Knowledge dynamics
a network analytical approach

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Background

- The science system is growing strongly, and is increasingly becoming international. Growth leads to increasing variety.

- Need for a lean typology to classify research fields in terms of their specific dynamics.

- Knowledge configurations: policy, organizational forms, and institutions adapted to knowledge dynamics.

Knowledge dynamics

- Internal dynamics of research fields (specialties, disciplines)
- Identifying (forms of) change

- Identifying influence of external factors (societal demand; economics and innovation)

Focus

- Here we focus only discuss on the internal knowledge dynamics
- Elsewhere:
  - The dynamics of technological knowledge (e.g., through patents)
  - The interaction between science and technology

Search regimes

- Growth (slow – fast)
- Development (convergence – divergence)
- Complementarities (hard/technical – soft/cognitive)

Two types:

- ‘mature’ fields: slow growth, converging, with hard complementarities
  - astronomy; physics
- ‘new’ fields: fast growing, diverging, with soft complementarities
  - Nano, genomics, ict, biotech.

Era-dynamics project

- Extensive experimenting with approaches and indicators for knowledge dynamics and search regimes.

- Methodological issues
  - Level of analysis (papers or journals)
  - Indicator for diversity: title words? Or is this related to growth?

- Theoretical issues
  - Only two types of knowledge dynamics?
  - Divergence or change?
  - Theoretical framework?

First methodological results

- Dynamics of research fields should be studied at the level of journals.
- Within that frame, title words of papers indicate the research front (topics).
- Early developments: key words (journal system does not yet exist).
- Growth and diversity need different indicators
  - More titles -> more new words

Theoretical

- Knowledge dynamics as changes in the structure of the scholarly communication network.

- Standard network properties can be used to study this

- Growth (nodes and their attributes)
- Change (position in the network)
- Complementarities (relations between the nodes)

Growth

- Nr of journals increases

- Journals become bigger (more papers)
- More authors / research institutions

- Indicators: number of journals, papers, authors

Change

- Divergence versus convergence is too restricted
  - Change can be divergence
    - Growth and specialization
    - New discoveries -> new specialties
  - Change can be convergence
    - New methods or theories make previously different specialties merge
  - Or both
    - Divergence within existing fields and merging of the resulting fragments: new configurations

Complementarities

- Technical:
  - Research facilities, instruments
- Cognitive (other research fields):
  - Codified knowledge
  - Tacit skills
- Institutional
  - Funding, evaluation, organizational forms
  - Required collaboration with users (for e.g., real life testing).

Indicators

- Growth = nr journals / papers
- Change = positional structure of the communication network
- Cognitive complementarities: knowledge sources – citations
  - (co-authorship; project collaborations = skills, tacit knowledge)

