

A Nap szerepe a légköroptikában, valamint az állatok és az ember tájékozódásában

Horváth Gábor

ELTE Biológiai Fizika Tanszék, Környezetoptika Laboratórium, Budapest


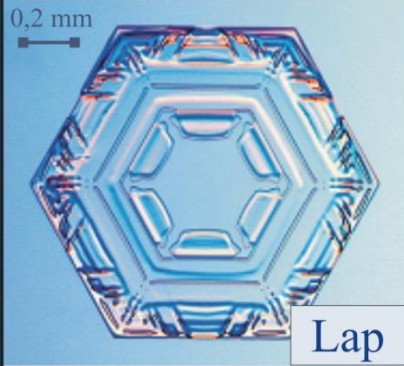


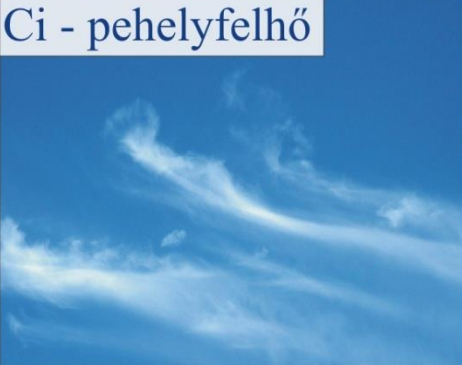
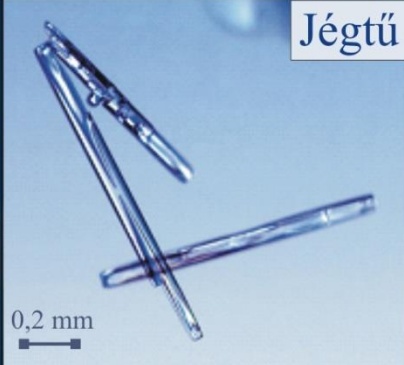
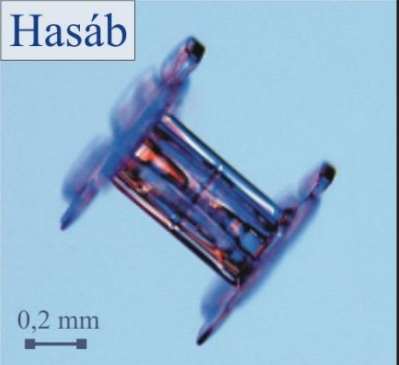





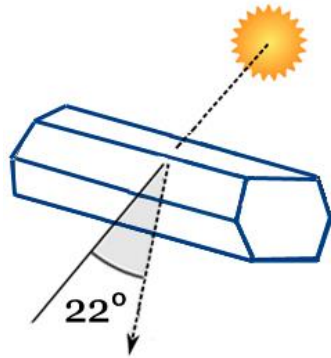
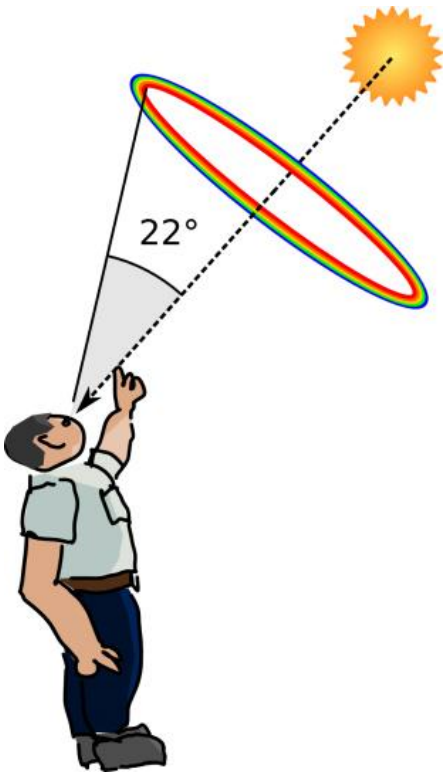
© C. Hinz

Halójelenségek kialakulása

A halókat a légköri jégkristályokban megtörő, vagy az azokról visszaverődő fény hozza létre.

<p>Cs - fátyolfelhő</p> 	<p>0,2 mm</p>  <p>Lap</p>	<p>0,2 mm</p>  <p>Hasáb</p>	 <p>HALÓKAT KIALAKÍTÓ FÉNYUTAK</p>
<p>Ci - pehelyfelhő</p> 	 <p>0,2 mm</p> <p>Jégtű</p>	 <p>0,2 mm</p> <p>Hasáb</p>	
<p>Cc - báránnyfelhő</p>  <p>MAGASSZINTŰ FELHŐK</p>	 <p>0,2 mm</p> <p>Jégtű</p> <p>JÉGKRISTÁLYOK MIKROSZKÓPOS KÉPE</p>		

22° haló



2014. ápr. 13., 2013. febr. 8. Mogyoród, a szerző felvételei



Melléknapok

„...az égen **vaknapok**at láttak...”

1548. Erdély



„'s mi a' legszebb **álnapok**at láttunk olly átható fény és világossággal...”

1840. december 14. Bakonybél

Roman Szpuk felvétele,
Churánov, Cseho.



„A' két egymással átal ellenben levő **fattyúnap**...”

1832. november 17. Erdély

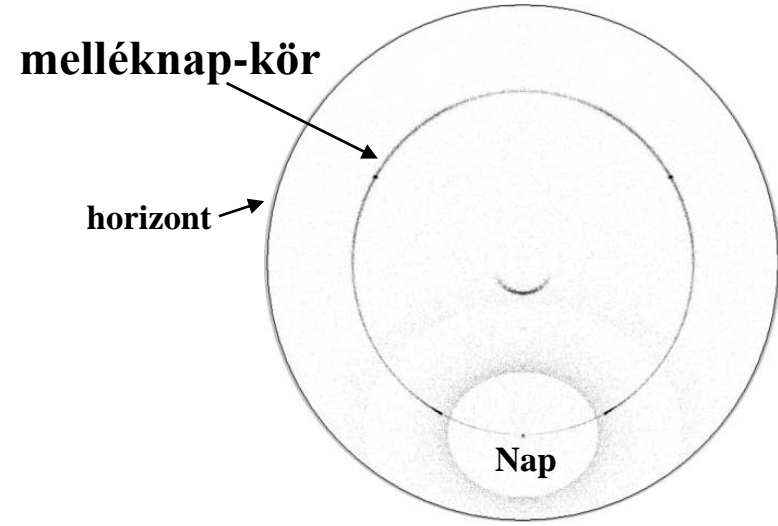
„...a Nap két oldalán kisebb **félnapok** pilácsolnak...”

1849. június 20.

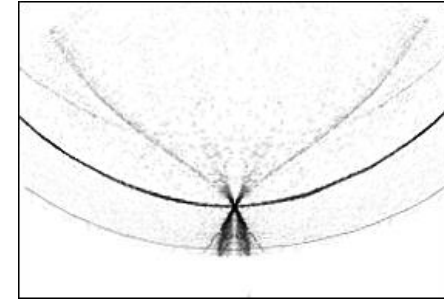


2008. március 15. Tardos, a szerző felvétele

Melléknap-kör



Nappal szemközti halók



Kalle Helenius fotója

2009. január 10. © Jan
Smejkal, Csehország -
http://www.ursa.fi/blogit/ice_crystal_halos





© Claudia & Wolfgang Hinz, 2014. január 30. Németország

Horizont alatti halók

© Rob Noble, Verbier, Svájc, <http://atoptics.co.uk/fz188.htm>



2010. október 18. Sonnblick, Hermann Scheer felvétele, meteoros.de



A poláros szivárvány

polarization color pictures

A



$\chi = 0^\circ$



B



$\chi = 45^\circ$



C



$\chi = 90^\circ$



D



averaged color picture



Jean-Baptiste Biot
(1774-1862)

A fény polarizációja – képző polarimetria

Stokes-polarimetria

Stokes-vektor (λ) = $\underline{S} = (I, Q, U, V)$

λ = hullámhossz > színek

intenzitás (λ)

$$I = I_r + I_p$$

lineáris polarizációfok (λ)

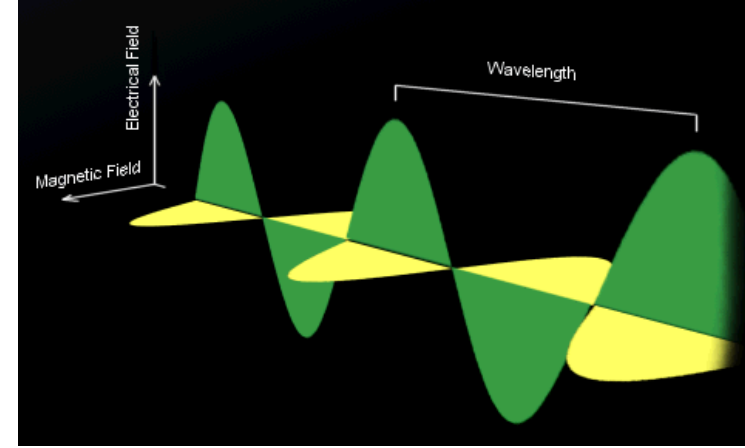
$$p = \frac{\sqrt{Q^2 + U^2}}{I}$$

polarizációirány (λ)

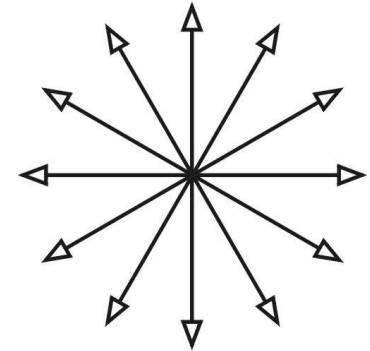
$$\alpha = \frac{1}{2} \arctan\left(\frac{U}{Q}\right)$$

ellipticitás (λ)

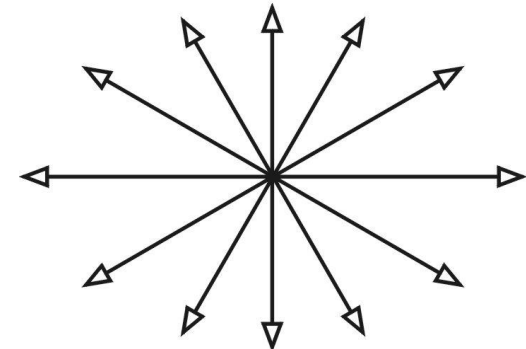
$$\varepsilon = \frac{1}{2} \arcsin \frac{V}{\sqrt{Q^2 + U^2 + V^2}}$$



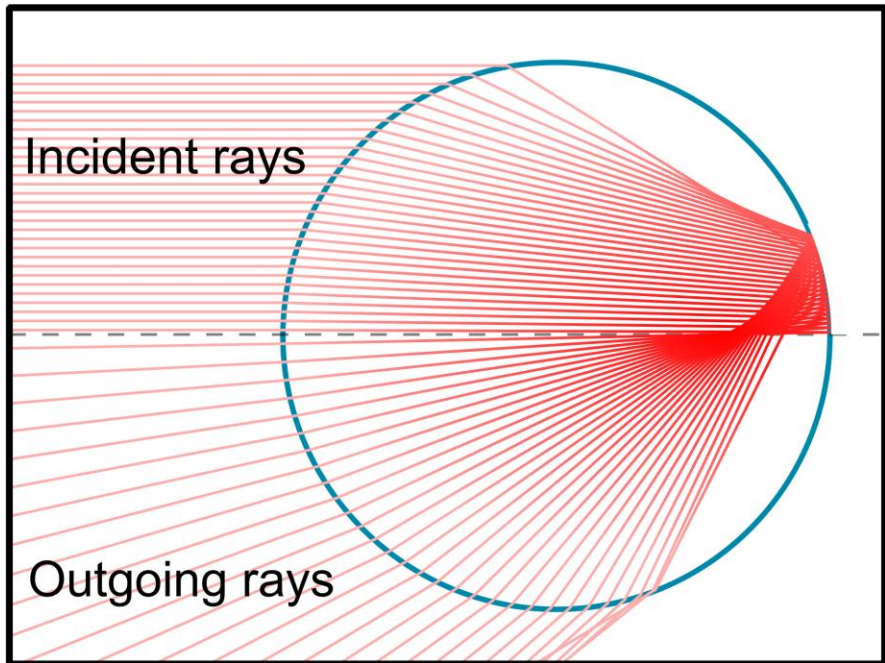
polarizálatlan



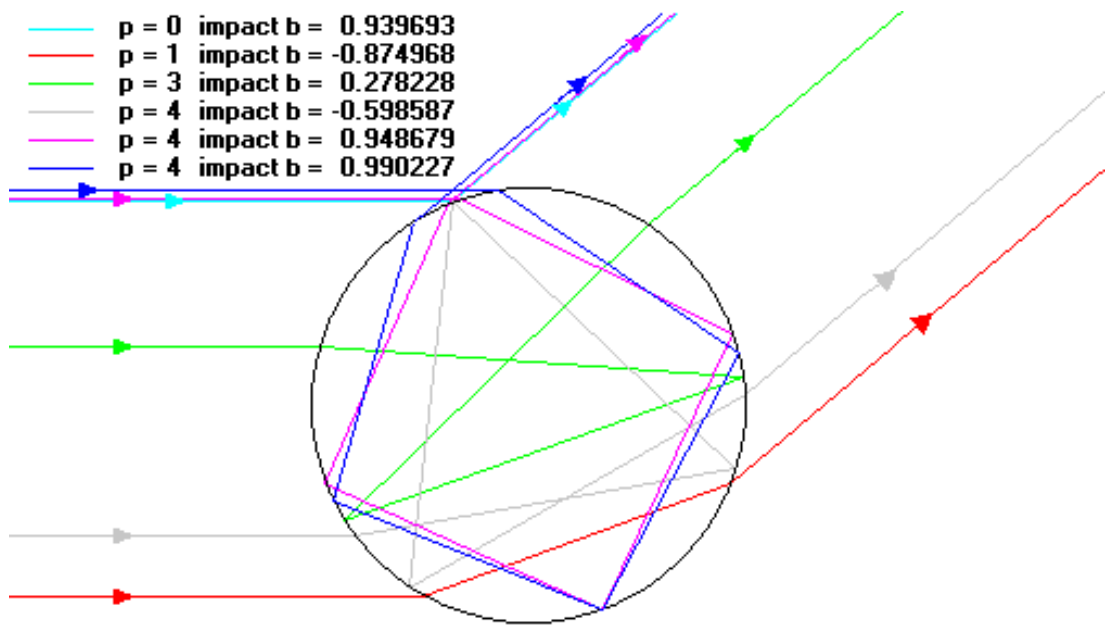
részlegesen lineárisan poláros



Sugármenetek gömb alakú vízcseppben

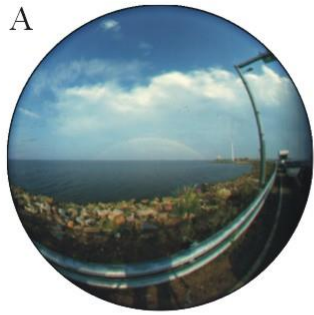


- $p = 0$ impact $b = 0.939693$
- $p = 1$ impact $b = -0.874968$
- $p = 3$ impact $b = 0.278228$
- $p = 4$ impact $b = -0.598587$
- $p = 4$ impact $b = 0.948679$
- $p = 4$ impact $b = 0.990227$

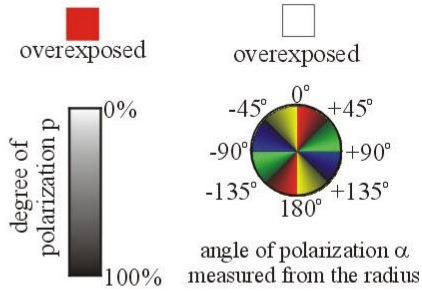


A poláros szivárvány

color picture



Jean-Baptiste Biot
(1774-1862)

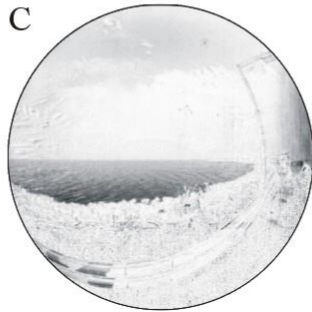


radiance I

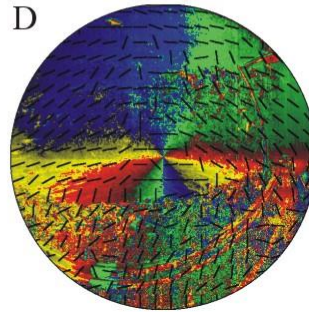


blue (450 nm)

degree of polarization p



angle of polarization α

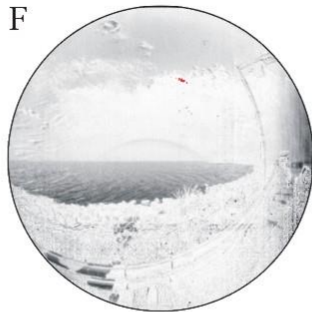


E

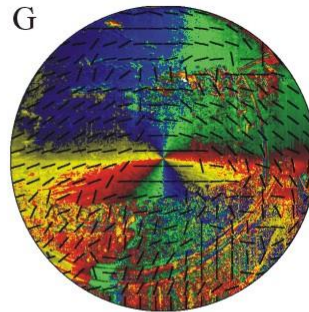


green (550 nm)

F



G

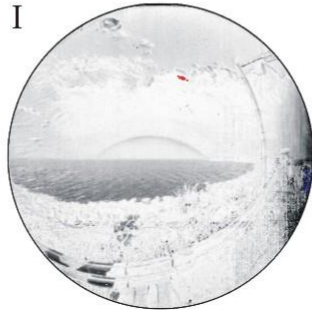


H

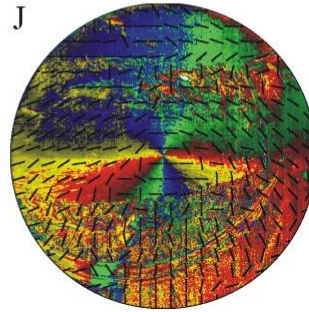


red (650 nm)

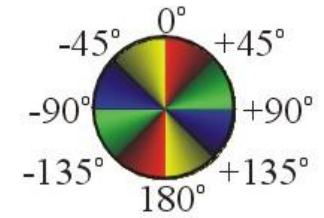
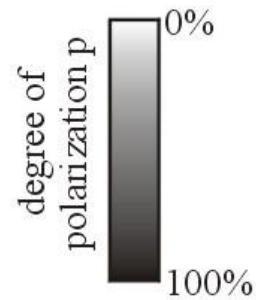
I



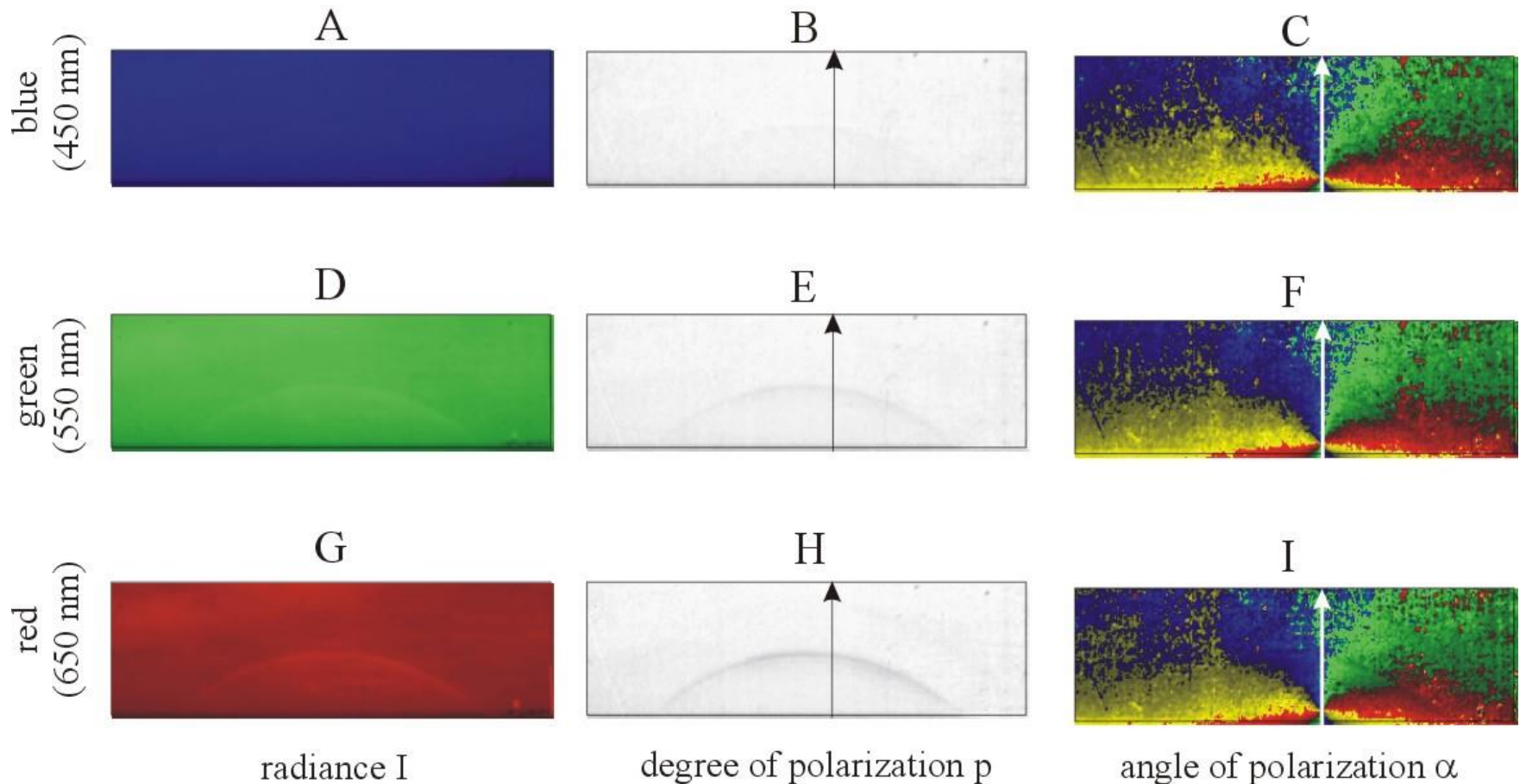
J



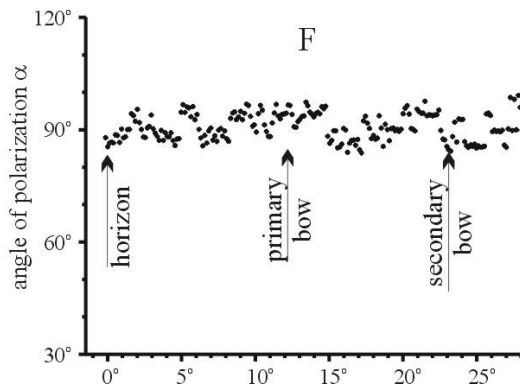
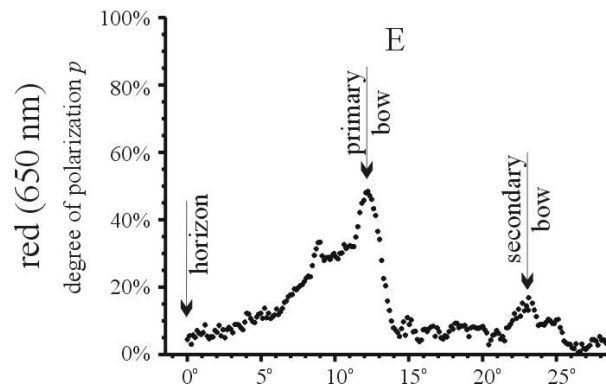
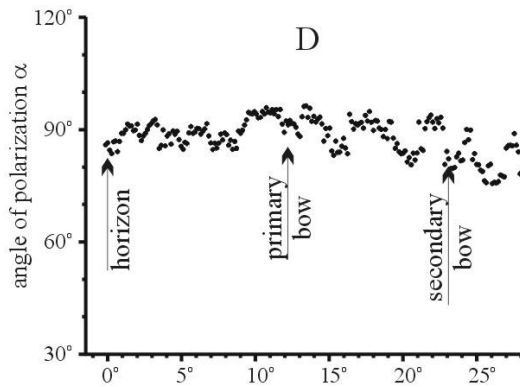
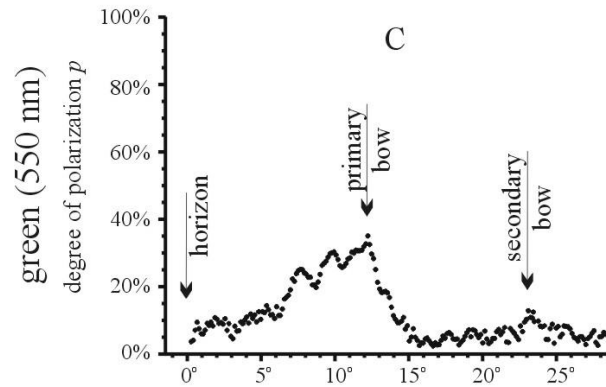
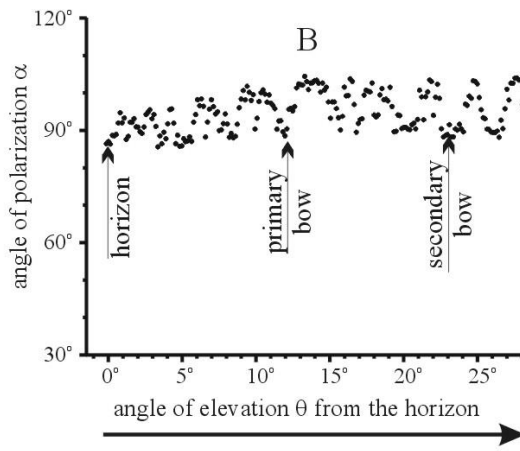
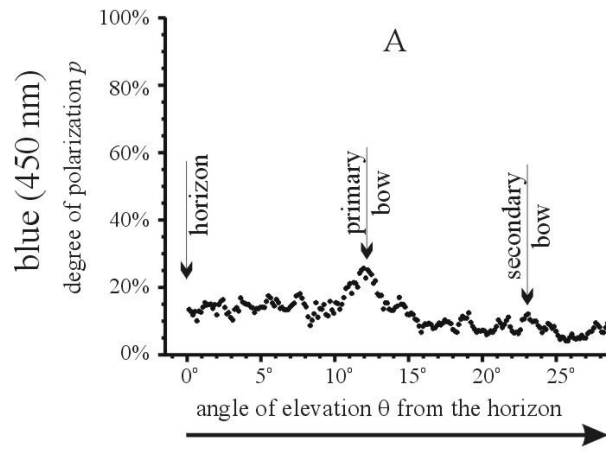
A poláros szivárvány



