Strategic Management of Knowledge in Big Science

Agustí Canals
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Agenda

1. Big Science organizations
2. Strategic knowledge mapping in big science projects: a methodology to identify and develop key strategic knowledge assets and explore their characteristics and relationships
3. Structure of interorganizational collaboration in scientific projects: analysis of collaboration networks
4. The role of simulations as a coordination mechanism in a big science project: simulations as dynamic boundary objects

Big Science Organizations

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Big science

- In many areas (genomics, high energy physics, climate sciences, ecology, astronomy, nuclear fusion,…) scientific research has moved in the last decades from small or medium-sized experiments to large and complex collaborations (Galison 1992)
- The idea of 'big science' put forward in the 1960's by Weinberg (1961) and Price (1963) has become commonplace (Hicks & Katz 1996, Knorr-Cetina 1999, Etzkowitz & Kemelgor 1999)
- Big science is taking an important part of research funding and it is worth looking at its different aspects
- Big science experiments provide very interesting management and organizational insights
- A good example: CERN experiments

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The Large Hadron Collider (LHC)

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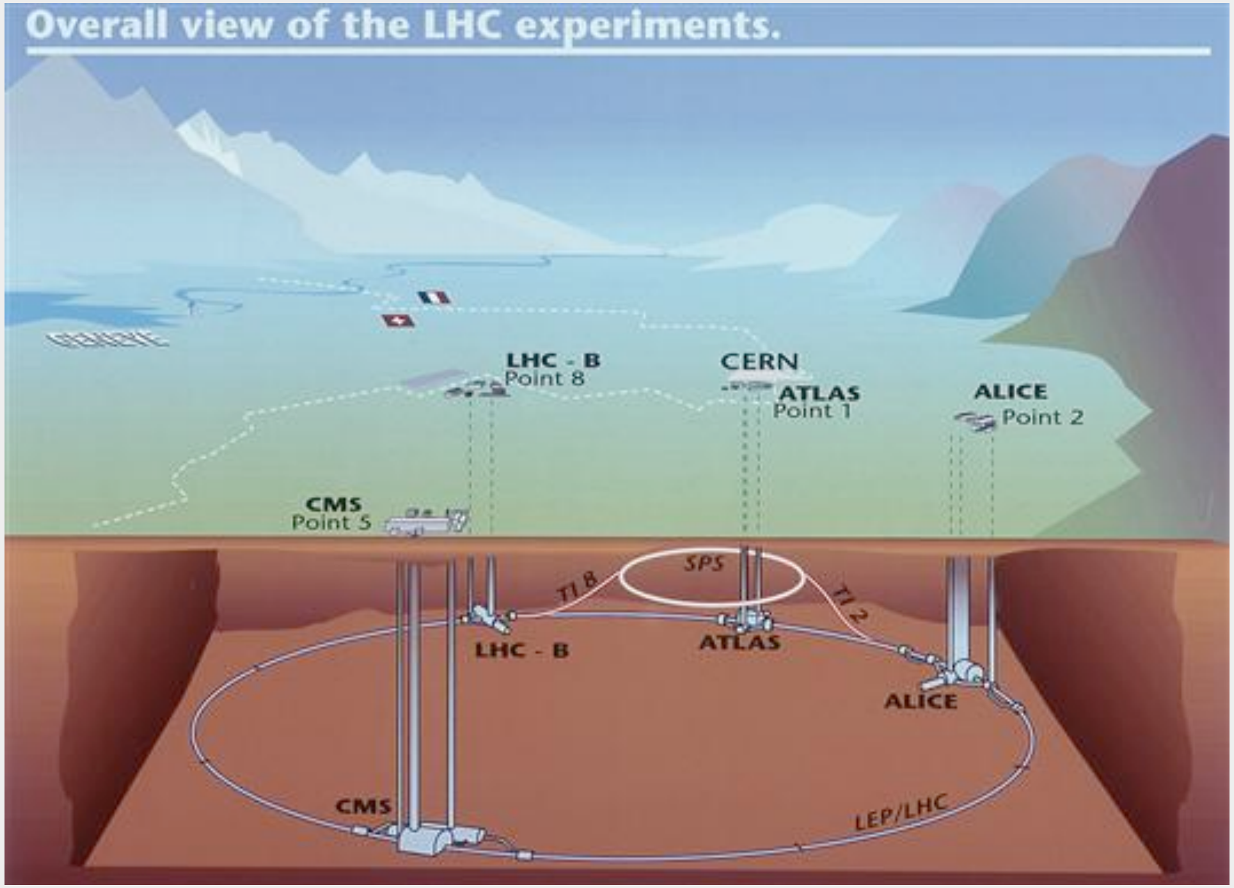
ATLAS: One of the LHC detectors



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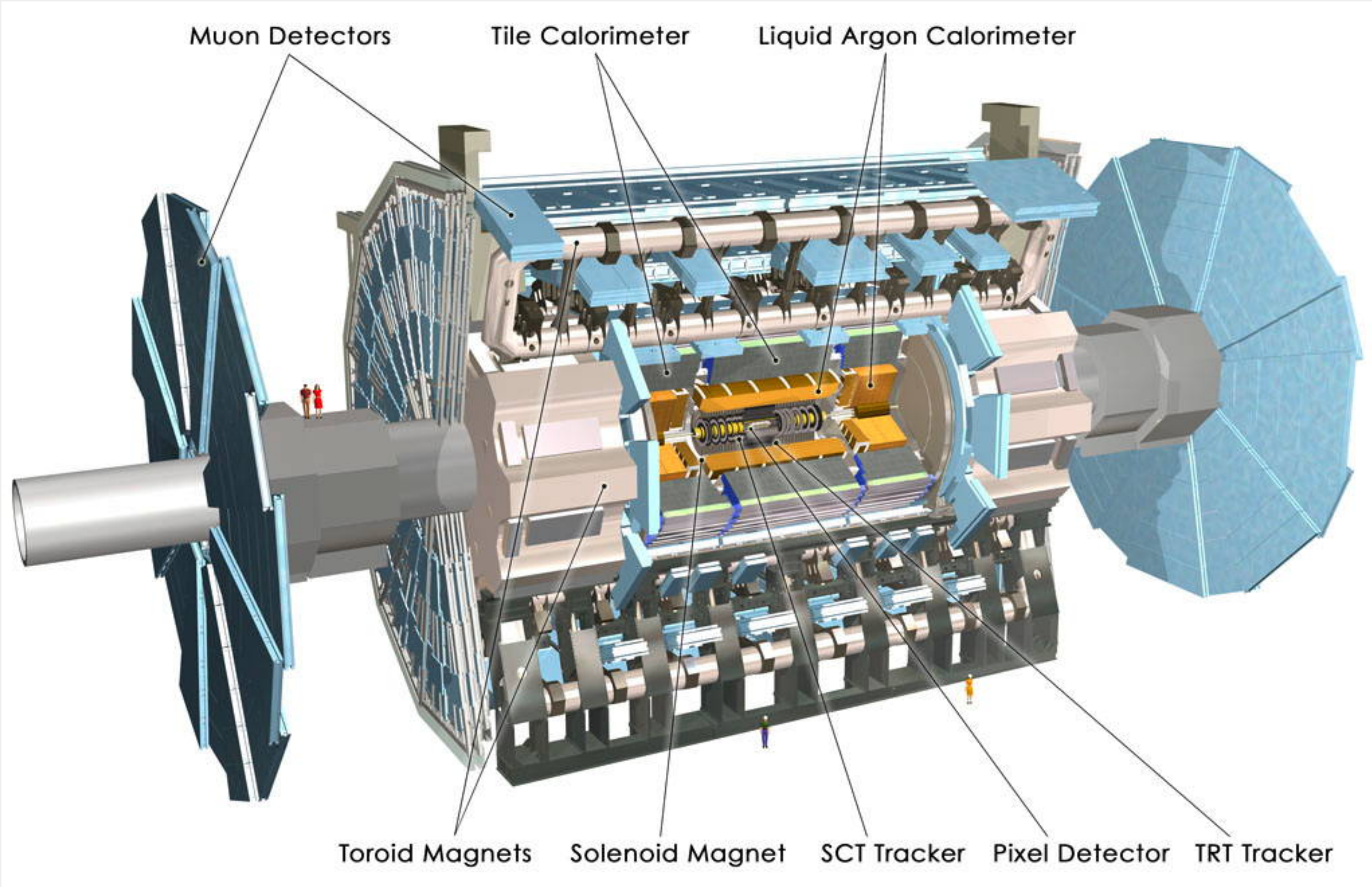
The ATLAS detector



The ATLAS Collaboration

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A complex organization

3000 physicists

174 universities
and labs

38 countries

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New kinds of organizations

- New virtual collaborations fostered by globalization and ICTs
- But managed in a traditional way: organizational authority systems and clear boundaries
- Some recent developments challenge this: distributed, non-hierarchical networks such as Linux
- Questions:
  - How is coordination actually achieved?
  - What happens when the task is complex and boundaries are fuzzy?
  - What level of complexity such networks can manage?
- The ATLAS case: bottom-up culture and very limited use of managerial authority

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Three Questions

ATLAS is an exceptional knowledge-based organization!

