Funnel-experiments with night-migrating passerines during sunset/early night and night on Christiansø, autumn 2008. Conflicts where magnetic N was deflected towards geographical W or E. Compass dominance and possible compass calibrations

By

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Introduction

The purpose of the 2008 experiments was in particular 1) to investigate the orientation on starry nights for **spurious directional influences of prisms**, and 2) to investigate whether a **sunset compass calibrated the magnetic compass** (Cochran et al. 2004, Muheim et al. 2006, 2007).

1) is reported elsewhere (doc. Prisme3). 2) is reported here.

As in the two previous autumns funnel experiments were carried out on Christiansø in August-September 2008 bringing the total of experiments in 2006, 2007 and 2008 up to about 1400. These Christiansø experiments are now considered terminated and most of the equipment is removed from the island..

In autumn 2008 the focus was on sunset/early night experiments (and not as usual night experiments) because as reported in the document ***conflict*** in www.jorgenrabol.dk we succeeded in course of autumn 2007 to compensate the spurious directional influence of the tree-frames of the magnetic coil fields under condition of **–"overcast"** and in **sunset/early night**. During the conditions of –"overcast" and night, or +"overcast" and sunset/early night there is no such influence – at least not under the second condition where the tree-frames are not visible through the translucent but not transparent plastic sheets covering the funnels.

Material and methods

As in the previous autumns we used freshly trapped migrants (more than 90% were juvenile birds of the yaer) from the same or the previous day(s), and eight artificial magnetic fields were in action (magnetic N deflected towards geographical W or E) on most days, evenings or nights. The birds were only tested once and then released.

In course of the autumn several kinds of compass conflict/calibration experiments were carried out. Two main categories could be distinguished:

1) Funnel testings **without previous sunset-exposure** in the baskets, i.e. the birds were transferred directly into the test-funnels on the Queens Bastion from the baskets in the

garden of the Millers House. Here the baskets housing the birds were covered on top with plywood plates excluding – or at least heavily diminishing – the possible coupling between the sun/sunset and the magnetic compasses. These birds were tested either in the undisturbed magnetic field of the Earth (the **controls**) or within the magnetic coils deflecting mN towards gW or gE (the **exp.s**).

2) Funnel testings **after previous exposure for the sunset sky** in baskets (or cans) at the test-site on the Queens Bastion (transferred from the baskets in the garden of the Millers House in the late afternoon well before sunset). In such a case some of the birds, the **exp.s** were caged within the magnetic coil fields where mN was deflected to gW or gE. The remaining birds, the **controls** were caged in the undisturbed magnetic field of the Earth. In all but a single case (the cross-experiment, see below) the controls were later on tested in funnels in the undisturbed magnetic field, and the exp.s in funnels within the deflected fields.

Both under condition of 1) or 2) tests were carried out in either a) **–"overcast"** or b) **+"overcast"***.
The expectation of 1a) and 2a) was **dominance** of the celestial compass(es) over the magnetic compass, and 1b) orientation in reference to the magnetic compass which under the condition of + "overcast" is supposed to be the only migratory compass available .
The expectation of 2b) was **calibration** of the magnetic compass by the sunset compass.
I.e. in both cases of –"overcast" there should be no difference between the controls and the exp.s.

+ "overcast" *means that the funnel is covered on top with an opaque plastic sheet. This sheet is translucent but not transparent, i.e. patterns such as the stars and the tree-frame containing the magnetic coil field cannot be seen through the plastic sheet. It is also supposed – but not actually measured* **–** *that patterns of polarized light on the sky cannot be seen/detected by the bird from its position inside the funnel. However, a blurred image of the sun is visible through the plastic sheet, and very probably the lighter part of a clear sunset sky is also detectable, i.e. the light intensity of the funnel ceiling on clear days/evenings is probably unevenly distributed as seen from the inside of the funnel.*
The open question is whether the direction towards the lighter sunset sky ***alone*** *(i.e. when patterns of polarized light on the sky are not detectable) may be used as a compass reference for the sunset/early night orientation. The general point of view probably is that such a "compass" is not used but only serves for setting the sign of N for the bimodal polarized light pattern of the sunset sky (references needed).*

In all sunset/evening experiments (if not otherwise mentioned) **counter-frames** were in use in the exp.s changing the bilateral symmetry of the tree-frames of the coil fields (as looked from the view of the bird inside the funnel) into a quadratic radial symmetric ceiling (Fig.2 in the document ***conflict*** in www.jorgenrabol.dk).

As described in the docs. Dron06 and **Dron06b** (www.jorgenrabol.dk) small **cans** were used in some cases instead of baskets in the sunset/early night phase before testing under the starry night sky. In the 2008 experiments only a single can was used per coil field, and the can was placed centrally within the field.

As in the doc. **Magnet2** (www.jorgenrabol.dk) we abandoned the detailed signs for the mean directions (or peaks of bimodal activities) and concentrations for the individual birds. Instead a **dotted dot** signals the mean/peak direction of a single control bird, and **black** and **white dots** the directions of the W- and E-deflected exp.s, respectively.

The designations **evening** and **sunset/early night** mean the same and in general cover the period from ½ hour before to 1½ hour after the sunset time.

Results

–"overcast" experiments without previous exposure for the sunset sky

Exp.1:

Africa-migrants (Pied Flycatcher, Garden Warbler, Redstart) on five **evenings** from 24 through 31 August.

28 August the application of the counter-frames was missed and a significant bimodal pattern arose in the exp.s in reference to pN (pN means paper N, and refers to the short-axis directions SW (W-exp.s) or SE (E-exp.s) within the coil fields). The orientation was 94°/274° - 0.927*** (N = 8) in reference to pN. On 28 August – when the sunset/early night sky was overcast - the controls were oriented 219° - 0.201 (n = 8).

On the four other evenings the sunset/early night sky was **clear**, and the orientation of the **controls** (Fig.1) was significantly W-WNW and thus directed into the sunset direction. The mean direction is rather deviant from the standard direction of SSW-SW, and it looks like a rather strong and dominant sunset-taxis.

Perhaps surprisingly the orientations of the **exp.s** are not directed into the sunset. In reference to **gN** the orientation of the W-exp.s is 13° - 0.282 (n = 14), and of the E-exp.s 46° - 0.178 (n = 16), i.e. there seems to be no significant difference. Applying the non-parametric two-sample M-W-W-test on the distributions of the controls and the exp.s (n = 30) resulted in no statistical difference but P close to 0.05. Now this test does not distinguish between differences in direction and concentrations, but anyway: The lack of a sunset-taxis is remarkable, i.e. the deflection of mN in reference to gN means something but this something is not easily understood as the outcome in one or another simple compass system.

In reference to **mN** the W-exp.s are oriented 103° - 0.282 (n = 14), and the E-exps 316° - 0.178 (n = 16), i.e. it looks like (but everything is statistically insignificant) that a compass related to gN (the sunset compass?) overrides the magnetic compass (for the reasons explained in Figs.2-3 in the document ***magnet2*** in www.jorgenrabol.dk).

Exp.4:

Robins in the **evenings** of 11 and 12 September.

On 11 September the **controls** were oriented 338° - 0.428 (n = 7). Unfortunately, counter-frames were first added to the exp.s after a delay of 8 minutes. However, this short period seemed to be sufficient for a spurious influence – at least the orientation in reference to pN was bimodal and about "E"/"W" (85°/265° - 0.491, n = 8). So the orientation of the exp.s on 11 September is abandoned.

On 12 September the counter-frames were in action. The orientation of the controls was 331° - 0.750* (n = 6), i.e. much like the orientation on the previous evening. If the two samples are combined (Fig.4) the mean vector is 334° - 0.576* (n = 13).

The orientation of the **exp.s** on 12 September is shown on Fig.4: In reference to **gN**: 44° - 0.533 (n = 5), and in reference to **mN**: 181° - 0.439 (n = 5).

The orientation of the **controls** seems too northerly for a simple interpretation of a dominant sunset-taxis (the sunset is in about WNW, but on both evenings the sky was almost overcast and the sunset sky in no way prominent, so very probably a sunset-taxis is not involved)

Anyway, the **exp.s** are not showing any kind of sunset-taxis. Compared with the controls the pattern in reference to gN describes better than the pattern in reference to mN. In conclusion a celestial compass probably overrides the influence of a magnetic compass – also in the controls.

Exp.N2:

Africa-migrants (mostly Pied Flycatcher) on the **starry nights** 8 and 9 September.

The orientation was very different on the two nights. Therefore these are considered separately.

8 September (Fig.N2A):

The **controls** were oriented 160° - 0.662 (n = 8). Two Redstarts were involved and one of these was reversely oriented (345°). The sample mean vector of the six Pied Flycatchers was 155° - 0.908** (n = 6).

The **exp.s** were very significantly oriented in reference to **gN**: 180° - 0.893** (n = 8). In reference to **mN** the pattern is bimodal with the four W-exp.s constituting the "W"-peak and the E-exp.s the "E"-peak.

Clearly the orientation of the exp.s seems without influence of the magnetic field.

9 September (Fig.N2B):

The orientation of the **controls** was 303° - 0.738* (n = 7). The orientation of the **exp.s** was 292° - 0.534 (n = 7) in reference to **gN**, and 120° - 0.357 (n = 7) in reference to **mN**.

Clearly the orientation of the exp.s seems without (much) influence from the magnetic field.

In conclusion, in these two – "overcast" conflicts between the stellar compass and the magnetic compass the birds very probably were steered by the former and the latter was (largely) ignored.

Exp.8:

Control Robins under the **starry night sky** of 28 September. The sample mean vector was 214° - 0.725* (n = 7).

The contemporary **exp.s** were tested under **+"overcast"** and during **sunset/early night** and are presented and discussed below (in the next section **+ "overcast" experiments - - - - sunset sky**).

The orientations of controls and exp.s are shown at Fig.8.

Exp.5A:

Sunset/early night experiments with Africa-migrants and Robins 14, 16, 17, and 18 September. Each day half of the birds were tested in –"overcast" and the other half in +"overcast". The factor in common for these experiments was that the sunset sky was **clear**.

Here we consider only the birds tested in **–"overcast"** (lower row at Fig.5A):

The orientation of the **controls** was 281° - 0.785*** (n = 18). The orientation of the **exp.s** in reference to **gN** was 222° - 0.301 (n = 14), and in reference to **mN** 119° - 0.364 (n = 14).

It certainly looks like a photo-taxic response in the controls directed towards the setting sun. However, the orientation of the exp.s was – as usual - not directed into the sunset. Compared with the controls the orientation of the exp.s is best described/understood in reference to gN.

Exp.5B:

Sunset/early night experiments with Robins 15, 19, and 20 September. Half of the birds were tested in –"overcast" and the other half in +"overcast". Contrary to Exp.5A the sunset sky was overcast on these three evenings, and there was **no clear/prominent sunset**.

Here we consider only birds tested in **–"overcast"** (lower row at Fig.5B):

The orientation of the **controls** was 131° - 0.251 (n = 16). The orientation of the **exp.s** in reference to **gN** was 181° - 0.449 (n = 11), and in reference to **mN** 231°/51° - 0.353 (n = 12).

Clearly, there is no tendency at all for a sunset-directed orientation – and logically enough because there was no prominent sunset sky as in case of Exp.5A. All three distributions are low concentrated so there is no reason to discuss whether gN or mN offer the best description compared with the orientations of the controls.

Conclusion for the –"overcast" experiments without previous exposure for the sunset sky:

The **night** orientation (both **controls** and **exp.s**) seems steered by a celestial (probably a star) compass – and directed about standard (however, see 9 September, Exp.N2B). There is no sign of a directional influence of the magnetic field.

The **evening** orientation of the **controls** seems much influenced by the clear sunset sky – and looks like a photo-taxic response. If no clear sunset sky a prominent W-NW orientation is not observed. The evening orientation of the **exp.s** is puzzling: There is no directional influence as such of the deflected magnetic compass. However, the sunset-directed orientation breaks down/disappears – because of the directional discrepancy between the celestial and magnetic compasses?

+"overcast" experiments without previous exposure for the sunset sky

Exp.5A:

Sunset/early night experiments with Africa-migrants and Robins 14, 16, 17, and 18 September. Half of the birds were tested in –"overcast" and the other half in +"overcast". The sunset sky was **clear**.

Here we consider only the birds tested in **+"overcast"** (upper row at Fig.5A):

The orientation of the **controls** was 272° - 0.440 (n = 14). The orientation of the **exp.s** in reference to **gN** was **277°**/97° - 0.444 (n = 13), and in reference to **mN** 7°/187° - 0.444 (n = 13).

Perhaps the insignificant westerly orientation of the **controls** signals the co-influence of a sunset taxis - weaker than in case of the controls tested in –"overcast" (Fig.5A). Clearly, compared with the controls, the orientations of the **exp.s** in reference to gN fit better than in reference to mN (and the pattern in reference to gN may be taken as a rather weak indication of the co-influence of a sunset taxis).

Exp.5B:

Sunset/early night experiments with Robins 15, 19, and 20 September. Half of the birds were tested in –"overcast" and the other half in +"overcast". Contrary to Exp.5A the sunset sky was overcast, and there was **no clear/prominent sunset**.