angle of polarization α
measured from the radius



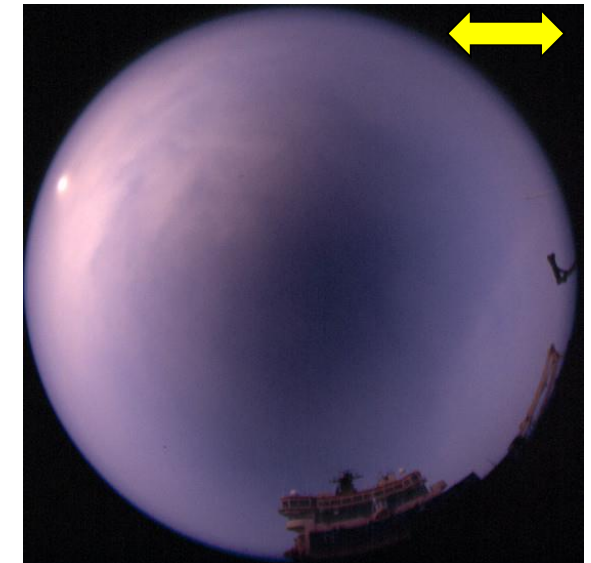
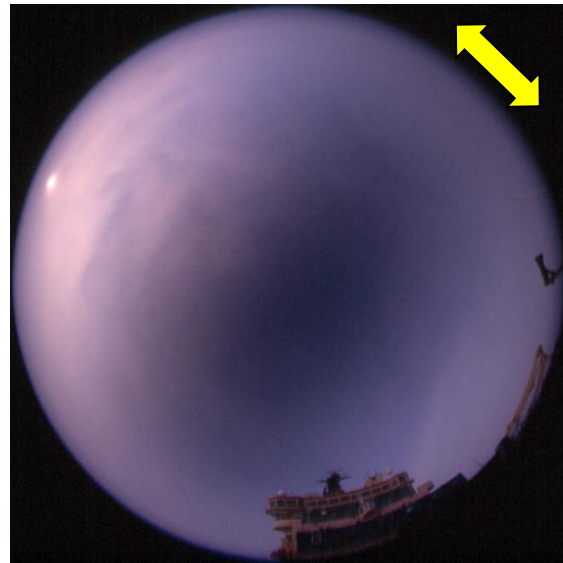
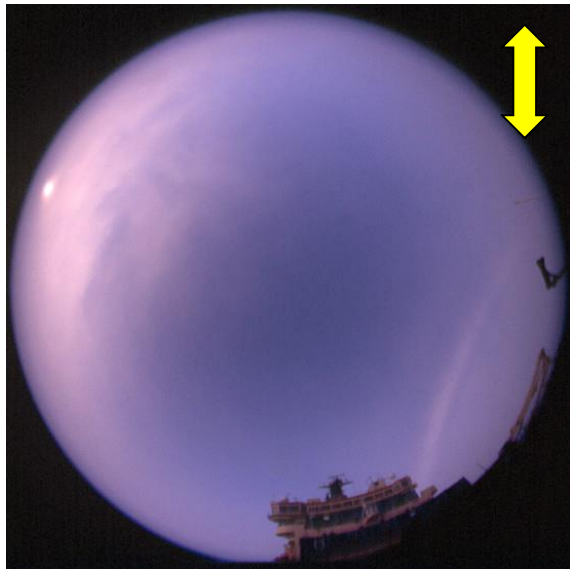
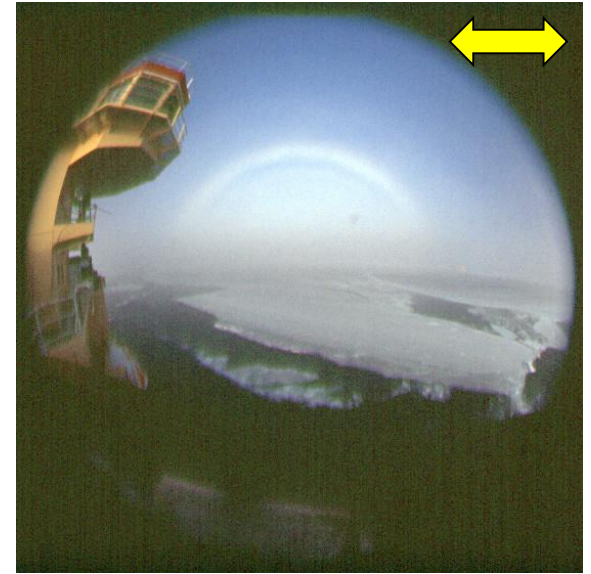
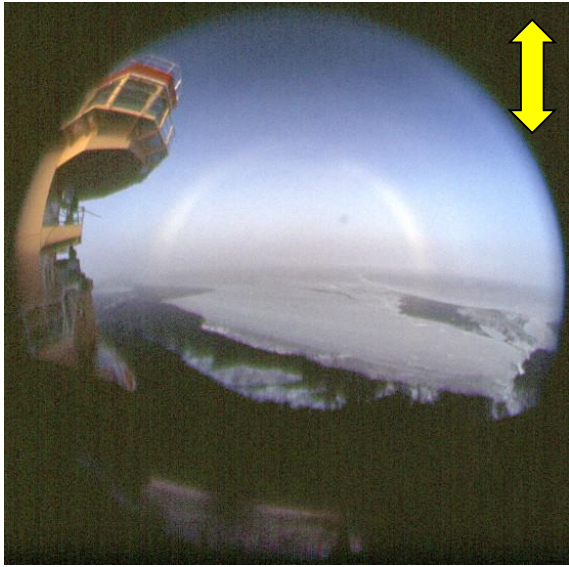
A poláros szivárvány



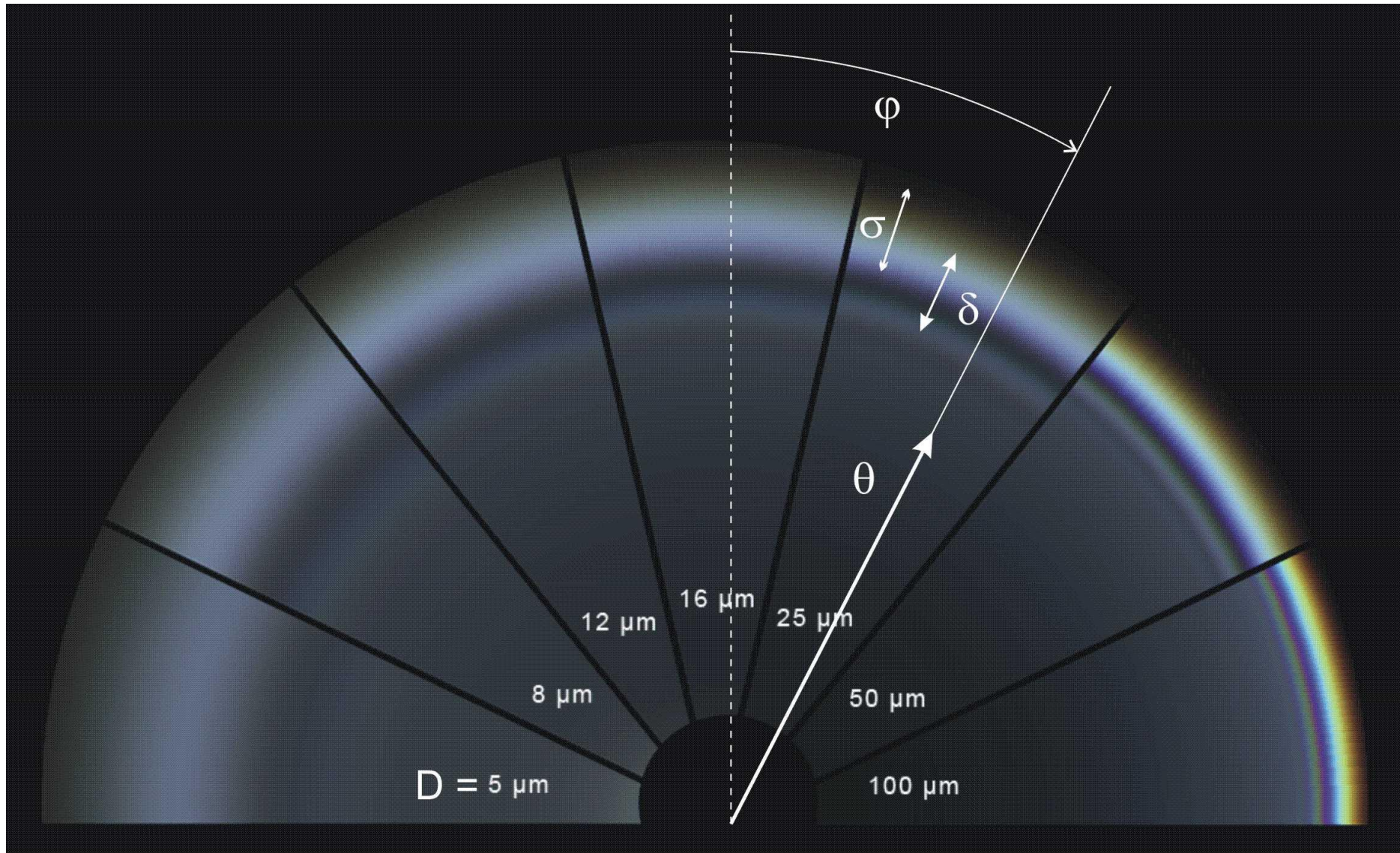
Fehér szivárvány, avagy ködív



Fehér szivárvány, avagy poláros ködív



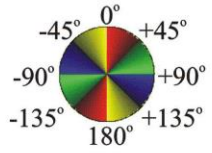
Fehér szivárvány, avagy poláros ködív



Fehér szivárvány, avagy poláros ködív

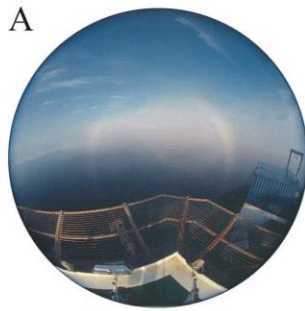
degree of linear polarization p

0% 100%

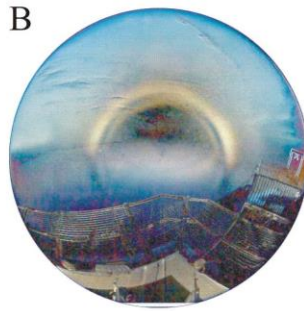


angle of polarization α from the vertical

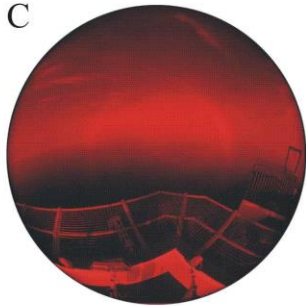
color picture



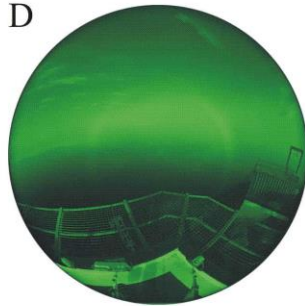
polarized radiance



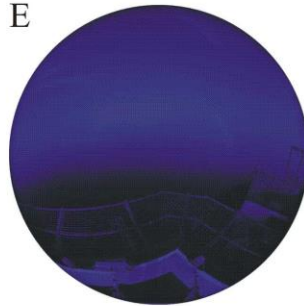
red (650 nm)



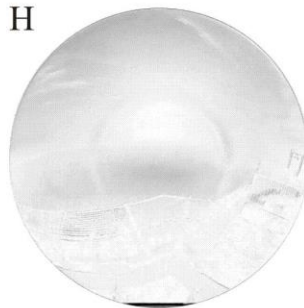
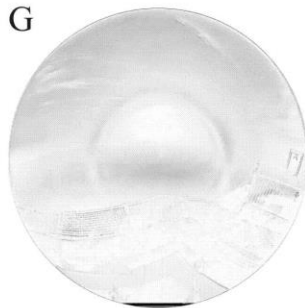
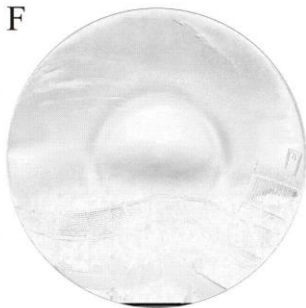
green (550 nm)



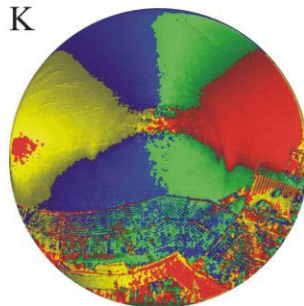
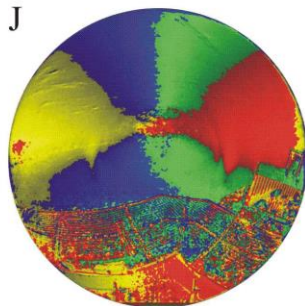
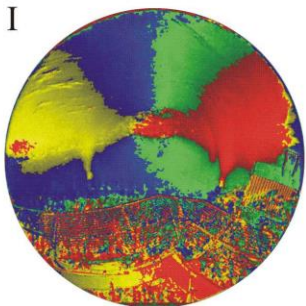
blue (450 nm)



radiance I

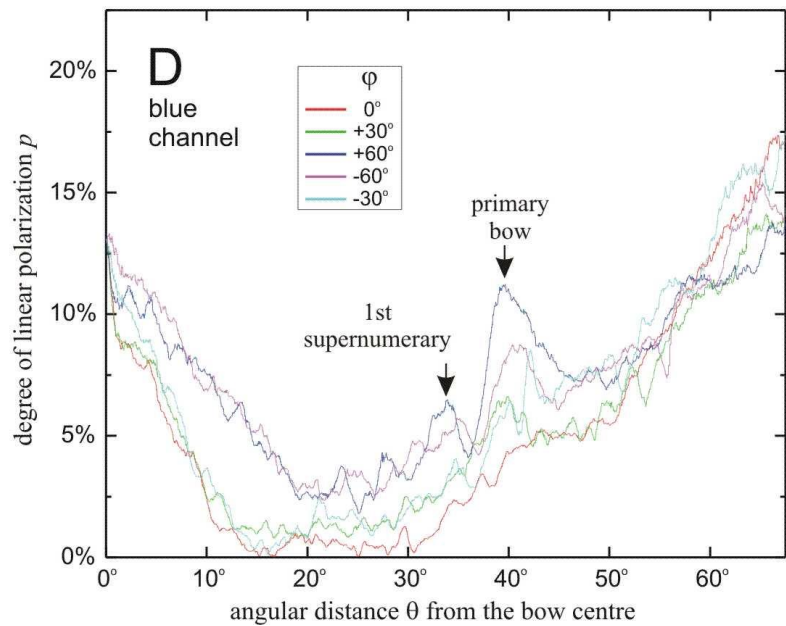
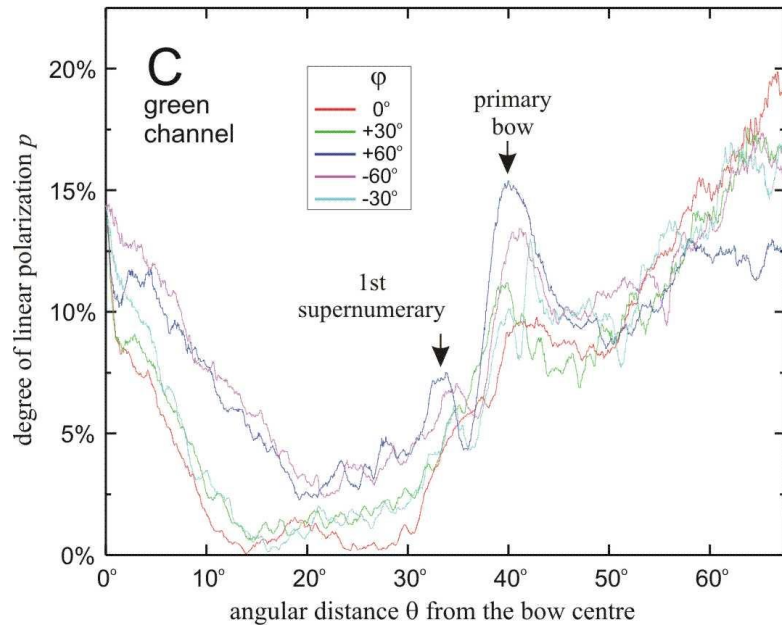
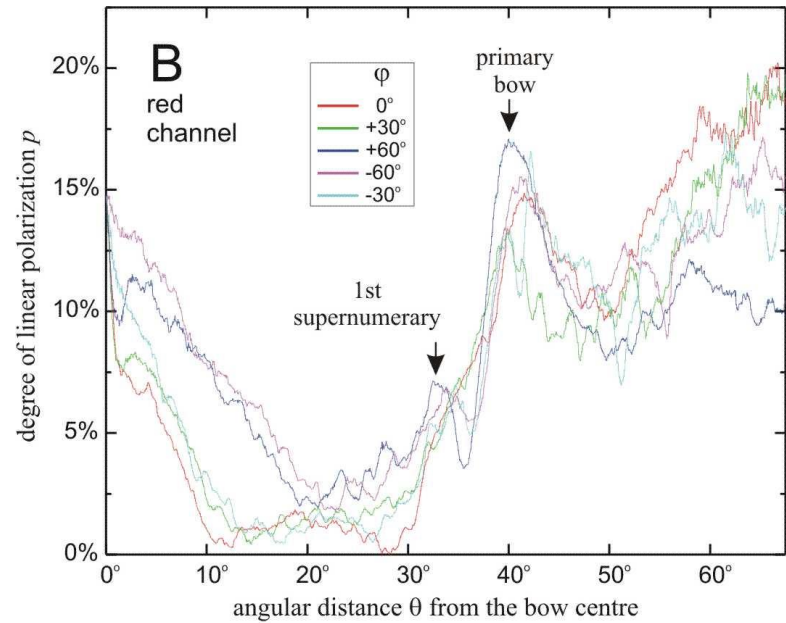
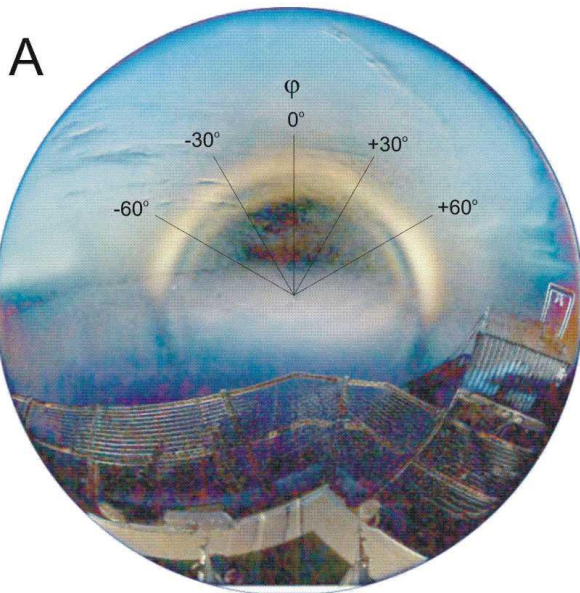