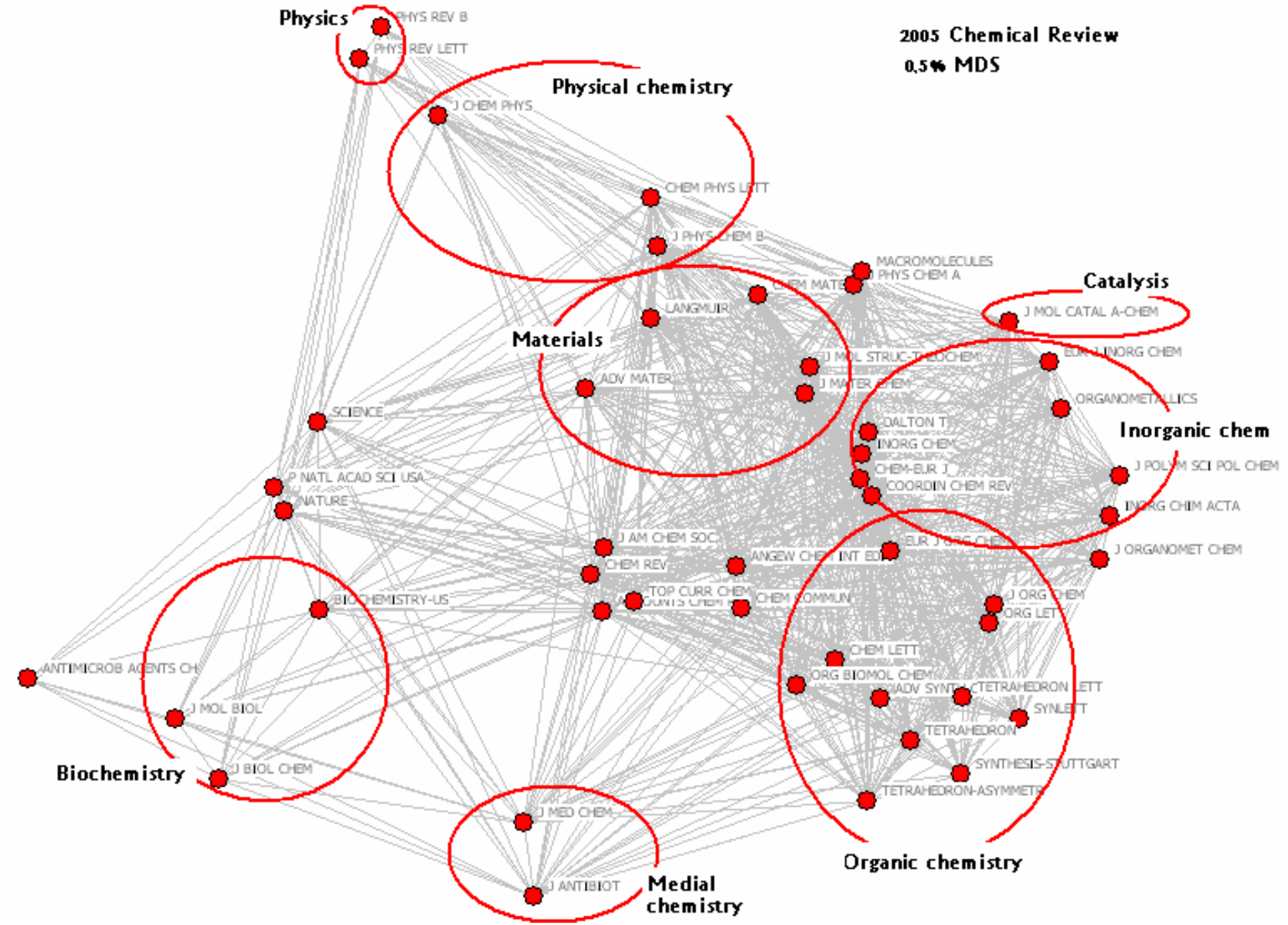
Again: focus is on change

- Stable research fields (established sub-disciplines) are embedded in fitting organizational and institutions frameworks
  - Organization of universities
  - Organization of councils
  - Evaluation systems

