

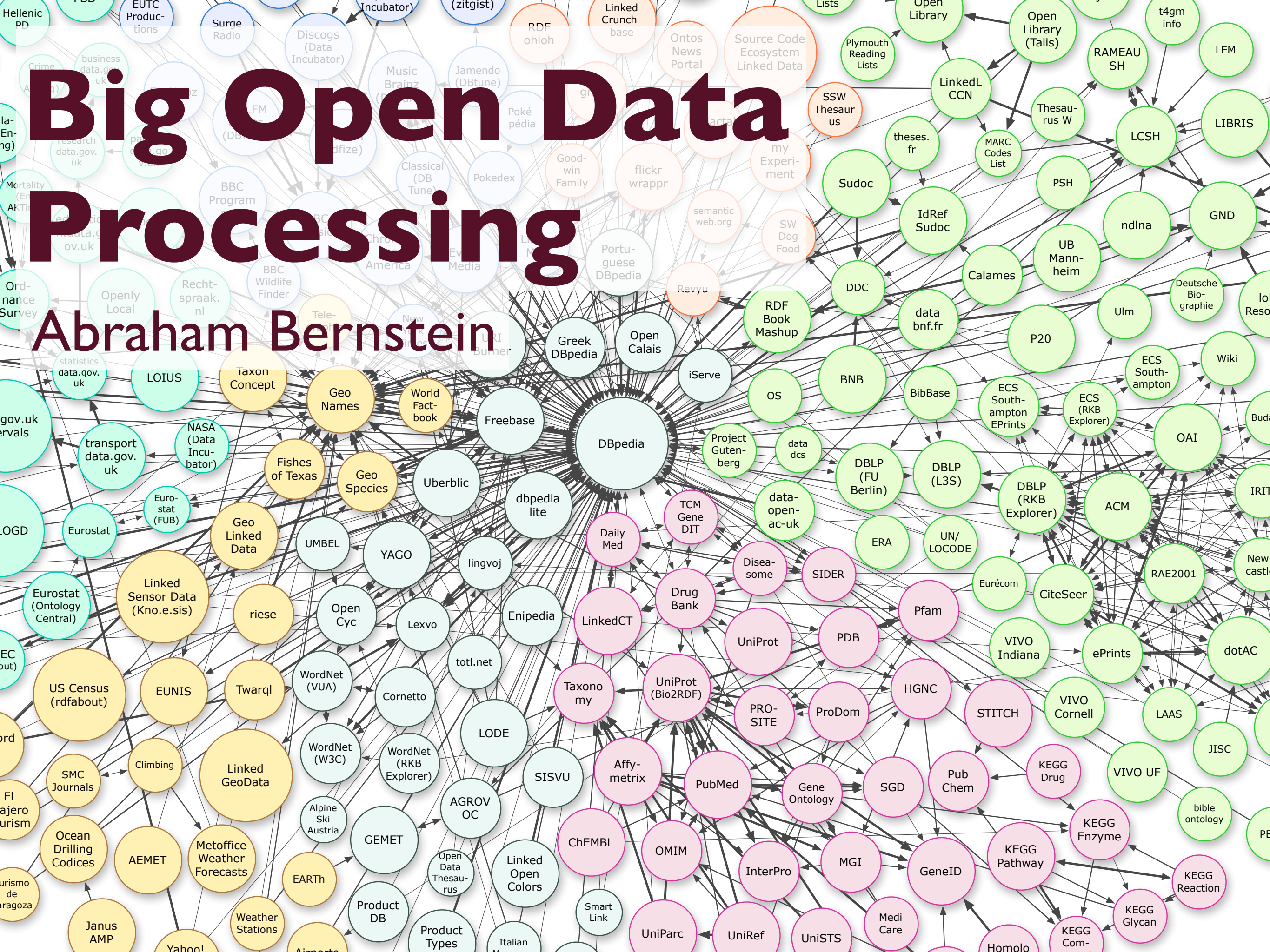


**University of
Zurich^{UZH}**



**Dynamic and Distributed
Information Systems**

Abraham Bernstein



The Dataspace Vision

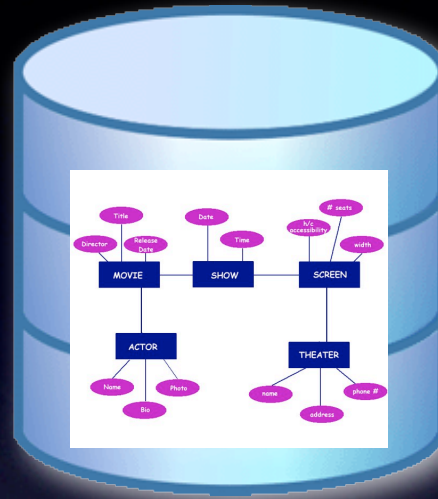
The Dataspace Vision

F16						
	A	B	C	D	E	F
1						
2						
3	<u>Date</u>	<u>Start time</u>	<u>End time</u>	<u>Pause</u>	<u>Sum</u>	<u>Comment</u>
4	2007-05-07	9,25	10,25	0		1 Task 1
5	2007-05-07	10,75	12,50	0	1,75	Task 1
6	2007-05-07	18,00	19,00	0		1 Task 2
7	2007-05-08	9,25	10,25	0		1 Task 2
8	2007-05-08	14,50	15,50	0		1 Task 3
9	2007-05-08	8,75	9,25	0	0,5	Task 3
10	2007-05-14	21,75	22,25	0	0,5	Task 3
11	2007-05-14	22,50	23,00	0	0,5	Task 3
12	2007-05-15	11,75	12,75	0		1 Task 3
13						
14						
15						
16						
17						
18						

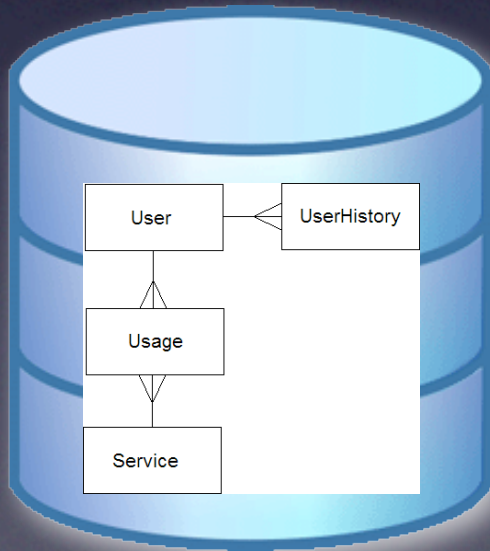
Intervals	Weather_07036	Manor_Kwh_D	Manor_Kwh_R	Manor_kVAR_D
Hour 00 - 01	40	0	0.12	0
Hour 01 - 02	39	0	0.12	0
Hour 02 - 03	38	0	0.12	0
Hour 03 - 04	39	0	0.12	0
Hour 04 - 05	37	0	0.12	0
Hour 05 - 06	36	0	0.12	0
Hour 06 - 07	36	0.05	0.21	0.2
Hour 07 - 08	39	0.85	0.05	0.98
Hour 08 - 09	49	3.35	0	1.86
Hour 09 - 10	51	7.4	0	3.28
Hour 10 - 11	55	13.62	0	5.26
Hour 11 - 12	57	37.52	0	12.76
Hour 12 - 13	59	45.49	0	15.24
Hour 13 - 14	60	46.79	0	15.6
Hour 14 - 15	61	44.38	0	14.89
Hour 15 - 16	62	40.01	0	13.57
Hour 16 - 17	63	32.57	0	11.21
Hour 17 - 18	63	22.76	0	8.15
Hour 18 - 19	61	8.62	0	3.72
Hour 19 - 20	56	0.39	0.32	0.81
Hour 20 - 21	53	0	0.02	0
Hour 21 - 22	47	0	0.12	0
Hour 22 - 23	47	0	0.12	0
Hour 23 - 00	47	0	0.12	0
Units	deg F	kwh_D	kwh_R	kVAR_D

The Dataspace Vision

F16 $f(x)$ Σ =						
	A	B	C	D	E	F
1						
2						
3	<u>Date</u>	<u>Start time</u>	<u>End time</u>	<u>Pause</u>	<u>Sum</u>	<u>Comment</u>
4	2007-05-07	9,25	10,25	0		1 Task 1
5	2007-05-07	10,75	12,50	0	1,75	Task 1
6	2007-05-07	18,00	19,00	0		1 Task 2
7	2007-05-08	9,25	10,25	0		1 Task 2
8	2007-05-08	14,50	15,50	0		1 Task 3
9	2007-05-08	8,75	9,25	0	0,5	Task 3
10	2007-05-14	21,75	22,25	0	0,5	Task 3
11	2007-05-14	22,50	23,00	0	0,5	Task 3
12	2007-05-15	11,75	12,75	0		1 Task 3
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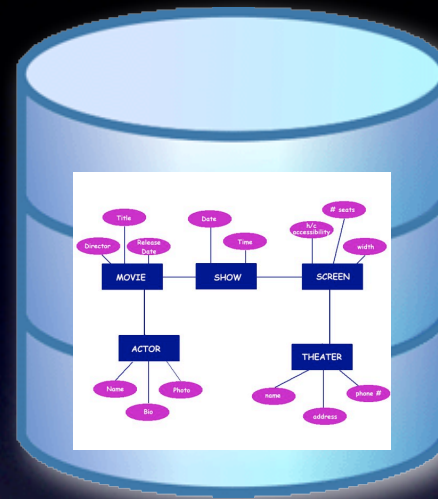


Energy Tracking				
Intervals	Weather_07836	Manor_Kwh_D	Manor_Kwh_R	Manor_kVAR_D
Hour 00 - 01	40	0	0.12	0
Hour 01 - 02	39	0	0.12	0
Hour 02 - 03	38	0	0.12	0
Hour 03 - 04	39	0	0.12	0
Hour 04 - 05	37	0	0.12	0
Hour 05 - 06	36	0	0.12	0
Hour 06 - 07	36	0.05	0.21	0.2
Hour 07 - 08	39	0.85	0.05	0.98
Hour 08 - 09	49	3.35	0	1.86
Hour 09 - 10	51	7.4	0	3.28
Hour 10 - 11	55	13.62	0	5.26
Hour 11 - 12	57	37.52	0	12.76
Hour 12 - 13	59	45.49	0	15.24
Hour 13 - 14	60	46.79	0	15.6
Hour 14 - 15	61	44.38	0	14.89
Hour 15 - 16	62	40.01	0	13.57
Hour 16 - 17	63	32.57	0	11.21
Hour 17 - 18	63	22.76	0	8.15
Hour 18 - 19	61	8.62	0	3.72
Hour 19 - 20	56	0.39	0.32	0.81
Hour 20 - 21	53	0	0.02	0
Hour 21 - 22	47	0	0.12	0
Hour 22 - 23	47	0	0.12	0
Hour 23 - 00	47	0	0.12	0
Units	deg F	kWh_D	kWh_R	kVAR_D