degree of linear polarization p

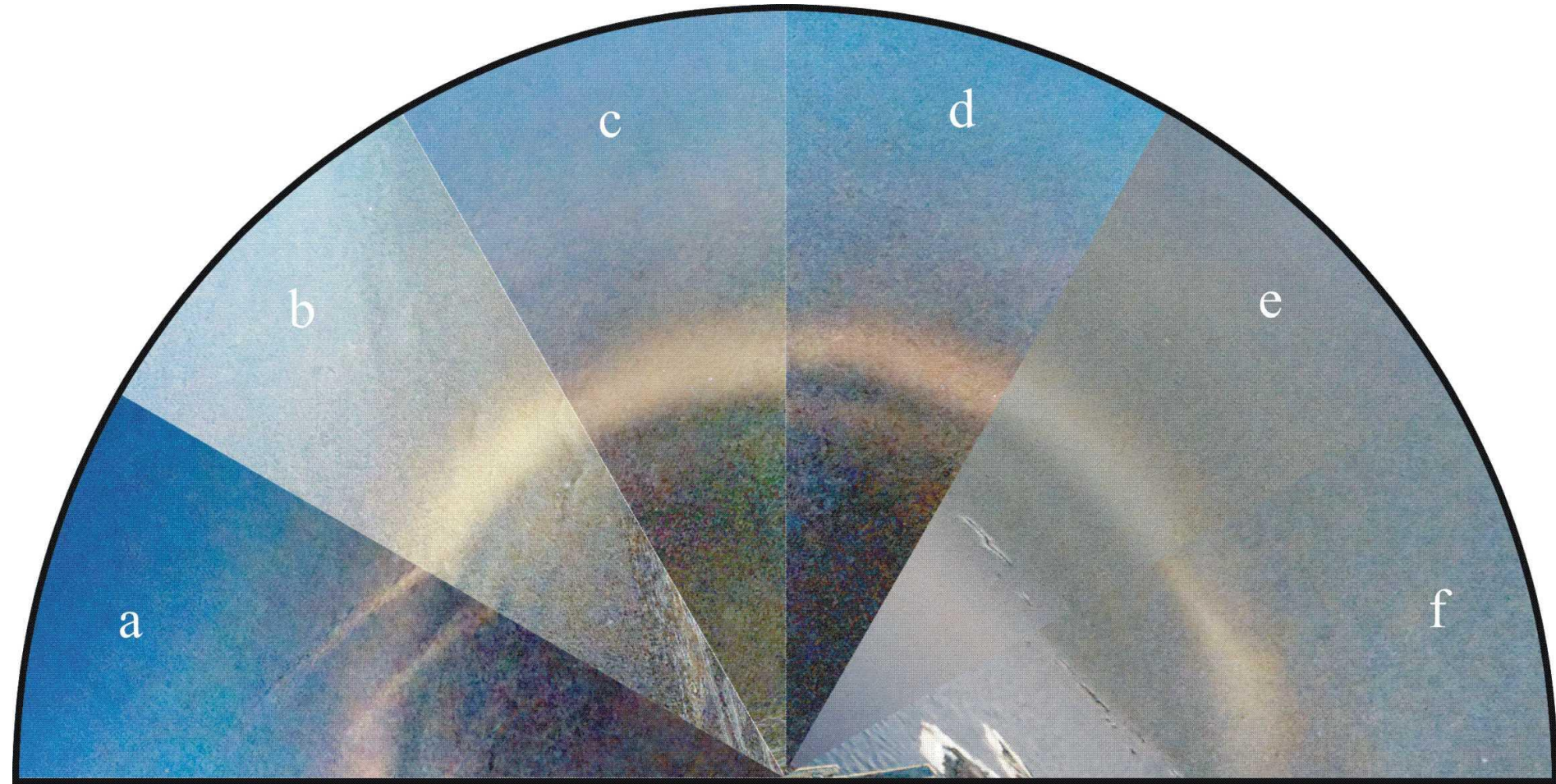


angle of polarization α

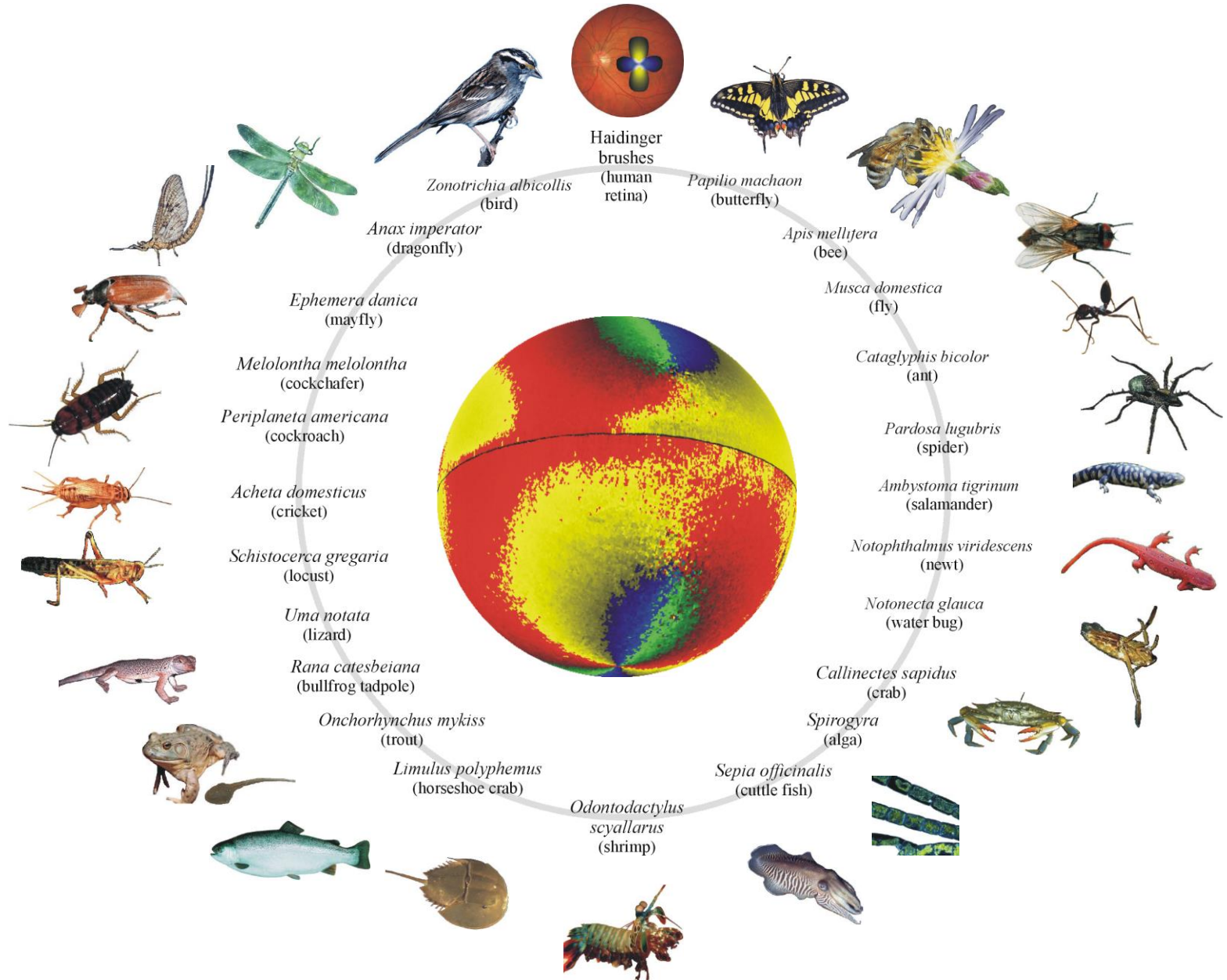
Fehér szivárvány, avagy poláros ködív



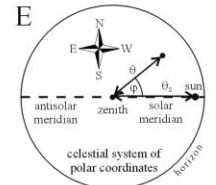
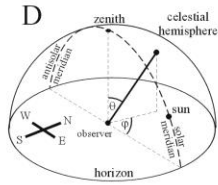
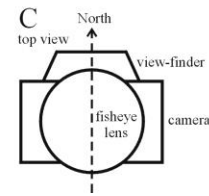
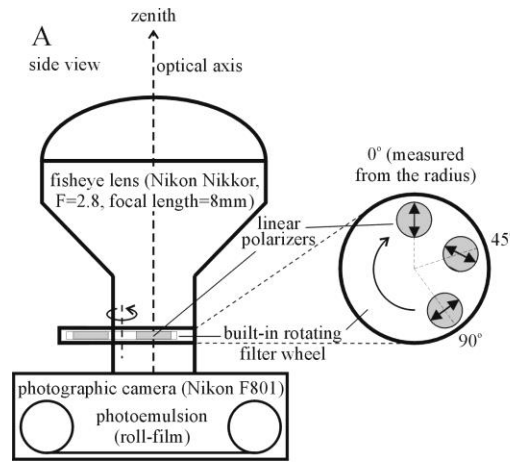
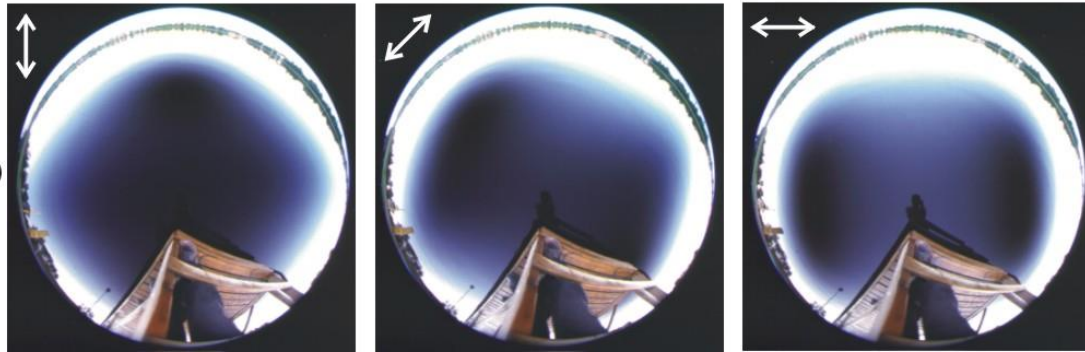
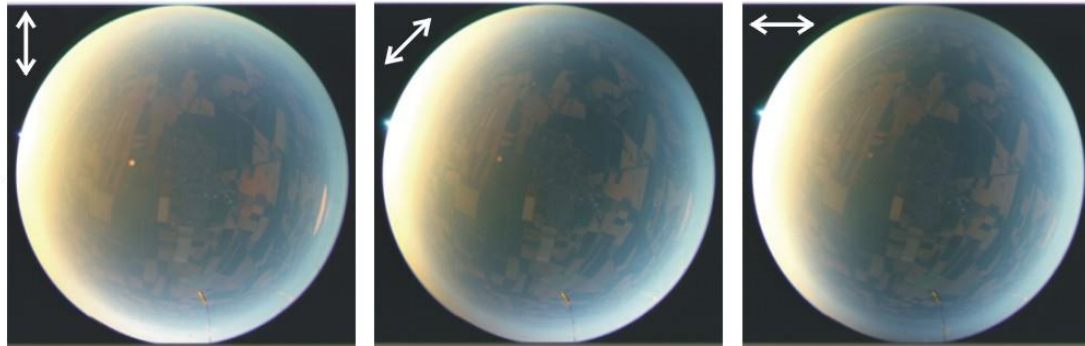
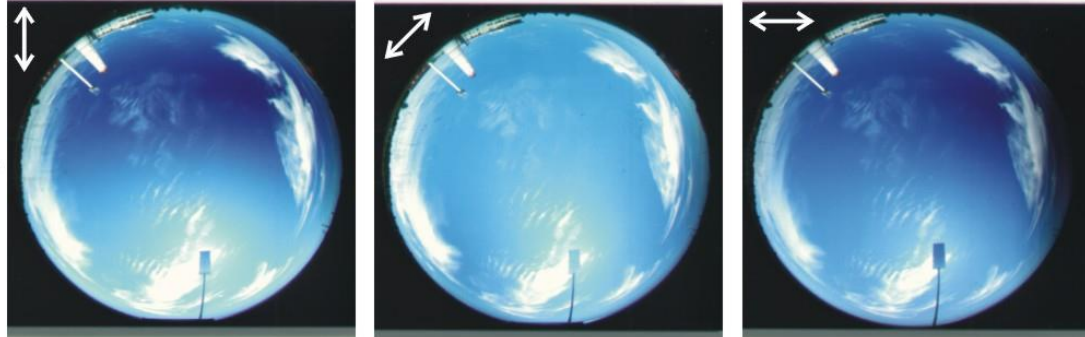
Fehér szivárvány, avagy poláros ködív



Polarizáció-érzékeny állatok

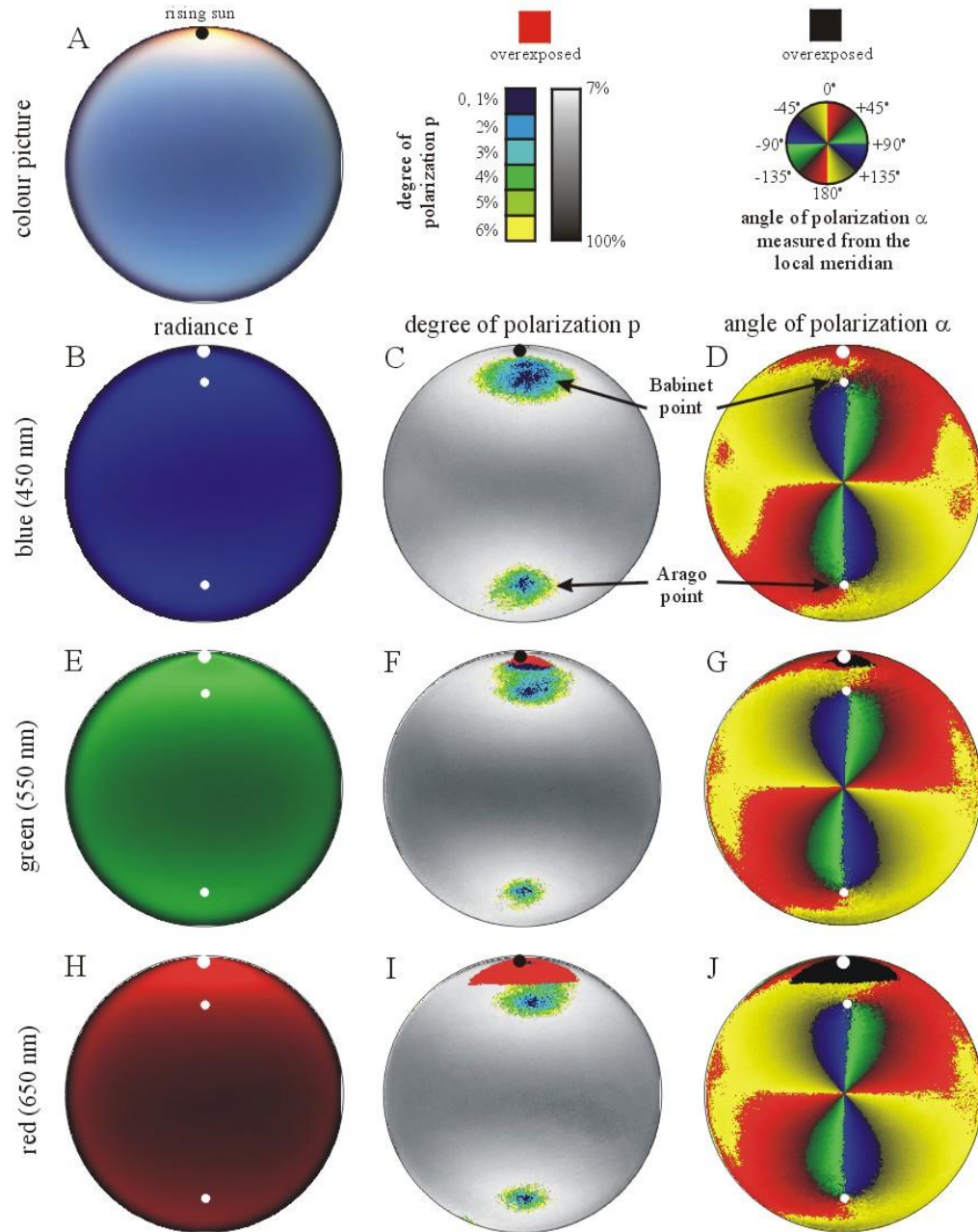


Lineárisan poláros világunk halszemoptikán át

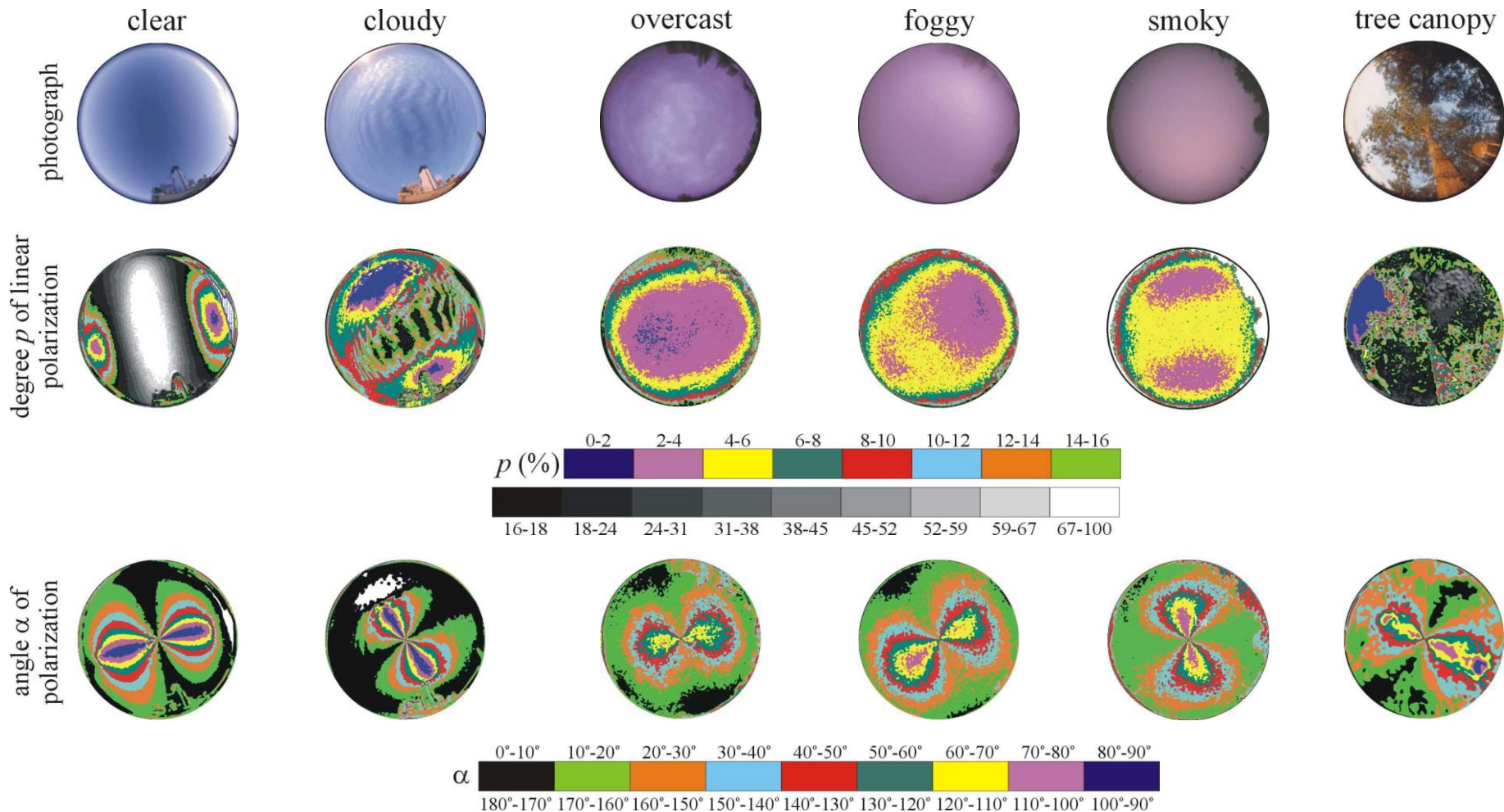


downwelling skylight measured on the ground at sunrise

Az égbolt polarizációs mintázatai



Az égbolt meteorológiai helyzettől független polarizációirány mintázata

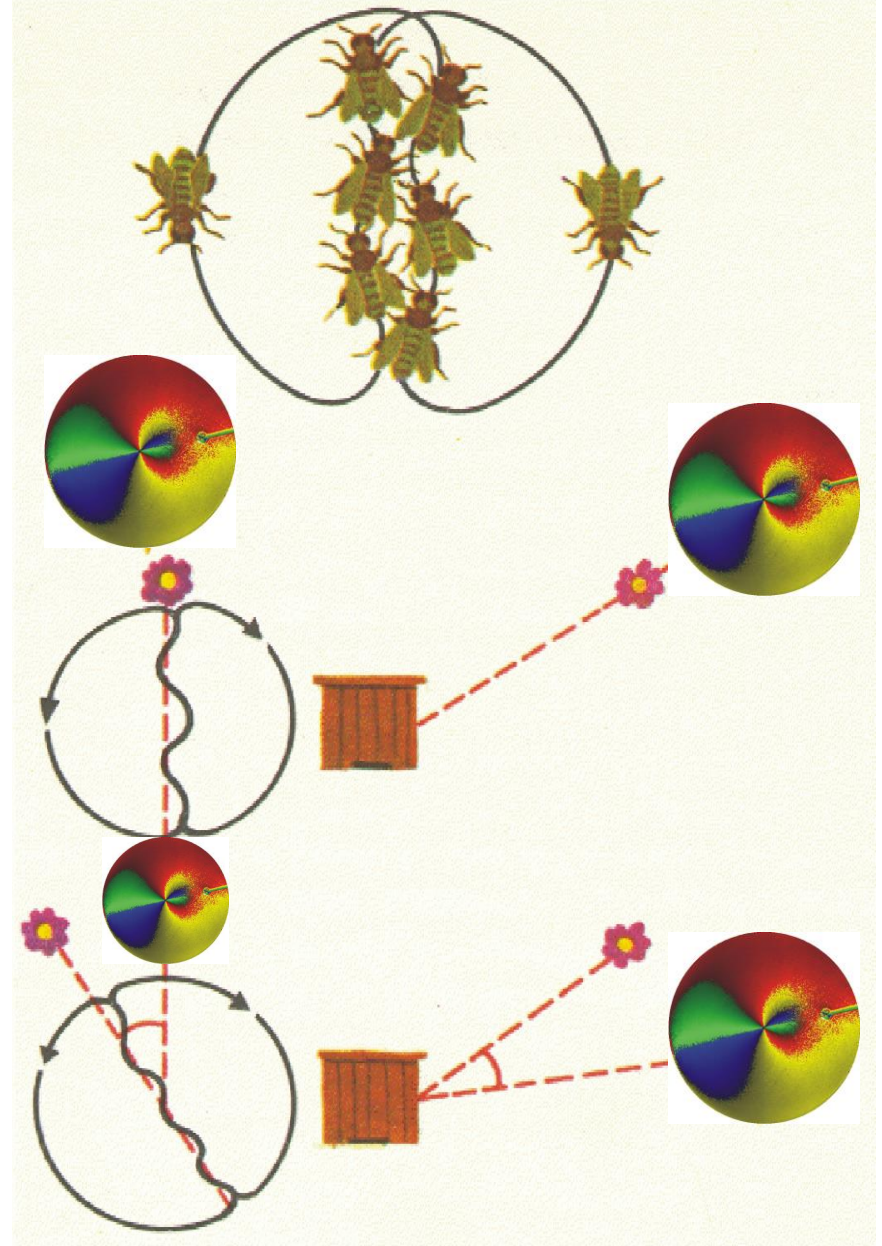


A háziméhek (*Apis mellifera*) tájékozódása az égbolt polarizációja alapján: 1949 (Nobel-díj: 1973)

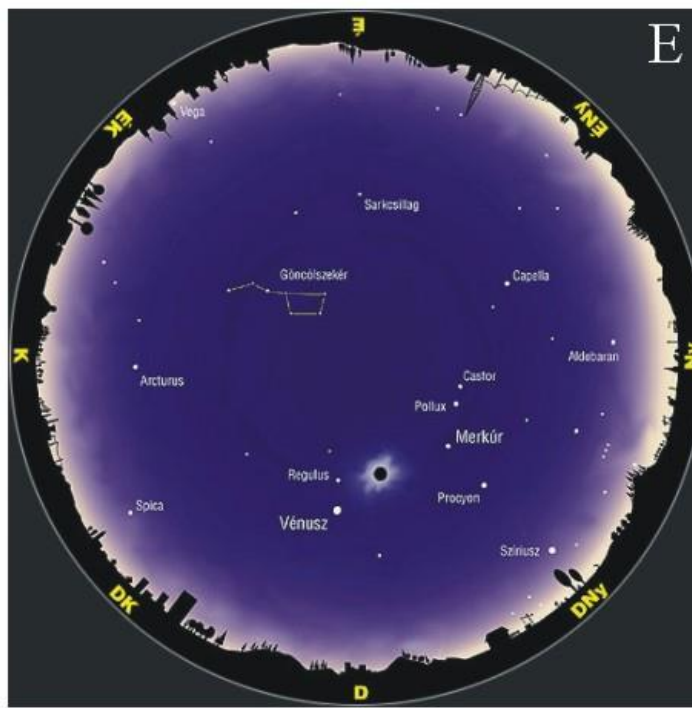
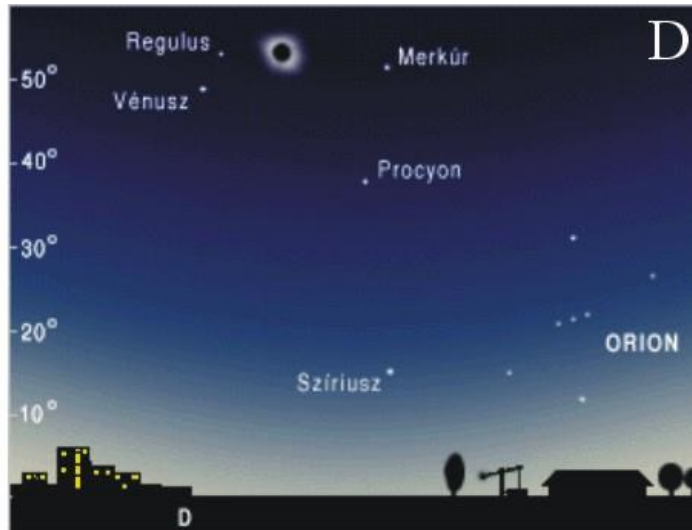
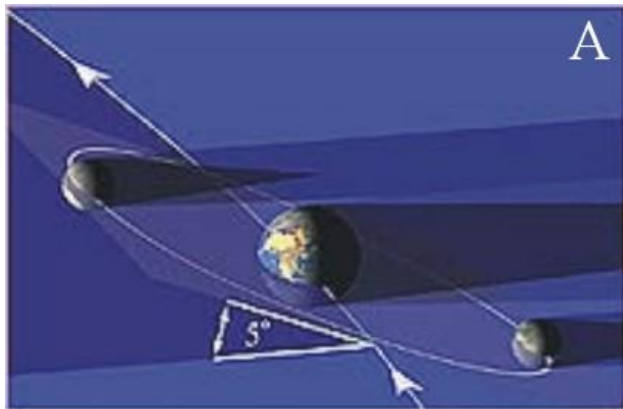


Karl von Frisch
(1886-1982)

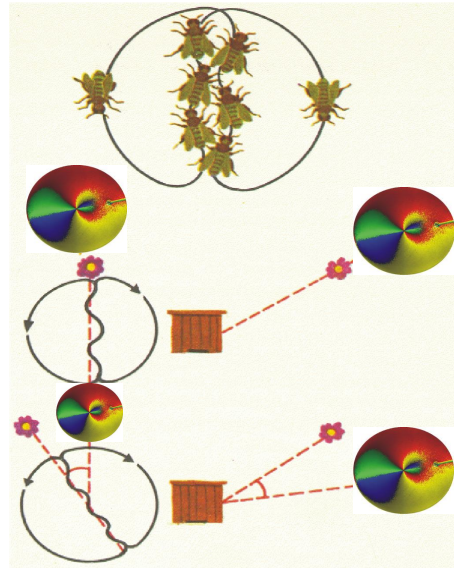
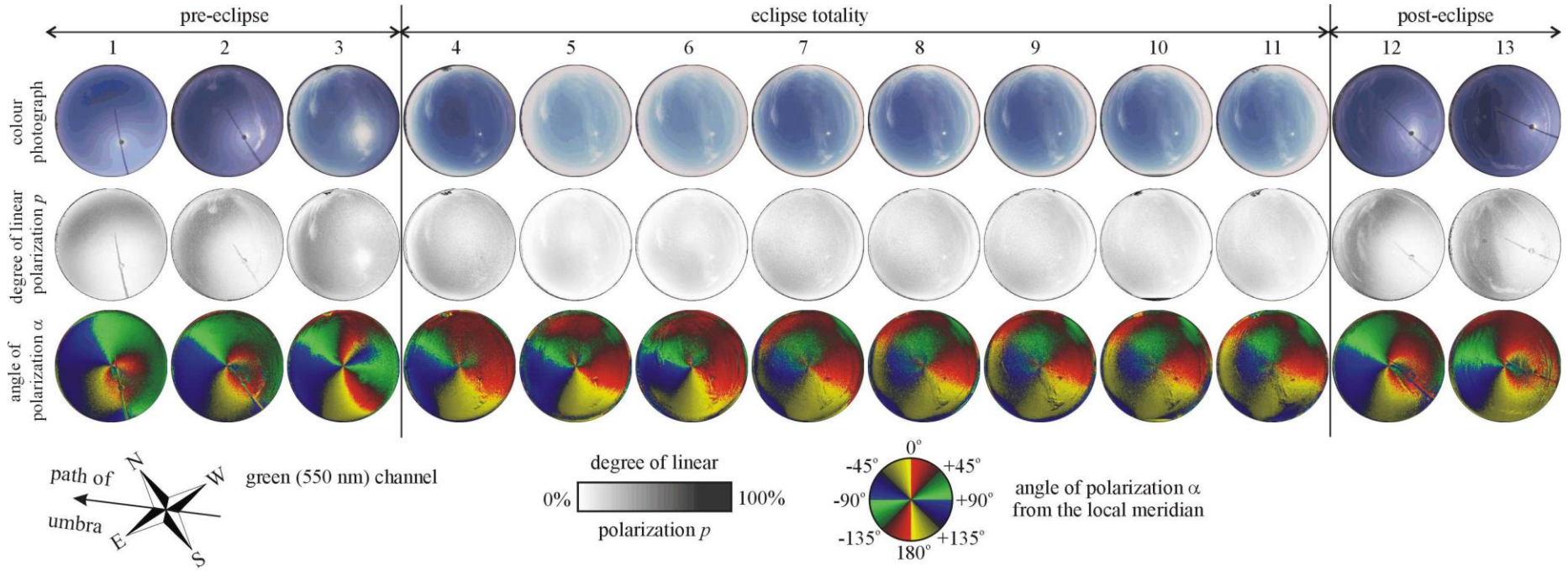
Karl von Frisch (1949) Die Polarisation des Himmelslichtes als orientierender Faktor bei den Tänzen der Bienen. *Experientia* 5: 142-148