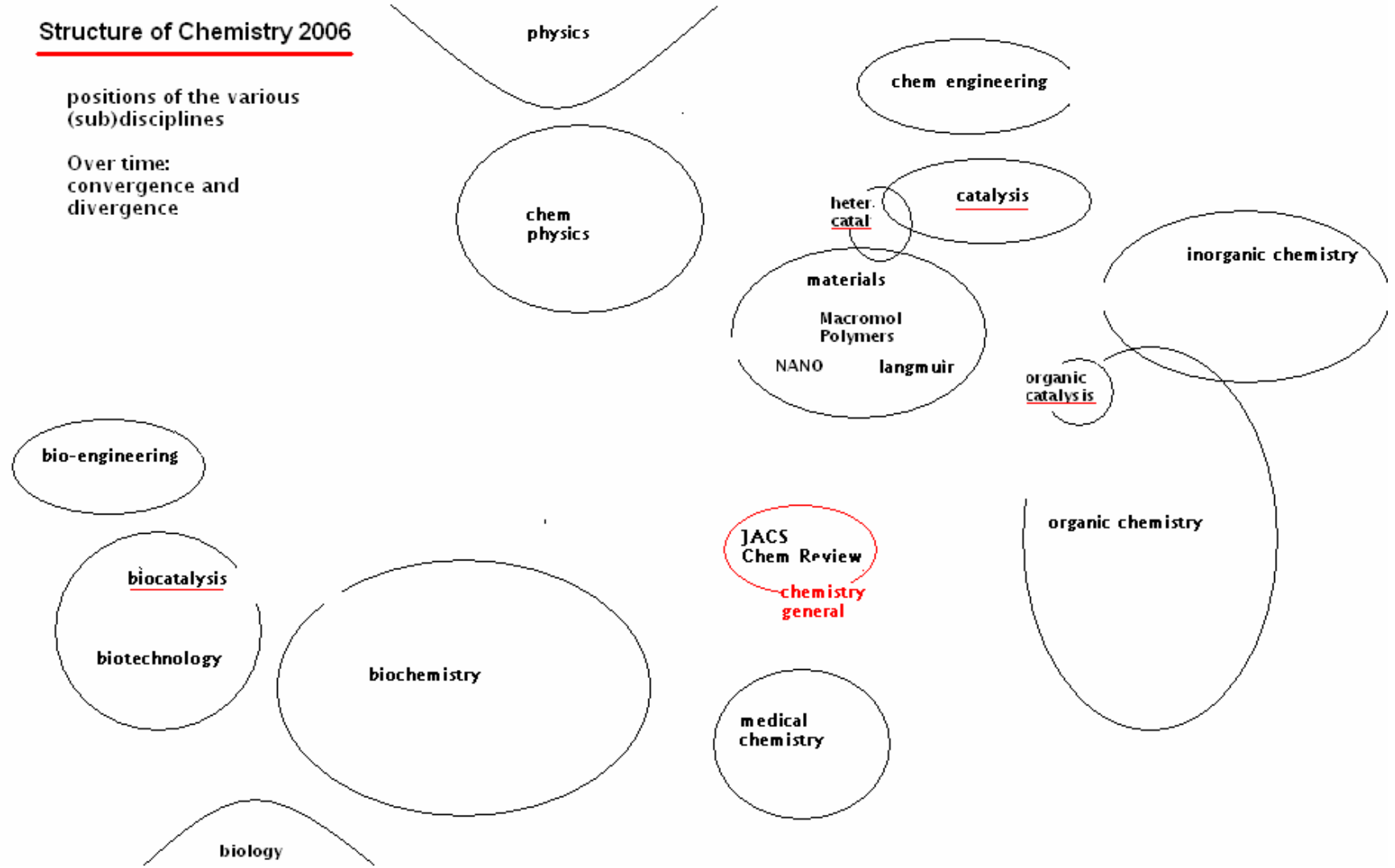
Basic method

- Determining the set of journals
  - Growth of network
- Analyzing the structure of the journal-communication network
- Network of journals shows network of research fields
  - Changing position of a research specialty shows knowledge dynamics
  - Citation relations between specialties show cognitive complementarities)

Chemistry (2006)



Structure of chemistry (2006)



Chemistry: development (1)

