Romantic Chaos

–

A study of the emergence of unpredictability in relationships

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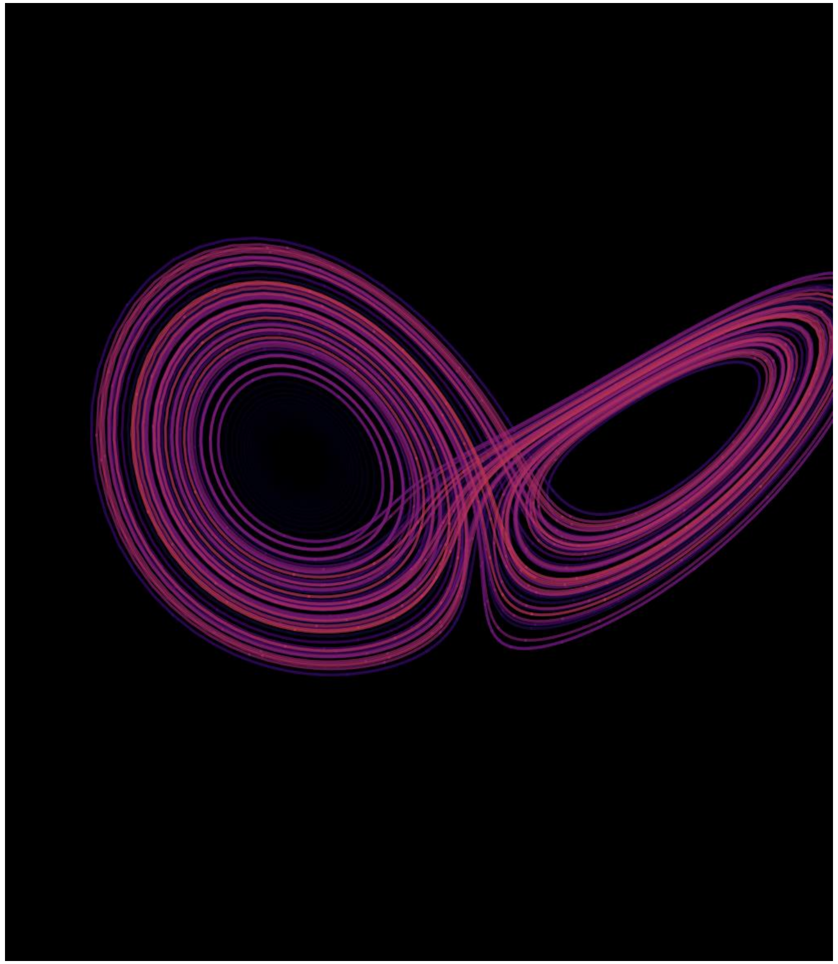
Background/Motivation

- Research question: **Under what conditions does complexity emerge in romantic relationships?**

- Chaos: "When the **present determines the future**, but the **approximate present** does not **approximately determine the future**".
  - it must be <u>sensitive to initial conditions</u>,
  - it must be <u>topologically transitive</u>,
  - it must have <u>dense periodic orbits</u>

- **Hypothesis**: Romantic complexity requires:
  - A particular <u>set of character traits</u> (parameters) – insecurity, wrong expectations
  - <u>External influences</u> (environmental noise or inspiration term)
  - <u>Third parties displaying interest</u> in one of the partners (Higher dimensional dynamical system, network model)



Lorenz, E. N. (1993). The Essence of Chaos

Outline

1. Base Model and Assumptions
2. Emergence of Chaos through Environmental Influence
   - Environmental Stress
   - Extra Emotional Dimensions
3. Unpredictability in triangular relationships
4. Love as a 6D dynamical system
5. Reduction to a 4D dynamical system and a basic network model

Base Model and Assumptions

$$f_i = R_i^L + R_i^A - O_i$$

R_i^L	Reaction to Love from partner
R_i^A	Reaction to the Appeal of their partner
O_i	Oblivion (natural forgetting) term

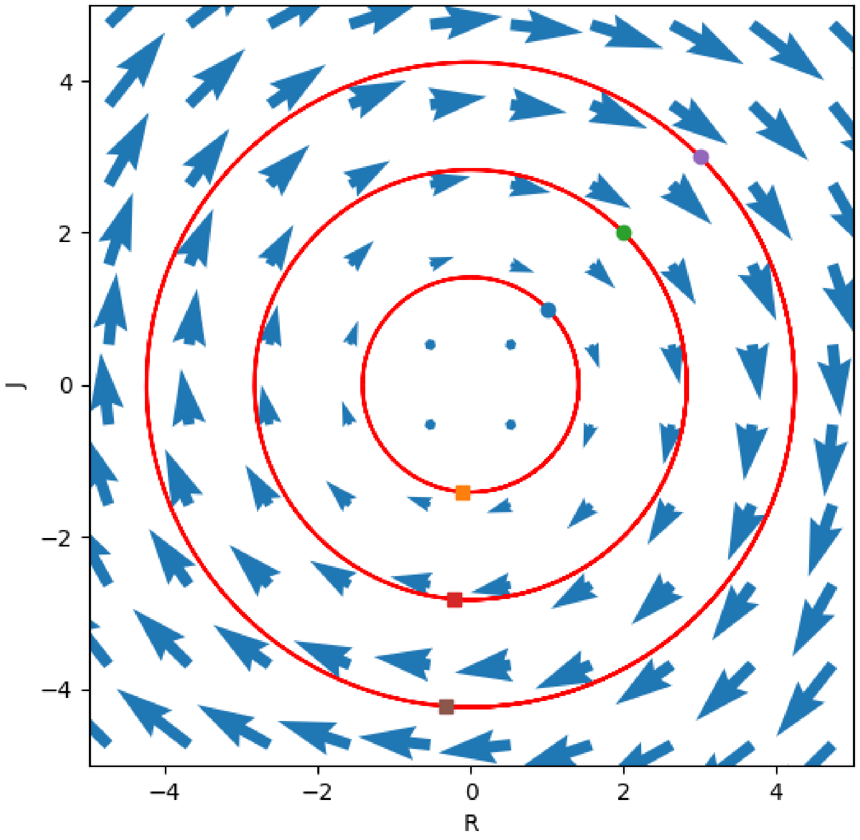
Rinaldi, S., Rossa, F. D., Dercole, F., Gragnani, A., & Landi, P. (2015). *Modeling Love Dynamics: Vol. Volume 89*. WORLD SCIENTIFIC. https://doi.org/10.1142/9656

Example: Love Dynamics of a couple

Romeo: Synergic lover
Juliet: Insecure lover

$$\dot{R} = aR + bJ$$
$$\dot{J} = cR + dJ$$

$$\dot{R} = aJ$$
$$\dot{J} = -bR$$
$$a > 0, b > 0$$



Strogatz S. (1988). *Love Affairs and Differential Equations,* Mathematics Magazine Volume 61

Different cases

Identically insecure lovers

$$\dot{R} = aR + bJ$$
$$\dot{J} = bR + aJ$$

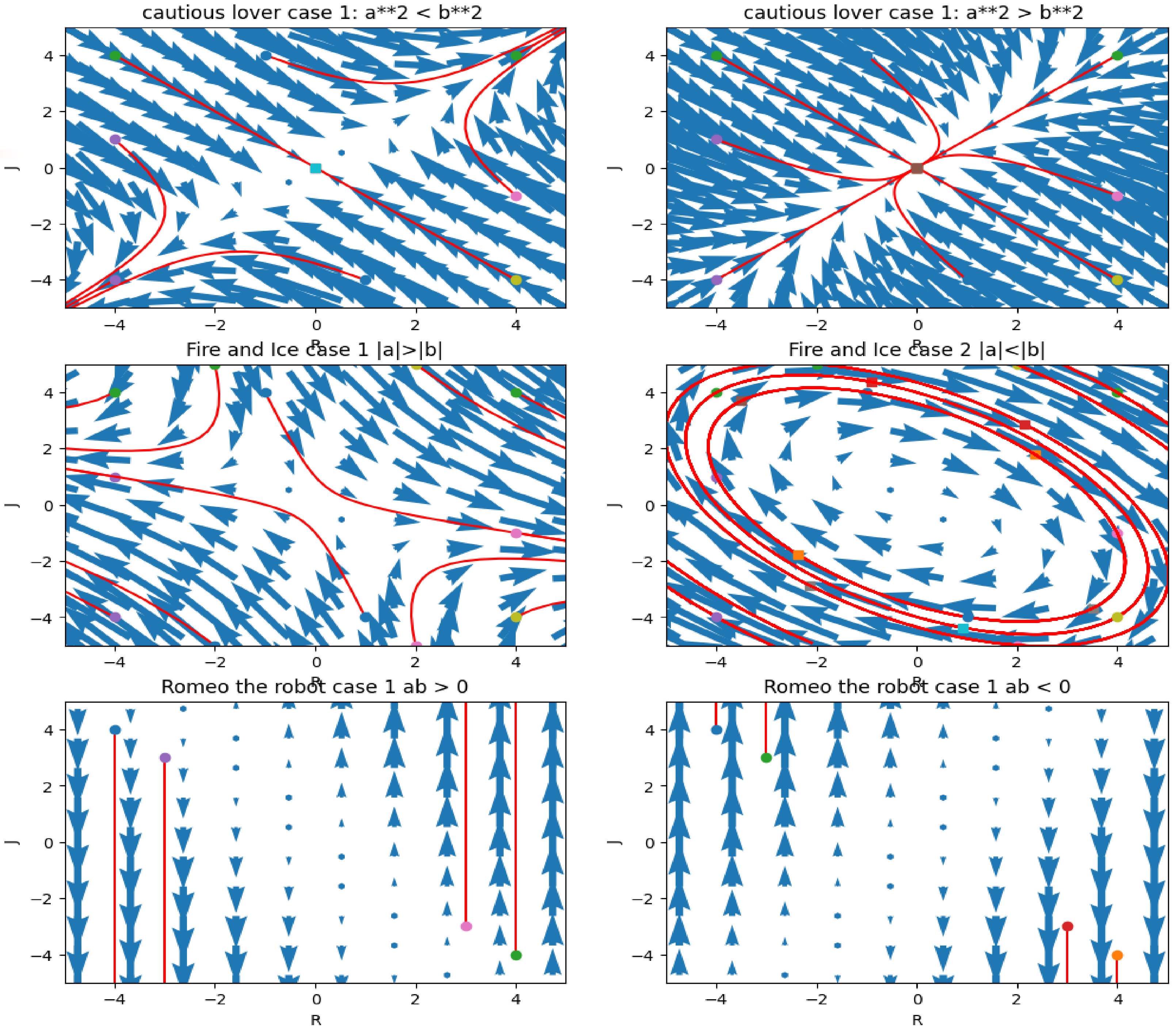
$$a < 0, b > 0$$

Fire and Ice (Do opposites attract?)

