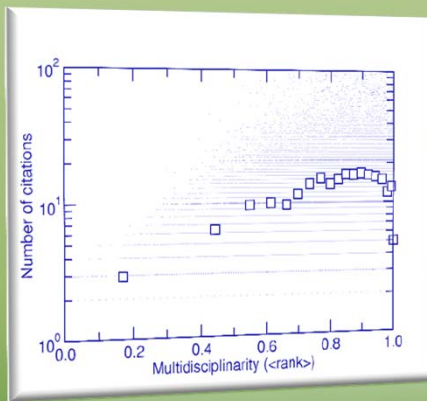
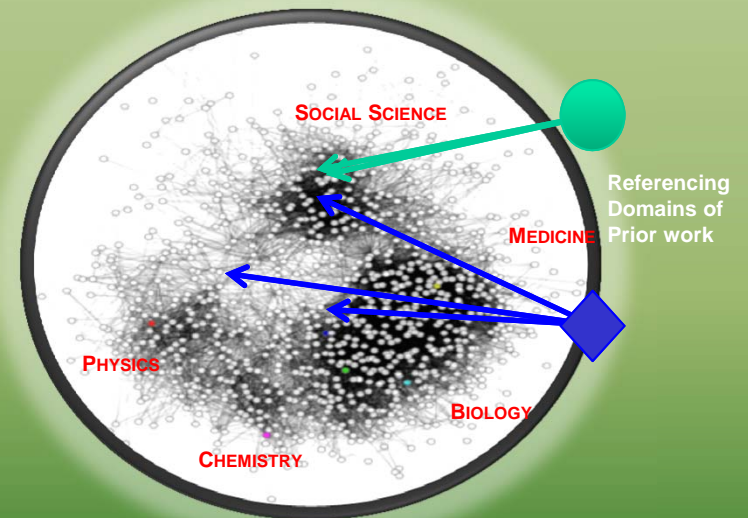


Atypical Combinations and Scientific Impact



Brian Uzzi
Kellogg School of Management
&
McCormick School of Engineering
Northwestern University

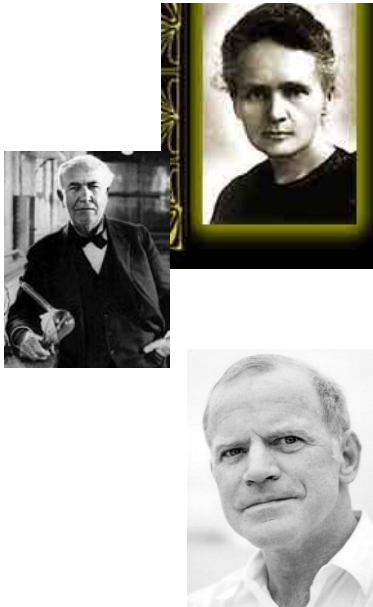
&
Northwestern University Institute of Complexity (NICO)



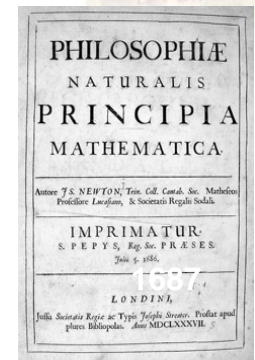
Research in Collaboration With: Satyam Mukherjee, Ben Jones, and, Mike Stringer

Atypical Combination and Creative Impact

- Creativity is spurred on when atypical knowledge is united (Becker 1982, Weitzman 1998, Uzzi & Spiro 2005)



- ❑ Curie: Radioactivity + neoplasms
- ❑ Edison: Light bulb = light + electricity
- ❑ Mullis: DNA replication = DNA + enzyme



- Idea ahead of its time” embodies knowledge (too) far from conventional beliefs
- Context: Science, All fields, all 17.9 million Papers in WOS, 1950 – 2000
- Findings
 - Novelty lifts Impact if mixed with convention
 - Teams source and assimilate novelty more
 - Universality of effects



Coding for Novelty and Conventionality

Step (1) Published Paper

Tetrahedron Letters Vol . 21 , pp 3603-3060
Pergerson Press Ltd, 1980. Printed in Great Britain