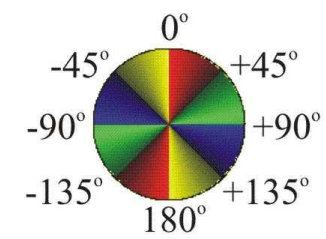
Az égbolt polarizációja teljes napfogyatkozáskor



Égboltpolarizáció teljes napfogyatkozáskor és a háziméhek végzetes eltévedése



Víztest polarizációs mintázatai



angle of polarization α from the vertical
blue (450 nm)

photograph

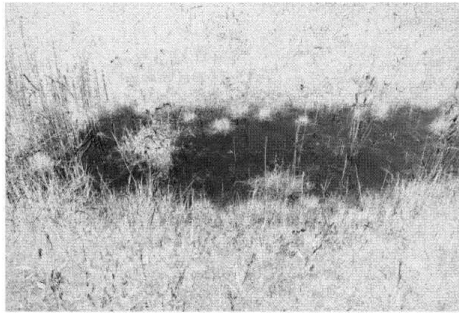


degree of linear polarization d

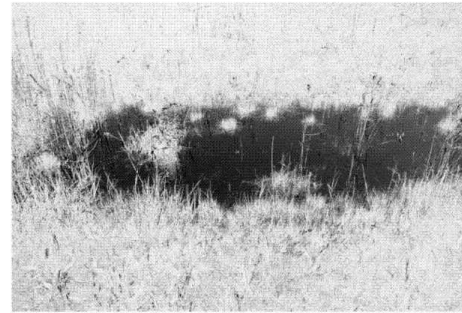


■ area detected as water

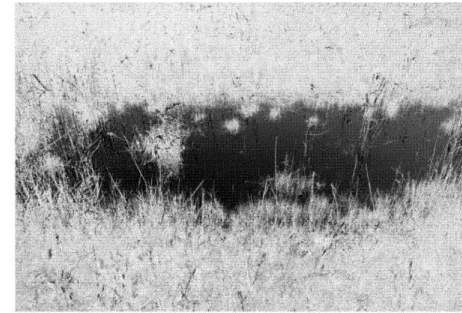
red (650 nm)



green (550 nm)

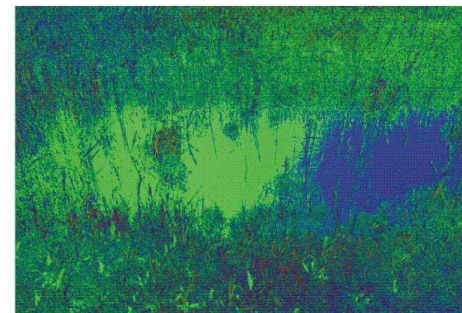
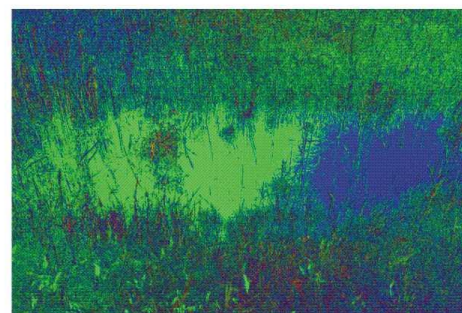
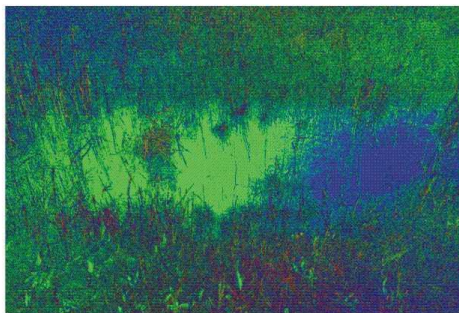


blue (450 nm)



degree of polarization d

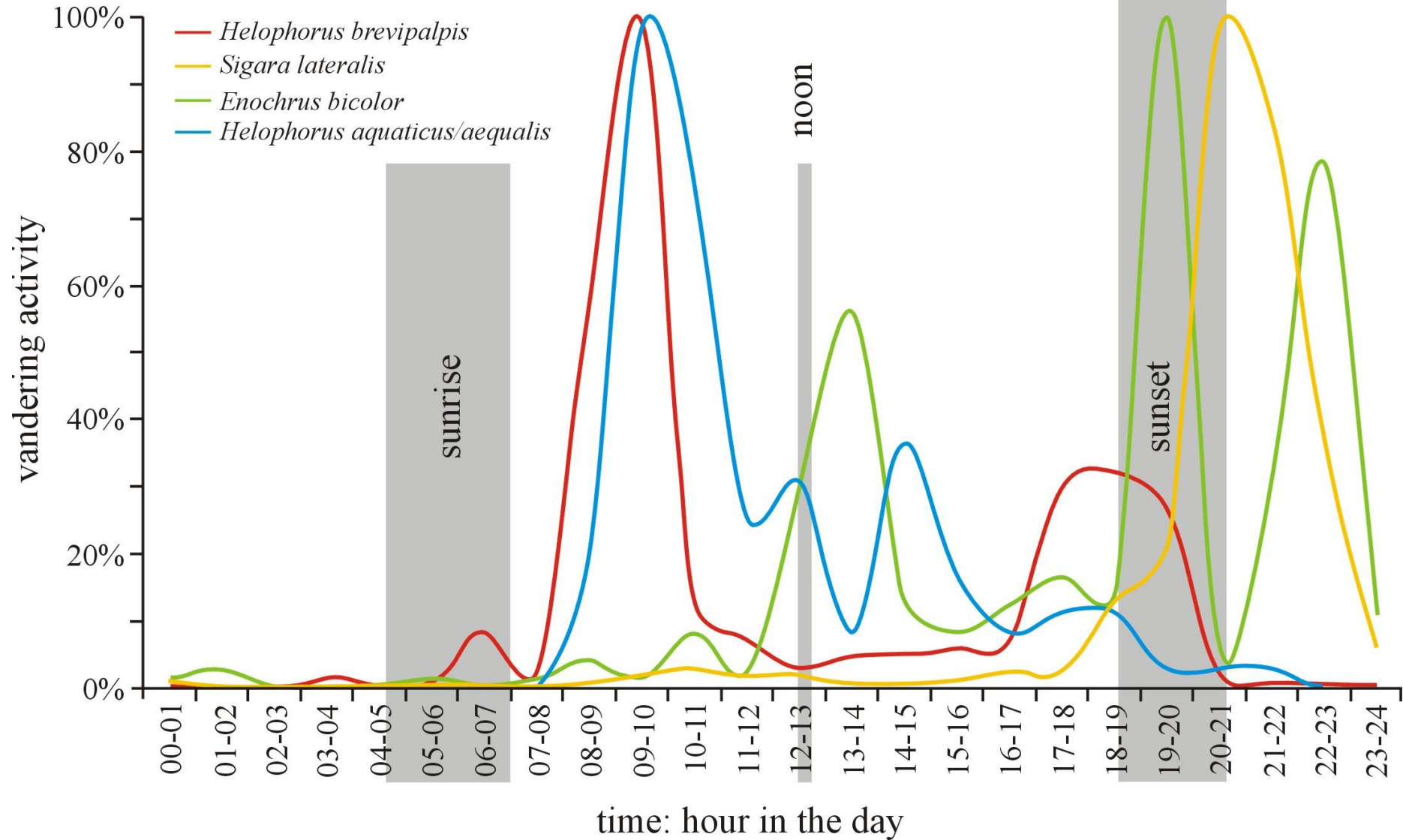
angle of polarization α



area detected as water

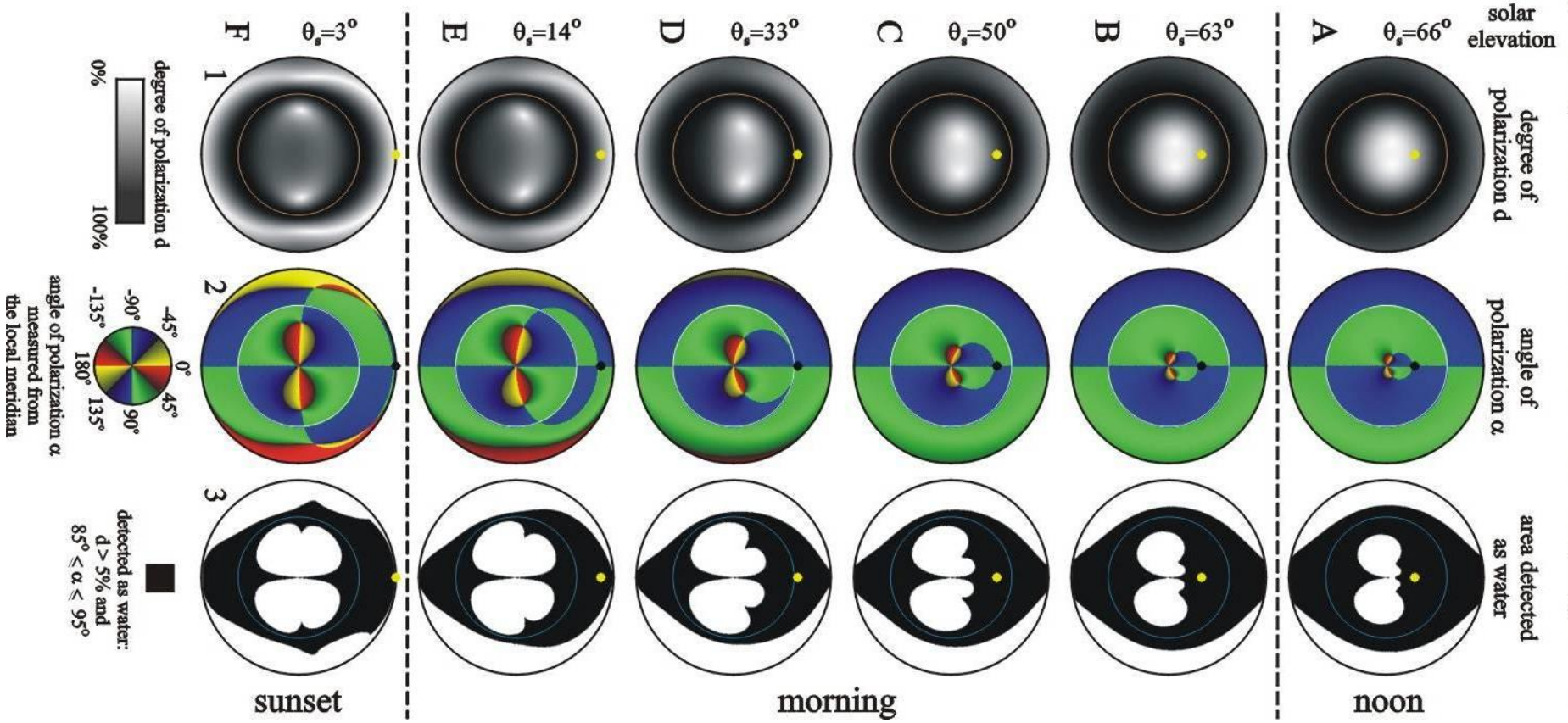


A vízirovarok napszakos repülési mintázatai

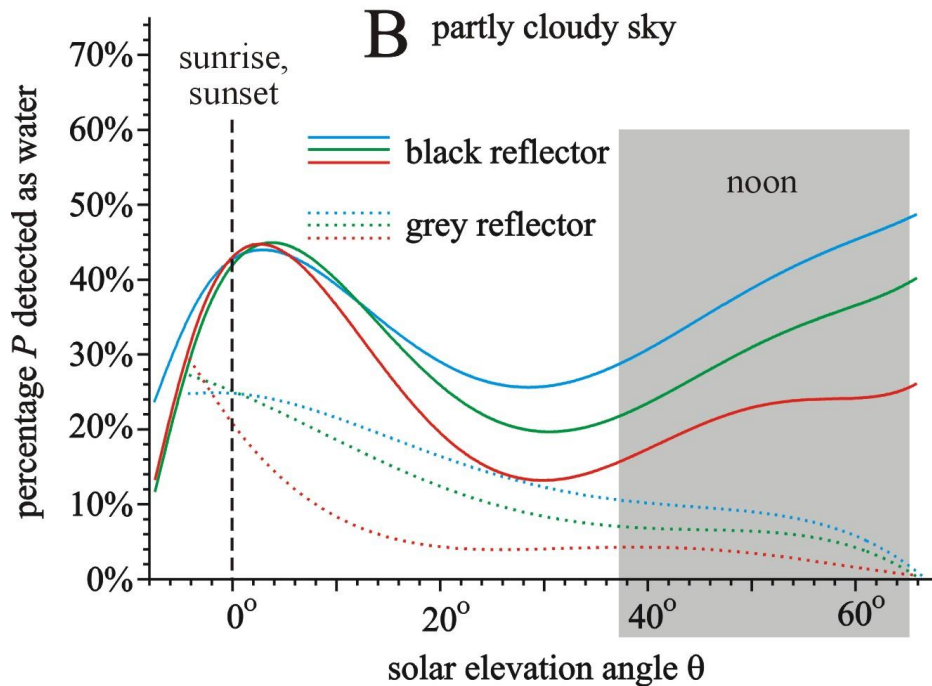
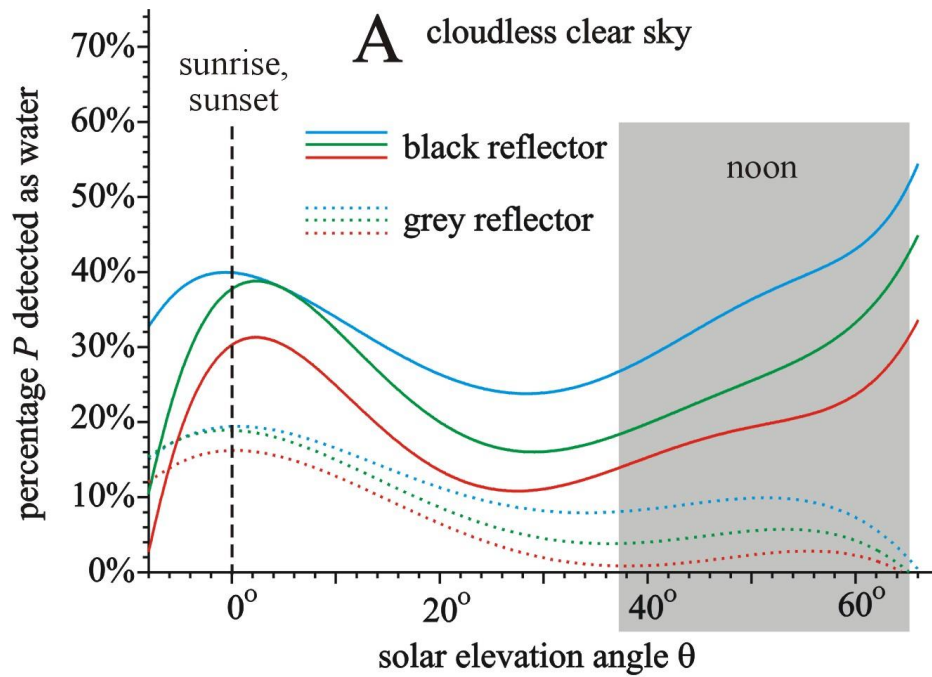


Vízfelszín polarizációs mintázatai és polarotaktikusan víznek érzékelt felületrészei a napmagasság függvényében

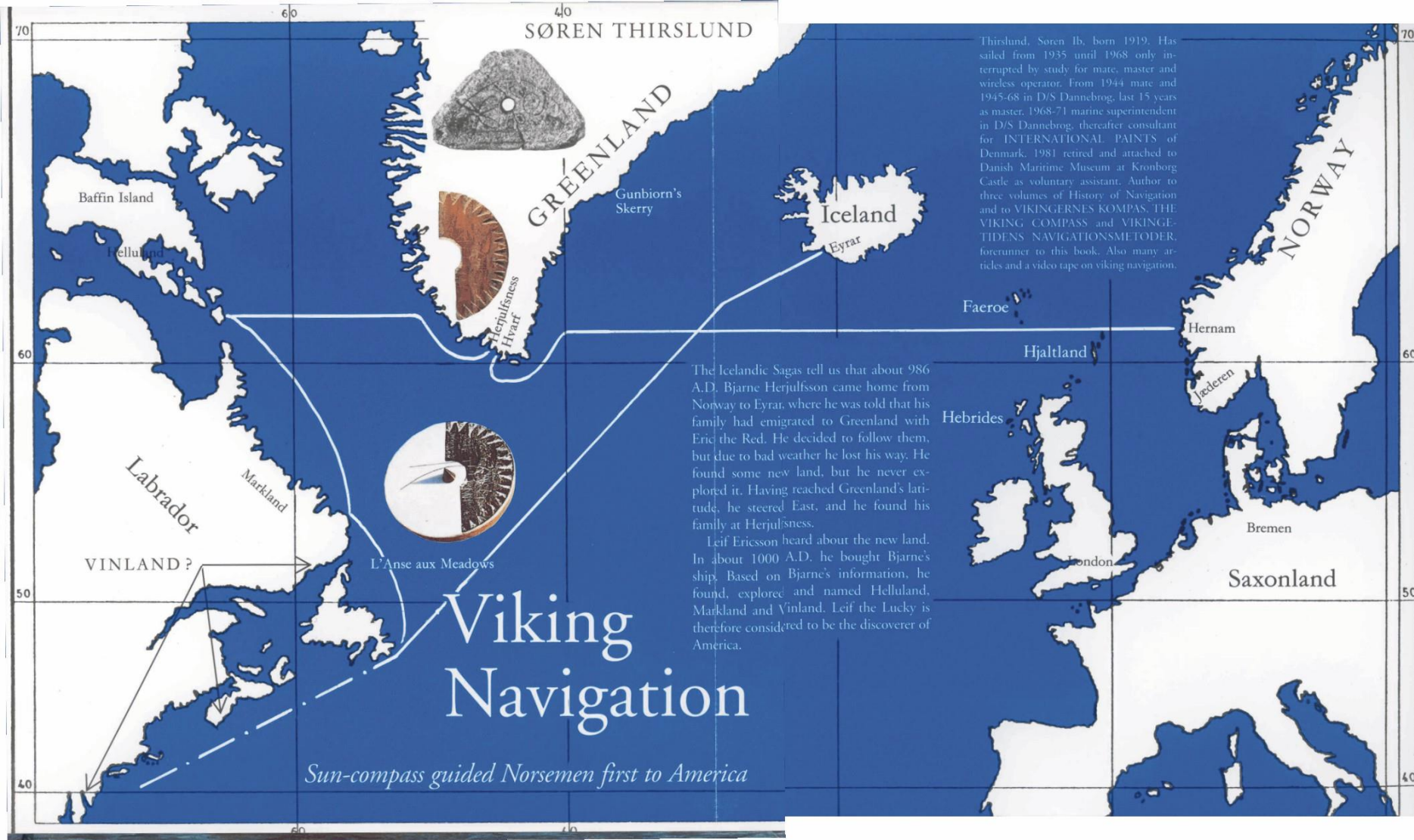
perfectly black reflector under clear Rayleigh skies



Sötét és világos vizek polarizációs detektálhatóságának függése a napmagasságtól



A vikingek mágneses iránytű nélküli tengeri navigációja



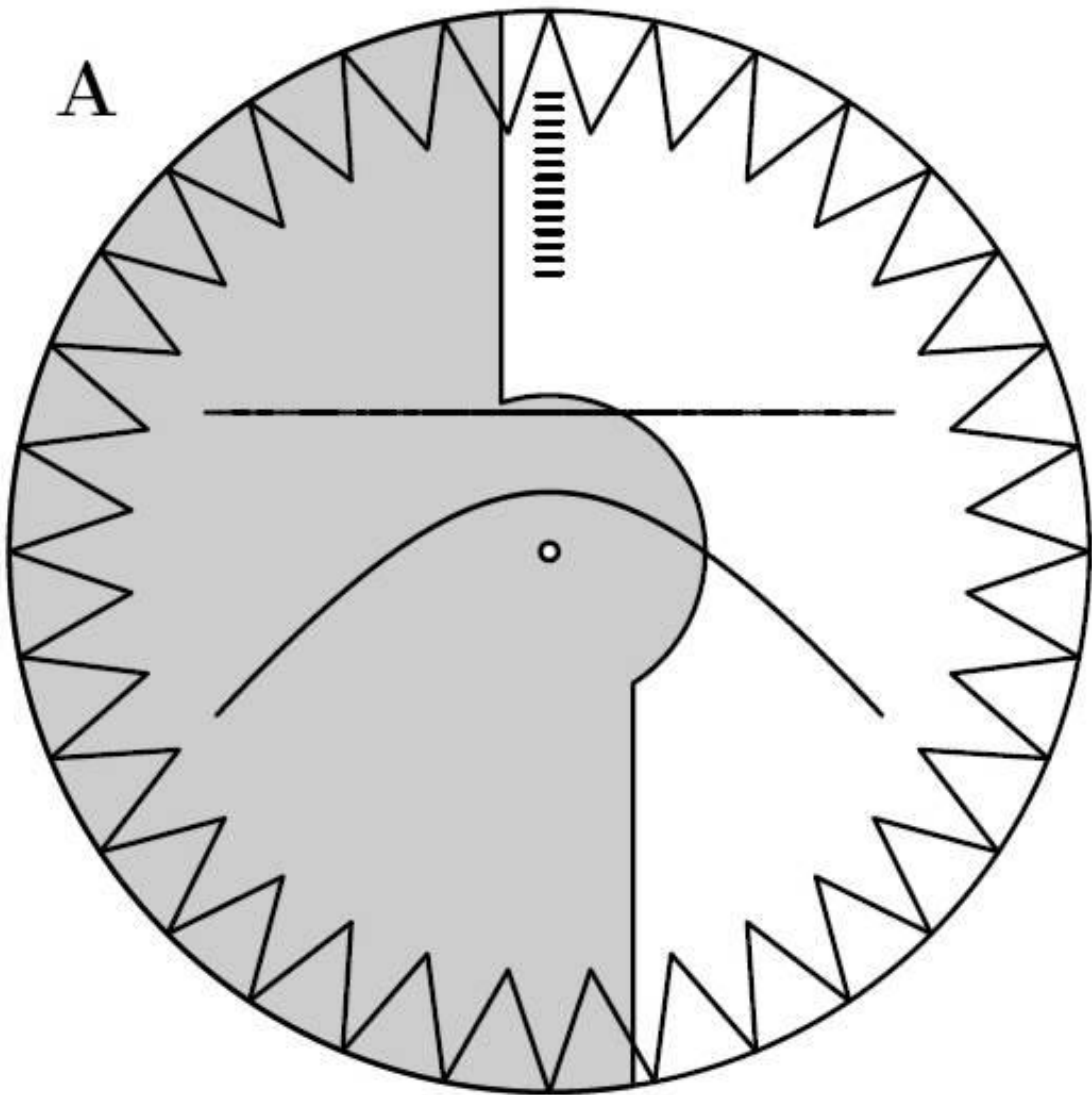
Thirslund, Søren Ib, born 1919. Has sailed from 1935 until 1968 only interrupted by study for mate, master and wireless operator. From 1944 mate and 1945-68 in D/S Dannebrog, last 15 years as master. 1968-71 marine superintendent in D/S Dannebrog, thereafter consultant for INTERNATIONAL PAINTS of Denmark. 1981 retired and attached to Danish Maritime Museum at Kronborg Castle as voluntary assistant. Author to three volumes of History of Navigation and to VIKINGERNES KOMPAS, THE VIKING COMPASS and VIKINGETIDENS NAVIGATIONSMETODER, forerunner to this book. Also many articles and a video tape on viking navigation.

The Icelandic Sagas tell us that about 986 A.D. Bjarne Herjulfsson came home from Norway to Eyrar, where he was told that his family had emigrated to Greenland with Eric the Red. He decided to follow them, but due to bad weather he lost his way. He found some new land, but he never explored it. Having reached Greenland's latitude, he steered East, and he found his family at Herjulsness.

Leif Ericsson heard about the new land. In about 1000 A.D. he bought Bjarne's ship. Based on Bjarne's information, he found, explored and named Helluland, Markland and Vinland. Leif the Lucky is therefore considered to be the discoverer of America.