How does it work?

- What are the critical knowledge assets that allow ATLAS to perform at such high levels?
- How is the structure of internal collaboration?
- How is coordination achieved in this complex, non-hierarchical knowledge system?

Strategic Knowledge Mapping

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Three kinds of knowledge

Structured (Codified and/or Abstract)

Abstract Symbolic Knowledge

- What can I extract from it which is stable or durable?

Narrative Knowledge

- What can I say about it?

Unstructured (Uncodified and/or Concrete)

Experiential Knowledge

- What can I sense?

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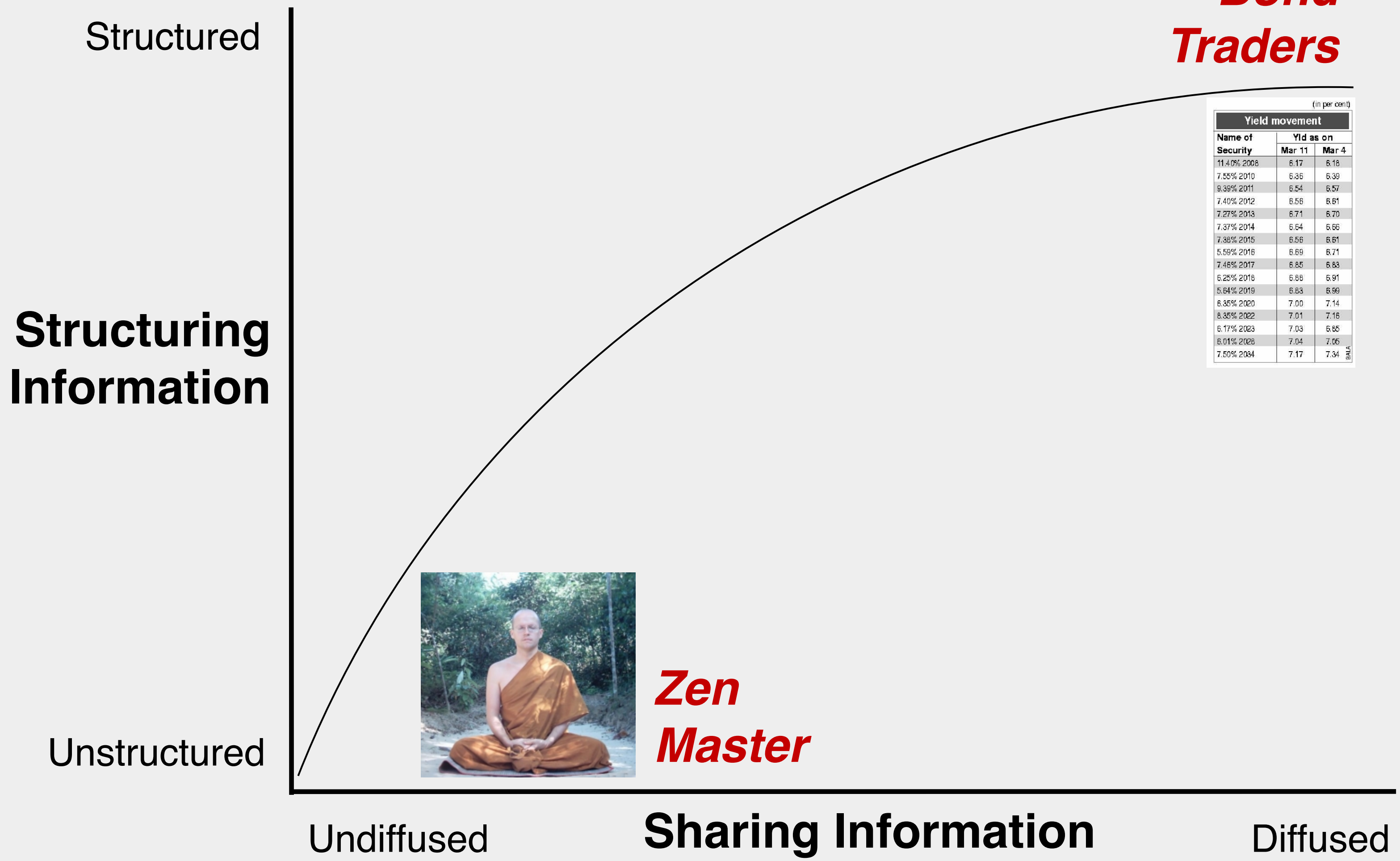
The I-Space



(in per cent)

Yield movement		
Name of Security	Yld as on	
	Mar 11	Mar 4
11.40% 2008	6.17	6.18
7.55% 2010	6.36	6.39
9.39% 2011	6.54	6.57
7.40% 2012	6.56	6.61
7.27% 2013	6.71	6.70
7.37% 2014	6.64	6.66
7.38% 2015	6.56	6.61
5.59% 2016	6.69	6.71
7.46% 2017	6.85	6.83
6.25% 2018	6.88	6.91
5.64% 2019	6.83	6.99
6.35% 2020	7.00	7.14
8.35% 2022	7.01	7.16
6.17% 2023	7.03	6.85
6.01% 2028	7.04	7.05
7.50% 2034	7.17	7.34

BALA

Boisot (1998). *Knowledge Assets*. OUP.

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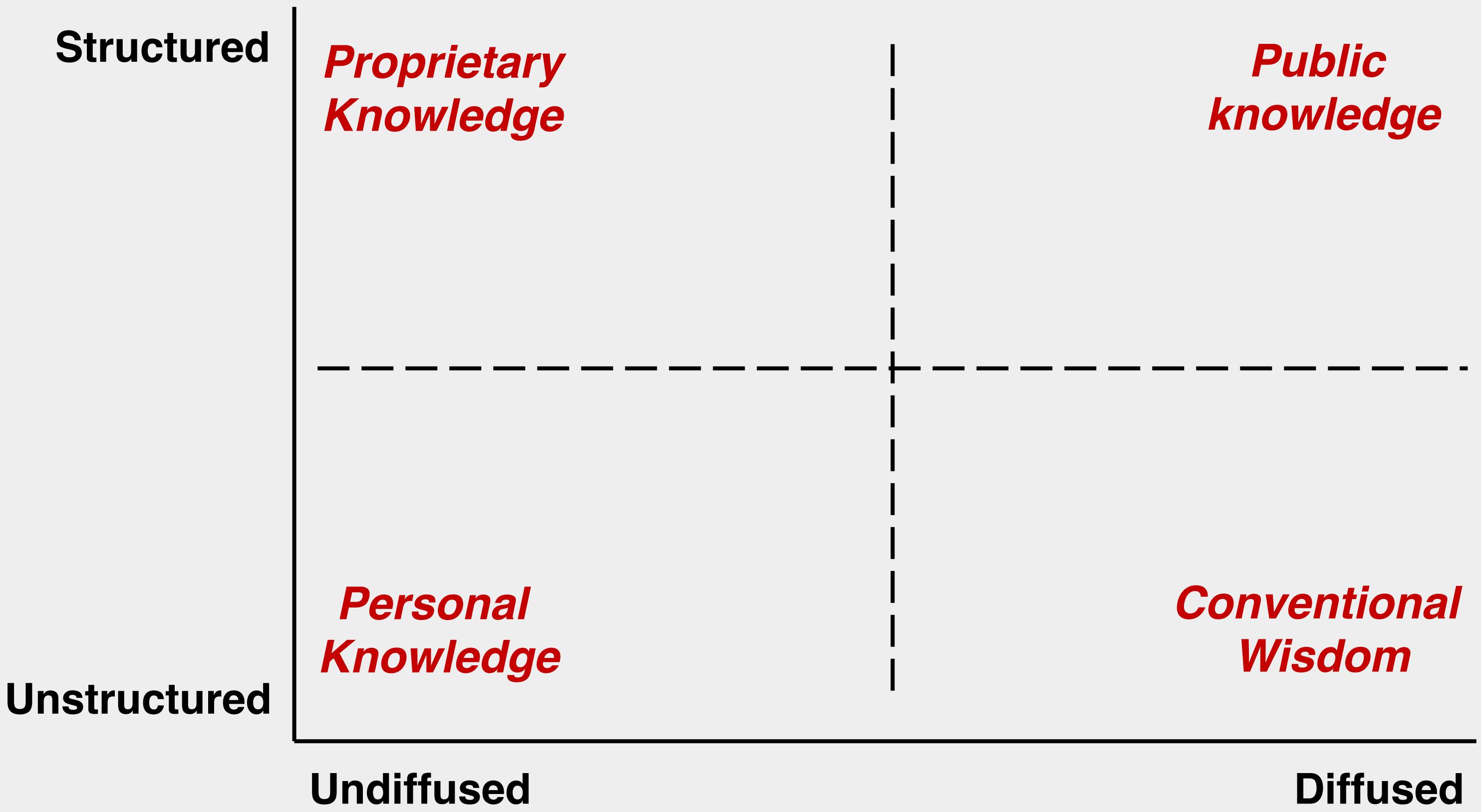
Knowledge in the I-Space