SYNTHESIS OF THE FIVE NATURAL CANNABIS SPIRANS

Leslie Crombie, Michael J. Powell and
Patoomratana Tuchinda

Step (2) Prior Work Referenced by Paper

References

BERCHT, CAL; VANDONGEN, JPCM; HEERMA, W; et al.
TETRAHEDRON Volume: 32 Issue: 23 Pages: 2939-2943 Published:
1976

BOEREN, EG; ELSOHLY, MA; TURNER, CE; et al.
EXPERIENTIA Volume: 33 Issue: 7 Pages: 848-848 Published: 1977

BUCHL, G; SPITZNER, D; PAGLIALU.S; et al.
LIFE SCIENCES Volume: 13 Issue: 8 Pages: 1143-1149 Published:
1973

BULL, JR; TUINMAN, A
TETRAHEDRON Volume: 31 Issue: 17 Pages: 2151-2155 Published:
1975

KETTENESVANDENBOSCH, JJ; SALEMINK, CA
RECUEIL DES TRAVAUX CHIMIQUES DES **PAYS-BAS**-
JOURNAL OF THE ROYAL NETHERLANDS CHEMICAL
SOCIETY Volume: 97 Issue: 7-8 Pages: 221-222 Published: 1978

...

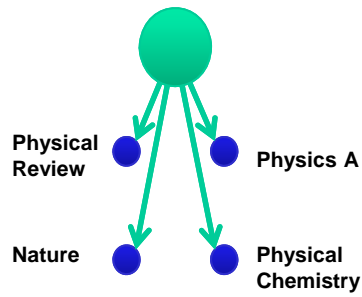
...



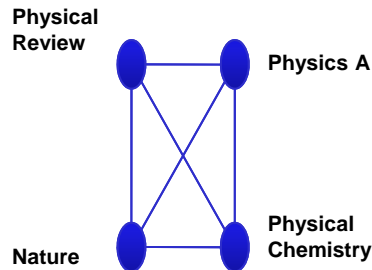
Measuring Convention and Novelty for All Papers- Details

Rosenkopf, L. and P. McGrath. 2011. "Advancing the conceptualization and operationalization of novelty in organizational research," *Organization Science*, 22:1297-1311.
 Method based on Henry Small, Co-citation in the scientific literature: a new measure of the relationship between two documents. *J. Amer. Soc. Inform. Sci.* 24 : 265-9, 1973

From observed reference
Network of a paper



...to observed co-journal
citation



Control using Monte Carlo bootstrap method:

1 random citation network
 • 500 million citations
 • ~50 billion link switches



Many random
citation networks

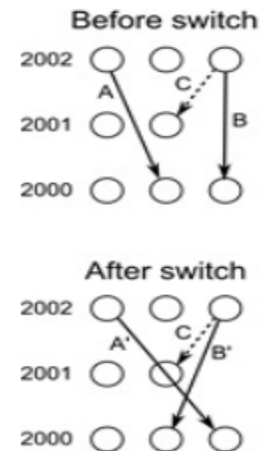
- Random Network Preserves structure of Observed Network:

- In-degree, out-degree & Time dynamics are preserved

- A 2000 paper that references a 1999, 1998, and a 1975 paper gets 3 random refs in the same years

- A 2000 paper with a citation from a 2001, 2002, and 2005 gets 3 cites from those same years

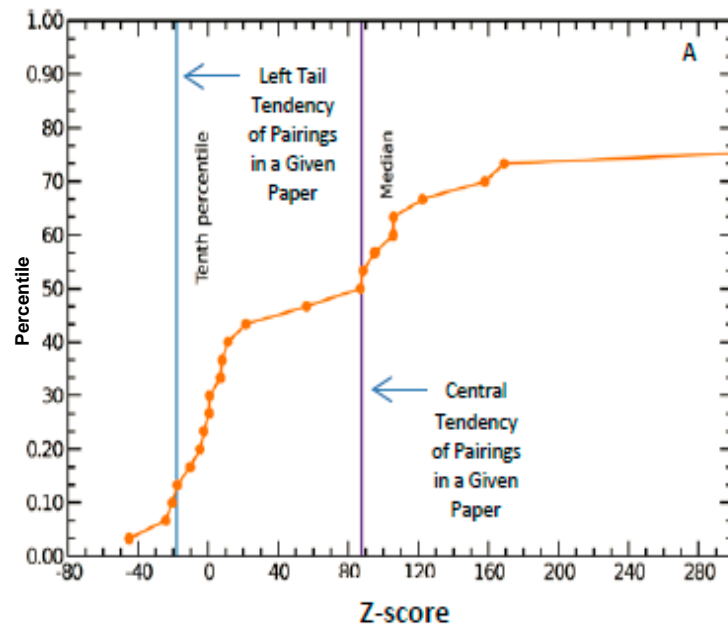
Null Model



Every pairing has a z-score; >0 means more conventional & < 0 means more novel pairing

