Taking census of Physics and of the Nobel Prize

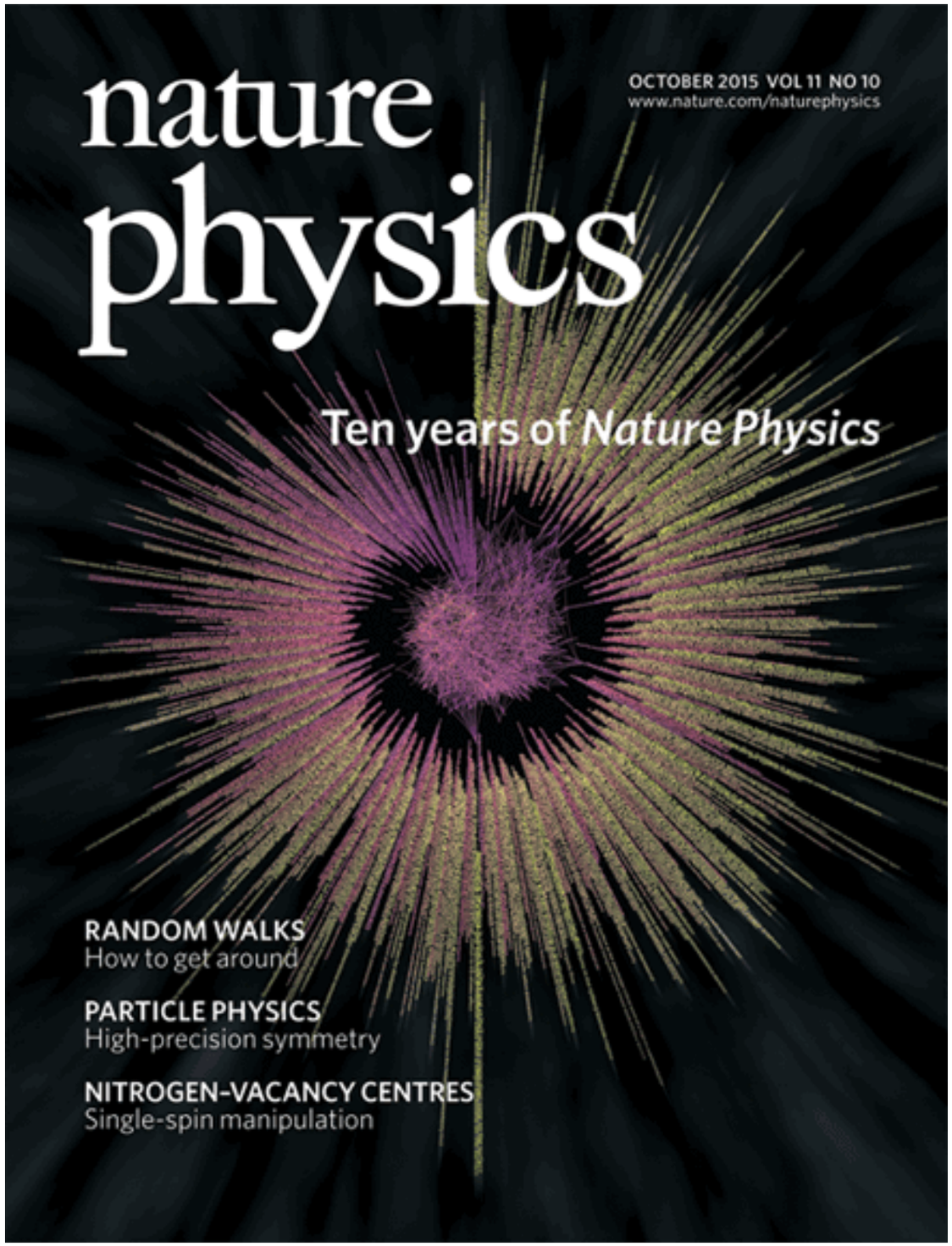
Michael Szell
with: R. Sinatra, Y. Ma, D. Wang, P. Deville,
A.-L. Barabási, F. Battiston, F. Musciotto

Lipari, July 16th 2019

@mszll
http://michael.szell.net
misz@itu.dk

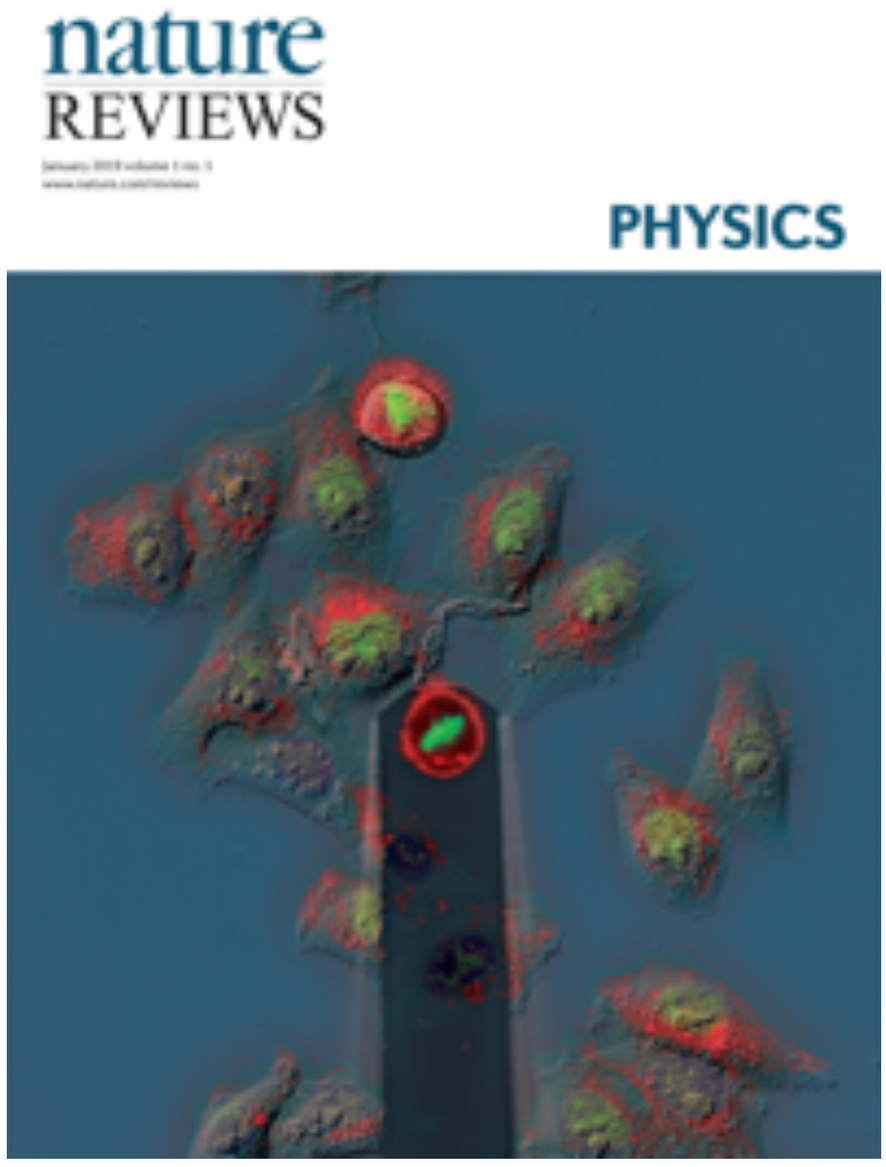
IT University of Copenhagen
NEtwoRks, Data, and Society (NERDS)

What is physics?



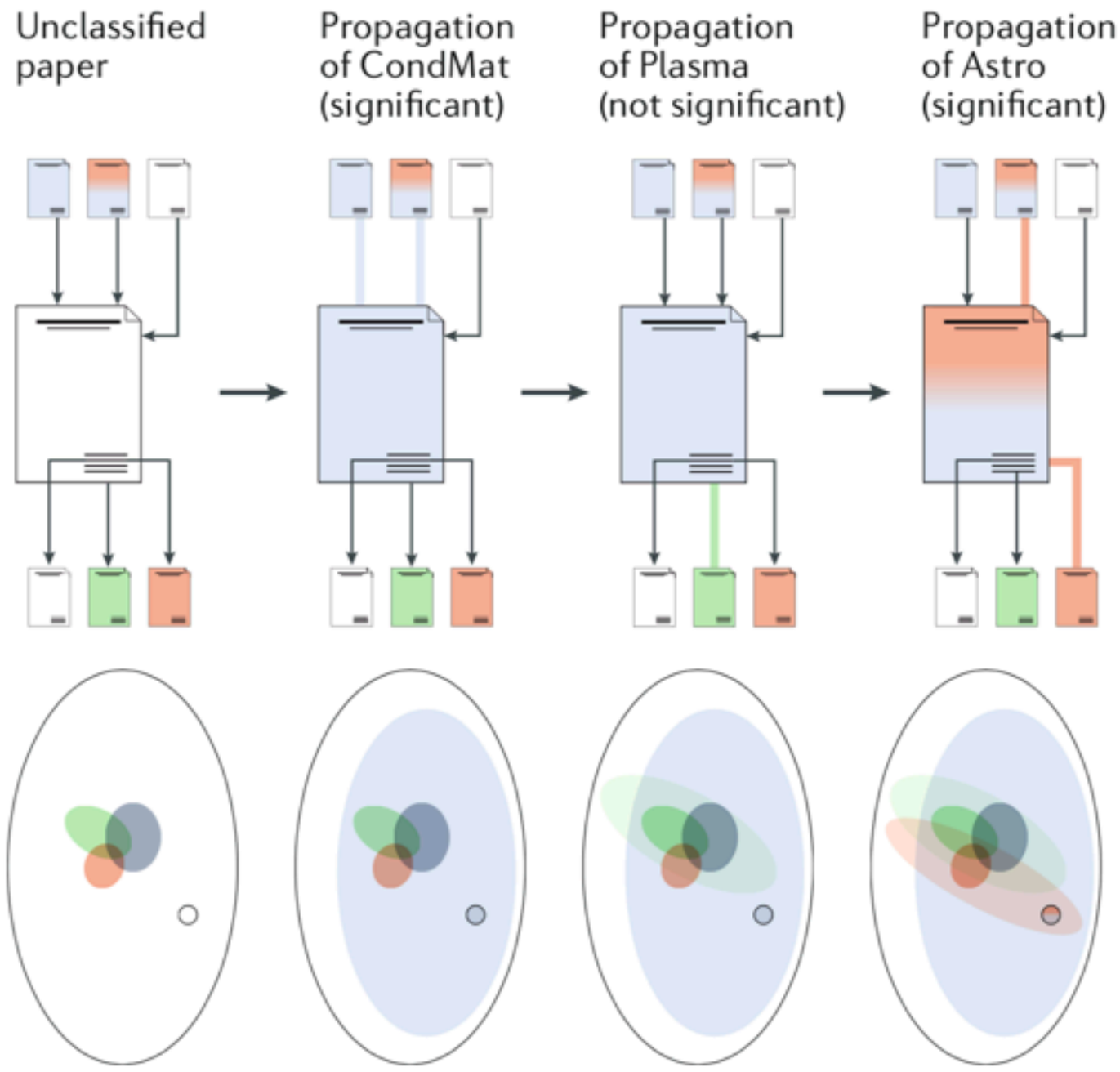
Sinatra et al., Nature Phys 11, (2015)

How is physics evolving?
Where are physicists going?



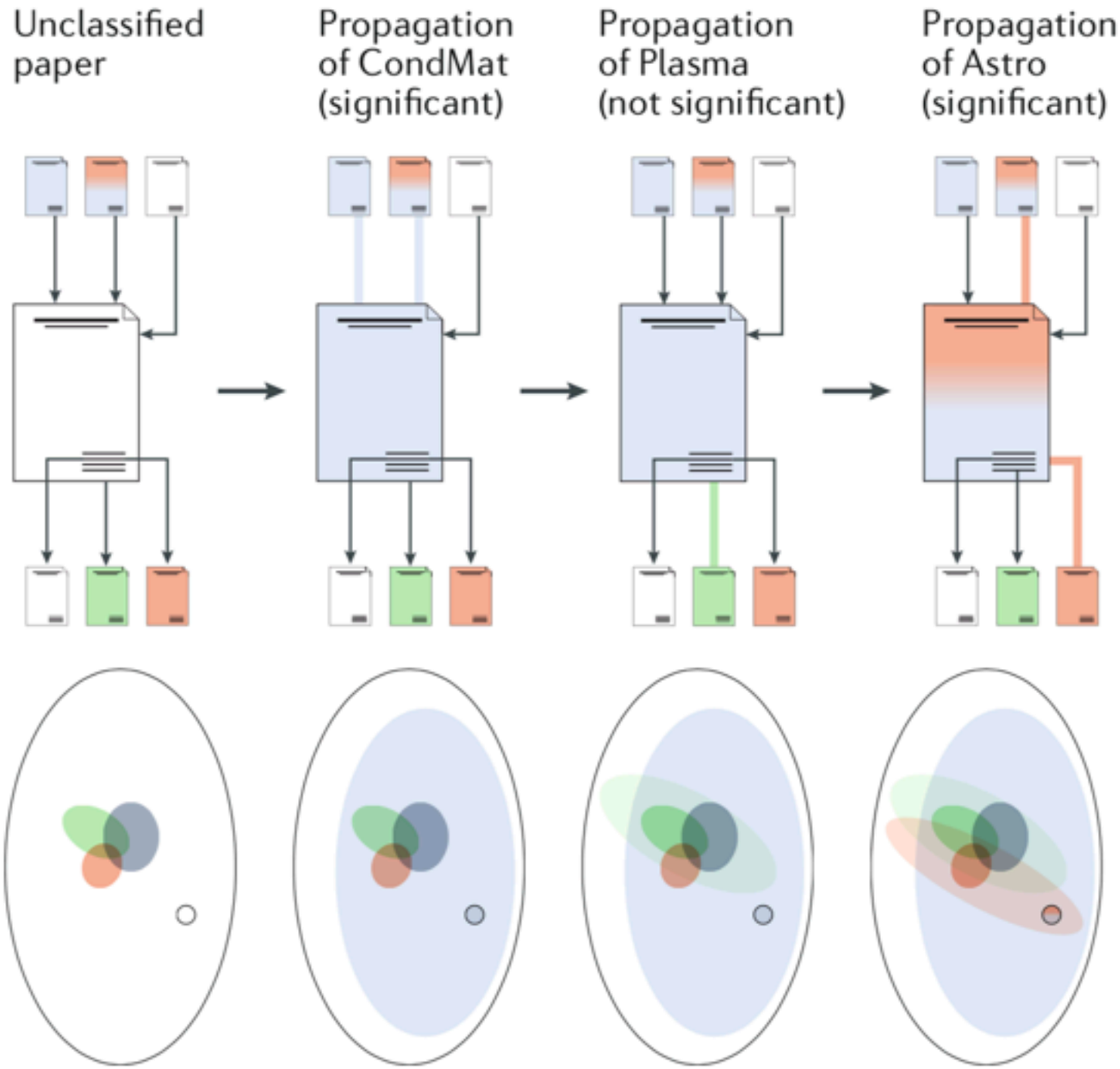
Battiston et al., Nature Rev Phys 1, (2019)

