

REPORT DOCUMENTATION PAGE

1a. **AD-A204 010**

1b. RESTRICTIVE MARKINGS

3. DISTRIBUTION/AVAILABILITY OF REPORT  
Scientific Officer N00014  
Administrative Contracting Officer, N 66 0  
Director, NRL, N00173

4. PERFORMING ORGANIZATION REPORT NUMBER(S)  
**88-1**

5. MONITORING ORGANIZATION REPORT NUMBER(S)  
Defense Technical Info. Center 547031

6a. NAME OF PERFORMING ORGANIZATION  
University of Texas at Austin

6b. OFFICE SYMBOL  
(If applicable)

7a. NAME OF MONITORING ORGANIZATION  
Office of Naval Research

7b. ADDRESS (City, State and ZIP Code)

8a. ADDRESS (City, State and ZIP Code)  
Center for Nonlinear Dynamics  
Austin, TX 78712

8b. NAME OF FUNDING/SPONSORING ORGANIZATION  
ONR

8c. OFFICE SYMBOL  
(If applicable)

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER  
Contract N00014-86-K-038

10. SOURCE OF FUNDING NOS.

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT NO.

11. TITLE (Include Security Classification)  
**Symmetry Breaking Bifurcations and the Growth of Chaos in a Rotating Fluid**

12. PERSONAL AUTHOR(S)  
Harry L. Swinney

13a. TYPE OF REPORT  
Annual

13b. TIME COVERED  
FROM 87 Oct 1 TO 88 Sept 30

14. DATE OF REPORT (Yr., Mo., Day)  
88 Nov 10

15. PAGE COUNT  
4

16. SUPPLEMENTARY NOTATION

DTIC ELECTED NOV 21 1988 E

17. COSATI CODES

FIELD	GROUP	SUB. GR.

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Laboratory experiments and numerical simulations on flow between concentric independently rotating cylinders (the Couette-Taylor system) reveal a primary bifurcation to a new state ribbons, which are traveling waves in the azimuthal direction but standing waves in the axial direction. Other experiments, conducted on a rigid rapidly rotating annulus, are designed to explore parameter regimes characteristic of planetary scale flows. Eastward jets are found to exhibit Rossby waves for a wide range of control parameters, and these jets (or, more precisely, the potential vorticity gradients in the core of the jets) act as a strong barrier to tracer transport; these observations have important implications for the transport of pollutants in oceans and the atmosphere. The behavior of westward jets is found to be markedly different from that of eastward jets: persistent vortices (like the Great Red Spot of Jupiter) are found to form spontaneously in a turbulent shear flow formed by westward jets.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT  
UNCLASSIFIED/UNLIMITED  SAME AS RPT.  DTIC USERS

21. ABSTRACT SECURITY CLASSIFICATION  
Unclassified

22a. NAME OF RESPONSIBLE INDIVIDUAL  
Harry L. Swinney

22b. TELEPHONE NUMBER (Include Area Code)  
512-471-4619

22c. OFFICE SYMBOL

This document has been approved for public release and its distribution is unlimited.

OFFICE OF NAVAL RESEARCH  
PUBLICATIONS / PATENTS / PRESENTATIONS / HONORS REPORT  
FOR 1 OCTOBER 1987 through 30 SEPTEMBER 1988

\*\*\*\*\*

CONTRACT N00014-86-K-0385

R & T NO. \_\_\_\_\_

TITLE OF CONTRACT: Symmetry Breaking Bifurcations and the Growth of Chaos  
in a Rotating Fluid

NAME OF PRINCIPAL INVESTIGATOR: Harry L. Swinney

NAME OF ORGANIZATION: The University of Texas at Austin

ADDRESS OF ORGANIZATION: Physics Department, Austin, TX 78712

\*\*\*\*\*

Reproduction in whole, or in part, is permitted for any purpose of the United States Government.

This document has been approved for public release and sale; its distribution is unlimited.

Accession For	
NTIS GRA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By _____	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	



88 11 21 00 4

PAPERS SUBMITTED TO REFEREED JOURNALS  
(Not yet published)

"Nonlinear standing waves in Couette-Taylor flow," R. Tagg, S. Edwards, H. L. Swinney, and P. S. Marcus, submitted to *Phys. Rev. Lett.* (1988).

"Laboratory model of a planetary eastward jet," J. Sommeria, S.D. Meyers, and H.L. Swinney, *Nature*, to appear.

"Divergence-free velocity fields in nonperiodic geometrics," L. Tuckerman, to appear in *J. Computational Physics*.

"Transformations of matrices into banded form", L. Tuckerman, to appear in *J. Computational Physics*.

"Steady-state solving via Stokes preconditioning: recursion relations for elliptic operators," L. S. Tuckerman, to appear in *Proc. of the Eleventh Int'l. Conference on Numerical Methods in Fluid Dynamics*, ed. by D. L. Dwoyer, M. Y. Hussaini, and R. G. Voigt (Springer-Verlag, Berlin, 1989).

