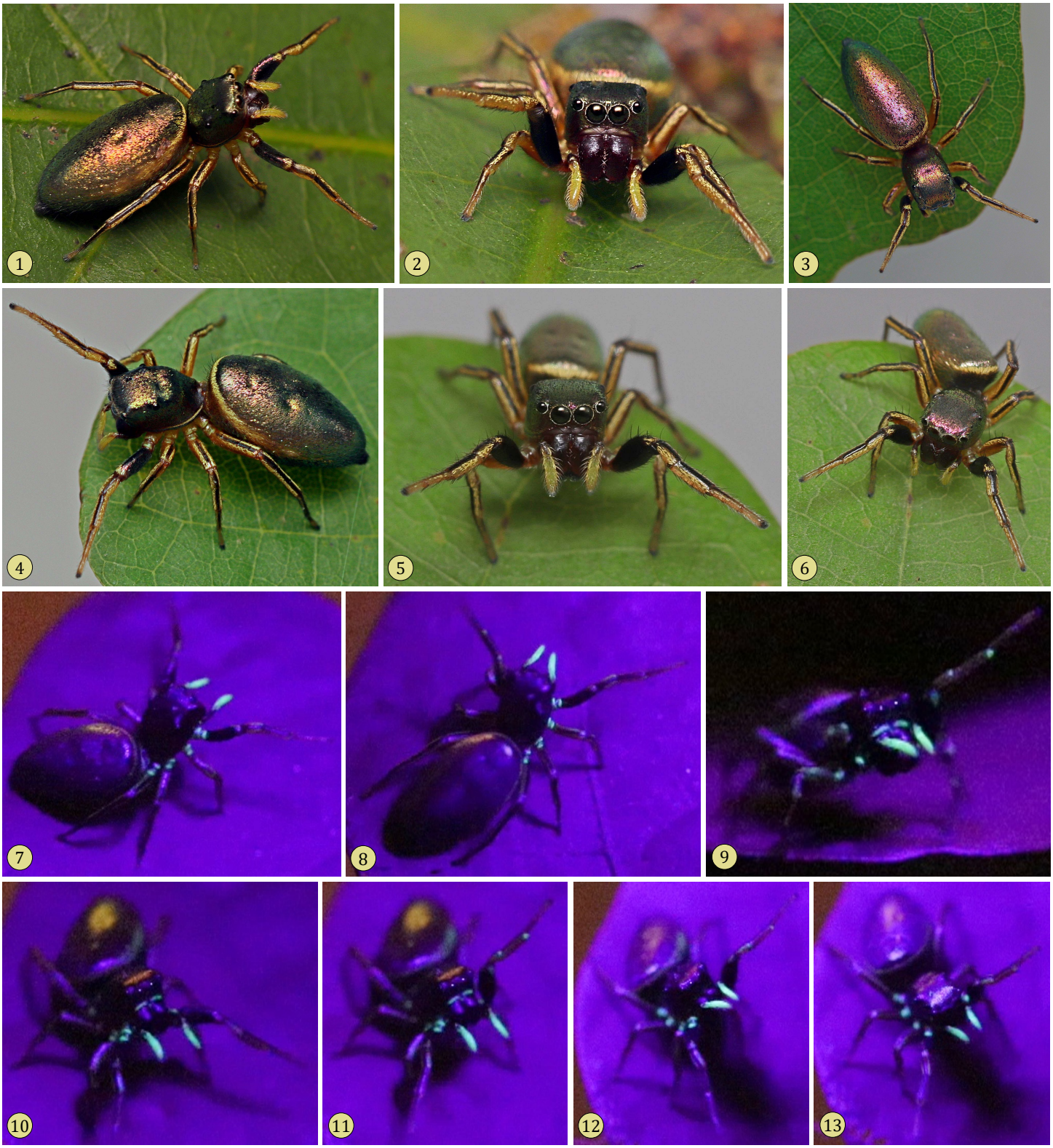

Figure 3. Adult female *Tutelina elegans*. **1-4,** Flash photographs of female from Greenville County, South Carolina. **5-6,** Female from Massachusetts. **7-13,** Blacklight (NUV, peak 395 nm) photos of female from Greenville County, South Carolina. The brighter, cyan structures are fluorescent.

Figure 4. Adult female *Tutelina* sp. A (undescribed) from Greenville County, South Carolina. **1-6,** Flash photographs of a series of females. **7-13,** Blacklight (NUV, peak 395 nm) photos of one female. The brighter, cyan structures are fluorescent. The male of this species has long black pedipalps and white leg I fringes that resemble those of *T. similis* (Banks 1895), but otherwise resembles the male of *T. elegans*.

