

# Modal decomposition of plasma simulations

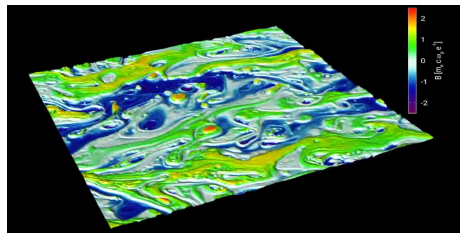
Herman Øie Kolden

MIT

May 12, 2020

# Plasma physics 101

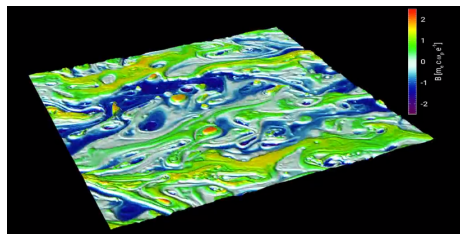
- An electromagnetically active multifluid



Source: Inchingolo et. al. (2017).

# Plasma physics 101

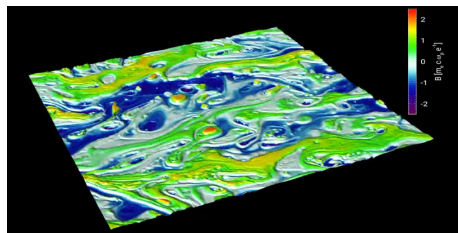
- An electromagnetically active multifluid
- Two main simulation regimes



Source: Inchingolo et. al. (2017).

# Plasma physics 101

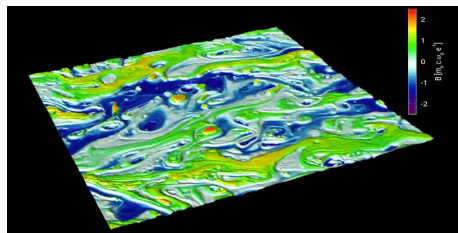
- An electromagnetically active multifluid
- Two main simulation regimes
  - ▶ Strongly collisional: Navier-Stokes & Maxwell



Source: Inchingolo et. al. (2017).

# Plasma physics 101

- An electromagnetically active multifluid
- Two main simulation regimes
  - ▶ Strongly collisional: Navier-Stokes & Maxwell
  - ▶ Weakly collisional: Particle-in-cell



Source: Inchingolo et. al. (2017).

# Modal decomposition methods

## Proper orthogonal decomposition

- 1 Plasma physics 101
- 2 Modal decomposition methods
  - Proper orthogonal decomposition
  - Dynamic mode decomposition
- 3 Outlook

# Modal decomposition methods

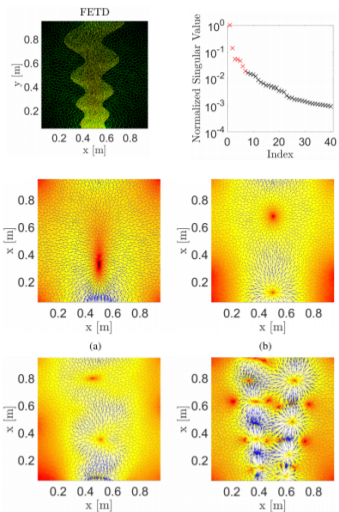
## Proper orthogonal decomposition

- Decomposition into most energetic spatial modes

# Modal decomposition methods

## Proper orthogonal decomposition

- Decomposition into most energetic spatial modes



Source: Nicolini et. al. (2019).