"Traveling waves in axisymmetric convection: the role of sidewall conductivity," D. Barkley and L. S. Tuckerman, submitted to *Physica D* (1988).

PAPERS PUBLISHED IN REFEREED JOURNALS

"Primary instabilities and bicriticality in flow between counterrotating cylinders," W.F. Langford, M. Golubitsky, R. Tagg, E. Kostelich, and H.L. Swinney, *Phys. Fluids* **31**, 776-785 (1988).

"Instabilities and chaos in rotating fluids," in *Nonlinear Evolution and Chaotic Phenomena*, ed. by G. Gallavotti and P. W. Zweifel (Plenum Publishing Co., 1988), p. 319-326.

"A laboratory simulation of the great red spot of Jupiter," J. Sommeria, S.D. Meyers, and H.L. Swinney, *Nature* **331**, 689-693 (1988).

"Numerical simulation of Jupiter's Great Red Spot," P.S. Marcus, *Nature* **331**, 693-696 (1988).

"Global bifurcation to traveling waves in axisymmetric convection," L. S. Tuckerman and D. Barkley, *Phys. Rev. Lett.* **61**, 408-411 (1988).

PAPERS PUBLISHED IN NON-REFEREED JOURNALS

None

TECHNICAL REPORTS PUBLISHED

None

BOOKS (AND SECTIONS THEREOF) SUBMITTED FOR PUBLICATION

None

## BOOKS (AND SECTIONS THEREOF) PUBLISHED

None

## PATENTS FILED

None

## PATENTS GRANTED

None

INVITED PRESENTATIONS BY H.L. SWINNEY AT TOPICAL OR  
SCIENTIFIC/TECHNICAL SOCIETY CONFERENCES

10/2/87	Schlumberger (Austin), Seminar
10/9/-10/87	J. H. Taylor Symposium, Rhodes College, Memphis
10/21-23/87	Dynamic Patterns in Complex Systems, Bahia Mar, Florida
12/14/-15/87	Ed Lorenz Symposium, M.I.T.
2/24/88	Duke University, Physics Department Colloquium
4/13/88	Chaos Review Panel, Jason, Scripps Institute of Oceanography
4/20/88	American Physical Society Annual Meeting, Washington, D. C.
4/21/88	Clarkson University, Physics Colloquium
5/4-5/88	Department of Energy Symposium on Energy Engineering Sciences, Argonne
5/12/88	Rutgers Statistical Mechanics Meeting, Newark, NJ
5/16-20/88	Advances in Fluid Turbulence, Los Alamos, New Mexico
7/26-8/5/88	Enrico Fermi International School of Physics, Nonlinear Topics in Ocean Physics, Varenna, Italy (3 lecture course)
7/29/88	National Institute of Optics, Florence, Italy, Seminar
9/15/88	Texas A&M University, Physics Colloquium
9/21-22/88	Chemical Engineering Colloquium, Rice University, Houston, TX

CONTRIBUTED PRESENTATIONS AT TOPICAL OR  
SCIENTIFIC/TECHNICAL SOCIETY CONFERENCES

11/23-25/87	"Stability of Flow Between Counter-Rotating Cylinders", Randall Tagg, Eric J. Kostelich, and Harry L. Swinney, Annual Meeting of the American Physical Society, Division of Fluid Dynamics
-------------	--

OTHER RECENT PROFESSIONAL ACTIVITIES  
(H. L. Swinney.)

Director, The Center for Nonlinear Dynamics, University of Texas, 1985-  
 Editor, Physica D-Nonlinear Dynamics (North-Holland Publishing Co.,  
 Amsterdam), 1982-1986  
 Member of the Executive Committee, Division of Fluid Dynamics,  
 American Physical Society, 1983-86  
 Co-organizer, Fluid and Plasma Turbulence Conference, Austin, Dec. 7-11, 1987  
 Co-organizer, Dynamics Days Texas, Houston, January 5-8, 1988  
 Member of the Organizing Committee, Complex Systems Summer School, Santa Fe,  
 June 13-July 18, 1988  
 Organizer of course entitled *CHAOS* — 7 lectures of 3 hours each held on 7 successive  
 Fridays at The University of Texas Applied Research Laboratory,  
 March 25-May 6, 1988  
 Organizing Committee, Year of Dynamics (1989-90), Institute of Mathematical Analysis,  
 University of Minnesota  
 Member, Advisory Board for the Warwick Nonlinear Systems Laboratory, 1986-  
 Member, Science Board of the Santa Fe Institute, 1987-  
 Member, External Advisory Board, Center for Interdisciplinary Complex Systems,  
 University of Arizona, 1987-

GRADUATE STUDENTS SUPPORTED UNDER  
 CONTRACT FOR YEAR ENDING 30 SEPTEMBER 1988

Bright Dornblaser  
 William S. Edwards  
 Andrew Fraser  
 John Good  
 Steve Meyers  
 Michael Schatz

POSTDOCTORALS SUPPORTED UNDER  
 CONTRACT FOR YEAR ENDING 30 SEPTEMBER 1988

Eric Kostelich  
 Randall Tagg  
 Laurette Tuckerman