Social Fröhlich condensation: preserving societal order through sufficiently intensive information pumping

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Andrei Khrennikov
Department of Mathematics, Linneuniversitet Fakulteten for Teknik, Vaxjo, Sweden

Abstract

Purpose – This paper aims to present the basic assumptions for creation of social Fröhlich condensate and attract attention of other researchers (both from physics and socio-political science) to the problem of modeling of stability and order preservation in highly energetic society coupled with social energy bath of high temperature.

Design/methodology/approach – The model of social Fröhlich condensation and its analysis are based on the mathematical formalism of quantum thermodynamics and field theory (applied outside of physics).

Findings – The presented quantum-like model provides the consistent operational model of such complex socio-political phenomenon as Fröhlich condensation.

Research limitations/implications – The model of social Fröhlich condensation is heavily based on theory of open quantum systems. Its consistent elaboration needs additional efforts.

Practical implications – Evidence of such phenomenon as social Fröhlich condensation is demonstrated by stability of modern informationally open societies.

Social implications – Approaching the state of Fröhlich condensation is the powerful source of social stability. Understanding its informational structure and origin may help to stabilize the modern society.

Originality/value – Application of the quantum-like model of Fröhlich condensation in social and political sciences is really the novel and original approach to mathematical modeling of social stability in society exposed to powerful information radiation from mass-media and Internet-based sources.

Keywords Social Fröhlich condensate, Societal stability, Order preserving, Quantum-like modeling, High social temperature, Information field, Information reservoir, Bose-Einstein statistics, Planck formula, Information overload, Indistinguishability, Social energy, Social atoms

Paper type Conceptual paper

1. Introduction

The debate about how much knowledge from physics can be effectively applied to modeling of human individual and collective behavior has long history, starting with psychodynamics project of Freud (1953) and structured nowadays in the framework of socio-physics (Galam, 2012). In this paper, we are especially interested in applications of the formalism of statistical mechanics and thermodynamics (both classical and quantum) to human sciences. Author's interest to such applications was initiated by the book of Schrödinger (1989), where he presented in the simple way the essence of the Gibbs (1928) approach to thermodynamics.

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The latter is based on consideration of virtual ensembles, instead of the real physical ensembles. Schrödinger did the important additional step towards decoupling of the formalism from the physical specialties by declaring that *energy* need not be considered as a special physical property of a system, but this is just *an observable quantity determined by a measurement procedure*. The crucial step in decoupling of the formalism and physics was done in two articles (Jaynes, 1957a, b). Since these works are not so widely known even in physics, we shall present the essence of the Jaynes' framework in Appendix 1. This can be generally useful for people working in applications of physical methods to humanities.

In this paper we demonstrate the possibility of applications of classical and quantum thermodynamics to modeling of social processes by considering *Fröhlich condensation* (Fröhlich, 1968a, b, 1970, 1975, 1977). As the illustrative example, we study the problem of order stability in an informationally open society exposed to powerful pumping of information and coupled to a huge reservoir of *social energy*. The latter is composed of the Internet-based information systems, including variety of social media platforms. This model can be applied to model the long-term order stability in democratic societies as in the USA and EU-countries, Australia, Canada; at least before pandemic of COVID-19. The latter essentially disturbed the social Fröhlich condensate.

Of course, the paper is not meant to provide a definitive model to establish social stability but rather to introduce an alternative way, based on physical concepts, to tackle societal problems.

By using mathematical models, one has always to remember that they are idealizations of the real phenomena [1]. Of course, "open societies" are not completely open and here censorship plays the important role. Another important remark is that thermodynamical stability is always accompanied by fluctuations. For human systems, such spikes of instability can have the form of demonstrations up to clashes with police and even army. Nowadays an essential part of large scale mass protests which often lead to color revolutions can be described by *the social laser theory* (Khrennikov, 2015b, 2016, 2018, 2020a, b, Khrennikov *et al.*, 2018, Khrennikov *et al.*, 2019), see Appendix 2 on social laser and a discussion on generation of societal instabilities, in authoritarian vs. democratic countries.

As was pointed out in paper (Wiesner *et al.*, 2019), "The idea that democracy is under threat, after being largely dormant for at least 40 years, is looming increasingly large in public discourse [2]. Complex systems theory offers a range of powerful new tools to analyse the stability of social institutions in general, and democracy in particular. What makes a democracy stable? And which processes potentially lead to instability of a democratic system?" The present paper suggested the answers to these questions within the paradigm of Fröhlich condensation.

As was emphasized by Waldner and Lust (2018): "we lack theories to explain backsliding *(from democracy)*, though we have long engaged in a perhaps interminable debate about the causes of democratic transitions, democratic breakdowns, authoritarian resilience and democratic consolidation". And there is a lack of work on the question of under which circumstances might instability in the democratic society can arise. In our framework instability is a consequence of violation of conditions for Fröhlich condensation. We remark that socio-physics presented a few models for generation instability, e.g. the model of opinion dynamics was developed by Galam (2012) to analyze minority opinion spreading which can lead to destabilization of democratic countries (See alsoMaass and Clark, 1984). We also point to numerous papers in traditional social and political sciences handling the problem of societal stability vs. instability, (see, for example Gilboa and Matsui, 1991; Feldman, 1997; Birner and Ege, 1999; Kay and Friesen, 2011; Hsiang and Burke, 2014; Li and Xi, 2019; Censolo and Morelli, 2020; Kachur *et al.*, 2020, van Bezouw *et al.*, 2021).