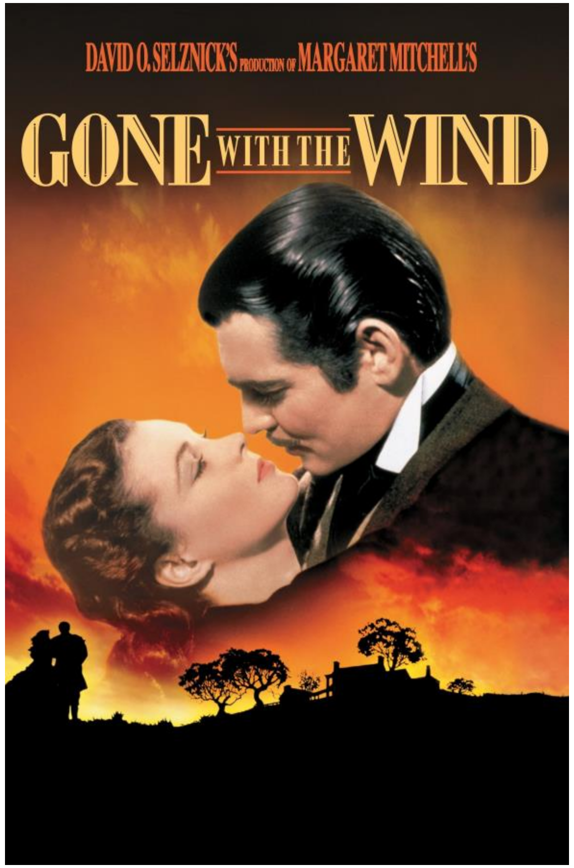
$$\dot{R} = aR + bJ$$
$$\dot{J} = -bR - aJ$$

Romeo the Robot

$$\dot{R} = 0$$
$$\dot{J} = aR + bJ$$

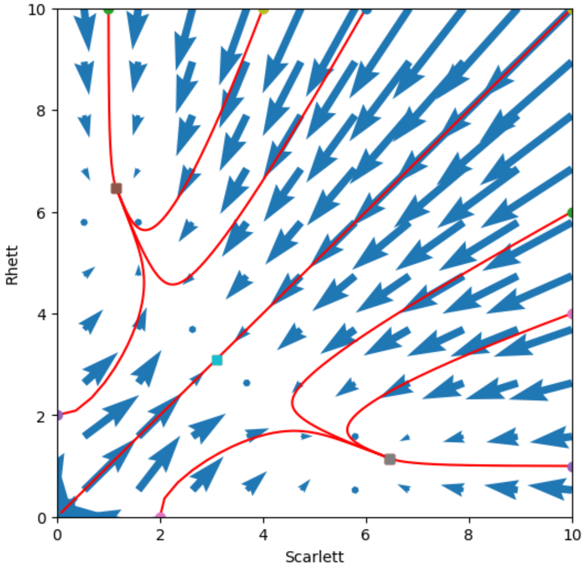


Nonlinear dynamics example: *“Gone with the Wind”* *(1939)*

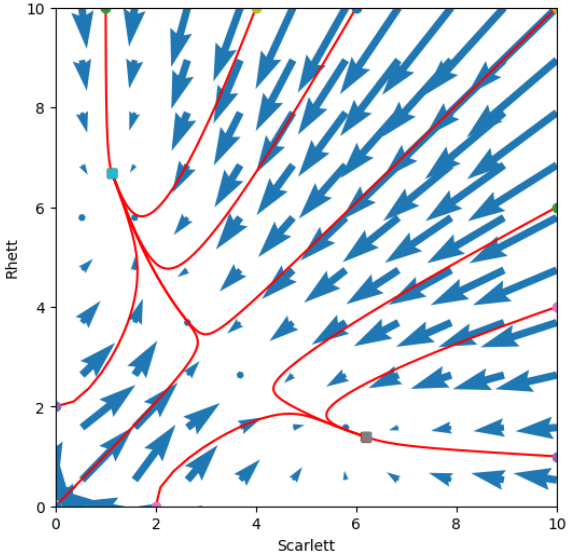


$$\dot{R} = -R + A_S + kSe^{-S}$$
$$\dot{S} = -S + A_R + kRe^{-R}$$

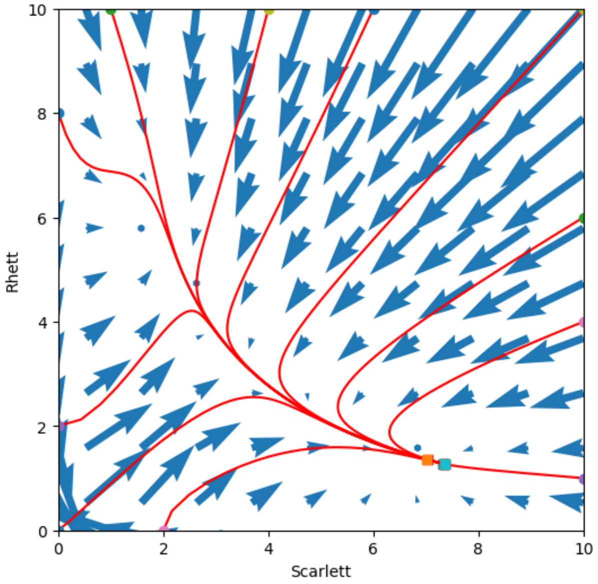
Both are insecure type



$A_S = 1, A_R = 1, k = 15$



$A_S = 1.2, A_R = 1, k = 15$



$A_S = 1.2, A_R = 2, k = 15$

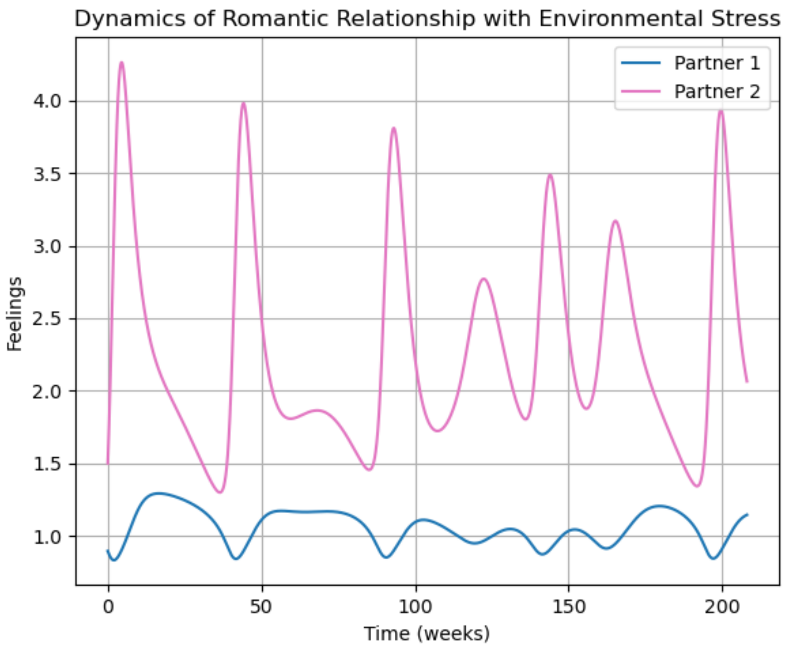
Rinaldi, S., Della Rossa, F., & Landi, P. (2013). A mathematical model of “Gone with the Wind”. Physica A, 392, 3231–3239. doi: 10.1016/j.physa.2013.03.034

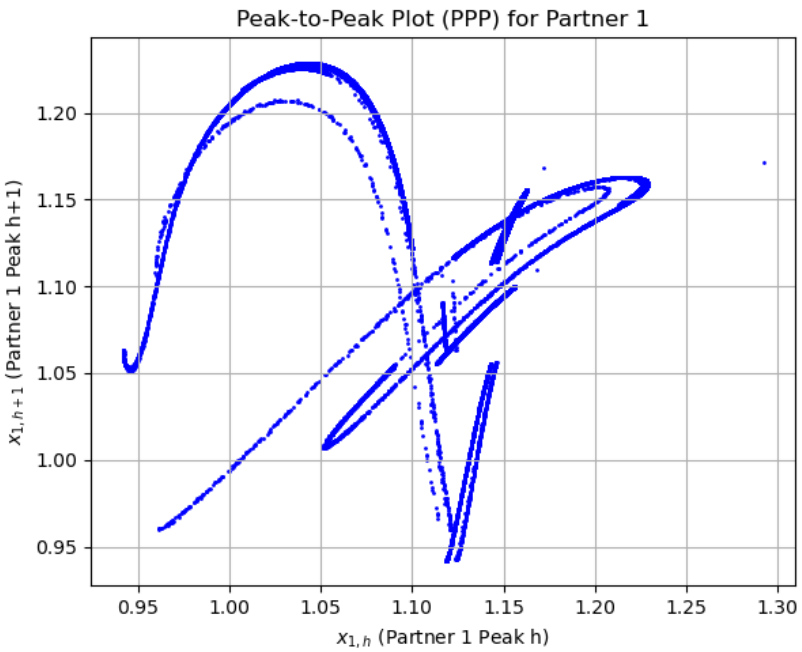

Frankly, my dear, I don't give a damn

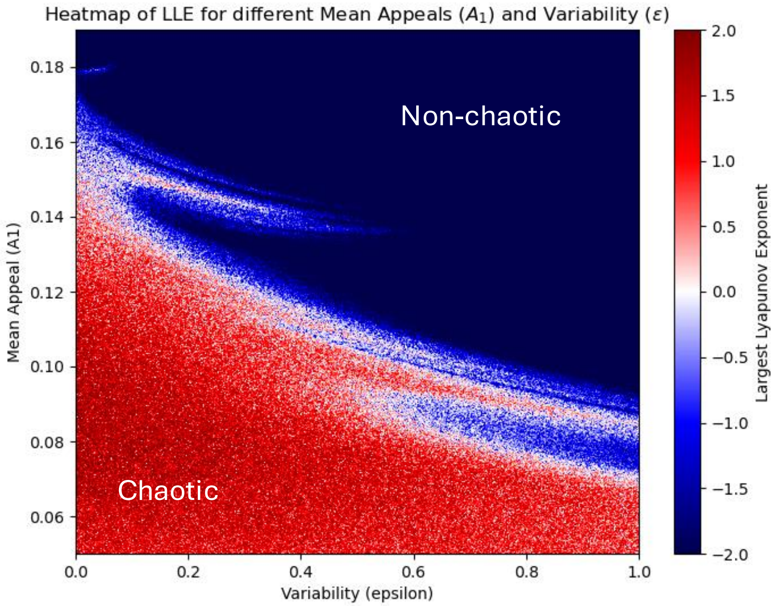
Environmental stress

$$\dot{x}_1 = -\alpha_1 x_1 + R_1^L(x_2) + \left(1 + b_1^A B_1^A(x_1)\right)\gamma_1 A_2$$