Here we consider only birds tested in **+"overcast"** (upper row at Fig.5B):

The orientation of the **controls** was **173°**/353° - 0.510* (n = 14). The orientation of the **exp.s** in reference to **gN** was 204° - 0.480 (n = 12), and in reference to **mN** 66° - 0.360 (n = 12). Concerning the latter there was a tendency for bimodal orientation as doubling the angles led to 128°/308° - 0.326 (n = 12).

Compared with the controls the exp.s in reference to gN made a better fit (but not so much) than in reference to mN.

Exp.8:

The "controls" of this experiment with Robins 28 September is presented above – carried out under –"overcast" and during night (starry sky).

The **evening** orientation of the **exp.s** in reference to **gN** was 244° - 0.413 (n = 7), and in reference to **mN** 234° - 0.563 (n = 7). See Fig.8.

The orientation of the exp.s in reference to mN offers the best description (compared – cautiously – with the "controls").

Exp.6:

This **evening** experiment with Robins on 23 September was carried out after two days of caging without possibility for a coupling/calibration between the compasses.

The orientation of the **controls** looks **standard**/reverse bimodal: **212°**/32° - 0.544 (n = 7).

The orientation of the **exp.s** in reference to **gN** was 220° - 0.834** (n = 7), and in reference to **mN** clearly bimodal with the W-exp.s showing 302° - 0.994* (n = 4), and the E-exp.s 138° - 0.786 (n = 4).

On beforehand this experiment was considered determined to display unimodal (standard) orientation in reference to mN; the sunset sky was almost overcast and the experiments started about one hour after local sunset, so it is difficult to accept the more or less non-existing sunset as the base for a photo-taxic response or the compass reference for migratory orientation. However, clearly the stimulus/compass reference for steering the orientation must be in reference to gN (also indicated by the bimodal pattern in reference to mN with the W- and E-exp.s in widely separated peaks).

Conclusion for the +"overcast" experiments without previous exposure for the sunset sky: There are only weak indications of the influence of mN as the steering compass (in general the orientation of the exp.s is better described as steered by a compass related to gN). There is no clear/convincing sunset taxis.

-"overcast" experiments with previous exposure for the sunset sky

Exp.3:

In this **evening cross**-experiment on 7 September with Pied Flycatchers half of the **exp.s** (i.e. eight birds) experiencing the deflected mN when caged in the baskets during sunset were later on tested in the undisturbed magnetic field of the Earth under the condition of –"overcast". The **controls** were tested in +"overcast".

The orientation is shown upper left in Fig.3: The **W-exp.s** displayed a bimodal **39°**/219° - 0.575 (n = 4), and the **E-exp.s** 192° - 0.505 (n = 3). Apart from the low sample-sizes, rather low concentrations and the statistical insignificances it looks like a NE-response in the W-exp.s and a SW-response in the E-exp.s.

Such a pattern is not easily explained/understood, but certainly the treatment i.e. the deflection of mN in the sunset-phase ahead seemingly had an effect: If simple dominance in the test-phase of a sunset compass or a magnetic compass one should expect the same sample orientation in the W- and E-exp.s.

If **standard orientation** (SW) is calibrated from the sunset compass into the magnetic compass we expect NW-orientation of the W-exp.s and SE-orientation of the E-exp.s.

If standard orientation (SW) is calibrated from the magnetic compass into the sunset compass we expect SE-orientation of the W-exp.s and NW-orientation of the E-exp.s.

Clearly none of these scenarios came out, and the observed pattern could in principle arise after calibration of a NW-course from the sunset into the magnetic compass, or after calibration of a SE-course from the magnetic into the sunset compass. As will be obvious from lower left of Fig.3 (see below) the first of these scenarios (if any) offers the most probable explanation.

+"overcast" experiments with previous exposure for the sunset sky

Exp.3:

This is part of the same **cross-experiment** as mentioned above but considers the other half of the flycatchers i.e. the exp.s tested under condition of **+"overcast"** (Fig.3, lower left). Furthermore, the controls spending the sunset phase in the baskets under condition of the undisturbed magnetic field of the Earth, and later on tested in +"overcast" in the deflected fields (Fig.3 right column).

As usual for the sake of interpretation we are lacking a third group of birds i.e. controls tested in the undisturbed magnetic field of the Earth. This lack is mostly a capacity-problem: Already the traditional approach used requires 24 birds (8 controls and 16 exp.s).

The orientation of the **controls** in reference to **gN** was 242° - 0.743* (n = 6). In reference to mN the pattern was bimodal with the birds tested in mN deflected towards gW constituting the NW-peak, and gE birds the SE-peak.

The orientation of the **exp.s** is shown at Fig.3 lower left. The orientation of the W-exp.s was **280°**/100° **-** 0.933* (n = 4) and of the E-exp.s **108°**/288° **-** 0.956 (n = 3). Apart from the small sample sizes and the statistical insignificances it looks like WNW-orientation in the W-exp.s and ESE orientation in the E-exp.s. As (presumably) only the magnetic compass was available when the birds were tested this pattern is most parsimoniously interpreted as calibration of the magnetic compass of a SSW-course established by the sunset compass in the sunset phase. If so the interpretation of the pattern in –"overcast" upper left Fig.3 is not straightforward. Neither is the pattern of the controls (right column, Fig.3).

Anyway, considered in isolation the pattern in lower left, Fig.3 may cautiously be taken as an indication of the outcome of a magnetic compass reference calibrated by the sunset compass.

Exp.2:

Evening experiments with Africa-migrants 1, 2, 4, and 6 September.

The orientation of the **controls** (upper figure, Fig.2) was 262° - 0.285 (n = 27). There seems to be a difference (P close to 0.01, M-W-W- test) between the pattern of small dots (indicating very low levels of activity) 149° - 0.549 (n = 7) and the pattern of larger dots 283° - 0.494** (n = 20). It is tempting to interpret the orientation of the latter as influenced by a sunset taxis. However, I have some problems believing so: Both in the sunset phase and during testing in +"overcast" the sky was overcast or close to, i.e. a polarized sunset sky may well be available (in the sunset phase but not during testing) but a prominent amount of more light intensity in direction of the sunset (WNW) was not present.

The orientation of the **exp.s** in reference to **gN** was bimodal **200°**/20° - 0.305 (n = 26), and in reference to **mN 110°**/290° - 0.306 (n = 26). However, there is a large difference between **W-exp.s** (36°/216° - 0.469*, n = 14) and E-exp.s (195° - 0.540*, n = 12) in reference to **gN**. In reference to **mN** the corresponding sample vectors are 126°/306° - 0.469* and 105° - 0.540* (and the difference is the same). At least concerning the E-exp.s the **gN** orientation offers the best fit to the pattern of the controls.

On the other hand, the pattern of orientation in reference to **mN** (Fig.2, lower right) may be understood as a calibration of the magnetic compass by the sunset compass: A standard direction of SW established in reference to the sunset compass comes out as a bimodal NW/SE orientation with the W-exp.s in the NW-peak and the E-exp.s in the SE-peak.

Exp.7:

Evening experiment with Robins 27 September. The birds were trapped 25 Sep., and during sunsets 25 and 26 Sep. 16 **exp.s** were caged in **baskets** (8) and **cans** (8), respectively. 8 birds within coil fields where resultant mN was deflected gW, and 8 other birds within coil fields where resultant mN was deflected gE. In the baskets the birds could see the surrounding landscape and the sky down to the horizon, whereas the surroundings and the about 20° - 30° lower part of the sky was screened away for the birds in the cans. During 27 Sep. all birds were **tested in the undisturbed magnetic field** of the Earth.

The expectation (following Muheim et al. 2006, 2007) was that only in case of the basket-birds the sunset compass calibrated the magnetic compass, i.e. for the can-birds the orientation should be the same in reference to mN = gN for both W- and E-exp.s. In case of the basket-birds the orientation should be about opposite for the W- and E-exp.s., e.g. NW and SE, respectively, for a standard direction of SW established in reference to the sunset compass and from here transferred to the magnetic compass.

The orientation of the **basket-exp.s** is shown at Fig.7 left, and of the **can-exp.s** at Fig.7 right.

The **can**-birds display an about **standard**/reverse orientation; All three E-exp.s in SW. Considering the four W-exp.s half are in SW and the other half in NE. Considered in isolation this result could be taken as an indication of the hypothesis mentioned above, i.e. the same SW/standard orientation in W- and E-exp.s. If so the orientation of the **basket**-birds should be bimodal NW/SE with the W-exp.s in the NW-peak. Clearly this prediction is not met. However, another expectation is (though not statistically significant because of the small sample sizes): The W- and E-exp.s orient about opposite directions. Anyway, the same pattern is observed more or less in the can-birds. In short, there is no unambiguous indication for an acceptation of the hypothesis.

Considered from another angle the directional pattern of the W-exp.s is bimodal **56°**/236° - 0.819* (n = 7), and that of the E-exp.s 245° - 0.846* (n = 6). The difference is not easily tested because of the bimodal W-exp.s but the numbers in the SW- and NE-peak, respectively, are 2, 5 for the W-exp.s and 6, 0 for the E-exp.s. Applying a Chi-square test (+ Yates correction) yields $P < 0.05$. Taken together this may tell that there is no difference between basket- and can-birds but a bimodal distribution with (most) W-exp.s in the NE-peak and E-exp.s in the SW-peak, and this may be taken as an indication of a calibration from the sunset-compass into the magnetic compass of a common NW-orientation (which may be a sunset-taxis) – **but I do not think so**.

In conclusion, there are some inconsistencies not easily explained or understood. The results are not straightforward.

Exp.N1:

On 29 August this **early night** experiment with Garden Warblers (Fig.N1) was carried out (the start was 1½ hour after sunset i.e. with a weak trace of a lighter sunset sky towards WNW).

The **controls** oriented 317° - 0.772* (n = 6).

The **exp.s** were oriented 307° - 0.739* (n = 6) in reference to **gN**, whereas the orientation in reference to **mN** was bimodal NNE/SSW (the W-exp.s showed 64°- 0.637, n = 3, and the E-exp.s 200° - 0.953, n = 3).

Two possible explanations are available: 1) The controls and exp.s are steered by a compass or taxis in common in the test-phase related to gN. However, the almost non-existent lighter sunset sky is not an obvious candidate. A more probable scenario is one of a calibration of a NW-course from the sunset compass into the magnetic compass. This leads to NE-orientation in the W-exp.s and SW-orientation in the E-exp.s in the test-phase. Such an outcome is seen lower right in Fig.N1.

Exp.N3:

Night experiment with Robins 24 September. The exp.s spent the sunset in baskets and cans within the magnetic fields where mN was deflected towards gW or gE. During night the birds were tested in +”overcast” and in the undisturbed magnetic field of the Earth. This experiment was intended to be a night-version of Exp.6.

As obvious from Fig.N3 most birds showed zero or very small activities and it is impossible to draw any firm conclusion except that night-experiments – as usual – are mostly bound to end up with zero or small activities when the birds are tested under condition of +”overcast”.

Conclusion of the experiments in +"overcast" after previous exposure for the sunset sky:

The experiments 2 and N1, and also possibly experiments 3 and 7, are indicative of the calibration of the magnetic compass in the sunset phase by a compass (or taxis) related to gN, probably the sunset compass.

Overall conclusion of all experiments involving deflection of mN into gW or gE.

There seems to be a general tendency (for tests in the sunset/early night period) of a sunset taxis in the controls – but not in the exp.s for birds tested under condition of – "overcast".
As mN does not seems to be the compass reference in charge this means that the discrepancy between the directions of gN and mN in some – not understood – way is outfoxing the appearance of a sunset-taxis. Perhaps we should – therefore – expect a bimodal standard/reverse orientation pattern in reference to gN (and perhaps we do, Fig.1).
If tested under +"overcast" a prediction (based on the observations mentioned up) could be that the controls should be bimodally standard/reverse oriented (because they cannot tell the difference between mN and mS)

During night and under the starry sky (- "overcast") the birds – both controls and exp.s – as usual are mostly well oriented in about the standard direction (in reference to gN).

After an exposure in the baskets (or cans) in the sunset period at least sometimes responses are following which most parsimoniously have to be interpreted as steered by a magnetic compass calibrated by the sunset compass.

Without previous exposure for the sunset sky the sunset/early night orientation is seemingly not standard neither in reference to gN nor mN.

In the single experiment carried out is was not possible to demonstrate a difference in orientation between samples experiencing previous exposure during sunset in baskets or cans, i.e. the Muheim et al. scenario (of the importance of being exposed for the lower part of the sunset sky) could not be confirmed.

Discussion

First, some important information concerning the screening effect of cloudiness on the sunset pattern of polarized light: In a newly published paper, Hegedüs, R., S. Åkesson & G. Horváth (2007) clearly showed that an overcast sky does not prevent the possibility of compass orientation in reference to the sky-pattern of polarized light. However, (commentary of mine) the question is whether the birds in the funnels under condition of a totally overcast sky can appreciate the direction towards the sunset (at least the eyes of mine cannot – normally). If not, the consequence should be that **without acknowledging the sunset direction in about "W" the birds (probably)**

lack the possibility of signing the ”N”/”S” axis as determined by the pattern of polarized light on the sky.