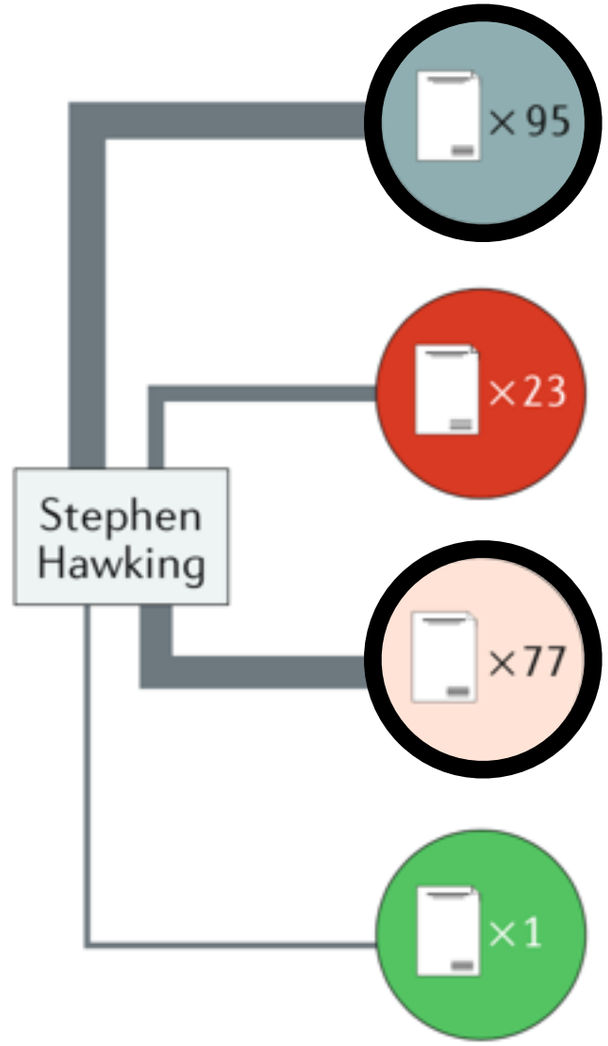
We propagated PACS to identify paper subfields



APS: 400k → WoS: 1.1 Mio papers

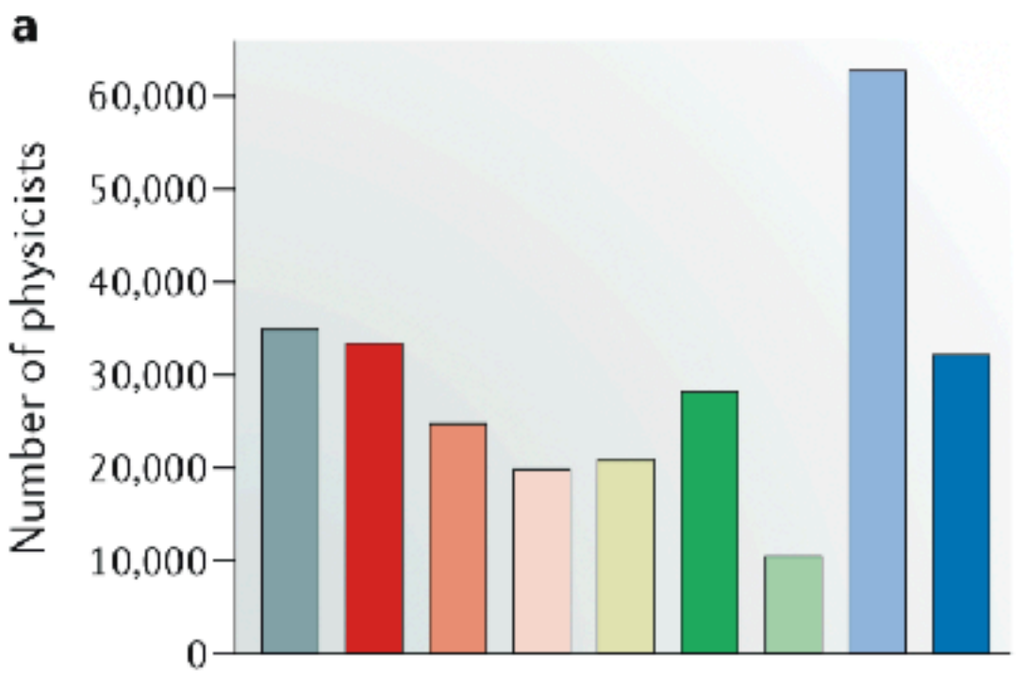
We propagated PACS to identify physicist subfields

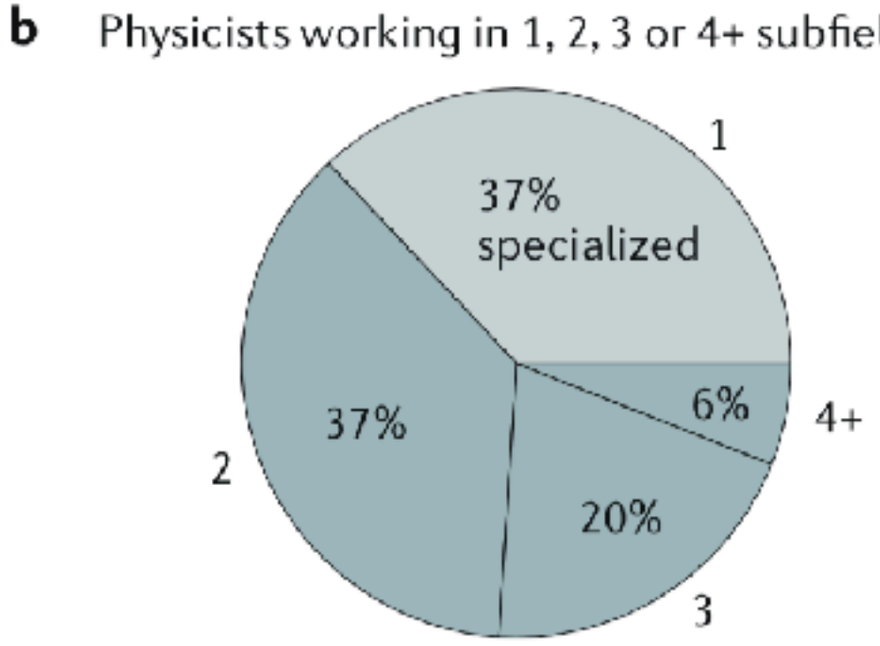




140,000 physicists

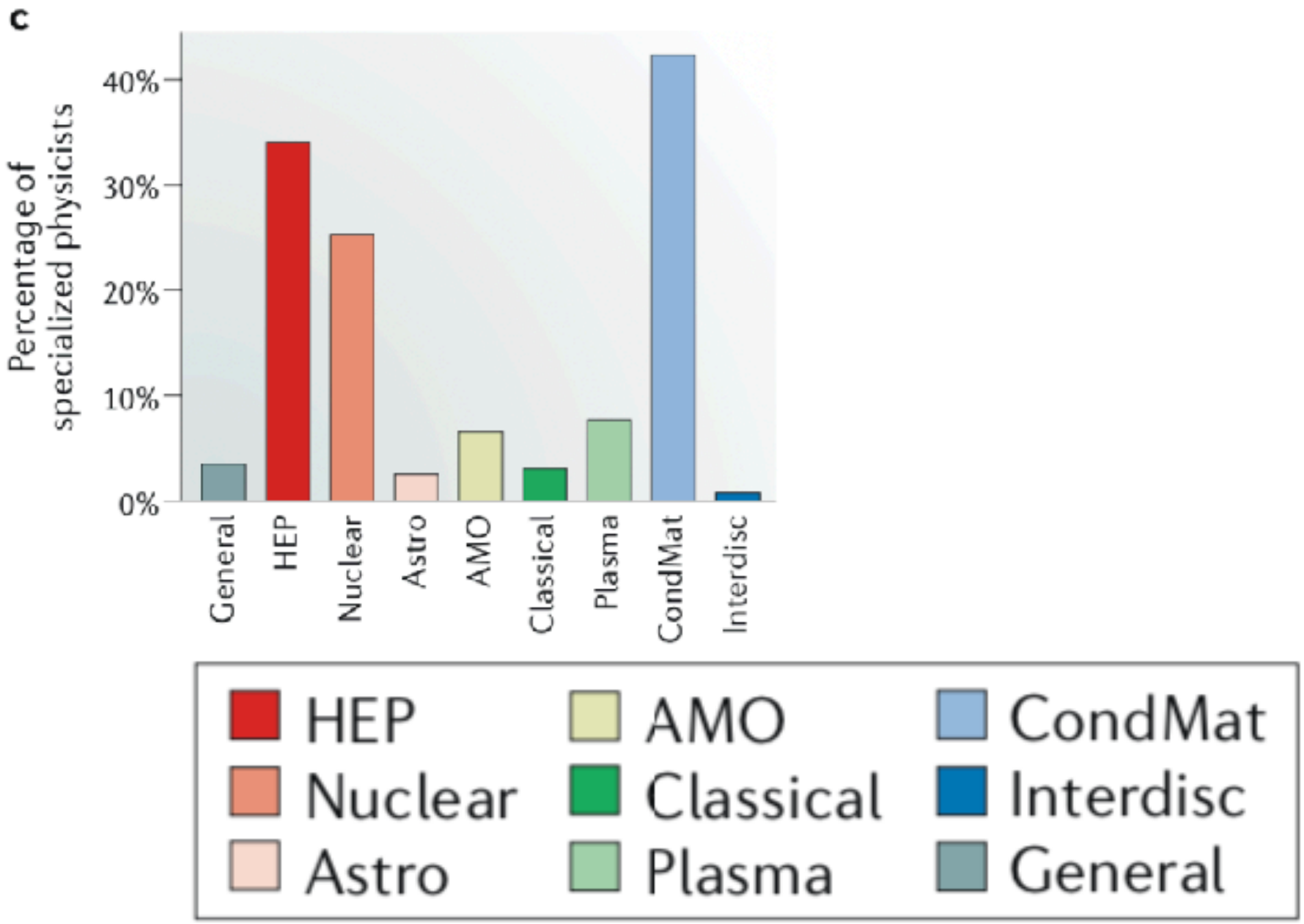
We sample physicists from all subfields



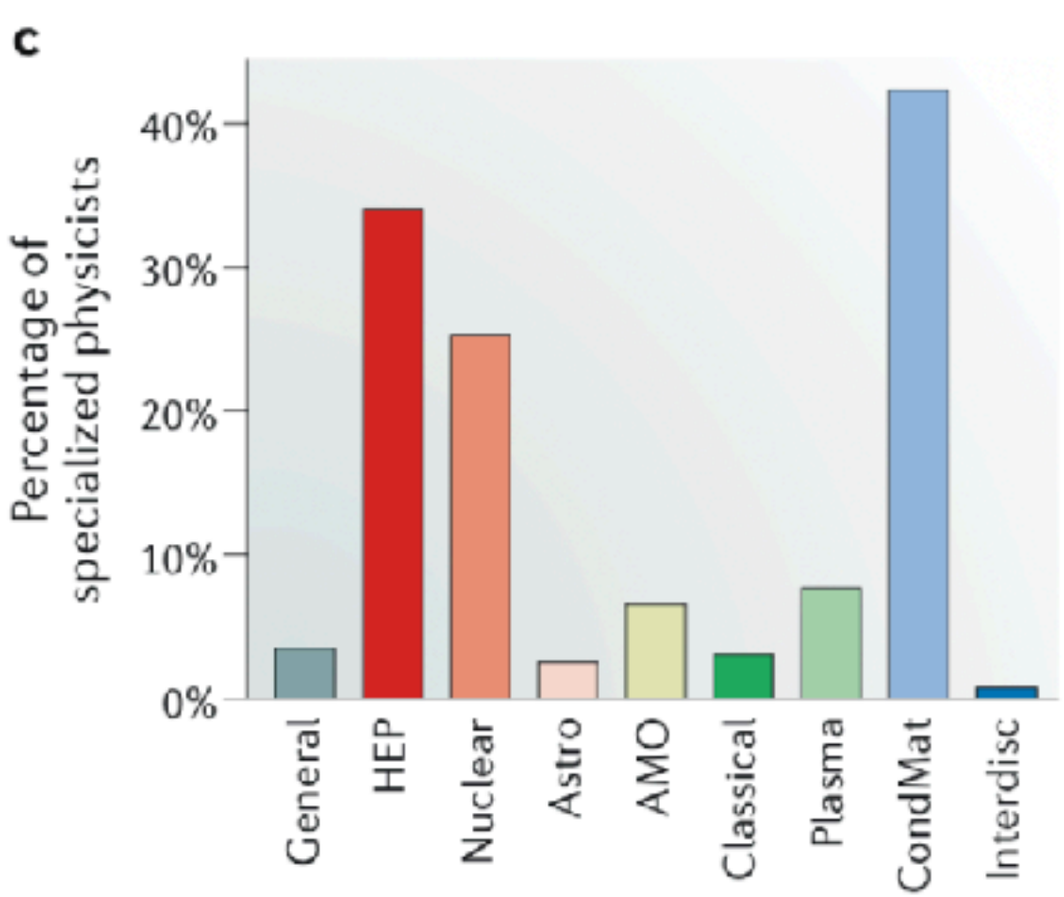


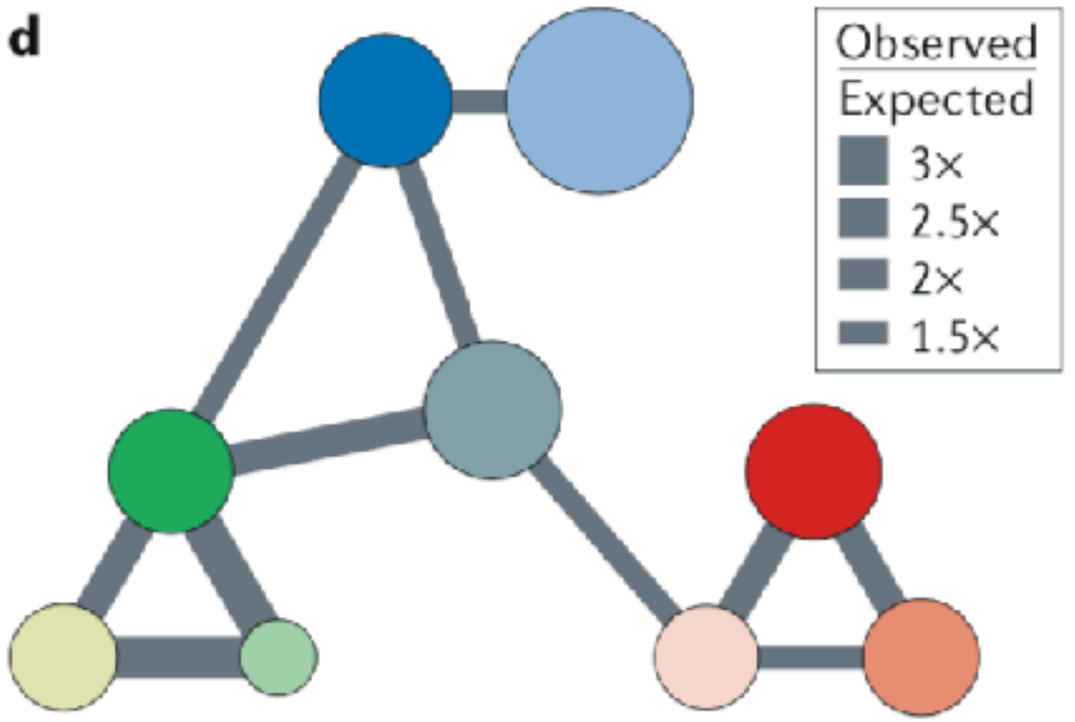
HEP
Nuclear
Astro
AMO
Classical
Plasma
CondMat
Interdisc
General