Figure 5. Adult male *Tutelina* sp. B (undescribed) from Greenville County, South Carolina. **1-6,** Flash photographs of one male. **7-12,** Blacklight (NUV, peak 395 nm) photos of the same male. The brighter, cyan structures are fluorescent. The female of this unusual species is similar in color and also has expanded, fringed tibiae I that resemble the head of an insect when viewed from the side.

Methods. We used a simple near ultraviolet (NUV, 395 nm peak) flashlight to illuminate living spiders in order to identify fluorescent structures. Flashlights of this kind are inexpensive and easy to obtain. As shown in Figure 6 (C), this illumination extended from invisible NUV into the visible spectrum. For some photographs a dim incandescent backlight was also used to better define the silhouette of each spider. Here we did not use spectrography to measure the spectrum of each color, but used online software tools to obtain an indication of each color from the respective photographs. These tools included the *Online Image Color Picker* (https://pinetools.com/image-color-picker) to determine hue, saturation and level (HSL) for the relevant part of each image, and *ColorHexa* (https://www.colorhexa.com/) to convert HSL to an equivalent wavelength. Thus the wavelengths that we show here represent only characteristics of the recorded image, and not the actual spectrum of emitted light. Nonetheless they do provide a good indication of the presence and approximate hue of peak fluorescence. Although we found some variation of this hue by species in (e.g. ~485 nm for *Tutelina* sp. A, and ~497 nm for *T. elegans*), in general the fluorescence that we observed fell within a fairly narrow range (480-500 nm, cyan). Spectroscopy and larger samples will be required to obtain more resolution of any significant differences.