Next question to serious (re)consideration is **whether compass conflict experiments are mostly for the benefit of publishing scientific papers** - i.e. perhaps these experiments are not really contributing to an understanding what is going on in real life. Perhaps they even deflect significant attention/focus.

There is a lack of intrinsic logic in many of these experiments: Often argumentations are not convincing, and no one takes into consideration the possible significance of other processes (such as gradient navigation) than simple compass orientations.

The intrinsic logic and the (evolutionary) reason for dominance of or calibration by a certain compass is that this compass is more reliable than another compass for establishing an appropriate course.

The **magnetic field** comes (logically) in as a compass reference, because the night sky may be overcast and no stars available. The same may hold true concerning the day-time sky when the sun is not visible (however, see Hegedüs et al 2007). The pattern of polarized light is probably only used/usable as a compass close to sunrise or sunset (*is this discussed seriously/convincingly somewhere?*). So we should not wonder about the presence and significance of a magnetic compass, but **it is not logical that such a compass should be dominant and calibrating** (at least not far from the magnetic poles and larger significant magnetic anomalies).

Clearly, a nocturnal migrant starting up preparing for the flight in the coming night focuses on its compasses. During afternoon it only has the sun (compass) and the magnetic compass. Then the sunset compass arrives on the scene, and later on the star compass(es).

If the magnetic compass is more difficult to use/takes longer time to go into action it makes sense that the sunset compass is dominant when available. But it is not clear why the sunset compass (and a star compass) should calibrate the magnetic compass unless the magnetic compass in some way becomes more accurate through this process of calibration – and/or because it is a safety procedure paying on the average for the risk of an overcast night to come. .

For me the most parsimonious expectation is that there is a use (“dominance”) of that compass most accurate – and present - under the conditions given. Therefore, perhaps Åkesson et al. (2002) could demonstrate the outstanding/mysterious **afternoon-**calibration by the magnetic compass into a sun compass. The logic could be that the sun altitude in the arctic shifts only slightly in course of the day and night, and therefore absolute time may be difficult to access, and time-compensations must be carried out in order for the “moving” sun to function properly as a compass.

Remember (significant parts of) the past (*to be controlled*):

Wiltschko and Wiltschko (1976) tested Robins under an artificial stationary “16-star-sky” and demonstrated transfer of standard orientation from the magnetic compass into this “stellar” nonsense pattern.

Next Able and Able (1990) using the same kind of “16-star-sky” now rotating to create the impression of a rotational point in (geographical) N demonstrated calibration of the magnetic compass by the “star” compass (in a pre-phase birds in four cages and in the normal magnetic field were presented for the rotating sky with the directions of the four cages in reference to the rotational centre in (geographical) N, E, S and W. Later on the birds were tested indoors without the “16-star-sky” and in the natural magnetic field).

Weindler et al. (1996, 1997) tested their birds under the stationary “16-star-sky” in a destroyed magnetic field – after a pre-phase in the normal magnetic field and under the rotating “16-star-sky”

Then followed Sandberg & Moore (1996) and Sandberg et al. (2000) who first funnel-tested their birds under the natural sunset/early night sky in magnetic fields where magnetic N was deflected E or W. These birds were later on released (and light-stick followed) during night under the stars and in the natural, un-deflected magnetic field – i.e. both the calibrating and the calibrated compass were present under the testings.

Also in Åkesson et al. (2002) where the deflected magnetic field was added in the afternoon hours before "sunset" both the magnetic compass and the sun/sunset compass(es) were present under the funnel-testing.

Then followed Cochran et al. (2004) where the birds spent the sunset/early night in an outdoor aviary within a magnetic field where magnetic N was deflected W. These birds were later on released during night and followed by radio-tracking. The directions observed indicated a course in reference to mN and calibration of the magnetic compass by the sunset compass. Again both the calibrating and the calibrated compass were available under the testing.

Muheim et al. (2006, 2007) made use of a calibration phase (night-i) in the natural magnetic field and under a polarization pattern of the sunset sky deflected 90° to the E or W (*correct?*). Later on (night-i+1) the birds were tested indoors and only the magnetic compass was available.

I started up (2001 and 2002 on Endelave, and 2006 and 2007 on Christiansø) with a program mimicking Sandbergs, i.e. a calibrating sunset/early night basket-phase in magnetic fields where mN was deflected towards gW or gE followed (same night) by a funnel-testing in the natural magnetic field and under the stars. Again both the calibrating and calibrated compasses were present in both the basket and the test-phase.

In 2008 the funnel-testings of mine were carried out in about half of the cases under condition of +"overcast", i.e. the stars were not present, i.e. only the (presumed) calibrated compass (the magnetic one) was present. .

In a standard experiment of mine the calibrating compass may be present or not not-present in the test-phase. **If present** the calibrating compass (still) may be dominant, or ignored, i.e. the orientation is steered by the calibrated compass. If not-present only the calibrated compass is available, and therefore the process of a previous calibration is unambiguously demonstrated.

The natural situation is that the magnetic compass – if available in the pre-phase - will always be available also in the test-phase, but a celestial compass may often disappear, so the process that a sunset (or a star) compass calibrates the magnetic compass make sense. However, the magnetic compass as the calibrating compass makes much less sense.

First it was a matter about calibration of the stellar compass by the magnetic compass. Then the scene shifted with the finding of Cochran et al. (2004) indicating that the magnetic compass – at least on the first night following the release – was calibrated by (was supposed to be) the sunset compass.

Then followed the papers by Muheim et al. claiming the same as Cochran et al. – at least if the (polarization pattern of the) sunset sky was/had been visible down to the horizon.

Following (unsuccessful) experiments trying to demonstrate magnetic calibration of the stellar compass, I shifted focus to the Cochran/Muheim scenario. However, the importance of some basic considerations/conditions were not under control/fully experienced/understood/realized.

Of the three compasses the magnetic one is always available. The stars are – sometimes – available during night, and the sun – sometimes – available during daytime. The sunset/sunrise compass is only available – sometimes* - in short periods. Here the latter compass is considered different from the sun compass. The sunrise/sunset compass is based on the polarized light pattern of the sky, whereas the sun compass is based on the sun(azimuth) in itself (probably the sun/sunset/sunrise sky play a secondary role for setting the sign of the N/S axis of the polarized light pattern of the sky).

The logical consequence of the conditions/availabilities mentioned above is that if the **magnetic compass** is a just as easy compass to use as the celestial compasses the latter should be superfluous – at least in our part of the world with zero or small declinations, and if only compass orientation is involved.

If the **magnetic compass** is less easy to use (i.e. if the establishment of magnetic N – or the process of maintaining magnetic N) than the celestial compasses it makes good sense (may be not to calibrate but) at least to coordinate the magnetic and stellar compasses. If based on visual processes in the eye/retina the magnetic compass may need some light – and more light than normally present during a dark, moonless night. To a smaller degree it also make sense than the magnetic compass calibrates a sunrise/sunset compass. If the sunrise/sunset compass could be used also under cloudy/overcast conditions (as it seems to be; Åkesson et al. 2002) it makes little sense that this compass is calibrated by the magnetic compass.

It makes a lot of sense that the **celestial compasses** calibrate the magnetic compass – as a backup compass when overcast.

Figs.12-14 in doc.dron06b www.jorgenrabol.dk give the principles for distinguishing between dominance and calibration.

Preferably the calibrated compass should be the one and only compass available when the birds are tested. This has been the case in the Muheim et al.and Cochran exp.s, and also in the Wiltschkos/Weindler-exp.s under the stationary "16-star-sky" (a problem here is the **stationary** "sky").

In the Sandberg exp.s the magnetic compass was present together with the stellar compass(es). The same was the case in the first experiments of mine on both Endelave 2001 and 2002, and Chr.ø 2006 and 2007. In 2008 the birds were tested in +"overcast" i.e. the stars and (presumably) also the sunset were not present when investigating whether the magnetic compass was calibrated by the sunset compass. The problem here is that +"overcast" in the night means almost no activity in the funnels.

On two occasions in 2001 (doc.magnet2, www.jorgenrabol.dk) the birds were – by a natural accidence – tested in an almost overcast night (cloud cover 6-7/8 in the start of the funnel-testing soon going to 8/8) after a clear sunset phase in the baskets. Thus the conditions for observing a sunset calibration of the magnetic compass seemed promising – and much better than the conditions for calibrating the stellar compass by the magnetic compass.

On **Sep.16** the sample mean vector of the **exp.s** tested in the **natural magnetic field** was 228° - 0.773*** (n = 15), and there was no significant difference between the two sub-samples W- and E-exps. The sample mean vector of the former was 239°- 0.802** (n = 7), and of the latter 218° - 0.774** (n = 8). The orientation of the **controls** tested within the **deflected magnetic fields** was best described in reference to **gN** (241° - 0.823**, n = 8) with the four **mN** = gW directions totally separated the four mN = gE directions. The two sub-sample mean vectors were 355° - 0.913* (n = 4), and 125° - 0.982* (n = 3). The conclusion should be, that there is no calibration of the magnetic compass by the sunset compass, but of course considered in isolation the magnetic compass could had been dominant in the night phase (standard orientation). If so the orientation should had been unimodal and standard in reference to mN of the controls tested in the deflected fields. But it is not.

It seems like close to standard orientation in reference to gN is carried out in both controls and exp.s – and the compass in charge must be the stellar compass (in spite of the few stars only occasionally available) or another unknown compass related to gN.

On **26 Sep.** the **exp.s** tested in the **natural magnetic field** show a bimodal standard/reverse pattern. The sample mean vector is 20°/200° - 0.509* (n = 16). The same holds true if the W- and E-exp.s are considered separately: **190°**/10° - 0.761** (n = 8), and 40°/220° - 0.405 (n = 8), respectively. Considering the **controls** in the **deflected fields** omitting two bimodals about N/S the sample mean vector in reference to **gN** is 245° - 0.793* (n = 6). If distinguishing between mN = gW and mN = gE the two mean vectors are **321°**/141° - 0.415 (n = 4) and **226°**/46° **-** 0.912* (n = 4), respectively, i.e. about at right angles to each other. If the controls are considered in reference to mN the sample mean vector (minus the two bimodals) is 97° - 0.295 (n = 6), and if distinguishing between mN = gW and mN = gE **51°**/231° **-** 0.415 (n = 4) and **136°**/316° - 0.912* (n = 4), respectively. Considered in isolation the orientation of the exp.s does not seems to be steered by compass calibration in the sunset/early night phase but the situation is not easily untangled.

When writing one or two **scientific papers** (two because perhaps we should distinguish between sunset/early night and night experiments) on **calibration**/dominance we should keep close to a scheme:

How many experiments under a certain condition are available, and how many of these gave indications of the process in consideration.

As in case of the more complicated process “gradient navigation” compared with the more simple process “compass orientation” (mentioned in Thorup & Rabøl 2007) we should always keep in mind that lack of response is not a proof against the general or sometimes presence/influence of the more complicated process. Perhaps the time and/or conditions present were not optimal/sufficient.

Until now we supposed that in **natural overcast** the birds could not use a sunset compass – based on a) the sunset itself or b) the polarized light pattern of the evening sky. However, recent work of Åkesson et al. invalidates assumption b).

Furthermore, the application of a non-transparent but translucent plastic sheet above the funnels (i.e. the condition **+”overcast”**) was – and is still – supposed to a) screen away the stars, and b) to outfox the characteristic light polarization pattern of the sunset sky. a) seems substantiated because at least for the naked human eye the stars are not visible trough the plastic sheet. However, b) has not actually been measured but remains a (reasonable/logical) supposition. Furthermore, c) we had – and till have – the meaning that (the direction towards) the **clear sunset sky** (but not a natural overcast sunset sky) could still be established under condition of +”overcast”, i.e. in principle a **positive sunset taxis** could arise and perhaps also a weak kind of **sun compass** could be used. Obviously, we need a clear statement what is meant with the designation sunset compass, i.e. whether it is implicitly based on the skylight polarization pattern or the direction towards the sun(set).

In both the Sandberg and Cochran experiments the **magnetic compass** was manifesting itself as a) the **calibrating** compass which b) were no longer active (or dominant). I copied the test conditions of S and C but when I could not confirm their findings the reason could be that b) was not fulfilled, i.e. the magnetic compass was still active and dominant when the night tests were carried out. Therefore, I cannot conclude that calibration was not carried out during sunset/early night: it might had been so but it was dominated by later processes. Obviously, I should had tested my exp.s under conditions of a zero magnetic field, or a (strong, heterogenous) vertical magnetic field.

In my earlier experiments I also – in principle as described above – missed the possibility for demonstrating **sunset calibration of the magnetic compass** – because the birds were later on tested under conditions of a clear (sunset or stellar) sky. However, at least partly in 2008 the condition of +”overcast” was present.

Until now I had a clear conception, that **cross-experiments were necessary to demonstrate calibration**. However, it is not necessarily so. I already knew that, but then the scenario was, that dominance in the funnel/test-phase in a standard experiment could mask/destroy the calibration in the pre-phase.