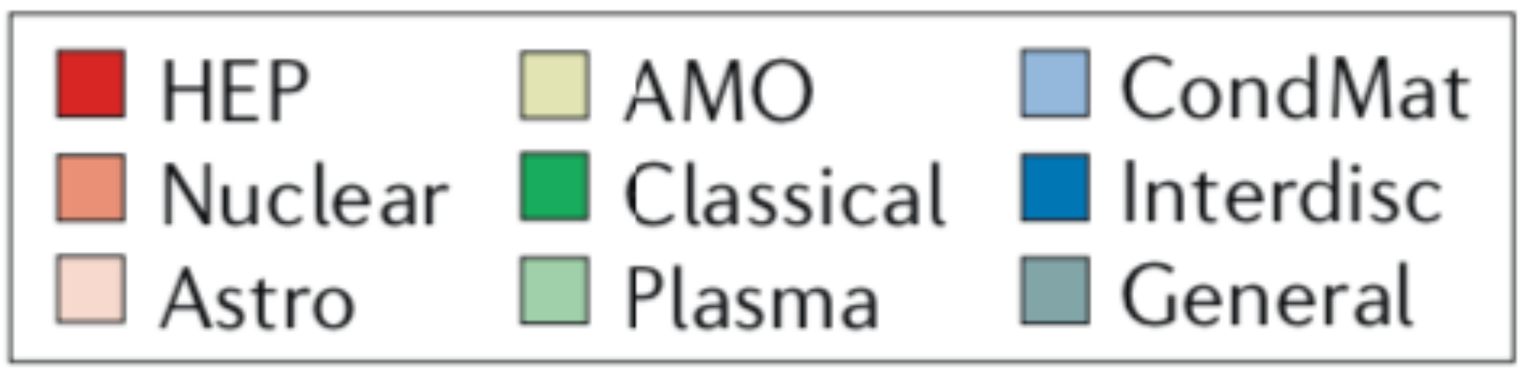
Specialization is highly heterogeneous



The network of individual co-activities reveals communities



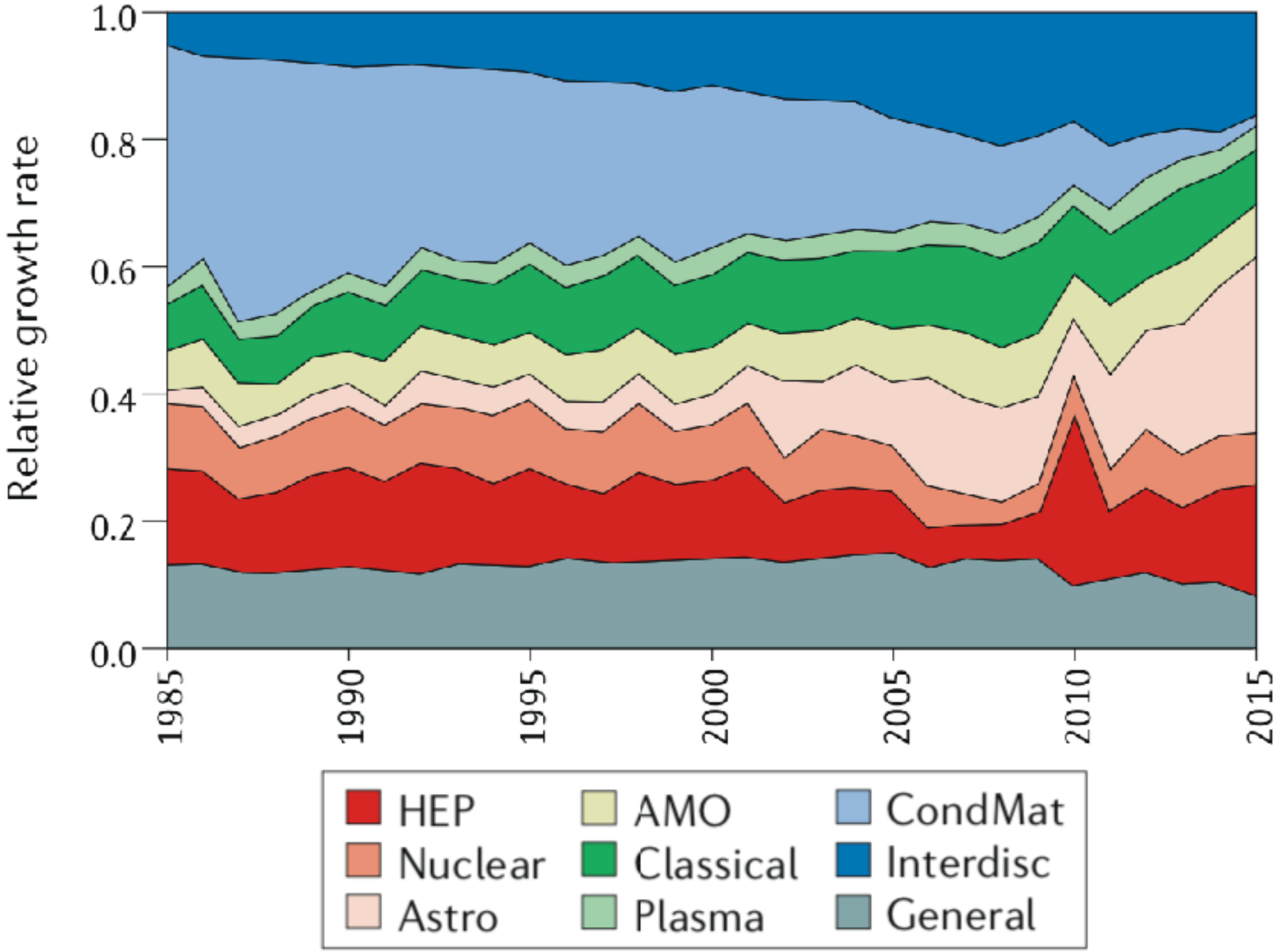




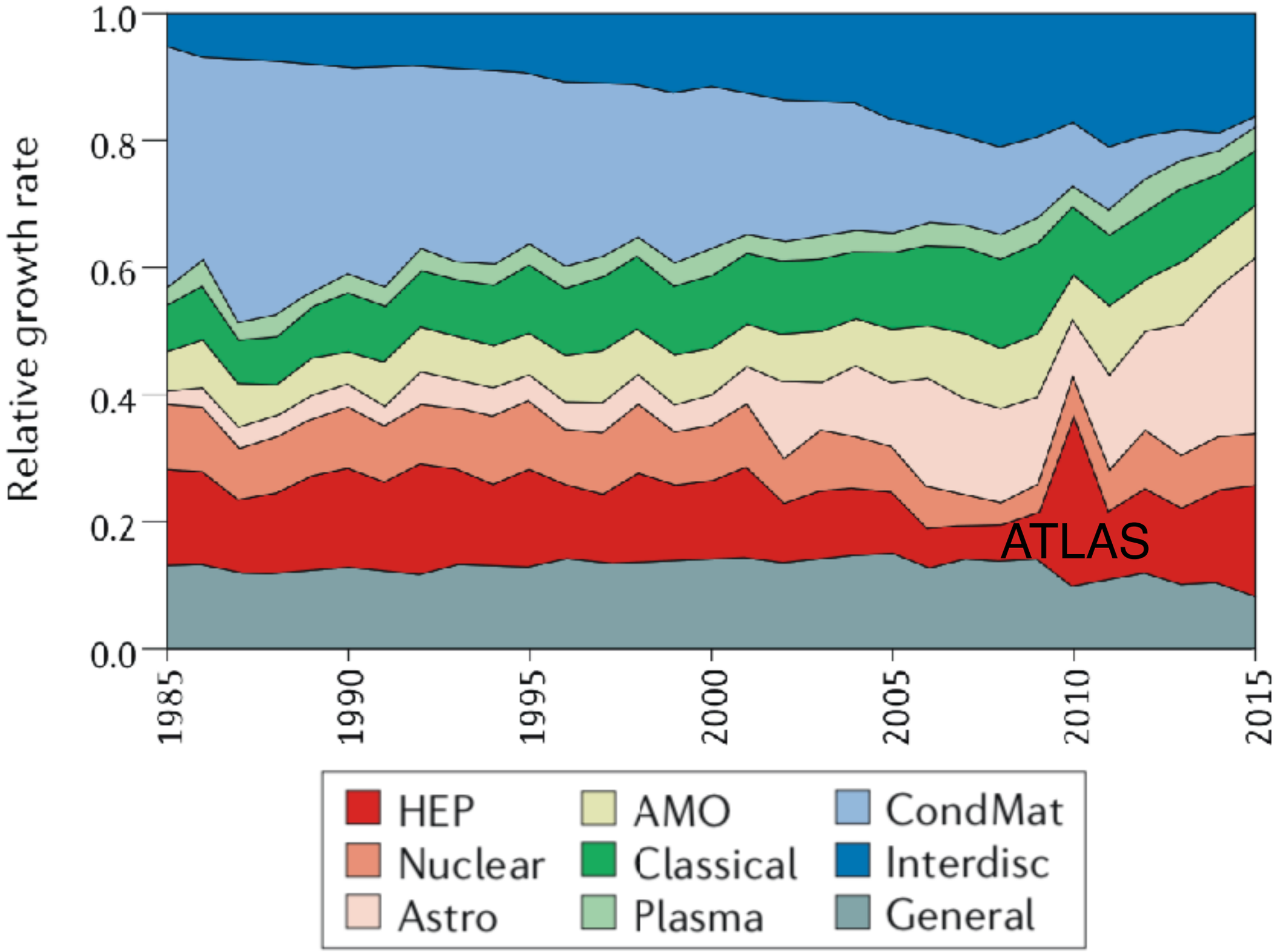
What about dynamics?

