R frfrpdzj H tsə Ɔdzqfj ʷʷ qL qfuj frʃqfH tʃ tɐqfdzqfʃ tsə tɐƆB tslsʳ dʒƆɐdzqlsdzsɡts ʢtsdʒʃ ƆfrƆ tʃ lsqfu dzƆ tʃ tɐqfdʒj tɐj frƆH tsə tsʔ frpzƆə ʢqf

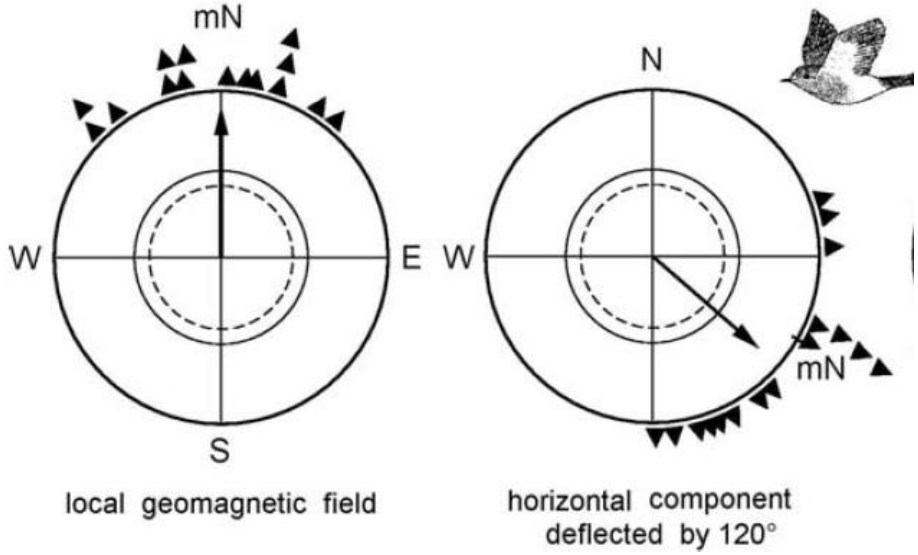
ʂ.ɾ .ʂ Ɔə tsʢqfdz

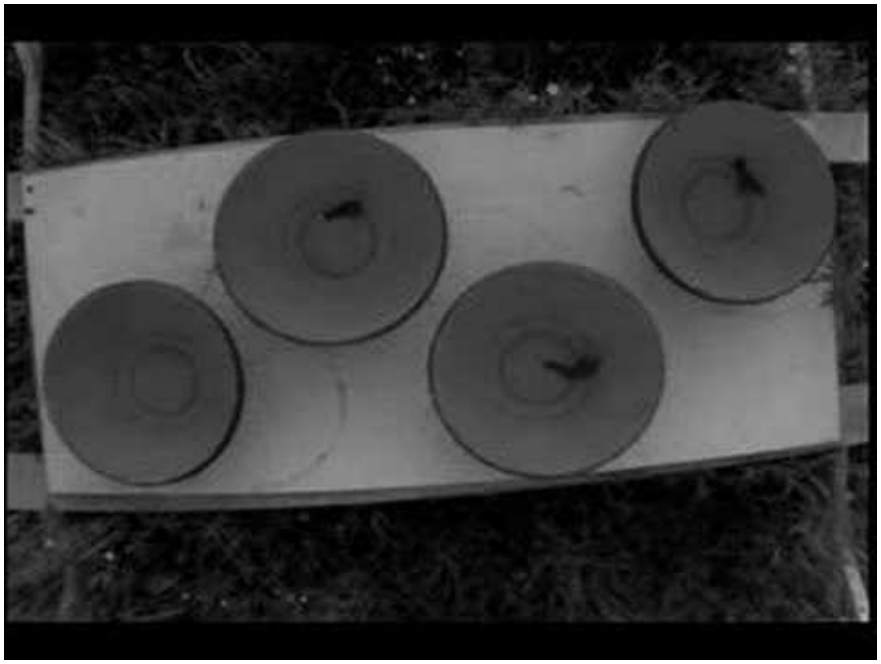
ɥʔ ʁɻʊ qfʌ ʊR qfdʒ R tsʷʷ j

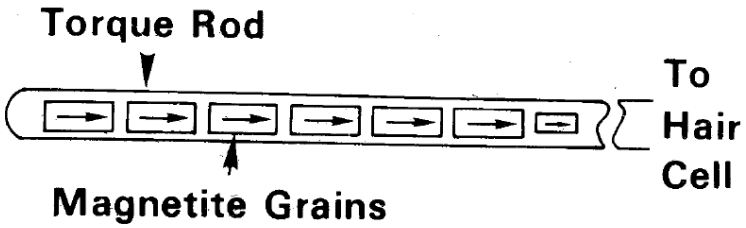
ɭ .ɥ . ʏj tɐdʑ ɥtsə, ɸ .ʌ . ɿ ƆH tsdʒtsə, ɾ .ɥ . ʂ tsʁʳ dʑtsə (ʁqftsfhsƆdzqfʷ «ʈʳ ʁƆɥqfʔ» ɿ R ɭ), ʒ .ɻ. ɹ tsʷtɐqfdzsə Ɔ (ɥʔ ʁɻʊ).