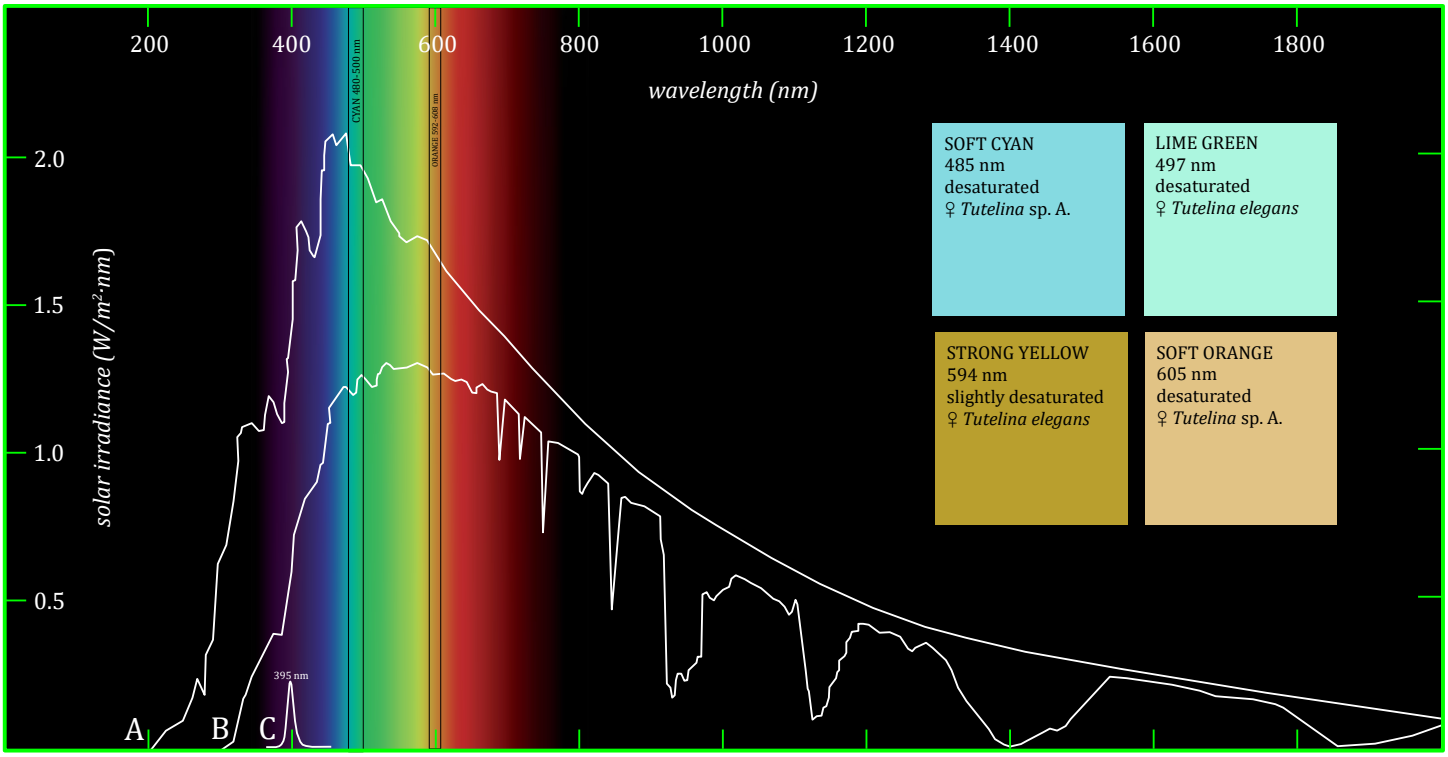

Figure 6. Comparison of illumination and observed fluorescent colors to the solar spectrum. **A,** Solar spectrum above the atmosphere of the Earth. **B,** Solar spectrum near sea level. Subtracted areas to the right (infrared) correspond primarily to the presence of H_20 molecules in the atmosphere. This curve will vary according to latitude, humidity, elevation, season and time of day. **C,** Spectrum of the NUV (peak 395 nm) flashlight (blacklight) used here. For this curve, irradiance is only relative and the scale at left does not apply. Vertical black lines delimit the fluorescent color (cyan) of *Tutelina* pedipalps (~480-500 nm), and their "natural" color (~592-608 nm) as recorded by flash photography. Color squares at the upper right compare the strong yellow to soft orange "natural" colors of the pedipalps of female *Tutelina* to their soft cyan to lime green fluorescent colors. The "desaturated" label indicates that these do not represent "pure" colors or single frequencies. Curves A, B by NASA.

Results. The fluorescence of both male and female *Tutelina elegans* is much the same (Figures 2-3). For each the dorsal surface of the cymbium, and for the female the distal tibia, of each pedipalp is fluorescent. For all legs and pedipalps, the flexible cuticle on either side of each trochanter fluoresces. There is a transverse fluorescent band associated with the proximal articulation of each paturon. Where visible, areas of flexible cuticle associated with other leg joints (e.g., proximal and distal ends of tibia, left leg I, in Figures 2:11, 3:9) are also moderately fluorescent.

For female *Tutelina* sp. A (Figure 4), we detected significant fluorescence for only the distal pedipalps. For the male *Tutelina* sp. B (Figure 5), the distal pedipalp segments did not fluoresce, but the flexible cuticle on either side of each trochanter did, for each leg and pedipalp. In addition, for this species, there were three fluorescent spots, one at the median and one on either side, at the rear margin of the carapace, and the rear or retrolateral side of each femur showed very moderate fluorescence at certain angles of illumination (Figure 5:12).

Discussion. Studies based on the use of spectroscopy and higher energy UV illumination (lamp, 302 nm peak) have revealed that fluoresence based on the presence of a variable set of *fluorophores* (fluorescent compounds) is of frequent occurence in the Araneae, particularly in the hemolymph and at the leg joints (Figure 7; Andrews, Reed & Masta 2007; Reed, Do & Masta 2008; Brandt & Masta 2017).