In the authoritarian society, order is preserved through establishing numerous constraints, including restrictions on information delivery and absorption. Since information carries social energy, such information restrictions can be considered as restrictions on highly energetic information flows (censorship, information filtering). The state authorities understand well the social energizing power of information and try to restrict it via the physical control. In spite such restrictions, some individuals are able to approach the state of high social energy and be stationary in such states. The corresponding population shifts can become substantial. In all authoritarian societies these passionate people [3] are the permanent disturbing factor. Physical struggle with those highly excited shifts of society and even elimination active people from social life (prisons, concentration camps, death penalties) led to distraction of economics, science and literature and arts.

In terms of social temperature, we can say that authoritarian ruling is directed to freezing of society, so to say up to absolute zero. As we known from physics, total isolation and freezing is expansive and demands a lot of energy. To preserve social stability through isolation, the regime should pay double price in social energy: 1) essential part of social energy is used to eliminate passional societal shifts; 2) the energy of passionate people is simply destroyed without being used for the needs of society. This social energy misuse is one of the main causes leading authoritarian regimes to collapse. They collapse, in spite of approaching high homogeneity in social energy structure of population.

What is an alternative to the "freezing control of society" (based on restriction of information flows carrying social energy)? This is the democratic control based on powerful information flows and creation of information reservoir (bath) with high social temperature. *How can such a highly energetic stability be modeled mathematically?* It happens that the corresponding model is widely used in bioscience and it is known as the model of *Fröhlich condensation* (Fröhlich, 1968a, b, 1970, 1975, 1977). This phenomenon can be mathematically structured in the framework quantum-like modeling similarly to the recently developed theory of information thermodynamics (Khrennikov, 2004, 2005, 2010a) and social (information) laser (Khrennikov, 2015b, 2016, 2018, 2019, 2020a, b, Khrennikov *et al.*, 2018, 2019; Tsarev *et al.*, 2019; cf. with genuine quantum theory for biological Fröhlich condensation, Wu and Austin, 1981; Zhang *et al.*, 2019).

Quantum-like models reflect the features of biological, cognitive and socio-political processes which naturally match the quantum formalism. In such modeling, it is useful to explore *quantum information theory,* which can be applied not just to the micro-world of genuine quantum systems. Generally, systems processing information in the quantum-like manner need not be quantum physical systems; in particular, they can be macroscopic biological or social systems. Surprisingly, the same mathematical theory can be applied at all biological scales: from proteins, cells and brains to humans and social systems; we can speak about *quantum information biology and sociology* (Asano *et al.*, 2015a). We remark that during the last 10 years quantum-like modeling flowered by attracting the interest of experts in cognition, psychology, decision making, economics and finance, social and political sciences (see Asano *et al.*, 2015b; Bagarello, 2012; Basieva and Khrennikov, 2017; Busemeyer and Bruza, 2012; Busemeyer *et al.*,. 2014; Dubois, 2009, 2014; Dubois and Toffano, 2016; Khrennikov, 2010b, 2015a; Khrennikova, 2016, 2017; Toffano, 2020a, Toffano and Dubois, 2020, for a sample of papers; googling on "quantum-like" gives around 250,000 references). Applications to social and political sciences are not restricted to theory of social laser, (also see Haven and Khrennikov, 2013; Robinson and Haven, 2015, Haven *et al.*, 2017).

We also remark that above discussion on concentration of population of authoritarian societies at the lowest social energy state can be modeled with the social analog of the phenomenon of Bose–Einstein condensation. In this paper we restrict the analogy to just this remark, we plan to elaborate this theme in one of further publications.

Finally, we make a remark on the general methodology of socio-physics (in particular, its quantum-like counterpart) and application to stability vs. instability of human societies. This methodology essentially differs from the traditional methodology of social, political and behavioral sciences (Golec de Zavala and Cichocka, 2012). The latter is directed to analysis of social and behavioral specialties of people leading to *social conflicts and protests*. For example, "social psychology explores the causes of the thoughts, feelings and actions of people and thus has a lot to offer to the study of social conflict and protest involve different motivational dynamics." (Van Stekelenburg, and Klandermans, 2013). In the probabilistic socio-physical approach one is not interested in concrete causes which are favorable for stability of social structures or to their disturbance, e.g. in the form of mass protests or even color revolutions. For example, the social laser theory (Appendix 2) presents the abstract framework of generation of social tsunamis. The national, economic, or historical specialties of a country which population is involved in the process of social lasing are not described by the theory. We are neither interested in concrete leaders of countries or oppositions; even concreteness of the cases leading to ignition of lasing (say killing of George Floyd in May 2020 in the USA) are not important [4]. Only basic features of "social atoms" and their interaction with the information field carrying social energy (section 2.2, 2.3) are examined. In the same way Newton's gravity law is valid for all bodies; planets are very different (material composition, age, atmosphere) but they follow the same law. Abstractness and generality are one of the distinguishing features of both physical and socio-physical modeling. Of course, this approach to modeling of social behavior does not contradict to the traditional sociology and social psychology which are interested, for example, in the concrete situation and humans' psychology which lead to societal stability vs. conflict. In the same way, one can study not only motion of a planet around Sun but say its atmosphere and other features.

2. The model: social analogs of conditions for Fröhlich condensation

We suggest applying the Fröhlich formalism to social energy and systems. We start with establishing correspondence between the components of the Fröhlich model (Fröhlich, 1968a, b, 1970, 1975, 1977) and social entities. We use quantum-like formalization of works on social laser (Khrennikov, 2020a, b). Fröhlich by himself did not appeal directly to the quantum formalism. He used the methods of mesascopic physics and thermodynamics in the spirit of early Einstein's works on spontaneous and stimulated emission and absorption of quanta of the electromagnetic field. The quantum reformulation of the Fröhlich model was done in paper (Wu and Austin, 1981) and completed in the recent paper of Zhang *et al.* (2019). For us it is convenient to proceed within similar framework because the quantum methodology provides the possibility to define the basic social entities formally, as quantum observables, and without to go deeply in social, psychological, cognitive and even neurophysiological issues.

