Epidemiology Interacting Many-Body Models

Fredrick Michael
Agathos Scientific

July 24, 2013

Abstract

Epidemics occur due to many complex reasons. When physical harm and or damage is brought upon humans by an outside biological agency, such epidemics can usually be traced to a harmful organism directly responsible such as an environment borne virus or an organism transmitted by a host that may or may not be itself harmed by the pathogen . We seek in this letter to derive theoretical models robust to the point of inclusion of any observable deemed relevant from psychological to social demographical to spatial and temporal to discrete and or continuous in interactions to describe statistically and dynamically interactions that lead to or are characteristic of an epidemic, deriving models of interacting many-body systems that are spatial and temporal and that are detailed models of the statistics of the species species interactionsthat are inherent to an epidemic and furthermore to characterize the outbreak of an epidemic as a resulting critical state of interacting many-body systems that includes the spatial and temporal details sought for.

1 introduction

Epidemics occur due to many complex reasons however when looked at as harm brought upon humans by an outside agency a cause can be traced to a harmful organism directly responsible as an environment borne virus or an organism transmitted by a host that may or may not be itself harmed by the pathogen. A pathogen that is a programmed or adapted killer or damage cause and harmful to humans...or an organism that victimizes humans behaves in a manner that to subjective human observation resembles a predator preying upon its victims . This analogy pushed too far breaks down as a virus is not a prey animal it is merely a biomolecular machine with a certain set of instructions coded into its DNA or RNA for replication the replication process casuing subverting of its victim's bio

molecular materials itself necessary for the victims' continued health and or continued life. However the logistics of species-species virus -human can be described by certain coupled sets of equations evolving in time and space with these model equations a type of predator-prey model such as was initially described by Lotka-Volterra, with generalizations and abstractions describing generally numerical logistics between two or more competing variables of two or more meta stable states.

These models are of great interest, in as far as the epidemic preventative process by a society, as mathematical descriptions helping to optimize qualitative approaches to preventative care and measures, requiring knowledge of rates of occurrences and the dynamics of occurrences...that is with such data the statistical dynamical mathematics of such predator-prey phenomenon can be written down and forecasts and predictions for best approaches to management(logistics) prevention(epidemics outbreaks) care(preventative vaccines and so forth) and cures(resource deployment of medicines and medical and other professional practitioners) an be applied. Not merely applying to gazelles being preyed upon by cheetahs, or infected mosquito females transmitting malaria to human tropics populations or similar identifiable two or more species 'competitive' interactions, but applying even to predator-prey modeling of human inter species interactions, such as between serial murderers and their potential victims...applying to criminal predation upon society in fact and with hopefully such predator-prey models aiding in their prevention in the field known as criminal 'profiling'. Such state of the art in use by law enforcement agencies say are of statistics and models that utilize data of demographics with limited details of possibly relevant data such as social psychology factors as an observable input into the mathematical models. Other limitations of current models beyond human interactions are a lack of spatial and temporal robust interacting many-body models. That is to say that though many models of numerical logistics of 'competition' exist in the literature, such as the Lotka-Volterra predator-prey model, they are all limited by the fact that they are numerical logistic equations that do not admit the inclusion of detailed observables and or information such as psychological factors, social demographics, or spatio-temporal variables and simultaneously.

Therefore we seek in this letter to derive such a theoretical model, robust to the point of inclusion of any observable deemed relevant from psychological to social demographical to spatial and temporal to discrete and or continuous in interactions, deriving models of interacting many-body systems that are spatial and temporal and such that social institutions of pooled resources for safety such as ideally a police force is may better optimize their capability and it is to be hoped better serve the public good by prevention of predation upon and victimization of the innocent, and in health areas of concern providing detailed models of outbreaks of epidemics as resulting critical states of interacting many-body systems that include the spatial and temporal details sought for .

2 derivation

A predator prey model is simply a coupled set of logistical equations one for the predator and one for the prey...thus the two species oscillate in numbers which are measured, for example as the number of gazelles increases the number of cheetahs increases also until the numbers of gazelles begin to decline resulting in a decline in cheetahs and so on. The equations are written as

$$dn_+ = n_+(1 + K_+ n_-)dt + \sqrt{b_+} dW(t) \tag{1}$$

$$dn_- = n_-(1 + K_+ n_+)dt + \sqrt{b_-} dW(t) \tag{2}$$

with the stochastic trajectories of the process equivalently described by Fokker-Planck PDE partial differential equations

$$\nabla_t P(n_-, n_+, t) = \vec{\nabla}[\vec{a}_{+,-}(n_-, n_+, t)\, P(n_-, n_+, t)] + \frac{1}{2}\vec{\nabla}^2(b_{-,+} P(n_-, n_+, t) \tag{3}$$

where here the 'forces' or the deterministic parts are the drift coefficients $a_+ = n_+(1 + K_+ n_-), a_-(1 + K_+ n_+)$ which contain the nonlinear coupling between the two SDE stochastic differential equations , and which Fokker-Planck PDE has solutions for short time transition probabilities as discussed in H. Risken's book "The Fokker-Planck Equation" [**?**]. This form of coupled equations is a typical Lotka-Volterra type of number logistics model.

Also it should be noted that for certain drift diffusion coefficients combinations, exact long time solutions exist that are made possible by Ito formula change of variables (at the stochastic level) of SDE stochastic differential equations, these equivalent to change of variables and transformations to solvable forms of $P(n_-, n_+, t)dn_- dn_+ = p(z, t)dz$, these changes of variables such that the resulting model is of a 'single' variable $z = z(n_-, n_+, t)$ with other changes of variables and transformations possible as we will report in this letter. Another note is that the diffusion coefficient b_+, b_- from the 'noise' terms in the SDEs are generalized by several authors, however aside from a more 'realistic' random environment modeling it does not cause a difficulty overmuch in the several solution methods. A final note is that it is well known that one is free to choose the partitioning of the drift+diffusion coefficients for best convenient mathematical form description of the very same process...that is $dx = a(x, t)dt + \sqrt{b(x, t)}dW(t)$ can be transformed to $dX = \sqrt{B(X, t)}d\hat{W}(t)$ with a change of variables $X = X(x, t)$.

It should be noted that the logistics are of numbers of species...including demographics is not straight forward and neither is including spatial variables to model say a geographic locale. Not straight forward is not however not possible, and we shall return to this model in later derivations.

Now we wish to derive the interacting species model. The model of $N_h(t), N_d(t)$ healthy and diseased 'species' , of . the model is derived by the definition of spatial extent or position of each person as $\vec{x}$ and its random fluctuations of which its moments of mean (first and second moments respectively) $< \vec{x} >$ and and variance about the mean $< (\vec{x}- < \vec{x} >)^2 >= \int (\vec{x}- < \vec{x} >)^2 P(\vec{x}, t)d\vec{x} = \frac{1}{2\beta(t)}$ are the relevant information, here $< ... >$ denoting averaging. And note that in the case of epidemiology the coordinate positions of the two species (say mosquito and humans) or of predator-prey mathematics models of gazelles and cheetahs and so forth are not available as a detail of the models however we will show how to derive these...Also discrete degrees of freedom such as infected or healthy or dead or alive can be included as 'spin' discrete degrees of freedom $+1,-1$ or with additional spin degrees of freedom describing other discrete states such as "happy, neutral, sad" of $+1,0,-1$ as examples of this discrete multi valued freedom here simple psychological states, this merely an example here, emotions and mental states complex to describe and model however statistically quantifiable as for example by a 'continuous' measurements as can be obtained from psychological tests of statistically significant numbers of members of the populations (ask 1000 people to describe their 'emotions' about an issue grading it on a 0-100 scale or on a point $+!,0,-1$ scale , etc...).

The observables then are of the moments and the degrees of freedom which can be modeled as discrete multi valued additional vectors which in interacting models of physics are "spin models" this from early descriptions of magnetization, and any other variable desired to be included, from sex of the person or animal or the psychology of such (happiness factor say $< h(t) >$ and variance $< (h- < h >)^2 >$), the wealth or education or other demographics...in summary variables of information observables whether physical or psychological or logistical or demographical can be included as information, either as continuous or discrete variables.

The interaction amongst persons places and things has to be defined... interaction between humans with discrete states of say happiness is made as spin-spin interaction, or a 'potential' or interaction term of the i^{th} person with the overall number of interacting bodies as $\sigma_i \Sigma_{j=1}^{N} \sigma_j$, which in the averaged model (the mean field model) is $\sigma_i \Sigma_{j=1}^{N} < \sigma_j >= \sigma_i\, m$ where $N = N_+ + N_-$, and the polarization 'density' (or excess or difference function) is $m(t) = \frac{N_+ - N_-}{N}$. The reader may have already noted the logistics of numerical values that enter the logistics equations such as the Lotka-Volterra predator-prey model, of the numbers of persons or cheetahs or what have you "$N(t)$", as having been explicitly described as a further function of the detailed model variables and parameters.