	1994	1996	1998	2000	2002	2004	2006
1	org	org	org	org	org	org	org
2	phys chem	inorg	phys chem	inorg	inorg	inorg	phys chem
3	inorg	phys chem	inorg	phys chem	phys chem	phys chem	inorg
4	bio chem	bio chem	bio chem	bio chem	bio chem	bio chem	bio chem
5	biopolymers	anal chem	langmuir / mater	polymer macromol	mater nano	mater	mater / nano
6	catal	biopolymers	NMR	langmuir / mater	physics / surface	physics / surface	langmuir
7	anal chem	polymer macromol	polymer macromol	physics / surface	med chem	polymer macromol	polymer macromol
8	polymer macromol	nature science	anal chem	NMR	NMR	med chem	nature science
9	nature science	med chem	nature science	med chem	anal chem	NMR	physics / surface
10	christallography	christallography	med chem	photo chem	polymer macromol	langmuir	med chem
11	med chem	physics / surface	physics / surface	nature science	nature science	nature science	NMR
12	physics / surface	langmuir		anal chem	langmuir	catal	catal
13	electro chem					anal chem	anal chem

Chemistry: development (2)

	1994	1996	1998	2000	2002	2004	2006
organic chemistry	1	1	1	1	1	1	1
phisical chemistry	2	3	2	3	3	3	2
inorganic chemistry	3	2	3	2	2	2	3
biochemistry	4	4	4	4	4	4	4
biopolymers	5	6					
chem mater& nanotech					5	5	5
langmuir (& chemical mater)		12	5	6	12	10	6
polymers & macromolecules	8	7	7	5	10	7	7
physics: cond matter / surf sci	12	11	11	7	6	6	9
nature, pnas, science	9	8	9	11	11	11	8
medical chemistry	11	9	10	9	7	8	10
analytical chemistry	7	5	8	11	9	13	13
NMR			6	8	8	9	11
catalysis	6					12	12
christallography	10	10					
photochemistry				10			
electrochemistry	13						

Growth

1994-2007	Chemistry	Catalysis	Biocatalysis
Journals	3%	4.5%	18%
articles	3.5%	6%	7%

Catalysis 1994

07/12

1994 catalysis journals	Catalysis	(heterogeneous) catalysis	biocatalysis
catal lett	,919	,311	
catal rev	,916		
j catal	,909	,324	
react kinet catal l	,902		
appl catal a-gen	,875	,365	
appl catal b-environ	,855	,353	
catal today	,841	,428	
j mol catal	,705		,436
kinet catal+	,545		
Zeolites		,901	
microporous mater	,480	,850	
Biocatalysis			,923

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a Rotation converged in 6 iterations.