Although the quantum-like formalization is based on the standard technique of open quantum systems (Ingarden *et al.*, 1997), Fröhlich condensation is a very delicate phenomenon and its occurrence is constrained by a few conditions of thermodynamical and quantum information nature. We formulate these conditions within discussions of the corresponding components of the model and then summarize them in section 3. On the other hand, we are not aimed to present the formal quantum-like derivation in the social framework; this will be done in one of the future works. The aim of the present paper is to discuss the basic social issues related to Fröhlich condensation.

2.1 The original biological model

Fröhlich considered in a biosystem (1) oscillating segments of giant dipoles in macromolecules and (2) a heat bath; say protein molecular in a cell filled with solution. The system is open and it is exposed by an external energy pump which couples to the oscillating units. Each unit is involved in processes of (1) direct energy absorption from external supply, (2) energy exchange with the heat bath, (3) redistribution of energy between the levels (E_i). Fröhlich found conditions on supply, bath and biounits which lead to concentration of all excitations in a biounit at the lowest positive energy mode E_1. But, this energy mode can be sufficiently high, i.e. this is not the Bose–Einstein type condensation around zero temperature. In contrast, temperature T of surrounding bath has to be sufficiently high.

2.2 Social energy and social atoms

The notion of social energy (*S*-energy) has already been elaborated in very detail in social laser theory (Khrennikov, 2020a,b). In contrast to works of psychologists and sociologists (starting with James, Freud and Jung), we introduce *S*-energy operationally, as an observable on social systems (see Appendix 1 for detailed presentation). Mathematically it is described as a quantum observable, i.e. by a Hermitian operator acting in the complex Hilbert space of mental states of humans. A human, a discrete indivisible system, is a social analog of atom - *S*-atom (again see Appendix 1). Any *S*-atom is characterized by its *S*-energy spectrum:

$$E_{0a} < E_{1a} < E_{2a} < \ldots < E_{Ma} \quad (1)$$

The ground state mode $E_{0a} \approx 0$ corresponds to the total relaxation of *S*-atom, the state of the passive rest; $E_{1a} > 0$ is the lowest active state mode.

In our previous works on social lasing, we considered mainly two level *S*-atoms (or following the physical lasing technology, 3–4 level *S*-atoms). The Fröhlich formalism handle multilevel systems, i.e. n can be sufficiently large. This is more realist situation; humans are socially complex systems and their energetic behavior is characterized by the multilevel structure.

Mental states are characterized by *S*-energy and additional variables (similar say to photon's polarization or direction) which were called in monograph (Khrennikov, 2020a, b) quasicolor of the mental state, $|\psi\geq |E_{ka}\alpha>$, where E_{ka} is the energy level and α-quazicolor. In this paper, the supplementary social observables are not considered and only the *S*-energy states ($|E_{ka}>$) are of the interest. Generally *S*-atom's state can be in superposition of these eigenstates:

$$|\psi\rangle = \sum_k c_k |E_{ka}\rangle \quad (2)$$

where c_j are complex probability amplitudes,

$$\Sigma |c_k|^2 = 1.$$

They encode the probabilities to find *S*-atom in the corresponding *S*-energy states

$$p_j = |c_j|^2 \quad (3)$$

We repeat once again that the *S*-energy of the *S*-atom should not be treated as its objective property; this is just a possible output of some special measurement procedure. In the same way, the physical energy of photon is not photon's internal property; this is an outcome of its interaction. We keep to the Copenhagen interpretation and do not assign any objective meaning to superposition (2). Following to Schrödinger, we consider it as an expectation catalog for outcome of measurement.

2.3 Information reservoir–social energy bath

One of the basic elements of the model is *the information reservoir*. It is composed of all possible types of information stored in published newspapers, journals, movies, videos, Internet-based social networks. The reservoir includes the business-information sea, including data on economics, finance, social and political situations, medicine and medical care, science (online lectures and videos, webinars, Wiki). S-atoms are involved in information exchange with this reservoir. They emit as well as absorb information excitations in the form of conversations, comments and posts, e.g. in YouTube, Twitter, or Telegram, different data bases.

Since information excitations carry quanta of S-energy, the information reservoir around S-atoms is at the same time the S-energy bath. And S-atoms exchange with it by quanta of S-energy. (We generally explore the duality between flows of information and social energy.)

One of the basic conditions for derivation of the Fröhlich condensation regime is the validity of the Planck formula for the average number of excitations corresponding to the concrete energy level. Consider the S-energy bath characterized by the spectra:

$$E_{0b} < \ldots < E_{kb} \tag{4}$$

Then the Planck expression has the form:

$$N_{ib} = 1/(\exp\{E_{ib}/\lambda\} - 1) \tag{5}$$

where the parameter λ has the dimension of energy. In physics, $\lambda = KT$, where T is temperature and K is the Boltzmann constant.

This formula can be derived by using the Gibbs methods of virtual ensembles (see Schrödinger, 1989). It is applicable to any type of systems, including social systems. To get the Bose–Einstein statistics, we have to assume that S-energy quanta are *indistinguishable* (and exclude the Fermi–Dirac and parastatistics).