An information measure for the i^{th} person or logistical member of the model in the case of cheetahs and gazelles and so forth, is written as $< I(t) >= c.\, \Sigma_{\sigma=-1}^{+1} \int P(\vec{x},\sigma,t)\, ln\, P(\vec{x},\sigma,t) d\vec{x}$ The information is varied for the extreme given the observables as $\delta < I(t) > +\delta[\beta(< (\vec{x}- < \vec{x} >)^2 > + < \sigma_i m >)] == 0$. The discrete variable $\sigma = +1,-1,...$ implies a matrix (a form of a spinor tensor) decomposition and is possible as a $2X2$ matrix which here is diagonal due to our *apriori* averaging. We obtain

$$P(\vec{x},\sigma,t) = || \; p(\vec{x})_{++} \qquad 0 \; || \\ || \; 0 \qquad p(\vec{x})_{--} \; || \tag{4}$$

which the off diagonal terms are here zero as we averaged the non-linear interactions linearizing them. The observables are obtained as expectation values or averages as $< N(t) >= N\Sigma_{\sigma=-1}^{+1} \int p(\vec{x},t)_{\sigma\sigma} d\vec{x} = N_+ + N_-$ and the excess function (the spin or polarization) $m(t) = \Sigma_{\sigma=-1}^{+1} \int \sigma\, p(\vec{x},t)_{\sigma\sigma} d\vec{x} = N_+ - N_-$. Note that the excess measure or polarization $m(t)$ is measured by probability densities and therefore is a maximum or minimum at $+1,-1$ and that numerically the number of spins or persons having a particular measurable state is obtained by multiplying by the total number. In physics the total number of a material's spin is constant and not a function of time unlike here, however this is straight forward. Here however the number of persons or what have you is changing in time, and we instead multiply the probability densities by the initial number or derive a variable number statistics. This we can do by adding observations of the changing number of persons or particles or cheetahs or HIV viruses depending on what is 'competing' or rather defending or kinetically moving or hunting or infecting as the case may be. The observables are added to both competing variables as $< N_m(t) >$ an average of the number...further moments are additive of course merely as further information for example the second moment about the mean $< (N_m(t) - < N_m(t) >^2) >$ but it should be noted that this introduces a full diffusion like treatment of the number of the variables, as opposed to the mean only which enters deterministically and can be related to the position vector...we will however return to a direct diffusive 2nd moment treatment of the numbers of the type of predator or prey later as it is of interest and derives certain useful results that connect to Lotka-Volterra. The integrals can be performed simply as they are simply Gaussian, obtaining the well known result $m(t) = tanh(\beta m)$.

Now the other 'competing' species logistics have to be derived...they are actually derived identically, with modifications for the degrees of freedom, let us assume them also two valued as $\tilde{\sigma} = +1, -1$ and with averaged excess function $h(t) = tanh(\beta h)$. Now we combine the two 'species' and maximize each interacting with itself *and* interacting with its 'competition' species as $\delta < I_h(t) > + \delta[\tilde{\beta}(< (\vec{x} - < \vec{x} >)^2 > + < \tilde{\sigma} h >) + < \sigma h >) + \mu_h < N_h > - \mu_m < N_m >] == 0$ and the other species (note these can be combined into a super spinor π to obtain an nXn matrix however we simply write them separately) $\delta < I_m(t) > + \delta[\beta(< (\vec{x} - < \vec{x} >)^2 > + < \sigma m > + < \tilde{\sigma} h >) + \mu_m < N_m > - \mu_h < N_h >] == 0$. The averaged excess functions are now $m(t) = tanh(\beta(m+h))$ and $h(t) = tanh(\tilde{\beta}(h+m))$ respectively.

The number of each is obtained by diagonal trace and averaging as $< N_m(t) >= \Sigma_{\sigma=-1}^{+1} \int p(\vec{x}, t)_{\sigma\sigma} d\vec{x} = N_+ + N_-$ however the competing species numbers were written as a risk causing 'potential'...the 'energy' like expression in the exponential PDF as $e^- \beta E$ has position variables moments and number statistics...the opposite sign of the competing species logistics makes sure that high numbers of competitors increases energy and therefore effectively risk whilst low numbers minimizes energy and therefore a defined equivalent risk function. This becomes important in the later numerical logistics model derivation we alluded to.

The rate of change in time of the observables derived from the two 'species' model we have thus far is $\frac{dm(t)}{dt} = \frac{\partial \beta(t)}{\partial t} \frac{\partial}{\partial \beta} tanh(\beta(m+h))$ which after approximating $tanh(x) \approx x - k_m x^3$ obtains $\frac{dm(t)}{dt} = \frac{\partial \beta(t)}{\partial t}[(m+h) - k_m 3\beta^2(m+h)^3$ which after some algebra in order to obtain the lowest order nonlinear terms $O(mh)$ and discarding all higher order terms we obtain and $dh(t) = \frac{\partial \tilde{\beta}(t)}{\partial t} h[1 - k_h 3\tilde{\beta}^2(hm)]dt$ which is the excess number of say uninfected or not at risk population in this model as each population has its degrees of freedom and statistics. This additional information can be removed however with redefinition of the several degrees of freedom, for example the $\sigma = +1, -1$ can be redefined such that the -1 degree of freedom is a reference point and a constant such that the polarization or excess logistical function measures the relevant population numerical logistic directly as $m \approx n_+ + constant$. The result of course is two coupled DE differential equations that with the addition of driving stochastic terms obtains SDEs stochastic differential equations as $dN_h = a_h(N_h, N_m, t)dt + \sqrt{D_h}dW_h(t)$ and the competing $dN_m = a_m(N_h, N_m, t)dt + \sqrt{D_m}dW_m(t)$ where the diffusion coefficient is here simply of the form $1/\beta = D(t - t')$.

3 numerical logistics and spatial extent

It is not always the case that degrees of freedom are required in each 'population' of competing variables. Often it is sufficient to enumerate the population. This is the Lotka-Volterra model for example. We are interested in the logistics numbers of the populations but also their spatial extent. We have made a simple mean field (average) linear (mathematically) model derivation, this we can utilize to derive the logistics.

The coordinate dependence as moments we retain, discarding the 'polarization' however retaining the numerical statistics and now adding the next higher order moment that of the variance as $< (N- < N >)^2 >$. The variational extreme if beginning from information theory a minimization of our uncertainty of our information measure, and if beginning from disorder or entropy its maximization or rather the maximization of the possible degrees of freedom available to the system in order to best quantify and model it.

the measure as before and with the information set as defined is varied as $\delta < I_h(t) > + \delta[\tilde{\beta}(< (\vec{x}- < \vec{x} >)^2 > + \mu(< N_h > - < N_m >))] == 0$ and the second set of equations $\delta < I_m(t) > + \delta[\tilde{\beta}(< (\vec{x}- < \vec{x} >)^2 > + \mu(< N_m > - < N_h >))] == 0$ obtaining a 2X2 matrix somewhat similar to the previous result, however now the 'focus' is on the logistics though they may be coordinate dependent. The expectation value for the logistics are from the diagonal trace as we ignored the interaction terms we utilized previously...first we normalize or integrate to obtain the partition function $Z(t) = \int p_h(\vec{x}, t)d\vec{x} + \int p_m(\vec{x}, t)d\vec{x} = e^{\beta\mu(N_h - N_m)} + e^{-\beta\mu(N_h - N_m)} = cosh(\mu(N_h - N_m))$ and then we calculate the expectation value of the numbers of the populations as $< N >= \int (N_h + N_m)p_h(\vec{x}, t)d\vec{x} + \int (N_h + N_m)p_m(\vec{x}, t)d\vec{x}$, which can be obtained as a partial derivative of the partition function. Each expectation value separately calculated obtains $< N_h >=< N > - < N_m >$. This simple result is indicative that the coordinate dependent conditional expectation value for each type of logistics is simply $< N_h(\vec{x}, t)|\vec{x}', t' >= Erf[\vec{x}, t, N_m|t']$.

Moreover the rate of change of these quantities is obtained as before by differentiation
$dN_h = \frac{\partial\beta(t)}{\partial t}(-1)[(\vec{x} - \vec{x}')^2 - \mu_h N_h + \mu_m N_m] \frac{e^{-\beta(t)[(\vec{x}-\vec{x}')^2 - \mu_h N_h + \mu_m N_m]}}{Z} dt$
and similarly for $dN_m(t)$. The averages or expectation values resulting as can be seen from the identity $-\frac{1}{Z}\frac{\partial Z}{\partial \beta} = \sigma^2$ and its conditional version as desired...to summarize, coordinate dependent number logistics densities and their averaged conditional or fully averaged values are derived as set forth and following straight forward moments methods from within information theory and probability.