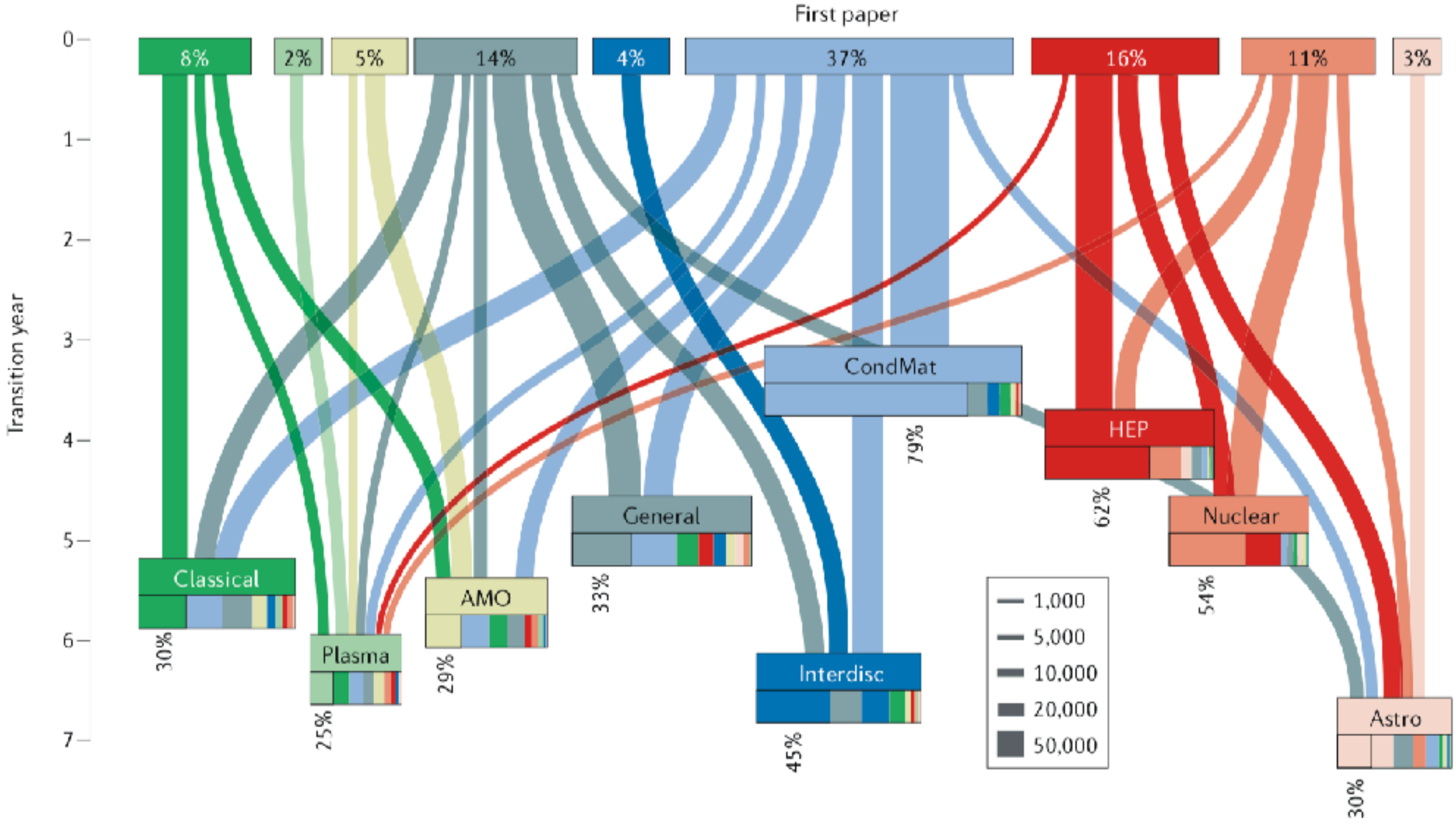
Birth, growth, and migration

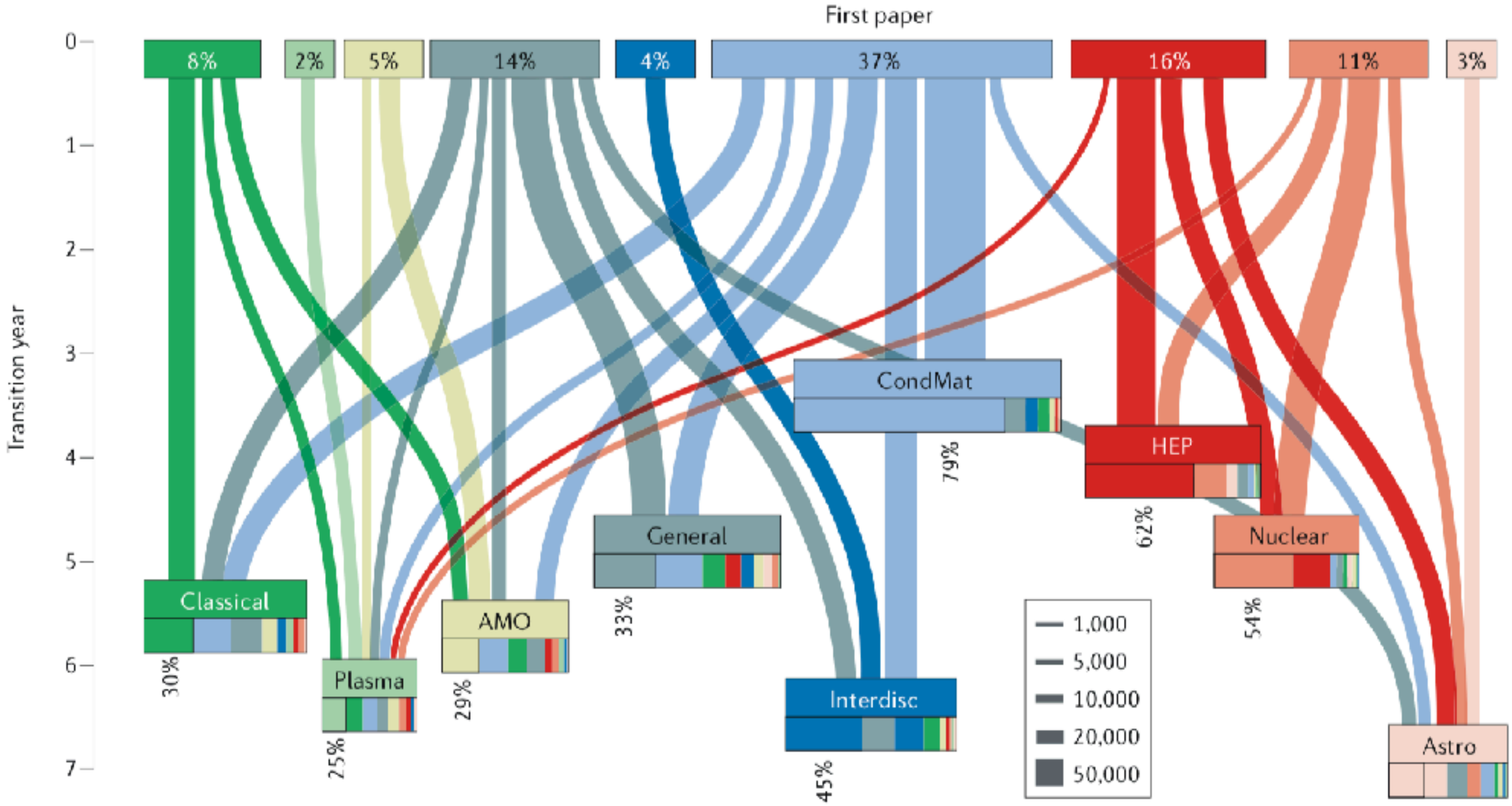
Some subfields grow, some shrink considerably



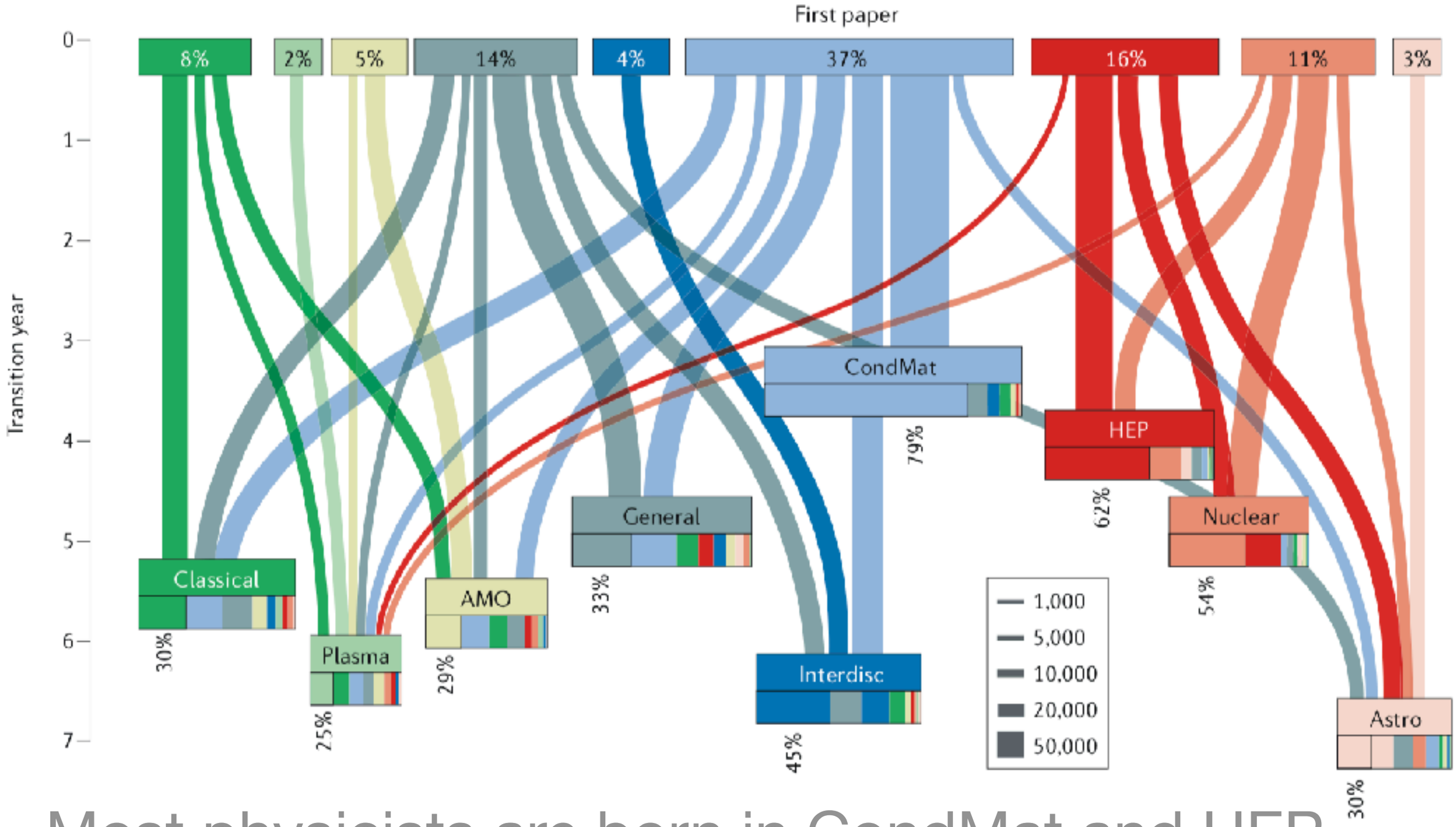
Some subfields grow, some shrink considerably




First paper
Transition year
0
1
2
3
4
5
6
7
8%
2%
5%
14%
4%
37%
16%
11%
3%
Classical
30%
Plasma
25%
AMO
29%
General
33%
CondMat
79%
Interdisc
45%
HEP
62%
Nuclear
54%
Astro
30%
1,000
5,000
10,000
20,000
50,000