A vikingek napiránytűje

A

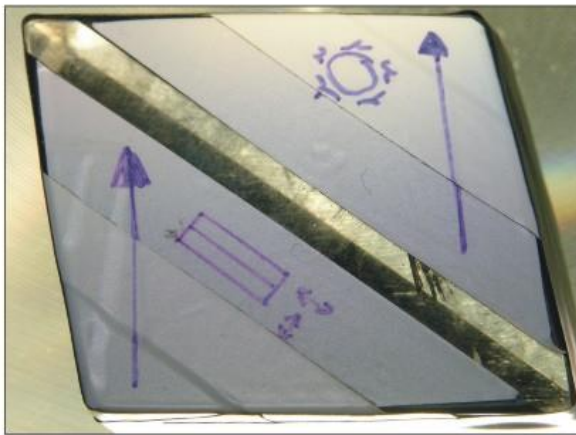


B



A vikingegek kalcit-napköve

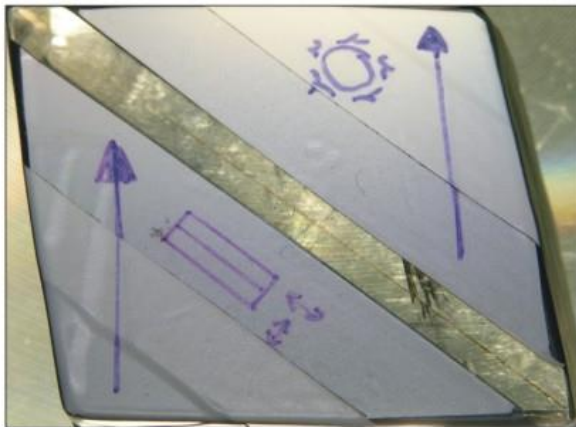
A



direction of linear polarization of light



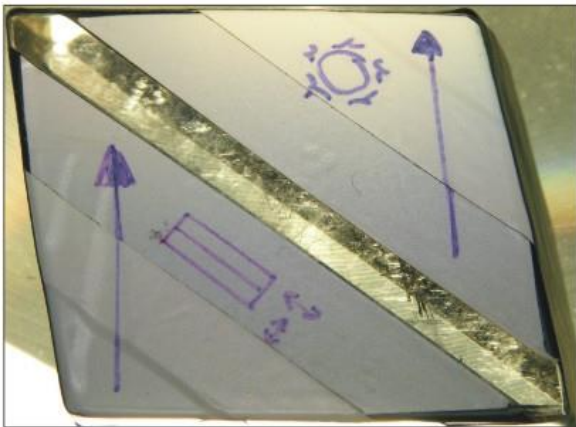
B



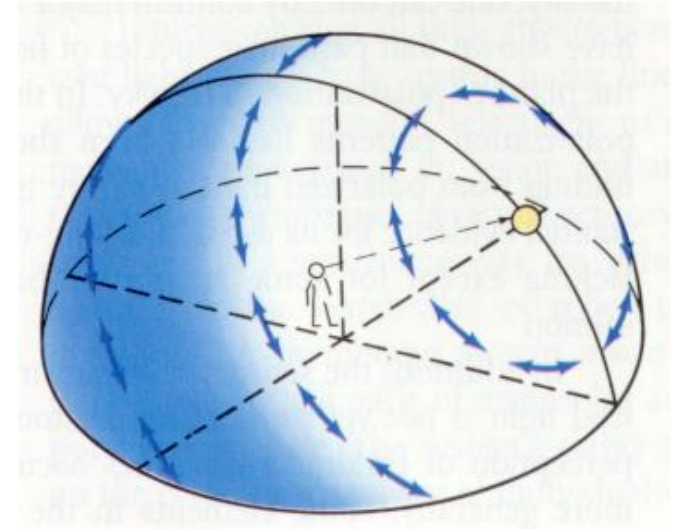
direction of linear polarization of light



C



direction of linear polarization of light

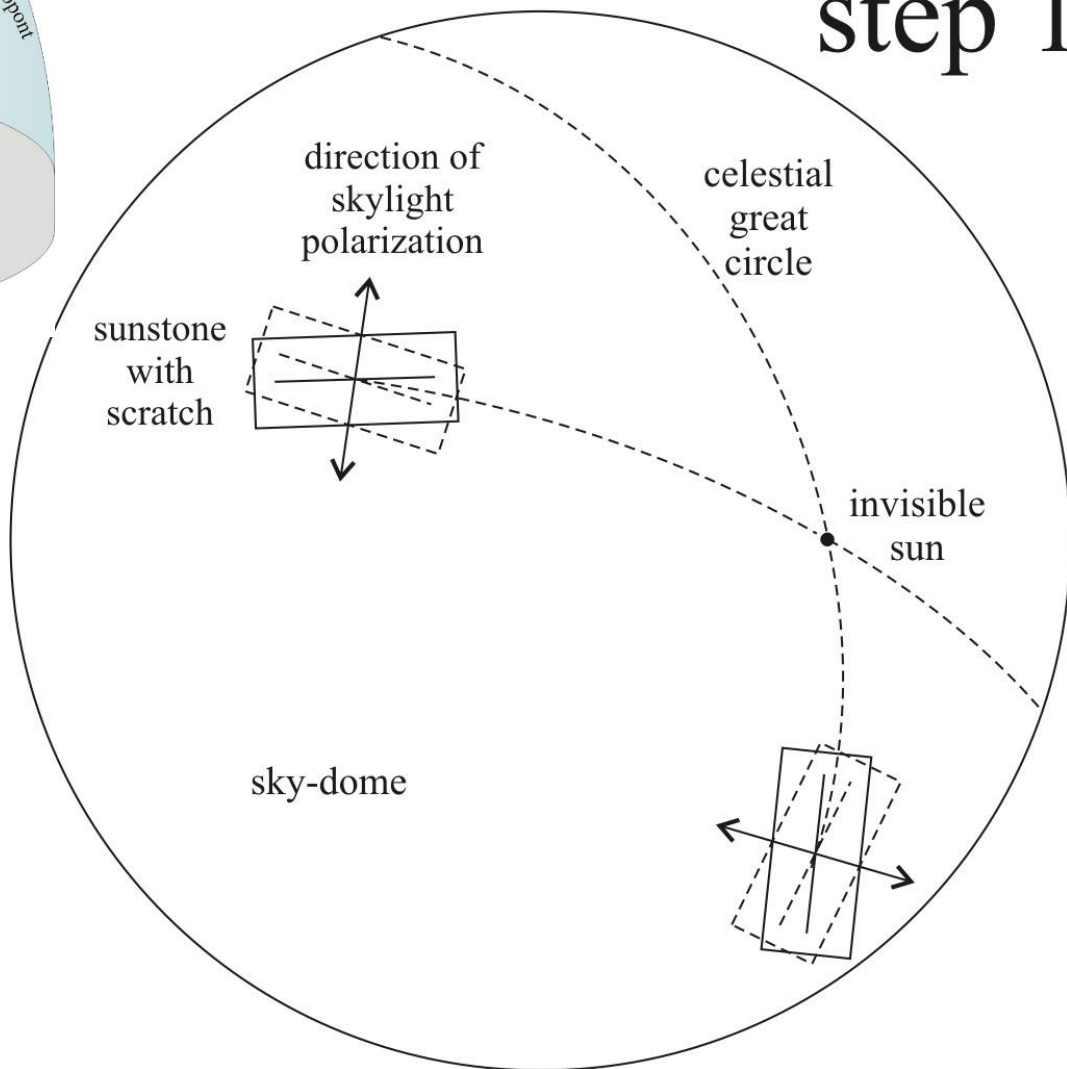
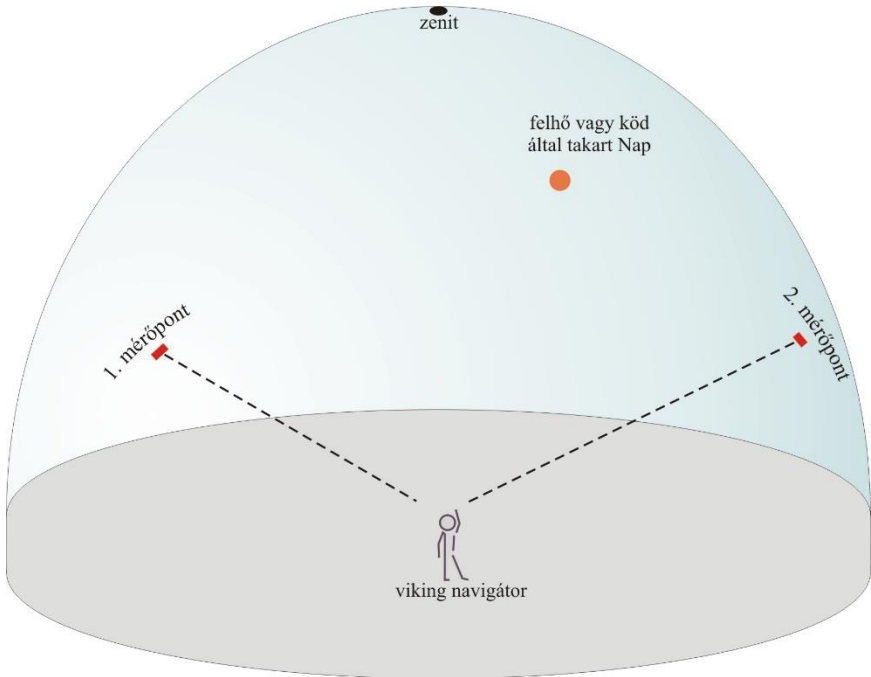


Az ég Rayleigh-féle polarizációirány mintázata

Az égbolt-polarizációs viking-navigáció

1. lépése

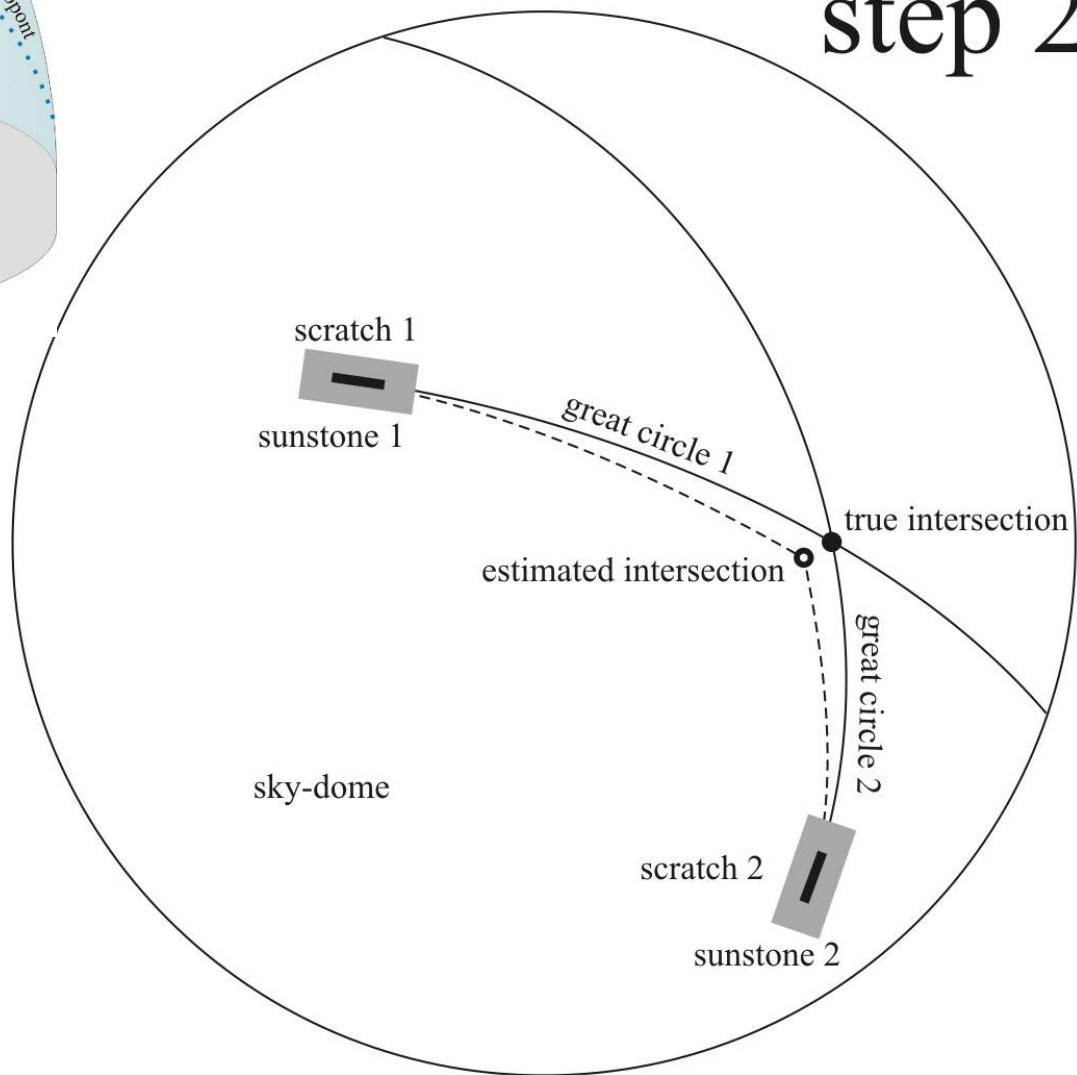
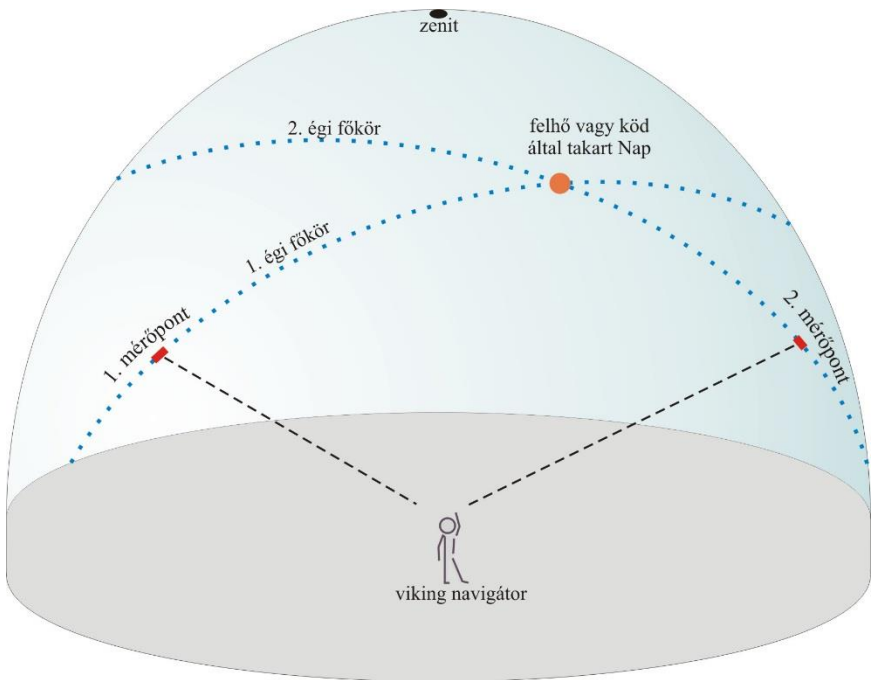
step 1



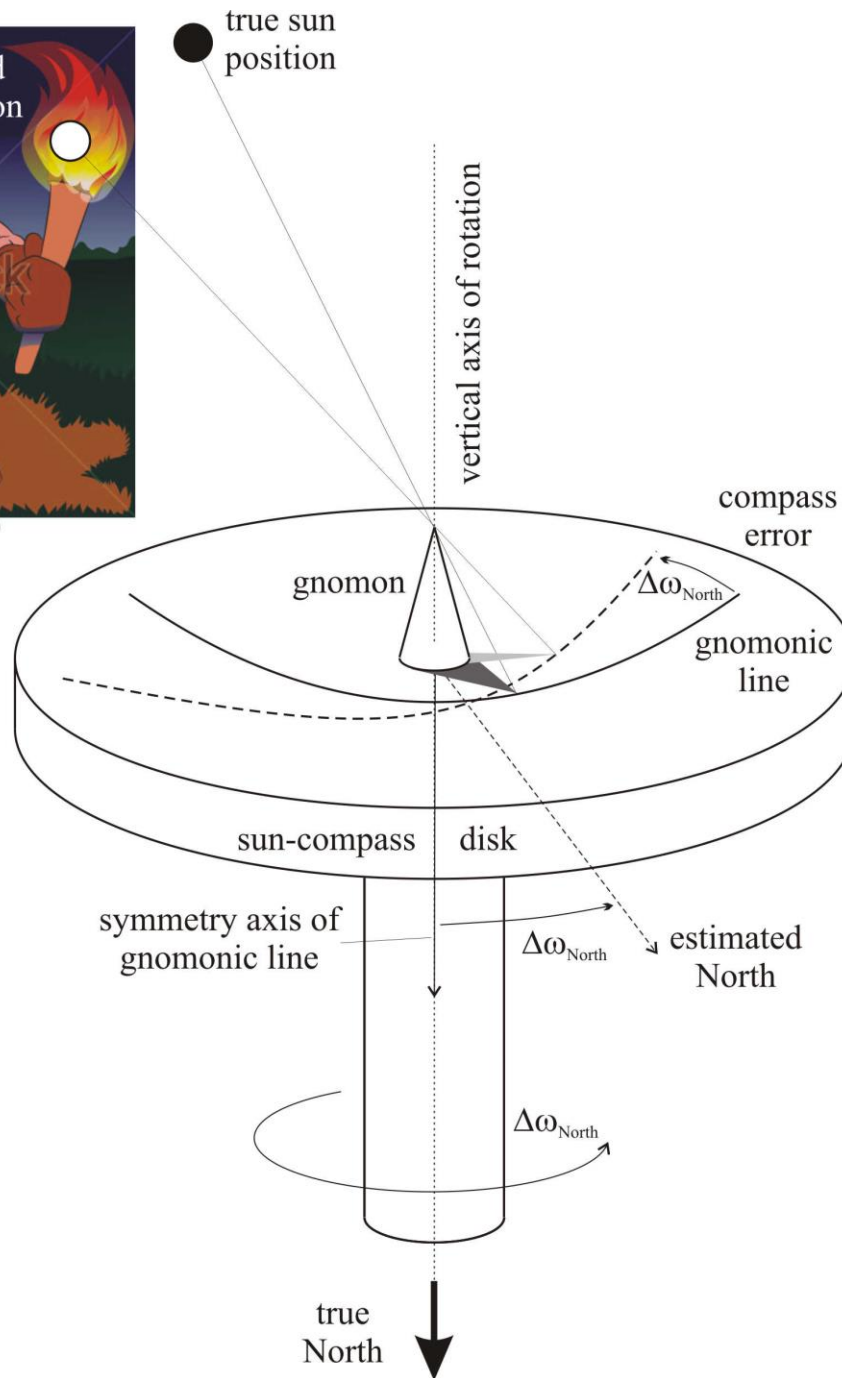
Az égbolt-polarizációs viking-navigáció

2. lépése

step 2



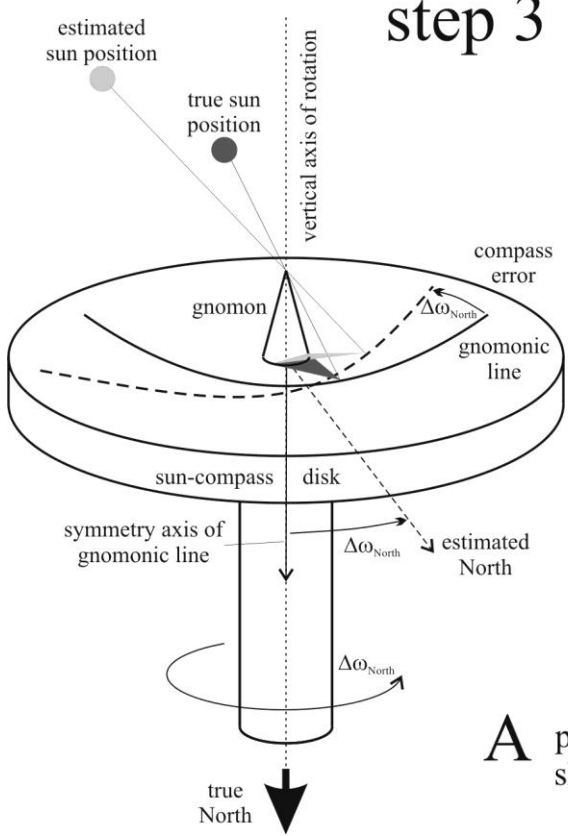
Az égbolt-polarizációs viking-navigáció 3. lépése fáklyával



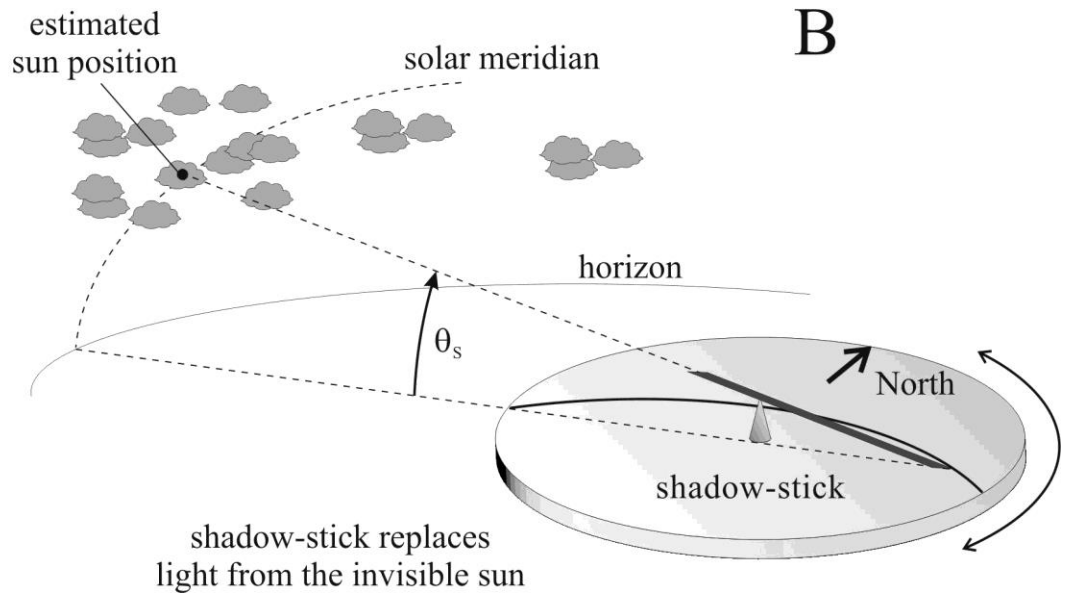
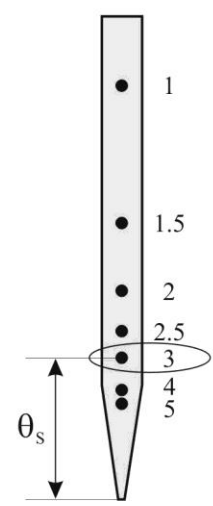
Az égbolt-polarizációs viking-navigáció

3. lépése árnyékpálcával

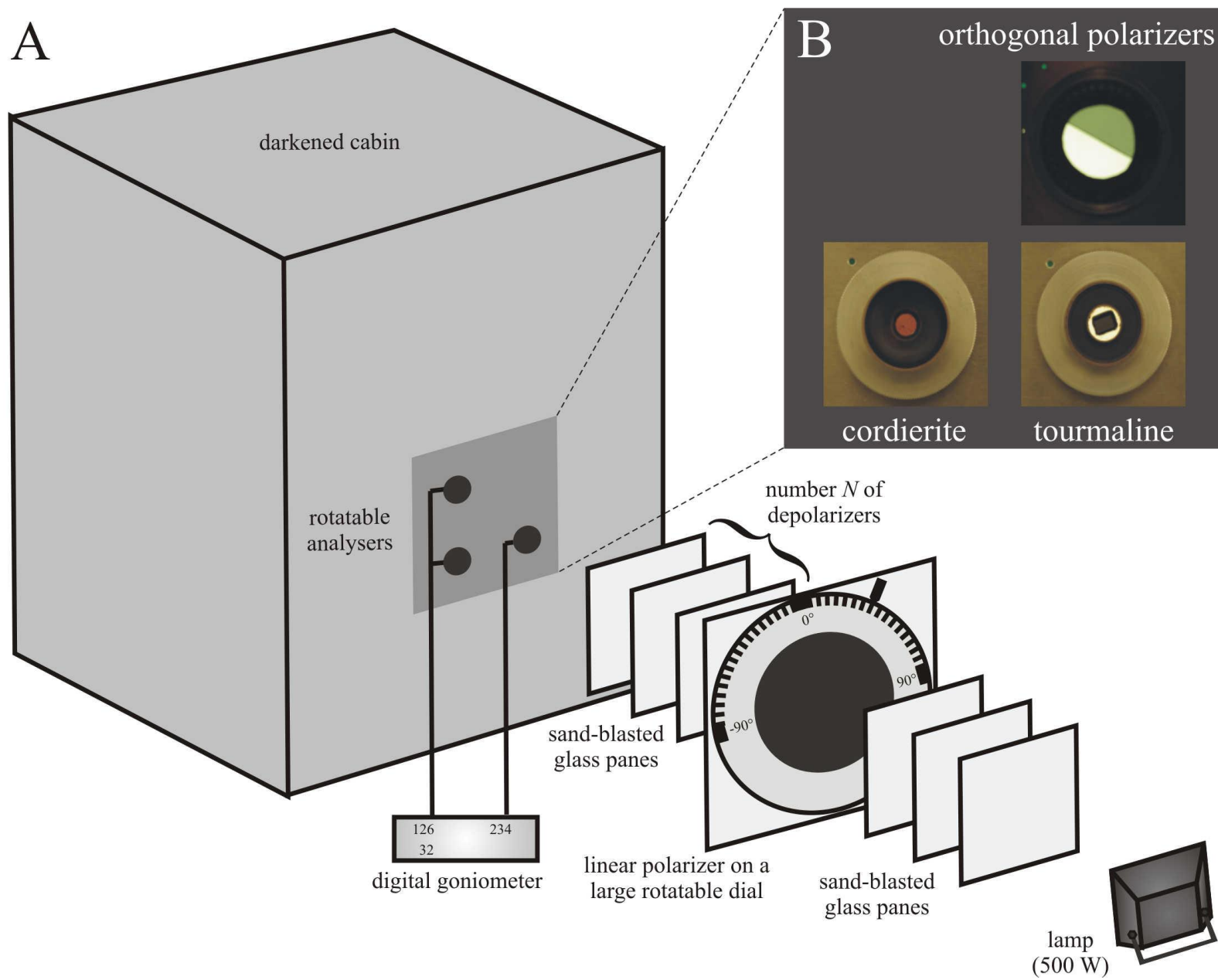
step 3



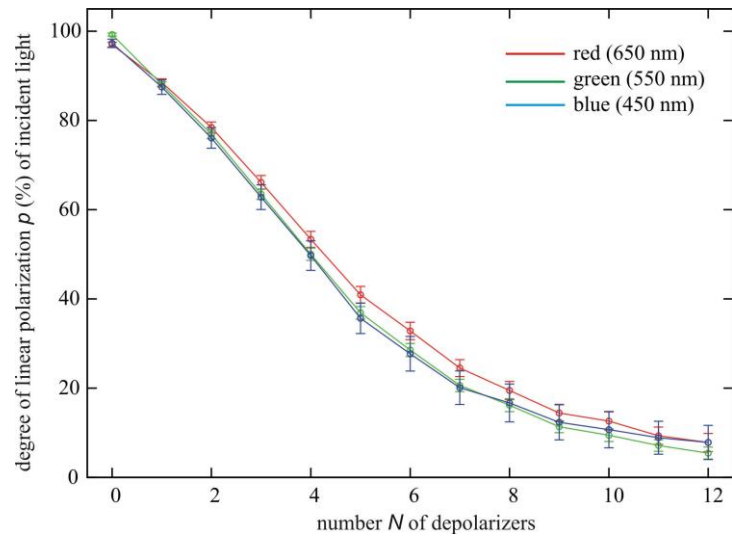
A precalibrated shadow-stick



Az égbolt-polarizációs viking-navigáció **1. lépése** hibájának pszichofizikai mérése