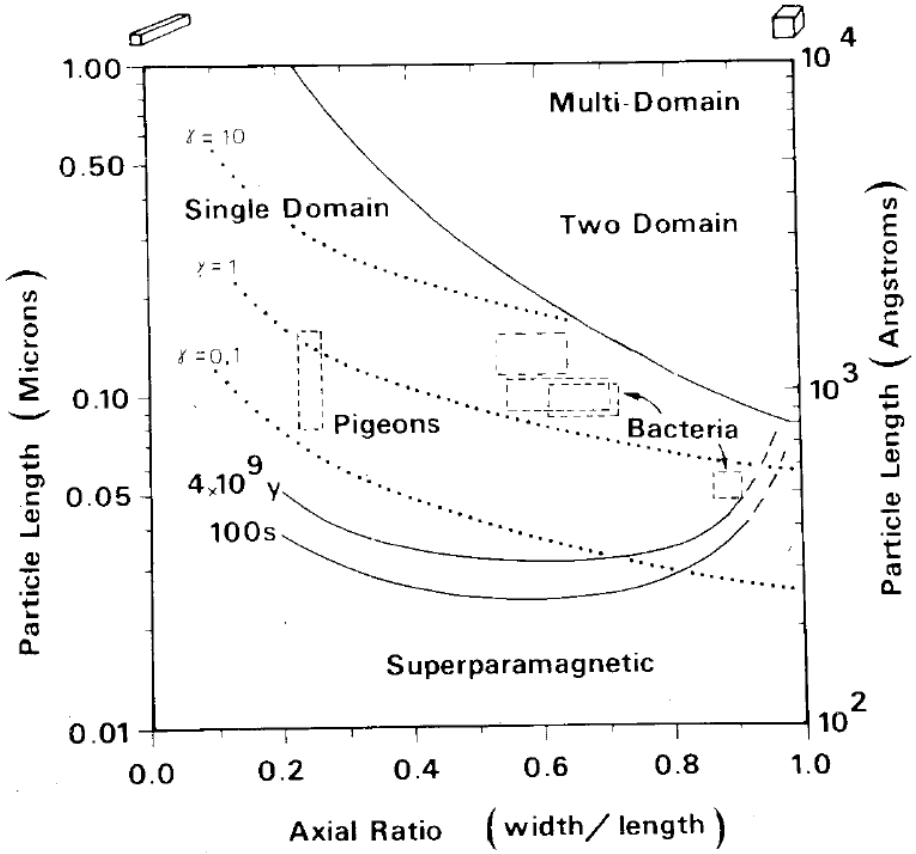
Migration - across the world in 8 days!