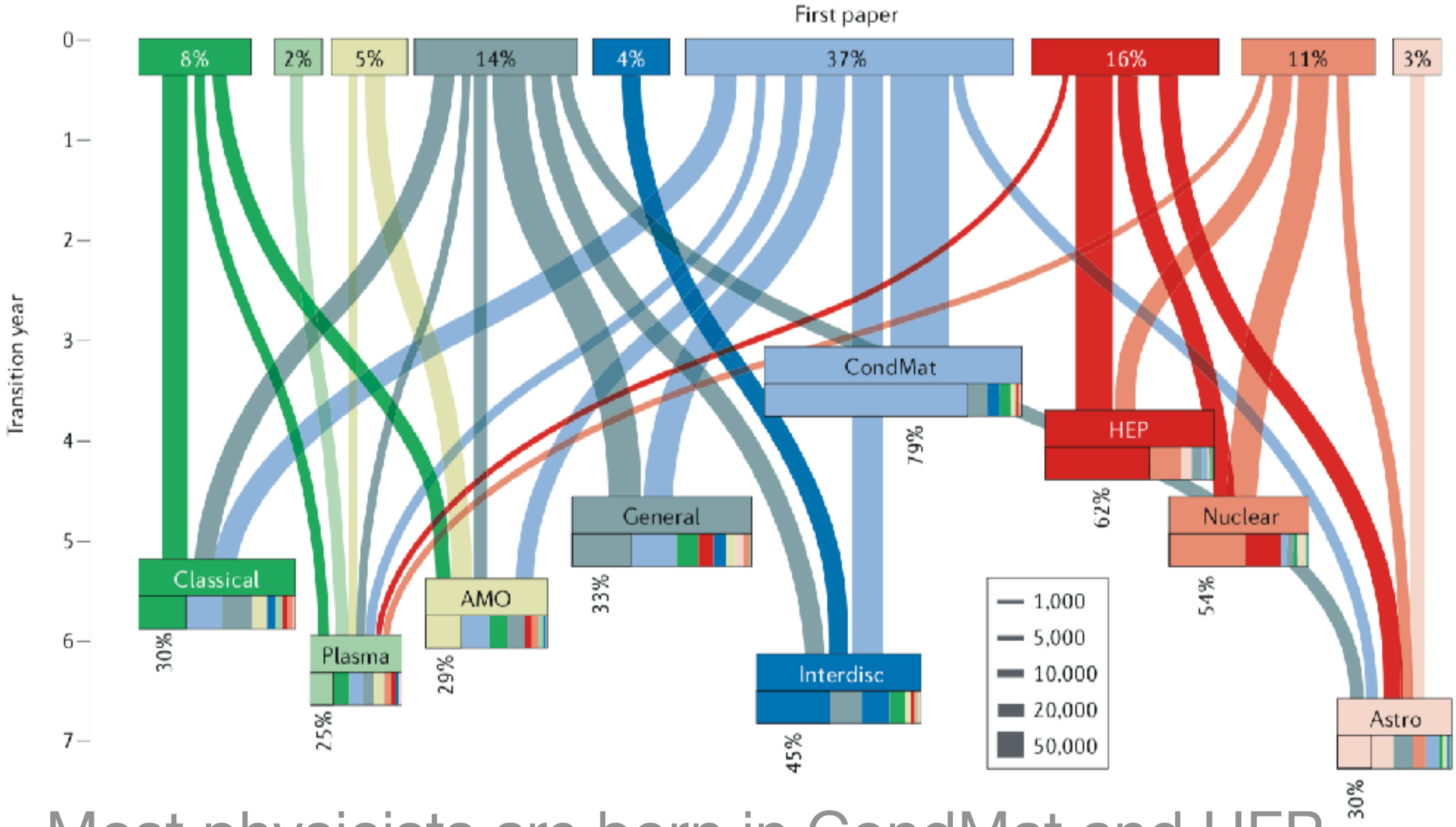


Most physicists are born in CondMat and HEP



Most physicists are born in CondMat and HEP

CondMat => Inter, HEP => Astro, Many => Plasma

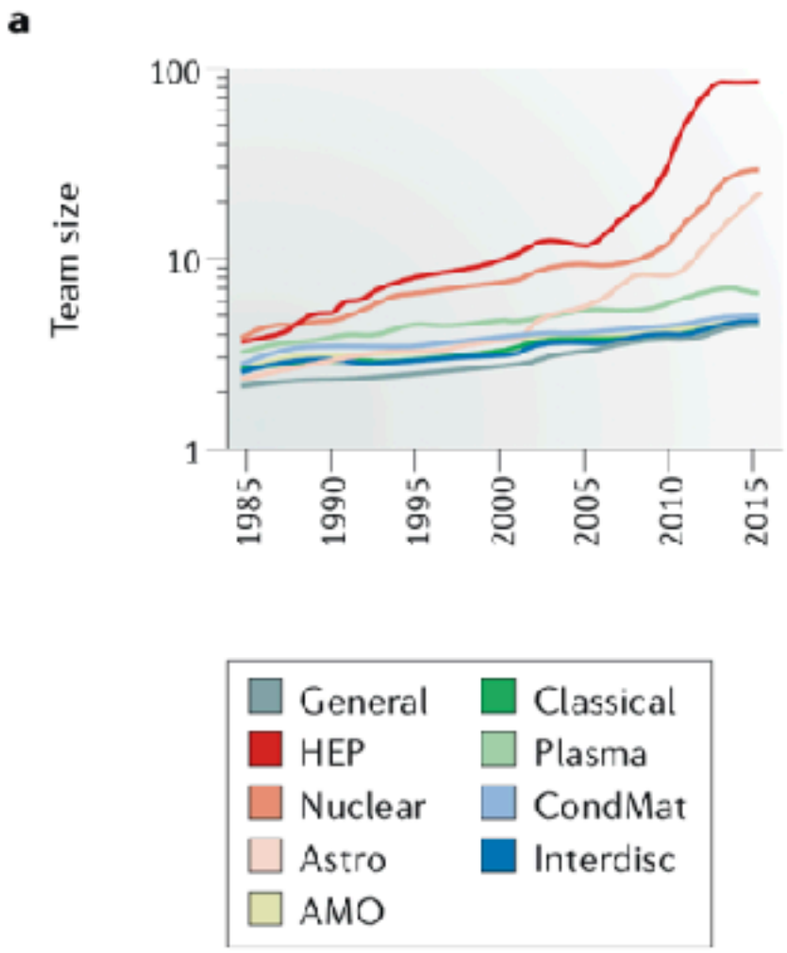


Most physicists are born in CondMat and HEP

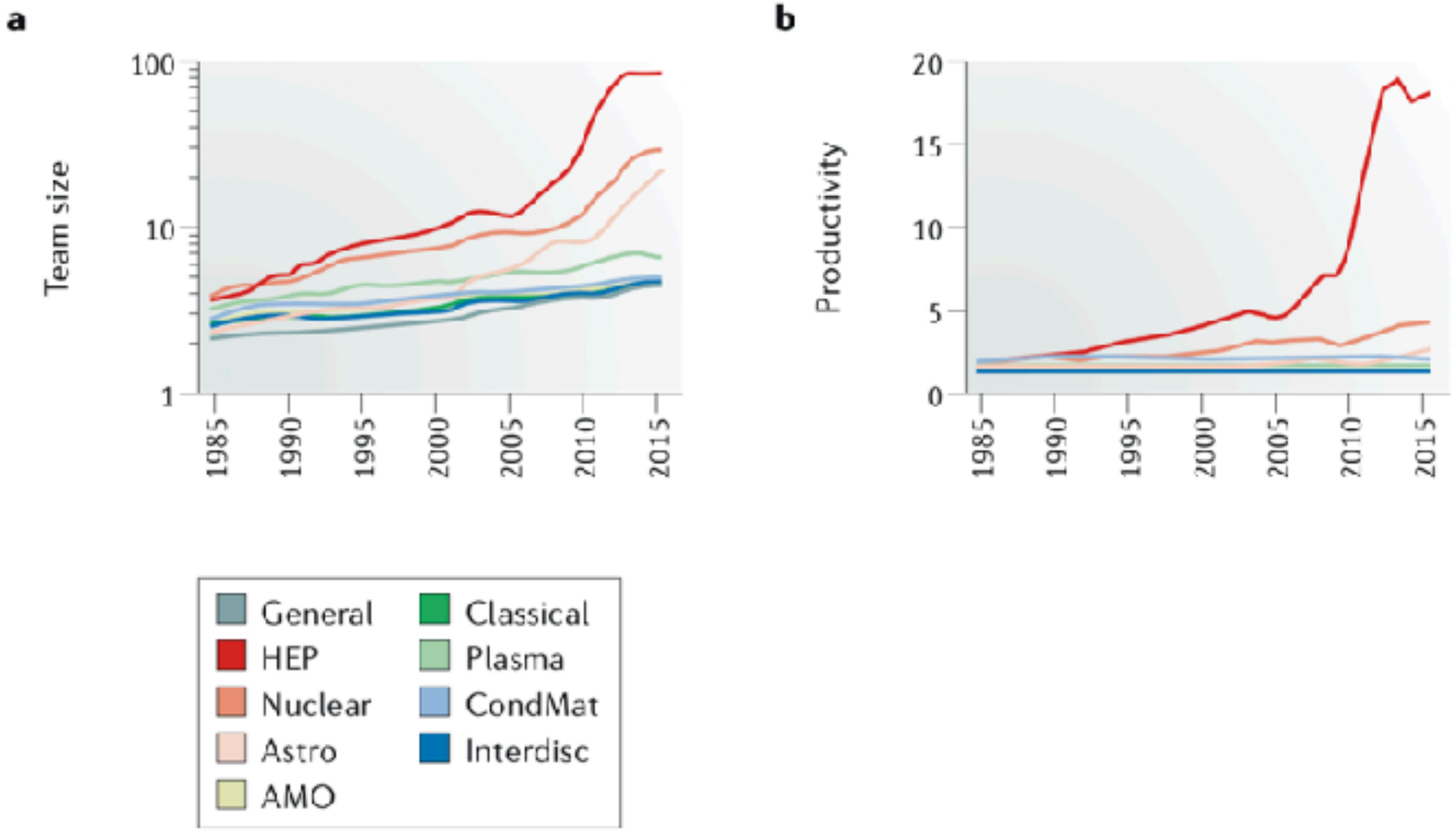
CondMat => Inter, HEP => Astro, Many => Plasma

Transitions to Interdisc and Astro takes longest

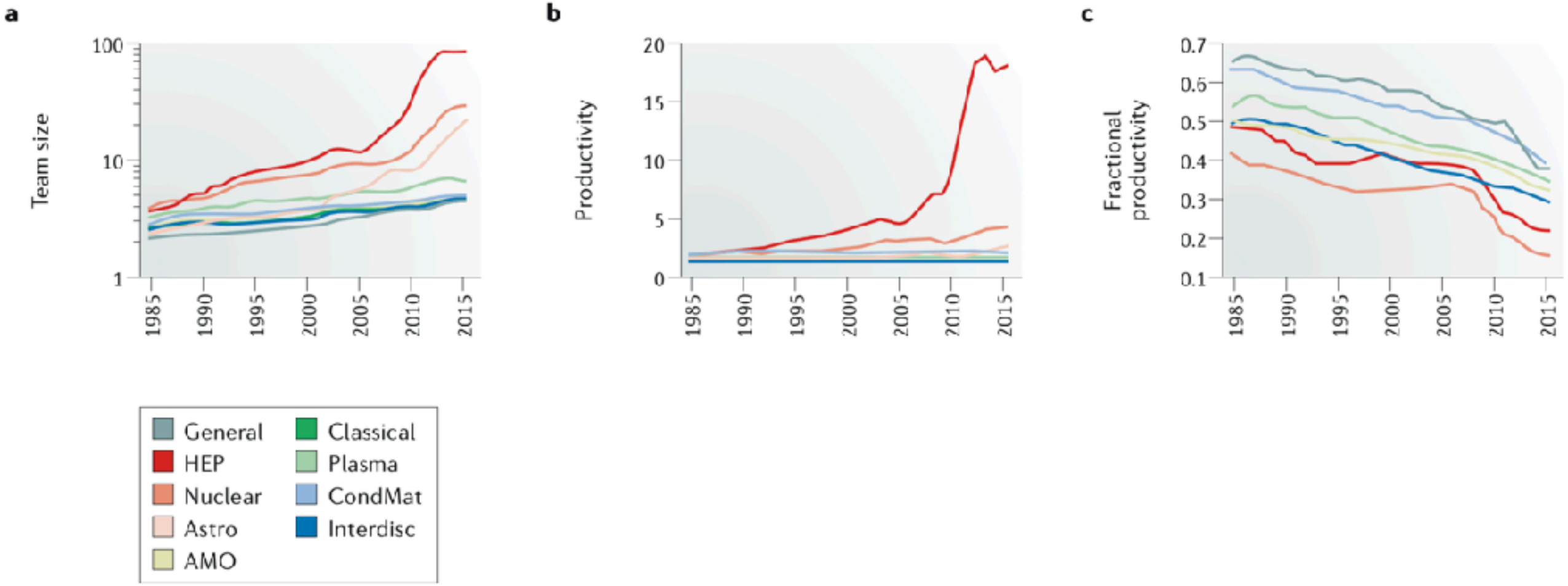
Team sizes grow, especially in HEP



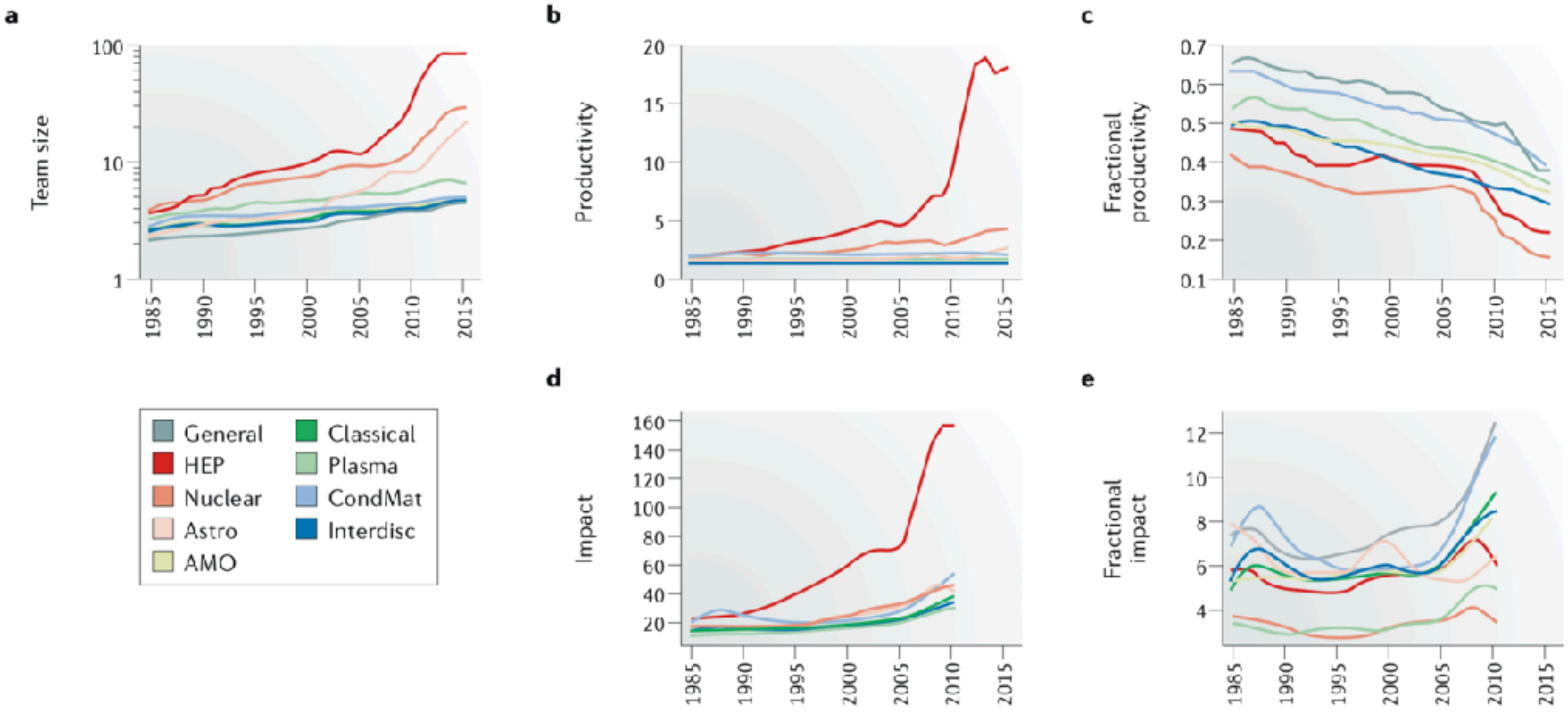
Producitivy grows, especially in HEP



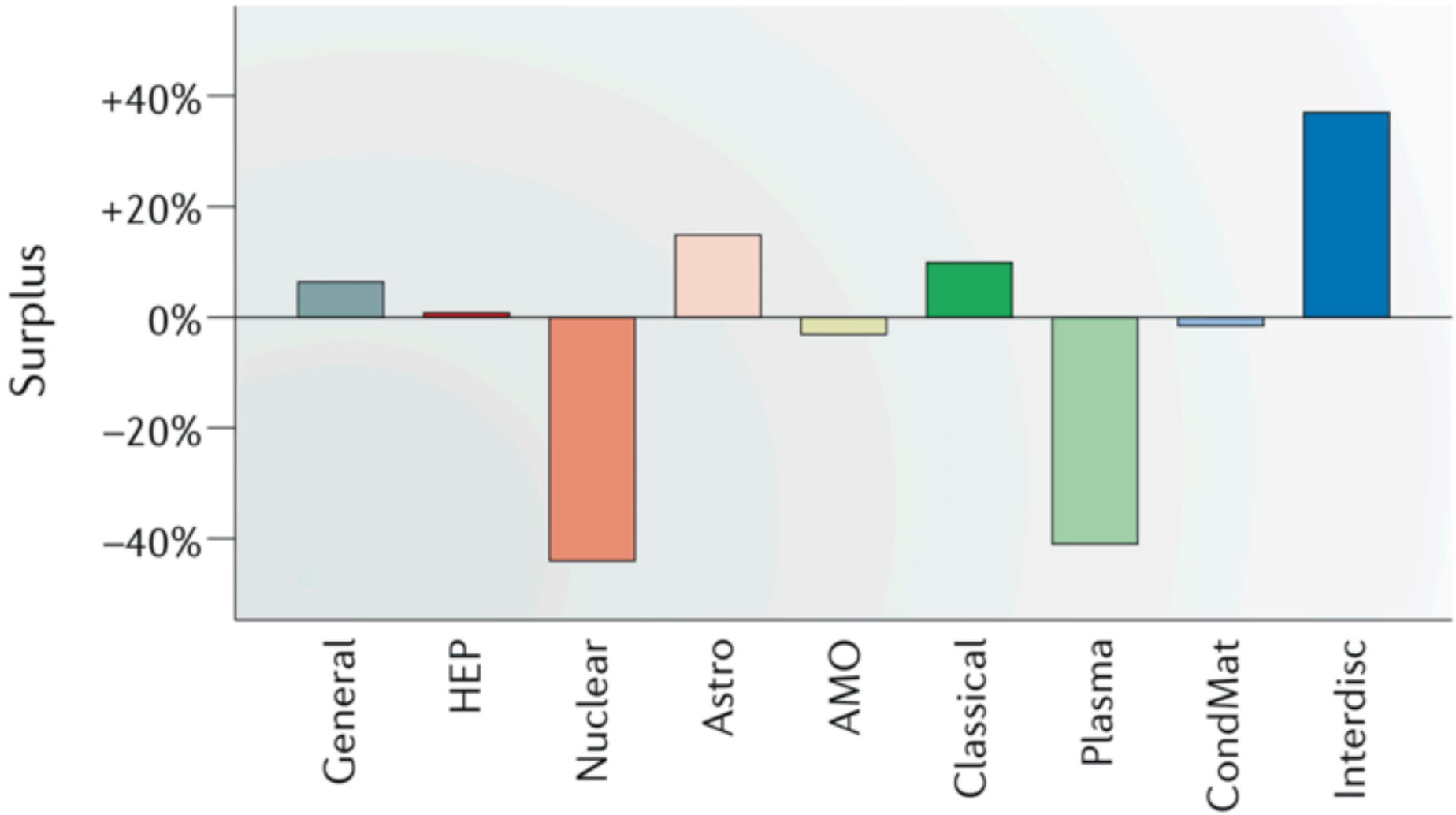
But productivity per researcher drops!
(because productivity grows slower than team size)



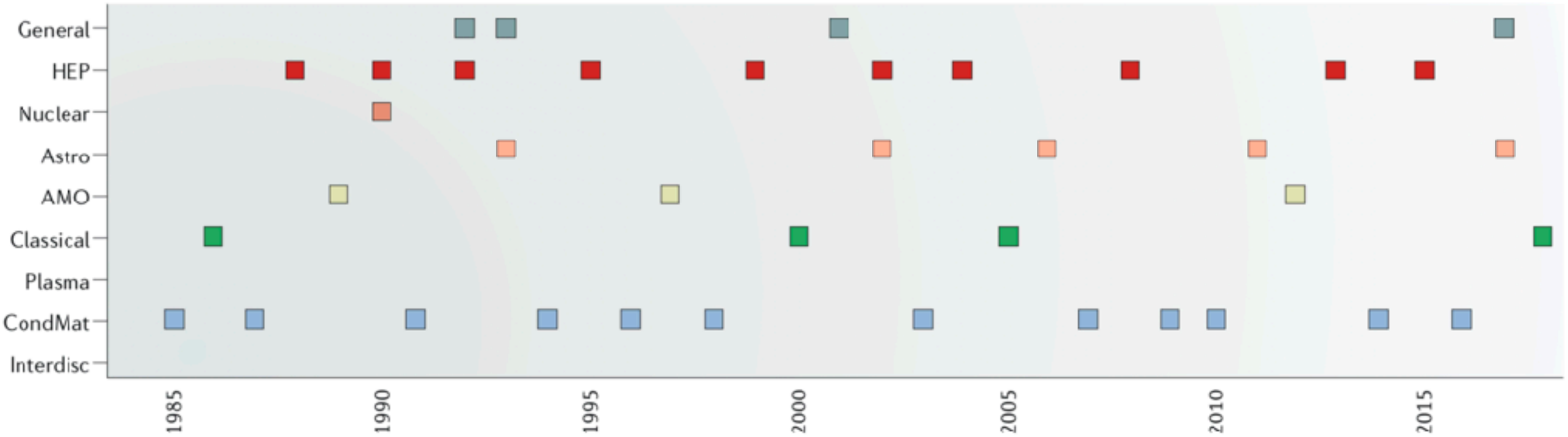
Impact grows, fractional impact is unclear