This is still so, if I – as before 2008 – make experiments where both magnetic N and celestial N are present/available in the funnel-phase.

However, perhaps a later dominance will never occur. Furthermore, in 2008 (the possibility for using) celestial N was taken away in the funnel-phase under condition of +”overcast”.

Summing up: The necessary (but not necessarily sufficient) condition for demonstrating calibration is a **pre-phase in the baskets before the funnel-phase**. This holds true both in case of cross- and standard experiments.

Therefore, also standard experiments may both in principle and (sometimes) in practice be used for showing/demonstrating calibration:

Example: The sunset compass calibrates the magnetic compass. Following the pre-phase in the baskets +”overcast” testing in the funnels evening or night converts a SW-orientation into a bimodal NW (E-exp.s)/SE (E-exp.s) orientation in reference to mN.

If on the contrary the magnetic compass in the pre-phase calibrates the stellar compass – and the magnetic compass later on in the funnel-test is ignored (or is destructed) – the SW-orientation in reference to mN ends up in a bimodal SE (W-exp.s)/NW (E-exp.s) orientation in reference to stellar N.

Unfortunately, this hindsight does not bring much practical clarification. The field dominance/calibration is often/mostly open for different interpretations.

Survey of and comparison between the three autumns 2006, 2007 and 2008, compared with autumns 2001 and 2002.

Initial remarks

We should arrange after (evidence of) 1) **dominance**, 2) **sunset calibration** of the magnetic compass, 3) **magnetic calibration** of the stellar compass, and 4) **sunset-taxes**. Concerning 1) the distinction should be between gN, mN and ?. Concerning 2) and 3) between clear, possible and no evidence. We need a common chapter of ***Material and methods*** where the differences between years are described. We also need figures exemplifying 1) to 4) above.

The main “problem” writing such a paper about the compass conflict experiments is 1) the almost “too many” experiments under different conditions/combinations, and 2) the difficulty to understand (in depth) and explain the concept and process of calibration. In this latter connection it is essential to explain the difference and significance of a bimodal pattern (with the W- and E-exp.s in different peaks) in a dominance situation and a calibration situation.

Because of 1) it is not possible to bring (details of) all the results in the paper; it must be done elsewhere e.g. on my homepage. It is important to bring generalizations such as the following one concerning sunset-taxes: *On evenings with a clear sunset sky we almost always – in the **controls** - observed a sample orientation directed more or less towards the setting sun. However, if the experiments were carried out under condition of +"overcast", or the sunset sky was not clear/prominent because of cloud-cover, such sunset-directed orientation was not normally present. Concerning the **exp.s** sunset-directed orientation was not normally observed. Furthermore, the orientation was not obviously related to mN, i.e. in some way the discrepancy between the celestial and magnetic compasses cancelled the influence of a sunset taxis.*

We need descriptions of the problems with **spuriousness** which in course of time/years were compensated for (the too near positioned funnels in 2006, and influence of the tree-frames on the orientation under conditions of evening and –"overcast" (2006, 2007).

We have to remember that only in the 2008 **evening** experiments we used a pre-phase in the baskets on the Queens Bastion just before actual testing in the funnels, and the condition of +"overcast".

Explicitly, we have to present and discuss the **logical frames for a compass calibration**. In principle, there may be two reasons for a calibration: 1) Transference to another compass because it is more easy to **maintain** an already established course in reference to this other compass (e.g. transference from a magnetic to a celestial compass). 2) Transference to another compass available if the calibrating compass becomes **un-available** (e.g. transference from a celestial to a magnetic compass).

We have to find out/decide whether these conflict/calibration experiments mostly are 1) a unserious/unimportant paper-machine, 2) a way for promoting ones favourite cue/compass (as is always the intrinsic agenda in a Wiltschko-paper), 3) a serious attempt to understand the interactions between the compasses, or 4) – as 3), but extended – to understand the orientation/navigation system of the birds.

Autumn 2006

These experiments are treated on the homepage as docs. **Dron06b** (night) and **Sunset** (sunset/early night). In my documents is also found the original doc. **Dron06** with more details.

The 2006 experiments were **all** carried out under condition of a clear sunset/starry sky, and – "overcast", i.e. the birds in the baskets and the funnels always were freely exposed for the clear sky. All funnel tests during night were carried out after spending some hours during sunset/early night in the baskets on the test-site on the Queen´s Bastion (the exp.s within the deflected magnetic fields). In all evening experiments the birds were transferred directly into the funnels from top-covered baskets in the garden of the Miller´s House.

Sunset/early night

Experiments were carried out on eight evenings (seven between 6 and 13 Sep., and a single 28 Sep.) with a total of 8 times 16 birds = 128 birds. Most birds were Robins (89), then followed Redstart (20), Garden Warbler (16), Pied Flycatcher (2) and Blackcap (1).

As told in **Dron06b** there was during **night** a clear tendency in the **controls** of N-orientation in the odd funnel numbers and S-orientation in the even funnel numbers (the funnels in pairs were very close to each other, and odd numbers always N of even numbers). This tendency was not prominent in the **evening** experiments, where instead the controls displayed a pronounced WNW-orientation which should be perceived as a photo-taxic response (Figs.1-2). Fig.3 shows the very pronounced bimodal “E”/”W” orientation (in reference to pN) in the exp.s. This pattern is spurious in reference to the rectangular tree-frames of the magnetic coil field (Fig.4).

Night

Experiments were carried out on fourteen nights, including eight **standard** experiments (each 16 birds) and six **cross** experiments (each 24 birds). In total 272 experiments including 81 Pied Flycatchers, 74 Robins, 57 Garden Warblers, 32 Blackcaps and 28 Redstarts.

A **standard** experiment means first a stay in uncovered, latticed structured baskets during sunset/early night (free sight to the sky and surroundings) and then a transfer during night to a funnel with the lower about 10° of the sky screened away. The **controls** are kept and tested under condition of the natural magnetic field of the Earth, whereas the **exp.s** are kept and tested within a magnetic field, where magnetic N is deflected towards E or W. Primarily, a standard experiment shall elucidate which compass is the dominating one in the test phase; this type is not appropriate for demonstrating a preceding compass calibration because both the calibrating and the calibrated compass are still present in the test phase (as they were during 2006 and 2007, but not always in 2008).

A **cross** experiment means that some of the birds (named the **controls**) are first spending the sunset/early night within the basket in the undisturbed magnetic field, but later on are tested in funnels within a deflected magnetic field. For another group of birds – named the **exp.s** – the magnetic treatment is the reverse one. The meaning with a cross experiment is to find out whether a possible compass calibration during sunset/early night is retained in the test phase during night.

As already mentioned there was a significant tendency of the controls in the odd funnels showing reverse (mostly NNE) orientation, whereas the contemporary controls in the even funnels mostly displayed standard (about S) orientation. In particular this tendency/bimodal pattern was prominent in the standard experiments. The explanation on this obvious spurious orientation undoubtedly was that the odd and even numbered funnels were arranged pair-wise and very close to each other with the odd number in gN and the even in gS. The distance between the pairs was much longer and therefore, probably, the birds in a pair could hear/sense each other resulting in some kind of “repulsion” between the birds. Anyway, this only seems to be part of the explanation as the necessary background seemed to be a delicate standard/reverse (NNE/SSW) equilibrium in the birds and in particular in the very start of the season.

The **standard** experiments (doc, Dron06b) in autumn 2006 is summarized in Figs.1-2, and Fig.1 shows the general tendency of a NNE/SSW bimodality of the **exp.s** in reference to gN, whereas the orientation in reference to mN is more dispersed and if anything about bimodal WNW/ESE. If the cross experiments are included (Fig.1) the same tendency is observed for the exp.s tested in the natural magnetic field, and for the controls tested in the deflected magnetic fields. This patterns signal influence of a compass related to gN.

If focusing on the single nights there is a tendency to most influence of mN twice in August, but otherwise gN seems to be the compass reference in charge.

Fig.1 in the doc. Dron06 depicts the orientation of the **controls in the natural magnetic field**. The distribution is clearly bimodal, 16°/196° - 0.308** (n = 60). At Fig.2 is distinguished between the N (odd numbered) and S (even numbered) funnels. The two sample mean vectors are 39° - 0.493*** (n = 29), and 185° - 0.523*** (n = 29), respectively. In conclusion, the spurious effect of the position of the funnel within a pair is very significant.

Fig.4 in the doc. Dron06 (**exp.s** tested within the **deflected** magnetic fields) signals a – statistically insignificant – "E"/"W" influence of the rectangular tree-frames ahead of the birds in the funnels also in the night experiments. Fig.5 in the same doc. shows a two or three peaks pattern in reference to gN (NE, SE-SSE, SW). The sample mean vector is 136° - 0.246* (n = 56), or following doubling the angles 31°/211° - 0.163 (n = 57). In reference to mN the sample mean vector is 316° - 0.072 (n = 56), or after doubling the angles 121°/301° - 0.163. Clearly, the orientation of the exp.s in reference to gN describes better (and is more like the controls) than in reference to mN.

Now the **cross** experiments in 2006 should be considered for a possible demonstration of compass **calibration** from 1) the sunset compass to the magnetic compass, or 2) from the magnetic compass to the stellar compass.

The test is to investigate the funnel orientation of the **exp.s in the natural magnetic field**. The condition for demonstrating 2) is that the magnetic compass has finished its role in calibrating the sunset/early night phase and remains inactive during night (at least if the sky is starry). If calibration the orientation of the W- and E-exp.s should be about opposite.

Considering the night of **24 Aug.** there is no difference between the E- and W-exp.s. The combined sample mean vector is 151° - 0.246 (n = 15), or after doubling the angles a bimodal patterns emerges, **198°**/18 ° 0.221 (n = 15).

28 Aug. is very special as the E-exp.s are oriented 355° - 0.897*** (n = 8), and the W-exp.s 346° - 0.765* (n = 8). Clearly, there is no difference between the mean directions of W- and E-exp.s and no sign of a previous compass calibration.

16 Sep. there is a significant difference between the distributions of the W- and E-exp.s following doubling of the angles (P < 0.02, W-W-test). However, the axial difference is small, only 40°, far from 180° signalling preceding compass calibration. On this night half of the exp.s were in **baskets** and half in **cans** in the sunset/early night phase. There was no difference between the bimodal patterns of the basket- and can-exp.s, 12°/192° - 0.617* (n = 8) and 21°/201° - 0.424 (n = 7).

On the nights **21-26 Sep.** there is no significant differences between the W- and E-exp.s (neither in baskets or cans), but there is a very significant difference between the exp.s spending the sunset/early nights in **baskets or cans**. All together the sample mean vector of the basket-exp.s is 222° - 0.0592*** (n = 22), and of the can-exp.s 159° - 0.652*** (n = 20). The difference is significant (P < 0.01, W-W-test). The interpretation of this result is not straightforward – but seemingly compass calibrations are not involved. If so we should expect calibrations from a sunset compass to a magnetic compass (baskets), and from a magnetic compass into a stellar compass (cans), and bimodal distributions with E- and W-exp.s in opposite peaks. However, clearly the cut off of the lower part of the sky in sunset/early night (the can exp.s) has some effect – perhaps a change from standard orientation to some sort of compensatory/right angle orientation (the question is whether controls tested in the natural magnetic field had reacted in a similar way).

Summing up these 2006 night experiments there is absolutely no indications of compass calibrations in the sunset/early night phase.

Autumn 2007

In my documents is a doc. **Prisme** which has been split up in three documents on my homepage www.jorgenrabol.dk : **Conflict**, **Prisme2** and **Magnav2**. The latter two docs. are about simulated geographical displacements using prisms or altered magnetic fields (altered intensities and inclinations), respectively.

In the present connection we are only interested in the doc. Conflict, where standard or cross experiments were carried out on evenings or nights under condition of –“overcast”.

In total we performed three evening and seven night (six standard and one cross) experiments, each involving 16 birds resulting in 160 experiments (158 Robins and 2 Blackcaps).

Sunset/early night

Most of the time was used constructing a useful **corrective tree-frame** the purpose of which was to change the bilaterial symmetry of the tree-frame housing the magnetic coil field into a **radial symmetrical structure** as seen from below by the bird in the funnel (Fig.2 in doc. Conflict). After mounting of a corrective tree-frame with 4 hanging legs the “operation” succeeded, i.e. the spurious “E”/”W” orientation in reference to pN disappeared (pN/pS defines the short axis of the rectangular tree-frame of the coil field).

Fig.9 in the doc. Conflict shows the evening orientation on 21-22 Sep. under clear sunset sky (-“overcast”) **with and without collars** (Fig.3, doc. Conflict). The birds were directly transferred to the funnels without previous exposure on the Queen´s Bastion. These were the only two experiments performed in 2007 with corrective tree-frames applied.

There seems to no difference between the orientation of the **controls with and without collars**, and the combined orientation is 241° - 0.298 (n = 14), or after doubling the angles **242°**/62° - 0.333 (n = 14).