Observed, expected and z-scores for a paper

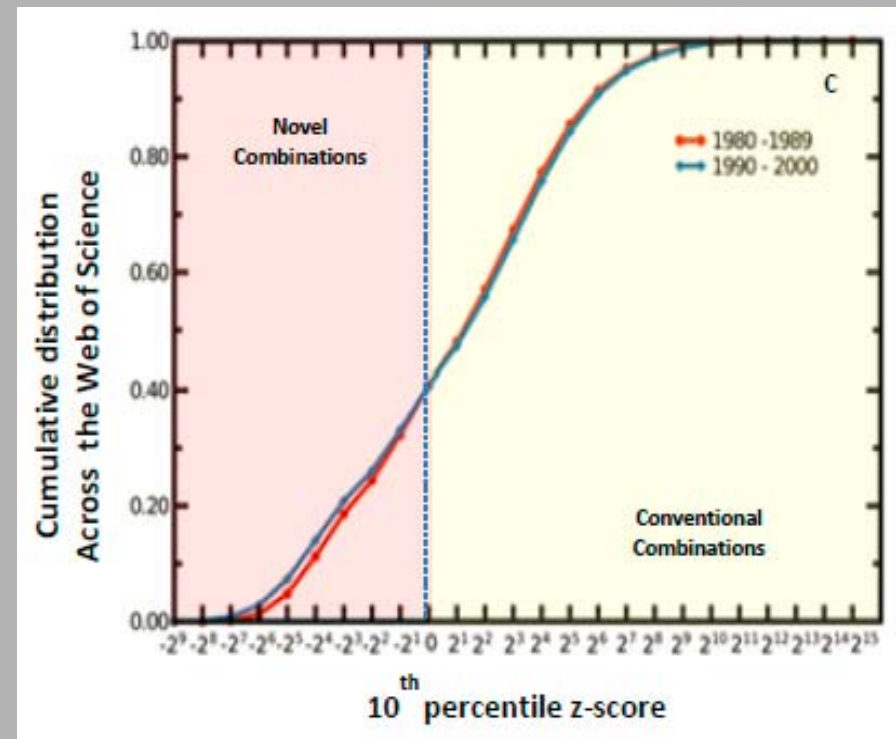
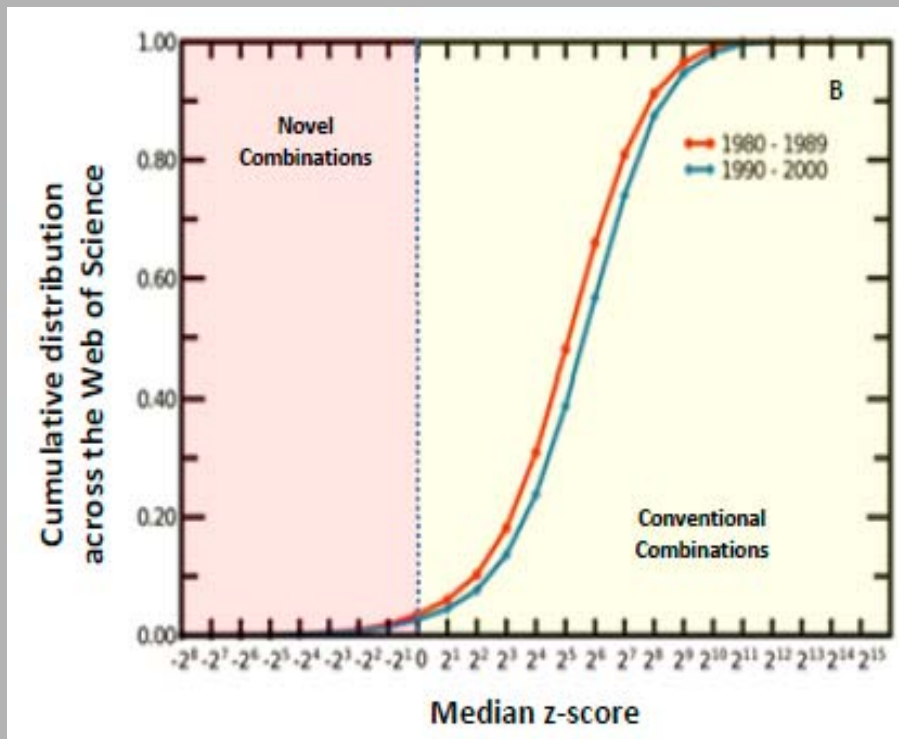
Journal Pairs	Observed	Expected	Z-score
Tetrahedron - Tetrahedron			637.77
Experientia - Experientia			95.07
Tetrahedron - Experientia			21.55
Experientia - Tetrahedron Lett			6.88
Conventional			
Chem Phar Bull - Life Sci			-2.4
Life Sci - R J Royal Neth C			-4.82
Life Sci - Tetrahedron			-17.67
Life Sci - J Organic Chemistry			-24.21
J Am Chem Soc - Life Sci			-45.07
Novelty			