$$\dot{x}_2 = -\alpha_2 x_2 + R_2^L(x_1) + \left(1 + b_2^A B_2^A(x_2)\right)\gamma_2 A_1, \qquad A_1(t) = \bar{A}_1(1 + \varepsilon \sin \omega t) \quad 0 \le \varepsilon \le 1$$







$$R_1^L(x_2) = \beta_1 k_1 x_2 \exp\left(-(k_1 x_2)^{n_1}\right) \quad R_2^L(x_1) = \beta_2 k_2 x_1 \exp\left(-(k_2 x_1)^{n_2}\right)$$

$$B_1^A(x_1) = x_1^{2m_1} / \left(x_1^{2m_1} + \sigma_1^{2m_1}\right) \quad B_2^A(x_2) = x_2^{2m_2} / \left(x_2^{2m_2} + \sigma_2^{2m_2}\right).$$

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External inspiration

Laura de Sade

Francesco Petrarch

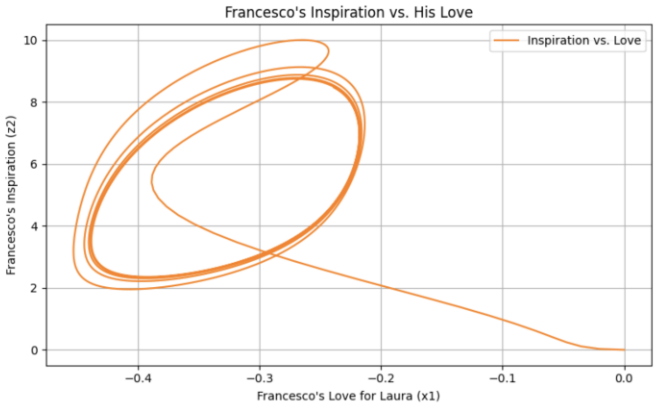
$$\dot{x}_1 = -\alpha_1 x_1 + R_1^L(x_2) + \gamma_1 A_2$$

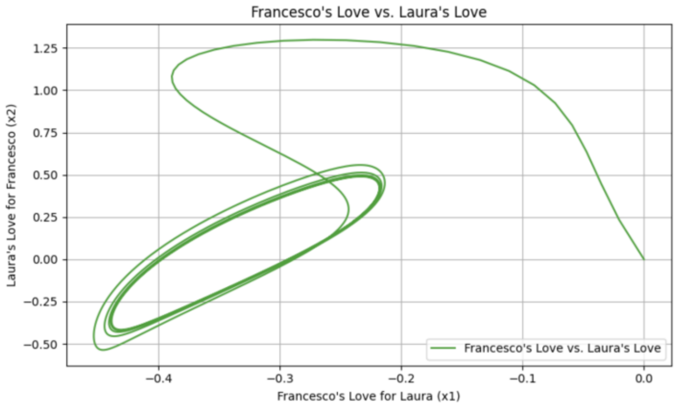
$$\dot{x}_2 = -\alpha_2 x_2 + R_2^L(x_1) + \gamma_2 A_1 \frac{1}{1 + \delta z_2}$$

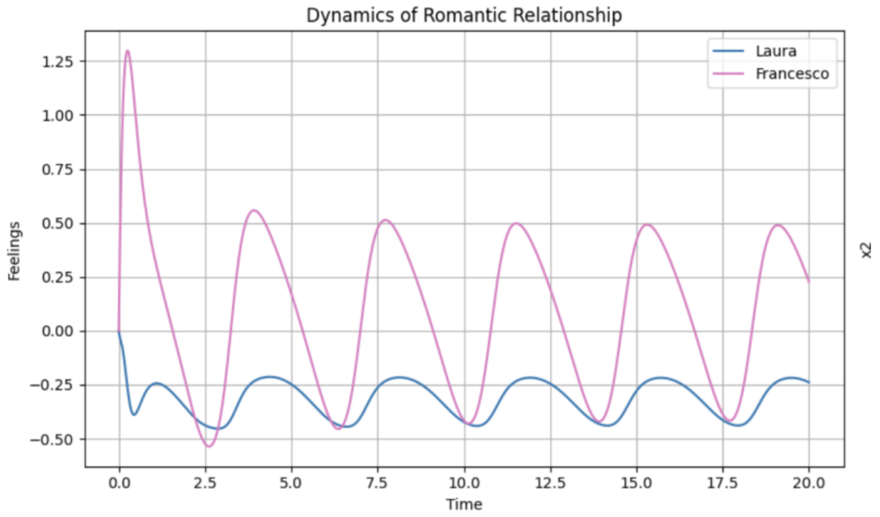
$$\dot{z}_2 = \varepsilon(\mu x_2 - z_2),$$

$$R_1^L(x_2) = \beta_1 x_2 (1 - (x_2/x_2^*)^2).$$

$$R_2^L(x_1) = \beta_2 x_1.$$







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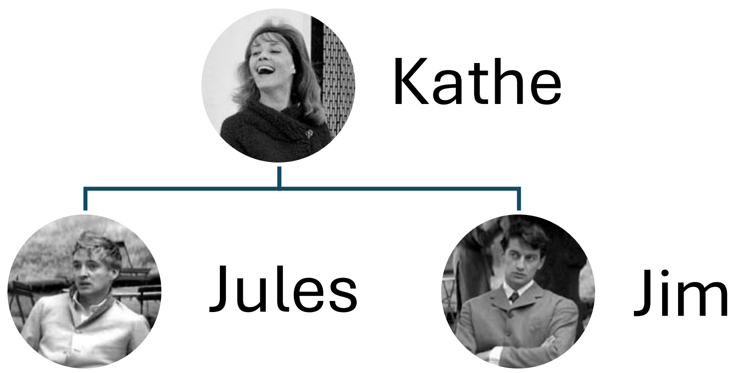
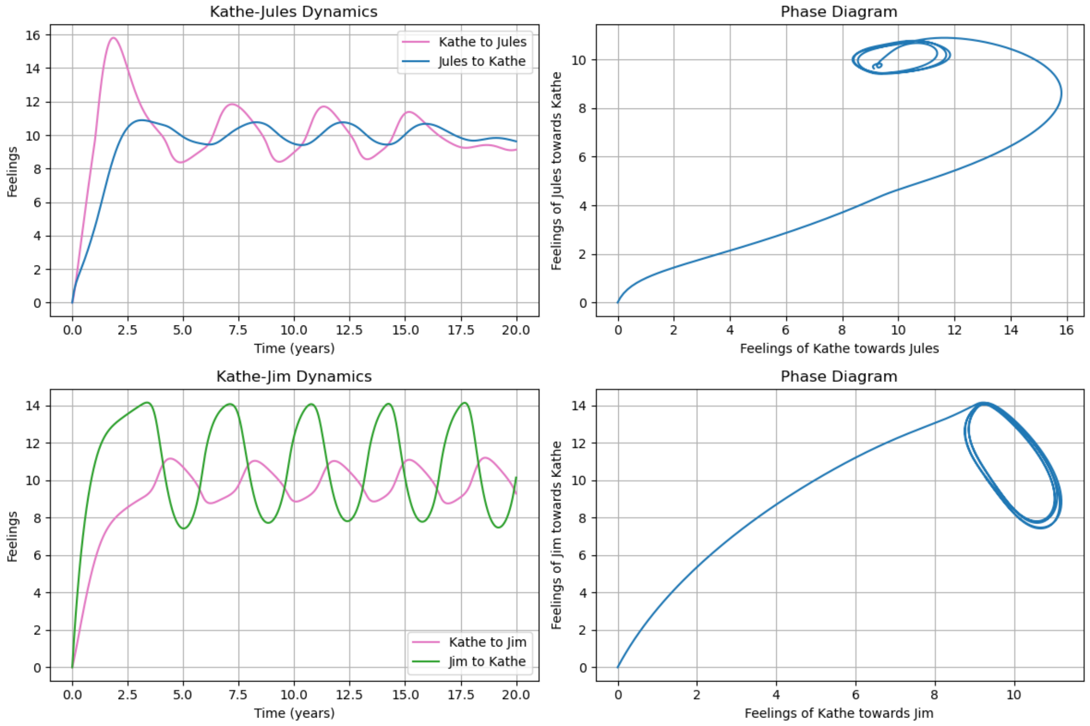
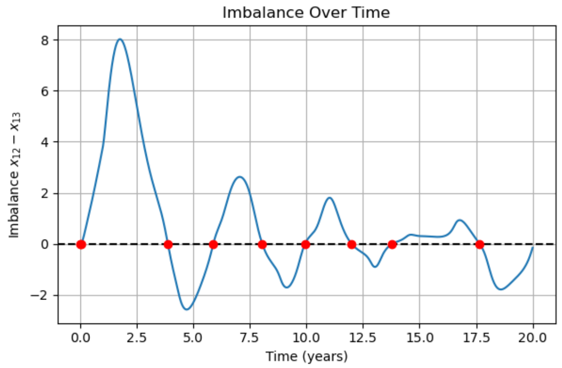
Triangular Relationships (1/3)

$$\frac{d}{dt}x_{12} = -\alpha_1 e^{\epsilon(x_{13}-x_{12})}x_{12} + R^L_{12}(x_{21},\tau_{I_{12}},\sigma_{L_{12}},\sigma_{I_{12}},\beta_{12}) + (1+S(x_{12},\tau_S,\sigma_S,s))\gamma_1 A_2,$$
$$\frac{d}{dt}x_{13} = -\alpha_1 e^{\epsilon(x_{12}-x_{13})}x_{13} + \beta_{13}x_{31} + (1+S(x_{13},\tau_S,\sigma_S,s))\gamma_1 A_3,$$
$$\frac{d}{dt}x_{21} = -\alpha_2 x_{21} + \beta_{21}x_{12}e^{\delta(x_{13}-x_{12})} + (1-P(x_{21},\tau_P,p,\sigma_P))\gamma_2 A_1,$$
$$\frac{d}{dt}x_{31} = -\alpha_3 x_{31} + R^L_{31}(x_{13},\tau_{I_{31}},\beta_{31},\sigma_{L_{31}},\sigma_{I_{31}})e^{\delta(x_{13}-x_{12})} + \gamma_3 A_1.$$