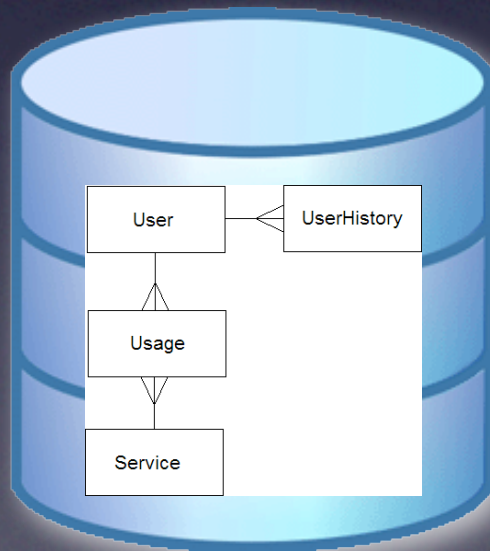


The Dataspace Vision

	A	B	C	D	E	F
1						
2						
3	<u>Date</u>	<u>Start time</u>	<u>End time</u>	<u>Pause</u>	<u>Sum</u>	<u>Comment</u>
4	2007-05-07	9,25	10,25	0		1 Task 1
5	2007-05-07	10,75	12,50	0	1,75	Task 1
6	2007-05-07	18,00	19,00	0		1 Task 2
7	2007-05-08	9,25	10,25	0		1 Task 2
8	2007-05-08	14,50	15,50	0		1 Task 3
9	2007-05-08	8,75	9,25	0	0,5	Task 3
10	2007-05-14	21,75	22,25	0	0,5	Task 3
11	2007-05-14	22,50	23,00	0	0,5	Task 3
12	2007-05-15	11,75	12,75	0		1 Task 3
13						
14						
15						
16						
17						
18						

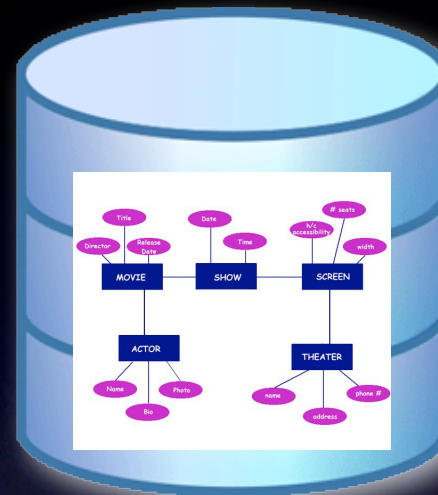


Intervals	Weather_070306	Manor_Kwh_D	Manor_Kwh_R	Manor_kVAR_D
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Hour 01 - 02	39	0	0.12	0
Hour 02 - 03	38	0	0.12	0
Hour 03 - 04	39	0	0.12	0
Hour 04 - 05	37	0	0.12	0
Hour 05 - 06	36	0	0.12	0
Hour 06 - 07	36	0.05	0.21	0.2
Hour 07 - 08	39	0.85	0.05	0.98
Hour 08 - 09	49	3.35	0	1.86
Hour 09 - 10	51	7.4	0	3.28
Hour 10 - 11	55	13.62	0	5.26
Hour 11 - 12	57	37.52	0	12.76
Hour 12 - 13	59	45.49	0	15.24
Hour 13 - 14	60	46.79	0	15.6
Hour 14 - 15	61	44.38	0	14.89
Hour 15 - 16	62	40.01	0	13.57
Hour 16 - 17	63	32.57	0	11.21
Hour 17 - 18	63	22.76	0	8.15
Hour 18 - 19	61	8.62	0	3.72
Hour 19 - 20	56	0.39	0.32	0.81
Hour 20 - 21	53	0	0.02	0
Hour 21 - 22	47	0	0.12	0
Hour 22 - 23	47	0	0.12	0
Hour 23 - 00	47	0	0.12	0
Units	deg F	kwh_D	kwh_R	kVAR_D

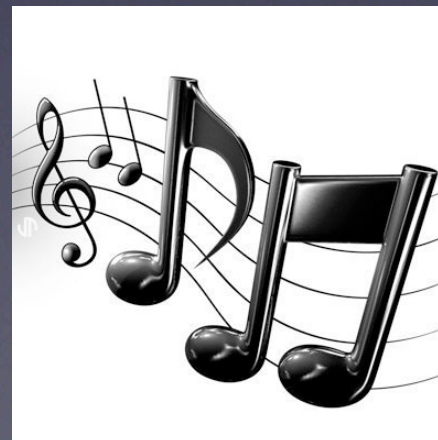
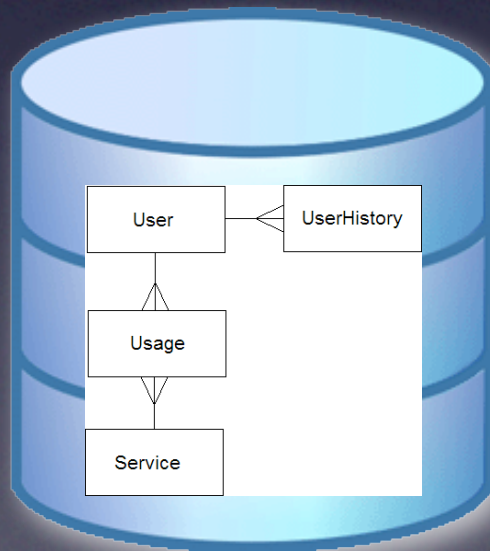


The Dataspace Vision

	A	B	C	D	E	F
1						
2						
3	<u>Date</u>	<u>Start time</u>	<u>End time</u>	<u>Pause</u>	<u>Sum</u>	<u>Comment</u>
4	2007-05-07	9,25	10,25	0	1	Task 1
5	2007-05-07	10,75	12,50	0	1,75	Task 1
6	2007-05-07	18,00	19,00	0	1	Task 2
7	2007-05-08	9,25	10,25	0	1	Task 2
8	2007-05-08	14,50	15,50	0	1	Task 3
9	2007-05-08	8,75	9,25	0	0,5	Task 3
10	2007-05-14	21,75	22,25	0	0,5	Task 3
11	2007-05-14	22,50	23,00	0	0,5	Task 3
12	2007-05-15	11,75	12,75	0	1	Task 3
13						
14						
15						
16						
17						
18						

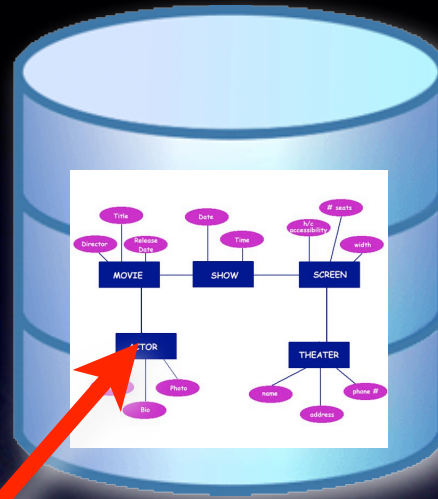


Intervals	Weather_07036	Manor_Kwh_D	Manor_Kwh_R	Manor_kVAR_D
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Hour 01 - 02	39	0	0,12	0
Hour 02 - 03	38	0	0,12	0
Hour 03 - 04	39	0	0,12	0
Hour 04 - 05	37	0	0,12	0
Hour 05 - 06	36	0	0,12	0
Hour 06 - 07	36	0,05	0,21	0,2
Hour 07 - 08	39	0,85	0,05	0,98
Hour 08 - 09	49	3,35	0	1,86
Hour 09 - 10	51	7,4	0	3,28
Hour 10 - 11	55	13,62	0	5,26
Hour 11 - 12	57	37,52	0	12,76
Hour 12 - 13	59	45,49	0	15,24
Hour 13 - 14	60	46,79	0	15,6
Hour 14 - 15	61	44,38	0	14,89
Hour 15 - 16	62	40,01	0	13,57
Hour 16 - 17	63	32,57	0	11,21
Hour 17 - 18	63	22,76	0	8,15
Hour 18 - 19	61	8,62	0	3,72
Hour 19 - 20	56	0,39	0,32	0,81
Hour 20 - 21	53	0	0,02	0
Hour 21 - 22	47	0	0,12	0
Hour 22 - 23	47	0	0,12	0
Hour 23 - 00	47	0	0,12	0
Units	deg F	kwh_D	kwh_R	kVAR_D

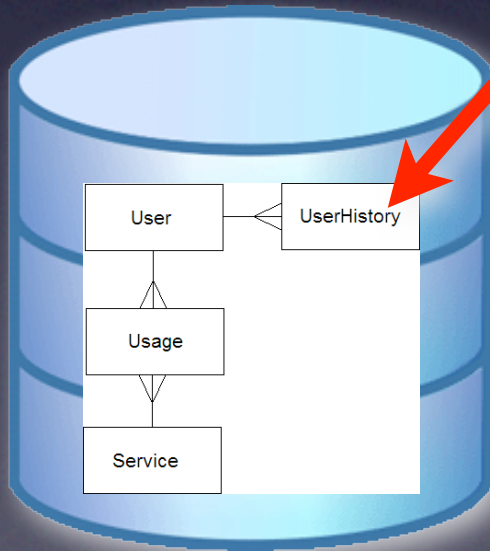


The Dataspace Vision

F16 $f(x)$ Σ =						
	A	B	C	D	E	F
1						
2						
3	<u>Date</u>	<u>Start time</u>	<u>End time</u>	<u>Pause</u>	<u>Sum</u>	<u>Comment</u>
4	2007-05-07	9,25	10,25	0		1 Task 1
5	2007-05-07	10,75	12,50	0	1,75	Task 1
6	2007-05-07	18,00	19,00	0		1 Task 2
7	2007-05-08	9,25	10,25	0		1 Task 2
8	2007-05-08	14,50	15,50	0		1 Task 3
9	2007-05-08	8,75	9,25	0	0,5	Task 3
10	2007-05-14	21,75	22,25	0	0,5	Task 3
11	2007-05-14	22,50	23,00	0	0,5	Task 3
12	2007-05-15	11,75	12,75	0		1 Task 3
13						
14						
15						
16						
17						
18						

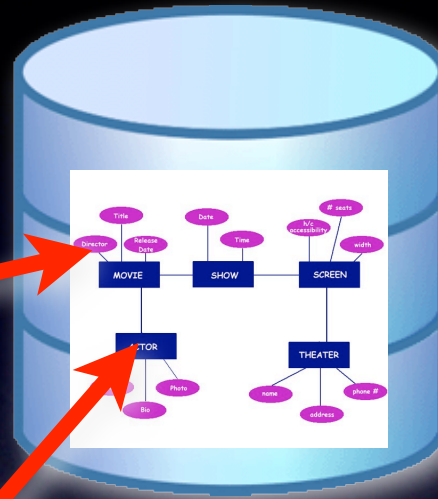


Energy Tracking				
Intervals	Weather_07836	Manor_Kwh_D	Manor_Kwh_R	Manor_kVAR_D
Hour 00 - 01	40	0	0.12	0
Hour 01 - 02	39	0	0.12	0
Hour 02 - 03	38	0	0.12	0
Hour 03 - 04	39	0	0.12	0
Hour 04 - 05	37	0	0.12	0
Hour 05 - 06	36	0	0.12	0
Hour 06 - 07	36	0.05	0.21	0.2
Hour 07 - 08	39	0.85	0.05	0.98
Hour 08 - 09	49	3.35	0	1.86
Hour 09 - 10	51	7.4	0	3.28
Hour 10 - 11	55	13.62	0	5.26
Hour 11 - 12	57	37.52	0	12.76
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Hour 13 - 14	60	46.79	0	15.6
Hour 14 - 15	61	44.38	0	14.89
Hour 15 - 16	62	40.01	0	13.57
Hour 16 - 17	63	32.57	0	11.21
Hour 17 - 18	63	22.76	0	8.15
Hour 18 - 19	61	8.62	0	3.72
Hour 19 - 20	56	0.39	0.32	0.81
Hour 20 - 21	53	0	0.02	0
Hour 21 - 22	47	0	0.12	0
Hour 22 - 23	47	0	0.12	0
Hour 23 - 00	47	0	0.12	0
Units	deg F	kWh_D	kWh_R	kVAR_D