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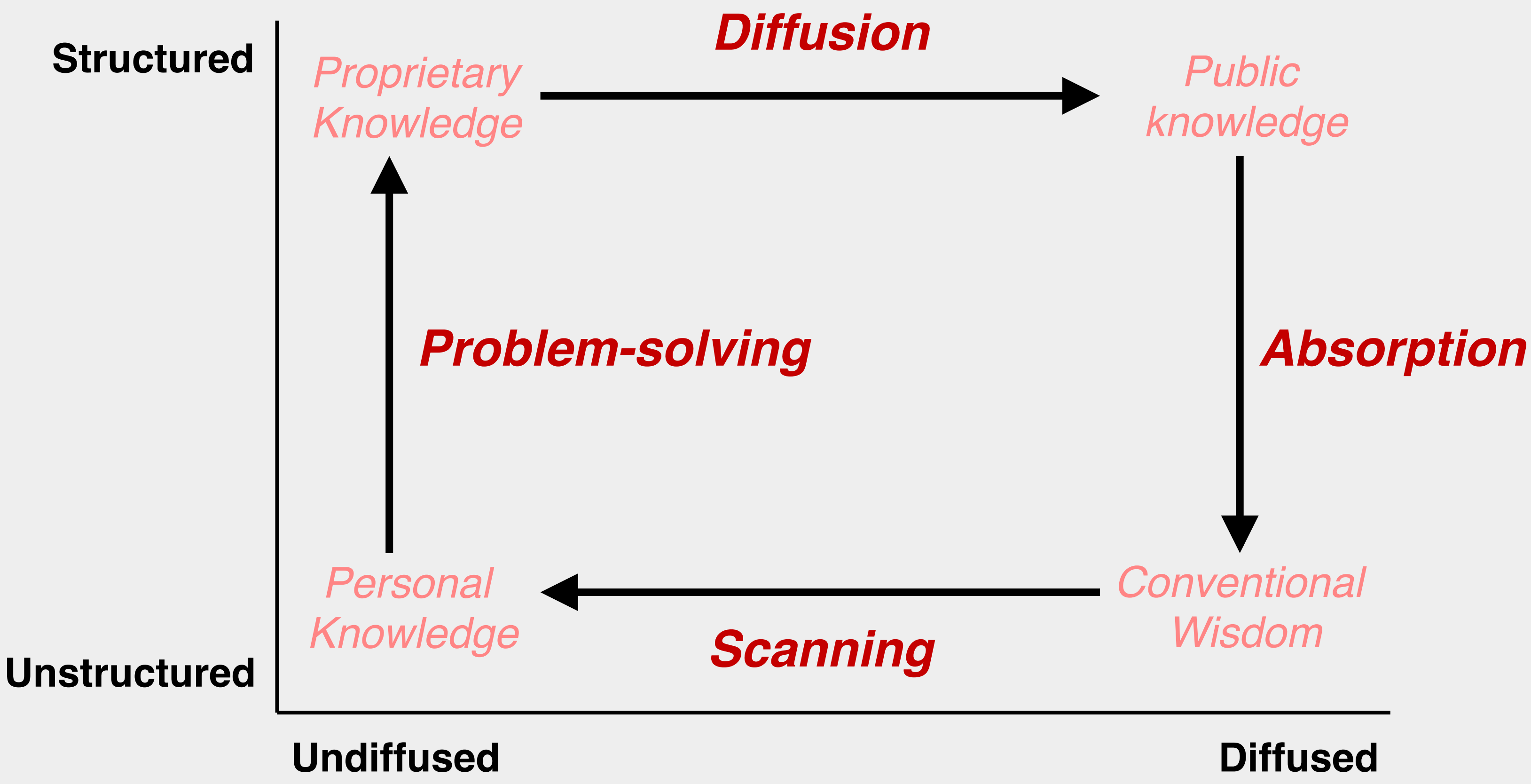
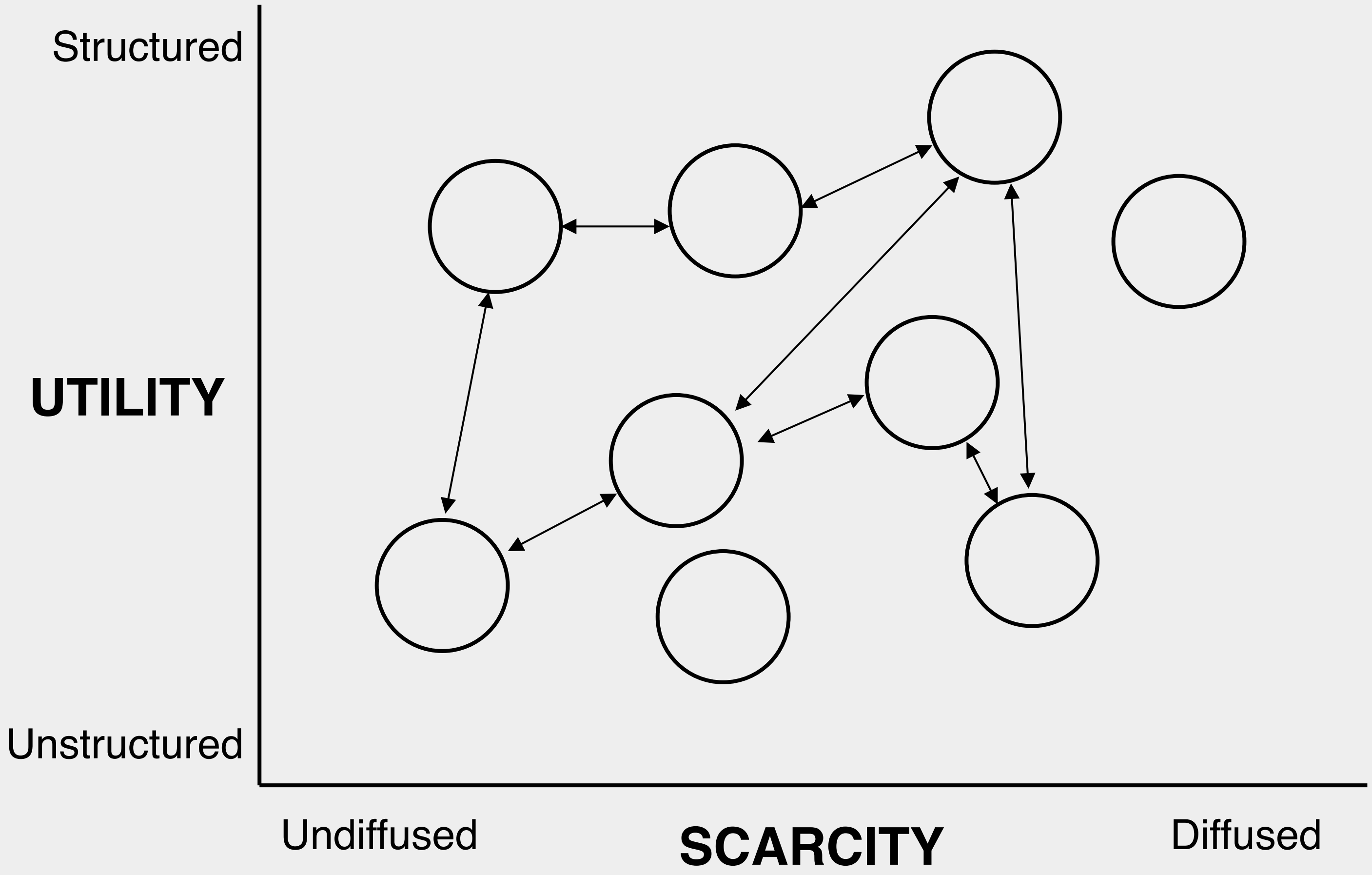
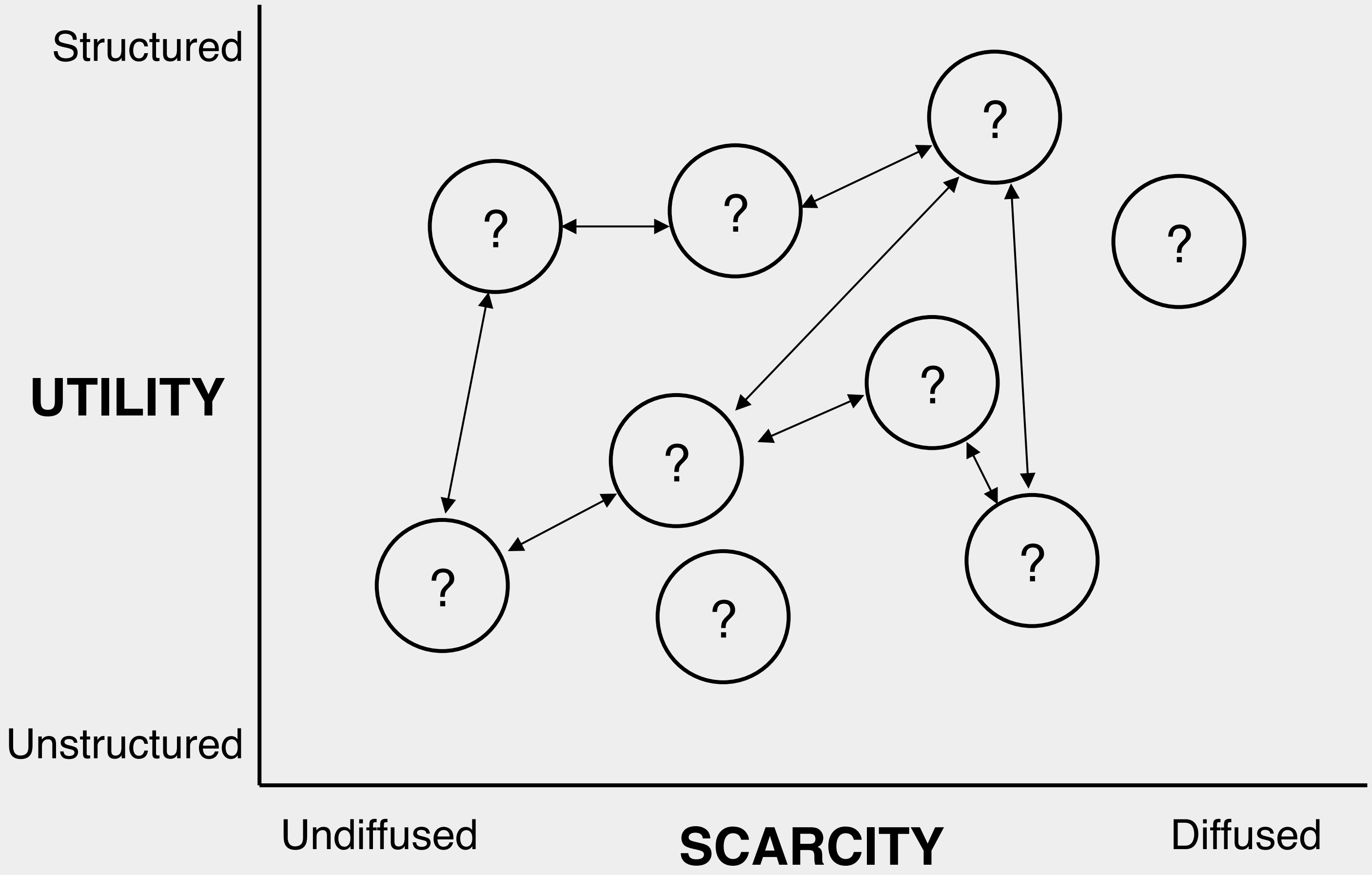
The Social Learning Cycle (SLC)