Population Distributions 1980s and 1990s

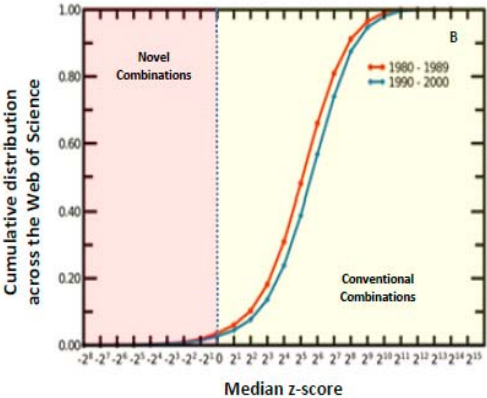
Median Conventinality

Tail Novelty



Data Analysis: Convention, Novelty & Impact

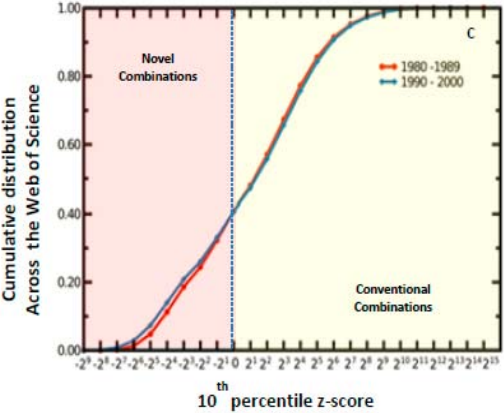
Median Conventuality



High
Paper's tail
< 0
Z-score

Tail Novelty

Tail Novelty



Low
Paper's Tail
> 0
Z-score

<p>High Novelty Avant Garde</p>	<p>Convention + Extension</p>
<p>Neither Fish Nor Foul</p>	<p>High Conventuality Established Knowledge</p>