To illustrate this further the averaged number logistics of each species are also obtained as $< N_h >= e^{\beta\mu(N_h - N_m)} \approx 1 + \beta\mu(N_h - N_m) + \frac{1}{2!}(\beta\mu(N_h - N_m))^2 + ...$ and where we have expanded the exponential . We note $< N_h >= N_h(t)$ (pointing out the 'mixed' notation often a source of confusion) as discussed and we differentiate to obtain $\frac{dN_h(t)}{dt} = \rho_h(t)N_h(1+\kappa_h(t)(N_m)) - O((N_h + L_h(t))^2) + ...$ and similarly for $\frac{dN_m(t)}{dt} = \rho_m(t)N_m(1+\kappa_m(t)(N_h)) - O((N_m + L_m(t))^2) + ...$, which if by the *adhoc* method of Lotka-Volterra addition of random driving 'forces' become a traditional predator-prey or logistics 'like' model' $dN_h(t) = a_h(N_h, N_m, t)dt + \sqrt{D_h}dW_h(t)$.

4 some interesting interacting many-body and path integral field theoretic methods

thus far we have derived two models, the first showcasing the many-particle or many-body interacting approach to complex and random interacting systems, the second its simplification to show its direct connection to traditional Lotka-Volterra models. Now we would like to derive the 'mapping' of a popular physics model (an interacting many-body model) to the problem of predator-prey logistics epidemiology competing variables and so on...The model is called the occupation number formalism, a '2nd quantization' of quantum dynamical statistics...quantum actually meaning 'discrete', it is not surprising that recently its lofty unapproachable statistics (it is merely statistical dynamics) theoretical mathematical structure was applied to human activity...most popular are the 'quantum finance', the 'quantum portfolios', the derivatives pricing by path integrals (field theory and Feynman diagrams of finance)...note path integrals and Green's functions are merely a 'source term' different. This means that $G = g + gVG = g + gVg + gVg'V'g'' + ...$ the infinite Feynman 'diagrammatic' sums [7] written as expectation values of unitary operators $< x, t|e^{i\hat{H}(t-t')}|x', t' >$ of which $H = H_o + V$ are transformed to Lagrangian dynamics and therefore Feynman 'path integrals' by the Legendre transformation and canonical variables transformations as is well known in classical mechanics such that the Hamiltonian and Lagrangian are 'related' by $H = pq - L$. Usually however one utilizes the path integrals Lagrangian approach in the calculation of the random paths of fields rather than (point or extended) particles, and therefore the specialization.

The only difference mathematically between a quantum mechanical '1st quantization' PDE and a diffusion or Fokker-Planck PDE once drift and potential terms are mapped to each other are the complex valued diffusion constant in the case of quantum mechanics $D_s = i\frac{\hbar^2}{m}$ and in the case of a diffusion PDE $D_r = \sigma^2$. This however is of profound importance as solutions of waves rather than decaying exponentials implying irreversible evolution are obtained in each case, though what should be noticed here is that from this point of view (the drift+diffusion partitioning freedom allows 'shifting' the coefficients around, for example real valued diffusion coefficients but complex valued drift coefficients from potentials) the variance in the case of quantum mechanics is complex valued.

The first quantization in the convenient representation of variable $<x>$ and its momentum $<p>$ which are 'conjugate variables' obtains an uncertainty relation noted by Heisenberg of $<x><P> \geq \frac{\hbar}{2}$. The equality is obtained only for free distributions that are Gaussian... the result is general and applicable to real valued diffusion processes sans the quantum Planck's constant $\hbar$.

The starting point of quantum mechanics is Hamiltonian and or Lagrangian, the previous derivation then of $\delta<I>+\delta[\beta<H>]==0$ obtaining least biased probabilities $\rho(H)=1/Ze^{-\beta H}$. With the Hamiltonian operator merely the free particle kinetic energy $<H>=\frac{\hat{P}^2}{2m}=-\frac{\hbar^2}{2m}\frac{\partial^2}{\partial x^2}$ where the operator form of momentum is its Fourier transform intermediate partial differential form $\hat{p}->-i\hbar\frac{\partial}{\partial x}$ and upon partial differentiation with respect to the β thermodynamic parameter of evolution we obtain the diffusion thermal quantum partial differential equation $-\frac{\partial}{\partial\beta(t)}\rho(x,t)=\frac{\partial^2}{\partial x^2}\rho$. The quantum statistics after Fourier transformed 'emerge' by analytical continuation to the complex plain as the Green's function of this diffusion like equation is $g(k,i\omega_n)=\frac{1}{i\omega_n-\epsilon(k)}$ and the complex rotation $i\omega_n->\omega\pm i\nu$ emerges the hyperbolic functions which partitioned are the Fermi-Dirac 'occupation' numbers statistics $n(k)=\frac{1}{e^(\beta\epsilon(k))+1}$ and the Bose-Einstein statistics $n(k)=\frac{1}{e^(\beta\epsilon(k))-1}$...interesting features is that Bosons particles 'bunching' can be infinite as the denominator becomes zero and the material 'condenses' into a super fluid whilst the Fermions of half integer spin such as electrons repel each other and are subject to quantum repulsion such as the Pauli exclusion principle.

The 2nd quantized form or the 'occupation number' formalism (or number logistics!) is obtained from is obtained by defining field operators, that create or destroy a particle , or rather add or subtract a number from the system. These can be written as expansions as $\psi^\dagger(x,t)=\sum_{k=0}^{inf}e^{-ikx}c_k^\dagger(t)$ the 'creation' operator and the conjugate $\psi(x,t)=\sum_{k=0}^{inf}e^{-ikx}c_k(t)$ the 'annihilation' operators. These operate as follows... define a system distribution as a basis set or a complete set $<n_1,n_2,...,n_k,...||n_1,n_2,...,n_k,...>==1$ with the $n_k=n(k)$ as defined from our discussion of Fermi-Dirac (only one particle per $n(k)$) and Bose-Einstein (many particles can have the same k and therefore $n(k)$) statistical distributions. The $<...|$ is the 'bra' and the $|...>$ the 'ket' of Dirac thus a 'bracket' symbolism, for example the $<x||x'>=\int e^{-i\hbar k.(x-x')}dk=\delta(x-x')$ and so forth (recall prince De Broglie defined wave particle duality and therefore $P=\hbar k$......

The destruction and creation operators remove or add a number of the many-bodies [7] each with spatial and temporal coordinates $\vec{x},t$ and momentum (Fourier wave number) $\vec{P}=\hbar\vec{k}$. This is accomplished by operating on the logistics basis sets as $c_k^\dagger|n_1,....,n_k,..>=n_k+1|n_1,....,n_k+1,..>$ and $c_k|n_1,....,n_k+1,..>=((n_k+1)-1)|n_1,....,n_k,..>$ such that $<c_kc_k^\dagger>=n(k)$.

Note the quantum mechanics of complex valued functions and exclusion statistics are not actually a hindrance but a helpful feature, as we are not here describing particles but creatures and human beings. They can not occupy the same 'space' therefore we can utilize the exclusion principle and its statistics the Fermi-Dirac statistics. They may have other degrees of freedom (healthy= $+\frac{1}{2}$, in need of treatment= -$\frac{1}{2}$) describable by discrete vectors as we discussed earlier that derive tensors that are representable as spinors and thus 'spin' degrees of freedom. They may be two different species of animals, say a predator animal ("positive" charge) and a prey animal ("negative" charge) that when occupying the same space 'annihilate' each other (low probability in real animal kingdom dynamics) or much more likely interact by some method we can model as a risk minimizing or maximizing 'potential' function, the simple examples of which we have discussed in the previous sections' derivations. By the by, the analogous 'non annihilating' model would be of two $different$ particles that are not particle-antiparticle pairs such as electrons-positrons but rather electrons and protons or electrons and neutrons and so forth. In elementary particle physics, from which this model is 'borrowed' or mapped to, CPT charge parity time are actual degrees of freedom that are coupled...in this model we map qualities of say human attributes or behavior and or differentiate between the two species (human=+1, mosquito=-1 as in malaria epidemiology models for example) or variables by assigning such degrees of freedom of spin,charge,parity and what have you (flavor, charm and good nature come to mind...) , a mathematical convenience once the many-body theory's formalism is abstracted as merely degrees of freedom of a statistical interacting dynamical mathematics.

Therefore we have a model that if we were to write as a Hamiltonian would be written as $\hat{H} = \sum_{i=1}^{N_h} \hat{\vec{P}}_i/2M_h + \sum_{j=1}^{N_m} \hat{\vec{P}}_j/2M_m + \frac{1}{2}\sum_{i=1}^{N_h}\sum_{i=1}^{N_m} V(\vec{x}_i, \vec{x}_j)$ where the two-body interaction term $V(\vec{x}_i, \vec{x}_j)$ is of a form that is either continuous or discrete, and if continuous and representative of 'attractive' (if a mosquito can be said to be 'attracted' to its victim and the interaction between mosquito and human as an attractive interaction) or 'repulsive' as of territoriality modeling inter species such as a simple model of solitary animals...A model of such potentials is from physical arguments that of a potential (of interactions and 'energy' or as we have defined it 'risk') that a) prevents two members of a species from occupying the same exact coordinates b) yet is attractive at farther distances such a potential for example can be written as $V(\vec{x}_i, \vec{x}_j) = \frac{a}{r^\nu} - \frac{b}{r^\upsilon}$ with the fractional exponents $\nu > \upsilon$ a generalized Lennard-Jones potential.