Portfolio of knowledge assets



Mapping the ATLAS knowledge



Strategic Knowledge Mapping Process

1. What are the organization's critical performance dimensions?
2. What are the knowledge assets that support those performance dimensions?
3. Where are the knowledge assets located in the *I-Space*?
4. What are the strategic implications of the knowledge map?
5. How can the knowledge system develop?

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Selecting knowledge assets

Wharton
UNIVERSITY of PENNSYLVANIA

Please select from the list below the *two* most important knowledge domains that you currently apply in executing your work:

☐ Standard Model	☐ Operating Systems	☐ Presentation Skills
☐ Beyond Standard Model	☐ Software Analysis and Design	☐ Interpersonal Communication Skills
☐ General P-P Collision	☐ Programming	☐ Detector Readout and Instrumentation
☐ Overall View of The State of The Art of Electronics	☐ Database Technologies (Hardware and Software)	☐ LHC Machine Parameters
☐ FPGA (Field Programmable Gate Arrays) and DSP (Digital Signal Processes)	☐ Networking and Point-to-Point Links	☐ MC Simulation
☐ Fast Memories	☐ Project Management	☐ Overview of The ATLAS Experiment
☐ Radiation Hard Electronics	☐ Financial Management	☐ Overview of The ATLAS Collaboration
☐ Backplanes and High Speed Serial Links	☐ People Management	☐ Outreach
☐ Hardware (Servers, Modular Electronics, ...)	☐ Meeting Management & Participation	

In what follows and for each knowledge domain, you will be asked six questions, each of which requires you to answer yes or no. In addition, you will be asked two questions requiring you to assign a score, plus two questions requiring a simple numerical estimate.

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TDAQ Questionnaire: Basic Statistics

GENERAL SURVEY COMPARISON STATISTICS

	First Round		Second Round		**Both Rounds**	
Number of people approached	74		101		**175**	
Questionnaire hits	43	58.11%	89	88.12%	132	75.43%
Responses	41	55.41%	49	48.51%	90	51.43%
Complete responses	36	48.65%	38	37.62%	**74**	**42.29%**
Knowledge responses	82		81		**163**	