The orientation of the **exp.s** describes best **-** and is in most agreement with the controls – in reference to **gN**, and there is no difference with or without collars: For the combined distributions the sample mean vector is significant, 283° - 0.522* (n = 15). Also no difference is found between the orientation of the W- and the E-exp.s in reference to gN. This observation points to zero influence of the magnetic compass in the test phase – and probably also lack of calibration sunset/early night. Looking at the distributions of W- and E-exp.s in reference to **mN** (Fig.9D) reveals most W-exp.s in the NNE-peak, and all E-exp.s in the SSW peak: The two sample mean vector are **15°**/195° - 0.587 (n = 8) and 184° - 0.489 (n = 8), respectively.

In conclusion the orientation seems to about standard in reference to gN plus some influence of a sunset taxis.

Night

First, the spurious directional influence between the pair-wise control funnels were removed by reducing the four pairs of funnels per table into four funnels per table with a maximal dispersion between the funnels (Fig.1 in doc. Conflict).

In the four nights (Sep.9 through 18, Fig.4) under a clear **starry** sky the **controls** are significantly oriented, 201° - 0.591*** (n = 27).

In reference to **pN** the orientation of the **exps**. is significantly bimodal in about “E”/”W”, 95°/275° - 0.338* (n = 28), and in fact this is the only indication we have that the rectangular tree-frames at least sometimes may exert a spurious influence on the orientation during **night** (no corrective tree-frames were added during these nights). In reference to **gN** the sample mean vector of the exp.s is significant, 146° - 0.487** (n = 24). However, it looks somewhat bimodal with a broad main peak in SSE-S and a smaller peak in NNE-NE. Doubling the angles leads to **214°**/34° - 0.196 (n = 28), so clearly this is no improvement. In reference to **mN** the sample mean vector, 159° - 0.198 (n = 24) is insignificant.

In conclusion, gN seems to be the compass reference in action for the exp.s. However, the difference between these and the controls is statistically significant (P < 0.02, M-W-W-test).

In the results above no consideration is taken to the fact that **collars** (8 cm height) were mounted on top of the funnels in half of the birds during the last two nights (Fig.5).

In short, there is no clear/significant effect of the treatment.

In the **controls** the sample mean vector of the **non-collars** was 212° - 0.973*** (n = 8), and in the **collar** controls 189° - 0.436 (n = 7).

In the **exp.s** – and in reference to **gN** – the **non-collars** display 189° - 0.549 (n = 6), which looks much like the controls. On the other hand, the **collar** exp.s are oriented almost significantly towards "E" (98° - 0.679, n = 6). This counter-clockwise rotation reminds of the can- contra the basket-birds in autumn 2006 (Doc. Dron06b, 21-26 Sep.). The orientation of the exp.s in reference to **mN** points towards no influence of a magnetic compass.

During two nights the sky was **totally overcast** in the test/funnel phase. On 11 Sep. the sunset/early night sky was partially covered, whereas on 17 Sep. also the sunset/early night sky was totally covered.

11 Sep. the **controls** are bimodally oriented in about **SW**/NE (n = 4), and the **exp.s** both in reference to gN and mN insignificantly about SSE.

17 Sep. the **controls** were significantly oriented, 272° - 0.788* (n = 8), and the **exp.s** too in reference to **gN**; 307° - 0.892** (n = 6). In reference to mN the exp.s are insignificantly oriented, **NE**/SSW. Clearly, gN describes best – but how should this be explained as the sky was overcast? It could be influence of the beams from the lighthouse, but the direction towards the lighthouse is in about NW-NNW so I do not think so.

On 13 Sep. we carried out the only **cross** experiment of this autumn (Fig.6).

Clearly, there is no sign of a compass calibration of the stellar compass from the magnetic compass, as the **exp.s** tested in the natural magnetic field displayed **203°**/23° - 0.768* (n = 7). If compass calibration the pattern should had been about NW/SE with the W- and E-exp.s in each peak. However, neither predictions are fulfilled.

The orientation of the **controls** tested in deflected magnetic fields is not easily interpreted. In reference to **gN** there is a SSW peak of birds tested in mN = gE, and a more diffuse ENE peak of birds tested mN = gW. In reference to **mN** the orientation is unimodal and significant, 140° - 0.814* (n = 6), so it looks as if the magnetic compass is the one in charge – however compared with the exp.s the direction is turned counterclockwise (we have not tested for the significance of this difference).

Autumn 2008

In course of the period 24 Aug. through 28 Sep. we carried out 22 evening experiments (21 standard and a single cross) with a total of 357 birds, including 197 Robins and 160 Africa-migrants. The latter were used in the cross experiment. Furthermore, four night experiment (standard) were carried out with 64 birds (48 Africa-migrants and 16 Robins). Thus a total of 421 compass conflict experiments were performed.
We already presented and commented these experiments above.

Autumns 2001 and 2002

These compass conflicts are presented and discussed in doc. Magnet2 on my homepage www.jorgenrabol.dk .
The experiments were carried out with three groups of juvenile migrants trapped on Christiansø and displaced to Endelave (about 300 km. due W), where the birds were caged for days or even weeks in baskets within magnetic fields where resultant mN was deflected towards gE or gW. The same individual birds were funnel tested several times in standard and/or cross experiments as described for the conflict experiments on Christiansø.
In fact, the 2006, 2007 and 2008 experiments on **Christiansø** were performed for that purpose to investigate the effects of **short-term deflections** compared with **long-term deflections (Endelave)** of mN compared with gN.
The **cross** experiments on Endelave showed the same as on Christiansø: There was no sign of sunset/early night calibration of the stellar compass by the magnetic compass – nor of the magnetic compass by the sunset compass.
The standard experiments on Endelave showed a general tendency of dominance of the stellar compass. However, sometimes the **magnetic compass** was the dominant one (in the exp.s tested in the deflected magnetic fields) – but then the influence was in about the **reverse direction** of the standard direction. This tendency was never seen following the short-term deflections on Christiansø, so it seems that prolonged caging in a deflected magnetic field under condition of clear sunset and starry nights induce a complicated reaction of the birds.

Survey autumns 2006, 2007, 2008

Positive sunset taxis

We need a survey of the sunset orientation – under a **clear**- and an **overcast** sunset sky and under conditions of **–"overcast"** and **+"overcast"** – this means four different categories.
Is standard orientation (about 215°) ever seen – in clean or as a mixture between standard and sunset directed orientation?
I have a feeling that sunset directed orientation is not just a phototaxic response, but perhaps a **right angle** response on the bimodal standard/reverse axis established as a compass axis in reference to the polarized sunset sky. These two directions will be close to each other and therefore it will difficult to find of the process going on.

Collars

We have two **night** standard experiments (16 and 18 Sep. 2007, Fig.5) after previous exposure in baskets on the Queen`s Bastion. Furthermore, two **evening** (21 and 22 Sep. 2007, Fig.9) experiments with direct transference into the funnels from the garden of the Miller´s House. The nights were clear and starry, and all sunsets also clear.

The expectation was that the magnetic compass should be more influential in + collars because of the screening away the lower part of the sky reducing the influence of the sunset compass (Muheim et al.) and perhaps also the star compass.

Clearly, this expectation was not met.

Cans

The collars (see above) were applied to the funnels whereas the cans were applied in the sunset/evening phase as an alternative to the baskets.

However, in both cases the expectation – following Muheim et al. – was that the magnetic compass should increase its influence either in the dominance hierarchy (the collars) or in the calibration process.

In case of a calibration of the magnetic compass by the sunset compass a SW standard response of the controls in the natural magnetic field (not tested) should change into a bimodal NW/SE-pattern in the exp.s (E-exp.s in NW, and E-exp.s in SE) in the natural magnetic field (cross experiment), i.e. in reference to both gN and mN. If the calibration is the other way around (from the magnetic compass into the star compass) then the W-exp.s should be in the SE-peak and the E-exp.s in the NW-peak.

As obvious from the experiments on Sep.16 and Sep.21-26 2006 such patterns are not observed, and the significant counterclockwise shift of the can-birds Sep.21-26 is the result of something else and basic in the orientation/navigation system.

In the **sunset/early night** experiment on 27 Sep. 2008 (Fig.7) the birds were tested in **+”overcast”** after previous exposure in **baskets** (4 W- and 4 E-exp.s) or **cans** (4 W- and 4 E-exp.s) under a clear evening sky.

The expectation was that the can-exp.s should not be calibrated by the sunset compass and therefore just display standard orientation in reference to mN in both W- and E-exp.s. On the contrary, in the basket-exp.s the magnetic compass should be calibrated by the sunset compass and then later on when tested in the funnels display NW orientation (W-exp.s) and SE orientation (E-exp.s) in reference to mN.

As seen in Fig.7 the W- and E-basket-exp.s (left) are in opposite peaks (NE-ENE and SW-WSW, respectively) but not in the expected directions. Furthermore, the can-exp.s (right) display bimodal ENE/WSW orientation (with insignificant differences between W- and E-exp.s).

The most parsimonious explanation (or rather description) is that W- and E-exp.s – irrespective of baskets or cans – display reverse/standard orientation, respectively (though the difference is not quite significant at the 0.05 level, Chi square test, + Yates corr.).

Summa summarum

In general, in experiments carried out sunset/early night **sunset-taxes** are often prevalent compared with standard orientation. Furthermore, **gN is usually the compass in charge** (compared with mN), and in these short-term expositions for gN/mN conflicts there is no component of reverse orientation in reference to mN (as in the exp.s in the standard experiments in the long-term exposures on Endelave). Finally, there is **no general tendencies of sunset/early night compass calibrations**. Perhaps sometimes the sunset compass calibrates the magnetic compass, but there is no signs of calibration of the stellar compass by the magnetic compass.

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Date	Sunset	Basket	Funnel	"overcast"	Weather basket	Weather funnel	Arrival
24-aug	20.10		20.30 to 21.15	-		NE 4, 7/8 - 5/8	E 4, 23 Aug
25-aug	20.07		20.10 to 20.40	-		W 2-3, 0-1/8	W 5-6, 25 Aug
28-aug	20.00		20.20 to 21.00	-		WSW 10-12, (7)8/8	W 4-6, 25-26 Aug
29-aug	19.57	19.25 to 21.25	21.35 to 23.25	+	NE 3-4, 1/8	NE 1-2, 0-1/8	W 7-8, 27-28-29 Aug
30-aug	19.55		20.25 to 21.00	-		W 3-4, 0/8	No wind, 30 Aug
31-aug	19.52		20.20 to 21.00	-		ESE 5-7, 0-1/8	NW 1-2, 30-31 Aug
01-sep	19.51	18.30 to 20.30	20.40 to 21.40	+	SSE 6-8, 2-3/8	SE 10, 5-6/8 to 8/8	SSE 10-12, 1 Sep
02-sep	19.48	18.40 to 20.05	20.10 to 20.45	+	SW 3-4, 8/8 (thin)	SSW 5-6, 8/8 (thin)	SSE 10-12, 1 Sep
04-sep	19.43	18.15 to 20.40	20.50 to 22.50	+	S 5-6, 2-3/8 to 7/8	S 5-6, 7-8/8 to 8/8	WSW 5-7, 4 Sep
06-sep	19.38	18.10 to 20.10	20.20 to 21.20	+/-	SW 1-2, 7-8/8	SW 1-2, 7-8/8	S 3, 6 Sep
07-sep	19.35	18.00 to 20.20	20.25 to 21.35	+/-	SW 1-2, 3-7/8	SSE 1-2, 4-5/8	S 2-3, 6 Sep, 7 Sep
08-sep	19.33		21.55 to 23.25	-		W 2-3, 0-1/8	SW 2, 8 Sep, 7 Sep
09-sep	19.30		00.10 to 02.00	-		S 1, 0-1/8	W 7-8, 9 Sep, 8 Sep
11-sep	19.25		19.55 to 20.55	-		NE 8-14, 7/8 to 5/8	ENE 7-8, 11 Sep
12-sep	19.22		19.20 to 19.40	-		ENE 15, 7/8 to 4/8	ENE-E 15, 12 Sep
14-sep	19.17		19.18 to 19.40	+/-		NE 10, 2-3/8	NE 12, 13 Sep
15-sep	19.14		19.20 to 19.48	+/-		NE 10-12, 8/8 (thin)	NE-ENE 10, 15 Sep
16-sep	19.12		19.15 to 19.35	+/-		NE 5-7, 4/8 to 7-8/8	NNE-NE 10, 16 Sep
17-sep	19.09		19.20 to 19.44	+/-		NE 5-7, 3/8 to 7/8	NNE-NE 4, 15-17 Sep
18-sep	19.06		19.15 to 19.40	+/-		NE 3-5, 2/8 to 5/8	N 3-4, 18 Sep
19-sep	19.04		19.10 to 19.38	+/-		N 3-4, 7-8/8 (thin)	NNE 3-4, 19 Sep
20-sep	19.01		19.06 to 19.36	+/-		NW 2-3, 7-8/8 (thin)	NNW 3-4, 20 Sep
23-sep	18.53		19.55 to 22.00	+		NE 8-9, 6-7-5-8/8	NNE-NE 5-6, 21 Sep
24-sep	18.51	17.20 to 20.50	21.00 to 23.30	+	NE 9, 2-3-1/8	NE 6-7, 2-3/8	NE 5-7, 24 Sep
25-sep	18.48	18.00 to 20.50			NNE 3-4, 1-2/8		NE-ENE 5, 25 Sep
26-sep	18.45	16.45 to 20.50			WNW 5-6, 5-7/8		NE-ENE 5, 25 Sep
27-sep	18.43		19.00 to 19.35	+		W 10, 4-6/8	NE-ENE 5, 25 Sep
28-sep	18.40		19.00 to 19.30	+		W 6-7, 3-4/8	W 10, 28 Sep

Table 1: The procedure and weather on the single nights or evenings. The same individuals were tested on 1 and 2 Sep., and following two evening exposures (25 and 26 Sep.) within baskets or cans and in a magnetic fields deflected towards mW or mE the birds were tested in the natural magnetic field in the third evening (27 Sep.).