Viking-napkövek irányulásfüggő optikai jele



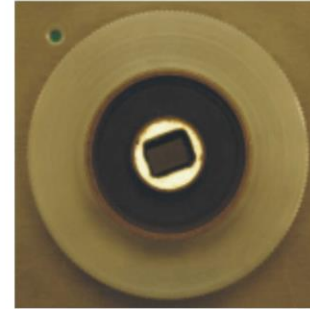
A

seen by test persons

cordierite



tourmaline

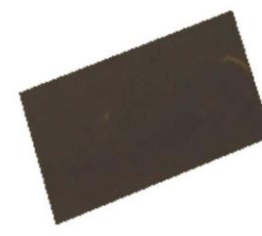
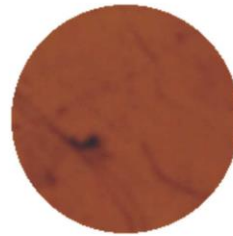


orthogonal polarizers



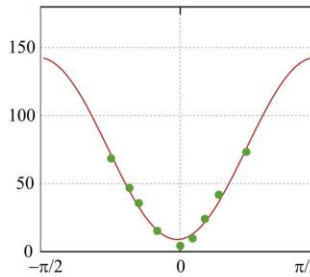
B

areas for intensity average



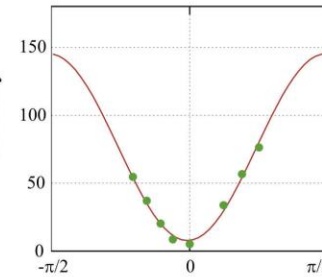
C

intensity



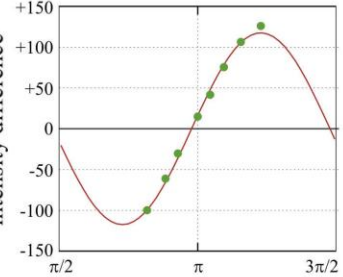
angle of rotation (radian)

intensity



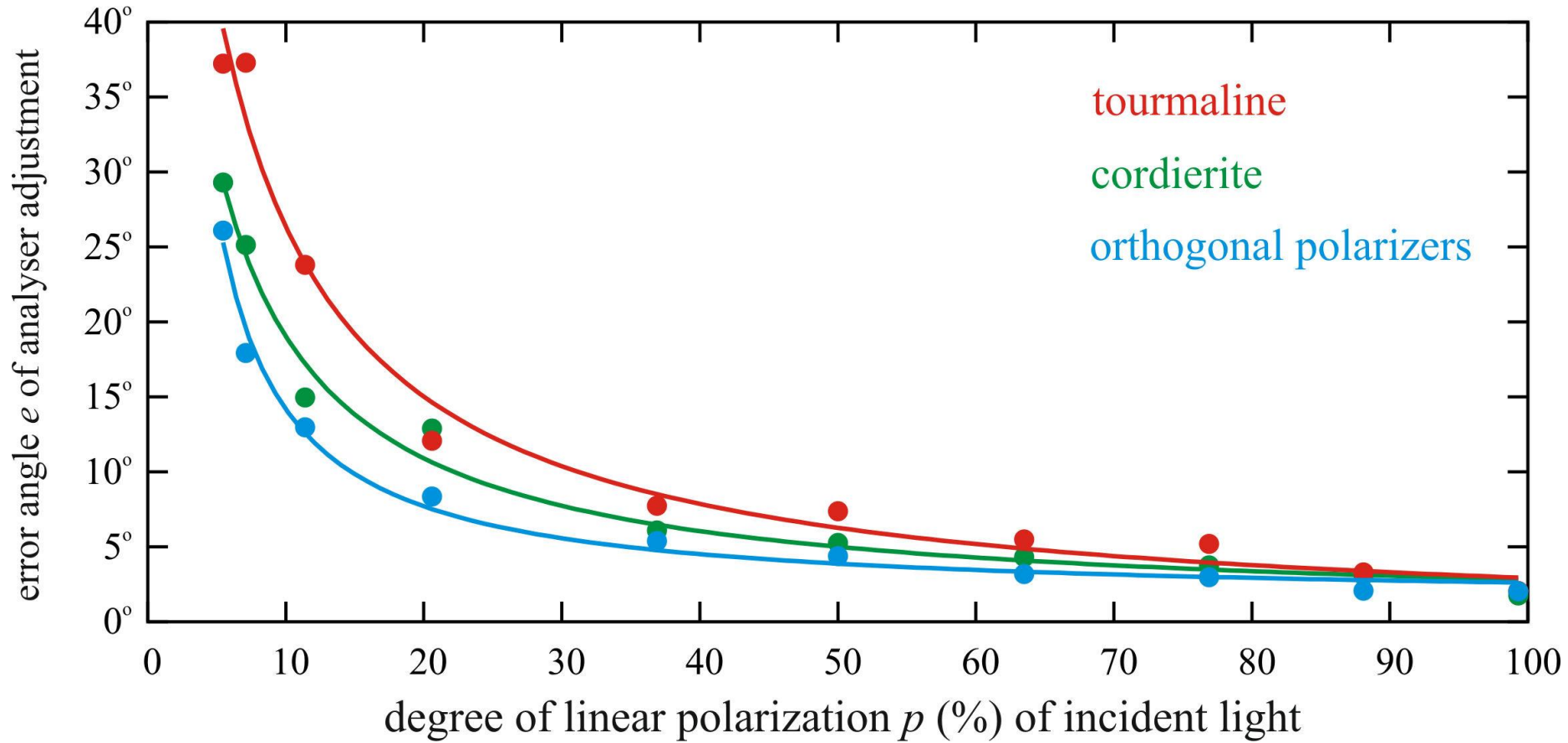
angle of rotation (radian)

intensity difference

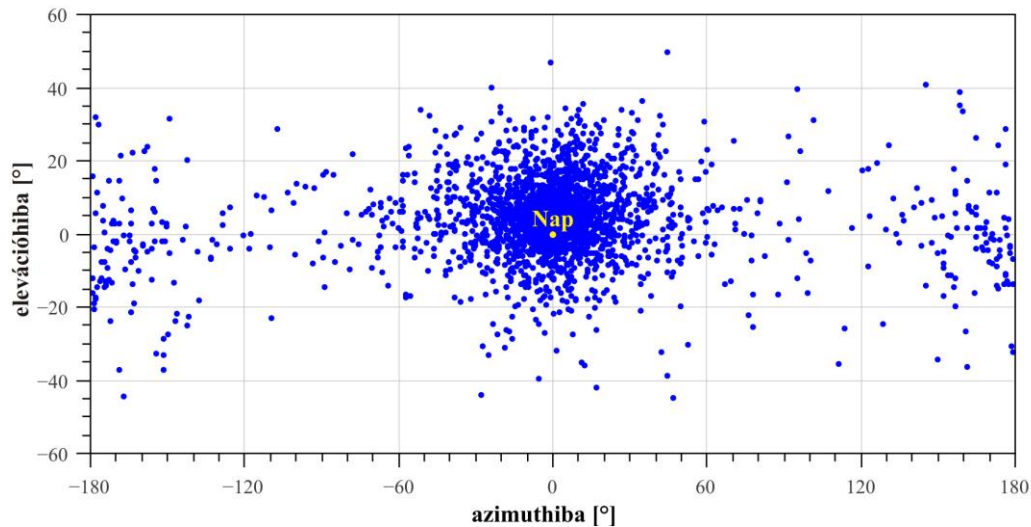
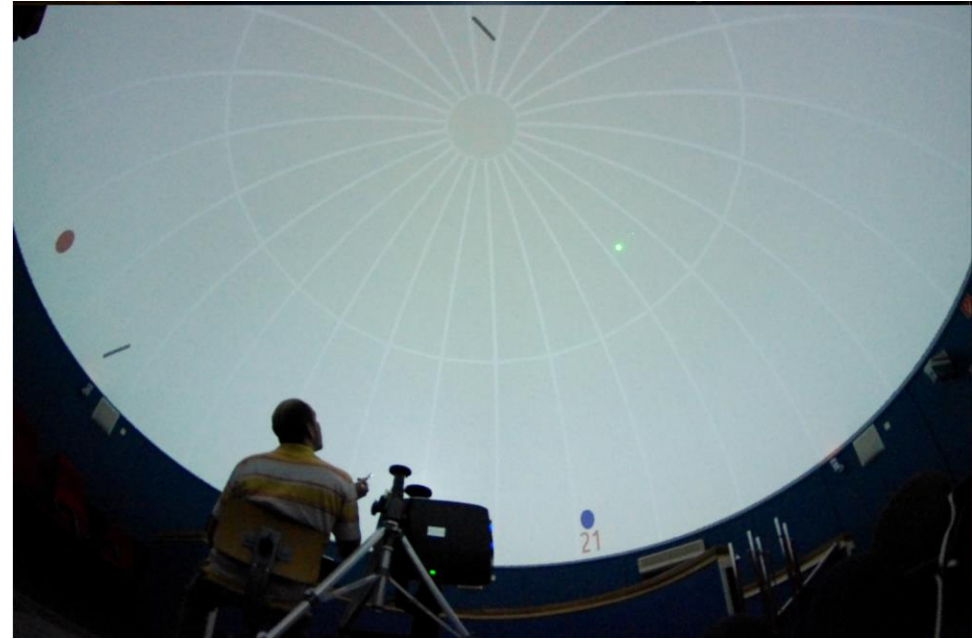
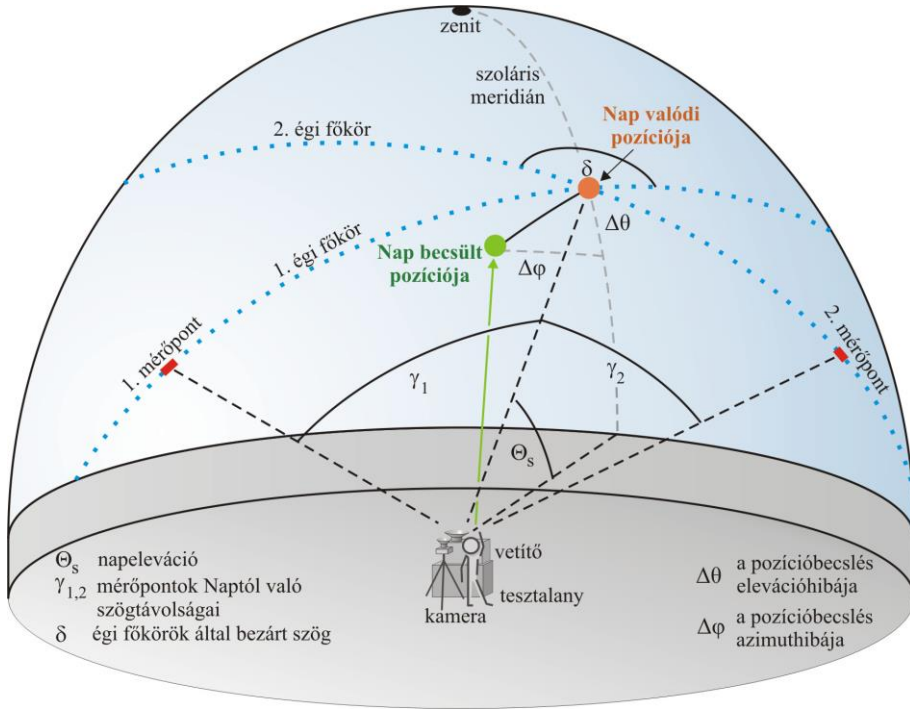


angle of rotation (radian)

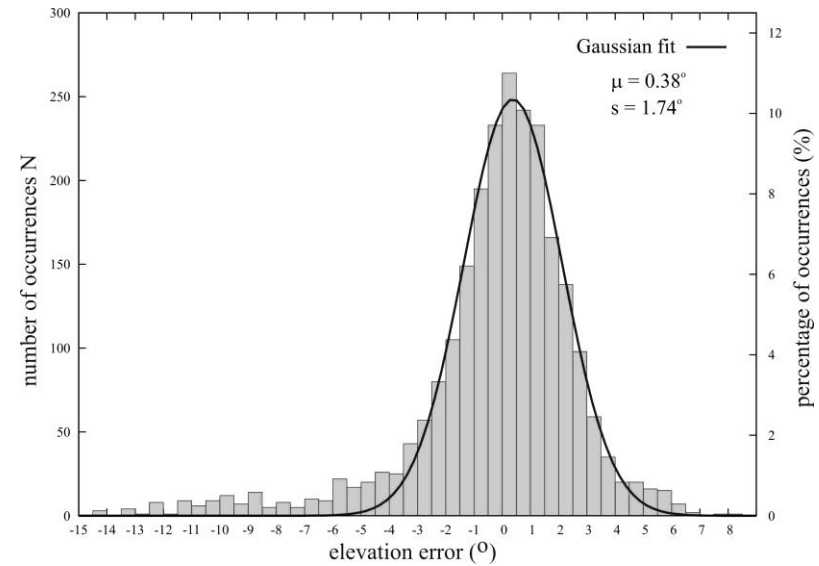
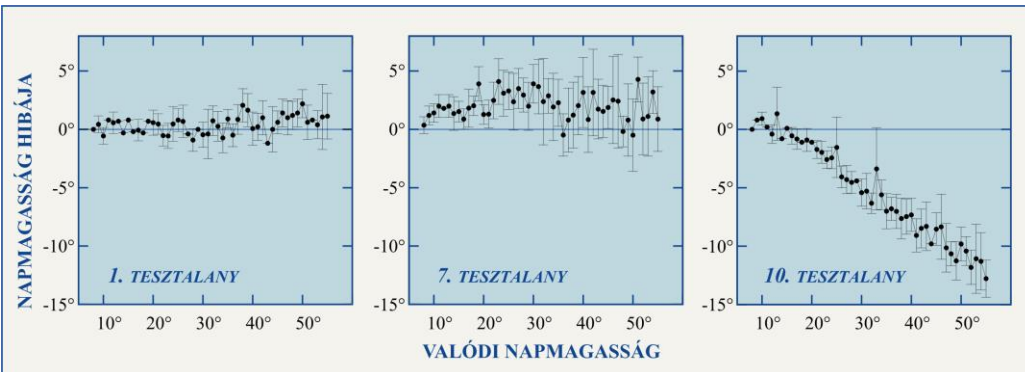
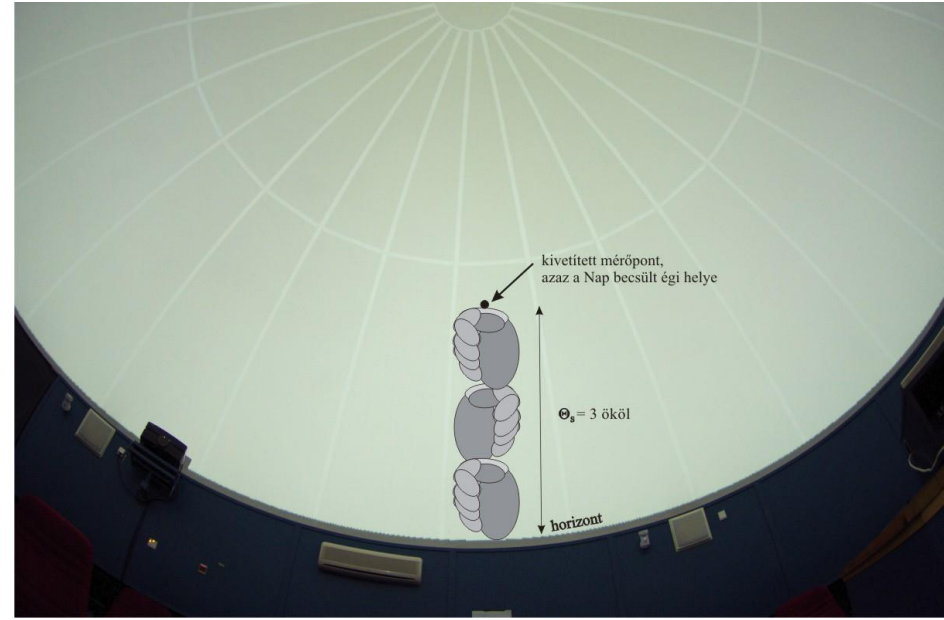
Viking-napkövek szögbeállításának hibafüggvénye (1. lépés hibája)



Az égbolt-polarizációs viking-navigáció 2. lépése hibájának planetáriumi mérése



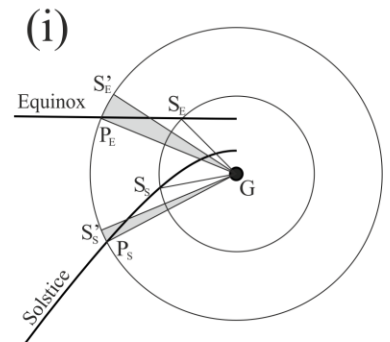
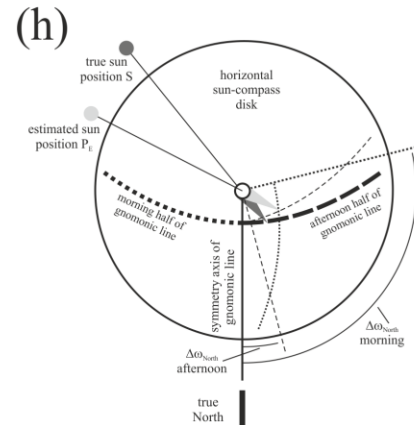
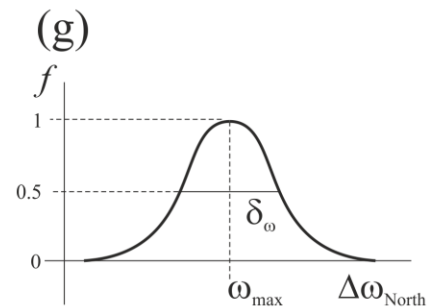
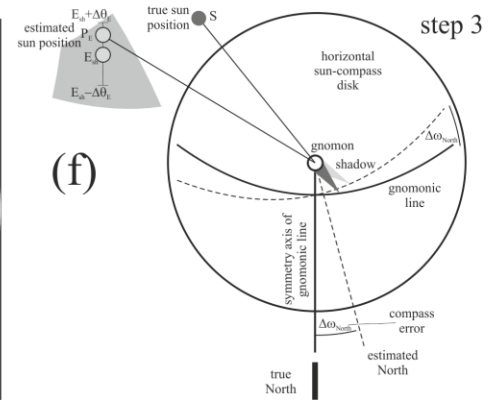
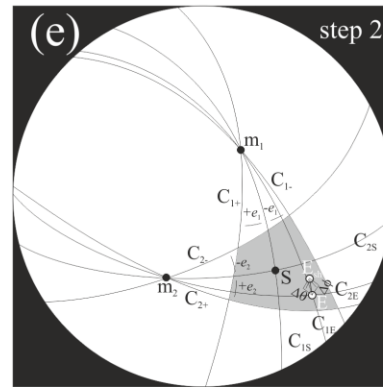
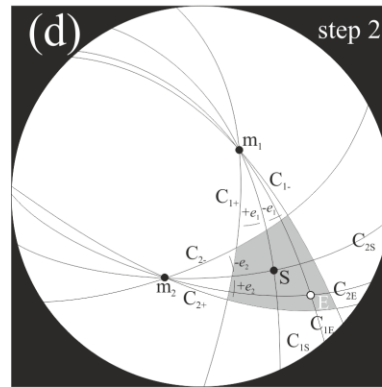
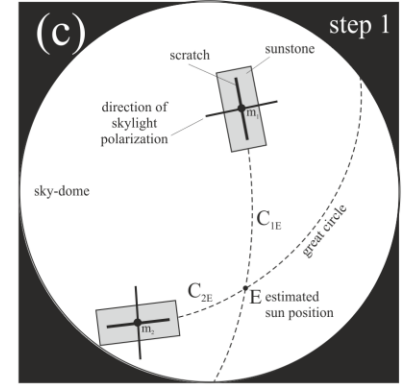
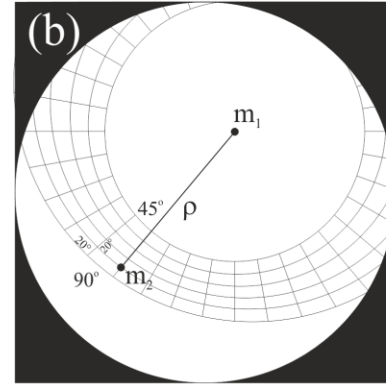
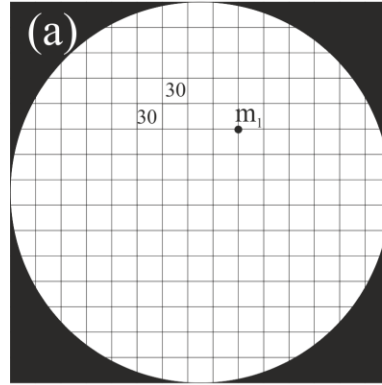
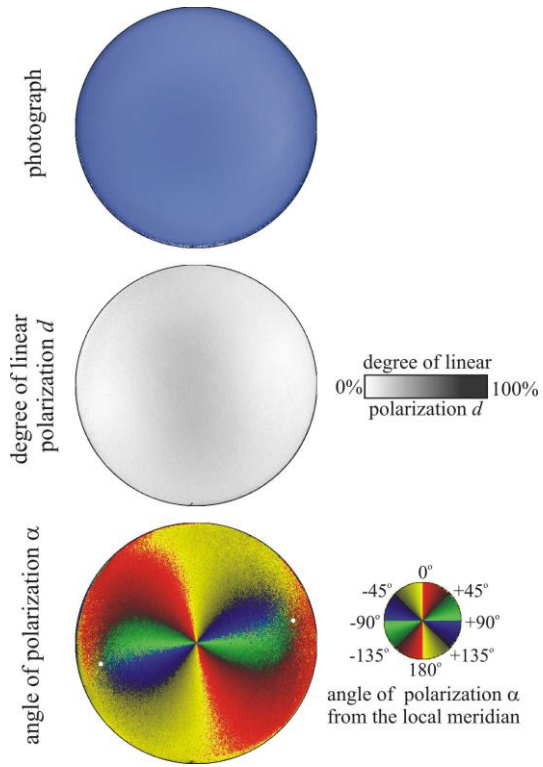
Az égbolt-polarizációs viking-navigáció 3. lépése hibájának planetáriumi mérése



Égboltpolarizációs mintázat 1080 különböző meteorológiai helyzetben: 10 napeleváció × 9 felhőzettség × 12 égbolt = 1080

Felhőzöttség (okta) Eleváció [°]	0	1	2	3	4	5	6	7	8
-5-1									
2-8									
9-15									
16-22									
23-29									
30-36									
37-43									
44-50									
51-57									
58-64									

Az északi irány-meghatározás hibájának becslése hibaterjedéssel

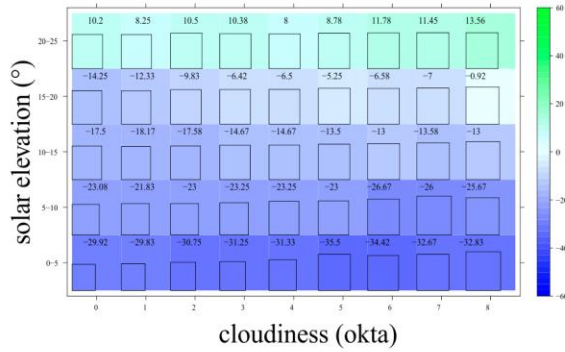


equinox

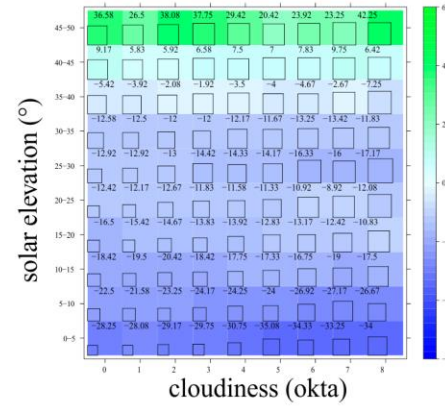
solstice

Az északi irány égbolt-polarizációs viking-navigációval történő meghatározásának hibája a meteorológiai helyzet függvényében