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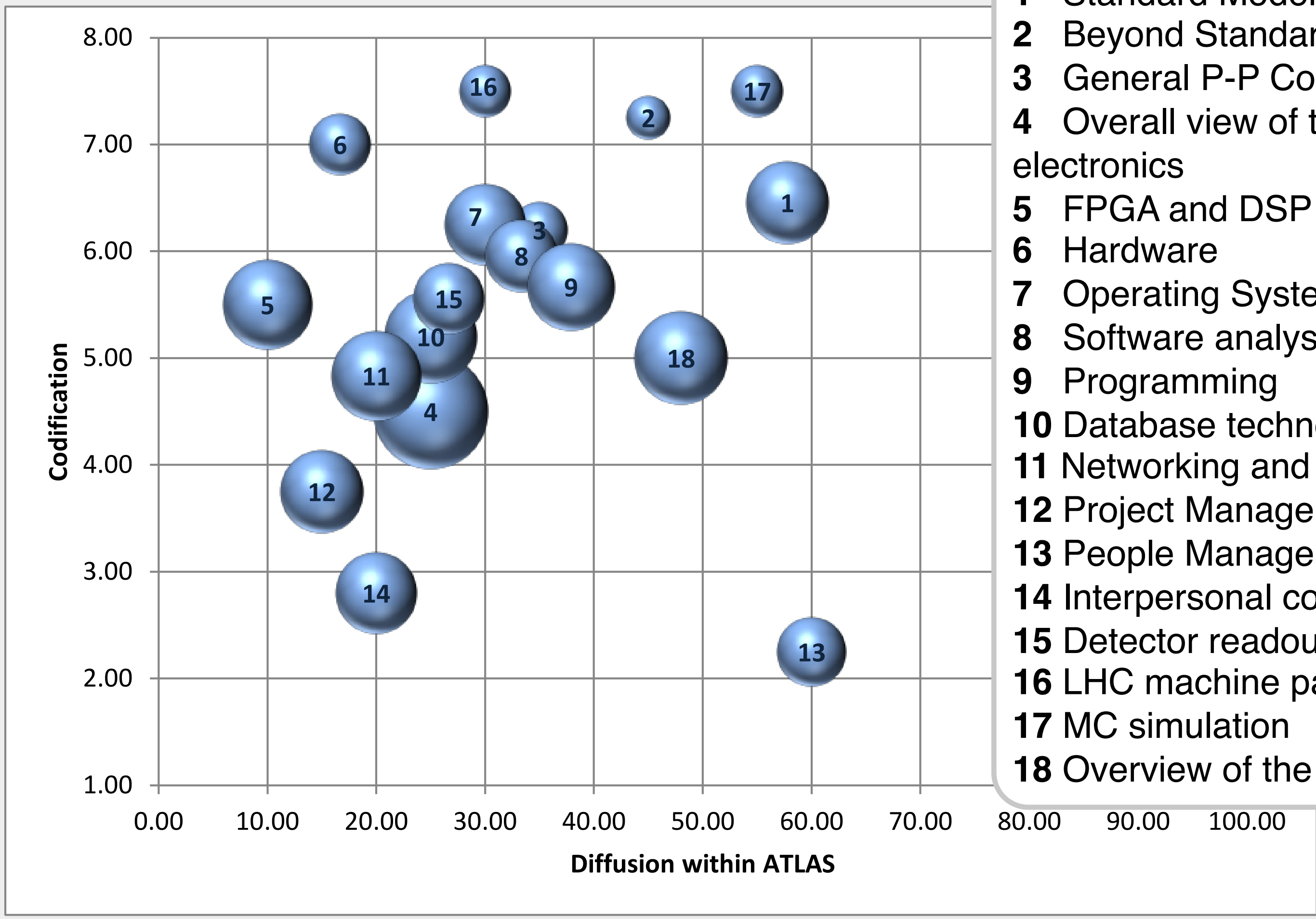
TDAQ Knowledge Map



1 Standard Model
2 Beyond Standard Model
3 General P-P Collision
4 Overall view of the state of the art of electronics
5 FPGA and DSP
6 Hardware
7 Operating Systems
8 Software analysis and design
9 Programming
10 Database technologies
11 Networking and Point-to-point links
12 Project Management
13 People Management
14 Interpersonal communication skills
15 Detector readout and instrumentation
16 LHC machine parameters
17 MC simulation
18 Overview of the ATLAS experiment

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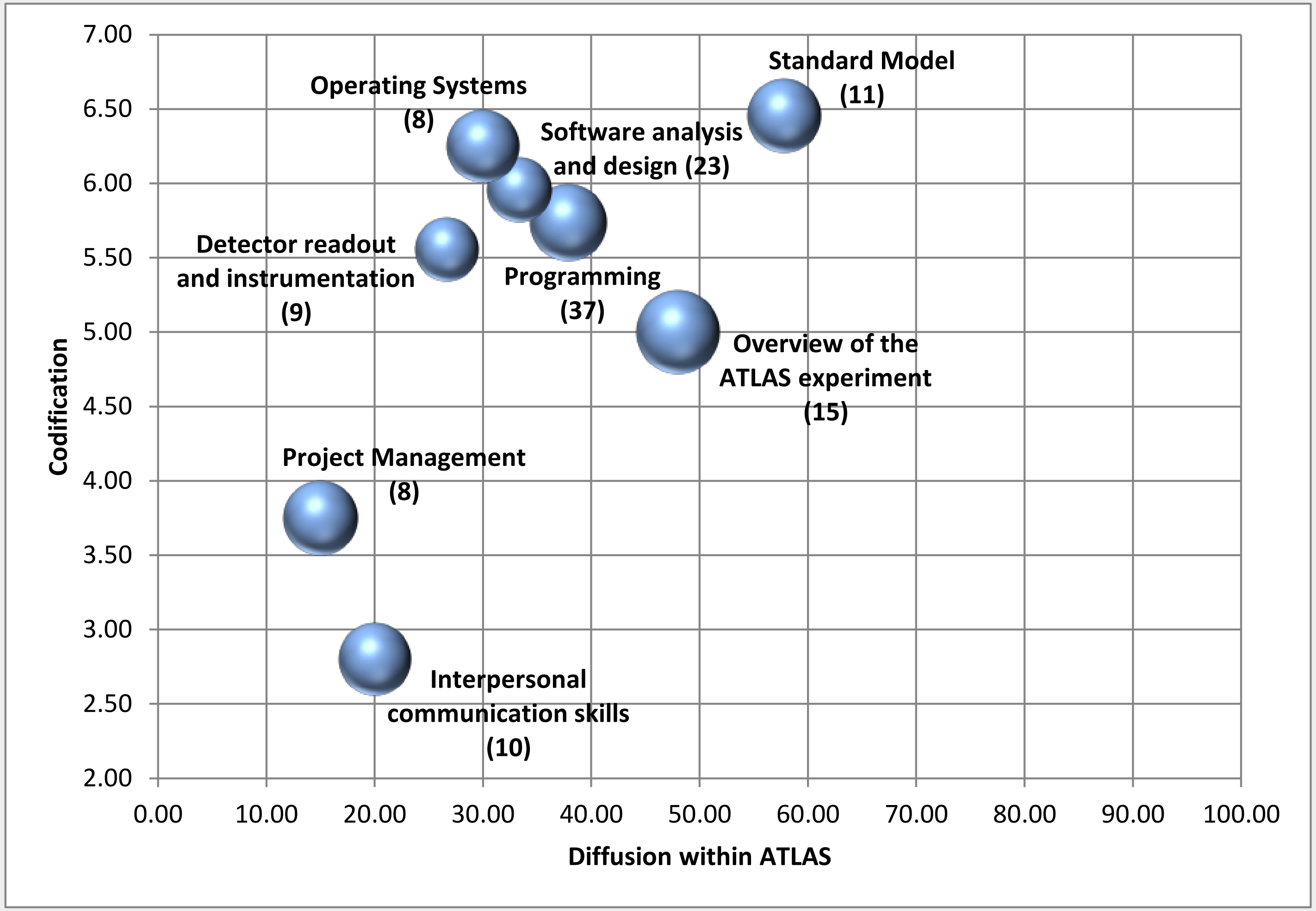
What is the most salient knowledge?



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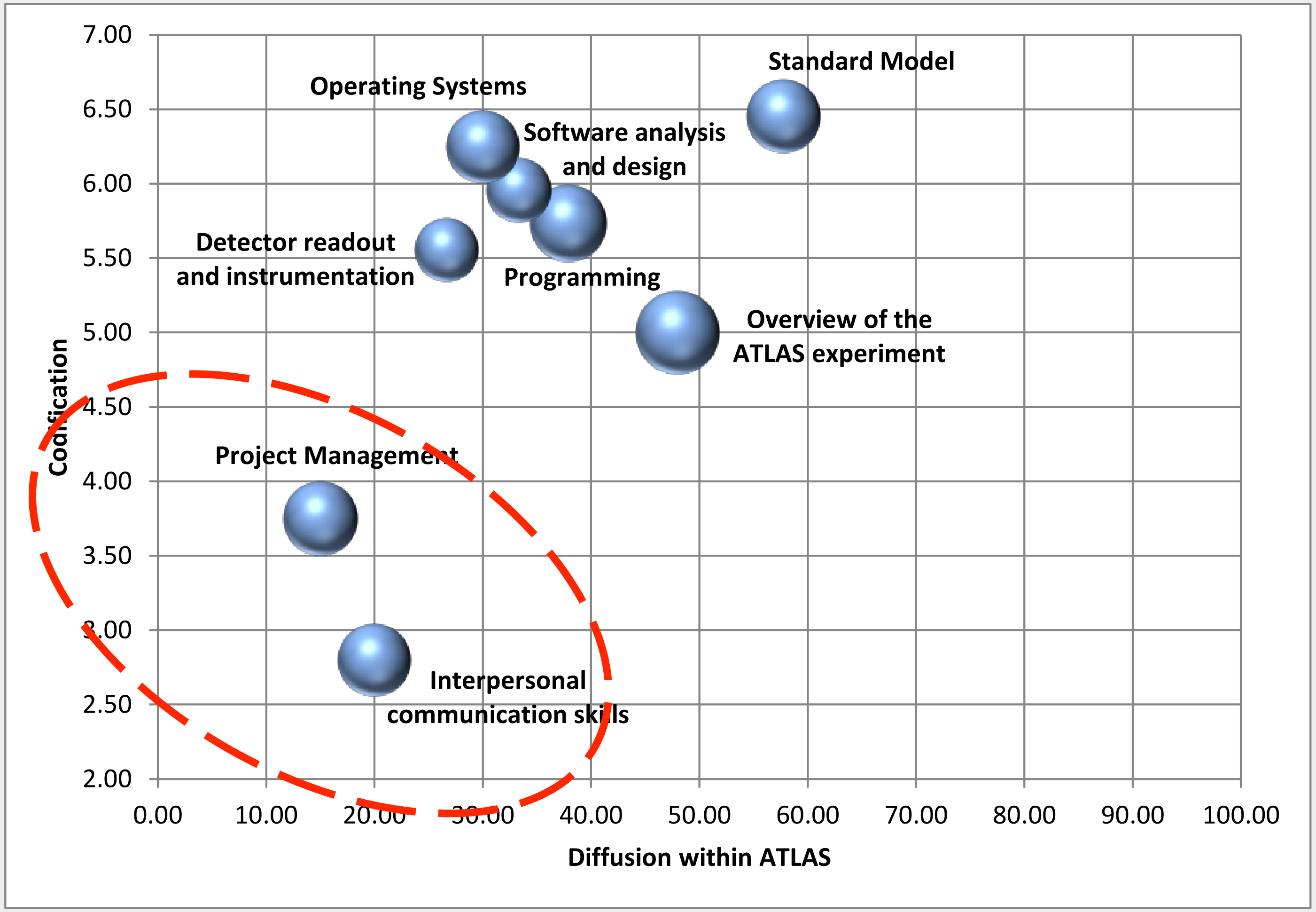
Soft/Management Skills in ATLAS