The meaning of the columns is:

Sunset is time of local sunset.

Basket means period of exposure during sunset/early night in the baskets (or cans) at the test site of the Queen`s Bastion.

Funnel means test period on the funnels at the Queen`s Bastion.

"Overcast" shows whether the funnels were covered with translucent but not transparent plastic during the test in the funnels (+ for covering, **-** for no plastic only net-covering).

Weather Basket informs about the weather (wind direction and strength (m/sec), and cloud cover) during the evening exposure in the baskets (cans).

Weather Funnel as above but during the test in the funnels during evening or night.

Arrival informs about the arrival weather around sunrise, and arrival/trapping date of the test birds (if two dates are mentioned the first delivered most birds).

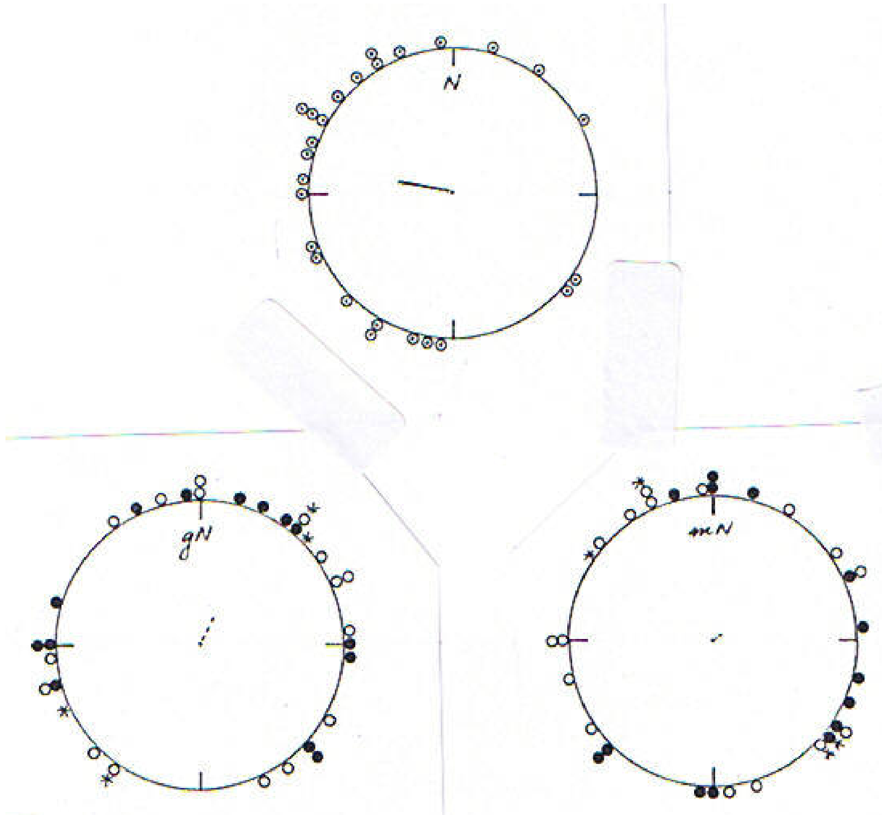

Fig.1: Sunset/early night orientation of four samples of Africa-migrants 24, 25, 30, and 31 August. The birds were placed in the funnels without previous exposure in the baskets for the sunset sky and tested under a clear sky (Table 1) without covering of opaque plastic sheets (-"overcast").

The upper figure shows the orientation of the **controls** (tested in the undisturbed magnetic field of the Earth). The sample mean vector is 282° - 0.398* (n = 26).

The two lower figures show the orientation of the **exp.s** tested in a deflected magnetic field (mN = gE (white dots) or gW (black dots)). The figure to the left depicts the orientation in reference to **gN** (27° - 0.217, n = 30), and the figure to the right in reference to **mN**: 58° - 0.074, n = 30. In fact, the description is a little better if doubling the angles: 147°/327° - 0.143, n = 32. Concerning the reference gN: There is no significant difference between W-exp.s (13° - 0.282, n = 14) and E-exp.s (46° - 0.178, n = 16). Concerning mN: The two mean directions are about the opposite, but both concentrations are very low. W-exp.s: 103° - 0.282, and E-exps. 316° - 0.178. gN and mN mean geographical N and magnetic N, respectively.

In this and most of the following figures all mean directions based on at least small activities are denoted as a large dotted dot (controls), or a large white dot (E-exp.s), or a large black dot (W-exp.s). For directions based on very small activities small dots were used. The crosses signal a bimodal activity pattern where the two peaks are about the same size.

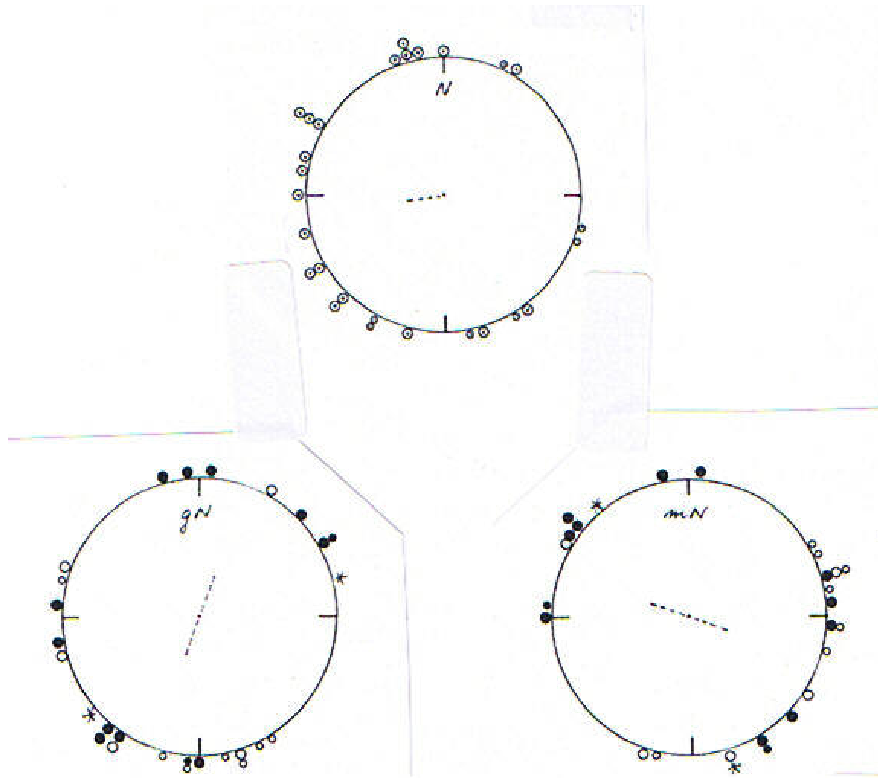

Fig.2: Sunset/early night orientation of four sample of Africa-migrants 1, 2, 4, and 6 September. The birds were placed in the funnels after previous exposure in the baskets under the sunset sky and tested under covering of opaque plastic sheets (**+"overcast"**). The controls were exposed and tested in the undisturbed magnetic field of the Earth, whereas the exp.s were exposed and tested within coil-fields were mN was deflected towards gW (W-exp.s) or gE (E-exp.s), respectively.

The upper figure shows the orientation of the **controls** (262° - 0.285, n = 27).

The two lower figures show the orientation of the **exp.s**. In reference to **gN** the sample mean vector is 210° - 0.277 (n = 25). However, the distribution is better described following doubling the angles: **200°**/20° - 0.305 (n = 26). In reference to **mN** the distribution is best described as **110°**/290° - 0.305 (n = 26).

There seems to be some difference (in reference to gN) between **W-exp.s** (36°/216° - 0.469*, n = 14) and **E-exp.s** (195° - 0.540*, n = 12). In reference to mN the concentrations are the same and the directions 126°/306° and 105°, respectively.

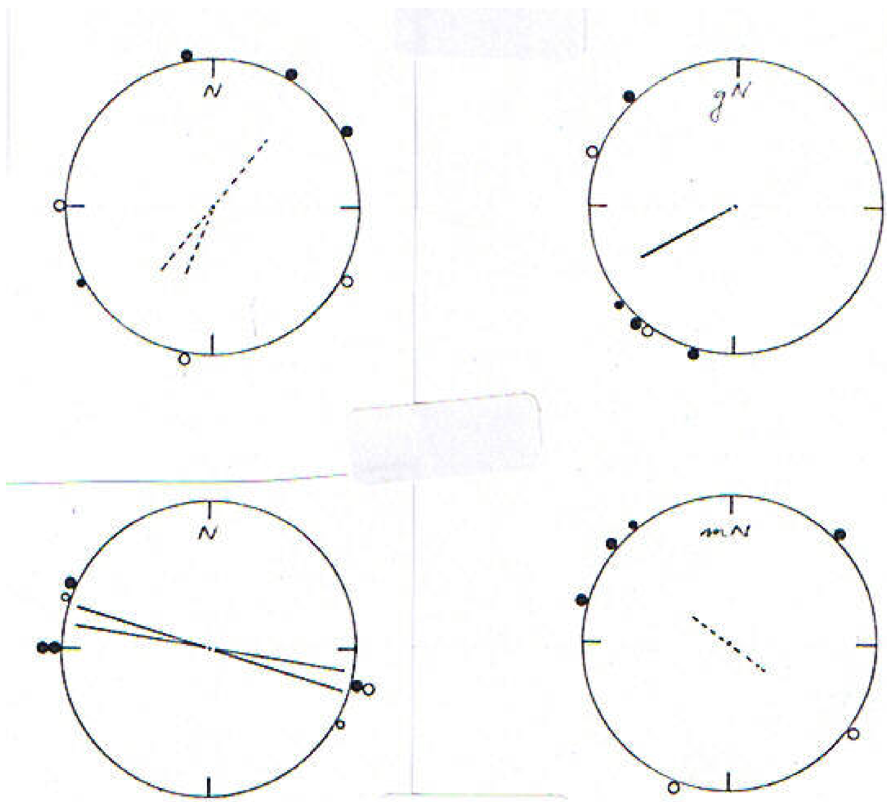

Fig.3: Sunset/early night orientation (Pied Flycatcher) 7 September. **Cross-experiment**, i.e.: The **exp.s** are first exposed for the deflected mN during sunset in the baskets and then tested in the funnels during sunset/early night in the undisturbed magnetic field of the Earth. The **controls** are treated the other way around.

The left column shows the **exp.s** tested in **–"overcast"** (upper figure), and in **+"overcast"** (lower figure). The black dots refer to W-exp.s (**39°**/219° - 0.576, n = 4) and the white dots to E-exp.s (192° - 0.505, n = 3).

The right column shows the **controls** tested in +"overcast" in the deflected magnetic fields. The orientation in reference to **gN** is 241° - 0.740* (n = 6), whereas the orientation in reference to **mN** is **305°**/125° - 0.314 (n = 6).

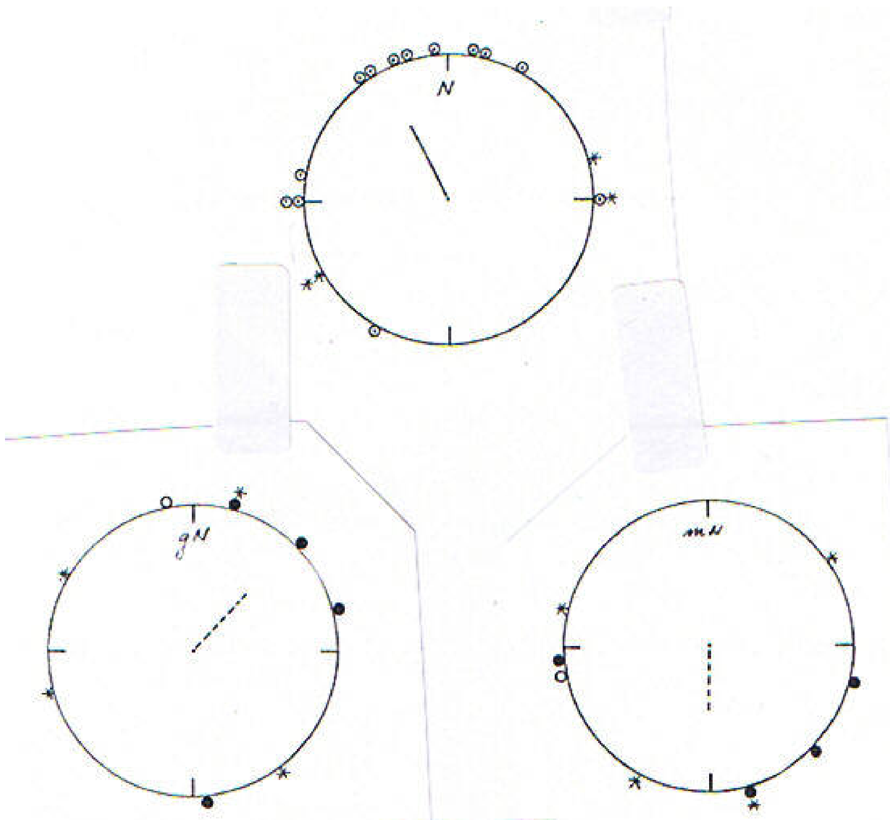

Fig.4: Sunset/early night orientation (Robin) 11 and 12 September. The birds were tested in **– "overcast"** without previous exposure in the funnels to the sunset/early night sky.

