# Analysis of $\mu$ behaviors in fusion reactors

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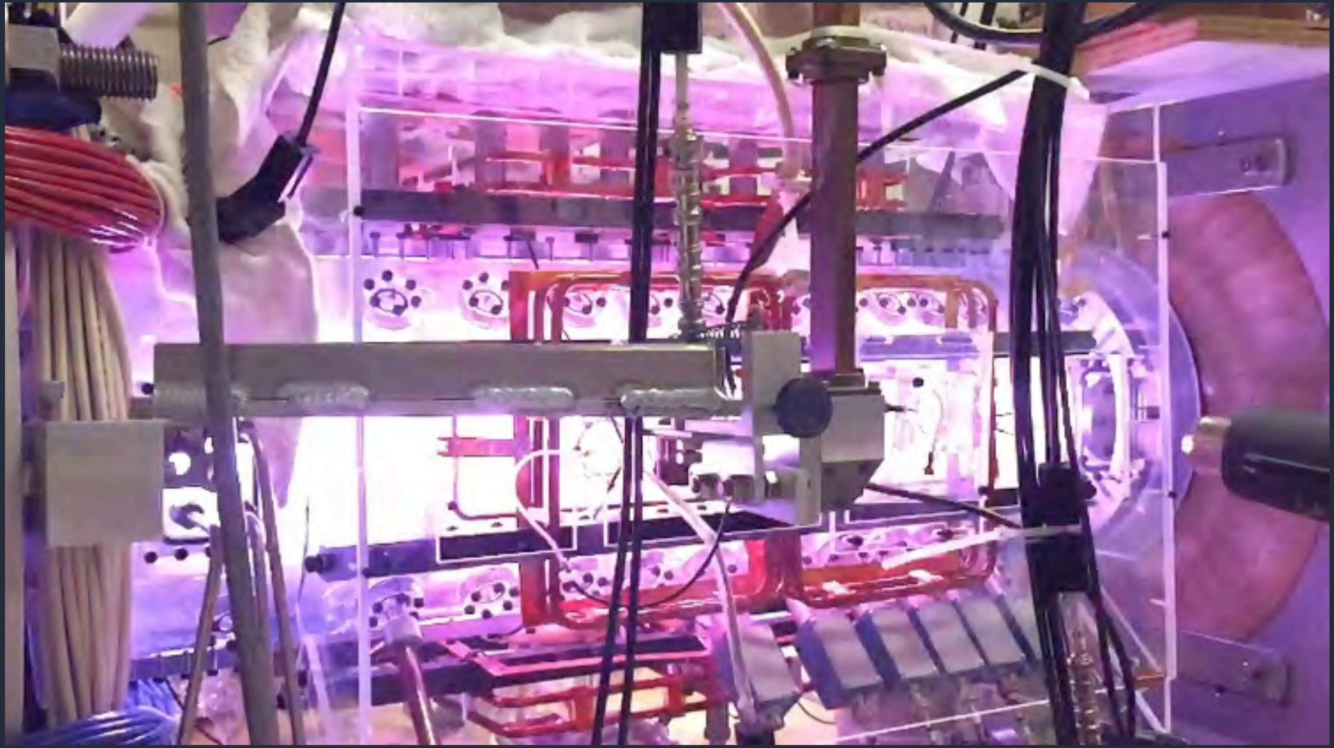
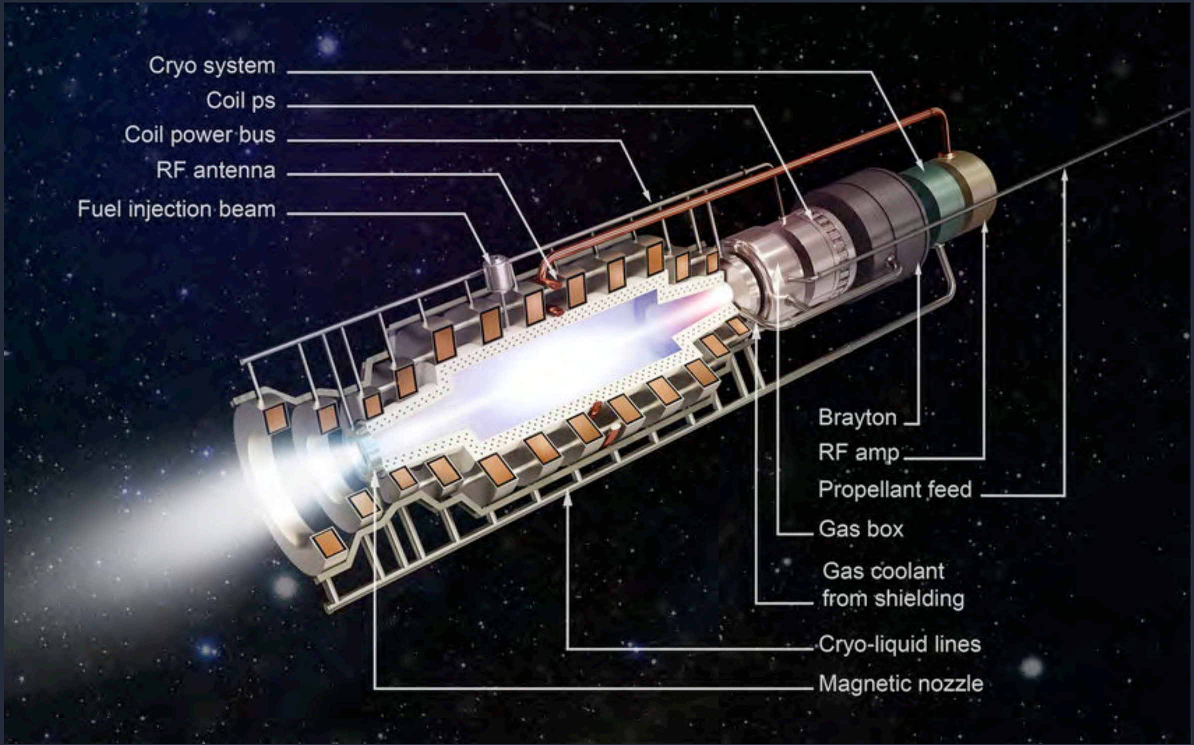
# Princeton FRC reactor