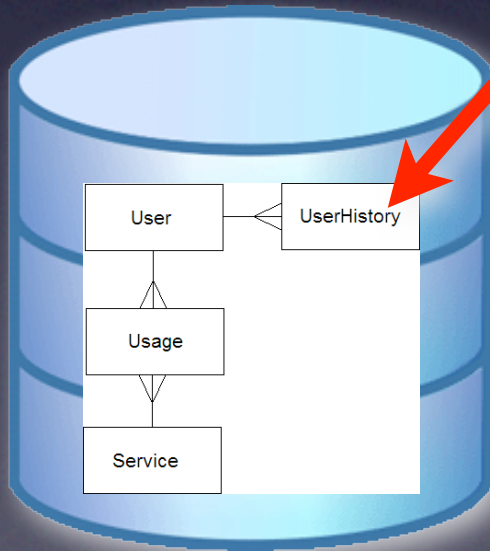


The Dataspace Vision

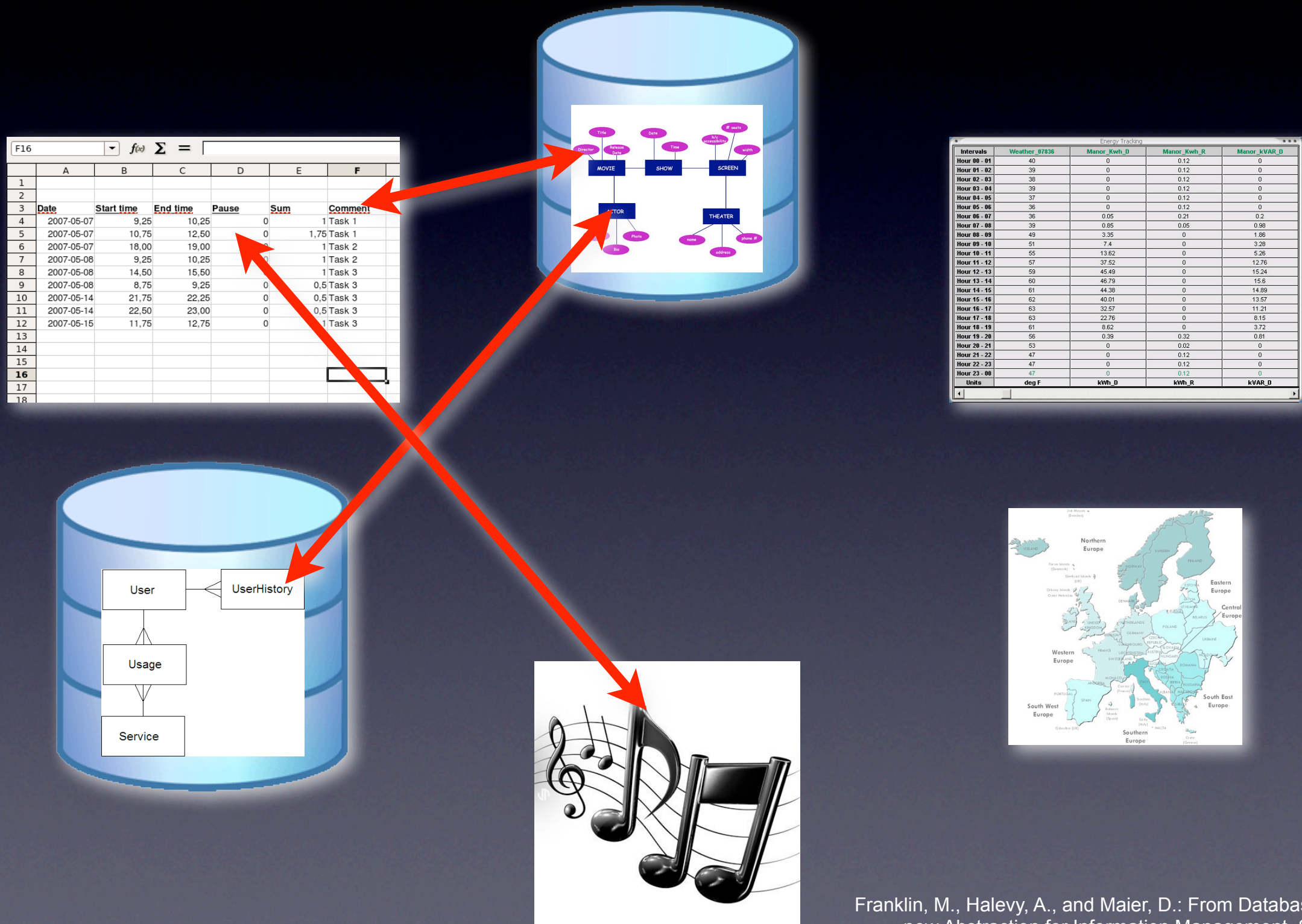
F16						
	A	B	C	D	E	F
1						
2						
3	<u>Date</u>	<u>Start time</u>	<u>End time</u>	<u>Pause</u>	<u>Sum</u>	<u>Comment</u>
4	2007-05-07	9,25	10,25	0		1 Task 1
5	2007-05-07	10,75	12,50	0	1,75	Task 1
6	2007-05-07	18,00	19,00	0		1 Task 2
7	2007-05-08	9,25	10,25	0		1 Task 2
8	2007-05-08	14,50	15,50	0		1 Task 3
9	2007-05-08	8,75	9,25	0	0,5	Task 3
10	2007-05-14	21,75	22,25	0	0,5	Task 3
11	2007-05-14	22,50	23,00	0	0,5	Task 3
12	2007-05-15	11,75	12,75	0		1 Task 3
13						
14						
15						
16						
17						
18						



Energy Tracking				
Intervals	Weather_07836	Manor_Kwh_D	Manor_Kwh_R	Manor_kVAR_D
Hour 00 - 01	40	0	0.12	0
Hour 01 - 02	39	0	0.12	0
Hour 02 - 03	38	0	0.12	0
Hour 03 - 04	39	0	0.12	0
Hour 04 - 05	37	0	0.12	0
Hour 05 - 06	36	0	0.12	0
Hour 06 - 07	36	0.05	0.21	0.2
Hour 07 - 08	39	0.85	0.05	0.98
Hour 08 - 09	49	3.35	0	1.86
Hour 09 - 10	51	7.4	0	3.28
Hour 10 - 11	55	13.62	0	5.26
Hour 11 - 12	57	37.52	0	12.76
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Hour 13 - 14	60	46.79	0	15.6
Hour 14 - 15	61	44.38	0	14.89
Hour 15 - 16	62	40.01	0	13.57
Hour 16 - 17	63	32.57	0	11.21
Hour 17 - 18	63	22.76	0	8.15
Hour 18 - 19	61	8.62	0	3.72
Hour 19 - 20	56	0.39	0.32	0.81
Hour 20 - 21	53	0	0.02	0
Hour 21 - 22	47	0	0.12	0
Hour 22 - 23	47	0	0.12	0
Hour 23 - 00	47	0	0.12	0
Units	deg F	kWh_D	kWh_R	kVAR_D