Therefore physical arguments must dictate the form of the model of interactions between species the potential function of the Hamiltonian of the many-body interacting models, and furthermore one can model the inter species dynamics and degrees of freedom as discussed in the previous sections with additional degrees of freedom that highlight or focus upon information such as sex, demographics(if human) , age and so forth.

A predator prey model which is what we have had a focus on, is an 'attractive' potential model by physical arguments. One assumes zero interactions between a species members (free 'particles') and interaction only between different species. The potential then is 'attractive' but as the two different species have one type of species wanting very badly to murder another member of a species, it 'wishes' to occupy the same coordinates as its victim in order to rape, spy upon, thieve from, bark as a rabid dog, slavishly attempt murder. The potential then is a simple 'Coulomb' attractive potential $V(\vec{x}_i, \vec{x}_j) = +\frac{q_h q_m}{|(\vec{x}_i - \vec{x}_j)|}$ where here the 'charge' $q_h, q_m = +1$ such that in the Hamiltonian which if conserved is the energy as the mosquito nears its human victim the energy or risk in subjective terms grows larger.

The inter species interactions can either be explicitly modeled by repulsive-attractive sharply minimum generalized Lennard-Jones like potentials as discussed or assigned to statistics of exclusion descriptions such as describing each inter species statistics by Fermi-Dirac statistics where the Fermi type of interactions repulse one another or can not occupy the same set of vector variables (space time etc..), excepting say when their degrees of freedom distinguish them such as some variables are exactly the same whilst others are not... Simply as an example following Fermi electrons statistics, no two electrons can occupy the very same space time unless they have opposite spins or other degrees of freedom (in the case of other 'types' of real or hypothetical systems) different freedoms. Two lady bugs or widgets for example repulse each other unless male and female with (male=+1/2, female=-1/2) 'occupying' the same space time coordinates, and this 'on the average' as it is merely a model of potential occurrence which then occur a fraction of the time, a fraction of the numbers of the species, and which fluctuate randomly thus giving formation of the observed fluctuating numbers of the species.... Note that here the author is attempting to impress upon you the reader that one writes down the deterministic and or known information re observables one is interested in measuring or observing, then vary for extreme one's information measure(s) and then one has a least uncertain mathematical statistics of the complex random system(s). Taken apiece, it seems counter intuitive (kindly put, perhaps felt to be in error is a better description) that one describes 'mating' as spin, however it is merely a simplistic method of describing a part of the dynamical complexity of interactions that result in births and deaths , and this facet or degree of freedom simply modeled by 'exclusion' statistics and or 'repulsion' or attraction' discrete and or continuous functions. It is well known that even 'simplistic' descriptions such as these 'capture' well the stylized facts (of the statistics...) of human interacting social psychological economical systems...We merely follow in this light and expect that our results will have a sufficiently robust mathematical descriptiveness to 'capture' or describe the stylized facts of a predator-prey or birth-death complex random system.

Therefore we assign inter species Fermi-Dirac statistics modeling inter species $\vec{x}, t$ coordinate similarity exclusion, this in order to avoid complicated (as will be seen) potentials functions of interactions inter species. Note that this means in terms of our mathematics that our Fourier transform of our thermodynamic variables $F(\beta) = \frac{1}{2\beta} \sum_{n=0}^{inf} e^{i\omega_n \tau} F(i\omega_n)$ where we define the thermodynamics as an evolution parameter 'running' from $-\beta < \tau < \beta$ and where upon analytical continuation of our Green's thermal Matsubara function $i\omega_n -> \omega + i\,\nu$ with the discrete frequencies of the transform ranging from $\omega_n = n\pi = 0, 1, 2, ...$ the hyperbolic functions are chosen such that either even $\omega_n = 0, 2, 4, ..$ Fermi-Dirac or odd $\omega_n = 1, 3, 5, ..$ Bose-Einstein statistical thermodynamic statistics are obtained. This beyond mere formality as the occupation number formalism 'depends' on this statistics, now our choice of basis sets acted upon by the creation and annihilation operators $|n_1, n_2, ..., n_k, ... >$ such that $< c_k c_k^{dagger} >= 1$ or only one particle per occupied degrees of freedom defined by the vector $\vec{x}, t$ and this as discussed aside from additional assignable degrees of freedom such as spin and so forth, these merely added by say superscripts or similar devices as for example n_k^{σ} where the (discrete...) spin may range as before from $\sigma = +\frac{1}{2}, -\frac{1}{2}$ or more. A reminder here that this is yet $+1, -1$ 'normalized, and other higher degrees of freedom such as $+1, 0, -1$ for a detailed model differentiating between malaria victims as $+1 = healthy, -1 = infected, 0 = dead$ referencing the instantaneous numbers of the time dependent species numbers concerned. To step aside for a moment, we remind the reader that spin is in actuality a complex mathematical structure where squared (at least) interactions produce multi valued such as two valued (at least) that are then matrices describable as spinors, these in short hand notation our superscripted or similar variables.

occupation formalism as $< H >_{occ}= \int \psi^{\dagger}(\vec{x}, t)\psi^{\dagger}(\vec{x}', t)\hat{H}\psi(\vec{x}', t)\psi(\vec{x}, t)d\Omega' d\Omega$ and where the additional summations $1 = \frac{1}{N_{h,m}} \sum_{i=1}^{N_{h,m}}$ are added to each species' 'free kinetic energy' terms, this a mathematical device such that the kinetic energies are calculated as $< KE_h >= \sum_{i=1}^{N_h} \sum_{j=1}^{N_m} \int \sum_{\vec{k}'''=0}^{inf} e^{-i\vec{k}'''.\vec{x}} c^{\dagger}(\vec{k}''', t)$ $\sum_{\vec{k}'=0}^{inf} e^{-i\vec{k}''.\vec{x}'} c^{\dagger}(\vec{k}'', t) \frac{1}{N_m} (\frac{-\hbar^2}{2M_h} \frac{\partial^2}{\partial \vec{x}^2}) \sum_{\vec{k}'=0}^{inf} e^{-i\vec{k}'.\vec{x}'} c(\vec{k}', t) \sum_{\vec{k}=0}^{inf} e^{-i\vec{k}.\vec{x}} c(\vec{k}, t) d\vec{x}' d\vec{x}$.

This seemingly complicated expression results by integrations and summations in $< KE_h >_{occ}= \sum_{\vec{k}}^{inf} \epsilon_h(\vec{k}) c_k^{\dagger}(t) c_k(t)$. The kinetic energy of the 'h' variable in occupation number formalism...further averaging or expectation values which we denote by un superscripted bra and ket as $<< KE_h >_{occ} >>= \sum_{\vec{k}}^{inf} \epsilon_h(\vec{k}) < c_k^{\dagger}(t) c_k(t) >= \sum_{\vec{k}}^{inf} \epsilon_h(\vec{k}) \frac{1}{e^{\beta(\epsilon_h(\vec{k})) - \mu_h N_h)} + 1}$ and where we have 'added' the referenced numbers of the species which merely 'enter' the Hamiltonian by superposition additively such that in effect we are working with $\hat{H} + \mu_h \hat{N}_h + \mu_m \hat{N}_m$, and we gather like terms together... another way of looking at this is that we begin to 'count' the energy (risk) as referenced from the number energy (risk), this 'shifting' of the reference level a convenient taking into account the grand canonical ensemble of varying numbers of particles here species members. It is easy to see the relation $< N_h >= \sum_{\vec{k}}^{inf} \frac{1}{e^{\beta(\epsilon_h(\vec{k})) - \mu_h N_h)} + 1}$ is in the thermodynamic limit of high temperatures the exponential $< N_h >= \sum_{\vec{k}}^{inf} e^{-\beta(\epsilon_h(\vec{k})) - \mu_h N_h)}$ which approximating by a continuum is $< N_h >= const. \int_0^{inf} e^{-\beta(D_h \vec{k}^2) - \mu_h N_h)} d\vec{k}$, or the Fourier transform and summation (integration) of the expression in terms of the coordinate vector $< N_h >= \tilde{c}onst. \int_0^{inf} e^{-\beta(\tilde{c}\vec{x}^2 - \mu_h N_h)} d\vec{x}$, this precisely the form of our initial derivations of our theories as applied to number logistics as pertaining to predator-prey models.

The interesting interaction terms are then obtained similarly, with however the two-body interactions introducing additional 'un gathered' terms such that $< V >_{occ}= \sum_{\vec{k}}^{inf} \sum_{\vec{k}}^{inf} V(\vec{q}) c_k^\dagger(t) c_K^\dagger(t) c_K(t) c_k(t)$ and where $\vec{q} = \vec{k} - \vec{k}'$. Now further averaging of expectation values will require gathering of like terms, and as we had traded the difficulty of exclusion accounting by more potential functions for *apriori* Fermi-Dirac statistical exclusion, now we pay the price by having to 'shift' around the creation and annihilation operator such that they are grouped near each other as $< c^\dagger c >$ to obtain the individual statistical $n(\vec{k}, ...)$ distributions. This is accomplished in the correct way by following commutator relations of $[c^\dagger{}_k c_{k'} - c_k c^\dagger{}_{k'}] = \delta_{kk'}$, where the discrete Kronecker delta function is $\delta_{kk'} = 0 \; if \; k \neq k' ... \quad = 1 \; if \; k = k'$ is the occupation number formalism version of the Heisenberg commutators of say position momentum $[x.p - p.x] = -i\hbar$.