The upper figure shows the orientation of the **controls** (334° - 0.576*, n = 13).

The lower figures show the orientation on 12 September in reference to **gN** (44° - 0.533, n = 5), and in reference to **mN** (181° - 0.439, n = 5).

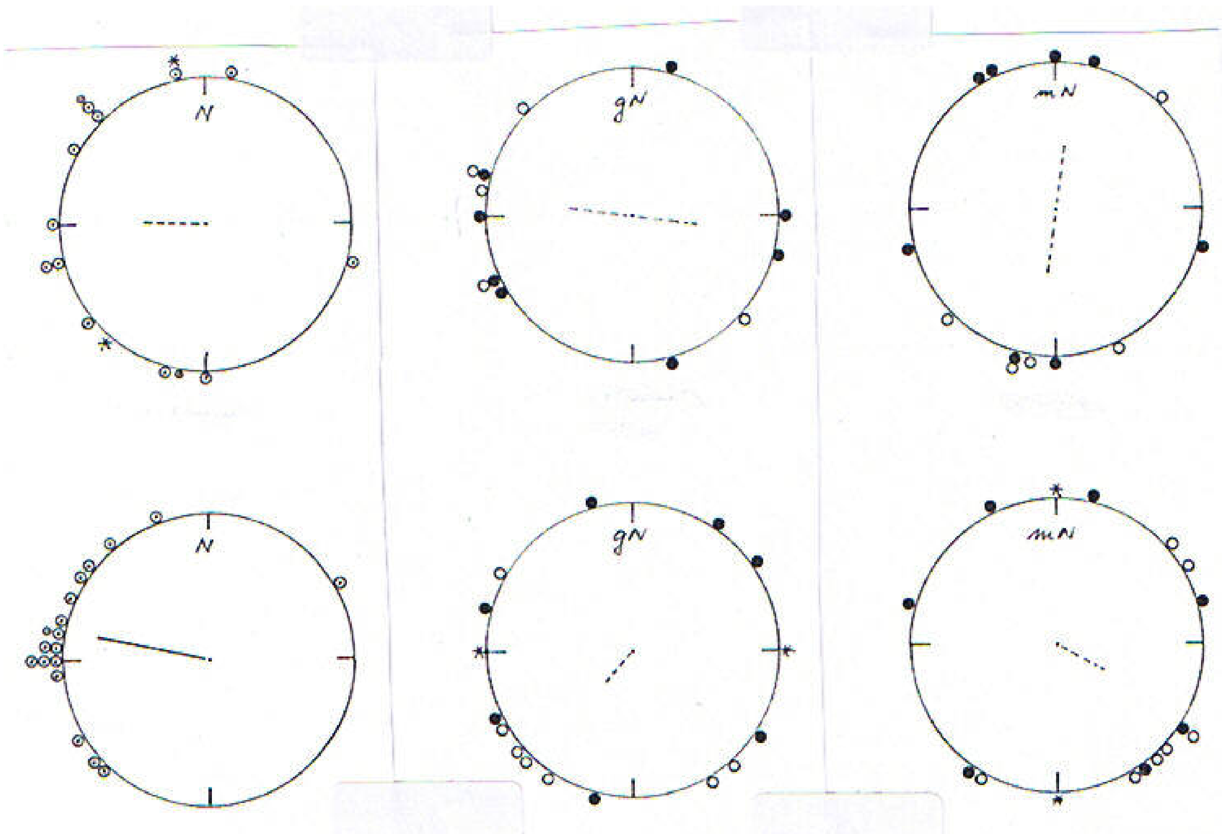

Fig.5A: Sunset/early night orientation in **+”overcast”** (upper row) and **–“overcast”** (lower row) without previous exposure to the sunset sky, 14, 16, 17, and 18 September (clear sunset sky). The birds on 14 and 17 was Africa-migrants, the rest were Robins.

The sample mean vector of the **controls** (left column) in **+”overcast”** is 272° - 0.440 (n = 14), and in **–“overcast”** 281° - 0.785*** (n = 18).

The orientation of the **exp.s** (central column) in reference to **gN** in **+”overcast”** (upper figure) is **277°**/97° - 0.444 (n = 13), and in **–“overcast”** (lower figure) 222° - 0.301 (n = 14). In reference to **mN** (right column) the sample orientation in **+”overcast”** (upper figure) is 7°/187° - 0.444 (n = 13), and in **–“overcast”** (lower figure) 119° - 0.364 (n = 14).

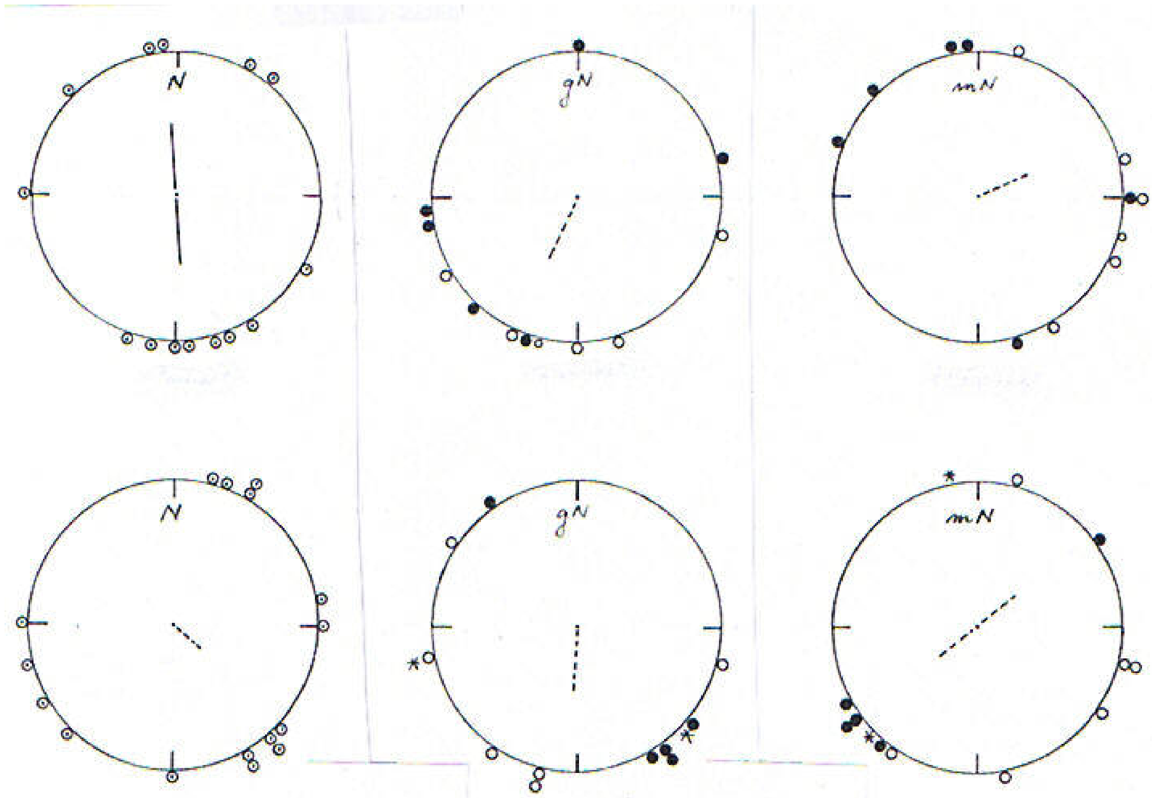

Fig.5B: Same as Fig.5B but now 15, 19, and 20 September (overcast sunset sky). All the birds were Robins.

The orientation of the **controls** (left column) in reference to **gN** in **+"overcast"** (upper figure) is **173°**/353° - 0.510 (n = 14), and in **–"overcast"** (lower figure) 131° - 0.251 (n = 16).

The orientation of the **exp.s** (central column) in reference to **gN** in **+"overcast"** (upper figure) is 204° - 0.480 (n = 12), and in **–"overcast"** (lower figure) 181° - 0.449 (n = 11). In reference to **mN** (right column) the sample orientation in **+"overcast"** (upper figure) is 66° - 0.360 (n = 12), and in **–"overcast"** (lower figure) 231°/51° - 0.353 (n = 12).

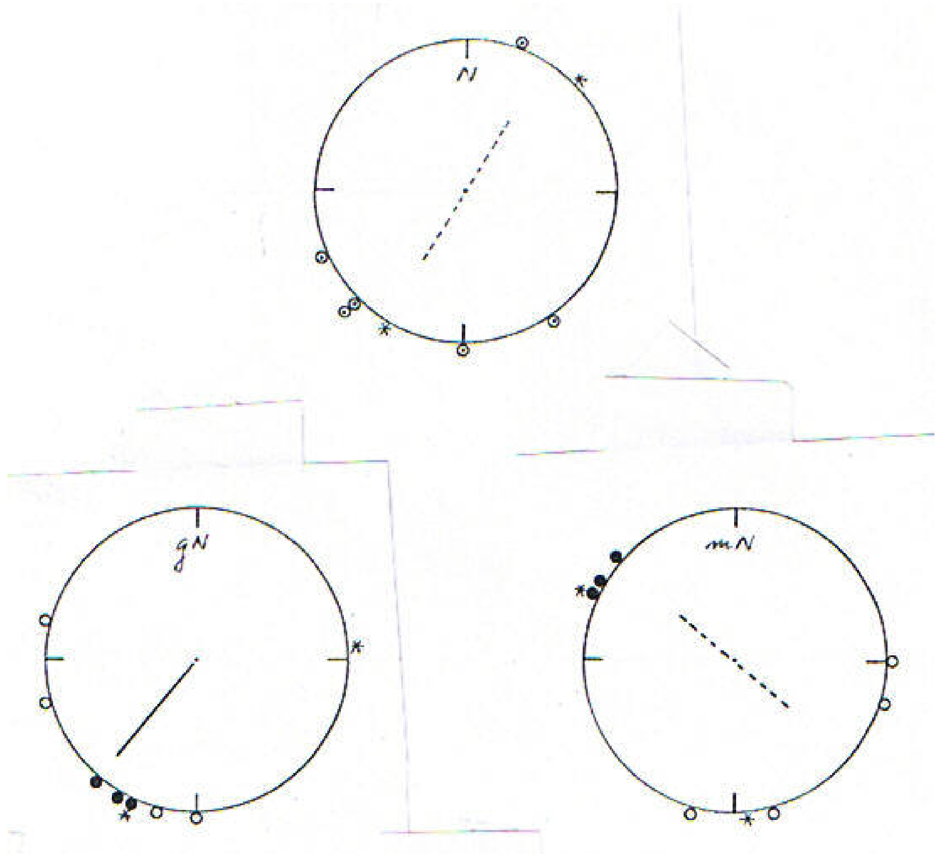

Fig.6:Sunset/early night experiments 23 September with Robins trapped two days before and caged under conditions with no possibility for coupling/calibration between the compasses. There was no previous exposure to the sunset sky and the test condition was **+"overcast"**.

The orientation of the **controls** (upper figure) was 207° - 0.510 (n = 6), or after doubling the angles **212°**/32° - 0.544 (n = 7).

The orientation of the **exp.s** in reference to **gN** (lower, left figure) was 220° - 0.834** (n = 7), whereas the orientation in reference to **mN** (lower, right) was bimodal 125°/305° - 0.476 (n = 8).