Indistinguishability of information quanta is a consequence of very big volume of information stored in the reservoir. S-atoms are not able to analyze consciously the information content which delivered permanently via numerous channels coupling it to the reservoir, sms, comments, posts, video.... The main characteristic of such information exchange is S-energy content. Of course, this is not a complete contentless exchange. However, S-atom distinguishes communications by just a few parameters forming aforementioned quazicolor α. This is clip-thinking, popcorn brain functioning, violation of the laws of Boolean logic (see Khrennikov, 2020a, b) for details.

2.4 Quantum information field

Another basic mathematical entity of the quantum-like model is the quantum information field. It formalizes mathematically external supply of S-energy into S-atoms population. It is generated by mass media including internet-based information sources; this delivery is characterized by concentration on a few social energy modes. Consider the S-energy spectra of external information field:

$$E_{0e} < \ \ldots \ < E_{me}. \tag{6}$$

The number of modes on which this field in concentrated is essentially less than in the information reservoir, in (4) k is essentially larger than m in (6). These are so to say the basic information flows, they are mainly highly energetic. Thus energy is delivered to the corresponding high energetic modes of S-atoms. The essence of Fröhlich condensation is that the high S-energy modes of S-atoms redistribute energy to lower energy modes and finally to the lowest active mode E_{1a}; a part of S-energy is emitted into S-energy bath (the information reservoir).

The field is the formal operator-valued entity expressed via the operators of creation and annihilation. We describe external S-energy supply with quantum information field. Mass-media including the Internet-based resources generate quanta of information associated with communications, the excitations of the field. Some quanta are absorbed inside the field (the information exchange between information delivery agencies), other quanta are absorbed by S-atoms. To behave quantumly, the information field should also satisfy the *indistinguishability* constraint, i.e. its excitations have to be identical up to their energy content. We repeat that we follow the Copenhagen interpretation and indistinguishability is feature of these quanta w.r.t. an observer, S-atom. The content indistinguishability regime is approached via *information overload*, i.e. field's intensity should be so high that S-atom would not be able to analyze communications carried by the field consciously. S-atom distinguish quanta only w.r.t. their energizing content. This model is oversimplified and in a more general model we consider additional information components of communications, quazicolor of the information excitation.

Indistinguishability and information overload go in tact with Fröhlich condensation: for the latter, intensity I of energy supply has to overcome some threshold I_0, i.e.

$$I \geq I_0 \tag{7}$$

The expression for threshold I_0 depends on energy spectra and a few other model's parameters.

2.5 Storage of social energy

The E_{1a}-mode is used for S-energy storage. In the absence of external energy supply, the population of S-atoms approaches the state of thermodynamics equilibrium and the majority of S-atoms are concentrated at the ground state $|E_{0a}$i. This is the simple consequence of the Planck formula:

$$n_{ia} = 1/(\exp\{E_{ia}/\Lambda\} - 1) \tag{8}$$

The term with $E_{0a} \approx 0$ strongly dominates over other terms and

$$n_{0a} \gg n_{1a} > \ldots > n_{Ma}.$$

Only for sufficiently high I (see (7)) the tendency of S-atoms to relax completely can be overcome and they can be concentrated at the active states with $i > 0$. This possibility to store energy in society is one of the distinguishing features of social Fröhlich condensation.

2.6 Social temperature

The formal operational determination of social temperature is based on determination of a class of measurement E_{ib} procedures and calibration. In contrast to physical temperature, such procedures are not well elaborated. Another possibility is to determine social temperature thermodynamically.

For the equilibrium state the parameter λ can be determined from the Planck formula (11):

$$\lambda = E_{ib}/\ln(1 + 1/N_{ib}), \tag{9}$$

The crucial feature of the equilibrium state that the right-hand side does not depend on i; it is homogeneous w.r.t. the energy spectrum of the reservoir, in our case the information reservoir. This feature can be used as a test for approaching of the information equilibrium state.

Then social temperature can be defined as scaling of λ by any parameter k with dimension energy/temperature. So,

$$T = E_{ib}/\mathrm{k}\ln(1 + 1/N_{ib}) \tag{10}$$

(Even in physics selection $k = K$ is just the subject for the agreement.) Thus we can write the Planck formula in same way as in physics:

$$N_{ib} = 1/(\exp\{E_{ib}/kT\} - 1) \tag{11}$$

The information reservoir with high social temperature is characterized by the large number of information communications carrying highly S-energetic excitations. If social temperature is low, then the majority of information communications carry low S-energetic excitations. Now we are ready to formulate social analog of the high temperature regime: $kT >> E_{1a}$. The information reservoir has to be hot and characterized by the presence of the large number of "exciting communications", news, videos, tweets, comments. In particular, the presence of a variety of hot news is the important condition for creation of social Fröhlich condensate.

One of the determining constants on social bath leading to Fröhlich condensation is the high temperature regime, i.e.

$$\lambda = kT \gg E_{1a}. \tag{12}$$

So, social temperature of the information reservoir has to be sufficiently high. Fröhlich condensation is impossible in cold social bath. This phenomenon is possible only in the information reservoir which is full of hot news, comments, posts and conversations. For societal stability, such hot information is crucial. This is the very special feature of this phenomenon: order and stability not via social cooling, but via social heating: *more shock news and information–higher degree of stability*.

2.7 Summary for conditions leading to Fröhlich condensation

(1) Discreteness of S-energy spectra for socio-information systems: S-atoms, social bath (information reservoir), information field; see (1), (4), (6).

(2) Indistinguishability, up to S-energy, of information excitations (more generally up to some additional characteristics–quazicolor).

(3) Bose–Einstein statistics of S-excitations filling social bath–the Planck formula (11).

(4) Sufficiently high intensity of external information supply, (7).