Note that simplifying the potential such that it is constant $V(\vec{q}) = V_o$ makes this derivation more transparent...we then have the gathering of terms such that we remainder $< c_k^\dagger c_k >< c_{k'}^\dagger c_k' >= n_{k'} n_k$ in the expression now containing $< V >= \sum_{\vec{k}'}^{inf} \sum_{\vec{k}}^{inf} (V_o) \frac{1}{e^{\beta(\epsilon_h(\vec{k})) - \mu_h N_h)} + 1} \frac{1}{e^{\beta(\epsilon_m(\vec{k}')) - \mu_m N_m)} + 1}$ which separably obtains $< V >= V_o N_h N_m$ as before.

5 summary thus far

We have thus far derived the interacting spin model, the interacting statistical model, and the interacting field theoretic many-body interacting model...we have shown where conveniently they are in a limit or another most transparently the same model. We have also shown in what limit they directly derive the Lotka-Volterra predator prey model , one type of logistics model. We have explicitly shown where freedom of detail can be introduced either by Legendre transformation as in the case of information measure the varied extreme $\delta < I > + \delta[\beta < observables \, of \, information >] == 0$ and as by superposition additivity to the infinitesimal evolution operators as in the Hamiltonian theory and its straight forward derivation by either information theoretic or rather 'negative entropy' thermodynamics and or Green's functions and occupation number formalisms...We note that this is a well known result in some theoretical physics communities though not as much in the supposedly disparate fields of researches such as multi agents, cellular automaton, rules based program, super-spins, games theory, networks, and other interacting complex systems research approaches, as generally discrete-continuous models such as the discrete interactions with (approximated) continuous parameterized evolution are 'mapped' to super spin models which are known to be a limit of a general field theoretic model or its particle equivalent. We are then applying these known methods to the problem of predator prey interactions, seeking to a) reproduce the Lotka-Volterra type of logistics b) generalize such to inclusion of spatial coordinate dependences c) generalize such to the inclusion of any detail of observables wished by a researcher to be included , thereby deriving applied robust models of human interactions, of species biodiversity, of logistics .

We then wish to apply the model to a real world concern, that of malaria...In this case there are two species of our focus, human and female mosquito the carrier of the infection material it a host to the pathogens responsible for the malaria. One can imagine a scenario where the male and female (+1,-1) of the mosquito species are to be accounted for as a clever human has invented a chemical way of say preventing male mosquito of reproducing with the female mosquito a common approach to pest eradication and tracking the logistics of this further interaction or detail or observable is of correlated importance to the model...however though seemingly a straight forward way of killing all mosquito in creation, to our knowledge no such clever death has been concocted by humans to be visited upon their pathogen hosting killers nor upon the pathogens carried by the female mosquito.

6 epidemiology statistical dynamics of malaria

The model to be derived consisting of humans and pathogen hosting female mosquito , the desired robustness of the model merely consists of a spatial extent model of the logistics ...that is the simplest model we derived should suffice as our starting point, that of the interacting number logistics many-body model (the simplified logistical limit of the 'super' spin model). Without spatial extent, or with the coordinate dependence integrated out as by averaging it is merely the Lotka-Volterra model, with 'rich' information about numerical logistics as a whole, however with no spatial density information, an often very important piece of information to have as concerted efforts in one particular region of high incidence of disease often serves to staunch the spread of the disease effectively stopping an epidemic in its tracks and ideally before it has become of epidemic proportions.

The model was simply $N_h(\vec{x},t) = f(t)((\vec{x}-\vec{x}')^2-\mu_h N_h-\mu_m N_m)e^{\beta(t)((\vec{x}-\vec{x}')^2-\mu_h N_h-\mu_m N_m)} = f(t)g(\vec{x},\vec{x}',..,t)P_o(\vec{x},t|\vec{x}',t')$ and for the mosquito a similar function.. we are utilizing the notation of density $= n_h(\vec{x},t)$ and number $= N_h(t)$ though we mixed notation between pre averaged and post averaging $< N_h(t) >= N_h(t)$. Also we remind that the interactions are here included as species-species, simply by Legendre transformation (addition) as before and where we have already discussed a) additivity b) partitioning of interactions re potentials c) here the simplest (constant) interaction is included, that which obtained the Lotka-Volterra form. As an additional check, recall that $n_k(t)$ of the Fermi-Dirac form once we Fourier transformed in the high temperature thermodynamic regime was merely a Gaussian $n(x,x't) \approx e^{-\beta(x-x')^2}$ which either integrates to an error function for half 'infinite' spaces or a square root $\sqrt{\frac{\pi}{\beta}}$ to within a factor of $\sqrt{2}$ for infinite spaces.

The stochastic differential equations obtained for the Lotka-Volterra model by *adhoc* methods or simply by adding randomness to $N_h = n_h(1 + K_h n_m)dt + \sqrt{D_h}dW(t)$, we do the same here, obtain the resulting Fokker-Planck and or change of variables transformations between $n(t) -> n(x,t)$ in order to verify our accuracy of derivation...that is the Lotka-Volterra predator prey 'model is a numerical logistics coupled set of SDEs stochastic differential equations that equivalently are numerical logistics Fokker-Planck PDEs partial differential equations that have no coordinate dependence, are of the form $\nabla_t f(n_h, n_m, t) = -\nabla_{n_h}[a_h(n_h, n_m, t)f] - \nabla_{n_h}[a_m(n_h, n_m, t)f] + \frac{D_h}{2}\nabla^2_{n_h} f + \frac{D_m}{2}\nabla^2_{n_m} f$.

The transformations must result in SDEs of coordinate dependent numerical logistics also known as number densities $n(x,t)$ and their Fokker-Planck equivalent evolution equations at the 'macro' level of the statistics (the SDEs equivalently the 'micro' level of stochastic or particular realizations of trajectories and or configurations). A simple direct Fokker-Planck to Fokker-Planck transformation is possible, by conservation of probabilities as of $f(n_h, n_m, t)dn_h dn_m = F(n_h(\vec{x}, t), n_m(\vec{x}', t))d\vec{x}d\vec{x}'$ where we 'know' the LHS and can presumably solve for the RHS in its terms...this can of course be looked at as a variable transformation, and as is the Ito formula SDE stochastic level transformation which is accomplished by transforming deterministically the variables within the stochastic differential equations resulting in an SDE-SDE transformation. Equivalence between the two 'descriptions' being noted, the important focus here is obtaining coordinate dependent density statistics, and comparing these with our presumably 'robust' interacting systems models that we have derived.

What we have then is the alternative approach result, that of the density derived from interacting systems models... the result is the error function form of the density or the Gaussian. It is the coordinate dependent first moment $< N >$ model, whilst the Lotka-Volterra model can be viewed as a 2nd moment coordinate free model $< N^2 >$...Note the disconnect between the two models...if we added 2nd moments to our interacting models we would obtain additional 'vectors' such that we would have 4Dimensional up to 8Dimensional (depending on detail of the description of each species 3D coordinates) or of $\vec{x} = x, y, z, n_h$ and the resulting Fokker- Planck PDEs which would contain 2nd order partial derivatives of the numerical logistic variables n_h, n_m...that is they would be independent variables, as opposed to the first moment interacting system model which derives or obtains dependent parameters. Generally this is not a difficulty unsurprisingly enough, a PDE-PDE transformation between 3D to up to 8D is not any more difficult than the current derivation, as it is merely extra variable transformations, with another view that our current $n(x,t)$ first moment coordinate dependent model from interacting systems the limit of $\tilde{D}_{h,m} -> 0$ or of the other diffusion coefficient pertaining to the 2nd moment of the n_h, n_m approaches zero in a limiting fashion leaving only a deterministic set of information in concert with the dynamical spatial extent set of information.

The transformation between PDF-PDF can be accomplished by the $P(n_h(\vec{x}, t))d\vec{x} = p(n_h, t)dn_h$, here we have separated the problem into each relevant variable and set of variables...this amounting to only solving for the Fokker-Planck of one of the coupled SDEs. We know the left hand side and the RHS distributions . The RHS distribution of the LK model a $dn = n(1 + Cn')d, t)t + \sqrt{D}dW(t)$ SDE with an Ito transformation of $dn = d[e^{-rt}N] = -rNe^{-rt}dt + e^{-rt}dN + O(> dt)$ resulting in $-r = (1 + Cn')$ and a de-mean process $dN = \sqrt{De^{2rt}}dW(t)$ which Fokker-Planck is $e^{2rt}\nabla_T p(N,T) = \frac{D}{2}\nabla_N^2 p(N,T)$ or the variable relation of the transformed 'time' evolution parameter $T = \int_0^t e^{2rt''}dt'' = \frac{1}{-2r}(e^{2rt} - 1)$...all of this of course resulting in $p(n,t) = \frac{1}{Z}e^{-2r\frac{n^2}{2D[e^{-2r(t-t')}-1]}}$.