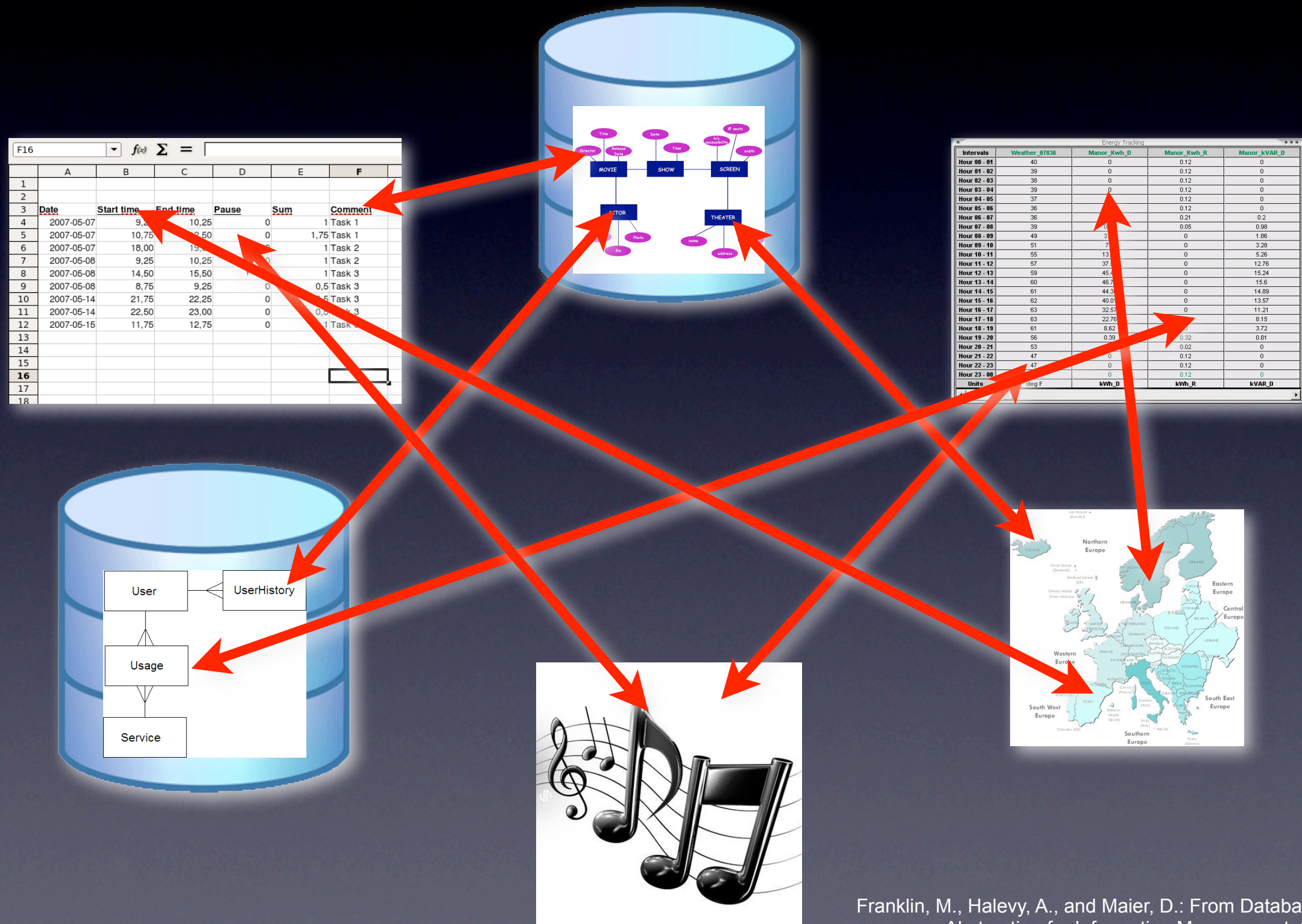


The Dataspace Vision



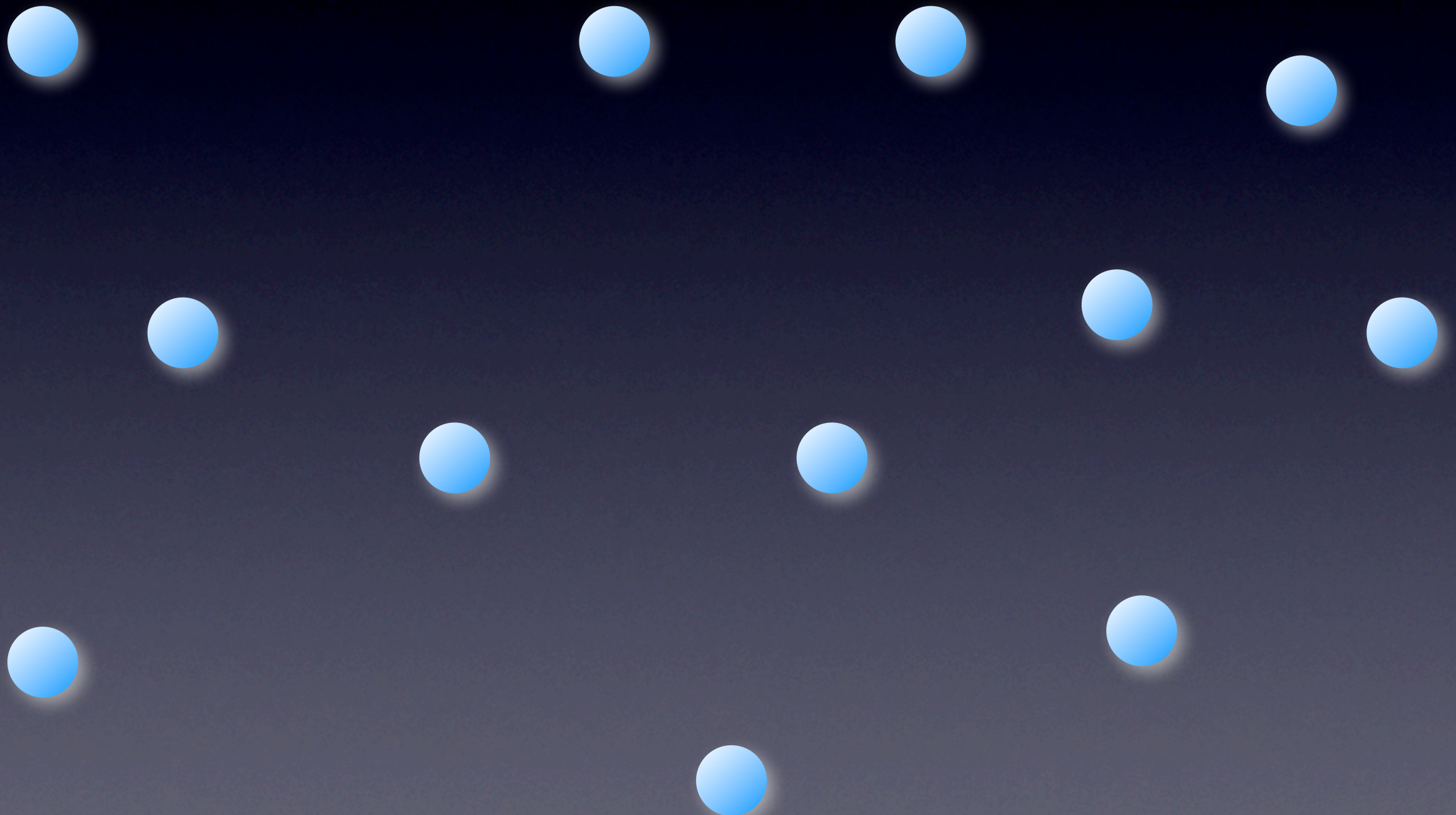
Franklin, M., Halevy, A., and Maier, D.: From Databases to Dataspaces A new Abstraction for Information Management, SIGMOD Rec. 2005.

The Dataspace Vision



Typed Graphs (RDF): The Universal Datastructure

Typed Graphs (RDF): The Universal Datastructure



Typed Graphs (RDF): The Universal Datastructure

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<http://www.universities.de/Saarbruecken>

Typed Graphs (RDF): The Universal Datastructure

http://www.mpi.de/Gerhard_Weikum

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http://www.ifi.uzh.ch/i_am_a_URI

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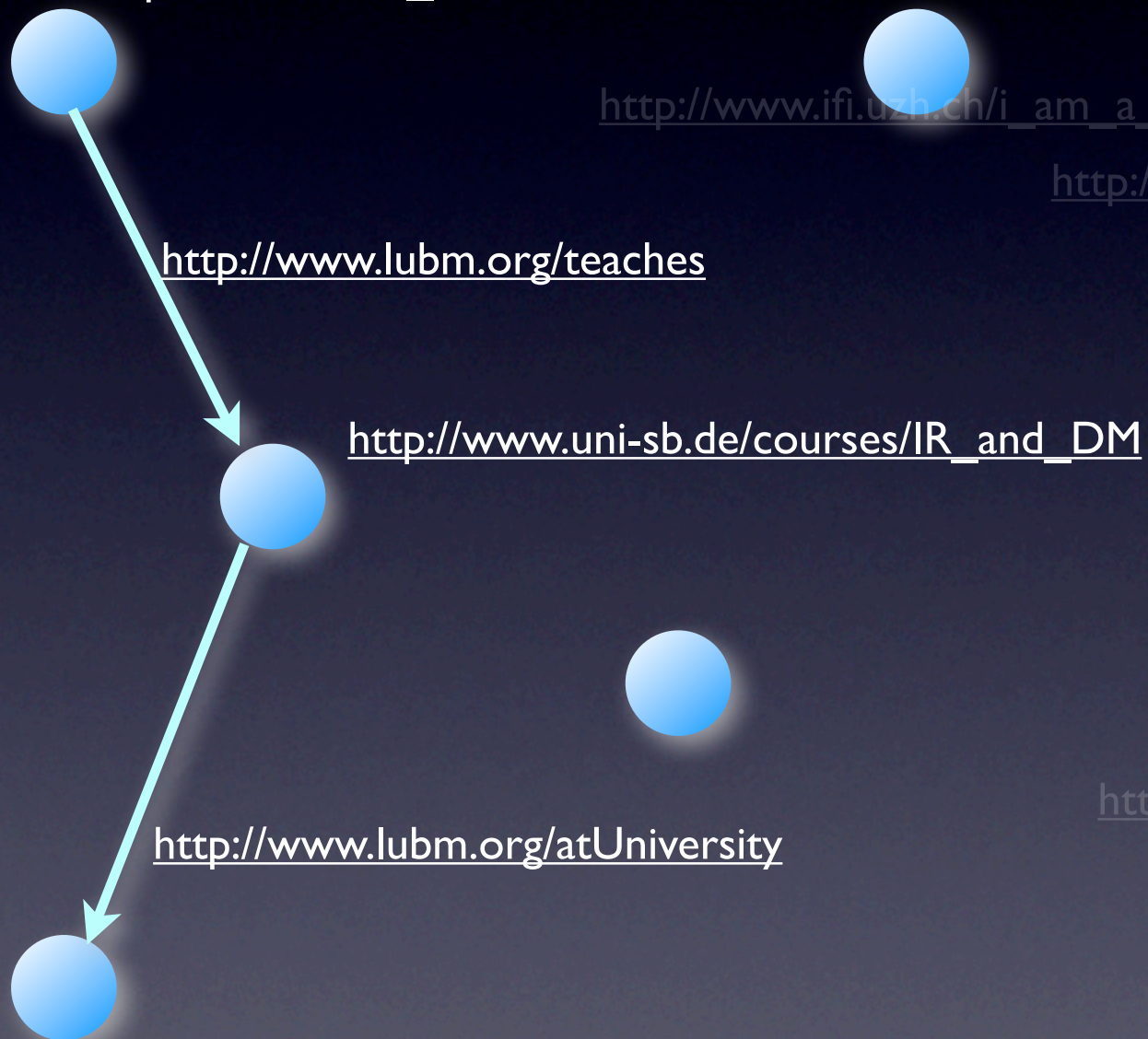
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<http://www.universities.de/Saarbruecken>

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<http://www.universities.de/Saarbruecken>