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Challenges for ATLAS

- Strategically developing value (competitive advantage)
  - Understanding the nature of one's core competences
  - Over and beyond the ATLAS project cycle (15 years)
- Fostering the further development of soft skills in ATLAS?
  - Manpower development in High Energy Physics
  - Formal courses (upper I-Space)
  - Apprenticeships (lower I-Space)
  - Correlation between position and choice of soft-skills?
- Managing the flow of people in and out of projects and between home institutions and ATLAS
  - Knowledge walking out of the door

Structure of Interorganizational Collaboration

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Scientific collaboration

- Scientific collaboration has a direct effect on the impact of the resulting publications (Benavent-Pérez et al. 2012), accentuated in the case of international collaboration (Kronegger et al. 2011)
- Important public funding is applied to scientific collaboration
- It can be analyzed from different perspectives: authors, institutions, countries (Sonnenwald 2007)
- In order to analyze it, scientific collaboration must be contextualized: by discipline, by geographical area, by type of research, … (Gzani, Sugimoto & Didegah 2012)
- We are interested in understanding collaboration patterns in 'big science'

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Studying scientific collaboration

- Usual methodology: co-authorship networks (Sonnenwald 2007)
- … but in big science co-authorship networks of published papers might be misleading

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In big science: genomics

nature International weekly journal of science

Search

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- About the journal

Human Genome

Nature **409**, 860-921 (15 February 2001) | doi:10.1038/35057062; Received 7 December 2000; Accepted 9 January 2001

article

Initial sequencing and analysis of the human genome

International Human Genome Sequencing Consortium Eric S. Lander[1], Lauren M. Linton[1], Bruce Birren[1], Chad Nusbaum[1], Michael C. Zody[1], Jennifer Baldwin[1], Keri Devon[1], Ken Dewar[1], Michael Doyle[1], William FitzHugh[1], Roel Funke[1], Diane Gage[1], Katrina Harris[1], Andrew Heaford[1], John Howland[1], Lisa Kann[1], Jessica Lehoczky[1], Rosie LeVine[1], Paul McEwan[1], Kevin McKernan[1], James Meldrim[1], Jill P. Mesirov[1], Cher Miranda[1], William Morris[1], Jerome Naylor[1], Christina Raymond[1], Mark Rosetti[1], Ralph Santos[1], Andrew Sheridan[1], Carrie Sougnez[1], Nicole Stange-Thomann[1], Nikola Stojanovic[1], Aravind Subramanian[1] & Dudley Wyman[1] for Whitehead Institute for Biomedical Research, Center for Genome Research:, Jane Rogers[2], John Sulston[2], Rachael Ainscough[2], Stephan Beck[2], David Bentley[2], John Burton[2], Christopher Clee[2], Nigel Carter[2], Alan Coulson[2], Rebecca Deadman[2], Panos Deloukas[2], Andrew Dunham[2], Ian Dunham[2], Richard Durbin[2], Lisa French[2], Darren Grafham[2], Simon Gregory[2], Tim Hubbard[2], Sean Humphray[2], Adrienne Hunt[2], Matthew

Full Author List

Genome Sequencing Centers. The centers are listed in order of total genomic sequence contributed.

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In big science: H.E.Physics


Physics Letters B 716 (2012) 1–29

Contents lists available at SciVerse ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC ☆

ATLAS Collaboration *

This paper is dedicated to the memory of our ATLAS colleagues who did not live to see the full impact and significance of their contributions to the experiment.

ARTICLE INFO

ABSTRACT

1. Introduction


ATLAS Collaboration / Physics Letters B 716 (2012) 1–29

17

ATLAS Collaboration

G. Aad [48], T. Abajyan [21], B. Abbott [111], J. Abdallah [12], S. Abdel Khalek [115], A.A. Abdelalim [49], O. Abdinov [11],

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Collaboration in Physics

- Most of studies look at the institutional level
- High degree of inter-institutional (~ 50%) and international (~ 30%) collaboration (Gazni et al. 2012, Benavent-Pérez et al. 2012)
- Higher degree of international collaboration (especially in Europe) and influence of geographical distance
- In a longitudinal analysis, Lorigo & Pellacini (2007) observe:
  - An increase in the number of inter-institutional collaborations
  - An increase in the strength of inter-institutional collaborations (number of papers)
  - An increase in the percentatge of nodes belonging to the largest connected component
  - Loss of centrality of CERN as an institutional node
- As Huang et al. (2012) suggest, collaboration networks like CERN need to be studied in depth

Research design

- Access to internal ATLAS data
  - Preprints database of the physical analysis phase (with editors)
  - Authors list with institutions
- Data (until 31/12/2012):
  - 371 papers
  - 1543 authors
  - 217 institutes
- Co-authorship network analysis at the institutional level

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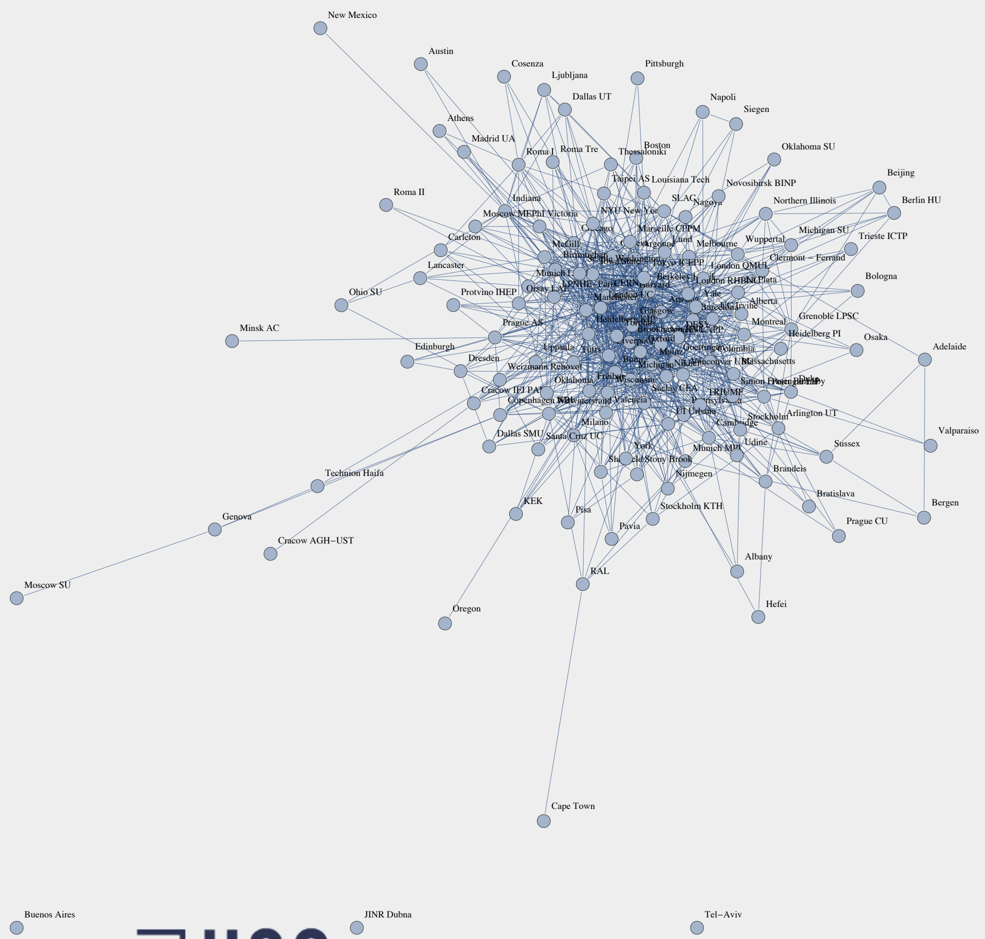
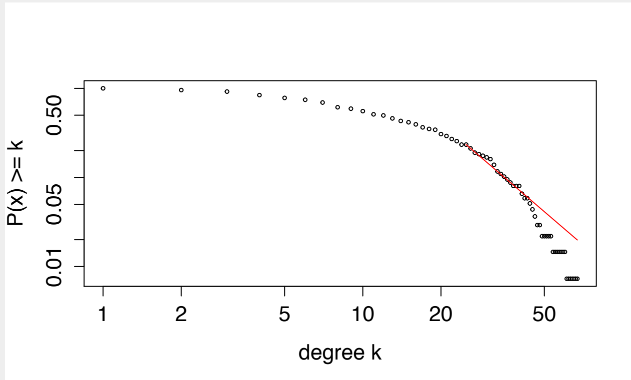
Co-authorship network