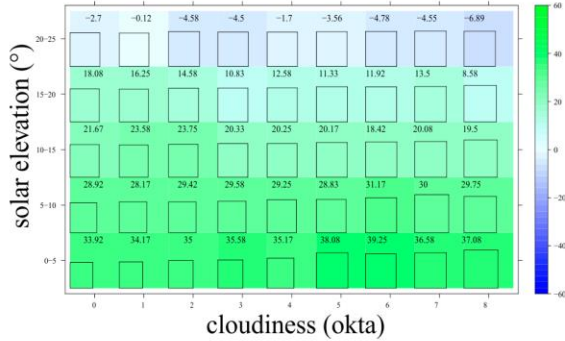
morning



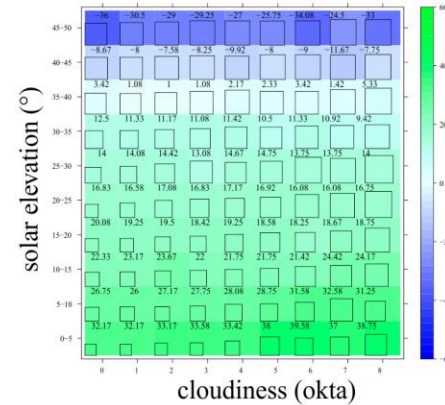
morning



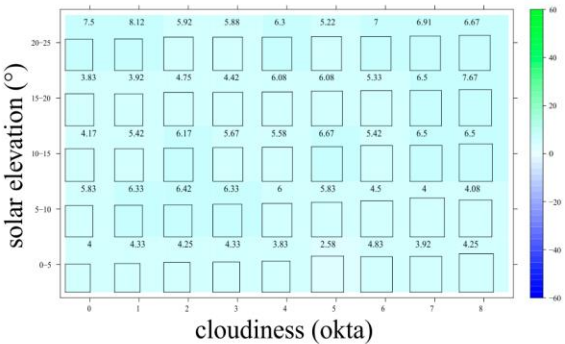
afternoon



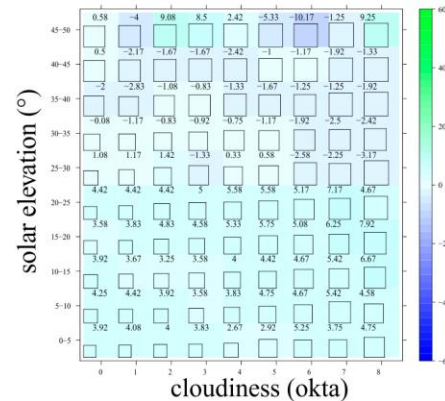
afternoon



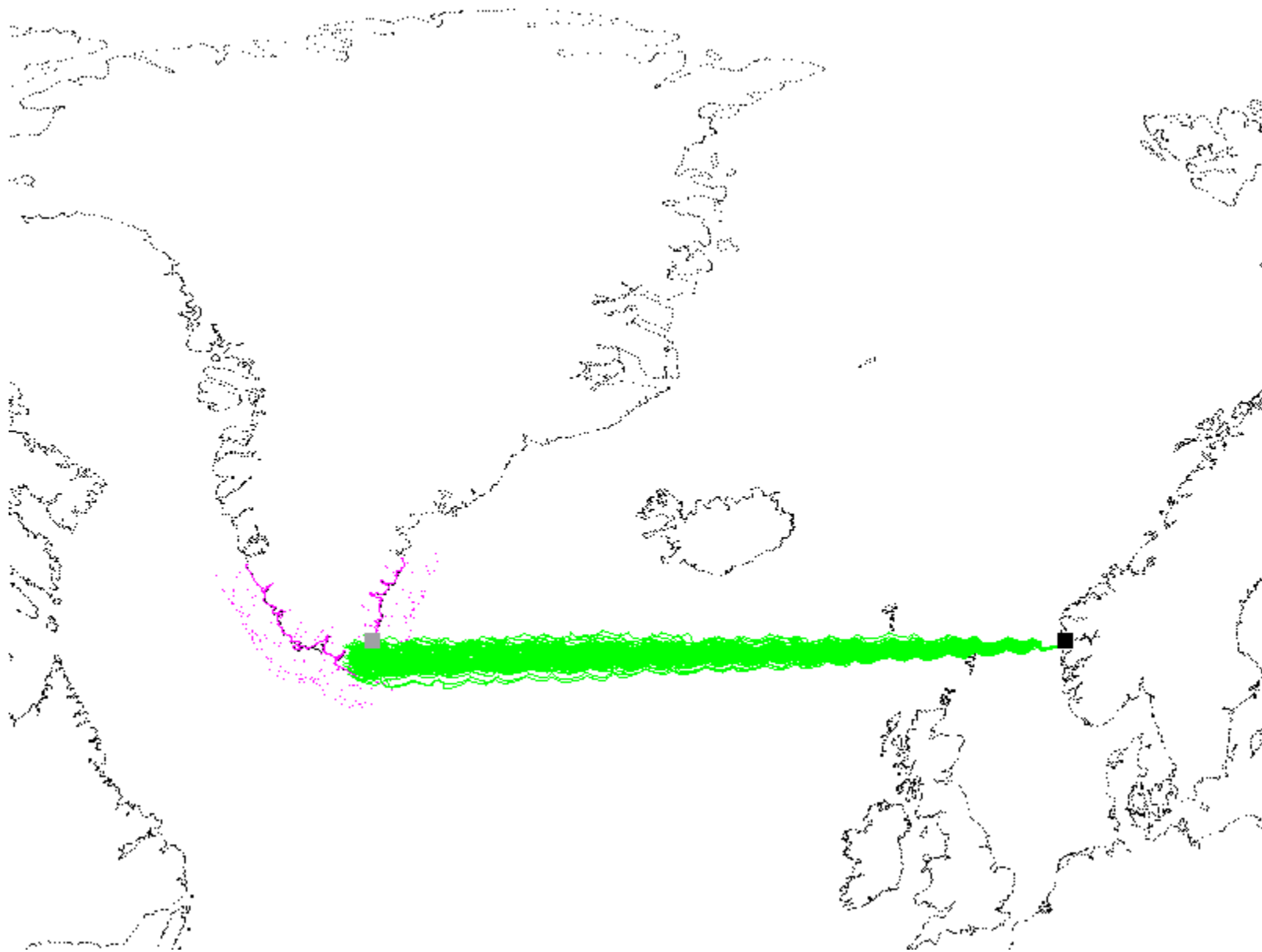
sum



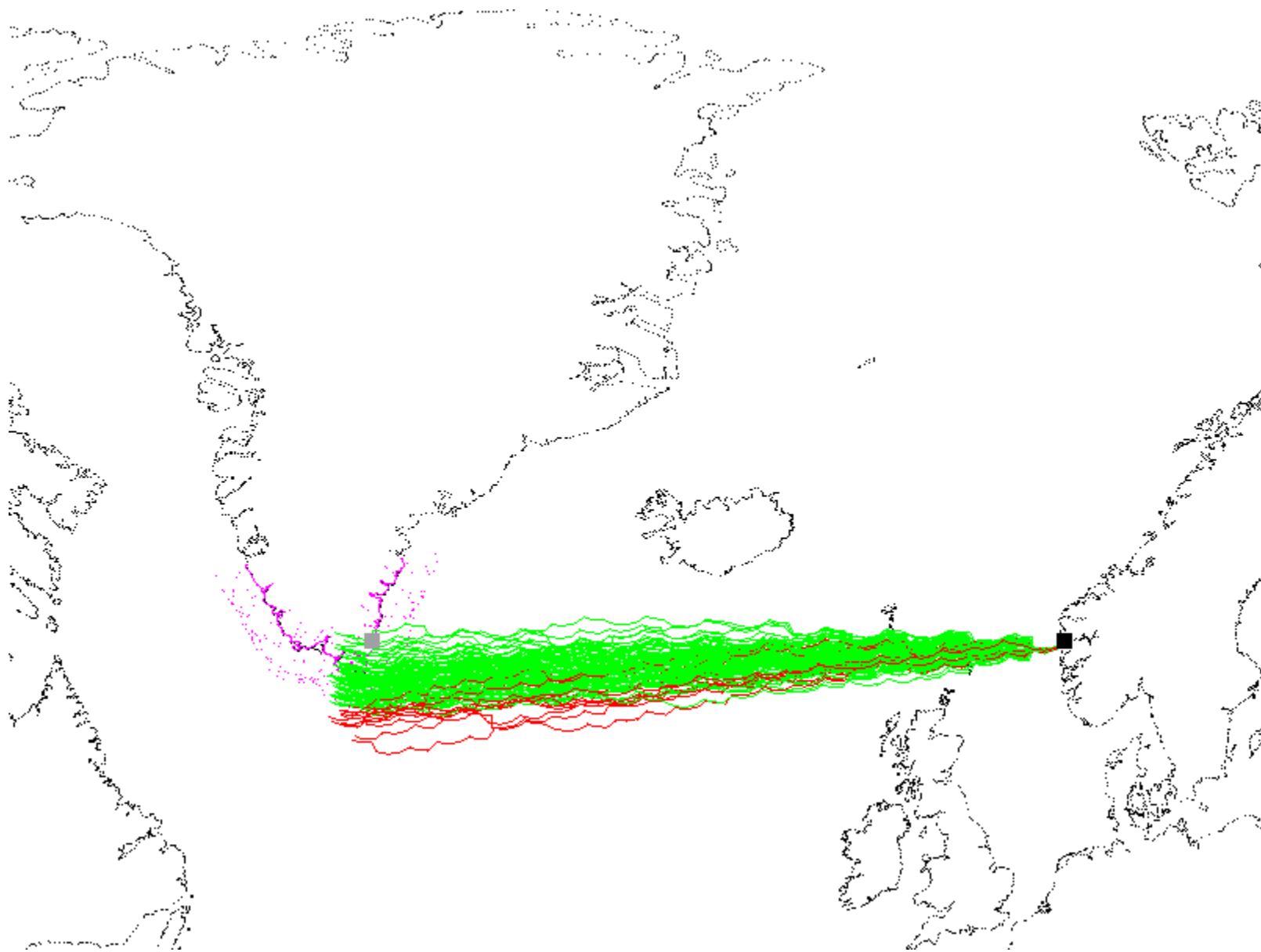
sum



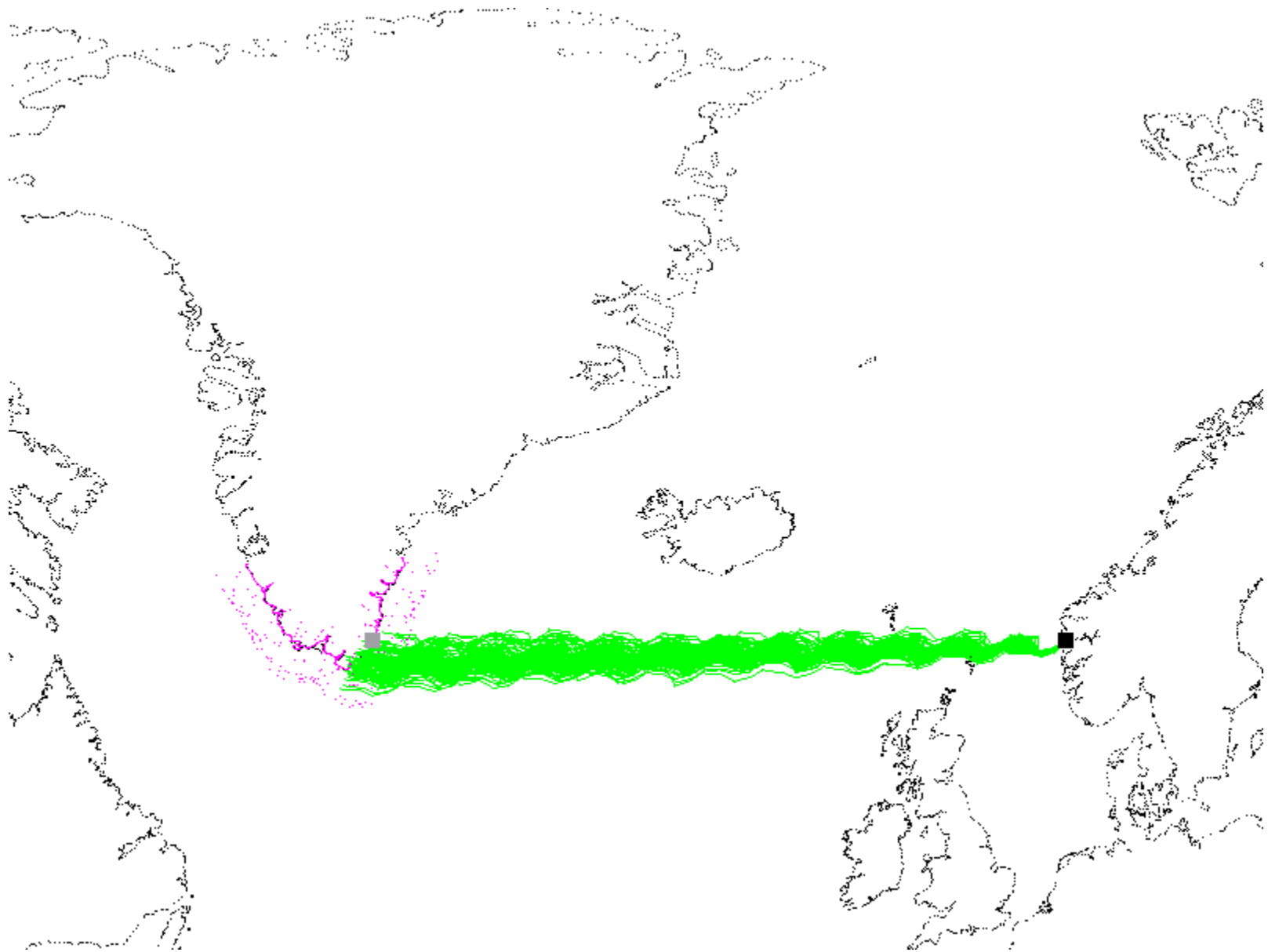
Kalcit napkővel 1 óránként navigálva napéjegyenlőségkor



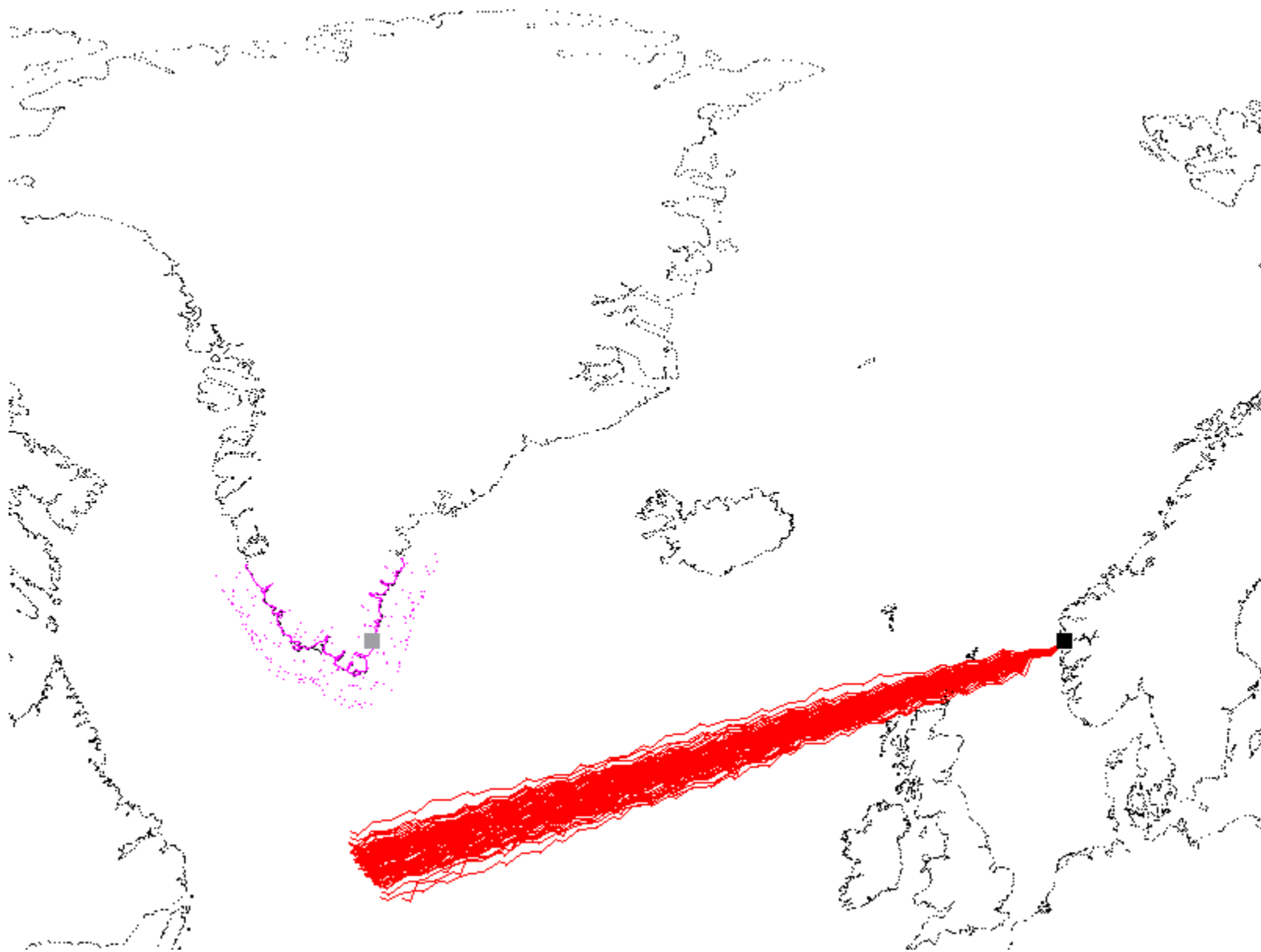
Kalcit napkővel 3 óránként navigálva napéjegyenlőségkor



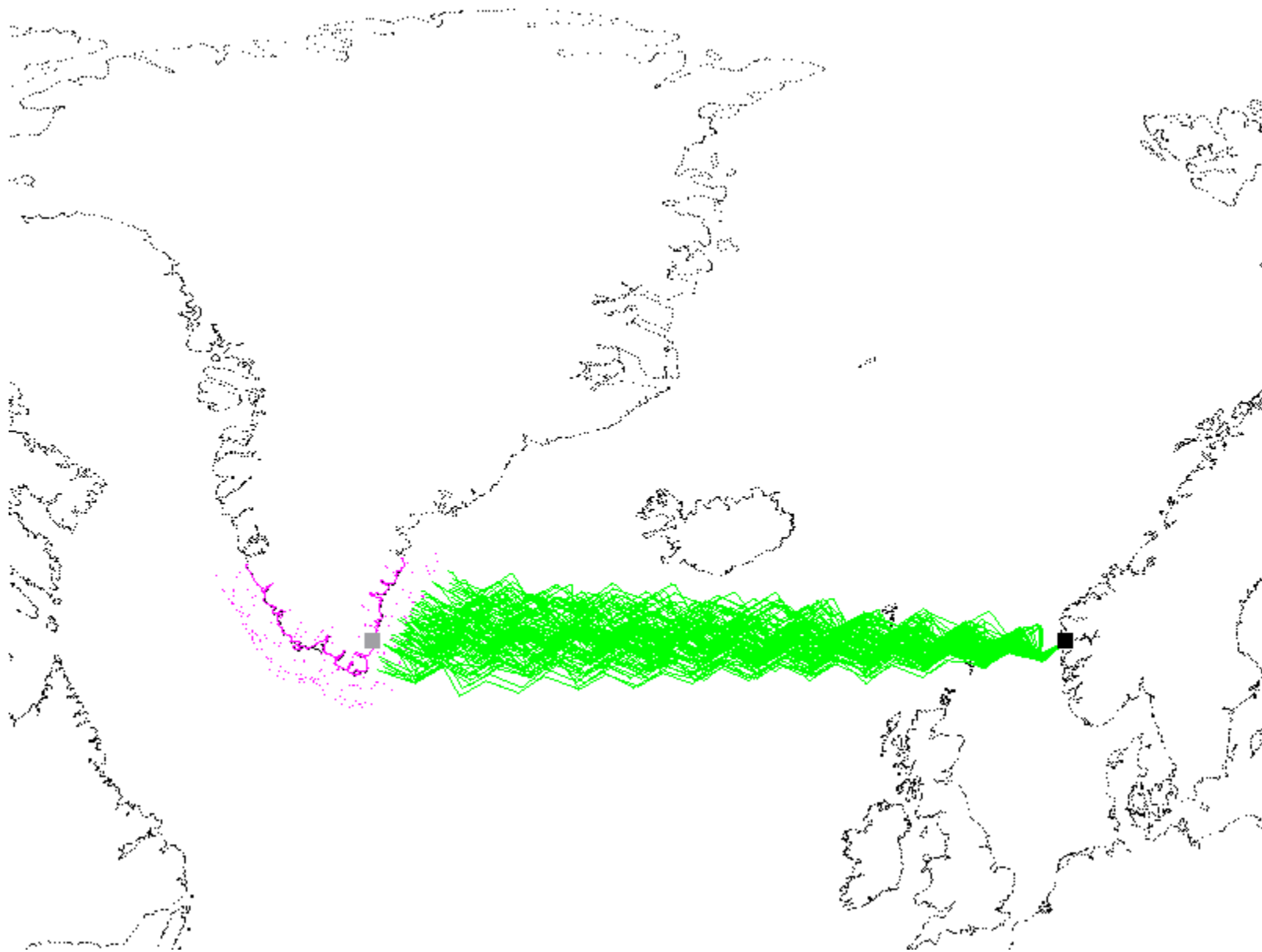
Kalcit napkővel 4 óránként navigálva napéjegyenlőségkor



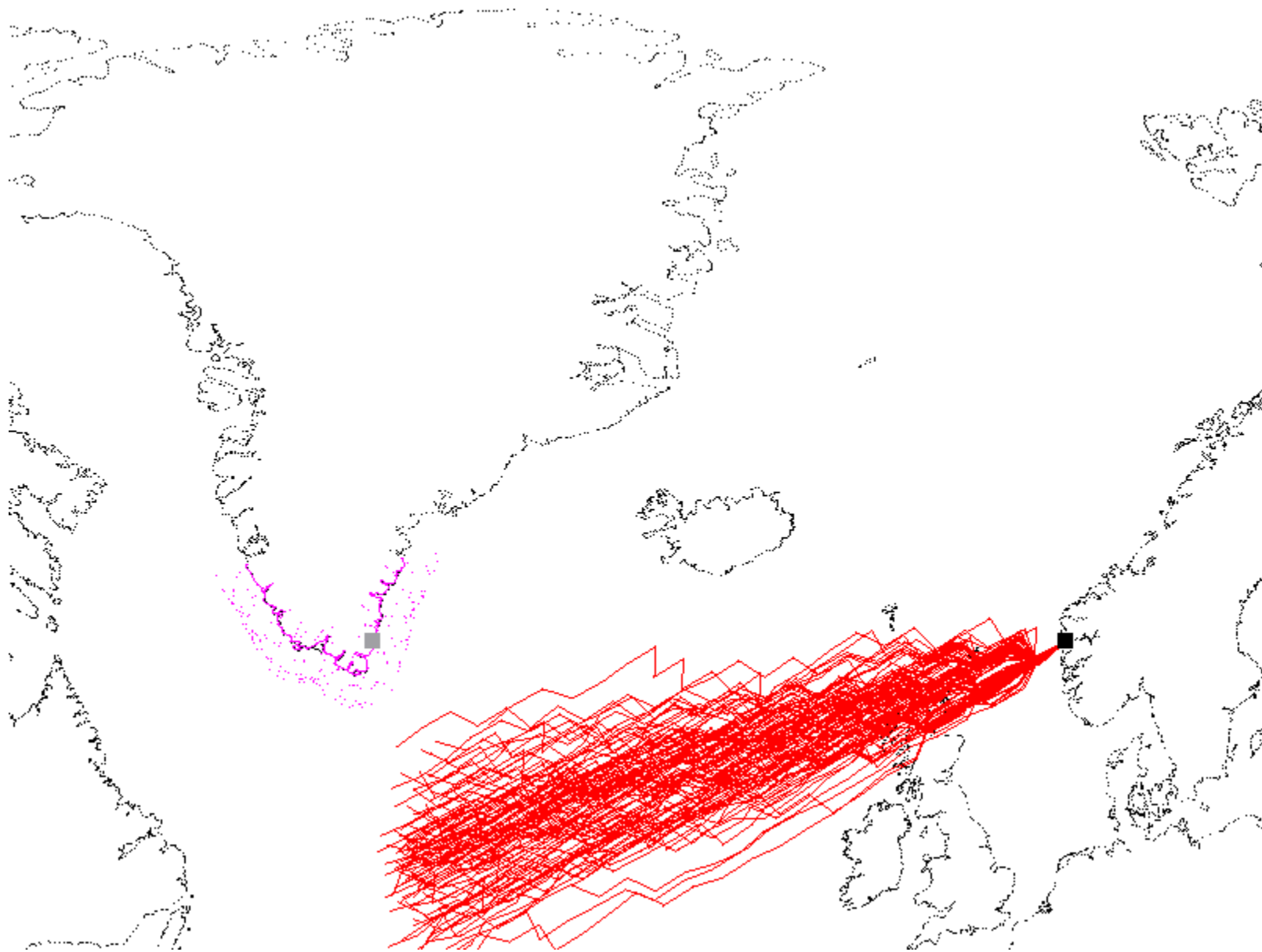
Kalcit napkővel 5 óránként navigálva napéjegyenlőségkor