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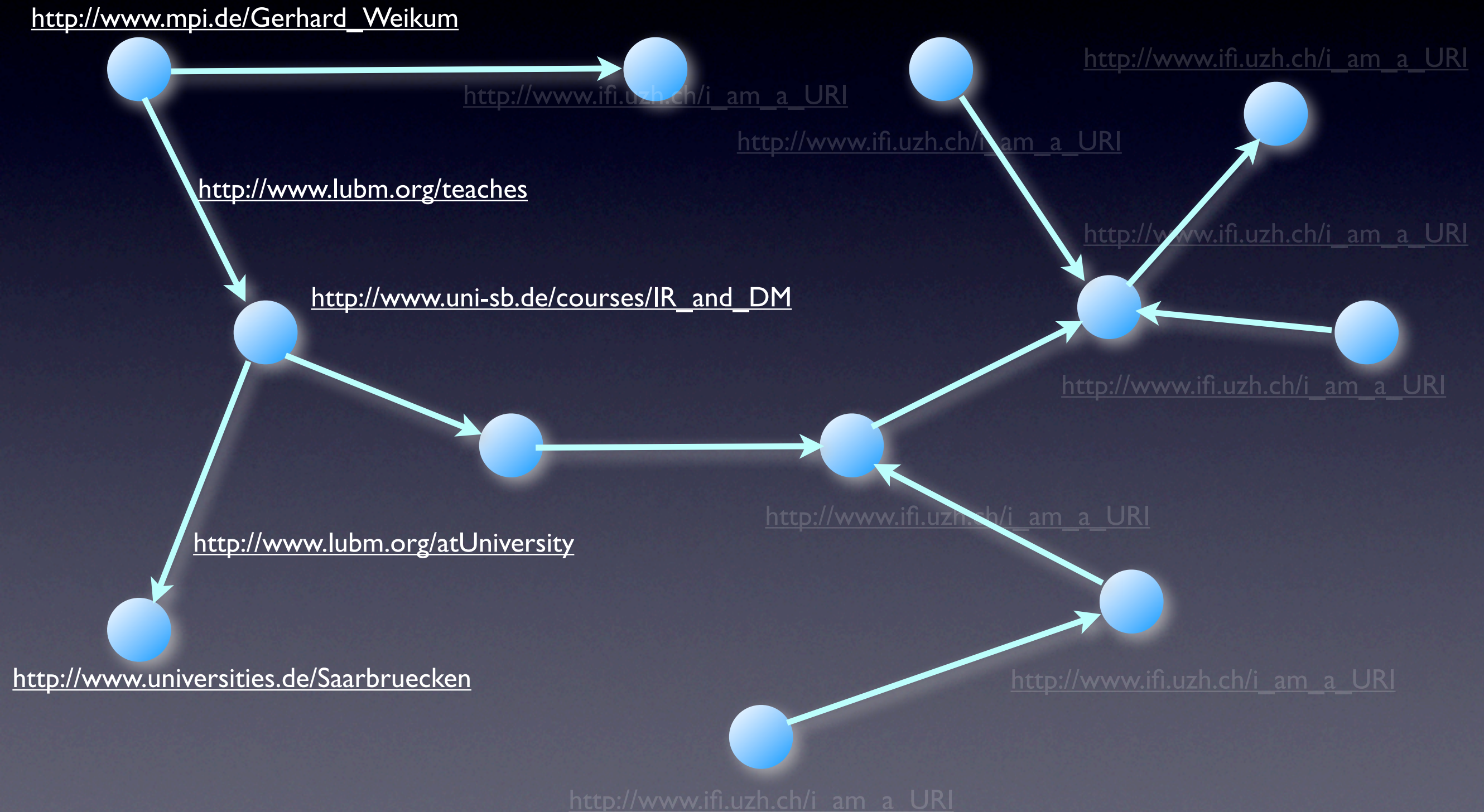
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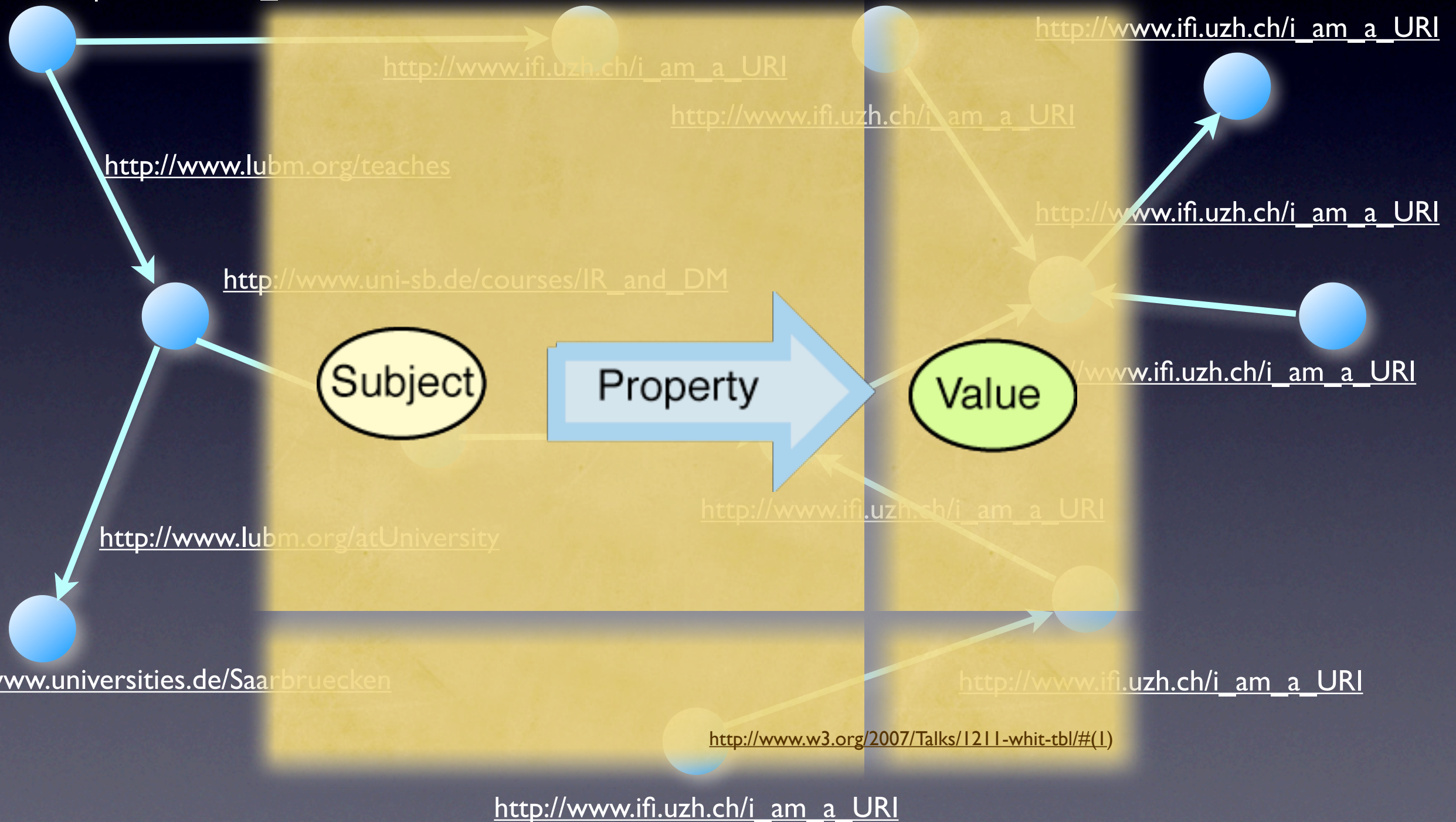
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Typed Graphs (RDF): The Universal Datastructure



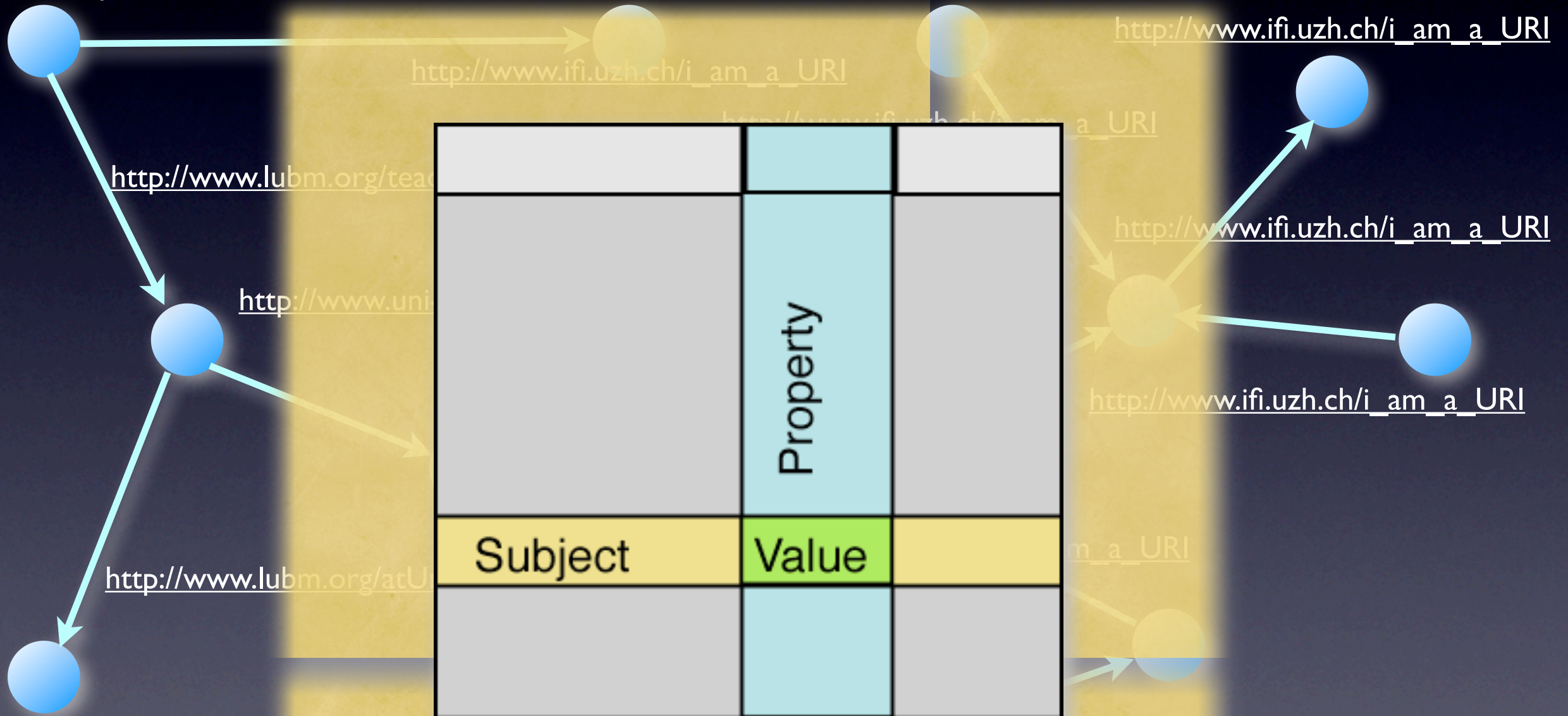
Typed Graphs (RDF): The Universal Datastructure

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Typed Graphs (RDF): The Universal Datastructure