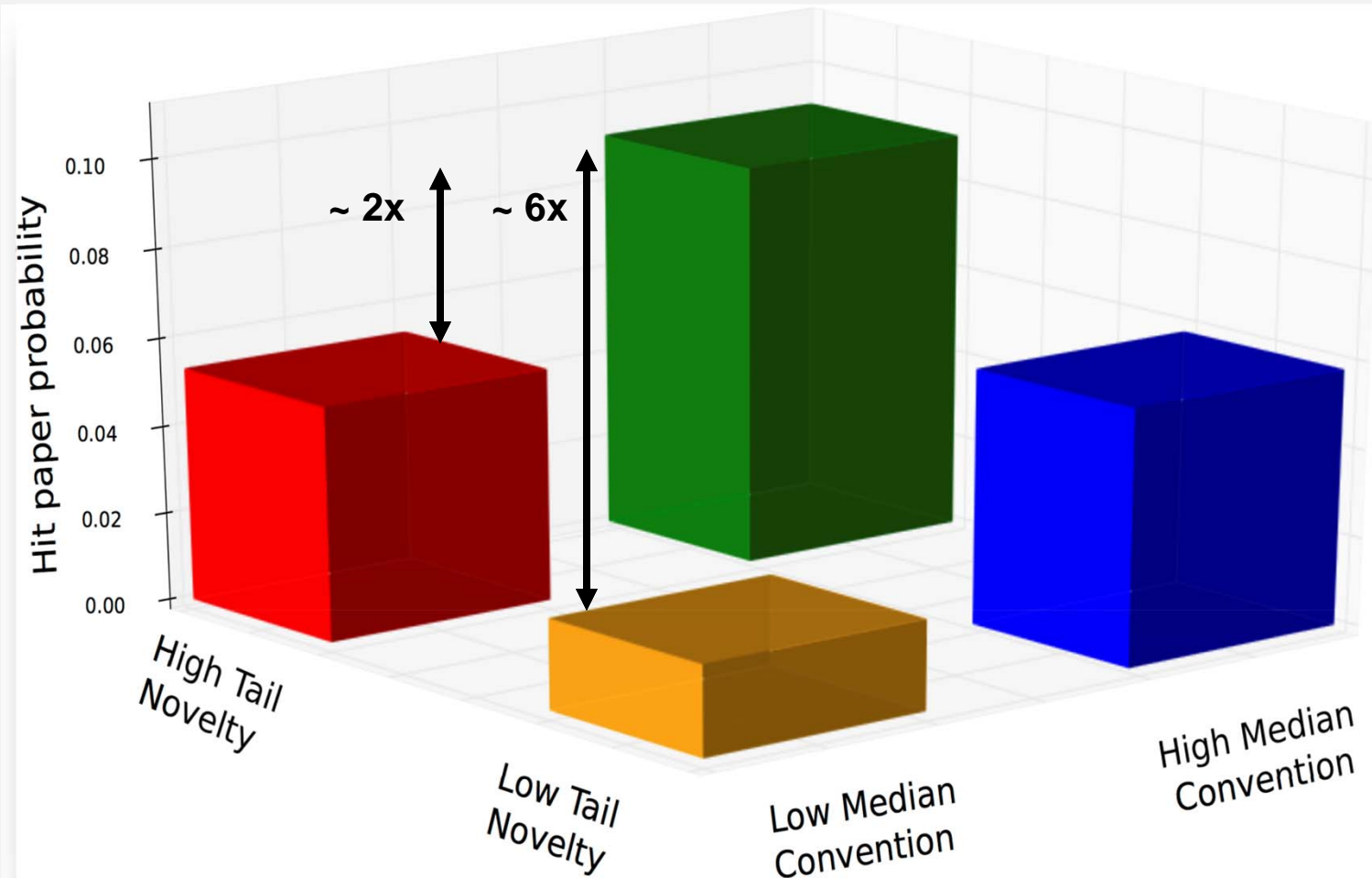
Low
Paper's median
below
population
Median

Median Conventuality

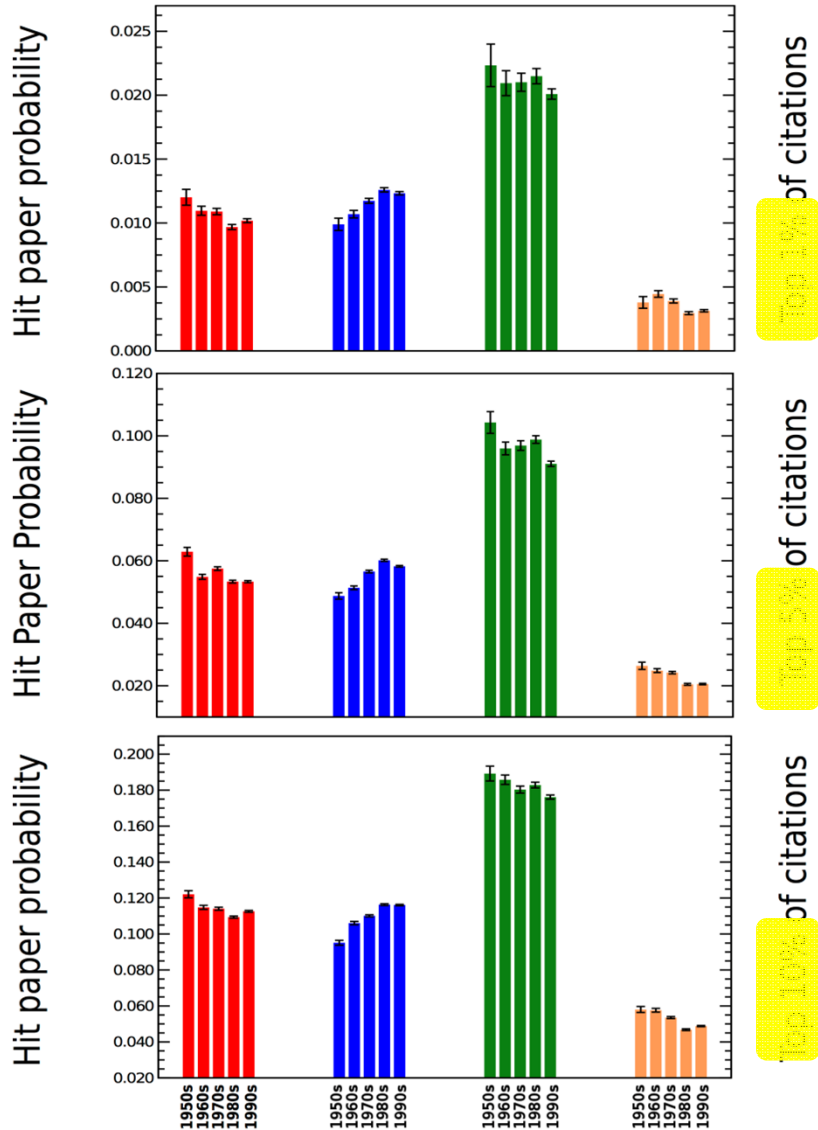
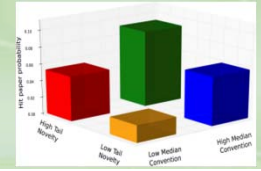
High
Paper's median
above
population
Median