Wolfgang Wiltschko



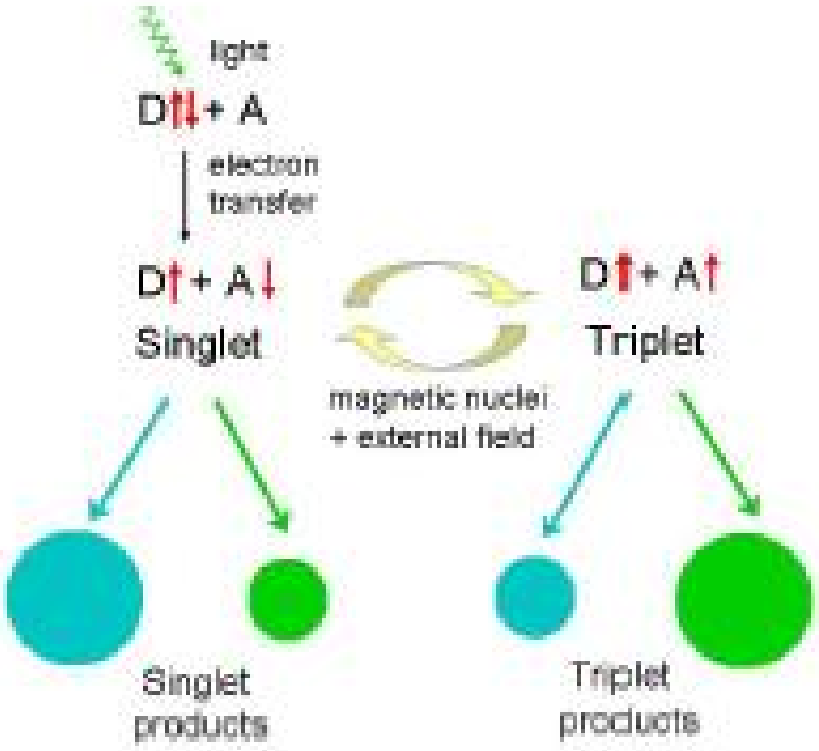


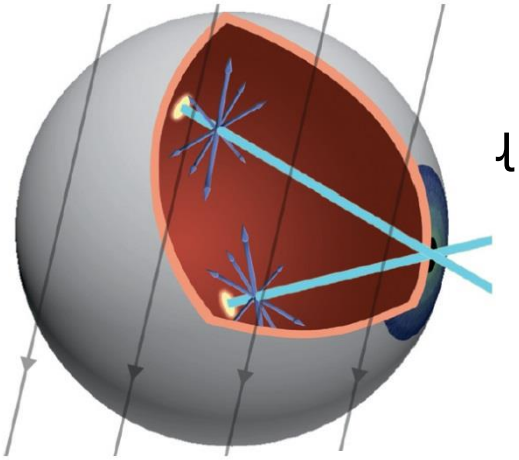


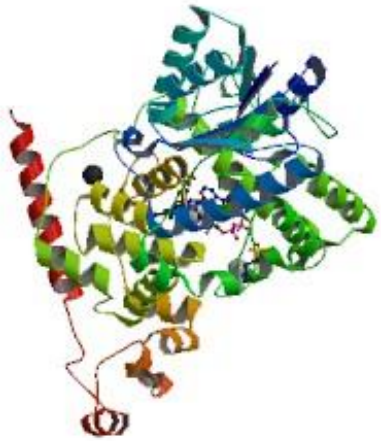


Kirschvink, Gould 1981

Radical pair reaction in cryptochrome



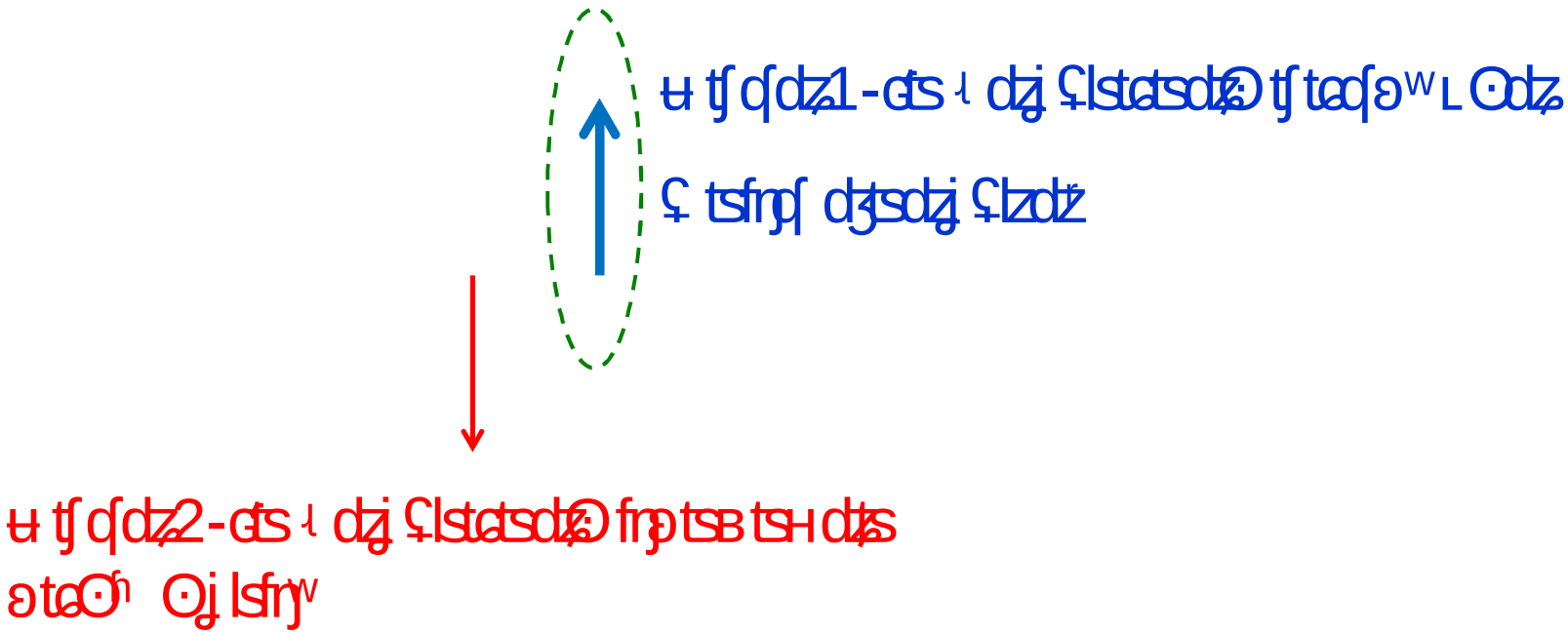




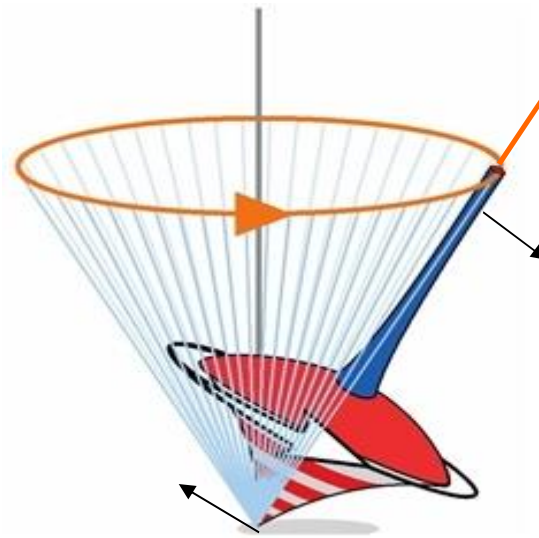
Ritz T., Adem S., Schulten K. 2000. A model for photoreceptor-based magnetoreception in birds // Biophys. J. V. 78. ¯ 2. P. 707ï 718.

