



ABSTRACTS

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**MATHEMATICAL ANALYSIS AND ITS
APPLICATIONS IN MODERN
MATHEMATICAL PHYSICS**

PART I

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September 23-24, 2022**

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APPLICATIONS IN MODERN MATHEMATICAL
PHYSICS

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PART I

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holds for $|p - p'| \rightarrow 0$ and $z \rightarrow -0$.

We remark that Theorems 1, 2 and 3 are play key role in the spectral analysis of the family of 3×3 operator matrices, associated with the lattice systems describing two identical bosons and one particle, another nature in interactions, without conservation of the number of particles.

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On invariant sets of a quadratic non-stochastic operator

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Non-linear dynamical systems arise in many problems of biology, physics and other sciences. In particular, quadratic dynamical systems describe the behavior of populations of different species with population models [1, 2, 3]. Let $E = \{1, 2, \dots, m\}$. A distribution on the set E is a probability measure $x = (x_1, \dots, x_m)$, i.e., an element of the simplex:

$$S^{m-1} = \{x \in R^m : x_i \geq 0, \sum_{i=1}^m x_i = 1\}.$$

In general, a quadratic operator V , $V : x \in R^m \rightarrow x' = V(x) \in R^m$ is defined by:

$$V : x'_k = \sum_{i,j=1}^m P_{ij,k} x_i x_j, \quad k = 1, \dots, m \quad (1)$$

In this talk we are interested to a non-stochastic quadratic mapping of simplex to itself, i.e. $V : S^{m-1} \rightarrow S^{m-1}$.

Definition. [3] A quadratic operator (1), preserving a simplex, is called non-stochastic (QuSO) if at least one of its coefficients $P_{ij,k}$, $i \neq j$ is negative.

Consider the following example of QuSO on the two-dimensional simplex S^2 .

$$\begin{cases} x' = \frac{1}{2}(z-y)^2 + \frac{3}{2}x(y+z) \\ y' = \frac{1}{2}(x-z)^2 + \frac{3}{2}y(x+z) \\ z' = \frac{1}{2}(y-x)^2 + \frac{3}{2}z(x+y). \end{cases} \quad (2)$$

Fixed points. The fixed points are solutions to the system (2)

$$\begin{cases} x = \frac{1}{2}(z-y)^2 + \frac{3}{2}x(y+z) \\ y = \frac{1}{2}(x-z)^2 + \frac{3}{2}y(x+z) \\ z = \frac{1}{2}(y-x)^2 + \frac{3}{2}z(x+y). \end{cases}$$

By full analysis this system one obtains the following family of fixed points:

$$a_1 = (0, \frac{1}{2}, \frac{1}{2}), \quad a_2 = (\frac{1}{2}, 0, \frac{1}{2}), \quad a_3 = (\frac{1}{2}, \frac{1}{2}, 0), \quad a_4 = (\frac{1}{3}, \frac{1}{3}, \frac{1}{3}).$$

Thus a_1 , a_2 and a_3 are saddle, but a_4 is an attracting fixed point.

Invariant sets. Recall that a set M is called invariant with respect to an operator V if $V(M) \subseteq M$.

Introduce the following sets:

$$M_1 = \{(x, y, z) \in S^2 : x > y > z > 1/6\},$$

$$M_2 = \{(x, y, z) \in S^2 : x > z > y > 1/6\},$$

$$M_3 = \{(x, y, z) \in S^2 : y > x > z > 1/6\},$$

$$M_4 = \{(x, y, z) \in S^2 : y > z > x > 1/6\},$$

$$M_5 = \{(x, y, z) \in S^2 : z > x > y > 1/6\},$$

$$M_6 = \{(x, y, z) \in S^2 : z > y > x > 1/6\}.$$

$$l_1 := \begin{cases} x = y \\ x + y + z = 1, \end{cases} \quad l_2 := \begin{cases} x = z \\ x + y + z = 1, \end{cases} \quad l_3 := \begin{cases} y = z \\ x + y + z = 1. \end{cases}$$

Theorem. The sets M_i , $i = 1, 2, 3, 4, 5, 6$ are invariant with respect to the operator (2). Moreover, each median of the simplex S^2 is an invariant.

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Comments on Chernoff and Trotter-Kato product formulæ

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The Chernoff \sqrt{n} -Lemma:

Lemma 1. Let bounded operator C on a Banach space \mathfrak{X} be a contraction, i.e., $\|C\| \leq 1$. Then one has the estimate

$$\|(C^n - e^{n(C-I)})x\| \leq \sqrt{n} \|(C-I)x\|, \quad x \in \mathfrak{X}, \quad n \in \mathbb{N}.$$

The following propositions revise the Chernoff \sqrt{n} -Lemma:

Proposition 1. Let C be contraction on a Banach space \mathfrak{X} . Then $\{e^{t(C-I)}\}_{t \geq 0}$ is a norm-continuous contraction semigroup on \mathfrak{X} and one has the estimate

$$\|(C^n - e^{n(C-I)})x\| \leq \frac{n}{\epsilon_n^2} 2\|x\| + \epsilon_n \|(I-C)x\|, \quad n \in \mathbb{N} \setminus \{0\},$$

for all $x \in \mathfrak{X}$ and $\epsilon_n > 0$. For optimal value of the splitting parameter ϵ_n one gets:

$$\|(C^n - e^{n(C-I)})\| \leq \frac{3}{2} \sqrt[3]{n} \|2(I-C)\|^{2/3},$$

which is called the $\sqrt[3]{n}$ -Lemma.

Proposition 2. Let $C \in \mathcal{L}(\mathfrak{X})$ be contraction on a Banach space \mathfrak{X} . Then following estimate

$$\|(C^n - e^{n(C-1)})x\| \leq \frac{n}{2} (\|(C-1)^2 x\| + \frac{\epsilon^2}{3} \|(C-1)^3 x\|),$$