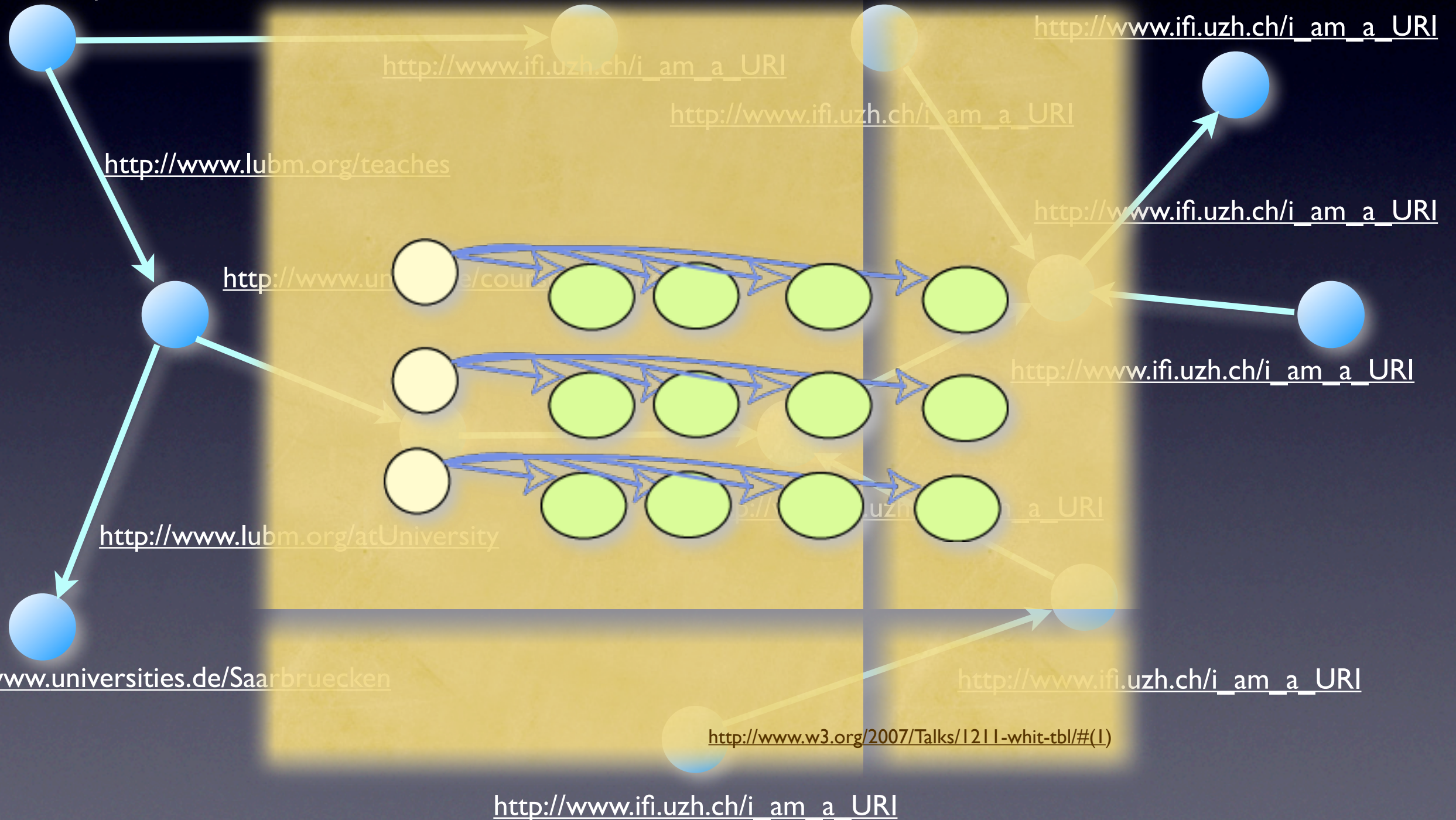
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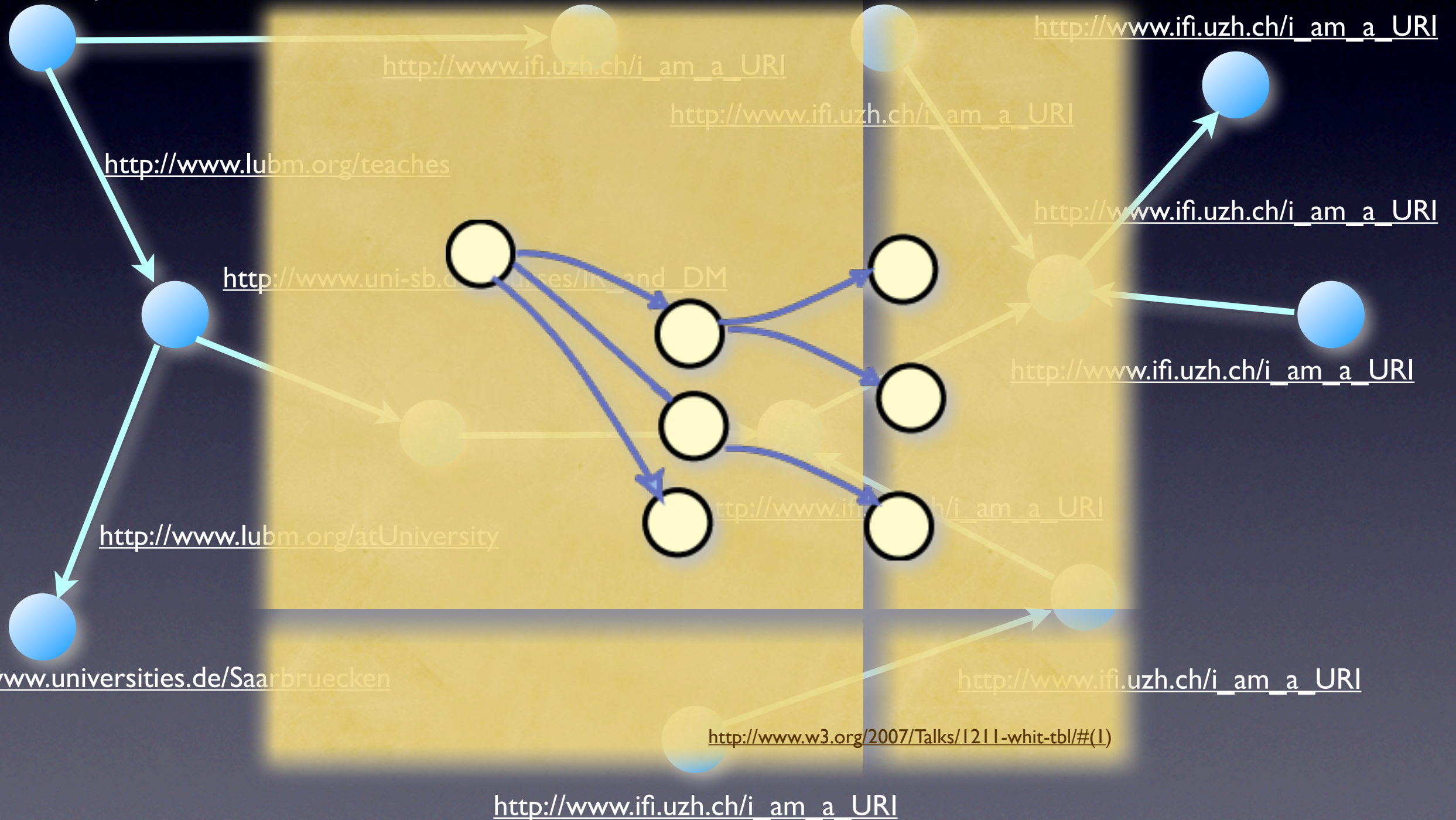
Typed Graphs (RDF): The Universal Datastructure

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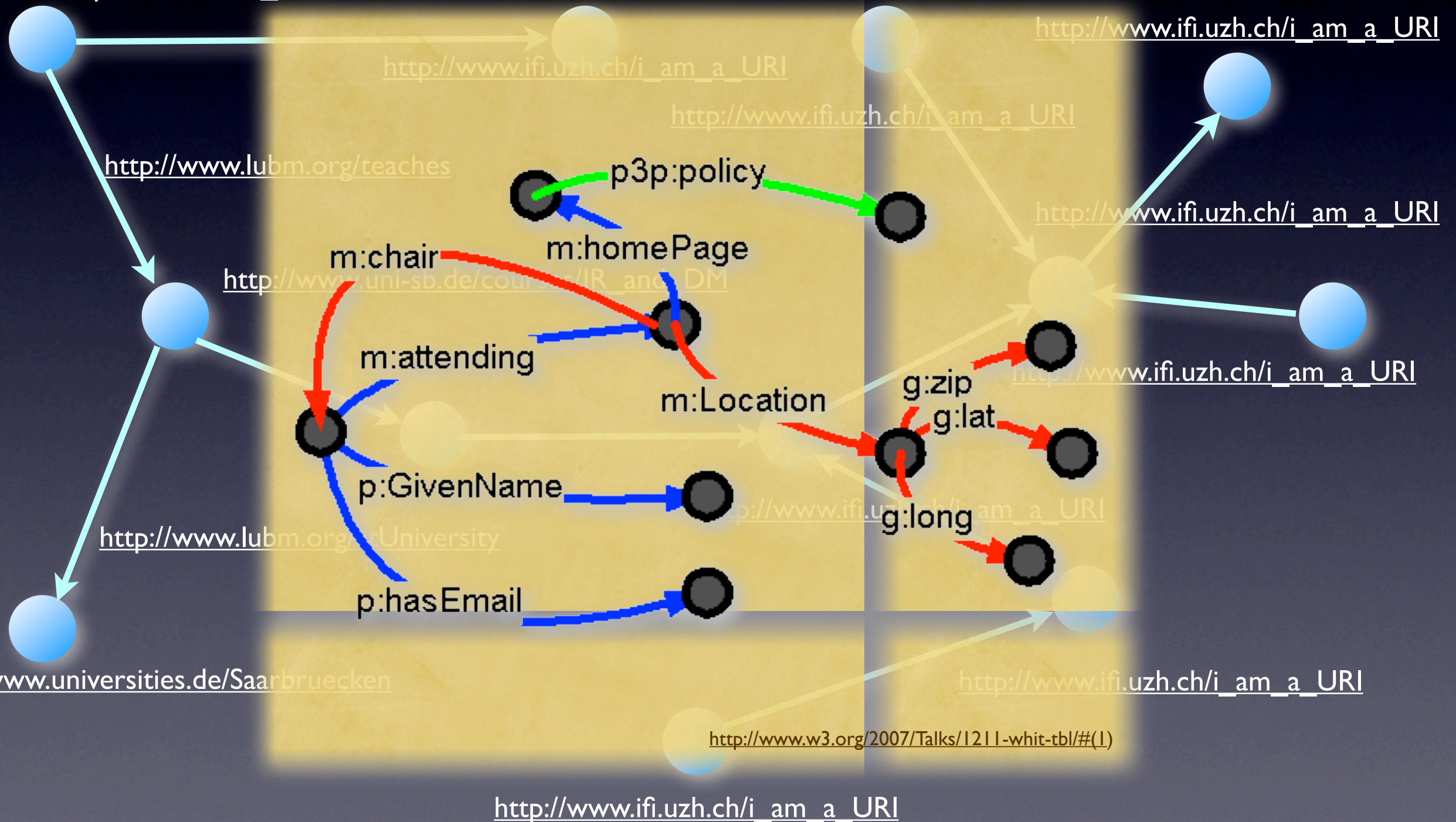
Typed Graphs (RDF): The Universal Datastructure