ɹ ɖʃtɑ⊙ɪ ɖʃʕ⊙dʑ dʑ⊙ʷ tɕʝ ⊙ʕ⊙ɥɖʃʷ (radical pair reaction)

ñProbe and referenceòmodel



[illegible]



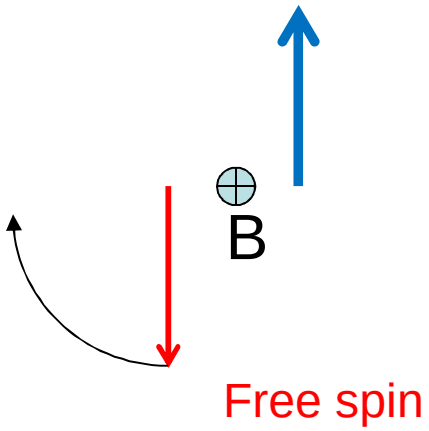
$\vec{L}$ - [illegible]

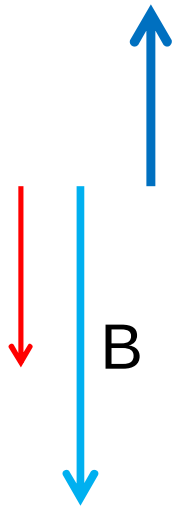
$$f_B = \gamma_e B$$

$\vec{B}$

$$\gamma_e = \frac{\mu_B}{\pi\hbar} \approx 28 Hz / nT$$

ñProbe and referenceòmodel





$$\tau_S > \left(2\pi f_B\right)^{-1}$$

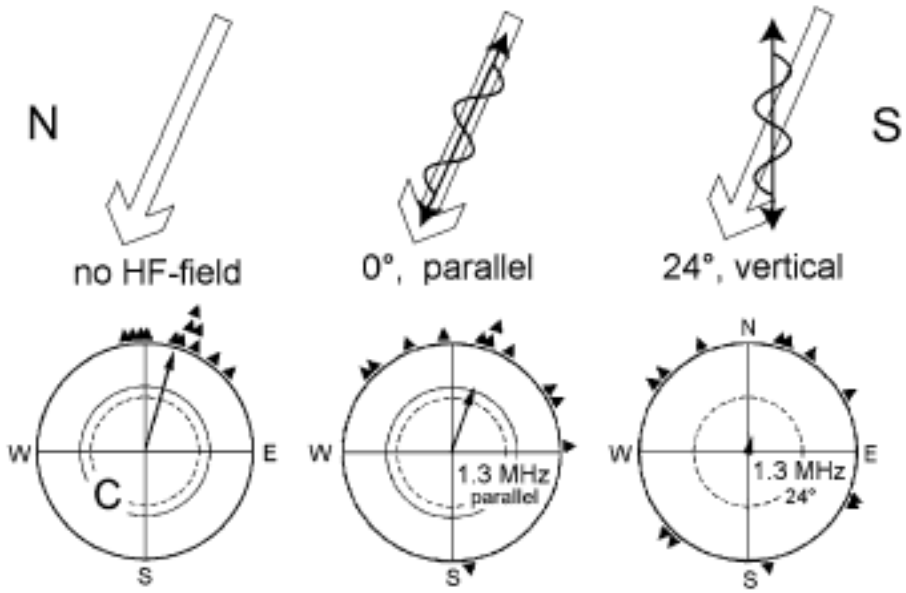
τ_S

B=0.5 G

$$\tau_S > 0.1\mu s$$

Experiments with oscillatory magnetic fields.