The LHS is the error function obtained for a half system or the result of Gaussian $dN_{h,m}(\vec{x}, \vec{x}', .., t)$ which we can utilize the same method of *adhoc* addition of noise to...the result is the logistics of two coupled DE which with noise are two coupled SDEs here however with spatially distributed density 'not yet averaged' as we discussed extensively...We have then $dN_h(\vec{x}, ..., t) = [f(t)g(..)P_o(..)]dt + \sqrt{\hat{D}_h}d\hat{W}_h(t)$ and so forth and the Fokker-Planck equivalent process... this implies the change of variables (not directly leading to a solution , that is obtained in the following sections) of $\frac{\partial N_h}{\partial x'} = f(t')2[(\vec{x}-\vec{x}')-\beta(t')(\vec{x}-\vec{x}')g(\vec{x}, \vec{x}', .., t')]P_{oo}(..)$ where here the spatial part of the distribution and the numerical part are written as $P_o = P_{oo}\nu_-(N_h, N_m)$ remaindering the expansionable Lotka-Volterra drift coefficient $\nu_+(N_h, N_m)$ 'separated from the (inverse) $(\frac{\partial N_h}{\partial x'})^-1$ variable transformation in the backwards Fokker-Planck (for N_h) of which the forward Fokker-Planck transformed and which introduces additional non constant (now) diffusion coefficients is $\nabla_t F(N_h(\vec{x}, t), t) = -\vec{\nabla}_{\vec{x}}[\vec{a}_{N_h}(N_h, ..., t)F] + \frac{1}{2}\vec{\nabla}^2_{\vec{x}}[b^2_{N_h x,y,z}(N_h, .., t)F]$. Note the diffusion coefficient is introduced as the square of the remaindered variable transformation inverses $b_x^2 = (\frac{\partial N_h}{\partial x'})^-2$ and similarly for the other coordinates. This of course implies the coordinate SDEs $dx = a_{x,N_h,N_m}(N_h, .., t)dt + b_{x,N_h,N_m}(N_h, ..., t)dW_x(t)$, with similar expressions for the remaining coordinates and noting that we have added the symmetrically similar expressions for N_m to these SDEs without explicitly writing them down, a form of short hand of the algebra if you will.

To summarize, the derivation of number logistics from several interaction models is possible and reduces to logistical and or Lotka-Volterra type of coupled DEs and with the addition of noise to coupled Lotka-Volterra type SDEs. We can obtain coordinate dependent forms of these equations and can add any observable we decide is relevant to the dynamics. We can furthermore transform between these equations as shown. We have also identified the point of 'disconnect' between the logistical equations which merely measure $N(t)$, the grand canonical ensemble derivation which includes information on numbers logistics of the form of first moments $< N >$, and theories that would seek to go 'beyond' this to 2nd moments $< N^2 >$ in the logistics, these becoming diffusion PDEs in the variables in their own rights and not necessarily adding any more to our information as we obtain coupling terms of order $< N_h N_m >$ from the first moment in the numerical logistics models.

7 numerical simulations

Deriving the theoretical models is satisfying in and of itself, as we feel we have shown how to specialize the models robustly to any 'competitive' two species logistics simulation required of a theorist. However real prevention of epidemics such as malaria require real number calculations, real identification of critical behavior, at real geographical locales on the earth susceptible to malaria outbreaks and using real data recorded by WHO world health organizations and academics and physicians dedicated to the eradication of the deadly disease.

Therefore we want to begin to make inroads towards this goal. We will accomplish this by numerical simulations of our coordinate dependent model(s) at the SDE stochastic coupled equations level, this equivalent as stated to Monte Carlo PDF probability distribution function simulations and to PDE partial differential function simulations, with simulations giving us a particular configuration of the many possible realizations, otherwise their average we already know mathematically.

Our simulations we then want to compare to real world malaria databases. We seek to apply stochastic methods to a) quantify statistics of the data and compare with statistics of the simulations , b) utilize stochastic forecasting to 'predict' the future evolution of epidemics ... We want moreover to be able to a) identify critical phenomenon similar to phase transitions of physical systems such as magnetic spin systems and ice to water and so forth to the prediction of critical points of outbreaks and potentials for outbreaks b) make short term and long term forecasts identifying any self similar stylized facts in the stochastic processes at many different high frequency to long time scales c) apply well known methods from stochastic processes in interacting complex systems such as are 'successfully' utilized in forecasting financial stock markets future evolution (roughly a bubble followed by a crash is analogous to the outbreak of an epidemic or predator population overpopulation and for similar 'abstracted' complex interacting systems reasoning as we formulated in this letter) and networks theory to the prediction and risk mitigation of outbreaks, d) apply well known methods from bistable systems of which Lotka-Volterra is an example, from stochastic resonance theory of which aperiodic (random) oscillation between bi stability is an example of to further characterizing the complex system parameters of malaria epidemics in specific and epidemiology in general.

This may seem like a lot of work, however we are heartened by the fact that thousands of PhD's doctorates in mathematical sciences have been hired by Wall street and the world equivalents of Wall street who routinely perform such 'much' work of providing such learned detailed analysis for the risk mitigation of random outbreaks of losses of fortunes...we only seek to perform the same learned detailed analysis for the risk mitigation of random outbreaks of losses of lives. We do 'disclose' however that we are very active in the financial stock markets, a fact we feel may aid us in achieving our goal.

The simulation of the geographical Lotka-Volterra model, the limiting form of our several detailed models and the sought for generalization of the logistical Lotka-Volterra type of model, is to be performed by SDEs stochastic differential equations. This is done on a computer utilizing a numerical calculation of the coupled integrated $N_h(\vec{x}, ...t), N_m(\vec{x}, ..., t)$..integrated here meaning an SDE $dx(t) = a(x,t)dt + dW(t)$ integrated is yet a random variable $x(t) = x(t') + \int_{t'}^{t} a(x, t'')dt'' + W(t) - W(t')$, and we are interested in the $N_h(\vec{x}, ...t), N_m(\vec{x}, ..., t)$ or the integrated forms. We have performed many such simulations, and we summarize our results in the section of figures graphs and charts.

8 further utilization of modern non extensive statistical dynamics in epidemiology

Recently in the late 1980's the research of nonlinear fractal and chaos systems gave a breakthrough in statistics. The statistics formulated by Gibbs (and Boltzmann) in the early part of the 1900's and on which all modern statistical mechanics including quantum statistical mechanics has been based and which entropy of the extensive form $S(AXB) = S(A) + S(B)$ such that the composition of two systems is satisfied by $S(A) = ln\, P(A)$ and which by variation extremes derives exponential distributions $P(A) = \frac{1}{Z}e^{c.A}$. This for statistical moments $< A >$ $< \vec{x}^2 >$ the Gaussian and the 'solution' of diffusion equations real valued , thermodynamical and quantum mechanical. These extensive or additive entropies formulations were generalized to non extensive forms where additional terms were needed to describe the composition of two systems such that $S(AXB)_q = S(A) + S(B) + (1 - q)S(A)S(B)$ an *apriori* nonlinear state function formulation and which was found to be solved by $S(A) = -a.\frac{P(A) - P^q(A)}{1-q}$ a power law entropy form that derived power law distributions as $P(A) = \frac{1}{Z_q}[1 + c(q-1)(A)]^{\frac{1}{1-q}}$. This for statistical moments $< A > = < \vec{x}^2 >$ a solution of the nonlinear in exponents PDE $\nabla_t P(\vec{x}, t) = \frac{1}{2}\nabla^2_{\vec{x}} P^{2-q}(\vec{x}, t)$ with $c = \beta_q(t)$ and the partition function $Z_q(t) = \frac{B[\frac{1}{2} - q, \frac{3}{2} - q}{\sqrt{\beta_q(t)(q-1)}}$ and this for $1 < q < \frac{5}{3}$ where the limit $q- > 1$ obtained the extensive form and in the case of the PDE Gaussian evolution.