"Jules et Jim" - Henri-Pierre Roché (1953)
"Jules & Jim" - François Truffaut (1962)





Partner changes: 7

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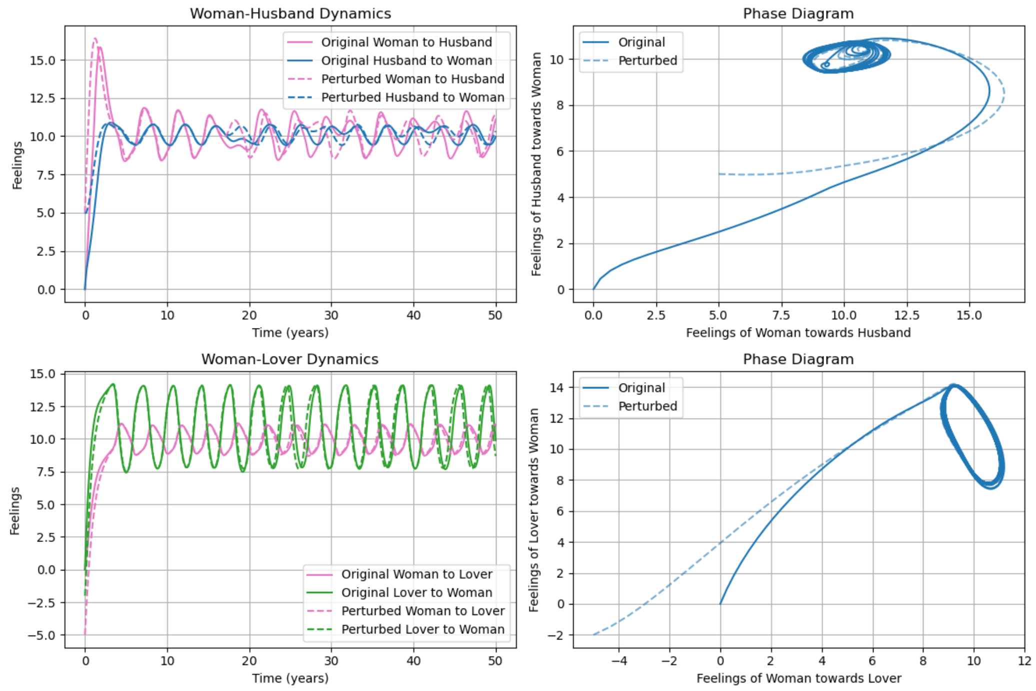
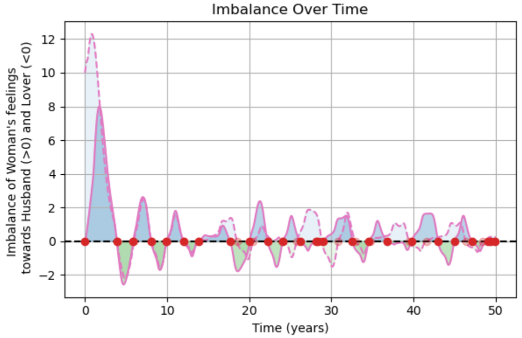
Triangular Relationships (2/3)

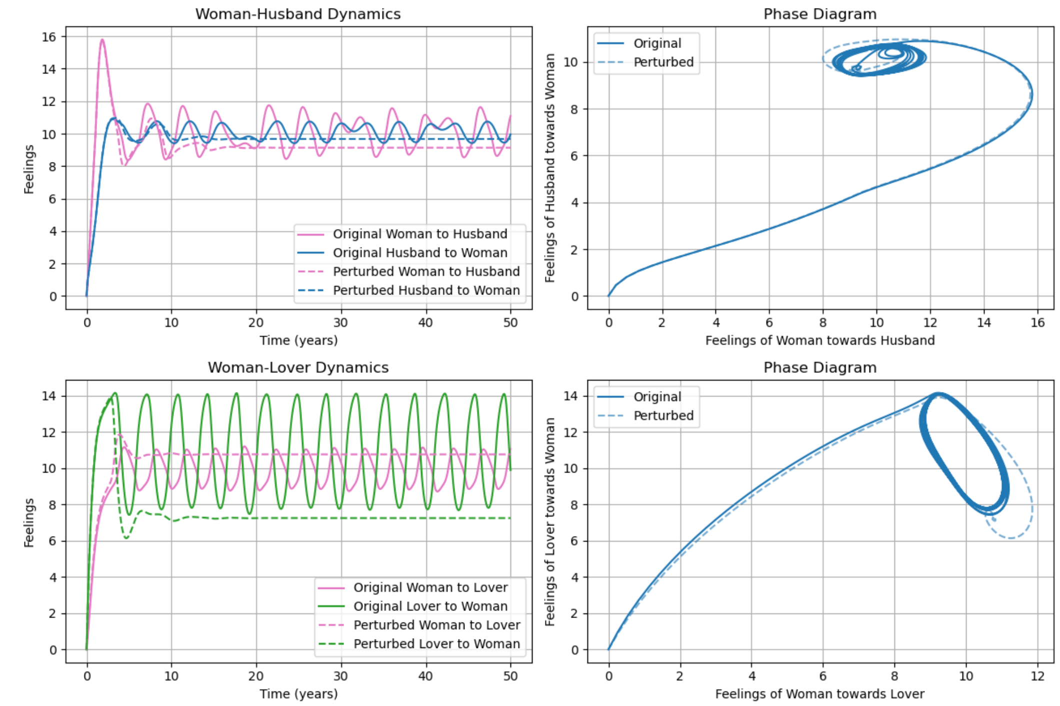
<u>Result:</u>
The outcome **doesn't depend on the initial conditions (feelings)**, but much more on the **intrinsic characteristics of the partners**!

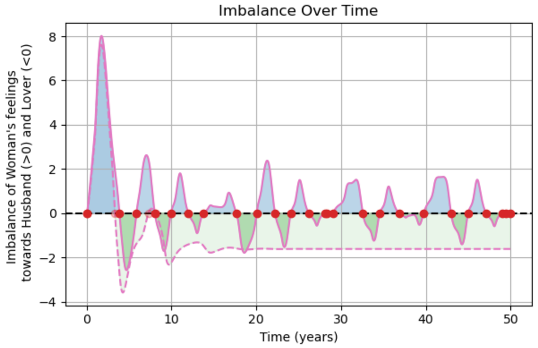




Partner switching: 23,
Perturbed partner switching: 16

<u>Perturbed initial conditions:</u>
+5 initial feelings for Husband,
-5 initial feelings for Lover





Partner switching: 23,
Perturbed partner switching: 3

<u>Perturbed parameter:</u>
Jim's appeal increases by 10%

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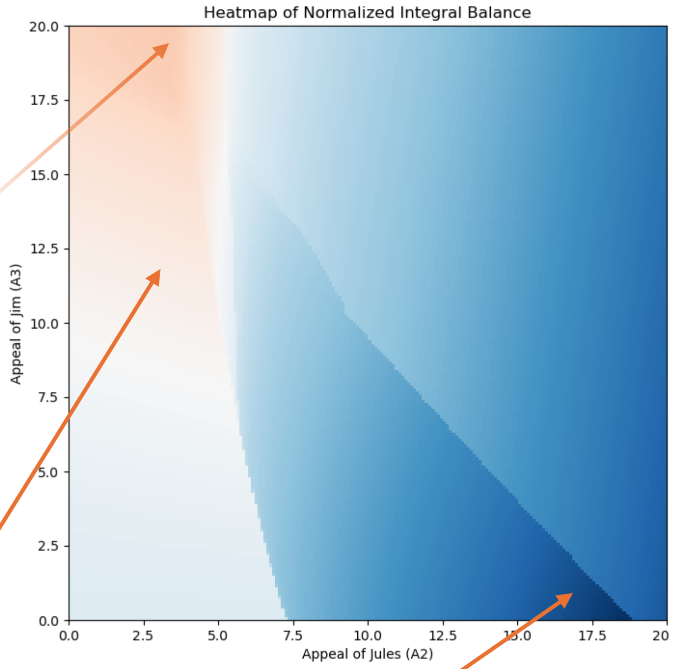
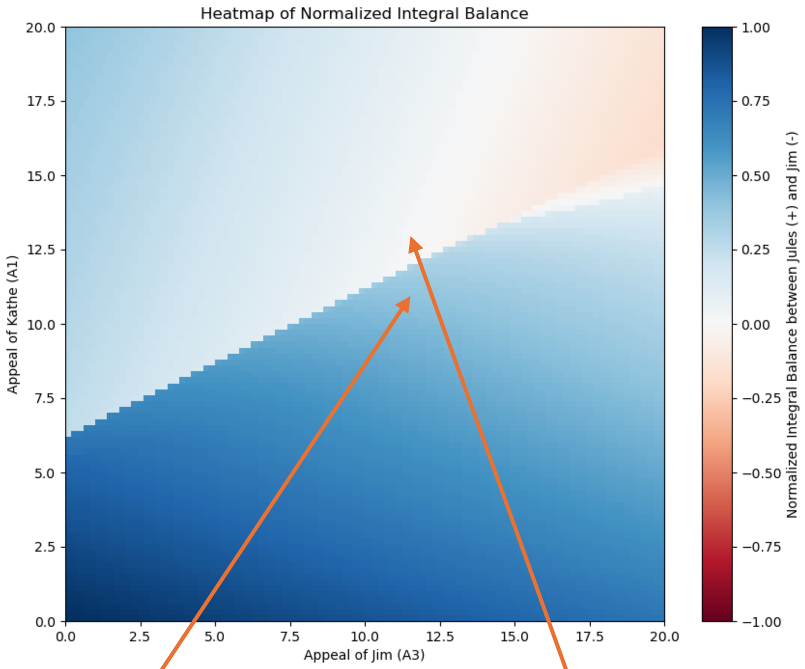
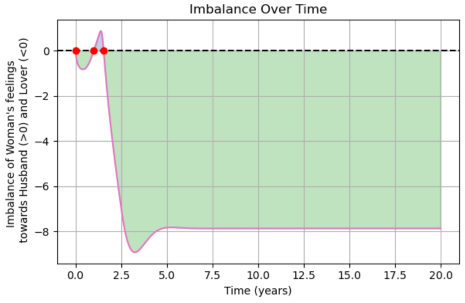
Triangular Relationships (3/3)