Probability of a Hit Paper

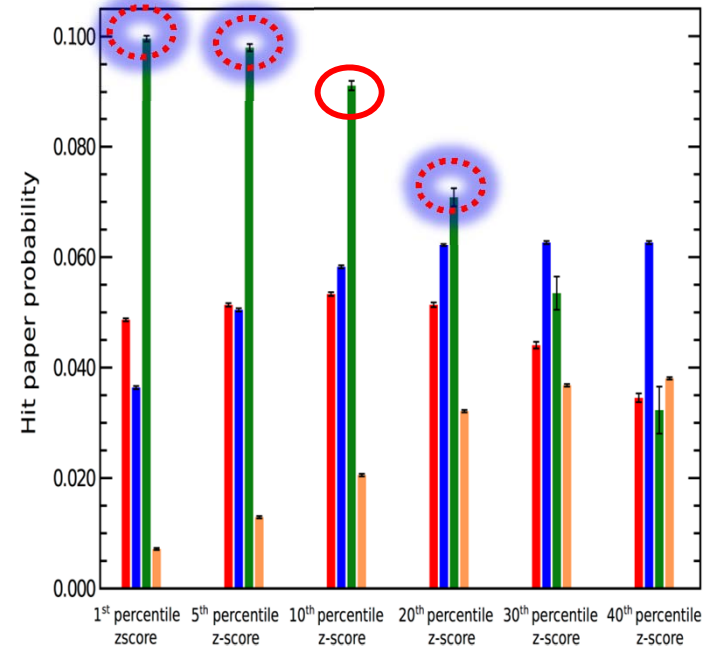
(Papers in top 5% Percentile of all papers)



Universality



Sensitivity tests for Hit paper cutoff confirm relationship



Sensitivity tests for novelty cutoff confirm relationship

	Field by Field Pattern Ranked			
Tower	1 st	2 nd	3 rd	4 th
A	20.25%	44.53%	28.74%	6.48%
B	9.71%	26.72%	50.61%	12.96%
C	64.38%	21.86%	3.64%	10.12%
D	5.66%	6.89%	17.01%	70.44%