# Applications:
# modular clean energy & astronautics



# Non-adiabaticity of magnetic moment $\mu$ in mirror machines

- MMs first devices to achieve long-term plasma confinement
- Working assumption since 1950s: $\mu$ adiabatically conserved $\rightarrow$ assume const. $\mu$ is particle escape criterion
- Recent work (Swanson) finds better criterion: scalar coeff. $K(\mu)$ in chaotic time series

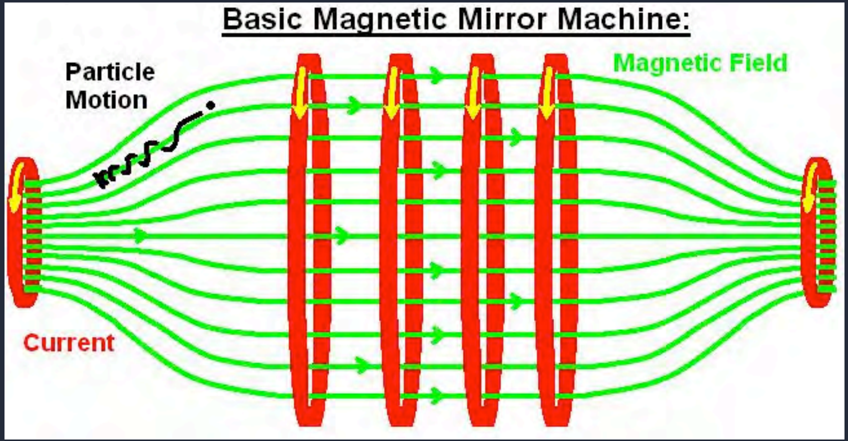
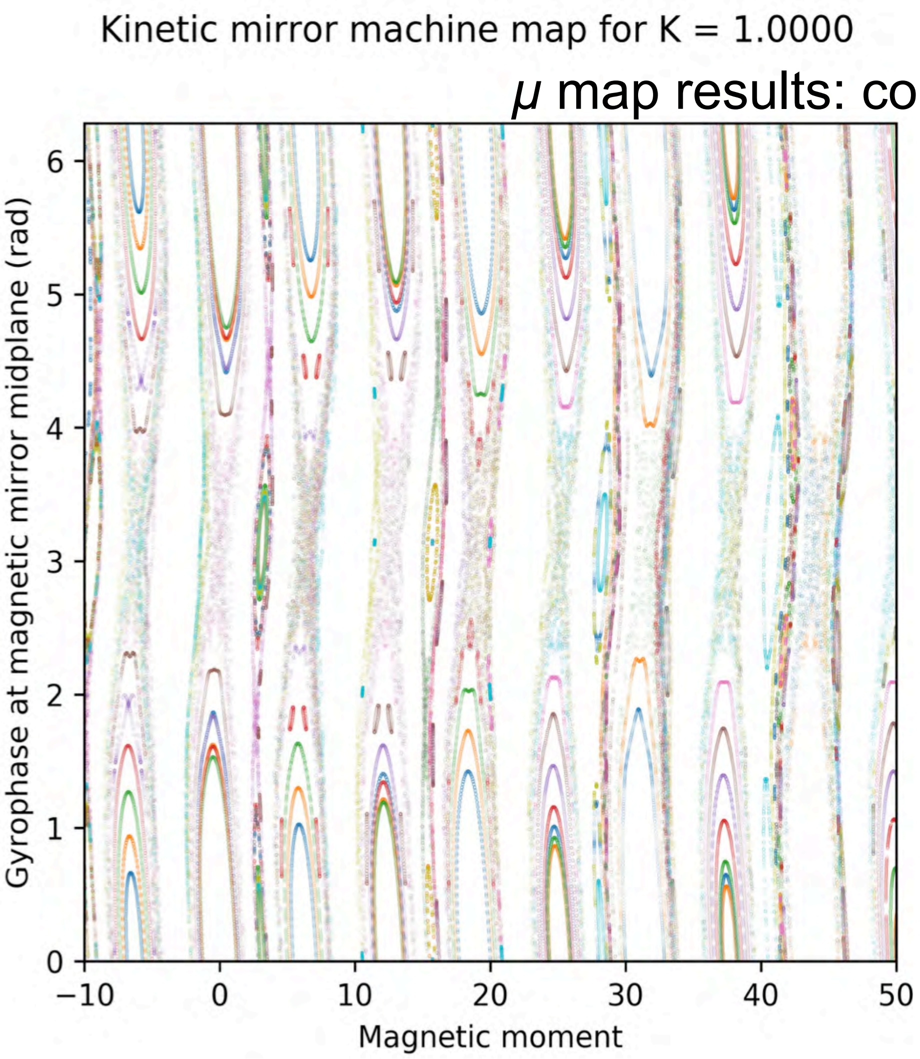
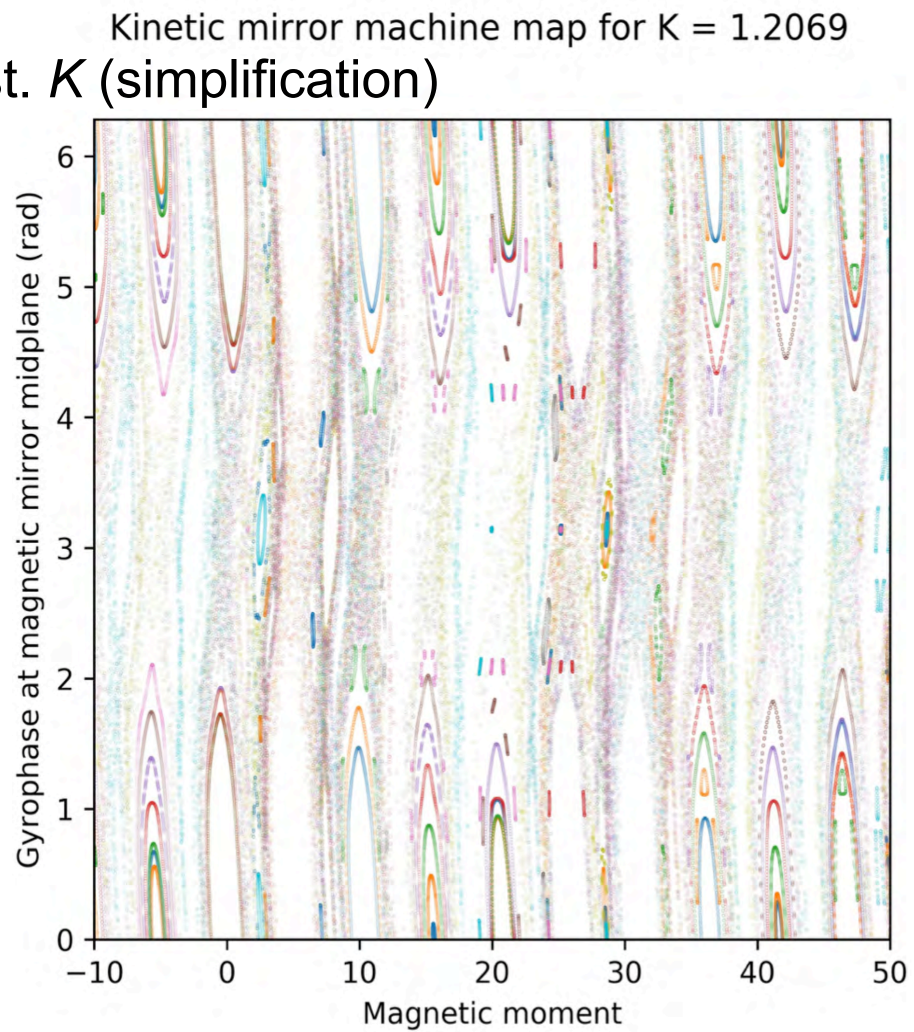


