Effect of Limited Stirring on the Belousov Zhabotinsky reaction

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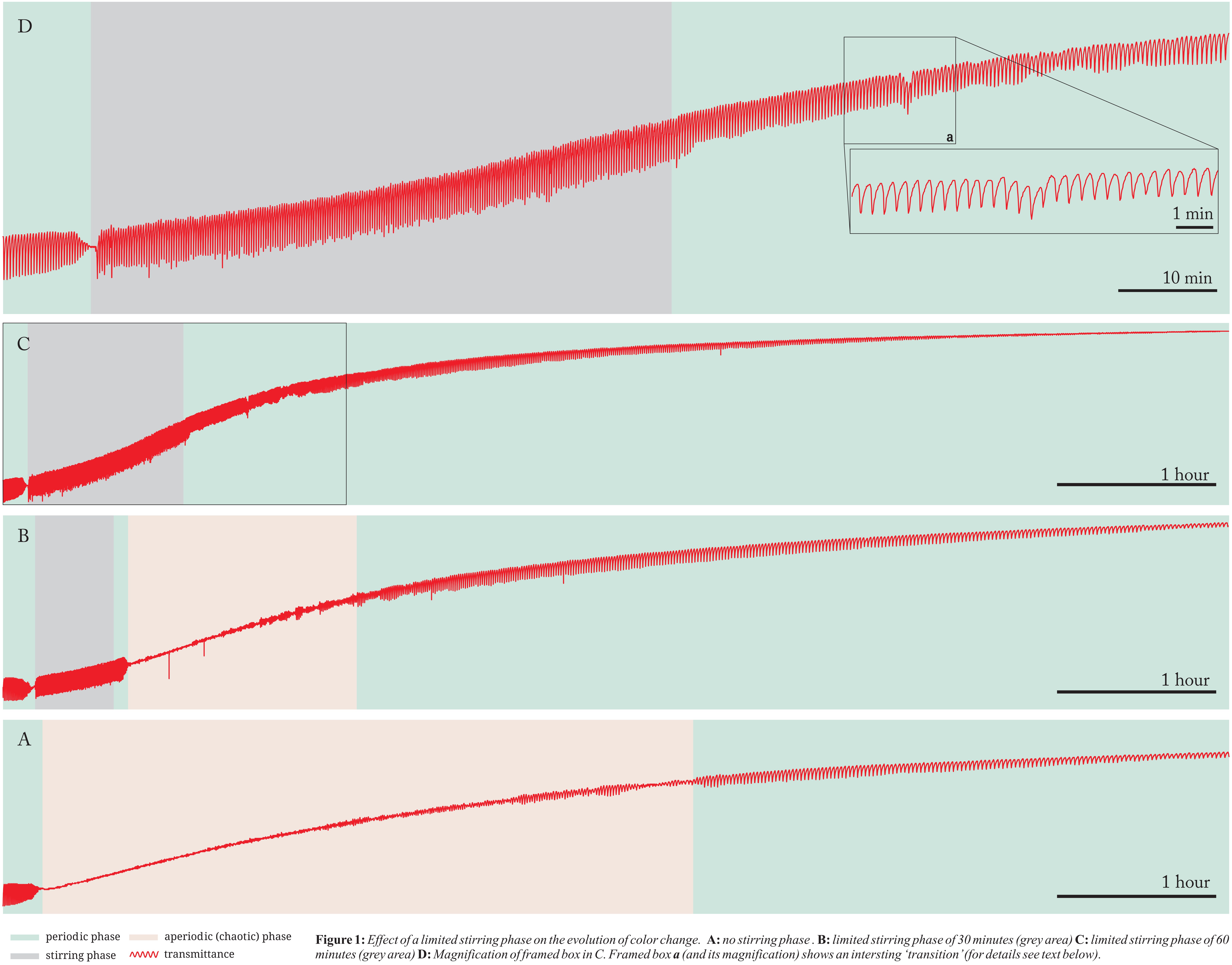

Figure 1: *Effect of a limited stirring phase on the evolution of color change.* **A:** *no stirring phase .* **B:** *limited stirring phase of 30 minutes (grey area)* **C:** *limited stirring phase of 60 minutes (grey area)* **D:** *Magnification of framed box in C. Framed box* ***a*** *(and its magnification) shows an intersting 'transition' (for details see text below).*

Abstract. ***The Belousov Zhabotinsky reaction (BZ reaction) serves a number of researchers as an example of a complex system that exhibits various types of behaviors ranging from periodic to chaotic. Our interest in the system arose from its high similarity to biological processes. In this work we report our investigation about the effect of a limited stirring phase on the behavior of the BZ reaction.***

Key words: Belousov Zhabotinsky reaction, stirring effect, rotational flow.

