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ALGEBRAIC K-FLOWS

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The algebraic approach to the study of Statistical Mechanics suggests an expansion of classical ergodic theory to a noncommutative ergodic theory. We indicate here how one can proceed in this spirit to generalize the classical concept of a Kolmogorov-Sinai flow.

Firstly we recall that a classical K-flow is constituted by: a probability space (Ω,Σ,μ) , a measurable group $\{T(t)\,|\,t\in R\}$ of measure preserving transformations of (Ω,Σ,μ) , and a partition $\xi\subset\Sigma$ such that:

(i) $\xi\subseteq T(t)[\xi]$ $\forall t\geq 0$; (ii) $\bigwedge_{t\in R}T(t)[\xi]=\hat{0}$; (iii) $\bigvee_{t\in R}T(t)[\xi]=\hat{1}$.

Secondly we construct from these elements: a separable Hilbert space $\mathfrak{H}=L^2(\Omega,\mu)$, a maximal abelian von Neumann algebra $\mathcal{R}=L^\infty(\Omega,\mu)$ acting on $\mathfrak{H}$, a cyclic and separating vector $\Phi(\omega)=1\ \forall\omega\in\Omega$ for $\mathcal{R}$ in $\mathfrak{H}$, a faithful normal state on $\mathcal{R}$ $\phi: f\in\mathcal{R}\mapsto\langle\phi;f\rangle=(f\Phi,\Phi)=\int f(\omega)d\mu(\omega)$, a continuous group of automorphisms of $\mathcal{R}$ $\alpha(t):f\in\mathcal{R}\to\alpha(t)[f]=f\circ T(t)$, and a von Neumann subalgebra $\mathcal{A}$ of $\mathcal{R}$ $\mathcal{A}=\{\chi_\Delta\,|\,\Delta\in\xi\}''$ with the properties:

(i) $\mathcal{A}\subseteq\alpha(t)[\mathcal{A}]\ \forall t\geq 0$; (ii) $\bigwedge_{t\in R}\alpha(t)[\mathcal{A}]=CI$; (iii) $\bigvee_{t\in R}\alpha(t)[\mathcal{A}]=\mathcal{R}$.

Thirdly we notice that a standard representation theorem allows to get back to the original definition from $(\mathcal{R},\phi,\alpha,\mathcal{A})$ where: $\mathcal{R}$ is an <u>abelian</u> von Neumann algebra acting on a separable Hilbert space $\mathfrak{H}$, ϕ is a faithful normal state on $\mathcal{R}$, $\alpha: R\to \mathrm{Aut}(\mathcal{R},\phi)$, and $\mathcal{A}$ is a completely selfrefining , generating von Neumann subalgebra of $\mathcal{R}$.

Fourthly the generalisation to the noncommutative domain now consists exactly in taking the above as an alternative definition of a classical K-flow, and in dropping from this definition the condition that $\mathcal{N}$ be abelian. For reasons which would be too long to make explicit here we also impose that $\mathcal{A}$ be stable under the modular automorphism group $\{\sigma_\phi(t) | t \in R\}$ canonically associated to ϕ, and that every maximal abelian subalgebra $\mathcal{K}$ of the centralizer $\mathcal{N}_\phi$ of $\mathcal{N}$ be already maximal abelian in $\mathcal{N}$. (Notice that both of the last two conditions are redundant when $\mathcal{N}$ is abelian since $\sigma_\phi(t) = id \; \forall \; t \in R$ in this case.)

We now can emphasize [1] that algebraic proofs can be given to several theorems which are well-known in the classical case, and which thus do generalize to the new situation just defined. For instance the system $(\mathcal{N}, \phi, \alpha, \mathcal{A})$ is ergodic (i.e. $N \in \mathcal{N}$ and $\alpha(t)[N] = N \; \forall \; t \in R \Rightarrow N = \lambda I$ with $\lambda \in C$); it is mixing (i.e. $<\phi; N\alpha(t)[M]> \to <\phi;N><\phi;M>$ as $t \to \pm\infty$ for all $N, M \in \mathcal{N}$); it has Lebesgue spectrum (i.e. $\alpha(t)$ is spatial and the generator H of the corresponding unitary group on $\mathfrak{H}$ has the property $Sp(H) = Sp_d(H) \cup Sp_{ac}(H)$ with $Sp_d(H) = \{0\}$ simple and $Sp_{ac}(H) = R$ has countable muliplicity). Furthermore a noncommutative entropy can be defined [2] which is strictly positive for all such systems.

We next remark that the generalization is genuine in the sense that, in addition to the classical case where $\mathcal{N}$ is abelian, there exist [1,3,4] K-flows where $\mathcal{N}$ is of type II_1, $III_\lambda (0 < \lambda < 1)$, or III_1 .

Finally a link has been established [3] between certain quantum transport phenomena, governed by an evolution equation of the diffusion type, and the generalized K-flows presented here.

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