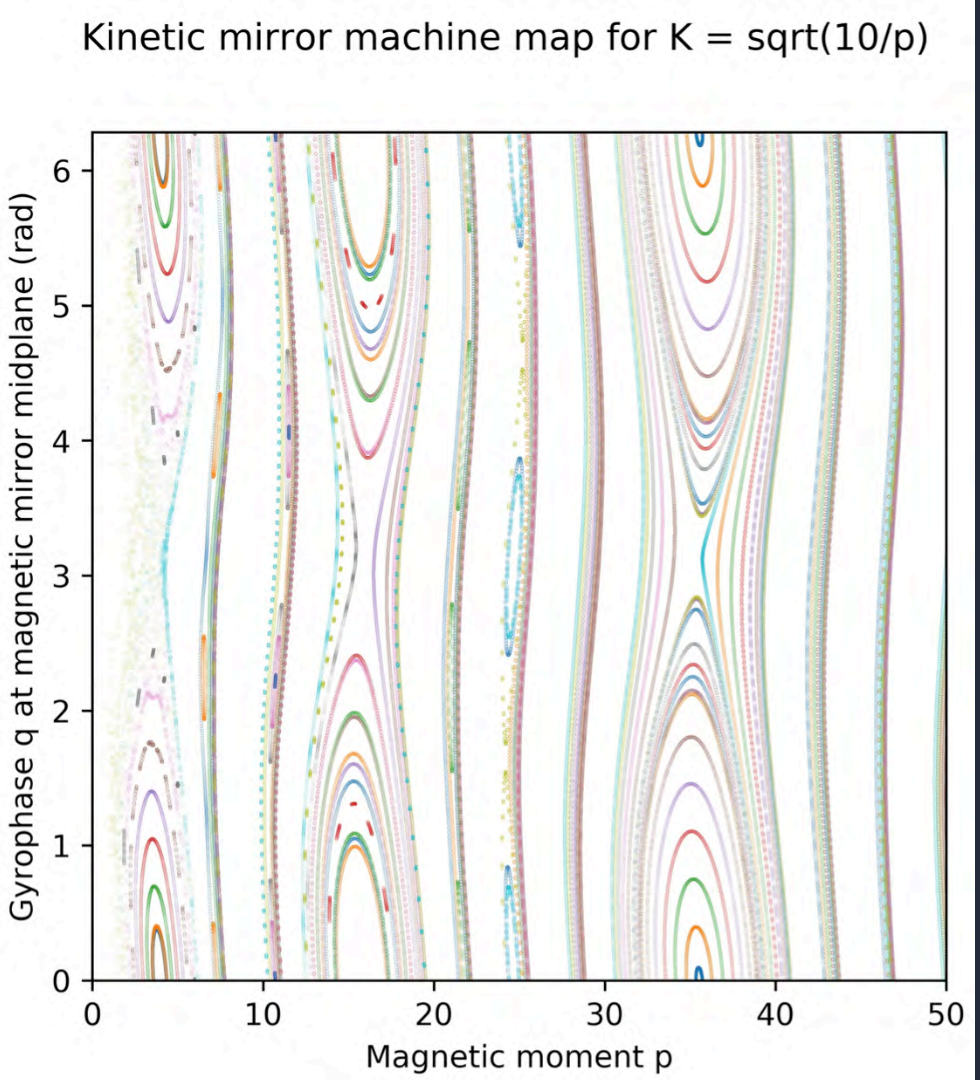

Image credit: Wikimedia Commons

## $\mu$ map results: const. $K$ (simplification)



# $\mu$ map results: variable $K(\mu)$



# Analysis of dimensionality of chaotic dynamical systems

**Goal**: determine if CDS is predictable from one time step to the next; find system dimensionality

**Expectation**: if an *n*-dim. system in *p* is predictable, then *p*[*t*] should be predictable given *p*[*t*-*n*], *p*[*t*-(*n*-1)], …, *p*[*t*-1]

System's conditional prob. dist. should be "*peaked*"

**Implementation**: for narrow ranges of *p*[*t*] create histograms of *t* values for which:

- 1D analysis: *p*[*t*-1] is in range
- 2D analysis: *p*[*t*-2] and *p*[*t*-1] are both in range