According to our knowledge until now the effect of a limited stirring phase has never been investigated systematically although we found a group of researchers who did experiments where they stirred the system for a limited time (Rustici et al. [1], Rossi et al. [2])

Experimental facts

In our experiments the effect of stirring on the BZ reaction has other effects too apart from the pure homogenization of the system:

- If the BZ reaction is stirred with a 'high' rate, the color oscillations stops immediatly, but when the stirring is stopped, the oscillations restart.
- If the BZ reaction is stirred with a 'low' rate, the color oscillations sustains and moreover the time period of the oscillations becomes regular (see fig. 1 grey areas)

Effect of a limited stirring phase

The effect of a limited stirring phase was investigated under different conditions (changing dimension and volume of the beaker, different stirring rates and times). In general we can distinguish three scenarios:

1) If the BZ reaction is not stirred it evolves from a periodic (PI) over an aperiodic (CH) to an again periodic behavior (PII) (shown in fig.1. A) (such a behavior is also reported by Rustici et al. [1])

2) If the BZ reaction is stirred for (at least) 30 minutes right after the first periodic phase (PI) the behavior changes. During stirring the oscillations become regular and after stopping they continue for some while. Then a chaotic phase (CH) as in case (1) starts which again after some time changes into a second periodic phase (PII) (shown in fig.1.B)

3) If the BZ reaction is stirred for (at least) 60 minutes right after the first periodic phase (PI) the behavior changes again. During stirring the oscillations become regular and after stopping they remain regular and the periodic behavior continues. I.e. the chaotic phase disappears.

Materials and methods

For the preparation of the Belousov Zhabotinsky reaction we used sodium bromate (8 ml of a 0.1 M solution), malonic acid (10 ml of a 0.375 M solution), sulfuric acid (10 ml of a 3.06 M solution), sodium bromide (4 ml of a 0.18 M solution) and ferroin (0.6 ml from the redox indicator, Reag. Ph. Eur., E0 in sulfuric acid 1 mol/l = +1,06 volt (Fluka) from Sigma Aldrich). For measuring the color change we used a LED/LDR combination as photometric unit, which was connected to the multimeter VC820 with USB that enabled us to record the color oscillations with the computer.

Discussion

We show here that a limited stirring phase changes the general behavior of the time evolution of the BZ reaction.
It seems that as long as the stirring rate is not too 'high' the stirring time is more important for this change. Moreover there seems to exist a threshold value in stirring time (more than 30 min and less or equal to 60 min) for which the chaotic (inter)phase disappears. If the stirring time is only 30 minutes the chaotic phase is still present, but compared to the non-stirred case it is shorter (approx. 35%); if the stirring phase is 60 min the phase is not present anymore. In that sense the stirring time plays the role of a 'bifurcation parameter' (see difference between fig.1. B and C).
In all experiments where we stirred the system for 60 min and more there appears an interesting 'transition' where the mean transmittance decreases for a couple of oscillations and then comes back again (see fig.1.D a).

So far we do not yet have a quantitative model describing such a complex behavior. However we have developed a first qualitative model, which was presented at the European Conference on Complex Systems 2011 [3] and is still one of our key topic of investigation.

Acknowledgments

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Literature

[1] M. Rustici, M. Branca, C. Caravati, N. Marchettini: *Evidence of a chaotic transient in a closed unstirred cerium catalyzed Belousov -Zhabotinsky system*; Chemical Physics Letters 1996, **263,** 429-434

[2] F. Rossi, M. A. Budroni, N. Marchettini, L. Cutietta, M Rustici, M. L. Turco Liveri: *Chaotic dynamics in an unstirred ferroin catalyzed Belousov-Zhabotinsky reaction*; Chemical Physics Letters 2009, **480,** 322-326

[3] S. Thurner and M. Szell (Eds.) Book of Abstracts ECCS'11 Vienna: *F. Wodlei, M. R. Hristea: Stirring effect on the Belousov Zhabotinsky reaction;* http://www.ilsr.at/eccs11_stirring_effect.pdf