Catalysis 2006

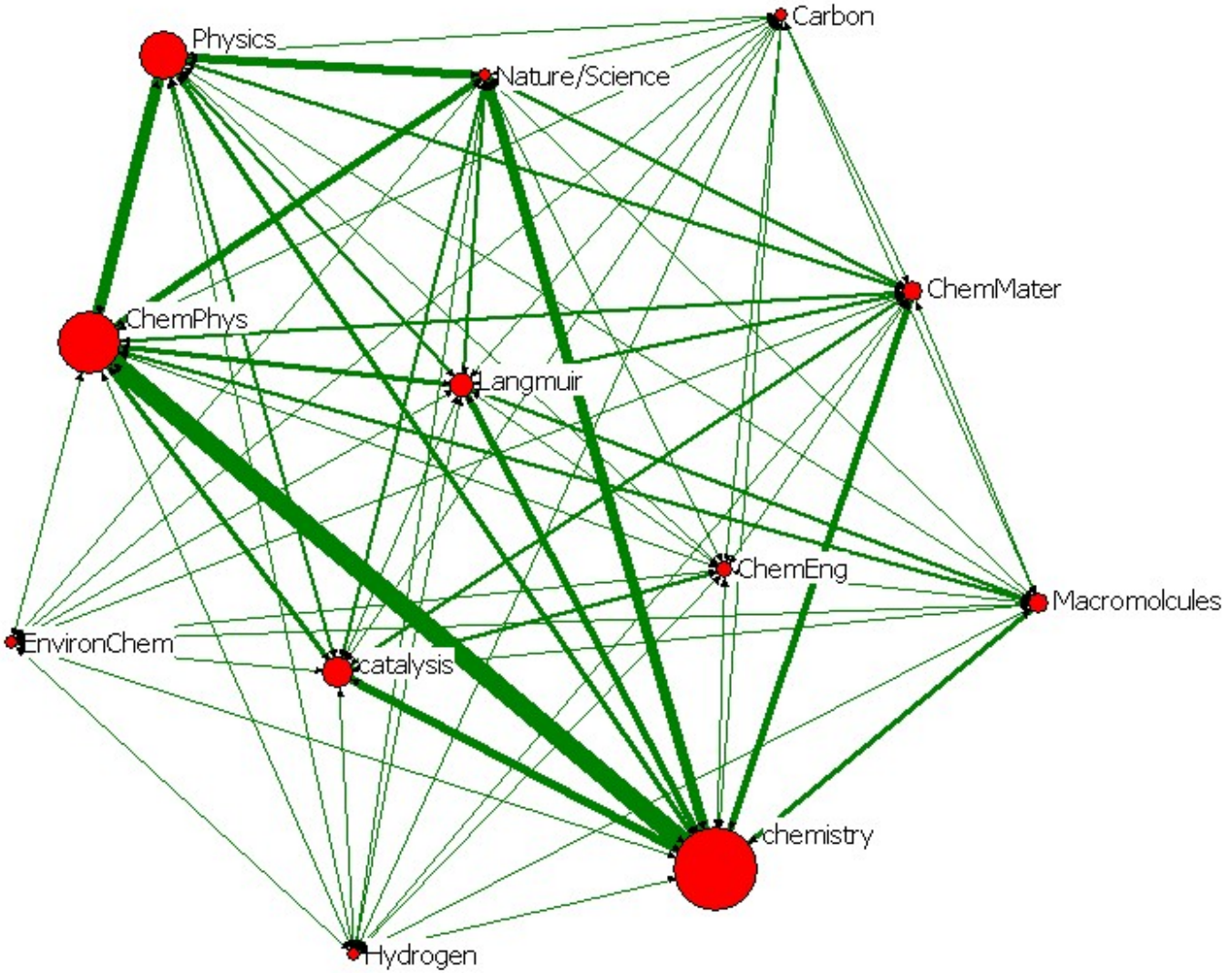
2006 catalyse journals	(homogenous) Catalysis	(heterogenous) Catalysis	(organic) catalysis	Biocatalysis
catal rev	.953			
catal lett	.923			
catal today	.912	.307		
appl catal a-gen	.910			
j catal	.900	.311		
appl catal b-environ	.874			
top catal	.834	.366	.307	
catal commun	.803		.410	
catal surv asia	.739	.373	.482	
Micropor mesopor mat		.929		
j porous mat	.405	.852		
stud surf sci catal	.424	.812		
adv synth catal			.912	
j mol catal a-chem	.489		.783	
kinet catal+	.423		.644	
adv catal	.554	.418	.619	
biocatal biotransfor				.912
j mol catal b-enzym				.899

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a Rotation converged in 5 iterations.

Catalysis development

- Larger in journals
- From three to four subfields
- Three subfields are related
  - Relations are stable (indicator: number of “double factor loadings”)
- Biocatalysis is completely separated
  - Moves from a position between *biochemistry* en *organic chemistry* to *biotechnology*
  - *J Mol Catalysis* splits an organic and a biotech part