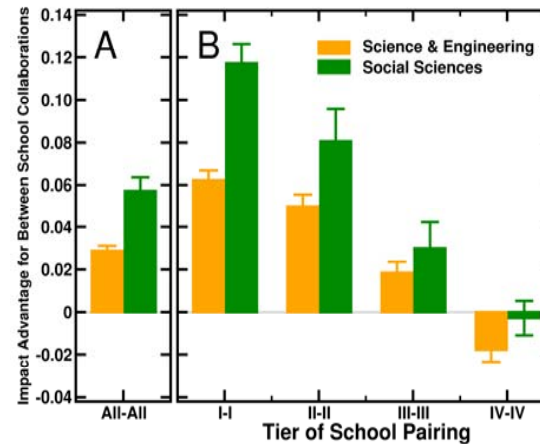
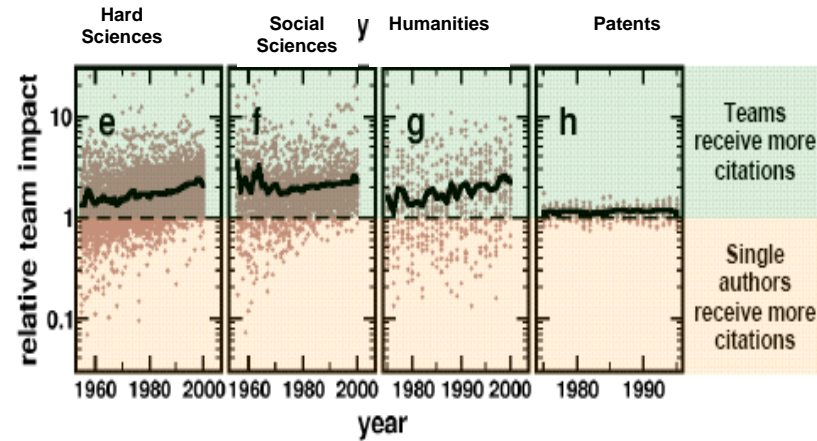
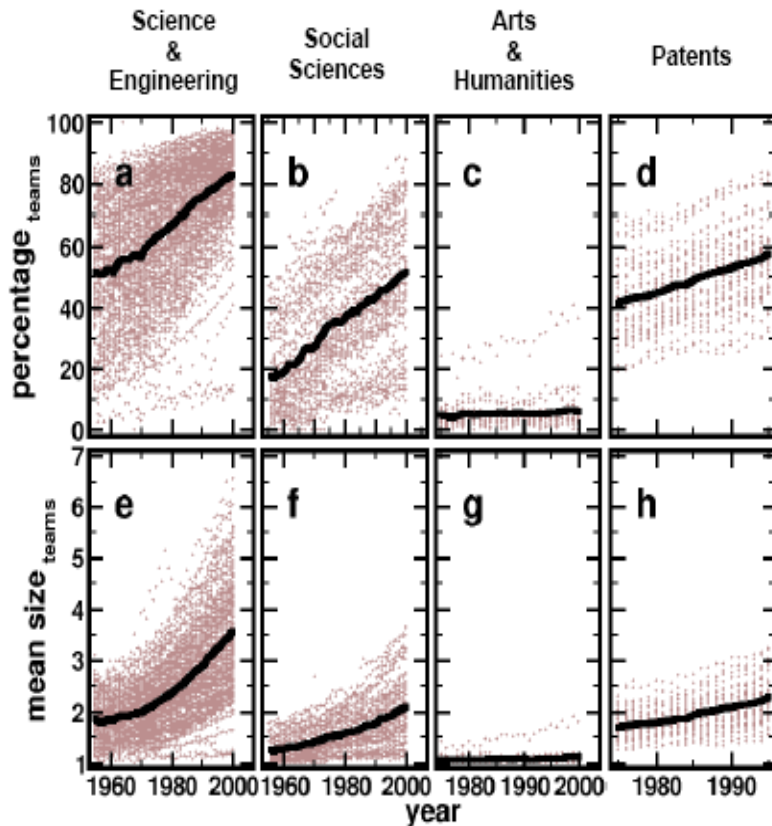
**Getting to the Frontier of Atypical
Scientific Knowledge**

Dominance of Teams in the production of High Impact Knowledge



Web of Science Data on Publications
 - 21.1 Millions Papers from 1945-2006
 - All Fields in Hard, Social, and Humanities
 - 1.9 Million Worldwide Patents