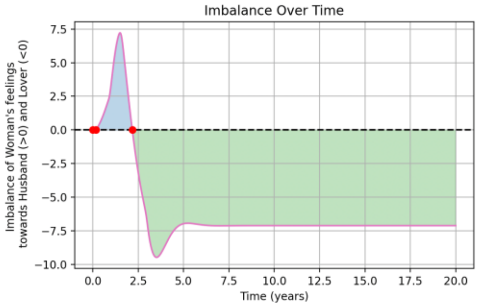
No.	Parameter	Sensitivity Ranking
1	A_1 (Appeal of Kathe)	5.440395
2	A_2 (Appeal of Jules)	5.412977
3	A_3 (Appeal of Jim)	4.712515
4	τ^I_{12} (Insecurity threshold for Kathe's reaction to Jules' love)	2.658608
5	β_{12} (Reaction coefficient to love for Kathe to Jules' love)	2.658058
6	σ_P (Sensitivity of platonicity for Jules)	2.632916
7	σ^L_{12} (Sensitivity of reaction to love for Kathe to Jules)	2.620549
8	σ^I_{12} (Sensitivity of insecurity for Kathe to Jules)	2.601021
9	τ_P (Platonicity threshold for Jules)	2.585060
10	p (Maximum platonicity for Jules)	2.583530
11	σ_S (Sensitivity of synergism for Kathe)	2.555528
12	τ^I_{31} (Insecurity threshold for Jim's reaction to love)	2.537742
13	β_{21} (Reaction coefficient to love for Jules to Kathe's love)	2.529236
14	σ^I_{31} (Sensitivity of insecurity for Jim)	2.470132
15	τ_S (Synergism threshold for Kathe)	2.441052
16	β_{13} (Reaction coefficient to love for Kathe to Jim's love)	2.413586
17	σ^L_{31} (Sensitivity of reaction to love for Jim)	2.348418
18	β_{31} (Reaction coefficient to love for Jim to Kathe's love)	2.287130
19	s (Synergism coefficient for Kathe)	2.099263
20	α_2 (Forgetting coefficient for Jules)	1.168884
21	α_1 (Forgetting coefficient for Kathe)	1.139572
22	α_3 (Forgetting coefficient for Jim)	1.006158
23	γ_3 (Reaction coefficient to appeal for Jim)	0.288601
24	γ_2 (Reaction coefficient to appeal for Jules)	0.286488
25	γ_1 (Reaction coefficient to appeal for Kathe)	0.276387
26	δ (Sensitivity of reaction to love for Jules and Jim)	0.011289
27	ϵ (Sensitivity of reaction to love for Kathe)	0.002545

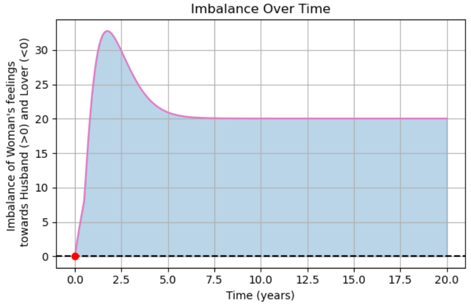
Table 1: Parameters sensitivity ranking for producing positive LLEs.

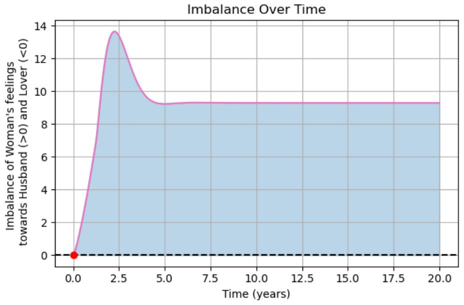


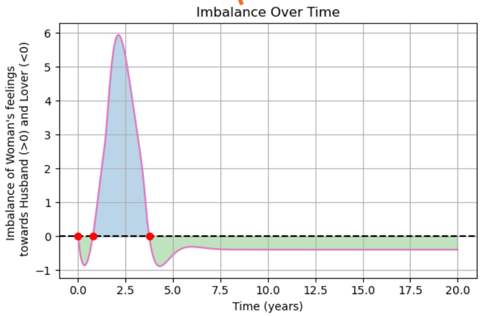












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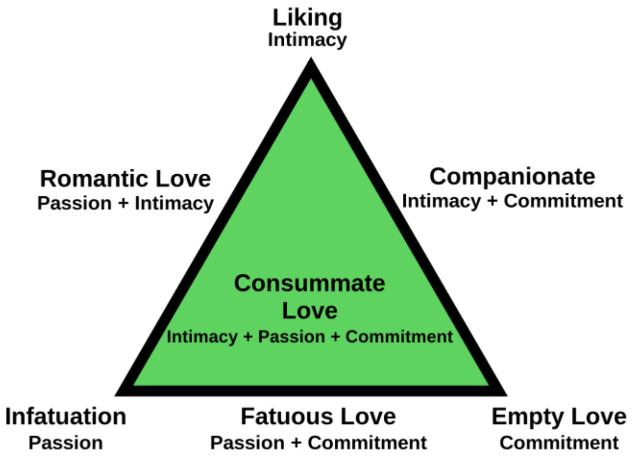
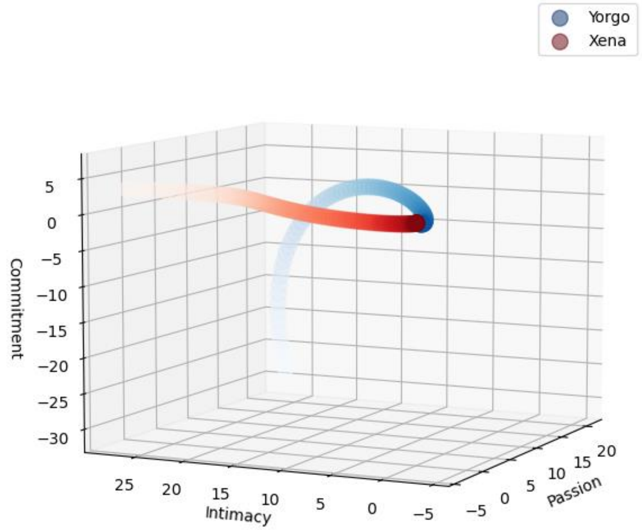
Love as a 6D dynamical system - Sternberg's "Triangular Theory of Love"





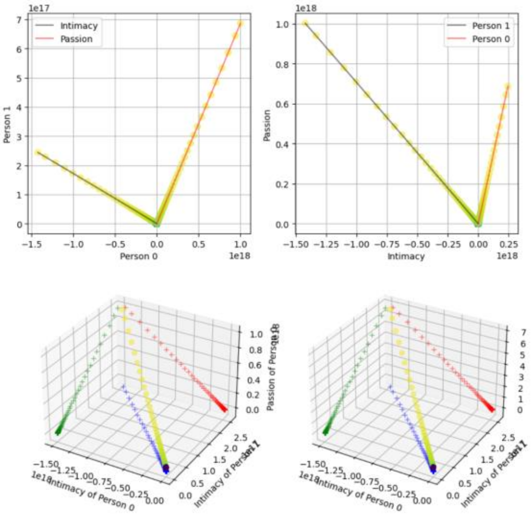
$$\frac{d}{dt}\begin{pmatrix} x_i \\ y_i \\ x_p \\ y_p \\ x_c \\ y_c \end{pmatrix} = \begin{pmatrix} a_{xx} & a_{xy} & b_{xx} & b_{xy} & l_{xx} & l_{xy} \\ a_{yx} & a_{yy} & b_{yx} & b_{yy} & l_{yx} & l_{yy} \\ c_{xx} & c_{xy} & d_{xx} & d_{xy} & n_{xx} & n_{xy} \\ c_{yx} & c_{yy} & d_{yx} & d_{yy} & n_{yx} & n_{yy} \\ m_{xx} & m_{xy} & o_{xx} & o_{xy} & p_{xx} & p_{xy} \\ m_{yx} & m_{yy} & o_{yx} & o_{yy} & p_{yx} & p_{yy} \end{pmatrix} \begin{pmatrix} x_i \\ y_i \\ x_p \\ y_p \\ x_c \\ y_c \end{pmatrix} + \begin{pmatrix} f_{xy} \\ f_{yx} \\ g_{xy} \\ g_{yx} \\ h_{xy} \\ h_{yx} \end{pmatrix}$$

Sternberg, R. J. (1986). A triangular theory of love. *Psychological Review, 93*(2), 119–135. https://doi.org/10.1037/0033-295X.93.2.119
ERBAŞ, K. C. (2022). Modeling Love with 4D Dynamical System. Chaos Theory and Applications, 4(3), 135-143. https://doi.org/10.51537/chaos.1131966

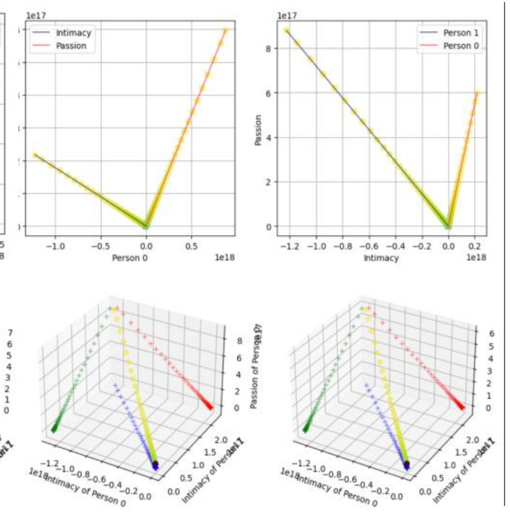
Reduction to a 4D Dynamical System – Network Model

- Omission of the commitment dimension for simplicity
- Small fully connected network (n=10, n(n-1)/2 = 45 number of edges!)
- Everyone knows (and is "in love" with) one another
    - Option to have everyone aware of each other's parameters (normalizing parameters) -> small changes in network cause other people to adapt how they perceive other people

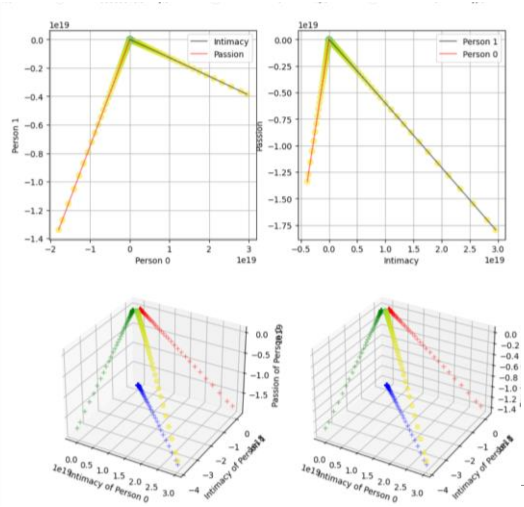
ERBAŞ, Kadir Can. "Modeling Love with 4D Dynamical System." Chaos Theory and Applications, vol. 4, no. 3, Akif Akgul, 30 Nov. 2022, pp. 135–143. doi:10.51537/chaos.1131966.