# Modal decomposition methods

## Dynamic mode decomposition

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- 2 Modal decomposition methods
  - Proper orthogonal decomposition
  - Dynamic mode decomposition
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# Modal decomposition methods

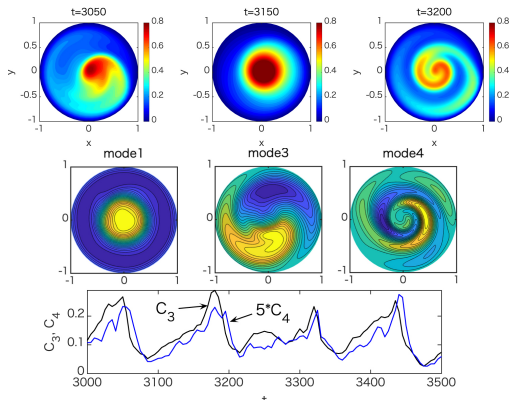
## Dynamic mode decomposition

- Decomposition into spatiotemporal coherent modes

# Modal decomposition methods

## Dynamic mode decomposition

- Decomposition into spatiotemporal coherent modes

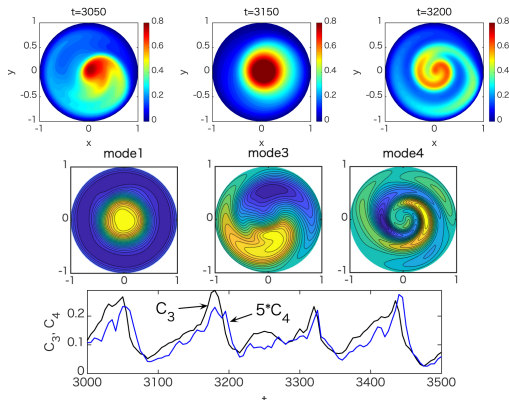


Source: Sasaki et. al. (2019)

# Modal decomposition methods

## Dynamic mode decomposition

- Decomposition into spatiotemporal coherent modes
- Extensions

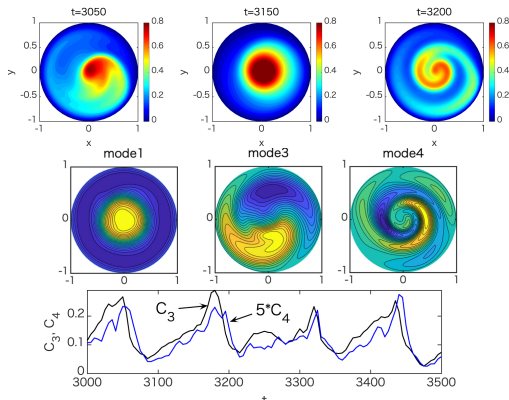


Source: Sasaki et. al. (2019)

# Modal decomposition methods

## Dynamic mode decomposition

- Decomposition into spatiotemporal coherent modes
- Extensions
  - ▶ Multiresolution data

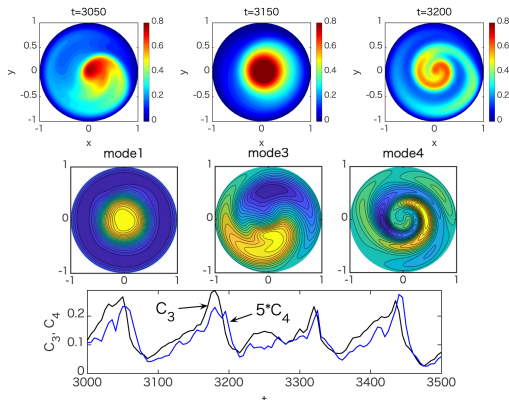


Source: Sasaki et. al. (2019)

# Modal decomposition methods

## Dynamic mode decomposition

- Decomposition into spatiotemporal coherent modes
- Extensions
  - ▶ Multiresolution data
  - ▶ Nonlinear dynamics

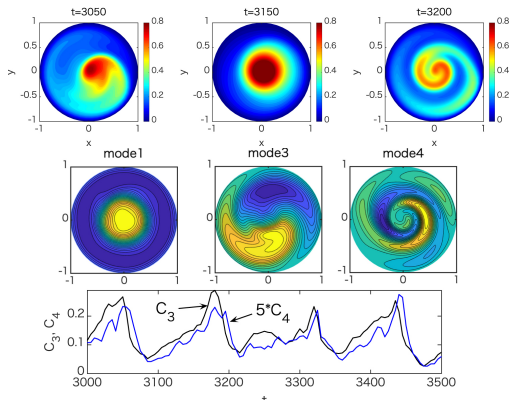


Source: Sasaki et. al. (2019)