Ritz et al, 2004; Thalau et al, 2005; Ritz et al, 2009

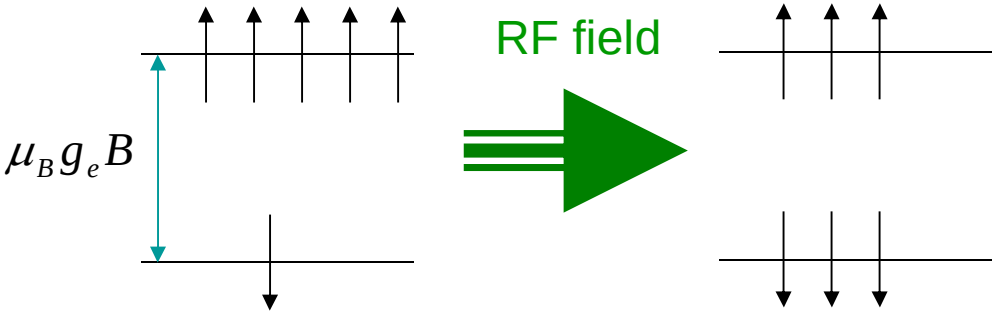


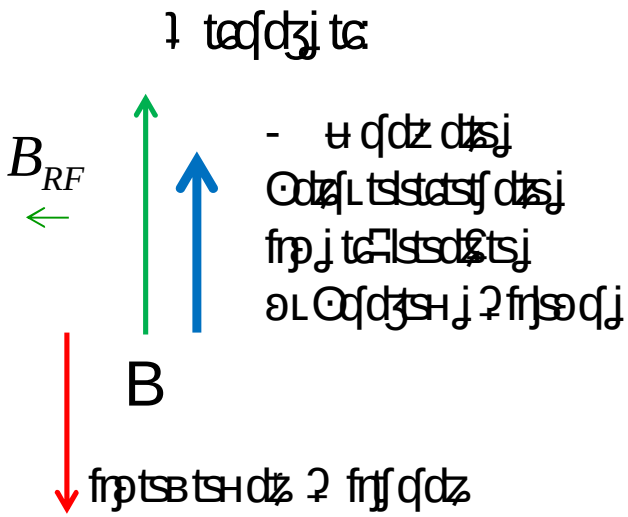
T.Ritz

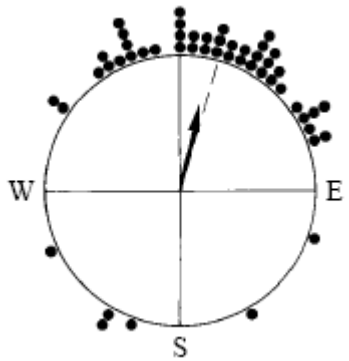
RF magnetic field
results in desorientation!

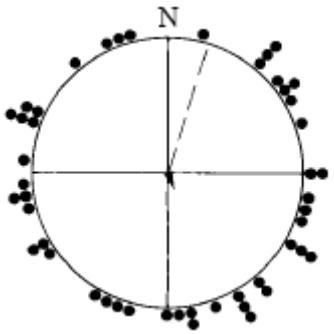
Broadband 0.1-10MHz, 85nT
monochromatic: 1.315MHz, 7MHz,
(and other frequencies in between
0.1 and 7 MHz), <500nT

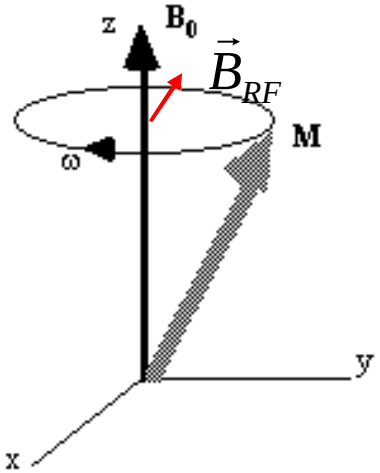
Electron spin resonance











$$f_{RF} = \gamma_e B_{RF}$$

[illegible]

[illegible] 15nT

[illegible] 22 [illegible]