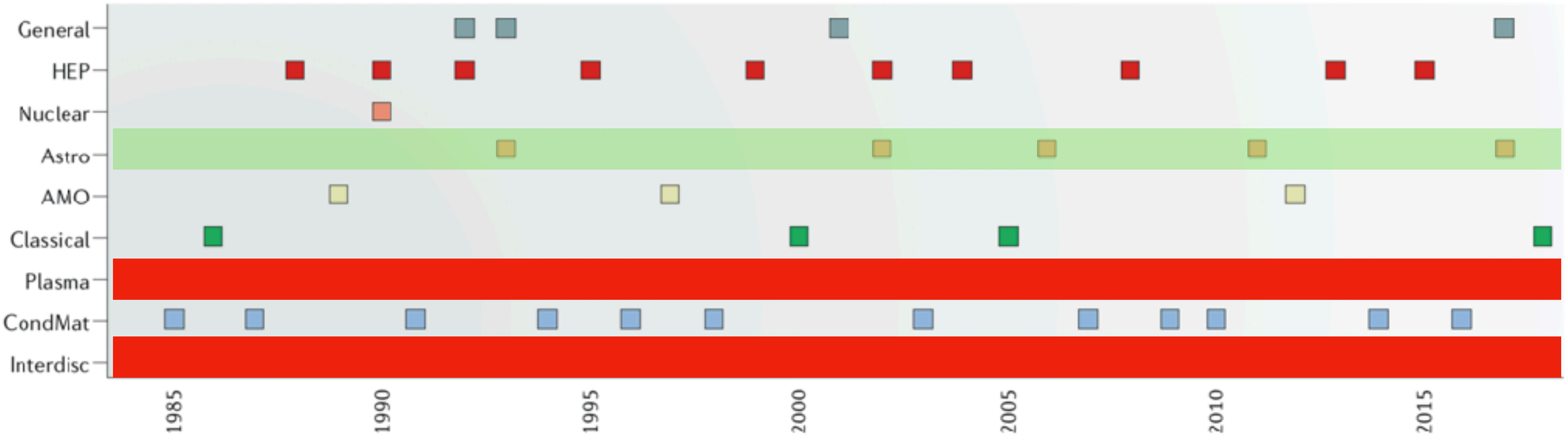
Subfield impact: Interdisc generates the highest number of high-impact papers compared with its size



Subfield impact: Nobel Prizes highly skewed



Subfield impact: Nobel Prizes highly skewed



Interdisc is left out :(

Interdisciplinary research is important

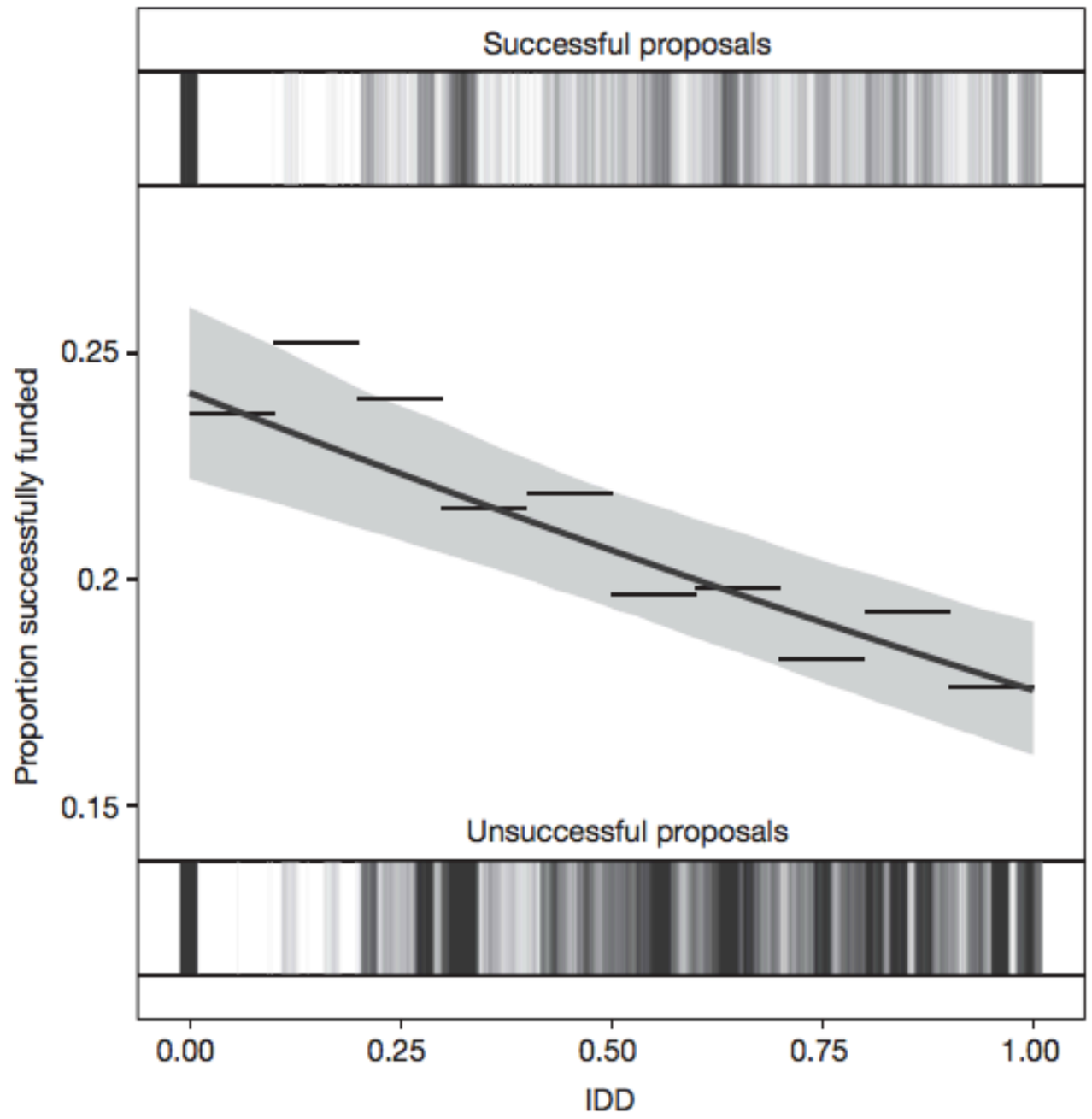
Why interdisciplinary research matters

Scientists must work together to save the world. A special issue asks how they can scale disciplinary walls.

16 September 2015 Corrected: 17 September 2015

PDF Rights & Permissions

Interdisciplinary research is important but discriminated



Bromham et al., Nature 534, 684-687 (2016)

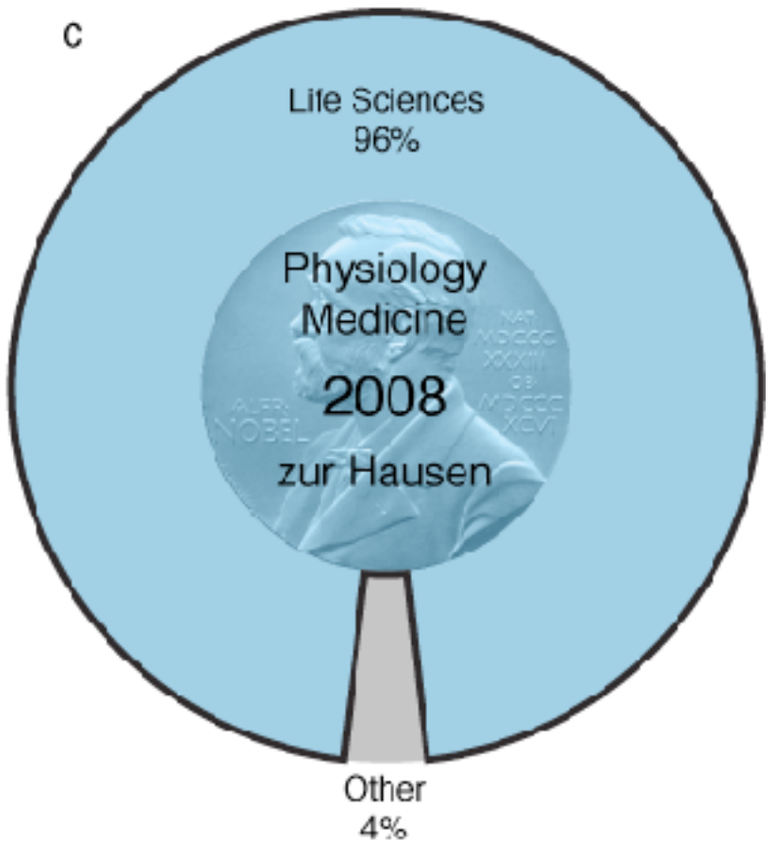
We acquired data from nobelprize.org

Issues

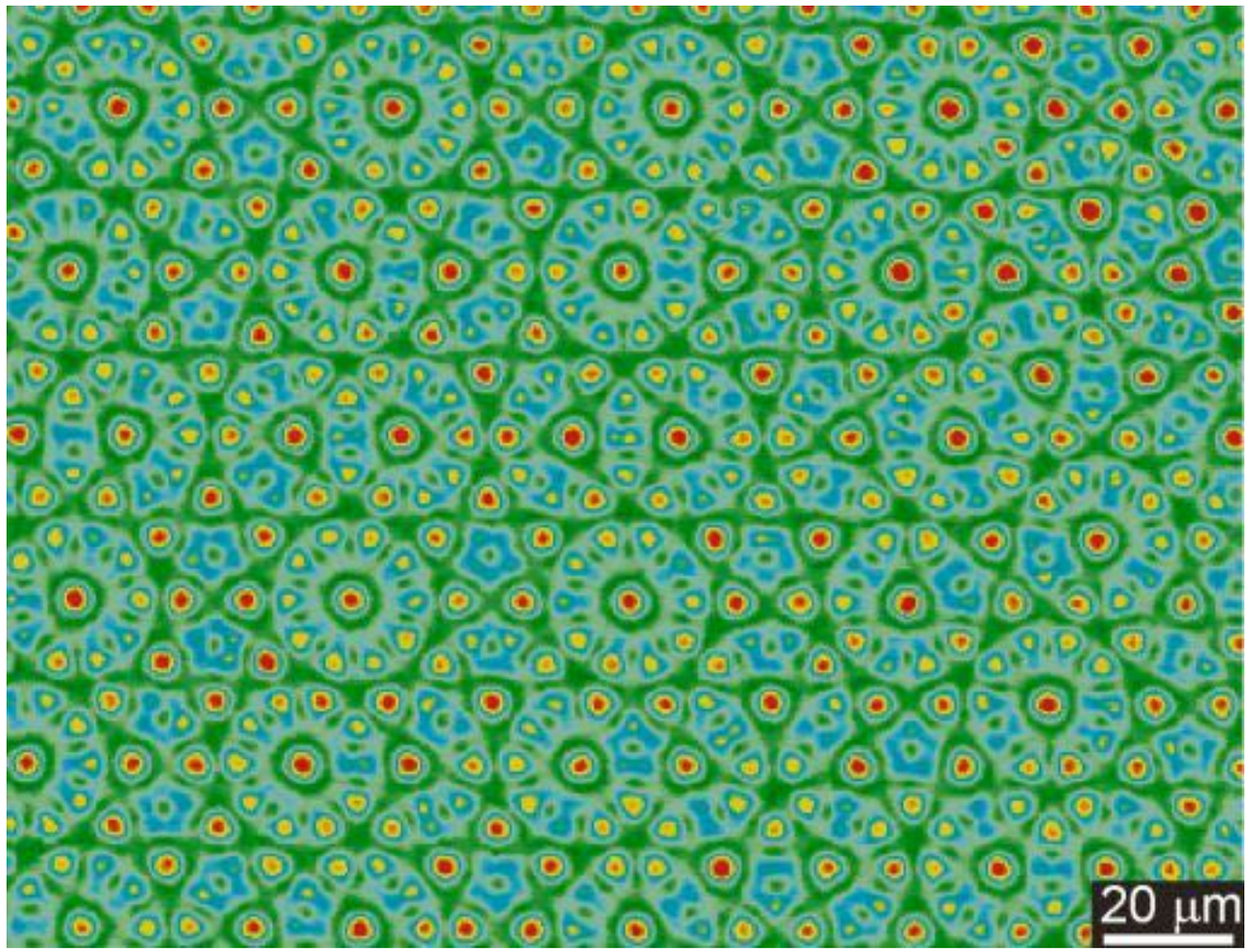
- Before 1995, key papers unclear
- No citation data for too recent papers
- Sleeping beauties

