Line-defec^l a en of n able l'ir al a e in cardiac i e

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Spiral wave propagation in period-2 excitable media is accompanied by line defects, the locus of points with \mathcal{A} period-1 oscillations. Here we investigate spiral line defects in cardiac tissue where ± 2 behavior has a known arrhythmogenic role. We find that the number of line defects, which is constrained to be an odd integer,

 $\mathrm{F}_{4}, \mathrm{1.8}$ $\mathrm{F}_{4}, \mathrm{1.8}$ $\mathrm{F}_{4}, \mathrm{1.8}$ the latter were chosen for intermediate action potential potential potential potential potential potential duration restitution slopes, which suffice to produce $\frac{1}{2}$ stable spiral waves with line defects in each geometry, but are not steep enough to cause wave breakup in this domain \mathcal{A} \mathcal{L}

We use a half plane wave as the initial condition to tiate a spiral wave obtained by first triggering a function $H_{\mathcal{F}}$ of $H_{\mathcal{F}}$, $H_{\$ wave and resetting part of the circular domain to the circular domain to the resting \mathcal{I} state

tions. The latter constraints the number of line defects to be number of line defects to be \mathcal{S} and integer and results from the change in beat number in beat \mathcal{A} across any closed circuit enclosed circuit enclosed the spiral tip for spiral tip for steadystate alternans. It follows directly from the definition of *a* E , 2 and the requirement that the voltage behaviour that the voltage behaviour that the voltage behaviour that the voltage E every where in space. In addition, $\qquad \qquad ,\quad \equiv \quad f', \quad \ldots \in \ f',$ slope of the action potential duration restitution curve defined by $D^{n+1}=fT \ D^n$, controls the onset of alternative of alternativ $D^{-1/2}$, where *D* is the action potential due to the action potential due to the action potential due to the action potential due ration at the period-doubling bifurcation $= 0$, measures $= 0$, m the scale over which the voltage dynamics is diffusively dynamics is diffusively dynamics is diffusively dynamics in \mathcal{A} coupled on the time scale of one beat. Δ stability problem is easily solved by the stability problem is easily solved by the solved by the stability μ $ar, t \quad e^t \quad r$, E, [3](#page-1-2) into a Helmholtz equation for r , $\mathcal{S}^{\mathcal{X}}$ is a then bench benc solved by separation of variables with the substitution

r, $R r$. $\sum_{i=1}^{N} a_i$ is found to be angular part is found to be a set of $\sum_{i=1}^{N} a_i$ is found to be a set of $\sum_{i=1}^{N} a_i$ is found to be a set of $\sum_{i=1}^{N} a_i$ is found to be a set of $\sum_{i=1}^{N} a_i$ is found t

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wave from the front curvature effects of the approximation of the approxim proximately described by the absolute in a propagating pulse one-dimensional *L*=2 r_i [20](#page-3-0)[,25](#page-3-1) \cdot ¹ this hypothesis, we computed the quasiperiodic frequency $\mathcal{L}_\mathbf{r}$ of the local medium dynamics induced by line-defect rotation for anchored spirals for the model of R . The model of R frequency was obtained by fitting the time series of tim $a \cdot \int JT /a \cdot 0$ and $f(x) = \int f(x) dx$ is $f(x) = \int f(x) dx$ in $f(x) = f(x)$, and the fitting parameters. For the theory, we use the theory, we used the theo dispersion relation T of T and \tilde{q} are giving the quasiperiodic frequency modulation alternation alternation a $e^{i \int T}$, in a one-dimensional ring de-rived in Ref. [20](#page-3-0) ,

 e^{iT} 1 $i/2$ $k = 1$ iwk $2k^2 f'$ $I + i/2$ k , 4 where $\frac{1}{L}$ $\frac{1$ single line defect and $=c' I / 2c^2$. The APD and C titution curves $fI = cI$ and $fI = cI$ dimensional cable as in Ref. [20](#page-3-0) . In addition, the intercellular coupling parameters and were estimated as 2 $/c$ *D* ^{1/2} [20](#page-3-0) . The comparison in F_i, [5](#page-3-3) shows that the ring-based theory predicts reasonably well theory predicts reasonably well theory predicts reasonably well the ringfrequency of line-defect rotation for anchored spiral waves of different period $T,$ which was varied here by increasing the by increasing the τ obstacle radius r_i in the simulations. Δ opposite limit that can also be readily understood is also be readily understood is a second is also be readily understood is

the one where σ is the spiral rotation period at the spiral rotation period σ exhibit line defects that move toward the pacing site, $T_{\rm eff}$ pacing site, which site generally occurs for steeper CV restitution. In this case, linedefect motion is expected to be dominated by the far-field σ spiral dynamics [20](#page-3-0) . We have checked that, for the twovariable model of ~ 20 ~ 20 , spiral line defects independent of in with a frequency equal to the product of the product of the velocity of th of the planar line defects and the inverse of the invers This property was purposely checked in a domain much larger than the spiral wavelength r_e = 18 cm and with an

 $r_i = 0.72$ cm sufficient to prevent spiral wave spira breakup inherent in this model. However, we expect this behavior to be generic for systems with traveling planets with the system \mathcal{A} defects and to also apply to freely rotating spirals with the spirals with three spirals with the spirals with three spirals with the sp line defects for parameters where breakup does not occur. In summary, we have surveyed spiral line-defect patterns of the surveyed spiral line-defect patterns of the surveyed patterns of the surveyed spiral line-defect patterns of the surveyed spiral line-defect patterns of the in simplified models of cardiac excitation with period-2 dynamics. Although far from exhaustive, this survey yields the survey yields the survey \mathcal{A} striking finding finding that freely propagating and and and and anchored spiral waves select different numbers of line defects. \mathcal{N}_{max} up to \mathcal{N}_{max} the possibility to distinguish free and and anchored spiral waves $I_{\rm T}$ and and anchored spiral waves $I_{\rm T}$ in cardiac tissue by monitoring the number of line defects. $\mathbf{w}^{(k)}$ have shown that spiral wave unstable modes with different modes with different modes with different $\mathbf{w}^{(k)}$ ϵ is a line defect of line defects correspond to topologically topologically $T_{\rm eff}$ $q = \frac{1}{\sqrt{2}}$ where $\frac{1}{2}$ oscillation on the period-2 oscillation amplitude in the spiral core, which is fundamentally different in the spiral core, which is fundamentally different in $\frac{1}{\sqrt{2}}$ for free and anchored spirals, selects the number of line defor $f_{\rm eff}$ for each form of the found that line-defect in rotation can be driven either by the core or by far-field wave

front dynamics, with concomitantly different frequencies. on canceae 62.1 (seu obel) 6-467.9(22.1) 311.6 (see 31 h \sim 31 $\%$ \sim F2dV \sim

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