$$t_{sf} \approx 0.01s$$

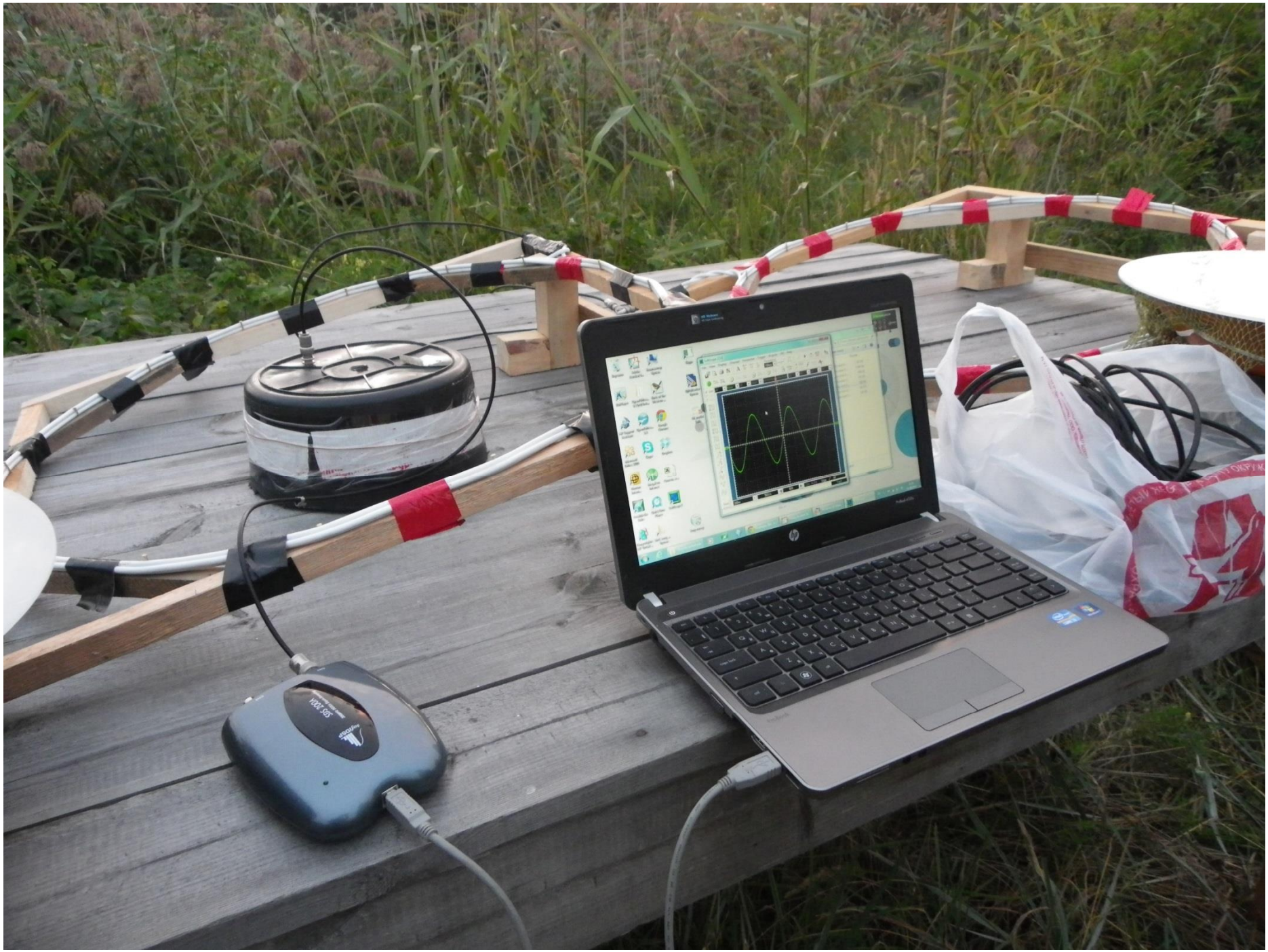
[illegible] 0.1-10MHz 80nT

$$t_{sf} = \left(\gamma_e \sin\alpha\right)^{-2} \left\langle B_{RF}^2 \right\rangle^{-1} \left(2\pi\Delta f\right)$$

$$t_{sf} \approx 1\,s$$

?????

K.V.Kavokin,The puzzle of magnetic resonance effect on the magnetic compass of migratory birds
*Bioelectromagnetics **30**, 402 (2009)*

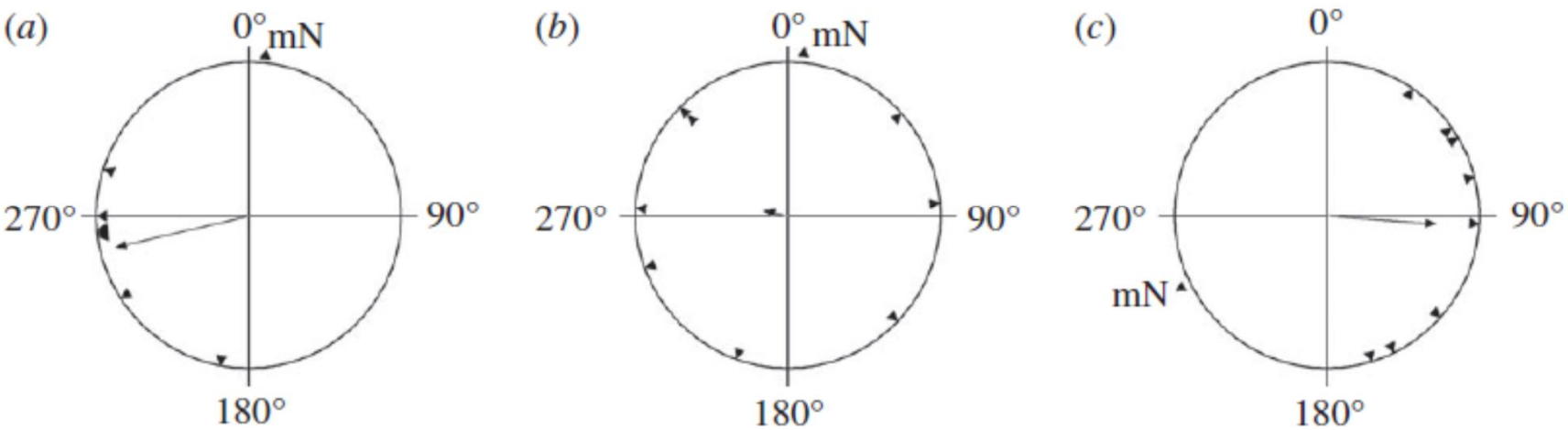


Magnetic orientation of garden warblers (*Sylvia borin*) under 1.4 MHz radiofrequency magnetic field

Kirill Kavokin, Nikita Chernetsov, Alexander Pakhomov, Julia Bojarinova, Dmitry Kobylkov and Barot Namozov