The SDEs $dN_h = N_h(1 + K_h N_m)dt + \sqrt{D_h}dW_h(t)$ and $dN_m = ...$ are such that drift coefficients deviate the evolution from free stochastic Gaussian evolution or $dN_{h_o} = \sqrt{D_h}dW_h(t)$...it is expected therefore that the solution will be a 'squeezed' Gaussian, otherwise solved alternatively by a particular data and or parameters (K_h, etc...) dependent $q > 1$ power law distribution. This perhaps more apparent if a two valued transformation to $dz(N_h, N_m, t) = a_Z dt + dW_t(t)$ is utilized and with its own different $q' > 1$ and $q \neq q'$...this indicates that one can describe the same process by different valued $q < q' < q'' < ...$ processes corresponding to higher reliance on nonlinearity but less reliance on nonlinearity supplied by explicit forms of the drift coefficients and if the symmetry of the problem is preserved. As an example of this we recently discussed the Lotka-Volterra model driven by non extensive diffusion coefficients [1] which would be written as $dN_h = N_h(1 + K_h N_m)dt + \sqrt{P(N_h, N_m, t)^{1-q}} dW_h(t)$ also $dN_m = ...$ ...we mention that this is equivalently described by alternative SDEs of the form $dN_h = +\sqrt{P(N_h, N_m, t)^{1-q'}} dW_h(t)$ with as before for these q values $q < q'$ as the nonlinearity 'squeezing' of the PDF which here appears in the stochastic trajectory itself as a feedback from 'macro' PDE statistics to the 'micro' SDE stochastic trajectories and is an example of well defined "history following' processes...the nonlinearity 'squeezing' is relegated (with appropriate reflection symmetry) to a higher $q' > q$ value which by itself 'squeezes' the PDF distribution into a sharper distribution near the origin and with a slow decay at the outliers, this describing nonlinear systems which cluster in small valued areas however transition unpredictably in large transitions (large transitions such as out lier crashes and bubbles are well described by these statistics) a statistically significant amount of the time of the evolution of the system. We note that quantum non extensive mechanics has recently been derived by Rajagopal et. al. [6] of further interest to our several current models complementing our 'classical' models. Also we note that we introduced the non extensive statistics to stock markets quantitative finance descriptions Michael & Johnson [3], and to the theory of the description of risk mitigation (Derivatives and options portfolio methods) generalizing Black & Scholes' formula and theory to the non extensive statistical ensembles, furthermore deriving non extensive derivatives risk mitigation valuation models [5]. We refer the interested reader to our cited papers and the references therein.

Furthermore in the 1950's E. Wigner derived his theory of many-body complexity applying it to nuclear matter, in which he utilized extensive statistical ensembles (Gibbs-Boltzmann) to derive random matrix theory and the celebrated Wigner level (Hamiltonian eigen "characteristic" values) spacing statistics. We recently Evans & Michael [2] motivated by research of quantum chaos have generalized Professor Wigner's RMT random matrix theory to the non extensive statistical ensembles, obtaining generalized Wigner qRMT "q" Random Matrix Theory which has the innovations that it is precise in describing nonlinear random complex systems, 'fitting' the data exactly over all regimes from regular Poisson to Gaussian to nonlinear 'chaos' systems classical and quantum mechanical...previously the traditional Gaussian RMT was utilized as a limit and or comparator of the presence of complexity (nonlinearity). We have recently introduced the theory to stock markets and quantitative finance, and we feel qRMT will achieve the same level of ubiquity in science as its traditional $q- > 1$ RMT.

Therefore we will introduce the non extensive statistics to epidemiology. We have already 'drawn the analogy' between epidemic outbreaks and stock markets crashes and bubbles and risk. It should not surprise the reader that Lotka-Volterra predator-prey equations have been utilized to model stock markets. We have ourselves [4] derived the non extensive interacting many-traders (many-body) model of markets whether stocks currencies materials (Gold, coffee etc..)...it is in fact the non extensive mean field 'super spin ' model, and which we apply regularly to the forecast of stock market evolution. We are then very much focused on the numerical statistical characterization of epidemic data, which we will furthermore take the steps of deriving 'indicators' of epidemics risk, and will derive risk mitigation theoretic and numerical methods that we feel are a) lacking in world health organization management of epidemic risk b) which will provide a set of mathematical theoretical and computational tools that will enable best practices by world leaders in reducing the deleterious effects of malaria as well as other epidemic blights.

This we will accomplish by our highly accurate statistics and statistical dynamical interacting models...We note the following, optimal (least risk) stochastic control is predicated on accurate stochastic descriptions. When to shift resources from one region to another, to the stock pile of vaccines or medicines, to the transformation of one environment over another and by what amounts given 'spread thin' resources or in an optimal fashion are predicated upon accurate stochastic and statistical descriptions. We have these tools now, we will apply them towards this problem. Note a similar analogous problem from finance.. the optimal allocation of investments such that risk of losses was mitigated known as portfolio theory was derived based on the known approximation of real stochastic systems such as markets by mathematical log normal forms such as $dx = a.x.dt + \sqrt{D}dW(t)$, this giving a log normal distribution and this introducing approximation errors and therefore riskier investment ...fixes such as additional information of random variance or volatility $dD = a_D.(D, x, t)dt + \sqrt{b_D}dW_D(t)$ were added later...this with decades of highly motivated researchers world wide studying the economics problems for which stochastic control (risk mitigation) was sought... We do not have even this approximate methodology in epidemiology. We feel that we can then accomplish both objectives, of introducing risk mitigation stochastic control and optimization methods to epidemiology, and furthermore introduce the recent advances' high accuracy and innovations in describing complex systems to epidemiology.

9 conclusion

In this letter we have sought to derive robust interacting many-body models of epidemics. We have also sought to 'connect' our model results to traditional methods of say Lotka-volterra predator-prey and similar logistics models. We furthermore have discussed the analogy to critical phenomenon, large transitions and 'phase transformations' between at least two metastable regimes these characteristics of interacting many-body systems. We have also introduced recent advances in statistics the non extensive statistical ensembles of Professor C. Tsallis to epidemiology. We have drawn the analogy between risk in stock markets interacting many-traders systems and risk in world health interacting many-body systems, utilizing approaches that we feel are novel and are innovations in the field of epidemiology. In the future we will focus more on the asset management and asset allocation optimization of medical and professional resources and risk mitigation borrowing from our previous published work on portfolio optimization and risk management utilizing the statistical and theoretical methods we have derived and or applied here.

10 figures

Fig.1 Predator Prey coordinate dependent model ..

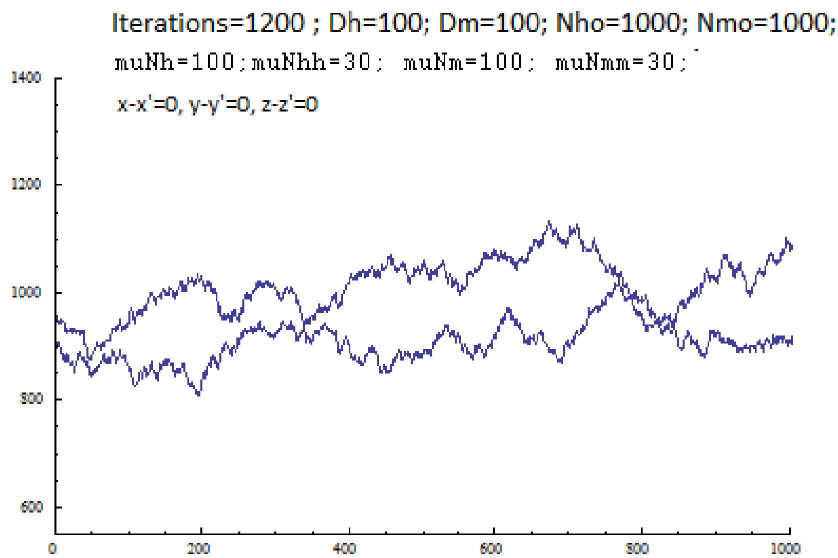
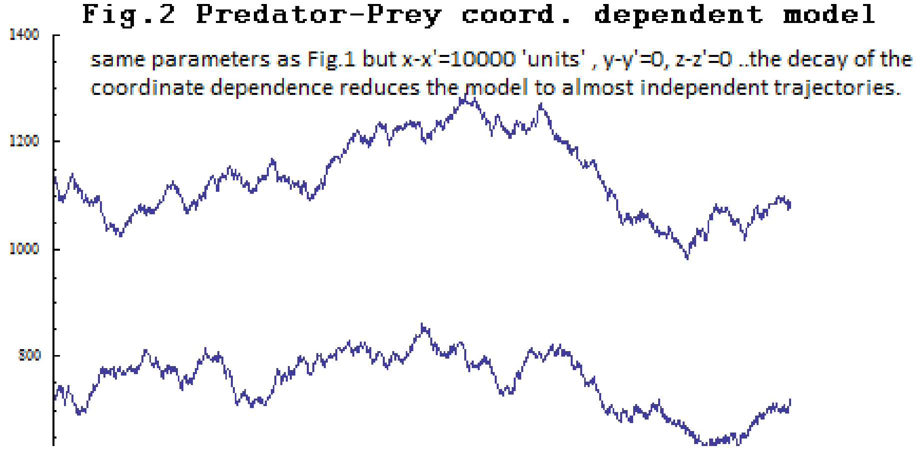


Fig.2 Predator-Prey coord. dependent model



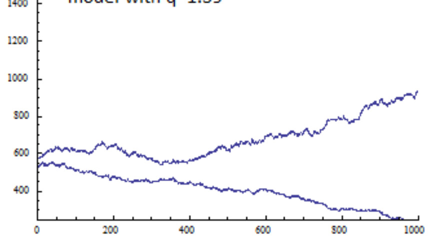
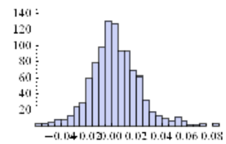