...gives us 108 papers and 70000 citations

Many discoveries have only disciplinary impact

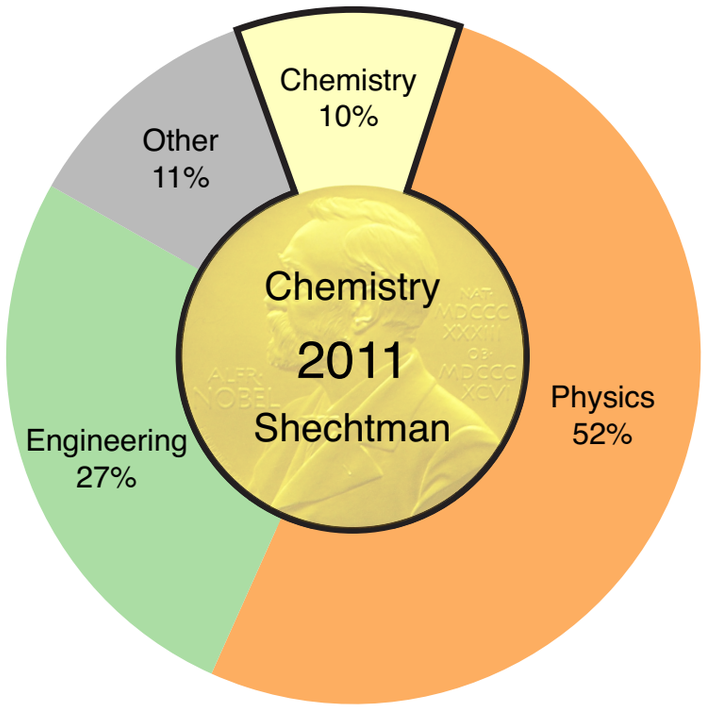


Some discoveries have multidisciplinary impact



Material scientist

Some discoveries have multidisciplinary impact



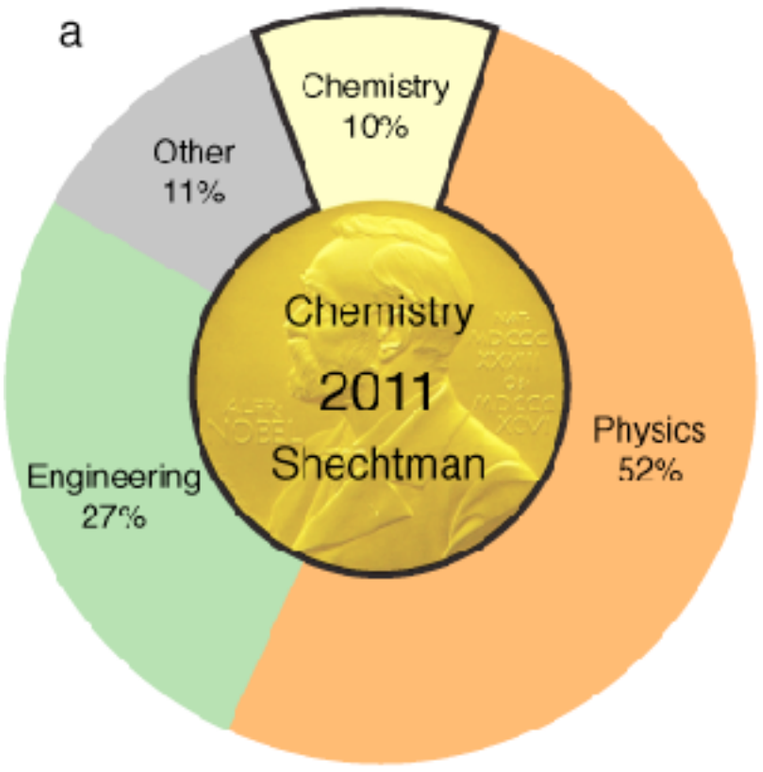
Material scientist

Nobel prize in chemistry

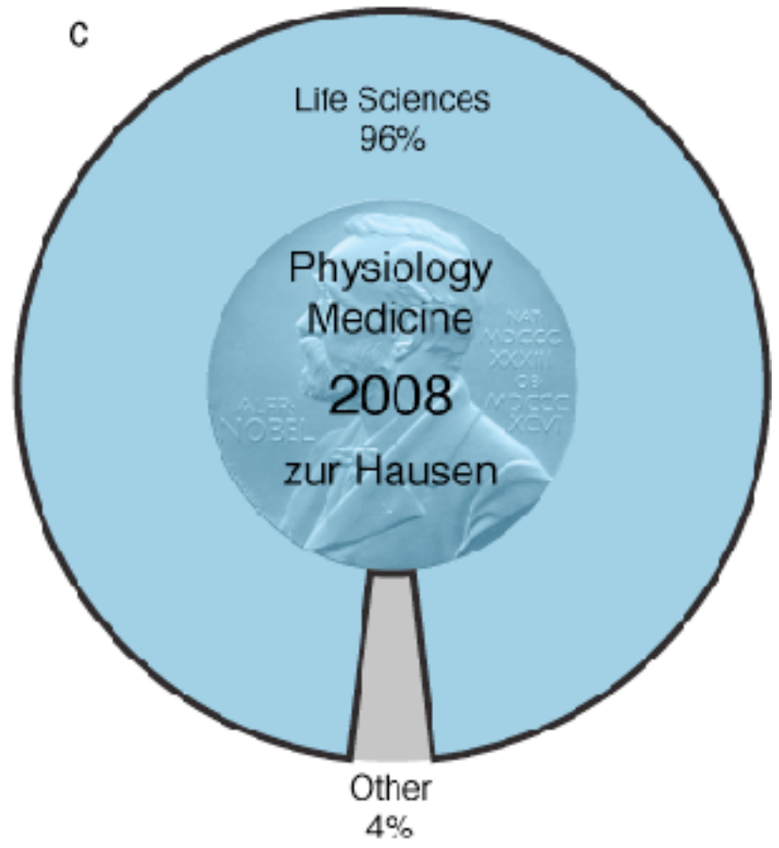
Cited by physicists (6x)

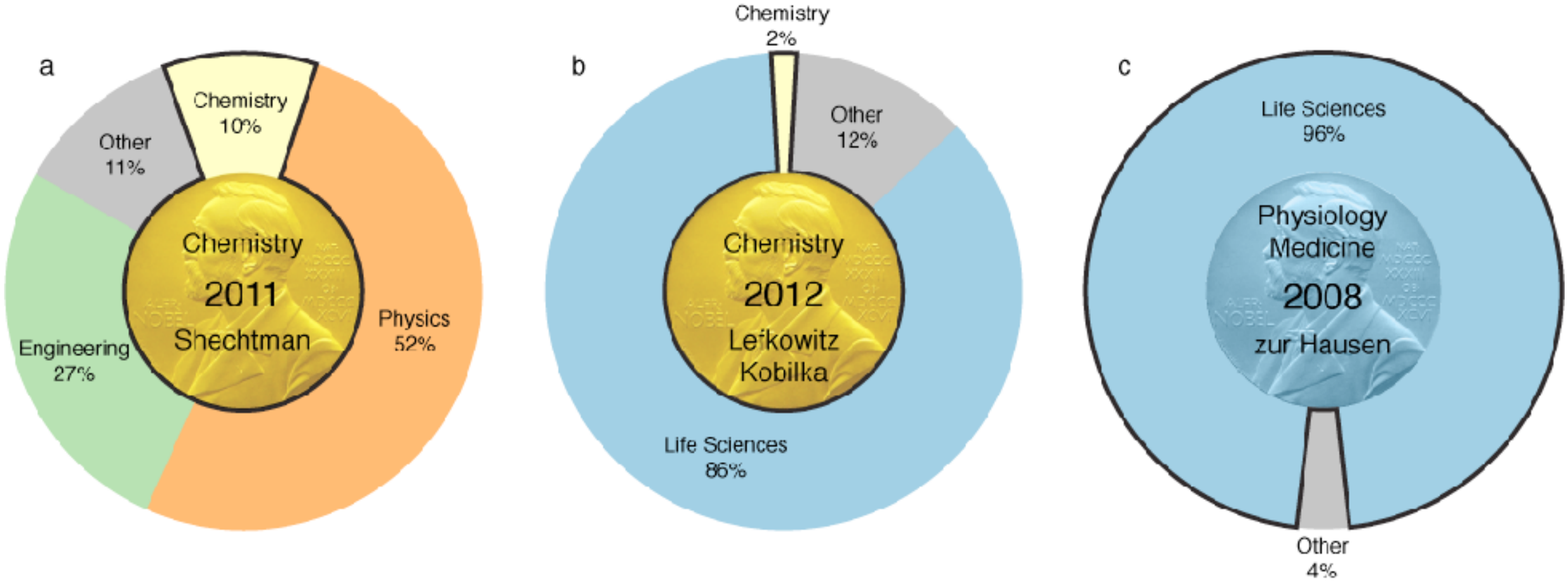
Shechtman et al., PRL 53, 1951 (1984)

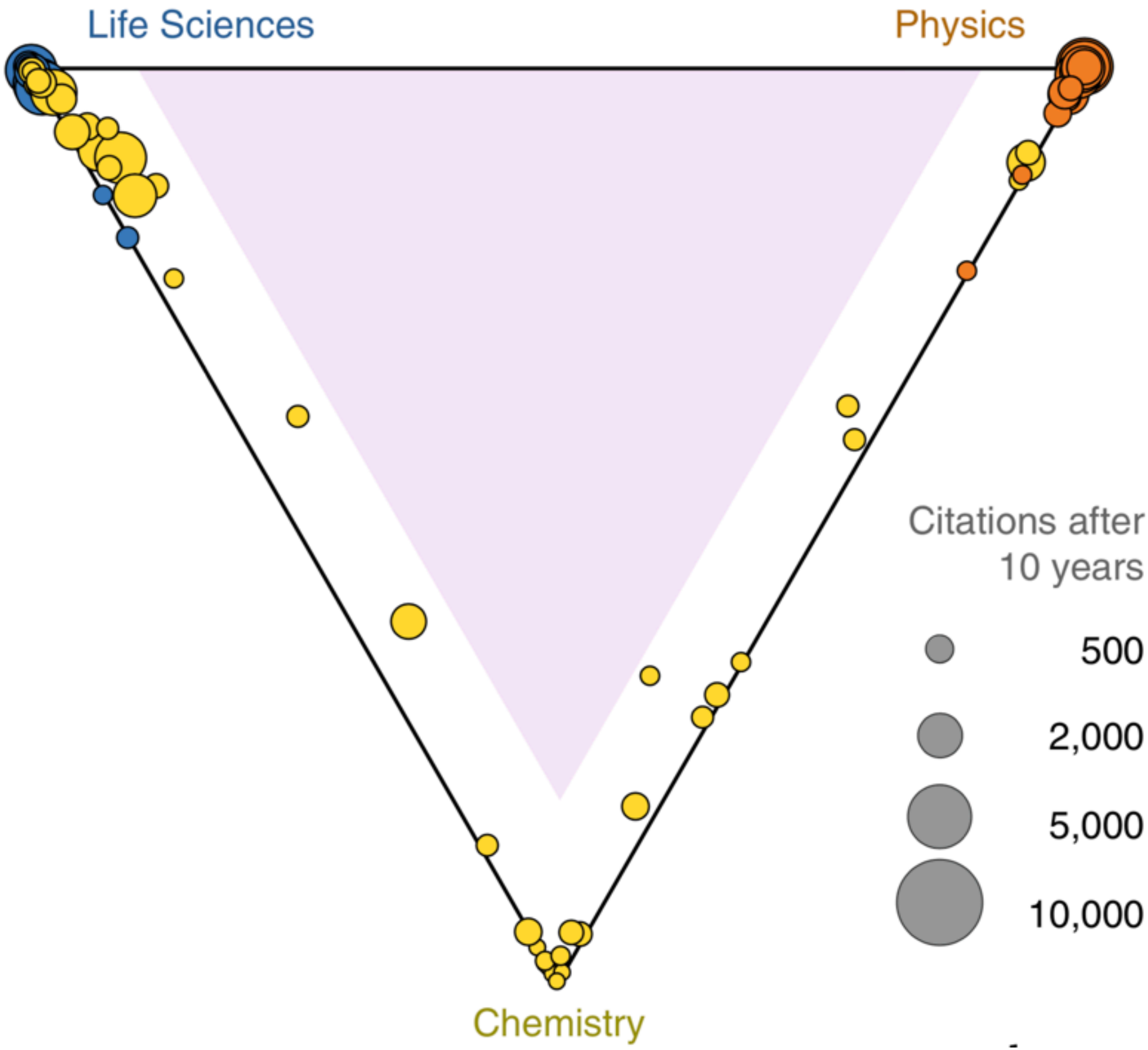
a

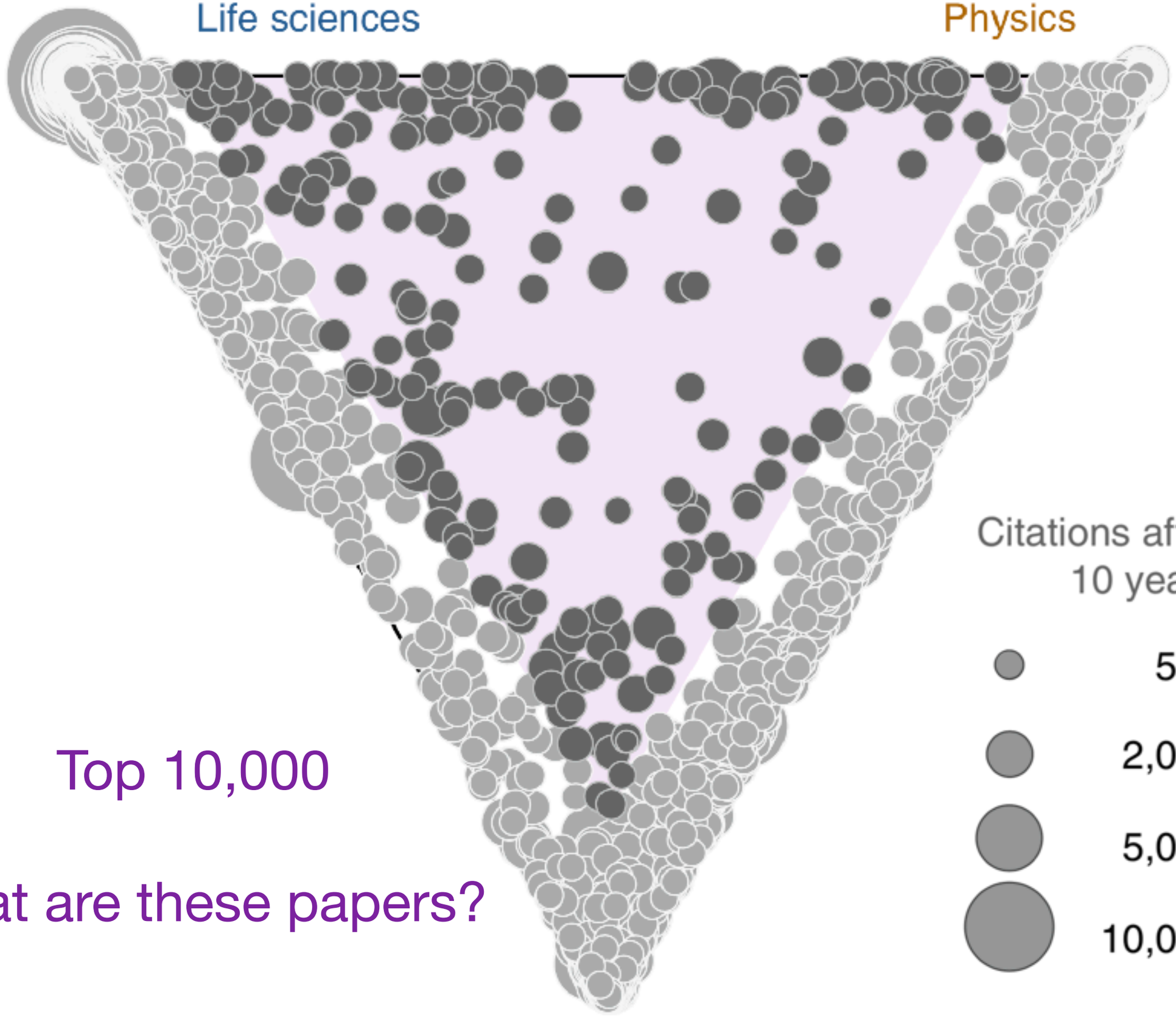

Chemistry
10%
Other
11%
Chemistry
2011
Shechtman
Physics
52%
Engineering
27%

c


Life Sciences
96%
Physiology
Medicine
2008
zur Hausen
Other
4%


a
Chemistry
10%
Other
11%
Chemistry
2011
Shechtman
Physics
52%
Engineering
27%
b
Chemistry
2%
Other
12%
Chemistry
2012
Lefkowitz
Kobilka
Life Sciences
86%
c
Life Sciences
96%
Physiology
Medicine
2008
zur Hausen
Other
4%