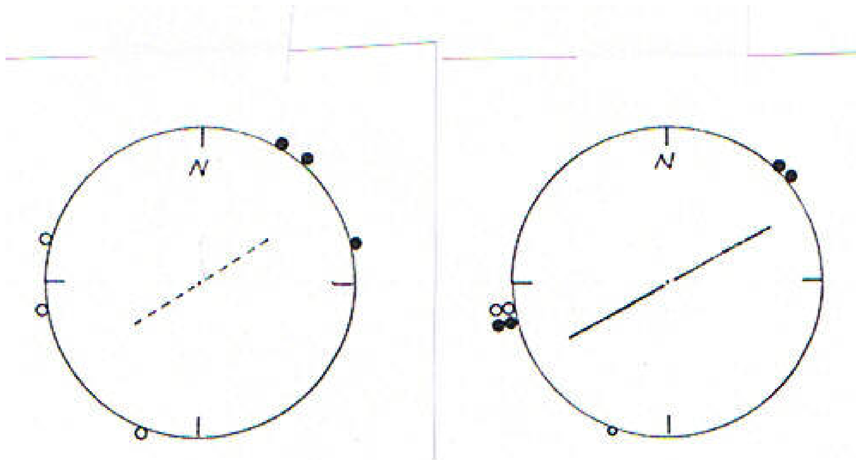

Fig.7: Sunset/early night experiments 27 September (Robins). The birds were tested in the funnels under condition of **+"overcast"** in the undisturbed magnetic field of the Earth following previous exposure in the deflected magnetic fields under the sunset sky in **baskets** (left figure) or **cans** (right figure).

The orientation of the basket-birds is bimodal 57°/237° - 0.515 (n = 6), and of the can-birds **242°**/62° - 0.752* (n = 7).

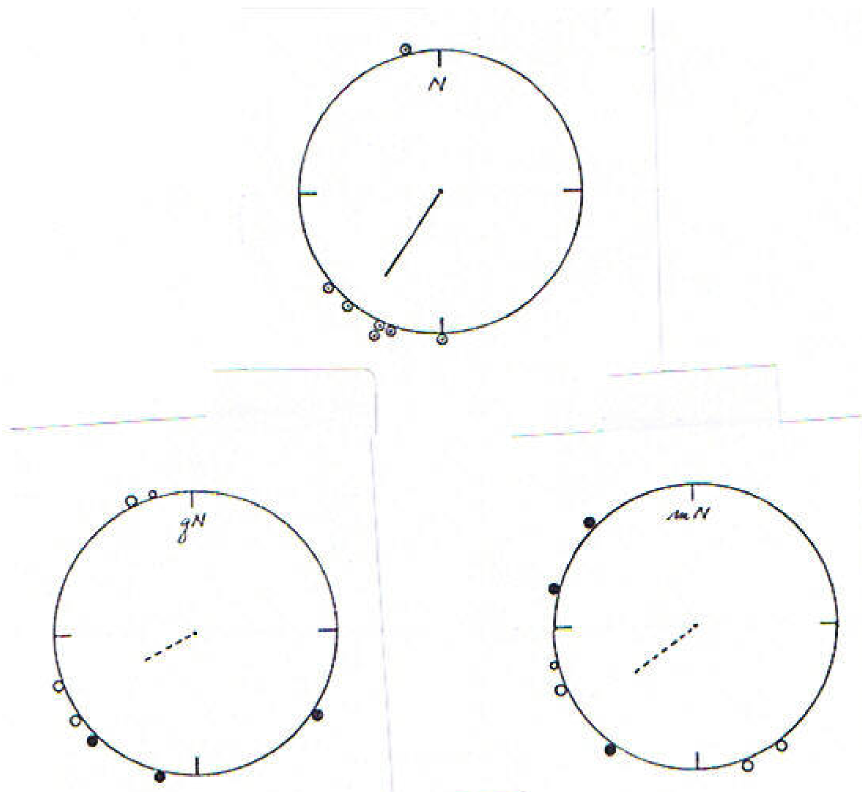

Fig.8: Experiments on 28 September. The birds (Robins) were caged for two days without possibilities for coupling/calibrations between the compasses. There was no previous exposure for the sunset sky.

The **controls** (upper figure) were tested during the starry night under condition of **–"overcast"**. The sample mean vector was 214° - 0.725* (n = 7).

The **exp.s** (lower figures) were tested sunset/early night under condition of **+"overcast"**. The orientation in reference to **gN** (left) was 244° - 0.413 (n = 7), and in reference to **mN** 234° - 0.563 (n = 7).

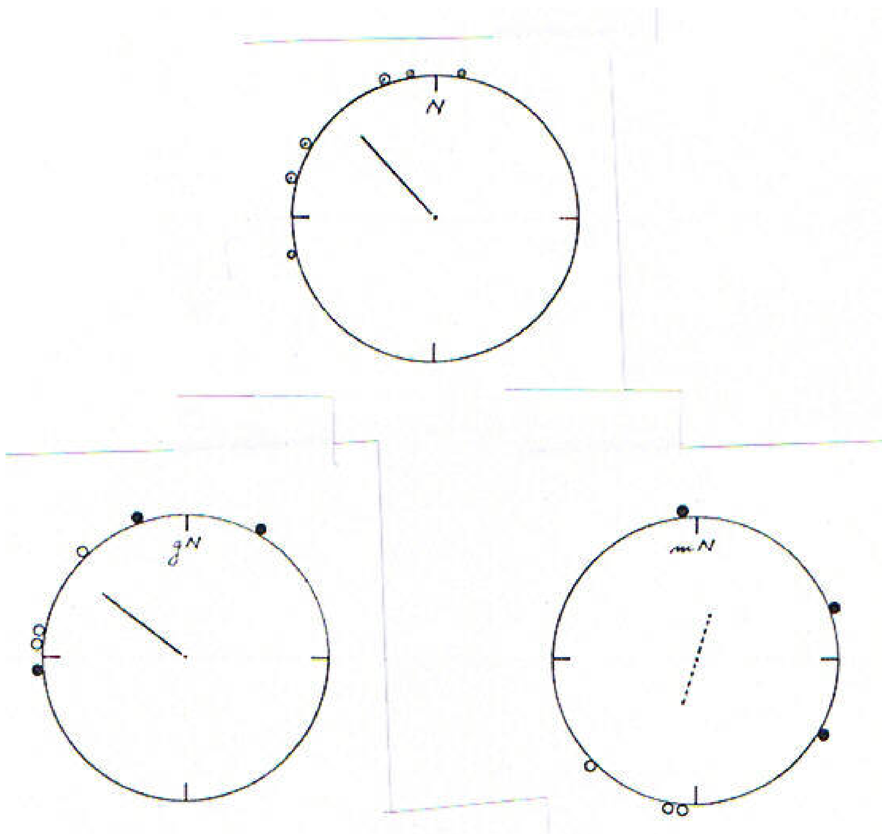

Fig.N1: Early night experiment on 29 August (Garden Warbler). The birds were tested in **+”overcast”** after previous exposure in the baskets under the sunset sky.

The **controls** (upper figure) was oriented 317° - 0.772* (n = 6).

The **exp.s** (lower figures) were oriented 307° **-** 0.739* (n = 6) in reference to **gN** (left) or 17°/197° - 0.331 (n = 6) in reference to **mN** (right).

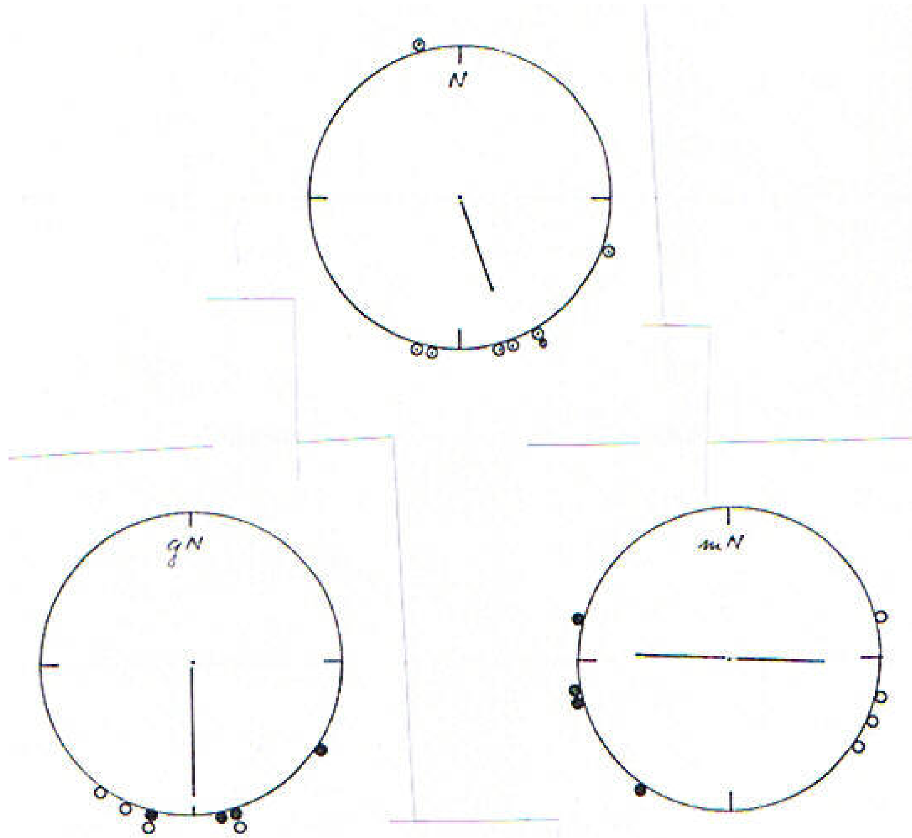

Fig.N2A: Night experiments without previous exposure for the sunset sky under a clear starry sky (**-“overcast”**) with Africa-migrants (mostly Pied Flycatcher) on 8 September.

The orientation of the **controls** (upper figure) was 160° - 0.662* (n = 8).

The orientation of the **exp.s** (lower figures) were 180° - 0.893** (n = 8) in reference to **gN** (left) or 92°/272° - 0.633* (n = 8) in reference to **mN** (right).

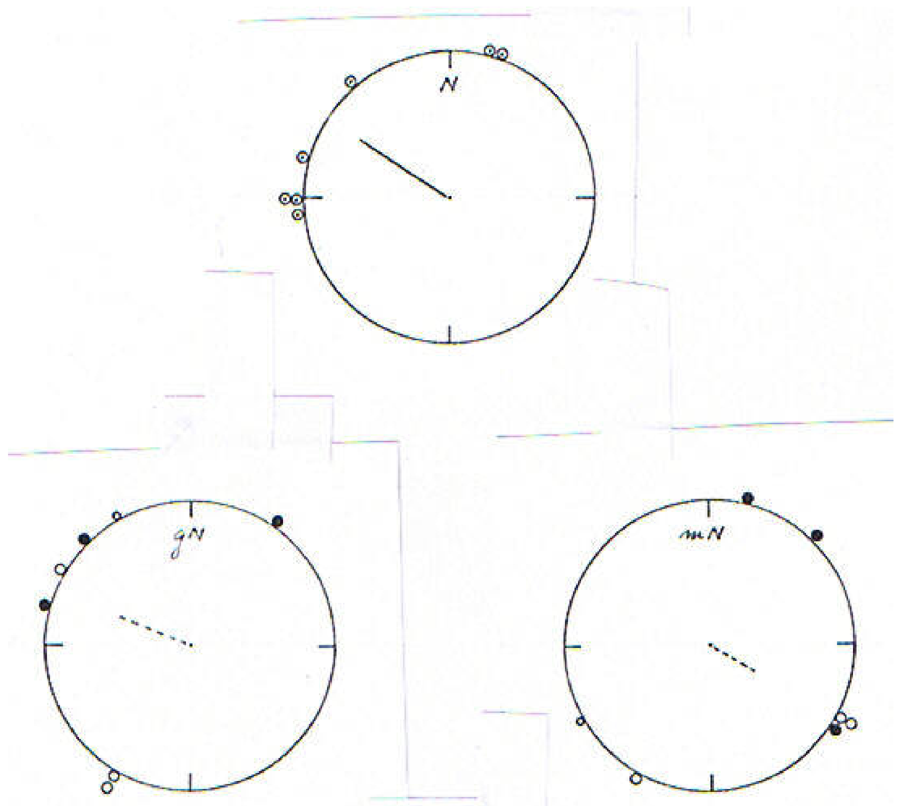

Fig.N2B:Night experiments as on Fig.N2A on 9 September (the two samples on 8 and 9 September were not pooled because of the obvious heterogeneity between the samples).

The orientation of the **controls** (upper figure) was 303° - 0.738* (n = 7).

The orientation of the **exp.s** (lower figures) was 292° - 0.534 (n = 7) in reference to **gN** (left), or 120° - 0.357 (n = 7) in reference to **mN** (right).

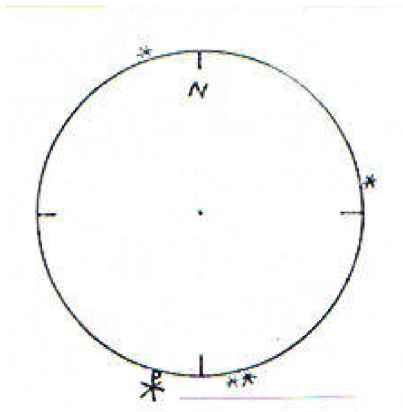

Fig.N3: Night experiments with Robins on 24 September in the undisturbed magnetic field of the Earth. The birds were tested in the funnels under condition of **+"overcast"** after previous exposure under the sunset sky in the deflected magnetic fields in **baskets** or **cans** (cf. Fig.7).

Very few birds displayed any significant activity. The few orientations – in the original notation – are denoted on the figure.