Fig.3 geographical nonextensive LK model with q=1.39



Histogram of N_h/Nm
t-t'= 1interval (days) data

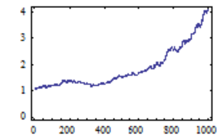
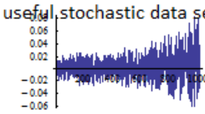


Fig.4 Nr= ratio of N_h /N_m a useful stochastic data set



Nr= N_h/Nm t-t'= 1interval (days) data

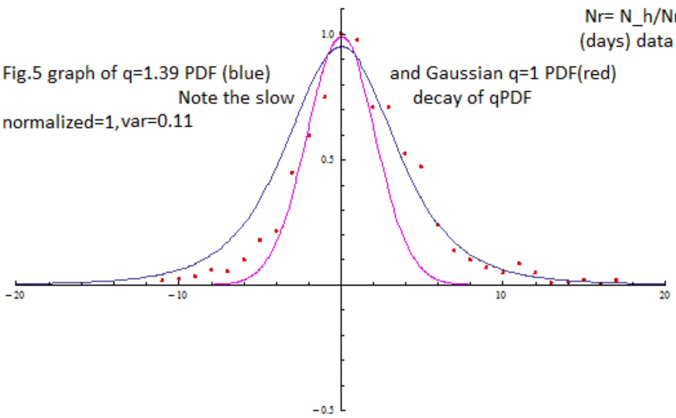
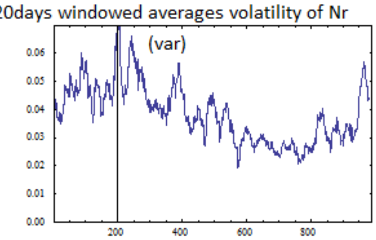


Fig.5 graph of q=1.39 PDF (blue) and Gaussian q=1 PDF(red) normalized=1, var=0.11

Note the slow decay of qPDF

20days windowed averages volatility of Nr



uptrend/downtrend consecutive #days ~3000 days follows nearly an exponential decay with rate r~ 0.67/day. In reality there is usually a slight mismatch between uptrends and downtrends, and the decay is actually better fitted by a power-law. However substitute 'interval' instead of 'days' and this 'se;f-similar' decay occurs on any fluctuations' time scales from 'days' to weeks to months.

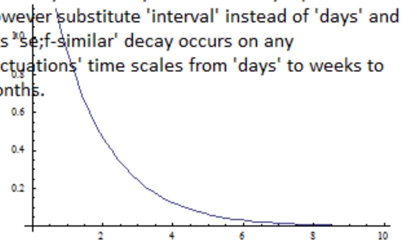


Fig.6
Traditional moving averages indicator...'smoothing' of stochastics by 3X,4X,5X averages here, short term species-species forecasts can be made...a lagging indicator however reasonably reliable at highs(peaks) and longer term trends (20X, 100X)...note for example that near days 950 crossover or momentum change signaled Nr=Nh/Nm impending decline of the human species by malaria deaths the range of this decline the StdDev from stochastic variance (approx. +/- 0.1)...this 'works' at any time scale of the 'self-similar' random evolution at different time scales

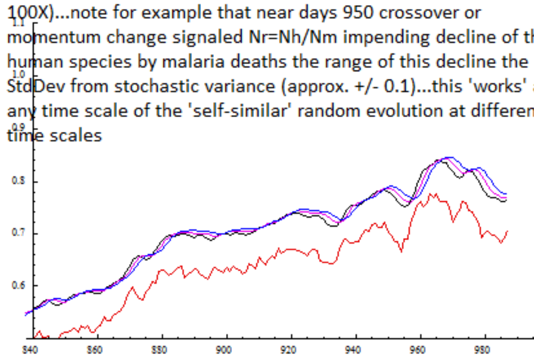


Fig.8 SuperSpin Nh= f(Nhup-Nhdown) model data with Nr=Nh/Nm graphed on '1days' intervals...also can be utilized with long term data for 'long term trends' which this 3-5days fluctuations from peak to trough are embedded...
This graph is reasonably reliable for sharp peaks and troughs or after extensions near the probabilistic limit of the #trend days and magnitude of moves during such trends

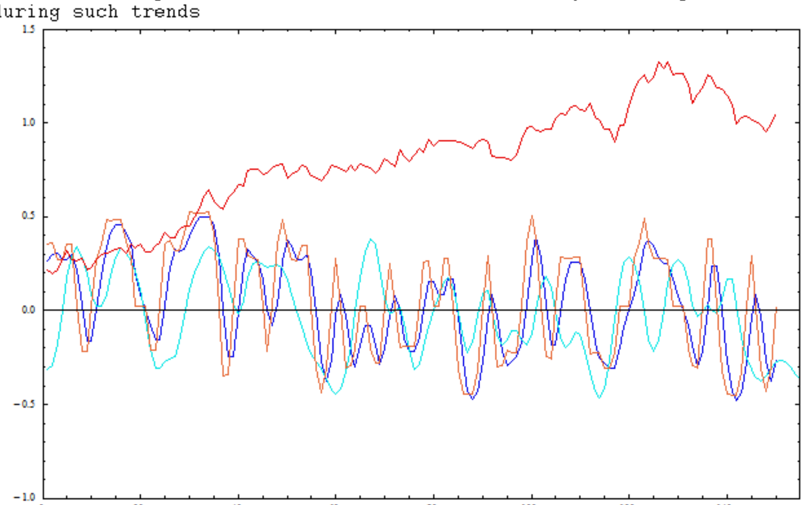
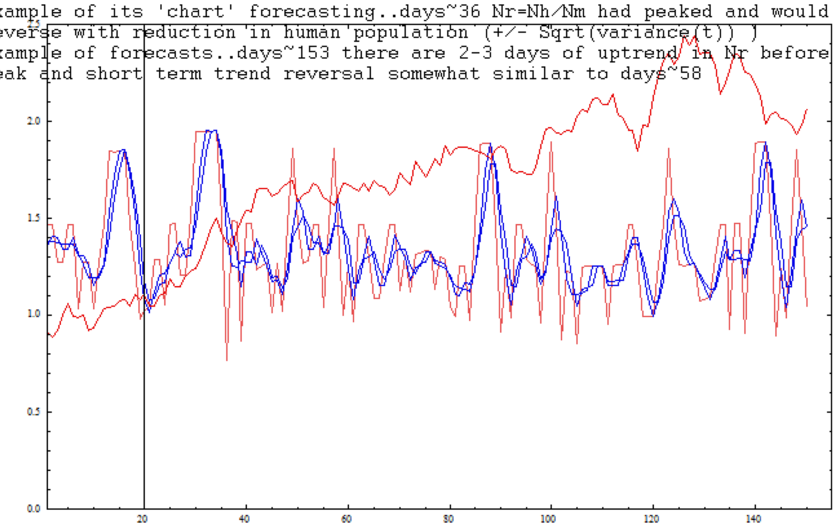


Fig.9 The susceptibility of the system to 'trend', or the 'Phase Change' susceptibility (from water to ice, magnet to nonmagnet, stable market to a crash, stable populations to epidemic affected...) in interacting many-particle physics...scaled with time dependent volatility (variance).
Reliable at sharp changes nearing the 'allowed' limits by probability of trend days either uptrending or downtrending..

Example of its 'chart' forecasting..days~36 Nr=Nh/Nm had peaked and would reverse with reduction in human population (+/- Sqrt(variance(t)))
Example of forecasts..days~153 there are 2-3 days of uptrend in Nr before a peak and short term trend reversal somewhat similar to days~58



References

[1] Fredrick Michael 2011 . http://www.ssrn.com/author=1705381 .

[2] John Evans and Fredrick Michael 2001. http://www.arXiv.org cond-mat ”Towards a Non Extensive Random Matrix Theory” . John Evans and Fredrick Michael 2002. http://www.arXiv.org cond-mat ”Rando Matrix Theory ...Quantum Chaos”. Fredrick Michael 2012 http://www.pittnachioff.com ’capabilities’ pages, and Agathos Scientific http://www.agathosscientific.org working papers (working papers 2008, preprint 2012).

[3] Fredrick Michael & M.D. Johnson. Physica A 2002. Institute of Physics.

[4] Fredrick Michael, John Evans and M.D, Johnson 2001. http://www.arXiv.org cond-mat ”Nonextensive Interacting Financial Markets Models ” .

[5] Fredrick Michael & M.D. Johnson. Physica A 2003. European IOP Institute of Physics.

[6] S. Rajagopal http://www.arxiv.org cond-mat 2002 ”Nonextensive Quantum Mechanics” and references therein.

[7] Gerald Mahan 2nd ed. ”Many-Particle Physics” Springer 1999.

[8] Risken, H. The Fokker-Planck Equation . Springer 2nd ed. 1997.