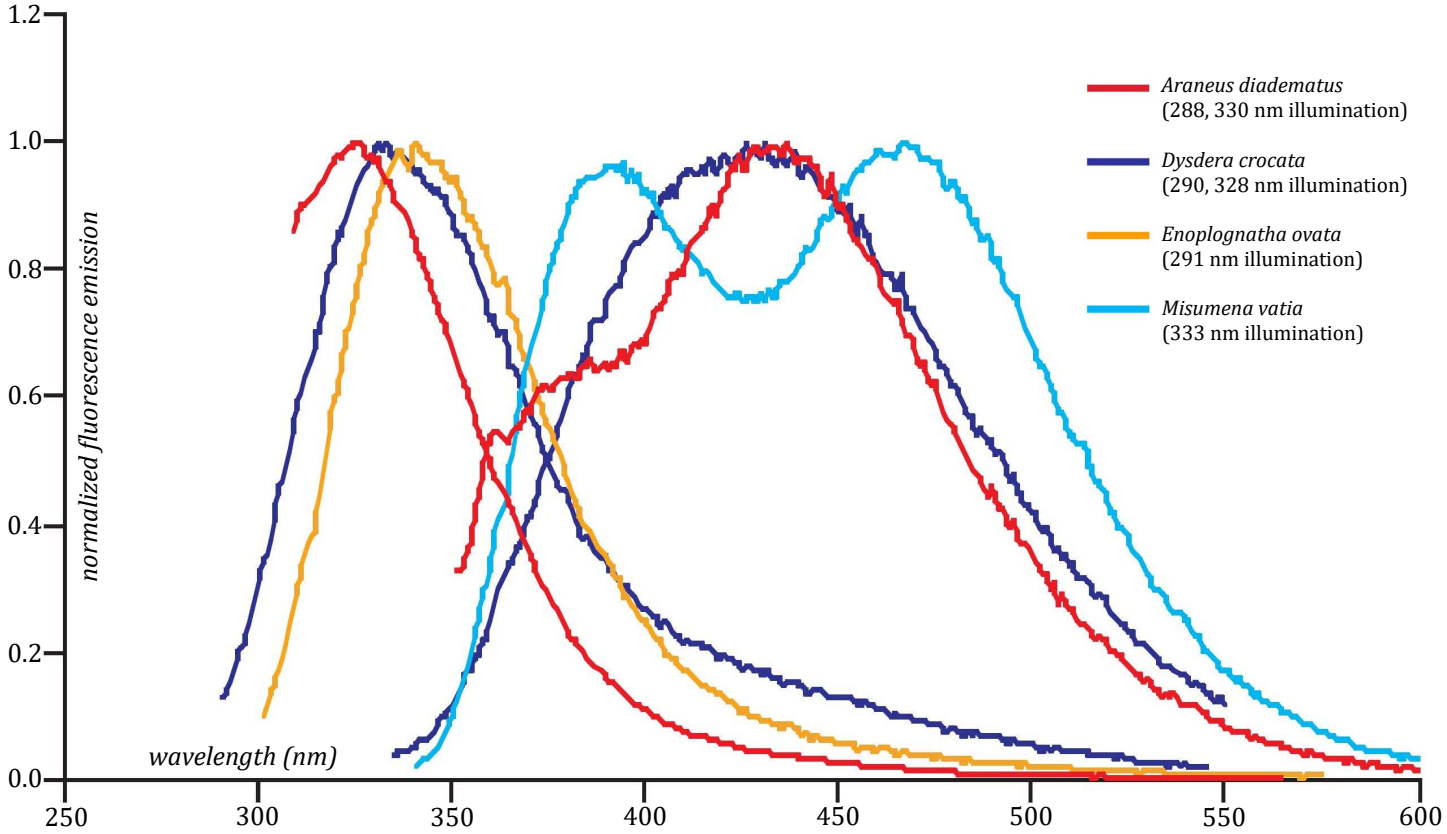

Figure 7. Fluorescent emission spectrum for four different spiders, based on use of a 302 nm lamp. Higher energy (288-333 nm UV) produced more fluorescence. The peak illumination for each emission spectrum shown here is given at upper right. Figure modified after Andrews, Reed & Masta 2007 (fig. 2), used by permission (Creative Commons Attribution).

Fluorescent proteins occur widely in animals. GFP (*green fluorescent protein*), converting blue to green, may have been present in the common ancestor of all Metazoa; a related tryptophan derivative, β-carboline (converts 360-370 nm to 445-490 nm light) is known from arachnids (Macel et al. 2020).

Fluorescence has previously been found in other salticids, notably on the pedipalps (only) of female *Cosmophasis umbratica* Simon 1903 (Lim, Land & Li 2007; Painting et al. 2017; Marshall & Johnsen 2017; Macel et al. 2020), and *Icius hamatus* (C. L. Koch 1846) (Colombo 2020). Our inspection of published photographs for *C. umbratica* indicates that these fluoresce at ~485 nm, suggesting the presence of fluorophores similar to, if not identical with, those found in *Tutelina*.

The function of fluorescence is open to question. Clearly fluorescence alters or enhances the color (hue, saturation, level) of respective structures in a manner that should be detectable by salticids. Fluorescent pedipalp color appears to increase the response of male *Cosmophasis umbratica* to females (Lim, Land & Li 2007; Marshall & Johnsen 2017; Macel et al. 2020). When we study these animals in the laboratory, we need to remember that visual signals in sunlight can be quite different from those that we observe under artificial lighting (Taylor & MacGraw 2013; Marshall & Johnsen 2017; Hsiung, Shawkey & Blackledge 2019). Fluorophores may also reduce tissue damage associated with ultraviolet radiation (Macel et al. 2020).

It is well-known that salticid vision can extend into the ultraviolet spectrum. For example, Peaslee & Wilson (1989) found that *Maevia inclemens* (Walckenaer 1837) responded to light in the 330-700 nm range, and ultraviolet light is known to play an important role in the behavior of *Cosmophasis umbratica* (Lim & Li 2006a, 2006b; Lim, Land & Li 2007; Lim, Li & Li 2008; Lim & Li 2013; Bulbert et al. 2015). Here we have examined only fluorescence resulting in the emission of visible light (appearing in photographs as cyan, 480-500 nm) in *Tutelina*. More detailed studies based on spectrography may reveal that, as in other spiders (Andrews, Reed & Masta 2007), *Tutelina* also fluoresce in the ultraviolet spectrum.

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