(5) High temperature of social bath (information reservoir), (12).

(6) Big S-energy capacity of social bath.

3. Stability and order preservation in highly informationally energized society

Social realization of the phenomenon of Fröhlich condensation provides a mathematical model for order preservation in the informationally open society such as in the democratic states of Europe, the USA, Canada and Australia. In contrast to the authoritarian states such as North Corea, China, Russia, Iran, the open societies are characterized by the absence of censorship and restrictions on information distribution [5]. To some surprise, intensive information supply, high social temperature in combination with the big information reservoir leads to concentration of social energy at the lowest active energy mode E_{1a}. This is done via redistribution of S-energy between the energy levels of S-atoms. The information reservoir (social bath) also absorbs a part of energy. But the main part of energy is stored at the lowest nontrivial mode E_{1a}. In this way the open society solves jointly the two problems: (1) peaceful elimination of passionate part of population; (2) sustainable functioning at the energy mode E_{1a}. This mode, although not very high, i.e. $E_{1a} << E_{Ma}$, is still essentially high, typically $E_{1a} >> E_{0a}$. The majority or population is full of social energy which is sufficient for active economic and societal life. At the same time the high energy states $E_{ja}, j >> 1$, are not attractors and an S-atom with high probability makes transition from $|E_{ja}>$ to $|E_{1a}>$ (generally via a chain of transition via intermediate states).

In spite of the absence of straightforward censorship [6] and rather smooth actions of the state repressive apparatus (comparing with dictatorial regimes), society escapes really disturbing protests and revolutions (including color revolutions) [7]. Of course, relatively mass protests happen in the open societies, but they are not dangerous for stability of the democratic regimes. For example, consider the recent COVID-19 protests in Berlin, August 1, 2021. Although videos showed huge crowds of angry people, the real number of demonstrates was around 30,000, comparing with population of Germany this number is negligible.

Although stability of the society and active and creative stability can be considered as its strong side, the total elimination of passional modes makes society grey-homogeneous. This is the good place to cite "Screwtape" of Lewis (1994):

"You are to use the word ('democracy') purely as an incantation; if you like, purely for its selling power. It is a name they venerate. And of course it is connected with the political ideal that men should be equally treated. You then make a stealthy transition in their minds from this political ideal to a factual belief that all men are equal. Especially the man you are working on. As a result, you can use the word democracy to sanction in his thought the most degrading (and also the least enjoyable) of human feelings. You can get him to practise, not only without shame but also with a positive glow of self-approval, conduct which, if undefended by the magic word, would be universally derided. The feeling I mean is of course that which prompts a man to say I am as good as you.

The first and most obvious advantage is that you thus induce him to enthrone at the center of his life a good, solid, resounding lie. I do not mean merely that his statement is false, and in fact, he is no more equal to everyone he meets in kindness, honesty and good sense than in height or waist measurement. I mean that he does not believe it himself. No man who says I am as good as you believe it. He would not say it if he did. The St. Bernard never says it to the toy dog, or the scholar to the dunce, or the employable to the bum, or the pretty woman to the plain. The claim to equality, outside the strictly political field, is made only by those who feel themselves to be in some way inferior. What it expresses is precisely the itching, smarting, writhing awareness of an inferiority which the patient refuses to accept."

We repeat once again that indistinguishability is the fundamental property of social systems leading to quantum statistics of S-energy distribution and the possibility to use quantum information societal control, including Fröhlich condensation. This is the price for stability of open society.

4. Conclusion

Under assumptions 1–6 (section 2.7), we can apply the quantum-like model of social Fröhlich condensation. This coherent condensation of population at the lowest active mode of S-energy explains stability of modern informationally open societies. This stability and order preservation are based on natural self-elimination of passionate individuals carrying too high S-energy; the individuals who in principle can destroy social order and generate various instabilities. This self-regulation is based on S-energy redistribution between states of S-atoms and active S-energy exchange with the information reservoir and external information field. The crucial condition of creation of social Fröhlich condensate is the loss of individuality of humans as well as the loss of the ability for detailed analysis of information based on the rules of classical Boolean logic. The latter is a consequence of information overload generated by external information supply. To create the stable social Fröhlich condensate, this supply should be very intensive–over some threshold depending on model's parameters.

Notes

1. For example, even in physics, only for simplest atoms as hydrogen, the structure of energy levels can be straightforwardly described by the quantum formalism with the Schrödinger equation. And one has to use the phenomenological *Hartree–Fock equation* to find approximate solutions matching with the experimental data.
2. "In the period since then, in just over 8 years, more than 1700 articles appeared on that topic, with the first 5 months of 2018 ($N = 309$) already topping the total for all of 2017 ($N = 304$)." See again (Wiesner *et al.*, 2019).
3. See, e.g. (Gerber, 1997; Winch, 2002; Hill, 2006; Kasser, 2013; Southworth, 2016; Thakkar, 2021), on the role of passionate people in society.
4. This concrete case would not lead to mass protests if it were not highlighted by mass-media and amplified by Internet-based Eco Chambers. The list of black people who were killed by American police in similar circumstances is very long, it includes hundreds (if not thousands) of names. The information power of mass-media ignited this social spike was essentially stimulated by coming elections.
5. Of course, we discuss the ideal situation. In reality even "open societies" are not totally open; even in say USA censorship exists, but it has more intelligent forms than say in Russia.
6. Officially censorship (the suppression of speech or public communication) in the United States is forbidden by the First Amendment to the United States Constitution.
7. This apparatus is the basic part of the state machines of even open societies. And a part of *S*-atoms in high energy states is controlled and often isolated in so to say unnatural way, i.e. without the Fröhlich condensation process. Drugs also play the important role in struggle with such highly energetic individuals. However, in any way these are just small fractions of population. The social thermodynamics makes the main job automatically. Once again, we discuss the situation in pre-COVID-19 times.
8. "Conventional arguments, which exploit all that is known about the laws of physics, in particular the constants of the motion, lead to exactly the same predictions that one obtains directly from maximizing the entropy. In the light of information theory, this can be recognized as telling us a simple but important fact: there is nothing in the general laws of motion that can provide us with any additional information about the state of a system beyond what we hate obtained from measurement. This refers to interpretation of the state of a system at time t on the basis of measurements carried out at time t." (Jaynes, 1957a)
9. We remark that, besides of physical lasers designed by people, there exist natural lasers, e.g. the cosmic ones.
10. Republican-oriented American press presented a plenty of materials on financial support of these mass protests from democratic-party funds.