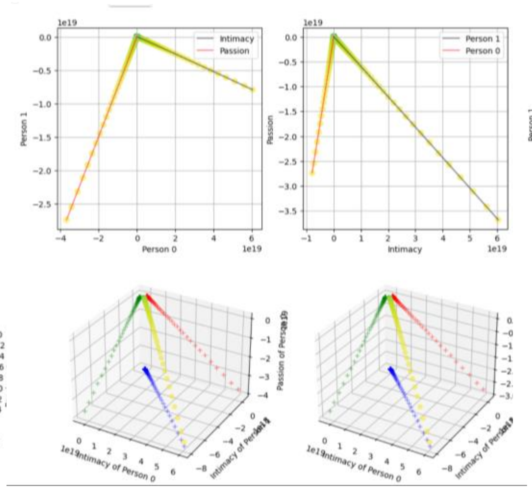
xi0 = 0



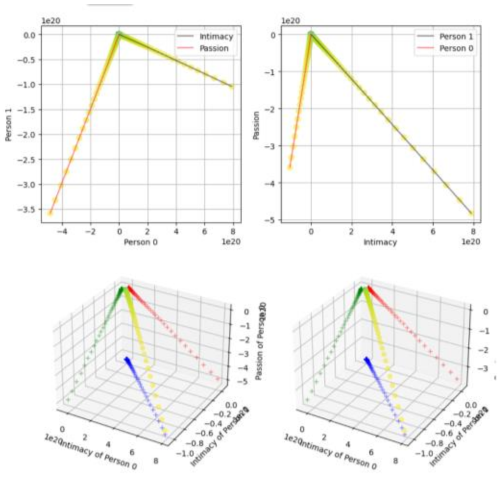
xi0 = 1000



xi0 = 38,965,846



xi0 = 77,931,691

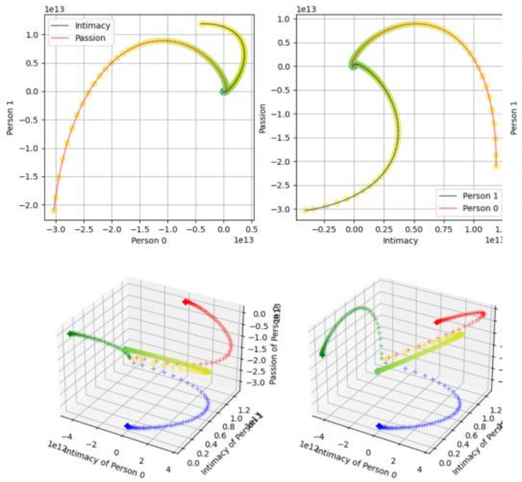


xi0 = 1e9

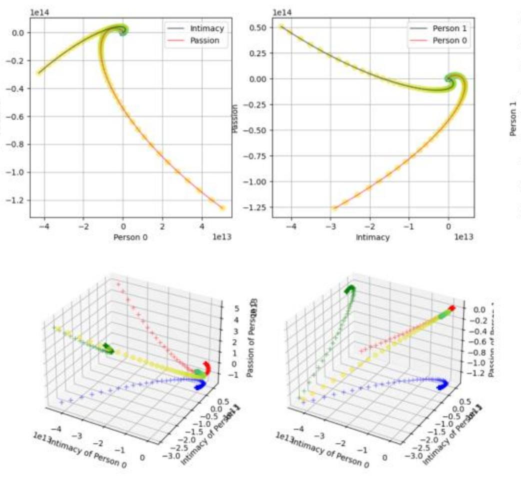
In the grand scheme of things, 1e9 is small compared to the starting scale of 1e18

Even attempted with xi0 > 1,000,000, also negative numbers, changing all 4 initial values causes no significant change