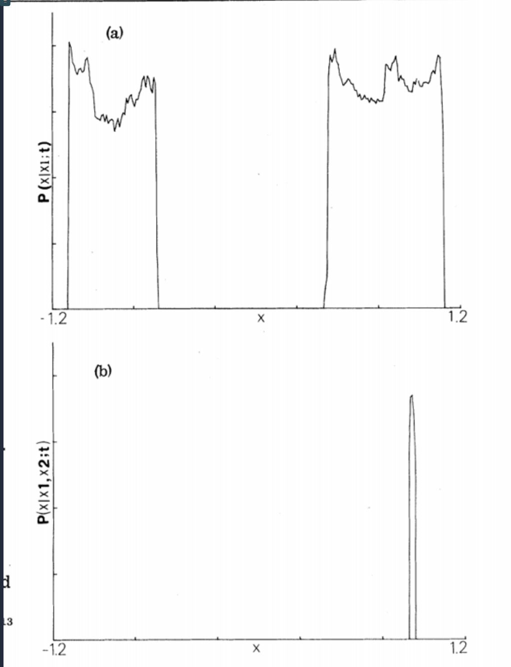
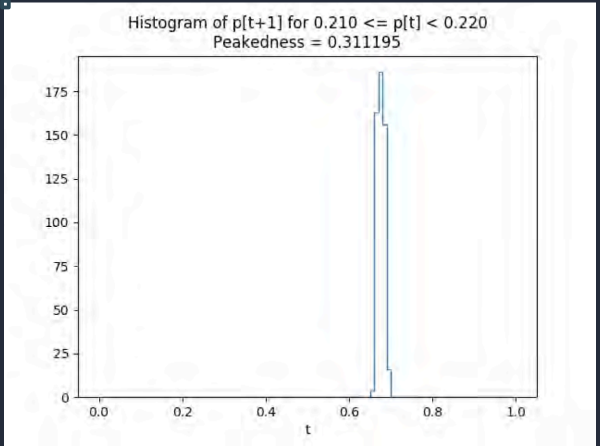



FIG. 3. Conditional-probability-distribution sequence for Eq. (1): (a) $x$ vs $P(x|x_1;t)$; (b) $x$ vs $P(x|x_1,x_2;t)$; where $x_1 = 0$, $x_2 = 0.495$, and $t = 0.2$ time units.

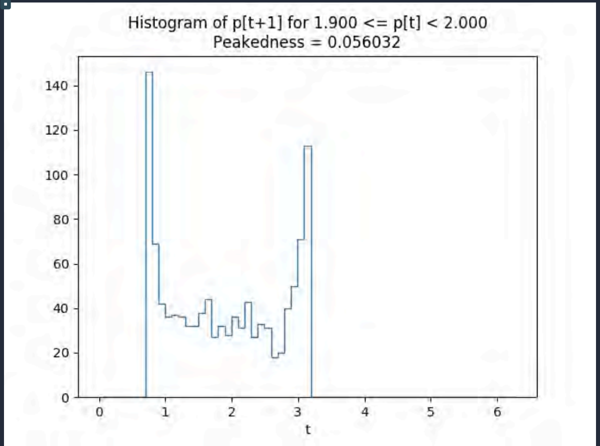
Packard et al. (1980)

# CDS dimensionality analysis (continued)

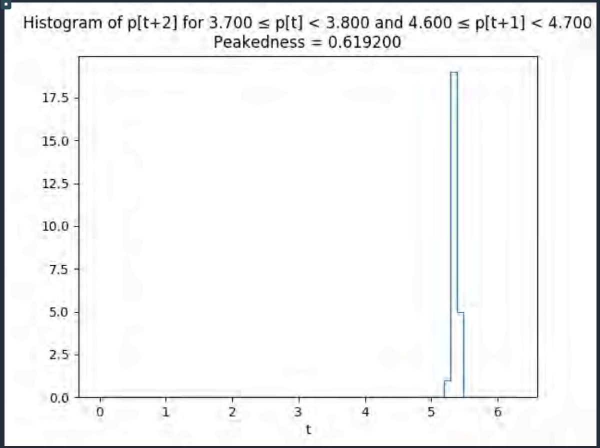
### 1D analysis on 1D system




### 1D analysis on 2D system




### 2D analysis on 2D system




$$p(t+1) = \pi p(t) \bmod 1$$

$$\begin{cases} p_t = (p_{t-1} + K \sin \theta_{t-1}) \bmod 2\pi \\ \theta_t = (\theta_{t-1} + p_t) \bmod 2\pi \end{cases}$$

# CDS dimensionality analysis (continued): Floating potential in PFRC