Kalcit napkővel 8 óránként navigálva napéjegyenlőségkor



Kalcit napkővel 9 óránként navigálva napéjegyenlőségkor



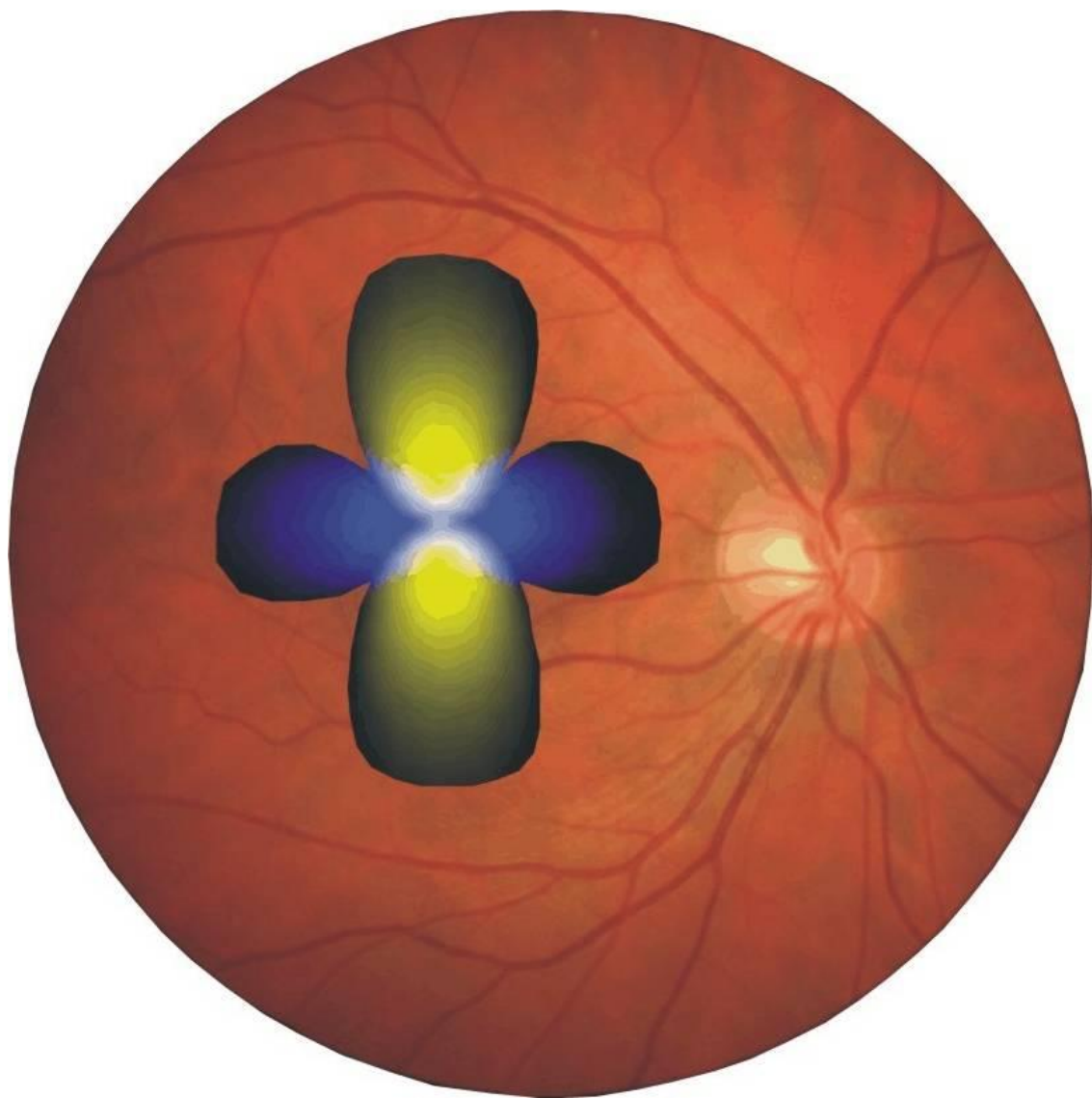
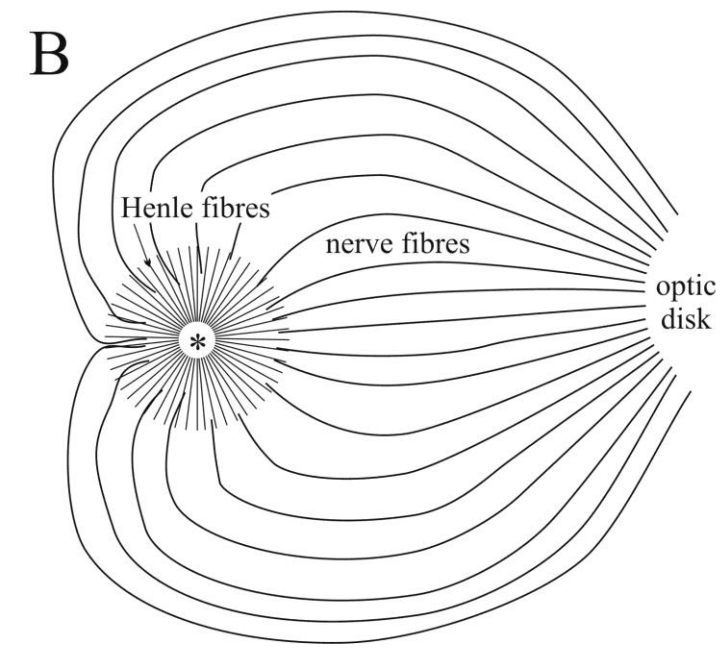
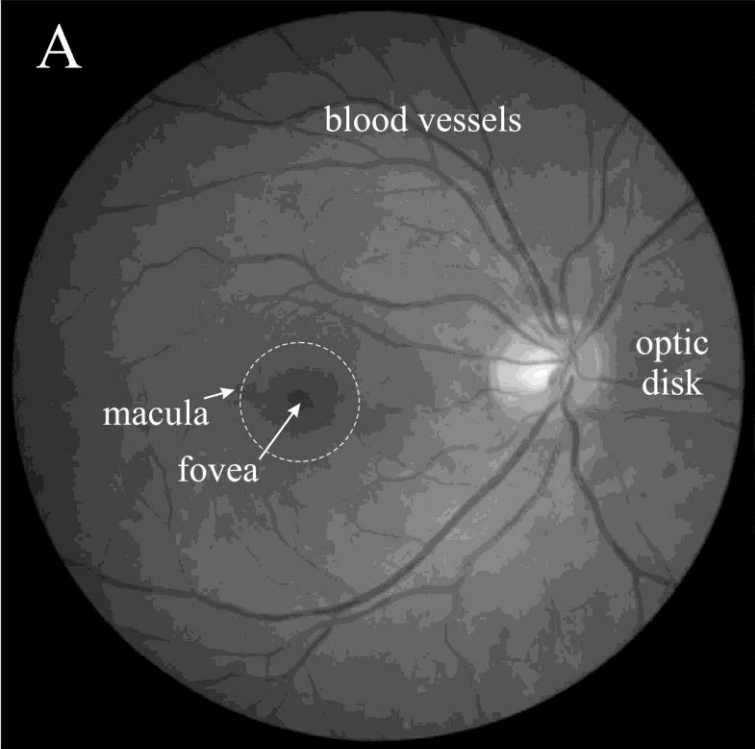
Az emberi szem polarizáció-érzékelésének fölfedezése: 1844



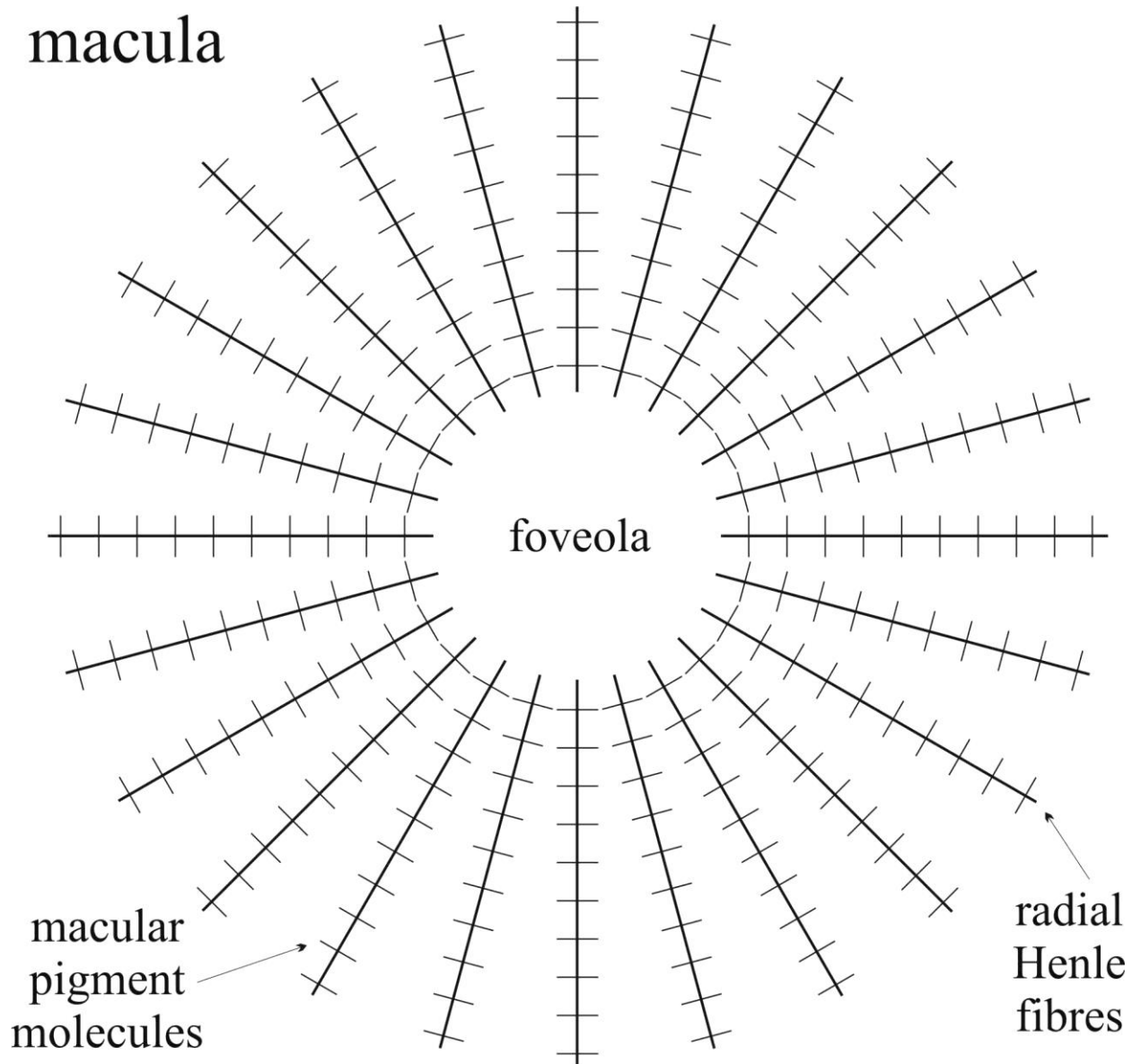
Wilhelm von Haidinger (1844) Über das direkte Erkennen des polarisierten Lichts und der Lage der Polarisationssebene. *Annalen der Physik* 63: 29-39

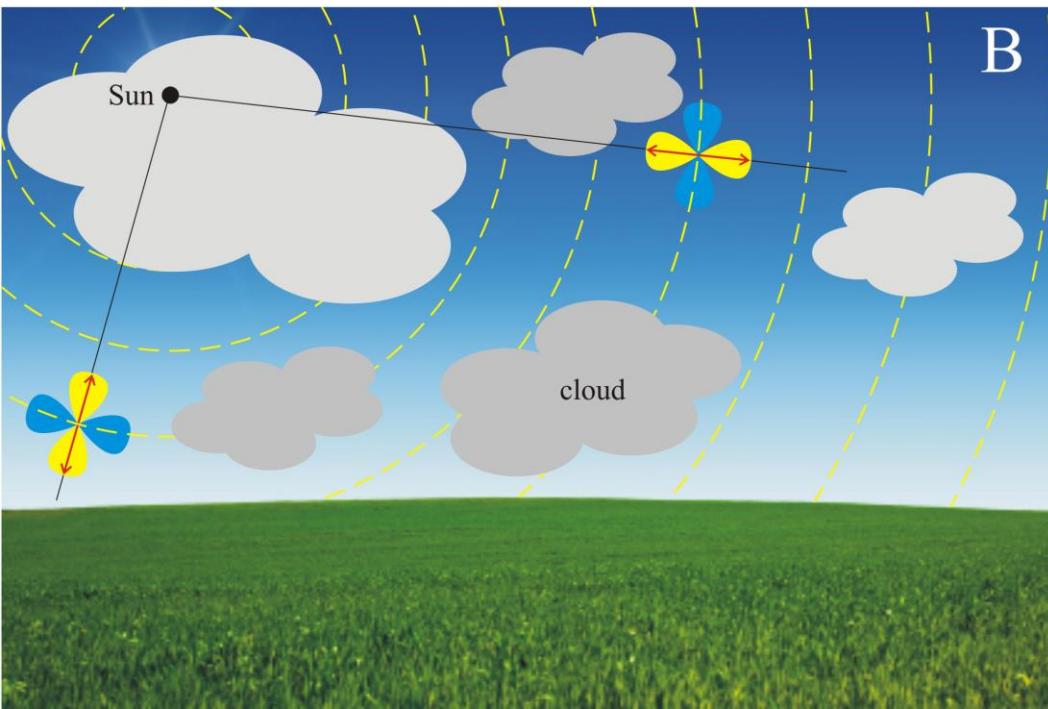
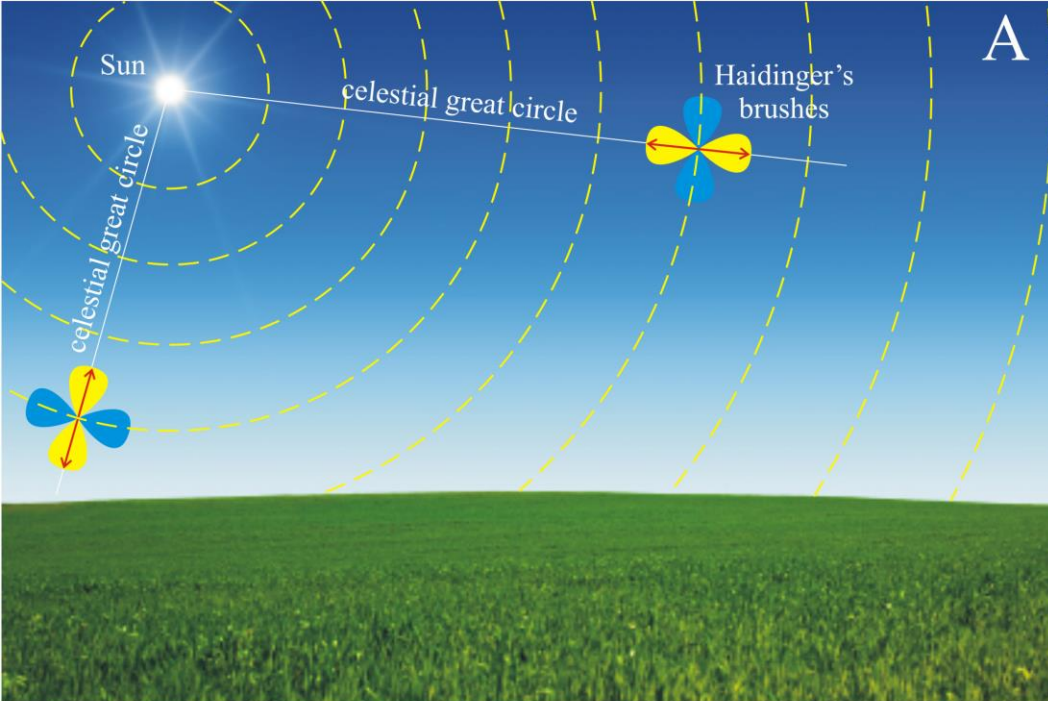
Wilhelm Karl von Haidinger
(1795-1871)

Az emberi szem polarizáció-érzékenysége



Az emberi szem polarizáció-érzékenysége





Égboltpolarizációs viking navigáció Haidinger-pamacsokkal

Égboltpolarizációs viking navigáció Haidinger-pamacsokkal

clear sky

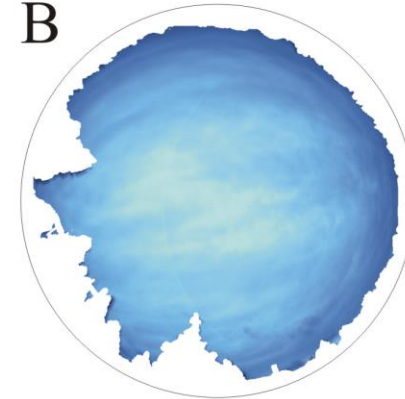
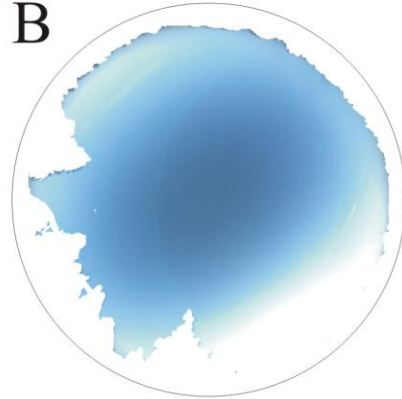
overcast sky

colour picture

colour picture
with white mask

colour picture

colour picture
with white mask

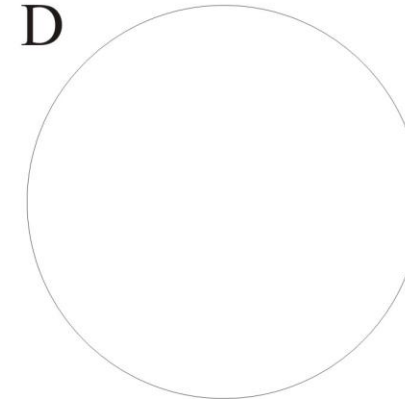
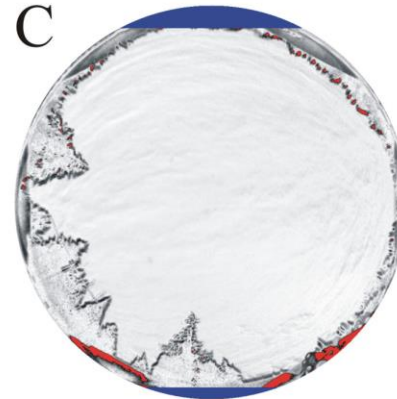
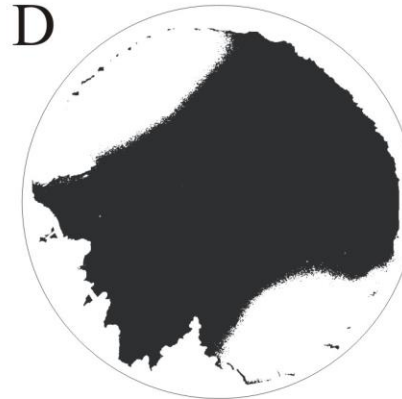
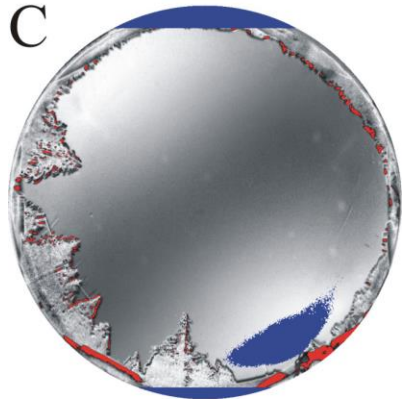


degree of linear
polarization d

area suitable for navigation
with Haidinger brushes

degree of linear
polarization d

area suitable for navigation
with Haidinger brushes



degree of linear
polarization d

0 % 100 %

underexposed

overexposed

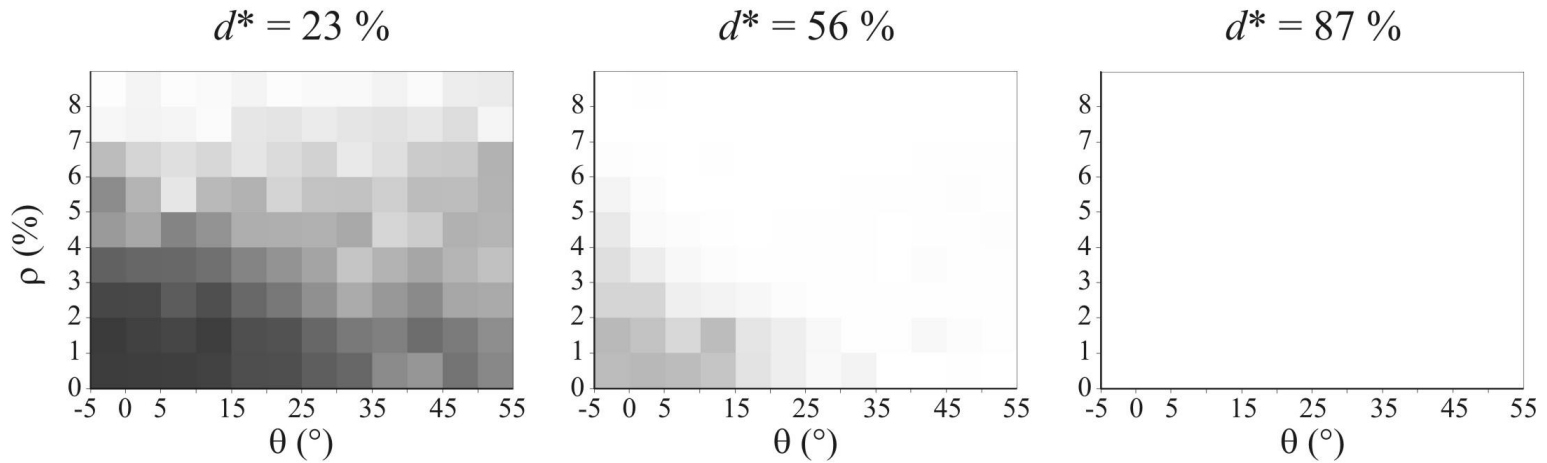
area with $d > d^*_{\min} = 23 \%$

Égboltpolarizációs viking navigáció Haidinger-pamacsokkal

A

$\langle P \rangle$ = average proportion of the sky where $d > d^* = 23, 56, 87 \%$

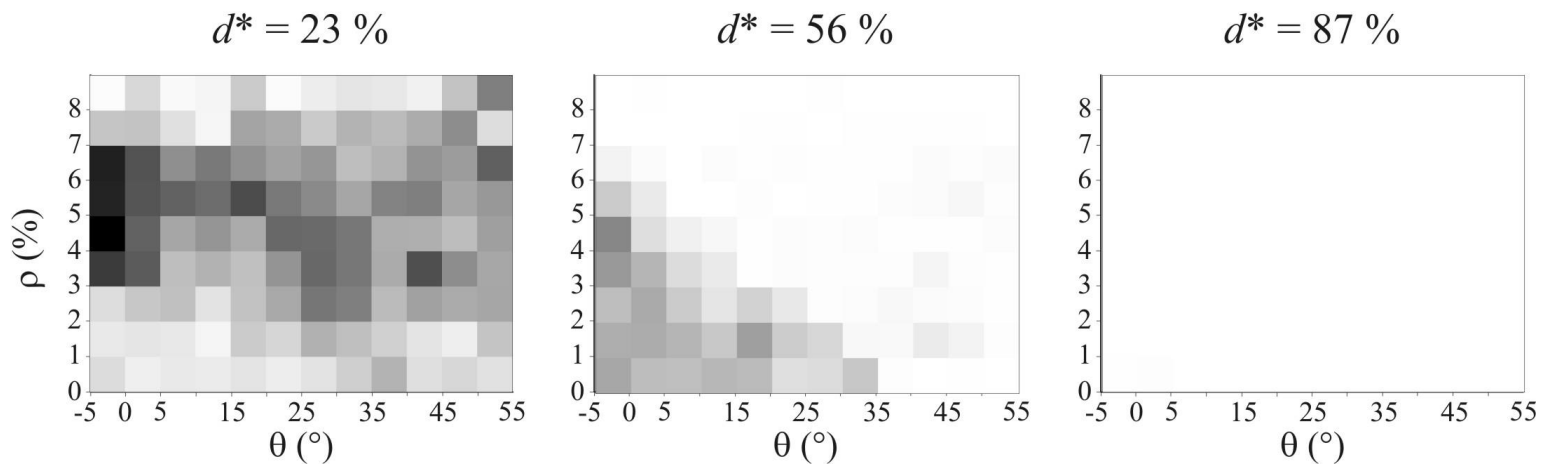
0 %  100 %



B

relative standard deviation $\Delta P / (\Delta P)_{\max}$ of P

0 %  100 %



2014 (2004-2014, p. 650)

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2016 (1995-2016, 485 o.)



György Kriska



Farkas Alexandra

Köszönöm a figyelmet!