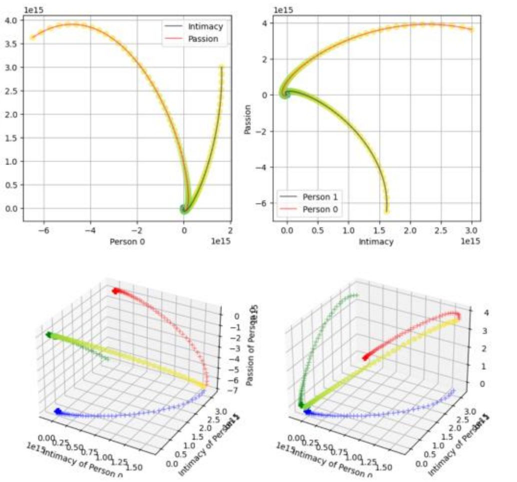
yp0=0



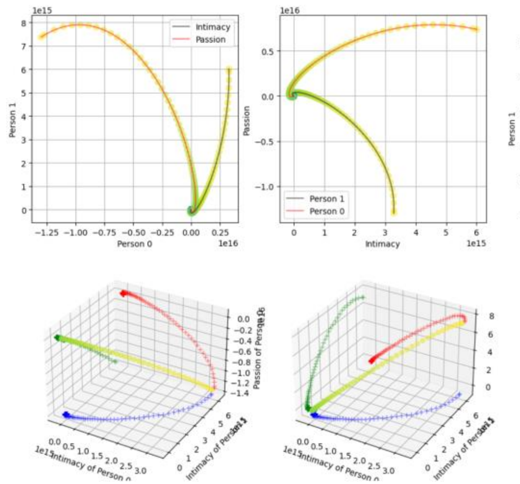
yp0=1000



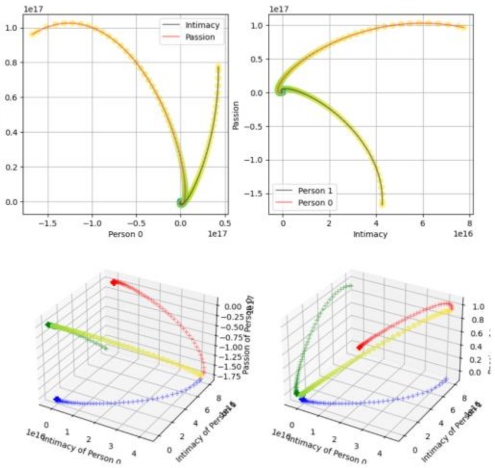
yp0=38,965,846

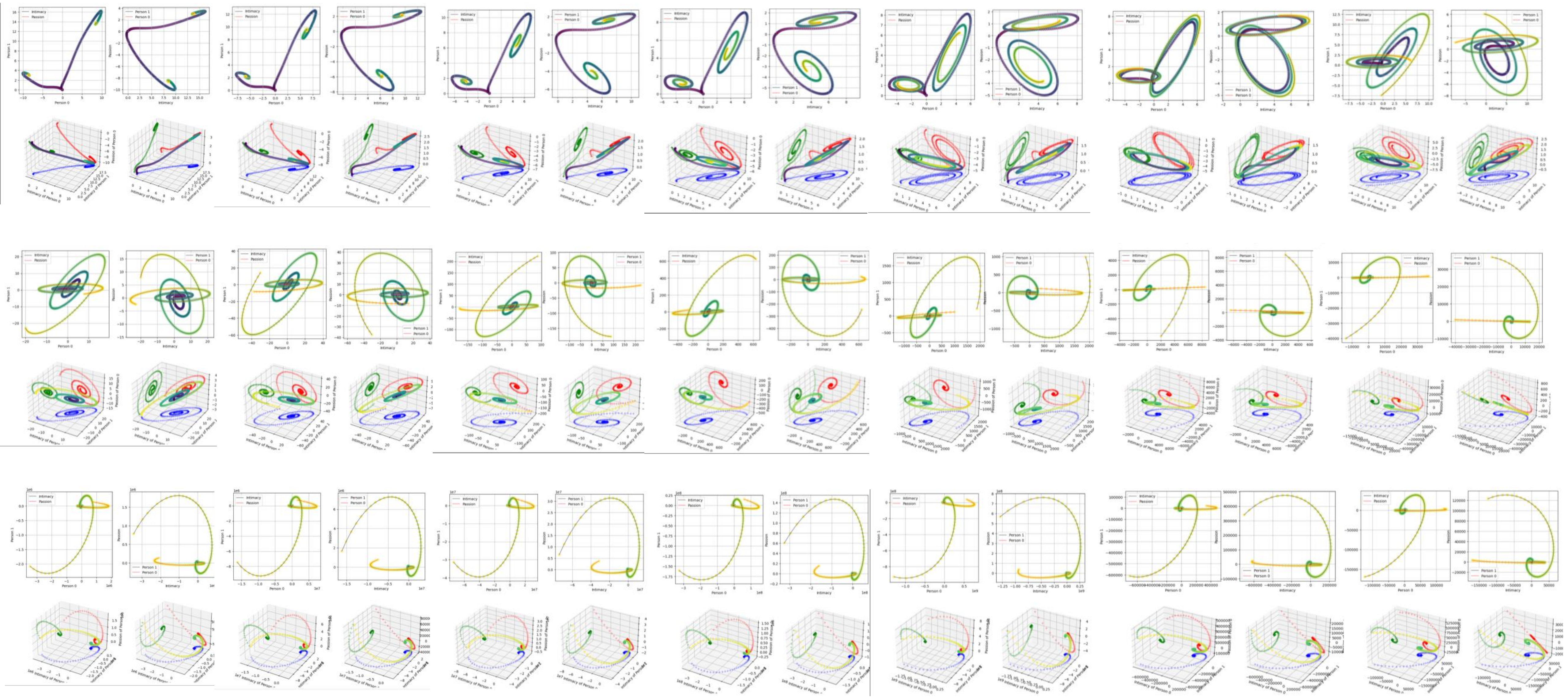


yp0=77,931,691

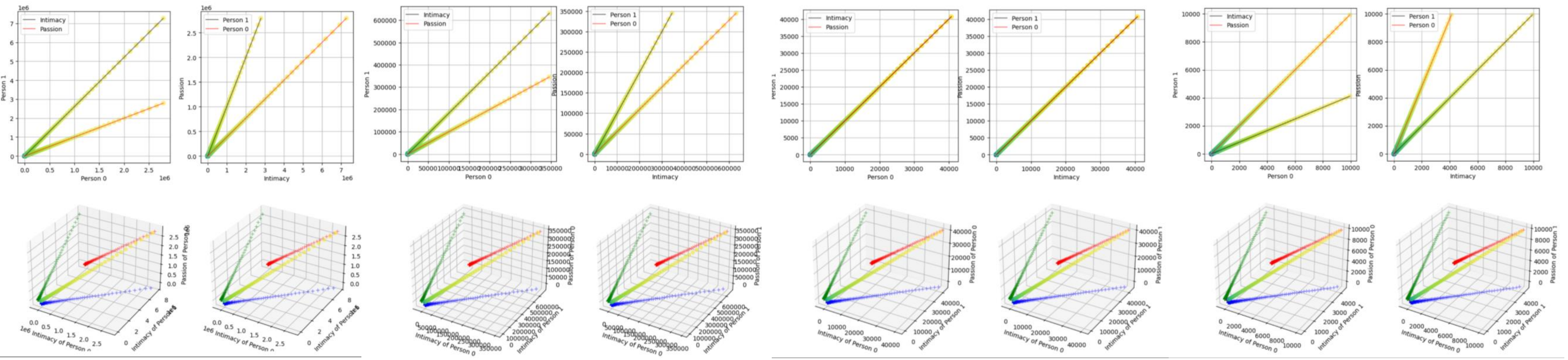


yp0 = 1e9

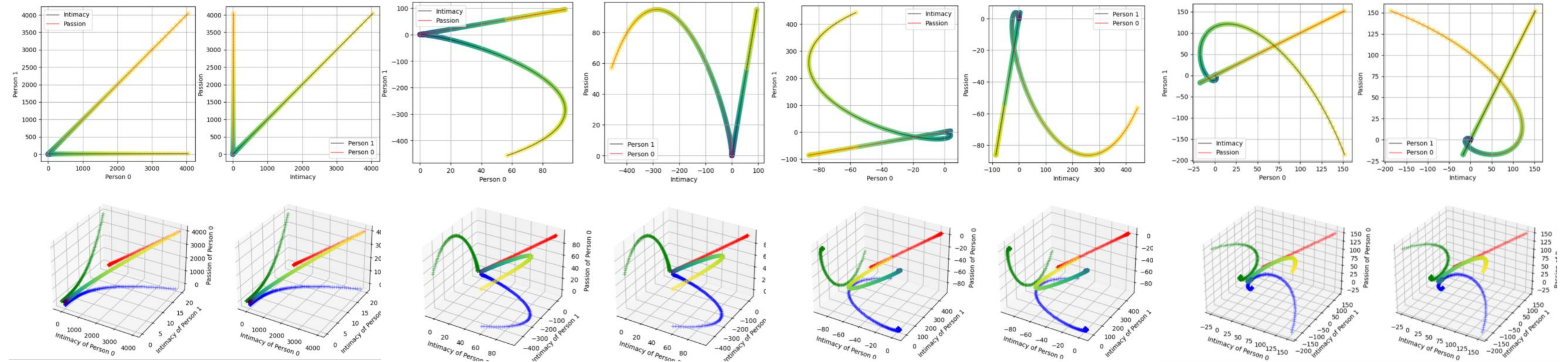


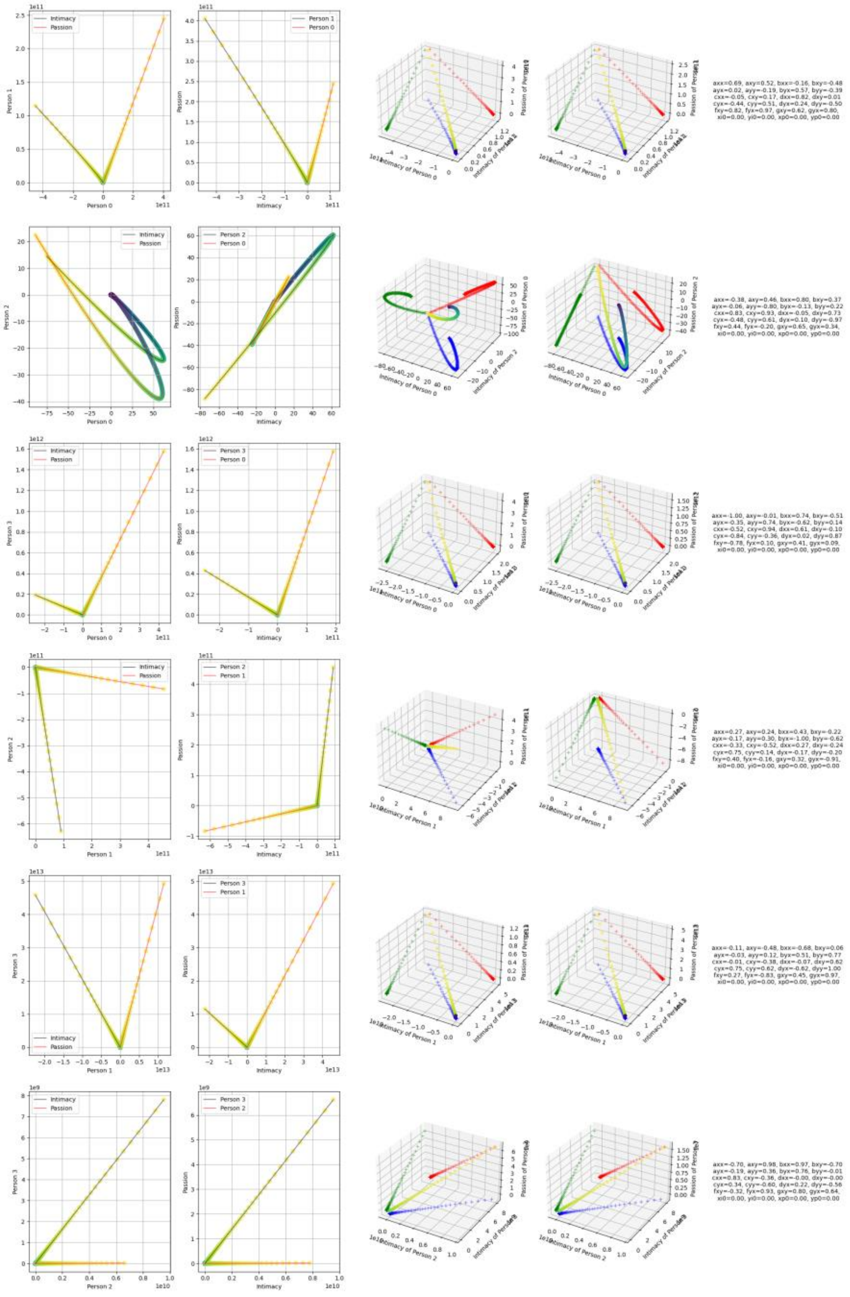


Change in axx from –1 to 1, stepsize = 0.1, not changing anything else

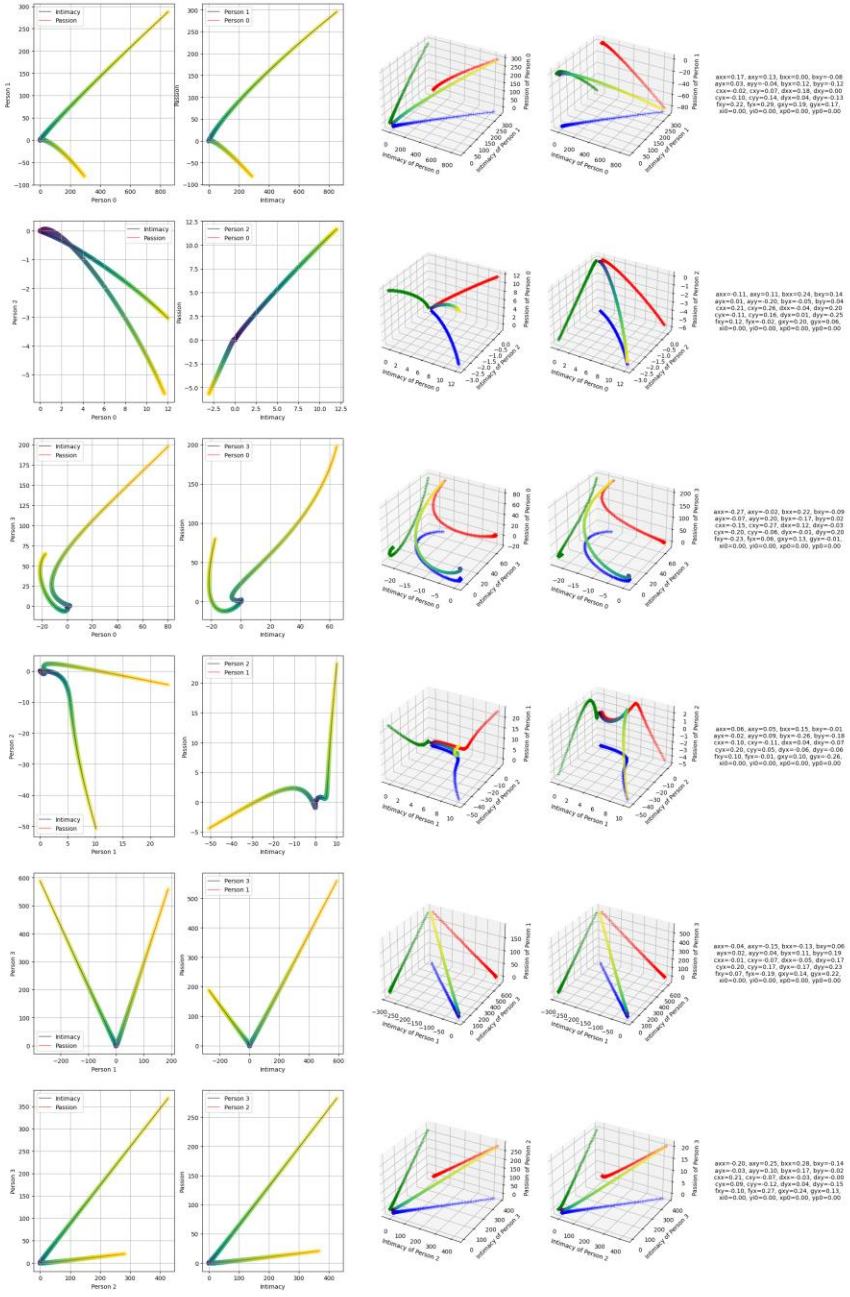


all params set to 0.1, change in graph as ayx = [1, 0.5, 0.1, -0.1, -0.2, -0.4, -0.7, -1]