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Appendix 1
Social physics

A1. Applicability of statistical mechanics outside of physics

We start with the extended citate from the famous paper Jaynes ():

"If one considers statistical mechanics as a form of statistical inference rather than as a physical theory, it is found that the usual computational rules, starting with the determination of the partition function, are an immediate consequence of the maximum-entropy principle. In the resulting 'subjective statistical mechanics,' the usual rules are thus justified independently of any physical argument, . . . they still represent the best estimates that could have been made based on the information available. It is concluded that statistical mechanics need not be regarded as a physical theory dependent for its validity on the truth of additional assumptions not contained in the laws of mechanics (such as ergodicity, metric transitivity, equal *a priori* probabilities, etc.)."

Following to Jaynes, we consider the following problem. The random variable x takes discrete values xi, (i = 1, . . ., n). We are not given the corresponding probabilities Pi; only expectation of some function f(x) is known:

$$< \mathrm{f} >= \mathrm{f(x1)P1} + \mathrm{f(x2)P2} + \ldots + \mathrm{f(xn)Pn} \tag{A1}$$

By having only this information (expectation value), what is the expectation value of another function g(x)? The problem seems to be unsolvable: the given information is insufficient to determine the probabilities Pi in equation (A1) and the probability normalization condition

$$\mathrm{P1} + \mathrm{P2} + \ldots + \mathrm{Pn} = 1 \tag{A2}$$

should be supplemented by (n > 2) more conditions.

The problem of specification of probabilities in the situation with little or no information available, is as old as the theory of probability (starting with Laplace). Jaynes suggested solving it by using *the principle of max-entropy*. Entropy is treated in the Shannon information framework:

$$\mathrm{S} = \mathrm{S(P)} = -[\mathrm{P1}\ln\mathrm{P1} + \mathrm{P2}\ln\mathrm{P2} + \ldots + \mathrm{Pn}\ln\mathrm{Pn}] \tag{A3}$$

Here one important remark on the interpretation of probability has to be done. As we know, there are two basic interpretations: *objective and subjective*. By the latter the *probability of an event is a quantitative expression of our expectation that the event will or did occu*r, based on whatever information is available. Jaynes stressed that the above problem of determination of the probability distribution P = (Pi) is meaningful only for the subjective interpretation. Information encoded in (A1) and (A2) is evidently insufficient to determine objective probabilities. But subjective probabilities can be assigned in many ways. Now, one has to suggest the optimal strategy for selection of the probability distribution P. Why should one consider the maximum of entropy? Entropy represents the measure of uncertainty in a probability distribution. Selecting P = (Pi) maximizing S is the fair choice, since it *minimize possible biases*. So, we have the constrained extremum problem. By inventing the Lagrangian multipliers μ and λ we get the following expression for probabilities:

$$\mathrm{Pi} = \exp\{-\lambda - \mu < \mathrm{f} >\} \tag{A4}$$

Define the partition function

$$\mathrm{Z}(\mu) = \Sigma\exp\{-\mu\,\mathrm{f(xi)}\}$$

Then the multiplier λ = ln Z(μ).

If function f is selected as energy, then the multiplier μ (known in statistical physics as the chemical potential) can be coupled with temperature, T = 1/k μ, where k is the Boltzmann constant. In this case one can introduce the free energy of the system:

$$\mathrm{U} - \mathrm{TS} = -\mathrm{kT}\,\mathrm{Z(T)}$$

As was stressed by Jaynes, this framework presents surprising simple derivation of all basic formulas of classical thermodynamics. In the second part of his paper Jaynes (1957b) generalized his approach to the quantum case.

Another surprising thing is that these formulas derived within the subjective probability framework coincide with formulas derived in classical physics with objective ensemble probabilities. Jaynes (1957a, b) analyzed the origin of this coincidence. Here we are not able to go into detail. Roughly speaking due to Jaynes essential part of the formalism of statistical mechanics is not coupled to concrete physical laws, but just a tool for prediction in context of insufficient information. In any event this viewpoint is very supportive for using the formalism of classical and quantum thermodynamics in cognitive and social sciences [8].

We point out that the subjective interpretation of probability can be used even straightforwardly. A scientist who makes predictions on the statistical behavior of some social group can directly apply the aforementioned part of the formalism of thermodynamics. This would be the best prediction based on the available information (even if P = (Pi) would deviate from the objective ensemble probability distribution). This point was highlighted in Jaynes (1957a, b).