Life Sciences
Physics
Chemistry
Citations after
10 years
500
2,000
5,000
10,000



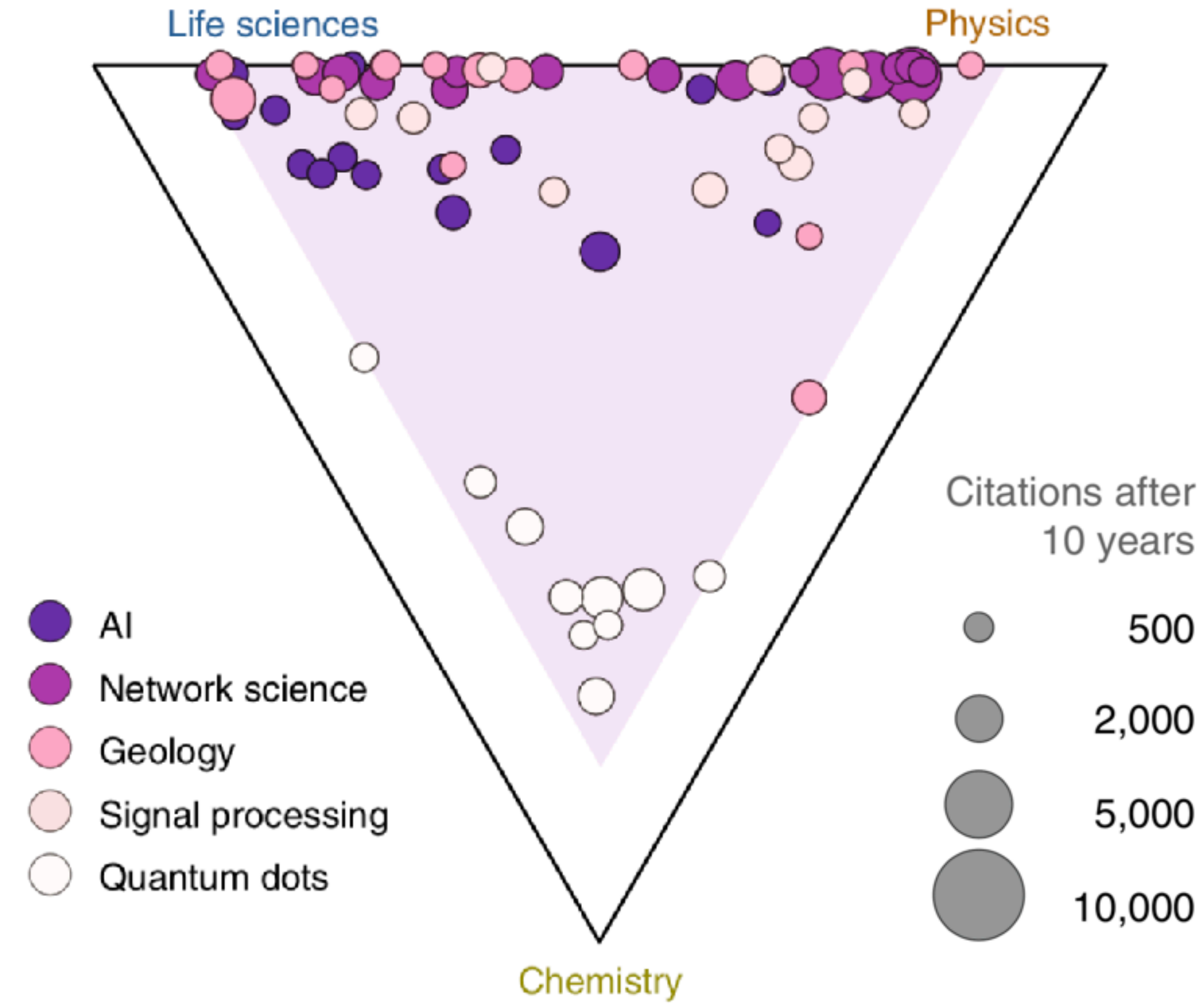
Top 10,000

What are these papers?

In the middle many are from network science!

Citation rank	Authors	Publication year	Title
69	Albert R.; Barabasi AL.	2002	Statistical mechanics of complex networks
137	Barabasi AL.; Albert R.	1999	Emergence of scaling in random networks
251	Watts DJ.; Strogatz SH.	1998	Collective dynamics of 'small-world' networks
822	Strogatz SH.	2001	Exploring complex networks
1159	Jeong H.; Tombor B.; Albert R.; Oltvai ZN.; Barabasi AL.	2000	The large-scale organization of metabolic networks
1168	Milo R.; Shen-Orr S.; Itzkovitz S.; Kashtan N.; Chklovskii D.; Alon U.	2002	Network motifs: Simple building blocks of complex networks
1247	Jeong H.; Mason SP.; Barabasi AL.; Oltvai ZN.	2001	Lethality and centrality in protein networks
1538	Albert R.; Jeong H.; Barabasi AL.	2000	Error and attack tolerance of complex networks
1778	Girvan M.; Newman MEJ.	2002	Community structure in social and biological networks
2078	Ravasz E.; Somera AL.; Mongru DA.; Oltvai ZN.; Barabasi AL.	2002	Hierarchical organization of modularity in metabolic networks
3063	Shen-Orr SS.; Milo R.; Mangan S.; Alon U.	2002	Network motifs in the transcriptional regulation network of Escherichia coli
3248	Pastor-Satorras R.; Vespignani A.	2001	Epidemic spreading in scale-free networks
3875	Newman MEJ.	2002	Assortative mixing in networks
4461	Maslov S.; Sneppen K.	2002	Specificity and stability in topology of protein networks
5516	Amaral LAN.; Scala A.; Barthelemy M.; Stanley HE.	2000	Classes of small-world networks
7207	Newman MEJ.; Strogatz SH.; Watts DJ.	2001	Random graphs with arbitrary degree distributions and their applications
7488	Newman MEJ.	2001	The structure of scientific collaboration networks
9335	Barahona M.; Pecora LM.	2002	Synchronization in small-world systems

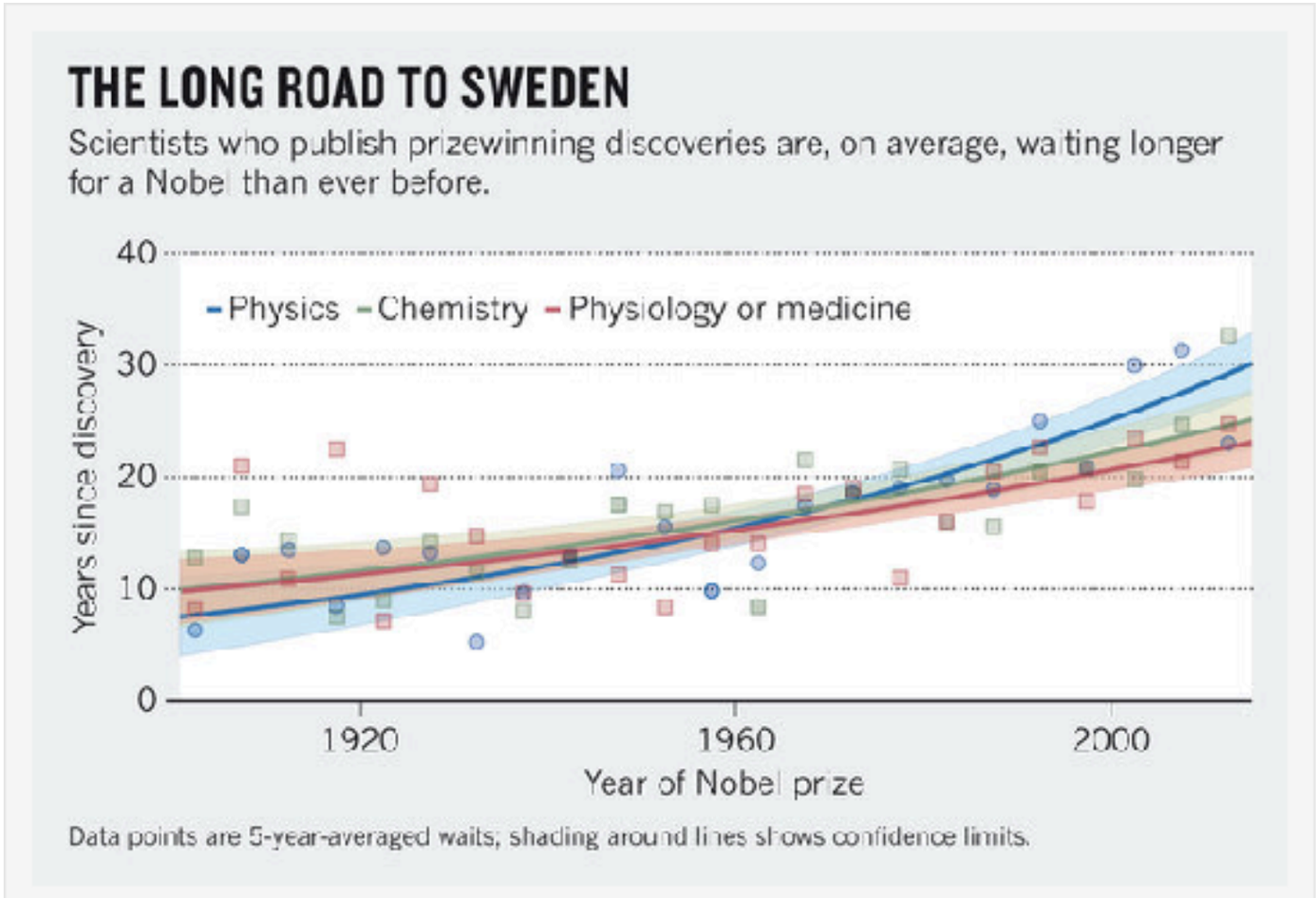
https://mszell.github.io/nobelplot/nobelplot.html



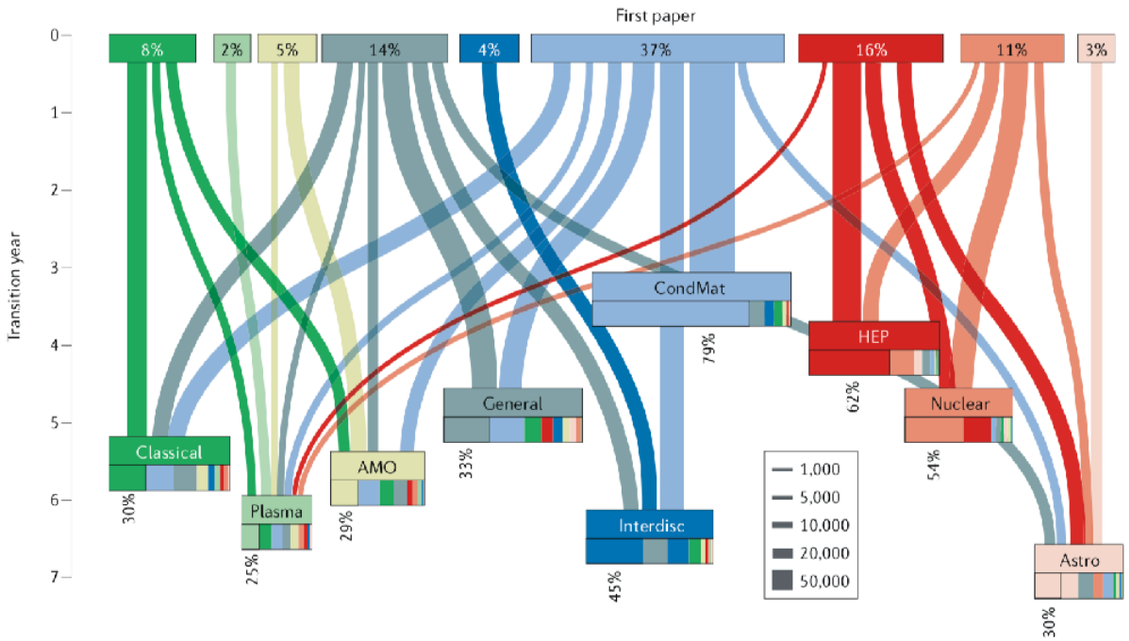
To fight bias/oppression we need to lay bare its mechanisms

1) Interdisciplinarity
2) Gender
3) Geography
4) Replication

...

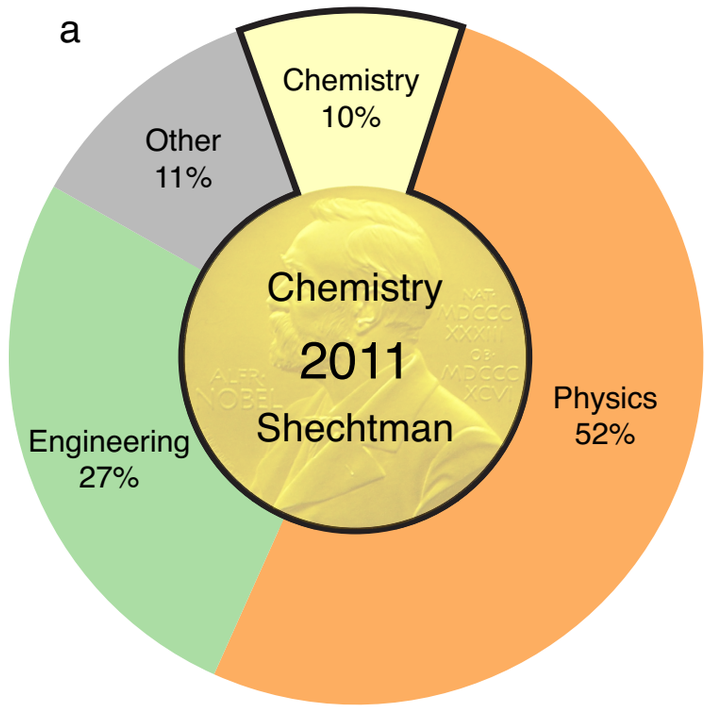


F. Battiston, F. Musciotto, D. Wang, A.-L. Barabási, M. Szell, R. Sinatra
Taking census of physics
Nature Reviews Physics 1, 89-97 (2019)



https://www.nature.com/articles/s42254-018-0005-3

M. Szell, Y. Ma, R. Sinatra
A Nobel opportunity for interdisciplinarity
Nature Physics 14, 1075-1078 (2018)



https://www.nature.com/articles/s41567-018-0314-6

@mszll
http://michael.szell.net
misz@itu.dk

IT University of Copenhagen
NEtwoRks, Data, and Society (NERDS)