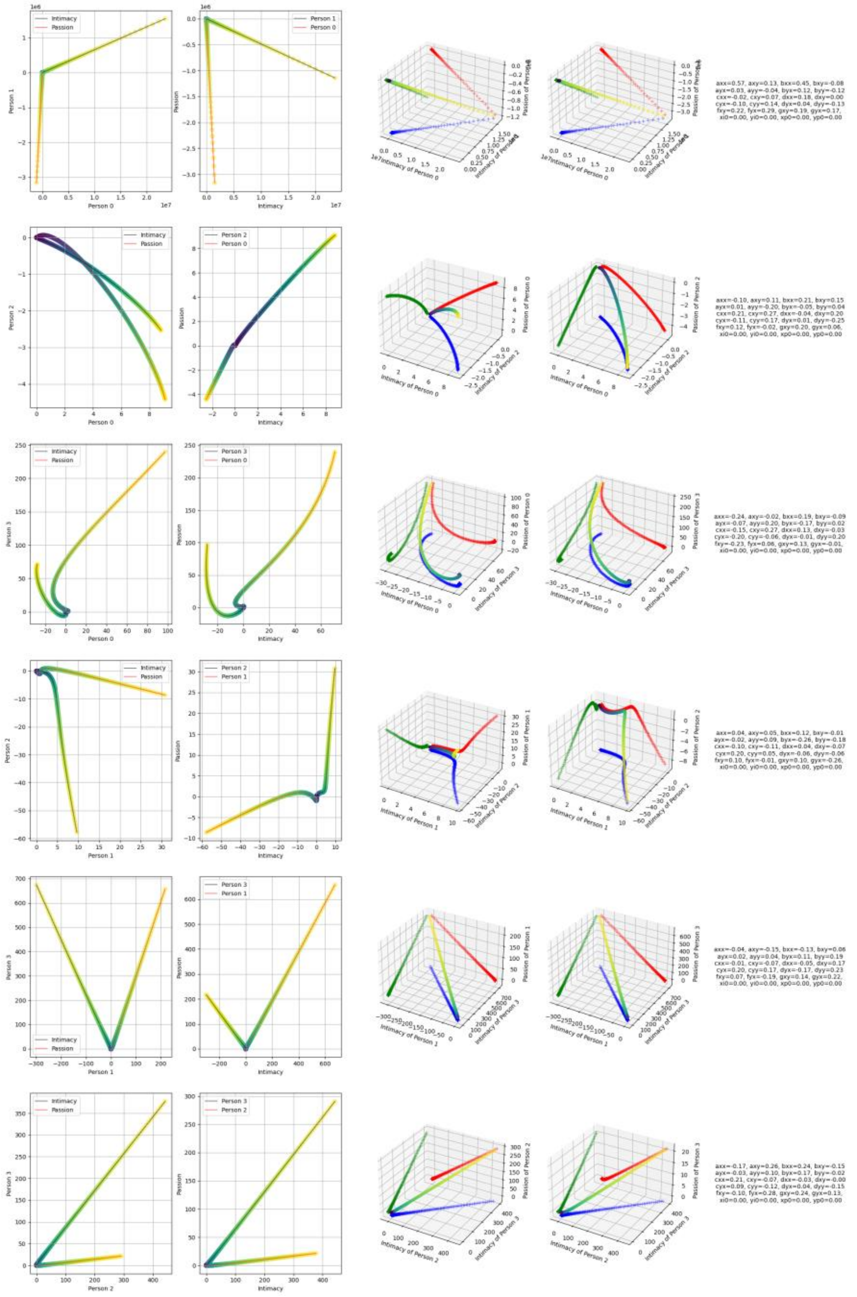




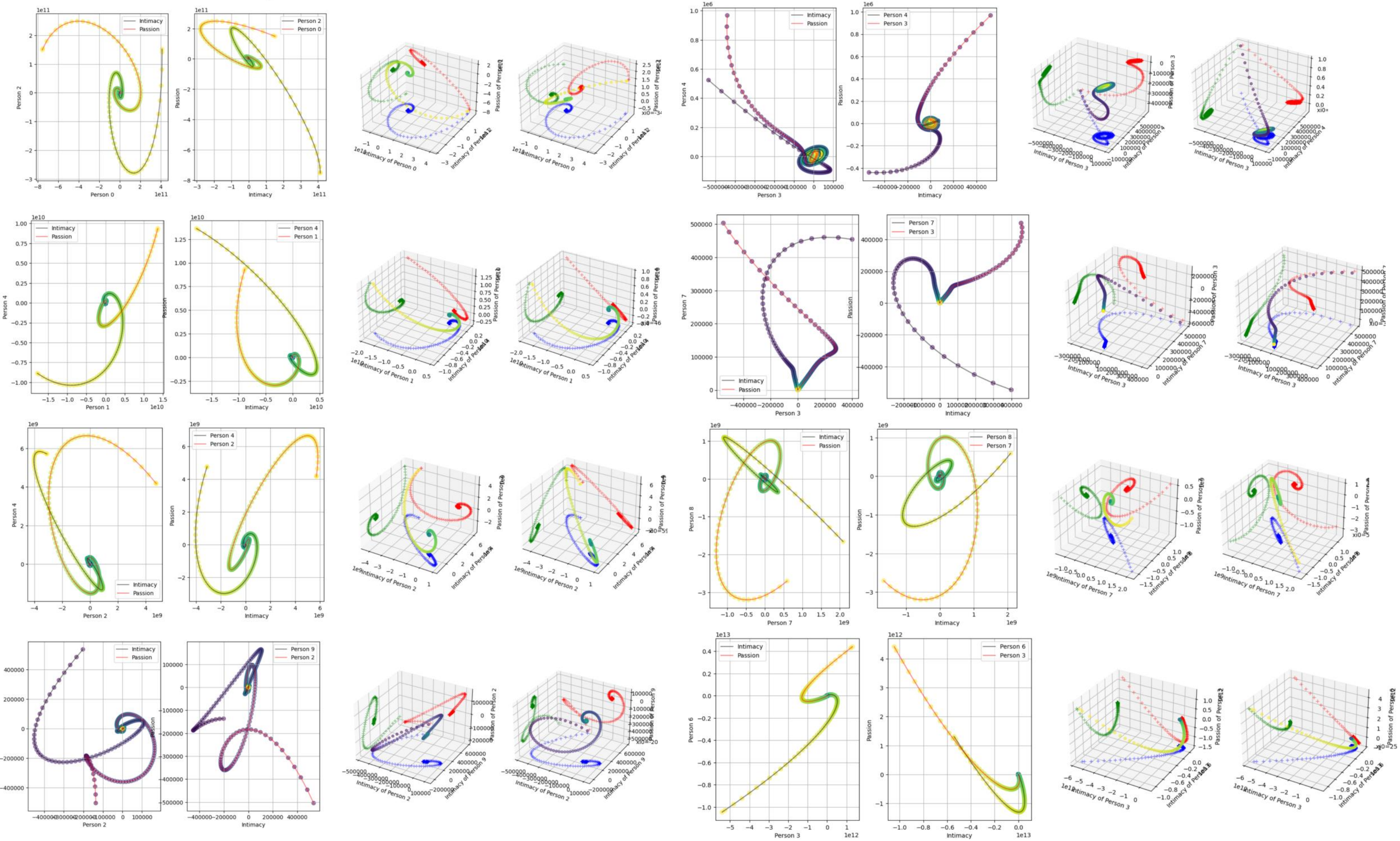
Program started from beginning with random parameters
axx=[0.69, -0.38, -1, 0.27, -0.11, -0.7]
bxx = [-0.16, 0.8, 0.74, 0.43, -0.68, 0.97]



Normalize params, sum=0,
axx =[0.17, -0.11, -0.27, 0.15, 0.20, 0.06, 0.03]
bxx = [0.00, 0.24, 0.22, 0.15, -0.13, 0.28]



axx=0.75, bxx=0.5, and renormalize, small change
axx=[0.57, -0.10, -0.24, 0.04, -0.04, -0.17]
bxx=[0.45, 0.21, 0.19, 0.12, -0.13, 0.24]


Intimacy
Passion
Person 0
Person 2
Intimacy of Person 0
Intimacy of Person 2
Passion of Person 2
Person 4
Person 3
Intimacy of Person 3
Intimacy of Person 4
Passion of Person 3
Person 1
Intimacy of Person 1
Intimacy of Person 4
Person 7
Intimacy of Person 7
Passion of Person 3
Person 8
Intimacy of Person 8
Person 9
Intimacy of Person 9
Passion of Person 9
Person 6
Intimacy of Person 6
Passion of Person 6

Final remarks:
Shortcomings of the Models

- Doesn’t account for individual differences:
  - sex differences,
  - Psychological differences,
  - Stochastic effects, etc
- For the 4D system:
  - When normalizing the parameters, the simulation is "restarting" from the beginning
  - The system is linear, different model needed