J. R. Soc. Interface 2014 **11**, 20140451, published 18 June 2014

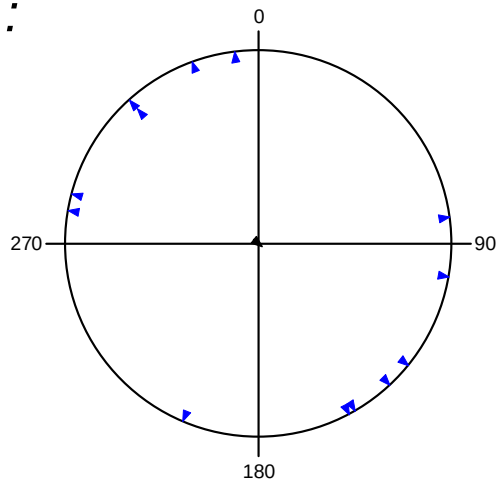
$$B_{RF} = 190nT \qquad \alpha = 30^{\circ} \qquad f = 1.403MHz$$



[illegible] 2014 [illegible]

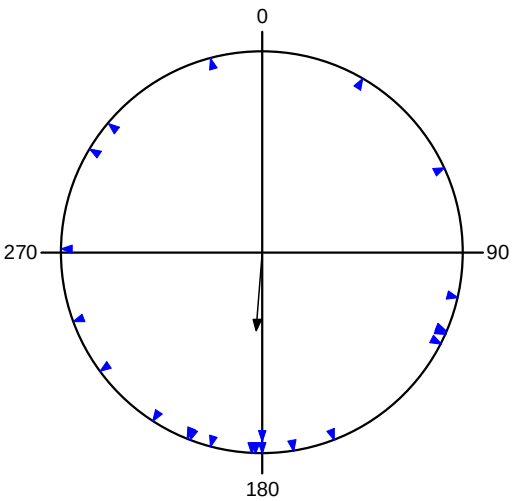
[illegible]