# Modal decomposition methods

## Dynamic mode decomposition

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- Extensions
  - ▶ Multiresolution data
  - ▶ Nonlinear dynamics
  - ▶ Noisy data

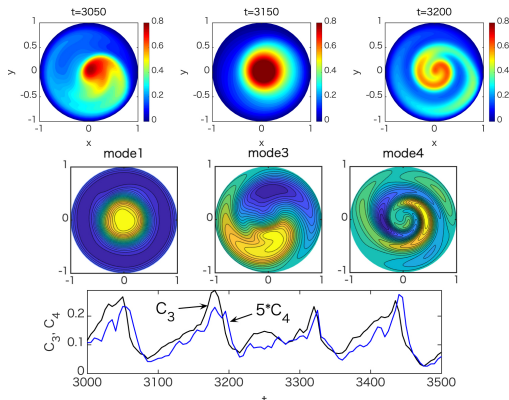


Source: Sasaki et. al. (2019)

# Modal decomposition methods

## Dynamic mode decomposition

- Decomposition into spatiotemporal coherent modes
- Extensions
  - ▶ Multiresolution data
  - ▶ Nonlinear dynamics
  - ▶ Noisy data
  - ▶ Actuated data



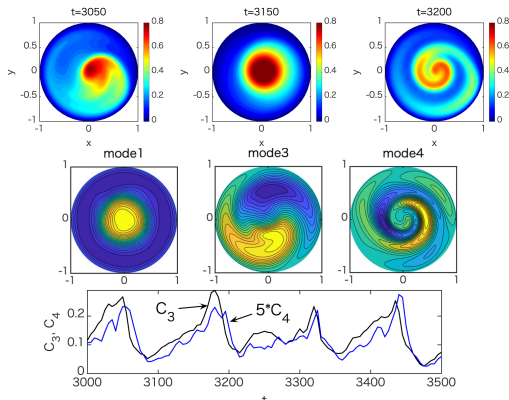
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# Modal decomposition methods

## Dynamic mode decomposition

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  - ▶ Nonlinear dynamics
  - ▶ Noisy data
  - ▶ Actuated data
  - ▶ Sparse data

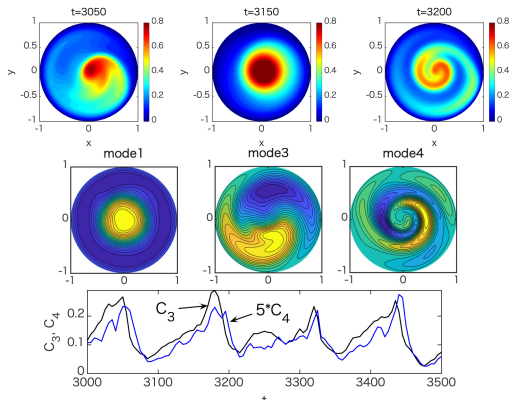


Source: Sasaki et. al. (2019)

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## Dynamic mode decomposition

- Decomposition into spatiotemporal coherent modes
- Extensions
  - ▶ Multiresolution data
  - ▶ Nonlinear dynamics
  - ▶ Noisy data
  - ▶ Actuated data
  - ▶ Sparse data
  - ▶ Streaming data



Source: Sasaki et. al. (2019)

# Outlook

## Dynamic mode decomposition

- Obvious applications

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  - ▶ Characterization of limit cycle dynamics

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  - ▶ Bifurcation analysis

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- Obvious applications
  - ▶ Characterization of limit cycle dynamics
  - ▶ Identification of instabilities
- Other applications
  - ▶ Bifurcation analysis
  - ▶ Data-driven control



Done.