A2. Psychic and social energy and measurement procedure

In psychology the notion of *psychic energy* (or *mental energy*) was introduced by James (1890) and Freud (1953). This is the energy by which the work of the personality is performed. Freud (1953) and then Jung (2001), see also (Jung and Pauli, 2014), actively operated with the concept of mental energies moving between conscious and unconscious, mental systems. Jung pointed out that psychic energy manifests itself through forces (actual or of potential) performing psychological work. Perceiving, remembering, thinking, feeling, wishing, willing, attending and striving are psychological actions as say motion or breathing are physical actions. The latter are based on physical energy and the former on the psychic energy. We remark that Freud considered psychic energy as a component of integral *psycho-physical energy,* and he built the detailed theory of transformation of physical energy of physiological processes in the nervous systems into psychic energy of unconscious and then of conscious. This theory is based on old-fashioned biological views. In principle, one can try to develop its modern version.

However, we prefer to proceed with the operational definition in the spirit of quantum theory, where *energy is introduced as observable* taking values (Ei) associated with special states ψi of a system S. Energy is characterized as the observable generating action. The latter has the dimension energy times time. For isolated systems, the states ψi are preserved and are not changed with time – the stationary energy states. The latter is the feature characterizing the energy-observable.

Social energy is the special form of psychic energy generating social actions. In the simplest scale the social energy observable takes just two values corresponding to the ground state and the excited state.

Now, we discuss the main problem: *the measurement problem*. Here, we can try to proceed with the following Jung's treatment of the problem of measurement of psychical energy. *The subjective estimate of social and private energies has to be combined with collective moral and esthetic values.* As an example, take the communications (July 2014) about the Boeing-777 crash in Donbas. The high value of social energy assigned to them is based on the moral values of the modern society. The communications about the previous crash of the Malaysian Boeing on the way to China carried essentially smaller energy, although the number of dead people was approximately the same as in Donbas.

The crucial difference from measurement of physical energy is that the outcomes of social energy observable are generated subjectively. The simplest measurement procedure can be designed for the dichotomous observable: E = +1 if a communication is exciting (has highly energetic level), E = 0, if a communication is nonexciting. The role of a measurement device is played by a person, call him an agent. He reads some communication (or see on the screen or as a video) and has to estimate the degree of excitement carried by it. In a socially homogeneous population reproducibility of the answers (w.r.t. selection of agents) should be sufficiently high.

This measurement is context dependent (as well as quantum measurements), where "context" is a socio-political context, "surrounding social atmosphere". In quantum theory the simplest form of contextuality is expressed via the join measurement of the basic observable A with some supplementary observable B. In our consideration A = E and as B we can select e.g. the truth-observable, B = +1, definitely true, B = 0, there are doubts that a communication is true (of course, finer scales can be considered).

A3. Social atom

The definition of the human being from an atomic point of view has long history: chemical entity (Johann Goethe, 1809), point atom (Humphry Davy, 1813) human molecule (Hippolyte Taine, 1869), social molecule (Thomas Huxley, 1871), economic molecule (Leon Walras, c. 1870s), human atom and human molecule (Ferninand Schiller, 1891), human molecule (Emile Boutmy, 1904), human molecule (Henry Adams, 1910), human chemical and human chemical element (William Fairburn, 1914), human molecule (Vilfredo Pareto, 1916), human molecule (Pierre Teilhard, 1947), social atom, acquaintanceship atom, collective atom, individual atom, psychological atom (Jacob Moreno, 1951), human molecule (C.G. Darwin, 1952), human atom (Erich Fromm, 1956), dissipative structure (Ilya Prigogine, 1971), human atomism (Arthur Iberall, 1987), social atom (Mark Buchanan, 2007), and many more. See (Thims, 2008).

Although these authors suggested different definition, generally they follow the same paradigm: operating with human beings as individual information processors described by just a few parameters characterizing information interaction. Thus, practically infinite complexity of human being was reduced to these basic parameters (in the simplest case to social energy). This reduction of complexity made humans treatable thermodynamically. On the other hand, ignoring human complexity diminishes the explanatory power of such models; typically, they can describe statistical behavior of humans, but not explain why they behave in one or another way.

The distinguished property of our approach is the quantum-like treatment of variables, as representing observations performed on S-atoms. Another distinguished property is invention of the information field, i.e. S-atoms can interact not only with each another (as in aforementioned theories), but also with the information field which is also interpreted and modeled in the quantum-like framework.

A4. From Bohr to measurement of mental observables

According to Bohr the outcomes of measurements of quantum observables cannot be treated as the objective properties of systems. They quantitively represent interrelation between a system *S* and an observer *O*. We can point to the famous citation (Bohr, v. 2, p. 40–41):

"This crucial point . . . implies the impossibility of any sharp separation between the behavior of atomic objects and the interaction with the measuring instruments which serve to define the conditions under which the phenomena appear. In fact, the individuality of the typical quantum effects finds its proper expression in the circumstance that any attempt of subdividing the phenomena will demand a change in the experimental arrangement introducing new possibilities of interaction between objects and measuring instruments which in principle cannot be controlled. Consequently, evidence obtained under different experimental conditions cannot be comprehended within a single picture, but must be regarded as complementary in the sense that only the totality of the phenomena exhausts the possible information about the objects."

Bohr's and generally Copenhagen's viewpoint on quantum observables is very supporting for our applications of the quantum methodology and formalism to humanities. This position had been already highlighted in quantum-like modeling, especially in authors' works, (e.g. Khrennikov, 2017, 2019). Mental observables, including social energy are not more exotic than quantum observables used in physics. Mathematically they can be modeled with the Hilbert space formalism, in the simplest case as Hermitian operators.

A5. Social temperature

As we have seen, temperature parameter can be introduced in theory via scaling of the chemical potential μ which in turn is introduced as one of the Lagrangian multipliers. Hence by justifying the notion of social energy as an observable we open the door to operating with the notion of social temperature. In principle, it can be identified with the chemical potential. One can proceed another way around to consider not energy, but temperature as the basic quantity (Jaynes, 1957a). It can also be handled as a mental observable, a kind of social thermometer.