Teams get *more Citations* than Solo authored Papers



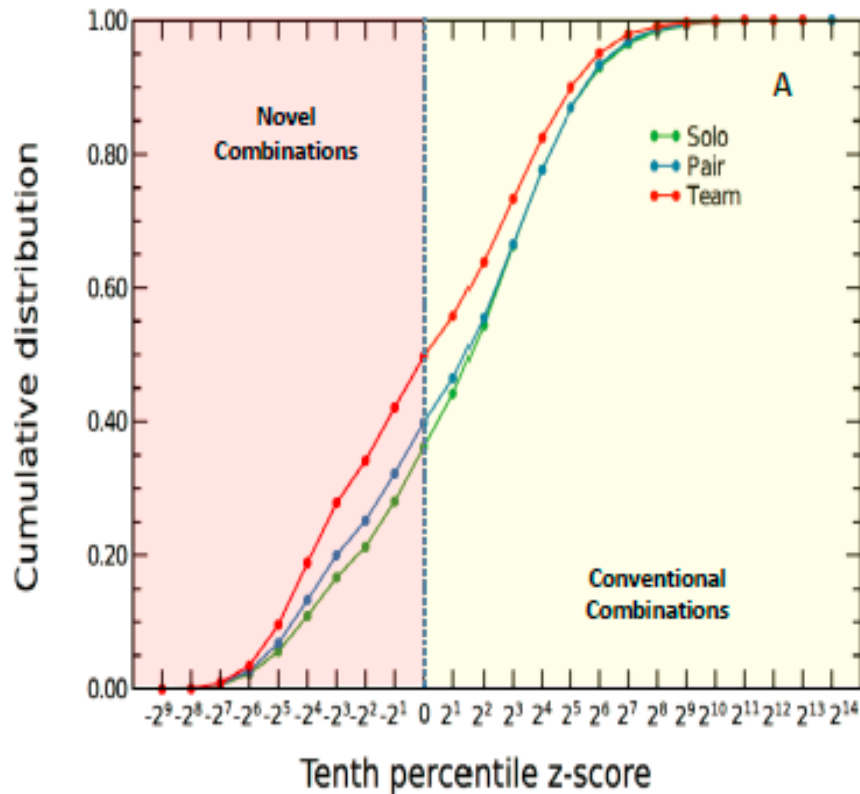
Between-school collaborations have a impact advantage over within-school collaborations all tiers.
Harvard+Oxford > Harvard+Harvard

Wuchty, Jones and Uzzi (2007) *Science*
 Jones, Wuchty, and Uzzi (2008) *Science*
 Guimera, Uzzi, Spiro and Amaral (2005) *Science*

Decline of the Impact of Solo Scientist and the rise of Team Science

Distributed Teams and the Frontier of Tail Novelty

Tail Novelty



Median Conventinality

KS Test: Teams have more Tail Novelty on average than Solo or Pairs

KS Test: Teams, pairs, & solo authors have same avg. conventionality

Teams, Prior Work, and IMPACT

Solo Authors

Duo Authors

Team Authors

Pr(P < 95)

0.14

0.12

0.10

0.08

0.06

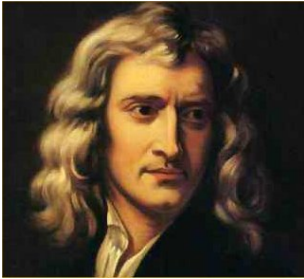
0.04

0.02

0.00

- 1) High Tail Novelty always better than low Tail Novelty for solo, pairs, and teams**
- 2) High Median Conventionalty is better up to a point then reverses**
- 3) Given the same material, teams write more highly cited papers than duos or soloists**
- 4) Universality**

Creativity and Prior Knowledge



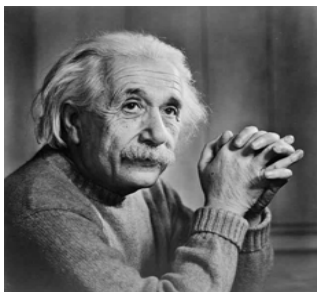
Isaac Newton

"If I have seen further it is by standing on ye sholders of Giants."



Henry Ford

"I invented nothing new. I simply assembled into a car the discoveries of other men behind whom were centuries of work....Had I worked fifty or ten or even five years before, I would have failed. So it is with every new thing.



Albert Einstein

"...knowledge has become vastly more profound in every department of science. But the assimilative power of the human intellect is and remains strictly limited. Hence it was inevitable that the activity of the individual investigator should be confined to a smaller and smaller section..."

Summary: Atypical Knowledge and Scientific Impact

- Highest Impact Scientific Work is associated with Novelty but only when Embedded in conventional knowledge
- Teams are better at grasping novelty and in combining convention and novelty in scientific research
- Universality