Cognitive complementarities



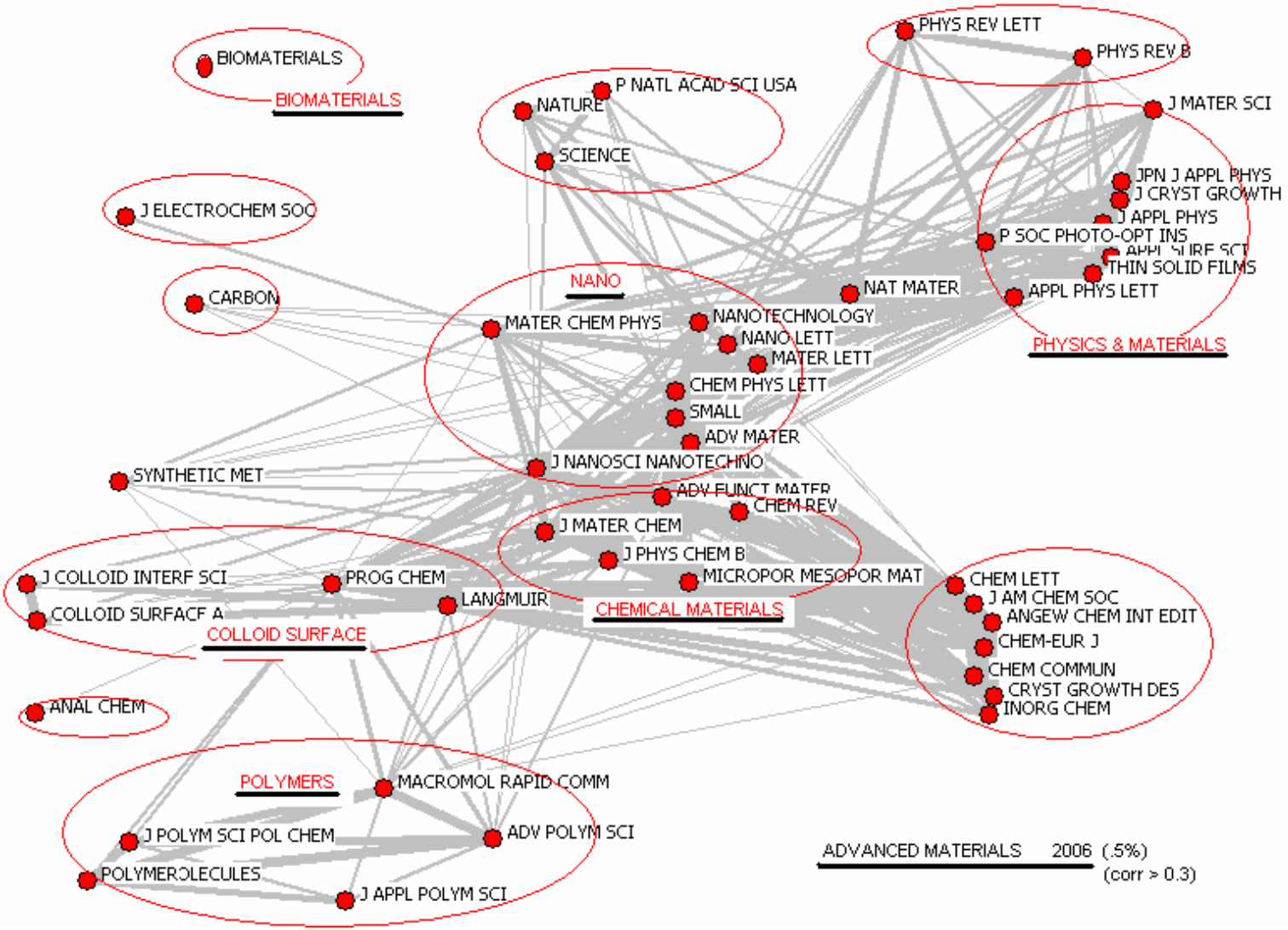
Chemical materials

- Chemical materials
- (Applied) physics
- Biomaterials

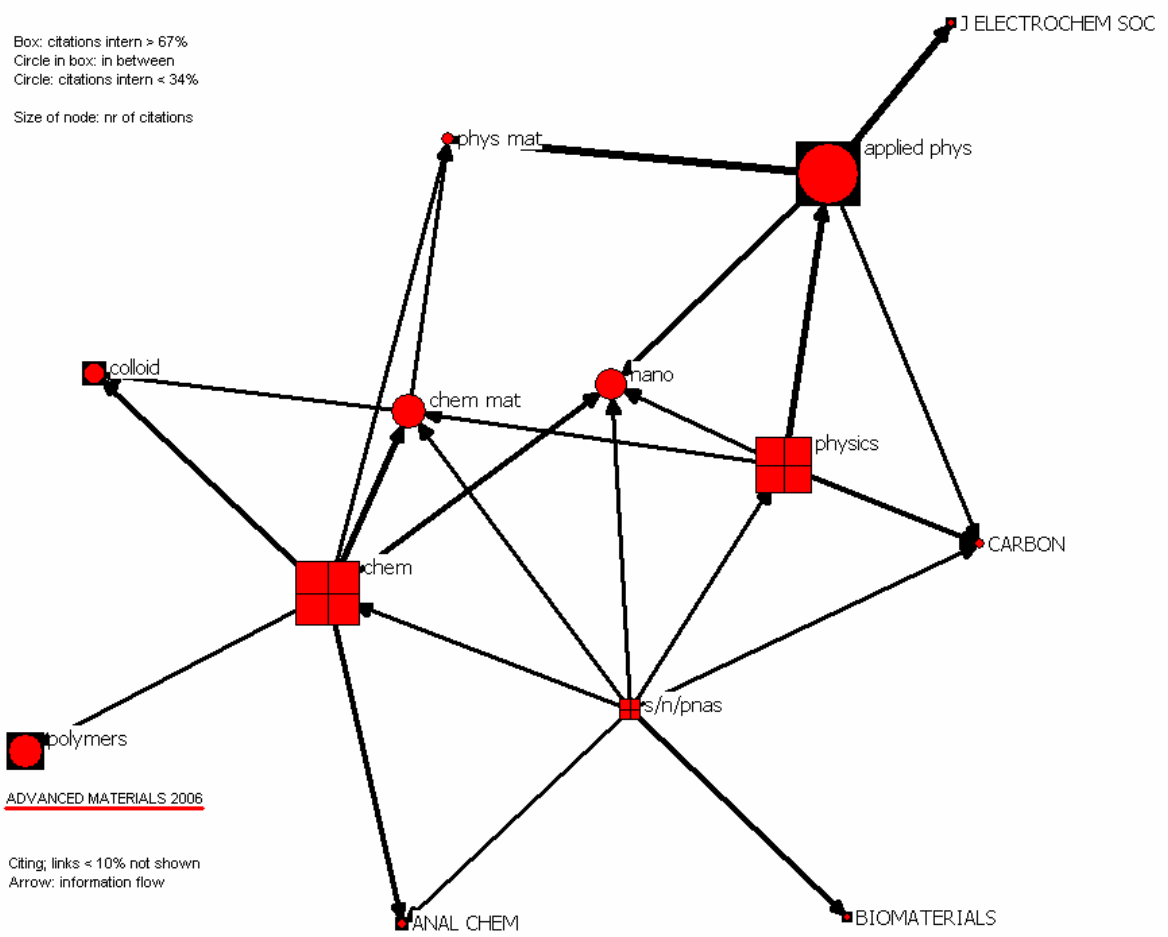
- Nano appears everywhere

- Over time parts of the ‘older’ fields converge into ‘advanced materials’ based on nanotechnology

Structure of advanced materials



Cognitive complementarities



Conclusion

- Different patterns of change
  - Converging, diverging and both
  - Journal spaces as indicators for the dynamics of divergence and convergence (in different combinations)

- Reshaping knowledge spaces
  - Traditional disciplinary structures remain
  - Multidisciplinary structures
  - New disciplines emerge in between the existing one's: interdisciplines become disciplines (eg NANO in the near future)

- Organizational and institutional adaptation?
  - Institutional conditions for fast adaptation to changes in the knowledge spaces
  - Patterns of change (and of stability) to assess claims of the stakeholders (e.g., for funding)