http://www.mpi.de/Gerhard_Weikum

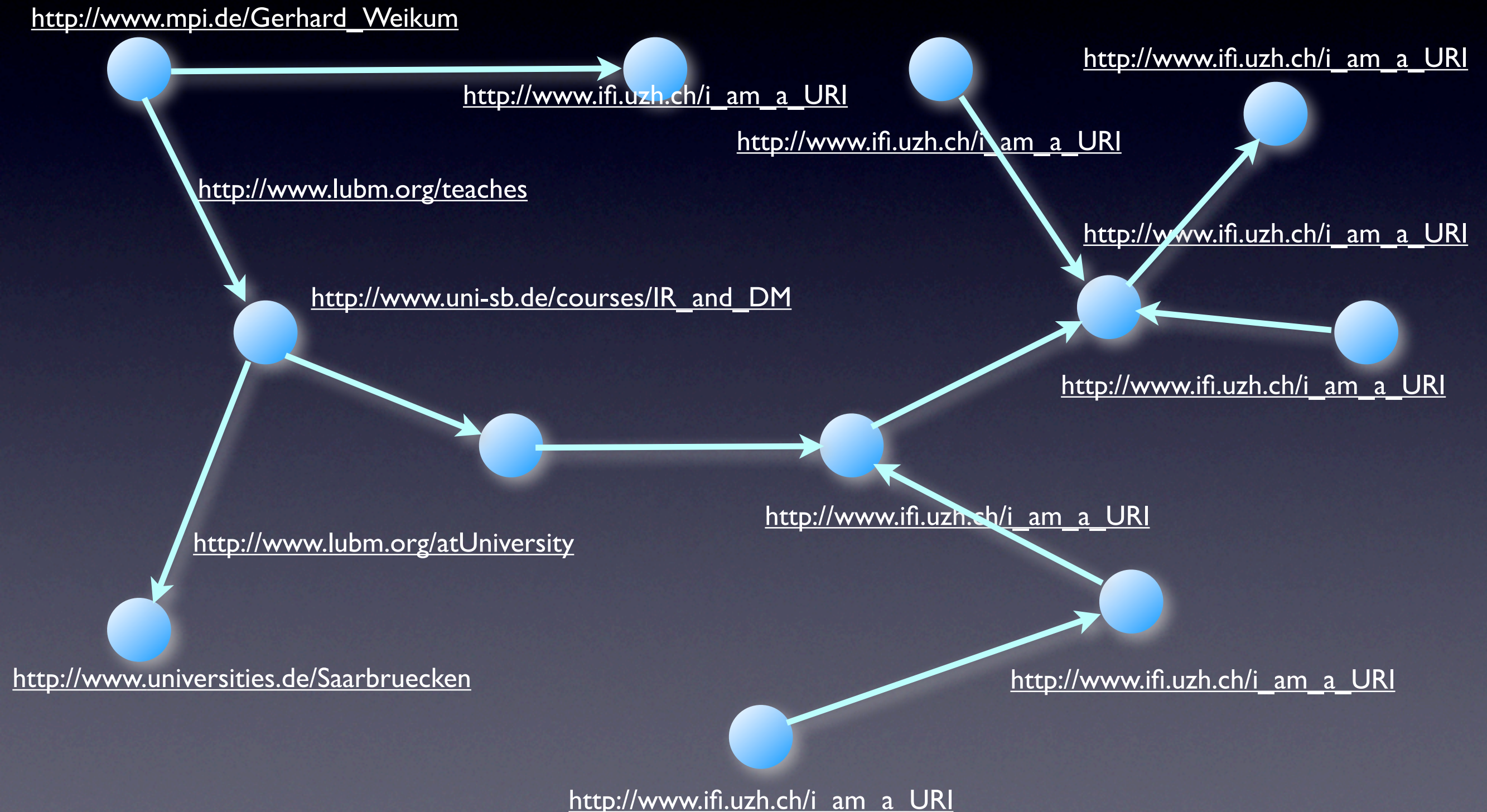


Typed Graphs (RDF): The Universal Datastructure

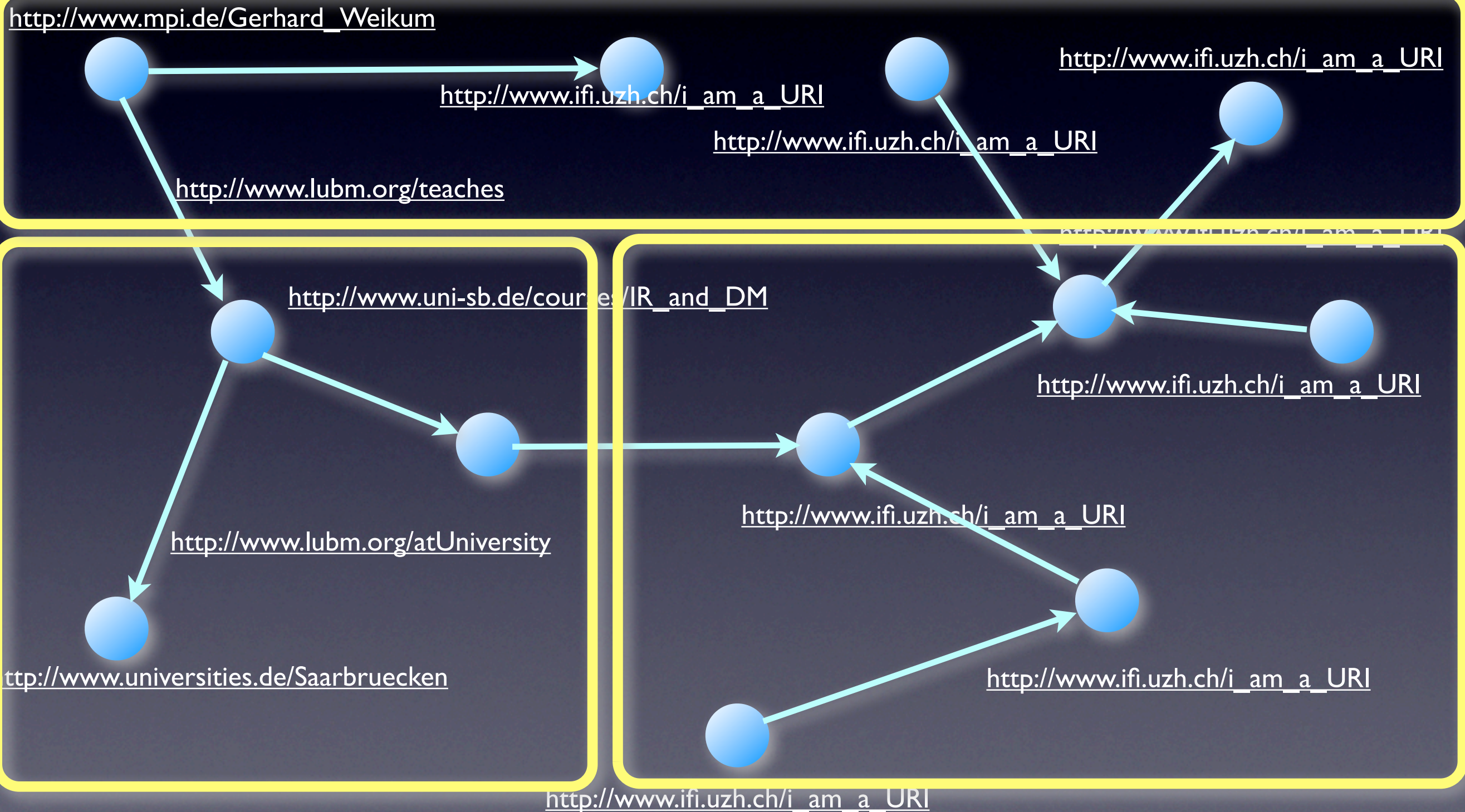
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Typed Graphs (RDF): The Universal Datastructure



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http://www.ifi.uzh.ch/ am a URI

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http://www.ifi.uzh.ch/ifi am a URI

<http://www.lubm.org/teaches>

[http://www.uni-sb.de/course/IR and DM](http://www.uni-sb.de/course/IR_and_DM)

<http://www.lubm.org/atUniversity>

<http://www.universities.de/Saarbruecken>

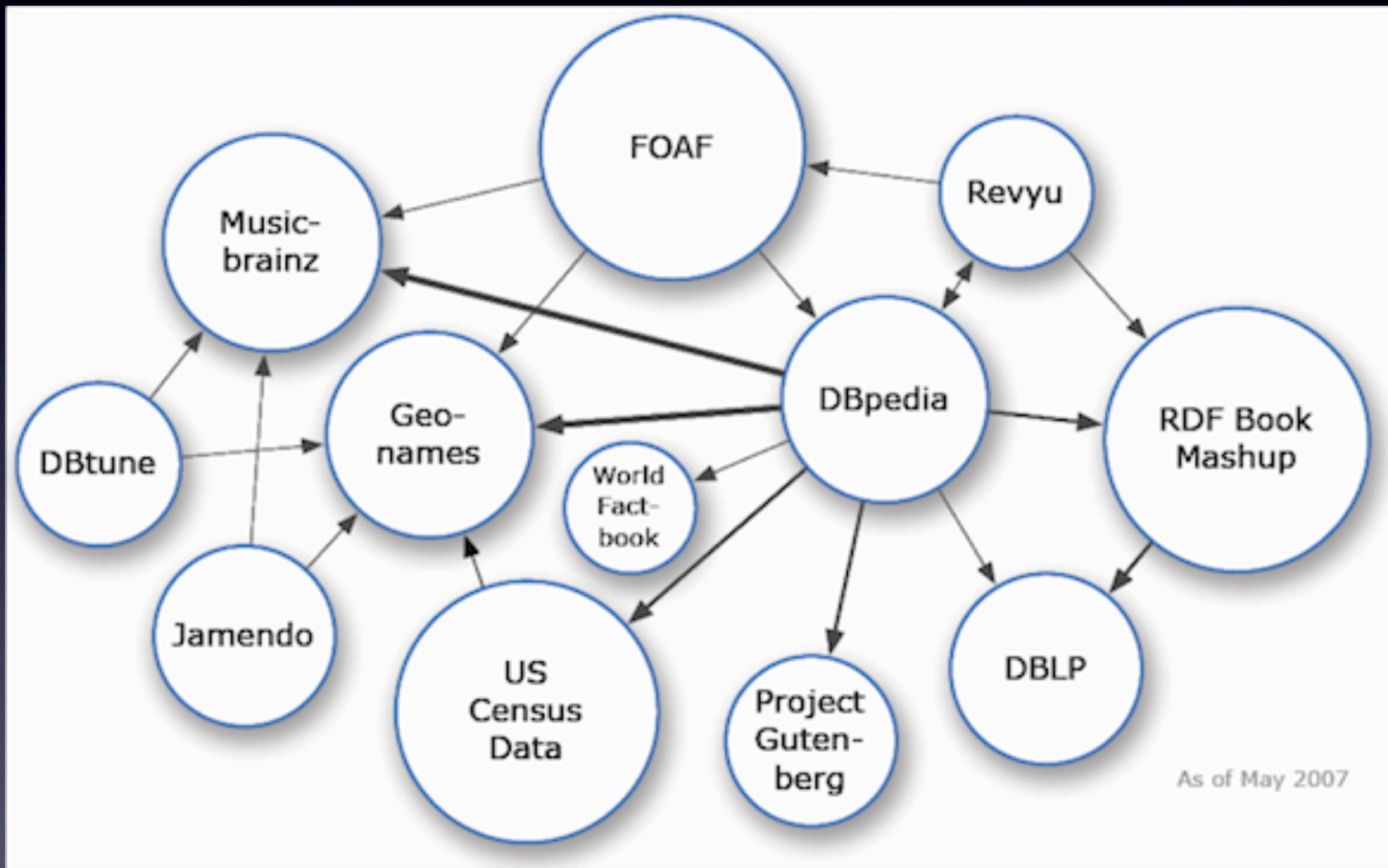
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http://www.ifi.uzh.ch/i am a URI

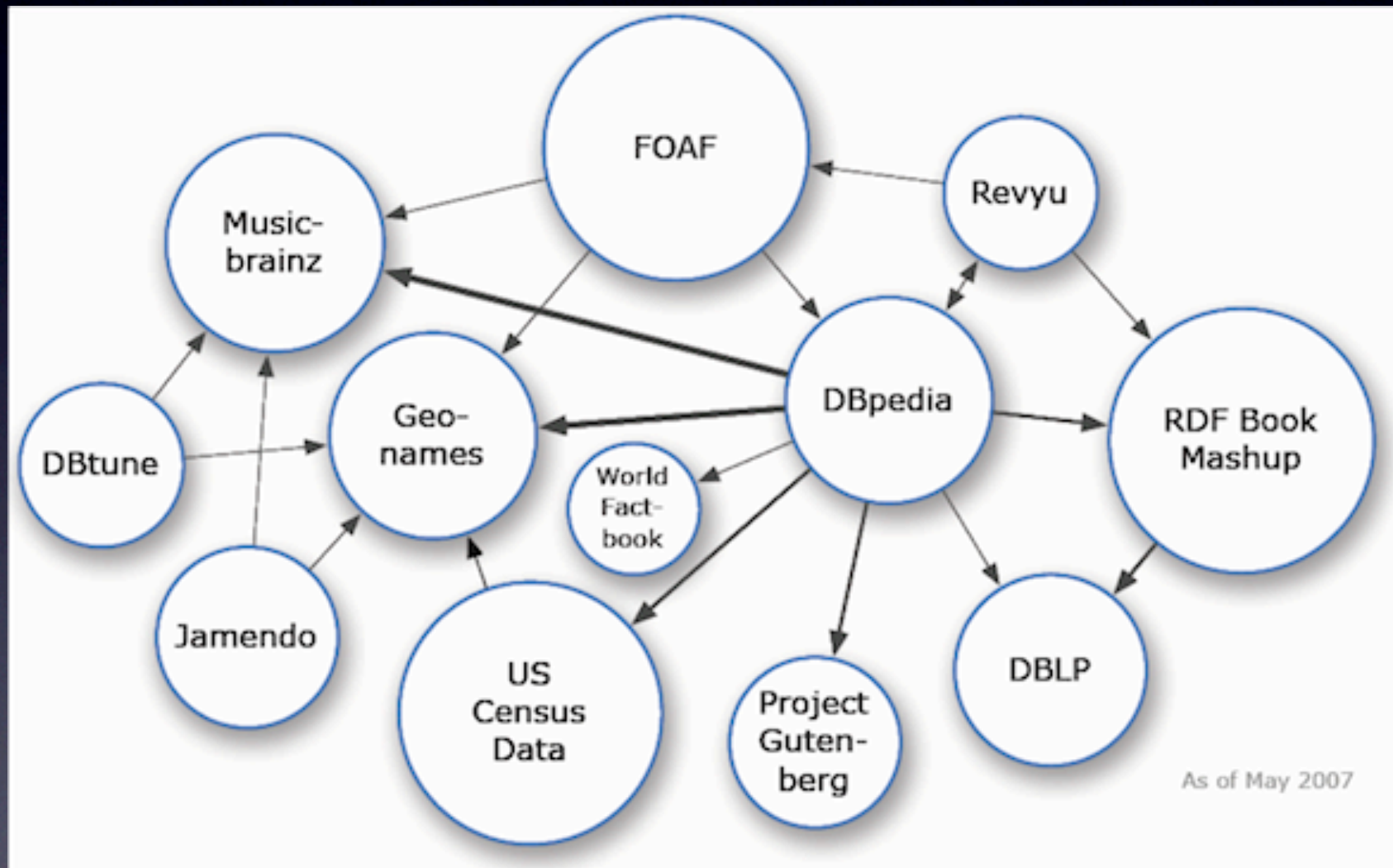
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http://www.ifi.uzh.ch/ am a URI