140 vertices
1073 edges
density = 0.11

avg degree = 15.33

clust. coef. = 0.39



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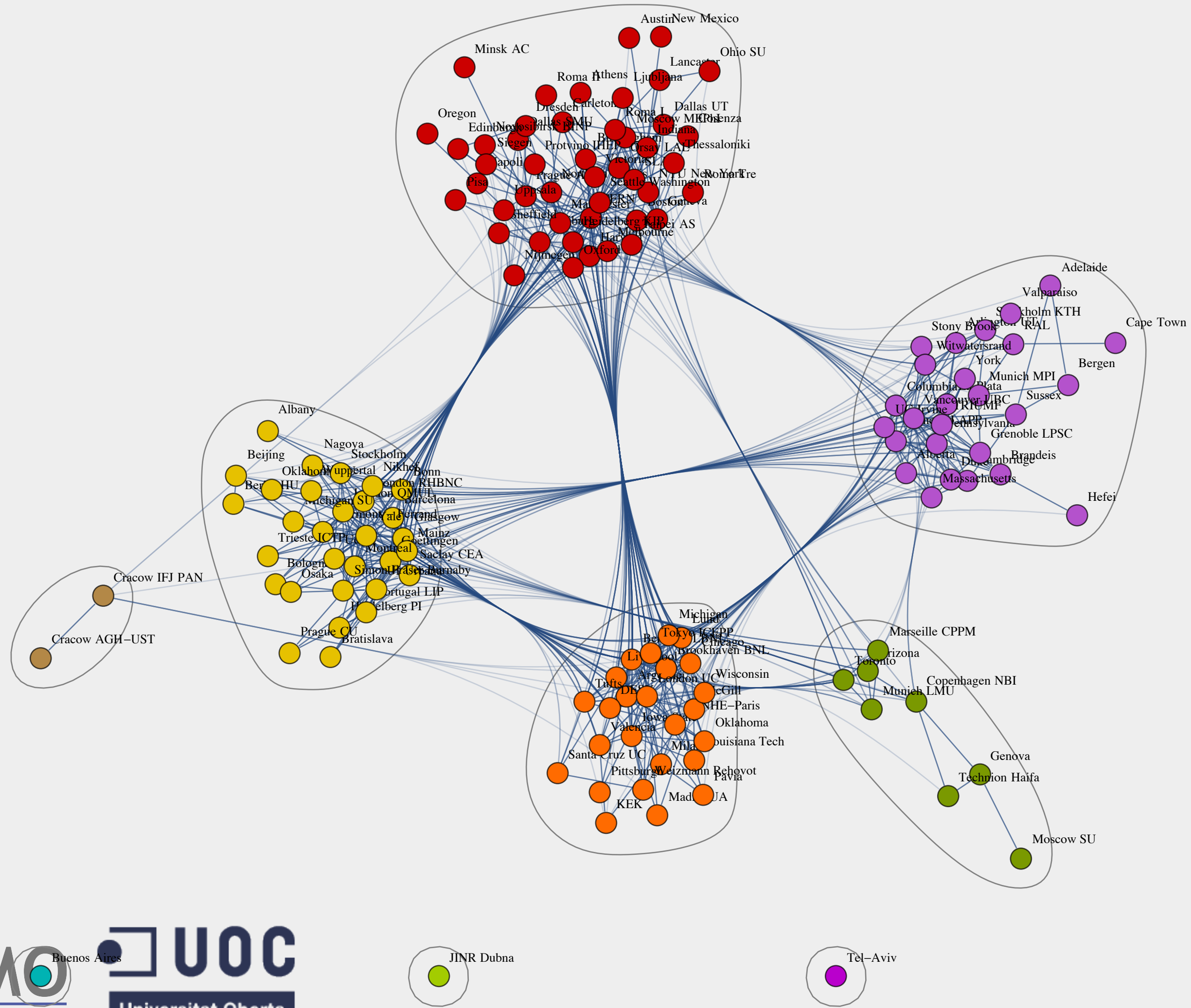
Community analysis



Modularity method (Greedy algorithm)

9 communities

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Discussion and conclusions

- Interesting findings
  - High degree of collaboration
  - Not a scale free network, as opposite to the co-authorship network of published articles (Newman 2001)
  - Apparently no effect of geographical distance
- Conclusions
  - Big science collaborations have an internal structure, sometimes different from the rest
  - In spite of the "one case" limitation, we may conclude that in disciplines where big science has become important, traditional co-authorship analysis should be taken with care when studying scientific collaboration

Simulations as Boundary Objects

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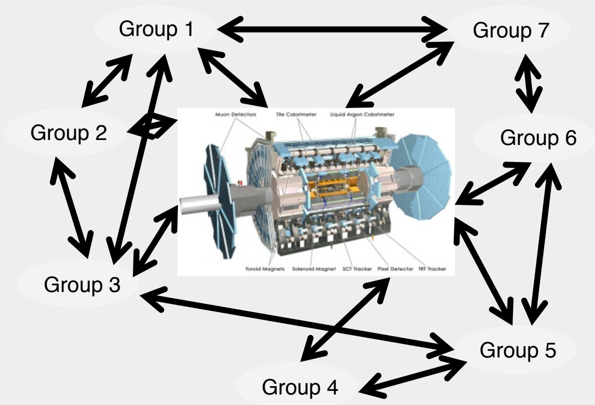
Coordination

- Cooperation needs transactions, that present some problems (bounded rationality, information asymmetries)
- Traditional solution: Management ("visible hand") through hierarchical control
- Alternatives:
  - Routines and rules: only effective under conditions of repetition
  - When all members agree upon the goals of the organization and the techniques for achieving these goals are within the ability of all members, few or no rules are required: small organizations oriented around expressive needs
- Under certain circumstances, the latter can apply to fairly large and geographically scattered organizations like ATLAS

The ATLAS Puzzle



- A complex task
- A project-oriented structure
- A complex organization
  - 3000 physicists
  - 175 universities and laboratories
  - 38 countries
- A non-hierarchical organization
  - Held together by Memoranda of Understanding
  - Decision making is bottom-up
  - Decision making is distributed