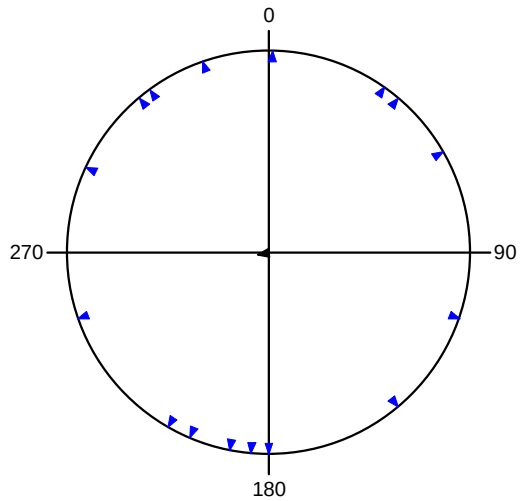
OMF



20nT

NMF



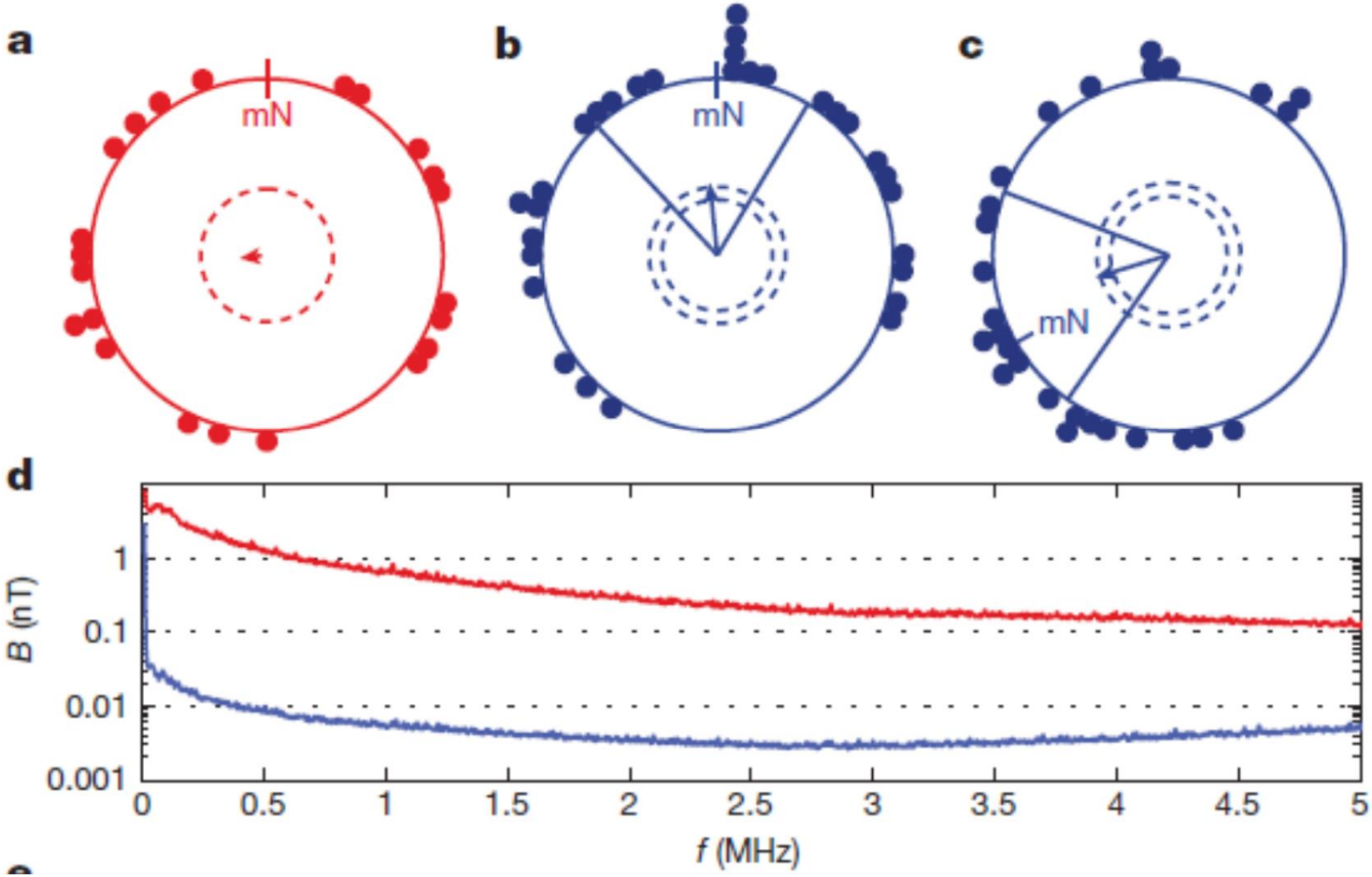


7nT

doi:10.1038/nature13290

Anthropogenic electromagnetic noise disrupts magnetic compass orientation in a migratory bird

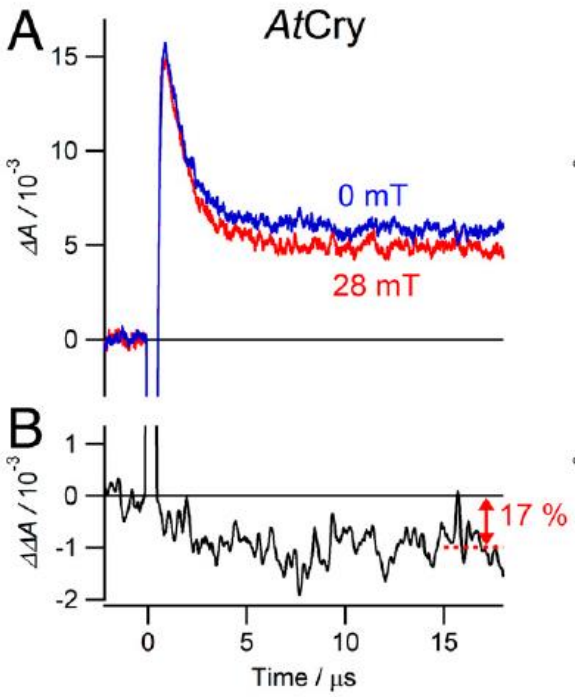
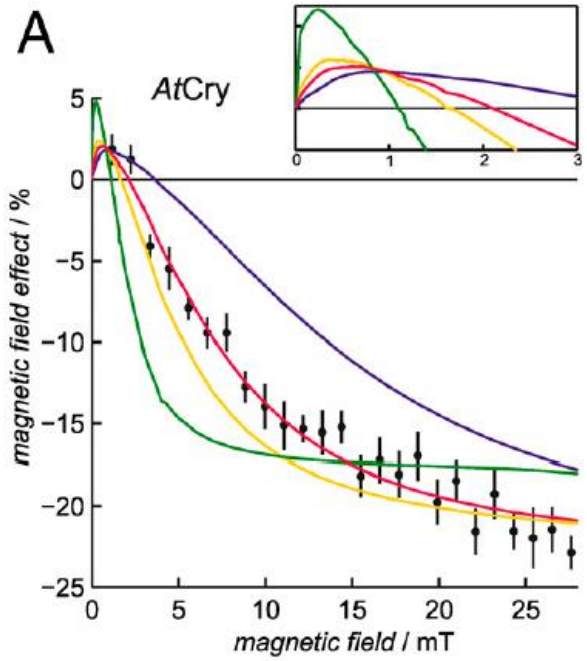
Svenja Engels[1,2]*, Nils-Lasse Schneider[1,2]*, Nele Lefeldt[1,2], Christine Maira Hein[1,2], Manuela Zapka[1,2], Andreas Michalik[1,2], Dana Elbers[1,2], Achim Kittel[3], P. J. Hore[4] & Henrik Mouritsen[1,2]



M

Peter Hore (Oxford)

Kiminori Maeda[a,1], Alexander J. Robinson[a,1], Kevin B. Henbest[a], Hannah J. Hogben[b], Till Biskup[b], Margaret Ahmad[c,d], Erik Schleicher[e], Stefan Weber[e], Christiane R. Timmel[a,2], and P. J. Hore[b,2]

4774–4779 | PNAS | March 27, 2012 | vol. 109 | no. 13

Arabidopsis thaliana
(ᑲᓇᒪᕐᓗᑦᑭᓯᐊᕐᓄᑦ)