Appendix 2

Social laser and instabilities in authoritarian vs. democratic societies

As was mentioned by Fröhlich (1968a, b, 1970, Fröhlich, 1975, 1977) as well as in works of Wu and Austin (1981), Zhang *et al.* (2019), Fröhlich condensation has some similarity with laser functioning. Both phenomena are based on elimination of all energy modes, besides one fixed mode. In Fröhlich condensation, this is the lowest active mode E_{1a}, in lasing this is the mode E_ν corresponding to the frequency of laser beam. Both processes generate coherent states. However, $|E_{1a}>$ is the stationary state and population of systems (giant dipoles in biomoleculaes) can stay in this state for very long time, but $|E_\nu>$ is not stable. Interaction with the external electromagnetic field generates stimulated emission of photons – the cascade process with the powerful beam of coherent radiation.

A social analog of laser was invented in papers (Khrennikov, 2015b, 2016). This social phenomenon was called Stimulated Amplification of Social Actions (SASA). It was used for modeling of so-called color revolutions and other applications of coherent social actions, including collective decision making on the state level. In the case of color revolution, the *S*-energy beam created in the information space is realized in physical actions, as mass protests, barricades and even bloody clashes with police and army. In the case of collective decisions actions are of the informational nature as well. We can mention the collective acceptance of COVID-19 pandemic restrictions of the basic human rights throughout the world in 2020–21. Only a negligibly small fraction of population did not accept this collective decision and participated in demonstrations against COVID-19 restrictions.

B1: How does a conventional laser work?

Stage 1: energy pumping.

(1) There is an active medium, a large ensemble of atoms. Energy is pumped into this medium, atoms are transferred to an excited state.

(2) Pumping occurs with quanta of light energy (excitations of the electromagnetic fields), photons.

(3) An unexcited atom, having eaten a photon, passes into a state of excitation.

(4) However, at any moment an atom can spontaneously fall into an unexcited state, spitting out the swallowed portion of energy. Energy pumping has to have sufficiently high intensity, higher than some threshold and the active medium reaches the state when more than half of the atoms are excited. This state is called *the population inversion state.* At first, almost all the atoms were in an unexcited state, and then, during the process of energy pumping, most became excited.

Stage 2: Stimulated emission.

(1) When active medium has approached the state of population inversion, a batch of coherent photons (quanta of energy) is injected into active medium. Photons fly in the same direction and they have the same characteristics.

(2) These injected photons generate the stimulated emission of photons (quanta of energy) by excited atoms.

(3) The main feature of emitted photons is their coherence copied from the injected photons.

(4) Each of emitted photons also interact with excited atoms and induce new emission – cascade process, exponential increasing of power!

Laser's resonator

To make the beam of photons even more powerful, laser is equipped with the resonator, typically optical cavity.

(1) The beam of photons generated from the initializing batch of photons should go back through the active media a few times, reflected within optical cavity.

(2) In this way, beam's power can be essentially increased.

B2. How does social laser work?

Social laser theory presents a general scheme for generating giant waves of social action. This scheme, like the scheme of a physical laser, is based on the two step process:

(1) Pumping the human medium with social energy.

(2) Stimulating coherent social action by injecting a batch of homogeneous messages into the agitated medium.

Modern powerful social resonators are based on Internet echo chambers, coupled to social networks.

B3. Social lasers as the powerful source of disturbance of social order: authoritarian vs. democratic societies

Since 1990s, social lasing generated a series of *color revolutions*; in particular, on the territory of former Soviet Union (e.g. Georgia, Kirgizstan (3 revolutions), Ukraine (2 revolutions), Belorussia, Armenia) and Arabic world (Tunisia, Libya, Egypt, South Yemen, Syria). Authoritarian regimes demonstrated instability w.r.t. social lasing. Some of them collapsed, others, as in Belorussia and Syria, still survive. We remark that according to socio-political studies color revolutions crucially differ from "traditional revolutions", as say the French and Russian revolutions. Color revolutions are characterized by the absence of ideology and bright leaders, they have the spike-like character with very short stages of up and down protesting, see (???).

What is the difference between authoritarian and democratic societies from the viewpoint of social thermodynamics?

We mathematically model stability of the open democratic society through creation of the social Fröhlich condensate. It cannot be created in the authoritarian society. There is no possibility for free flow of information and social energy is not redistributed between societal levels. If social energy pumping is sufficiently high, society approaches the state of population inversion. This process is also supported by the absence of a well-functioning reservoir of social energy (in the form of tense coupling of people with social networks) and the impossibility to express freely the opinions about the basic problems of society. In such societies the slice of highly excited people can grow during sufficiently long time. Finally, a sufficiently strong pulse of coherent information generates the cascade process of emission coherent social actions. The latter can essentially disturb this authoritarian society or even lead to its collapse.

In democratic society sporadic social lasing can also happen – both spontaneous [9] and driven by some political forces, as in June 2020 in the USA [10]. However, the slice of excited people is not so thick, but what is even more important the free distribution of information generates quick redistribution of social energy, from highly excited to less exited individuals and the wave of protests is quickly diminished. Nowadays the essential part of population of US and EU is deeply coupled to Internet-based information reservoir which absorbs permanently surplus of social energy.

Thus, social (quantum) thermodynamics can be used for modeling both of societal order stability and instability.

Corresponding author
Andrei Khrennikov can be contacted at: Andrei.Khrennikov@lnu.se