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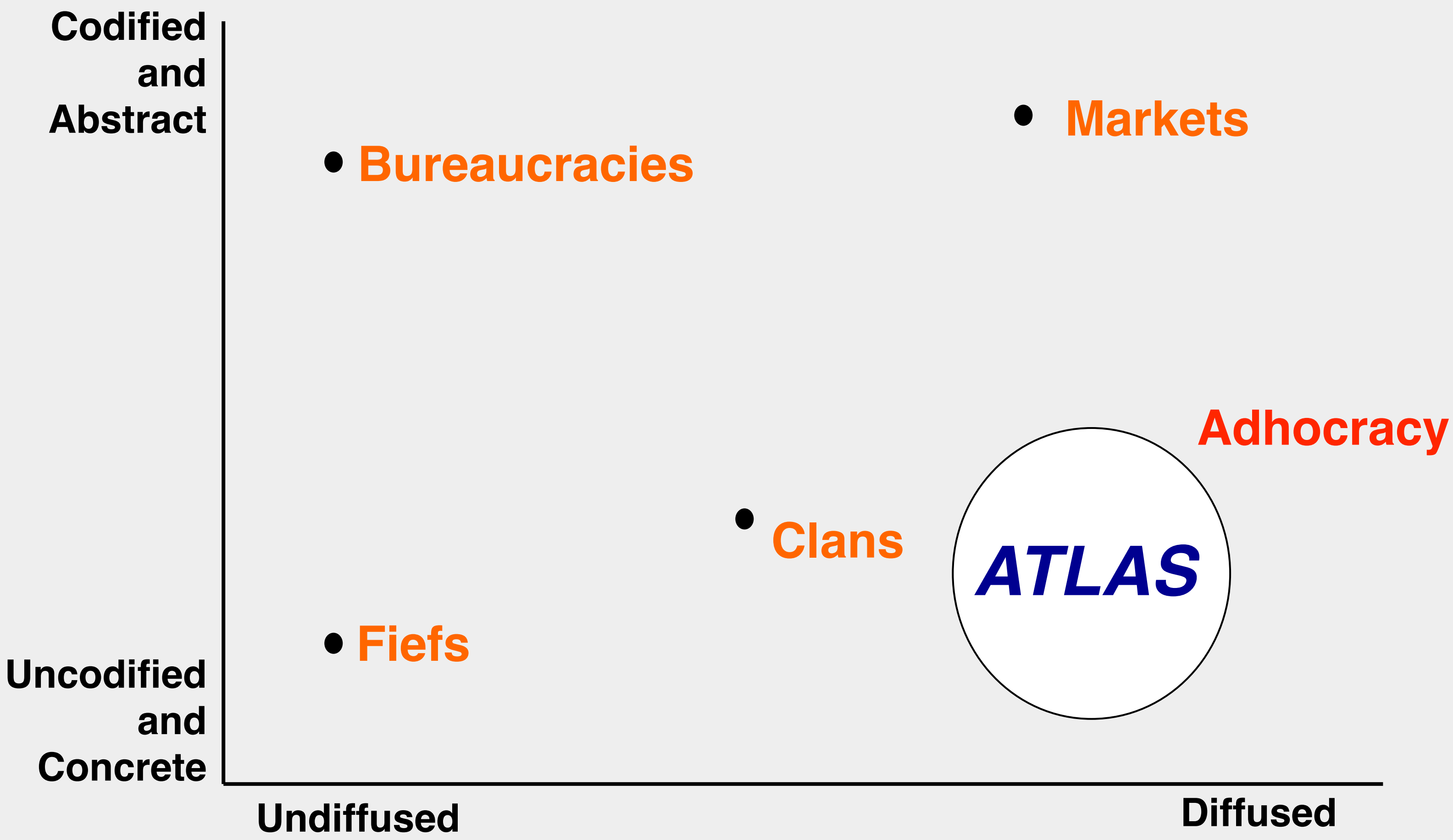
ATLAS in the I-Space



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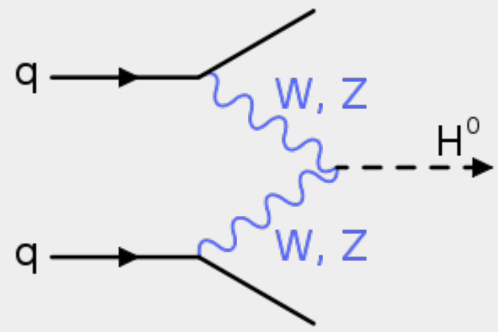
Boundary objects

- Boundary objects (Star 1989, Carlile 2002, 2004) act as a scaffolding that enables people to:
  - Gradually build up a shared understanding of common tasks facilitating knowledge flows
  - Provide coherence across intersecting social groups
- Examples of boundary objects: blueprints, maps, common interests, rules, plans, conceptual frameworks.

Feynman diagrams



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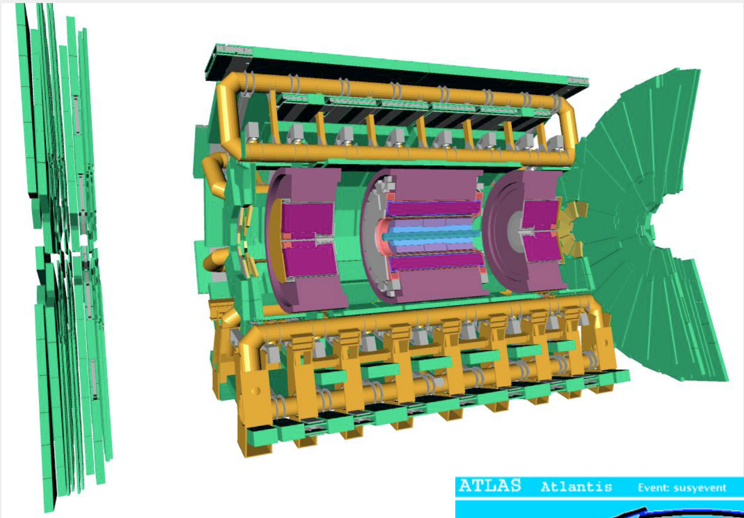
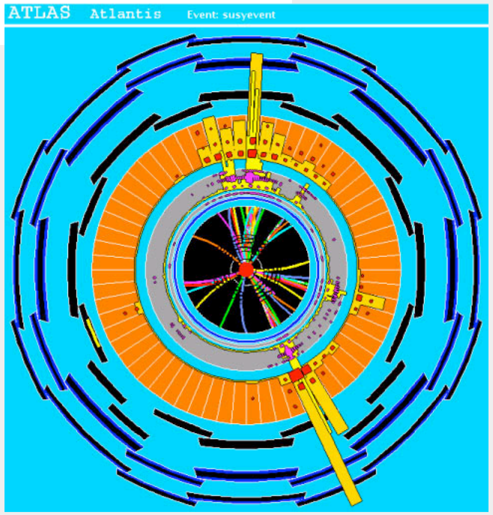
Research design

- Case study developed between March and December of 2009
- Part of a wider investigation about different aspects of knowledge creation, transfer and use within the ATLAS Collaboration
- Data collected through 30 semi-structured interviews to members of the Collaboration (9 senior members and 21 group leaders)
- Complemented with archival information from the ATLAS Collaboration and participating observation

Key role of simulations





- Monte Carlo simulation techniques
- Co-evolution of prototypes and simulation in the design phase
- Necessary to interpret the results in the operation phase

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Simulations as boundary objects

The beginning of this experiment was a simulation*. You simulate the whole experiment first until you're confident that all the bits and pieces which you imagine… all the different things you imagine you put them into the simulation and see how they perform.*

So you're really evolving two objects. ***You're evolving a virtual object and you're evolving a real object. […] And both are equally complex****. The one on the computer may even be more complex because it contains all the detail.*

[That core simulation is an object…] ***Not only to co-ordinate but to feed everybody with all the necessary information that the person needs in order to perform*** *within a complex…*

[…in bio-technology you've got lots of prejudices that compete with each other with people having different ways of doing…] Yeah, yeah. ***Well here also, but here you use the simulation to iron them out****.*

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Some insights

- Clans are governed by the *intangible hand* of trust and mutual esteem, what requires personalized interaction and, therefore, are limited in size, but the ATLAS case suggests that clans can be expanded through the use of external scaffolding acting as boundary objects
- Simulation absorbs complexity by capturing it in a “black box” and behaves as a boundary object that facilitates alignment between groups
- The needed coordination is provided by culture and boundary objects: the “intangible hand”
- Main implication: In cases of task complexity, boundary objects together with clan or adhocratic cultures may substitute for the traditional coordination mechanisms

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Conclusions and implications

- Is the ATLAS case unique?
- The ATLAS culture produced an ‘organized anarchy’ that works
- In *The rise of the creative class*, Florida (2002) suggests that this kind of organizations are set to grow
- The ATLAS case suggests that they may be not necessarily small scale organizations with few coordination problems, but also larger and more focused organizations

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Thank you!

Questions?

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