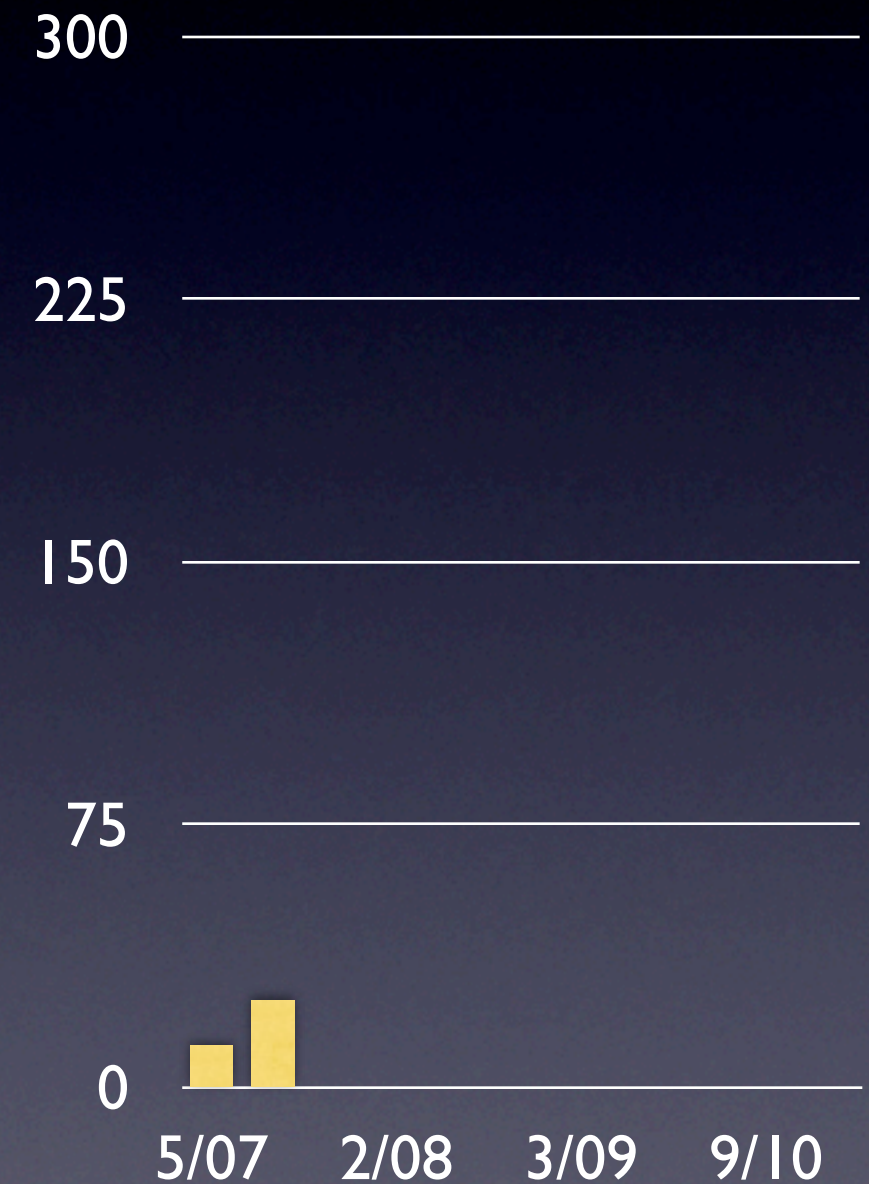
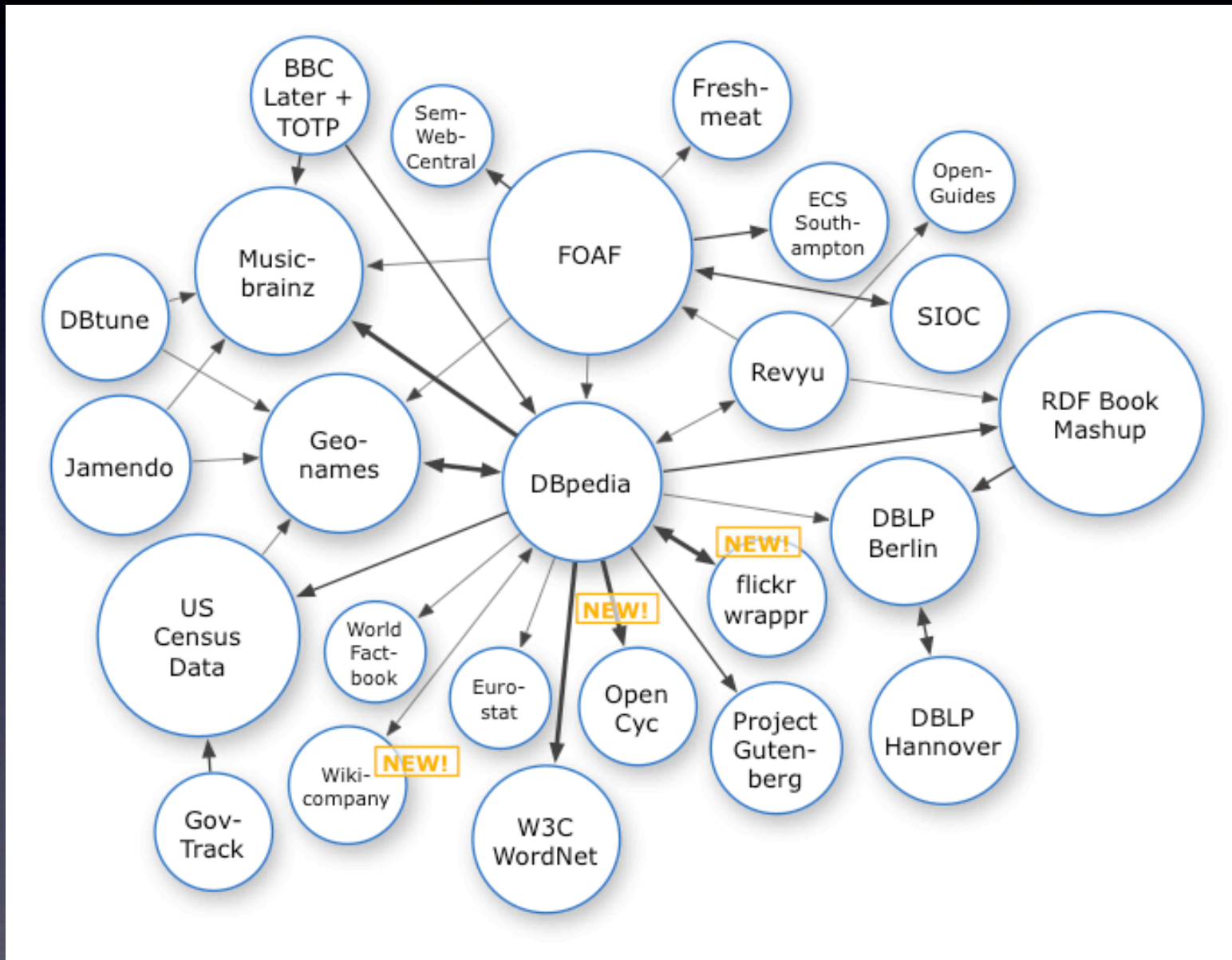
Large Graphs



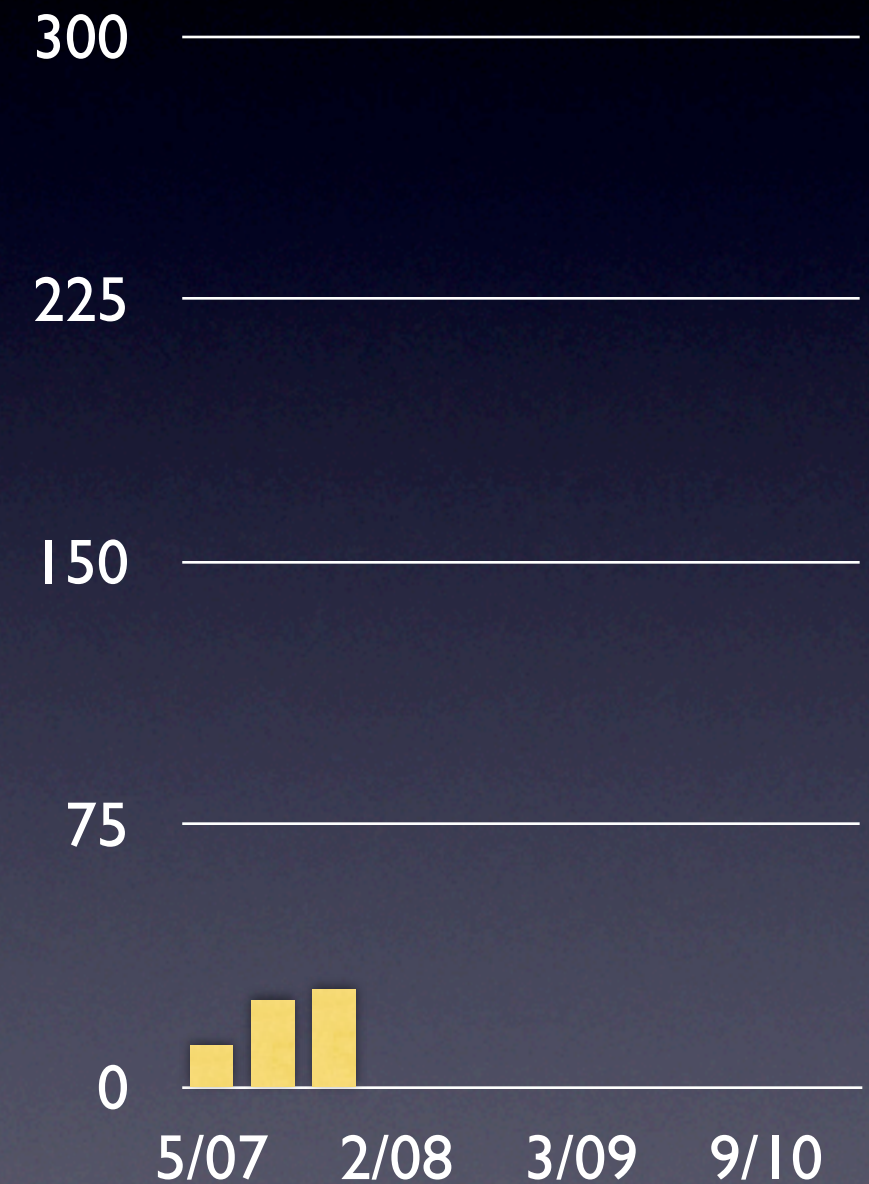
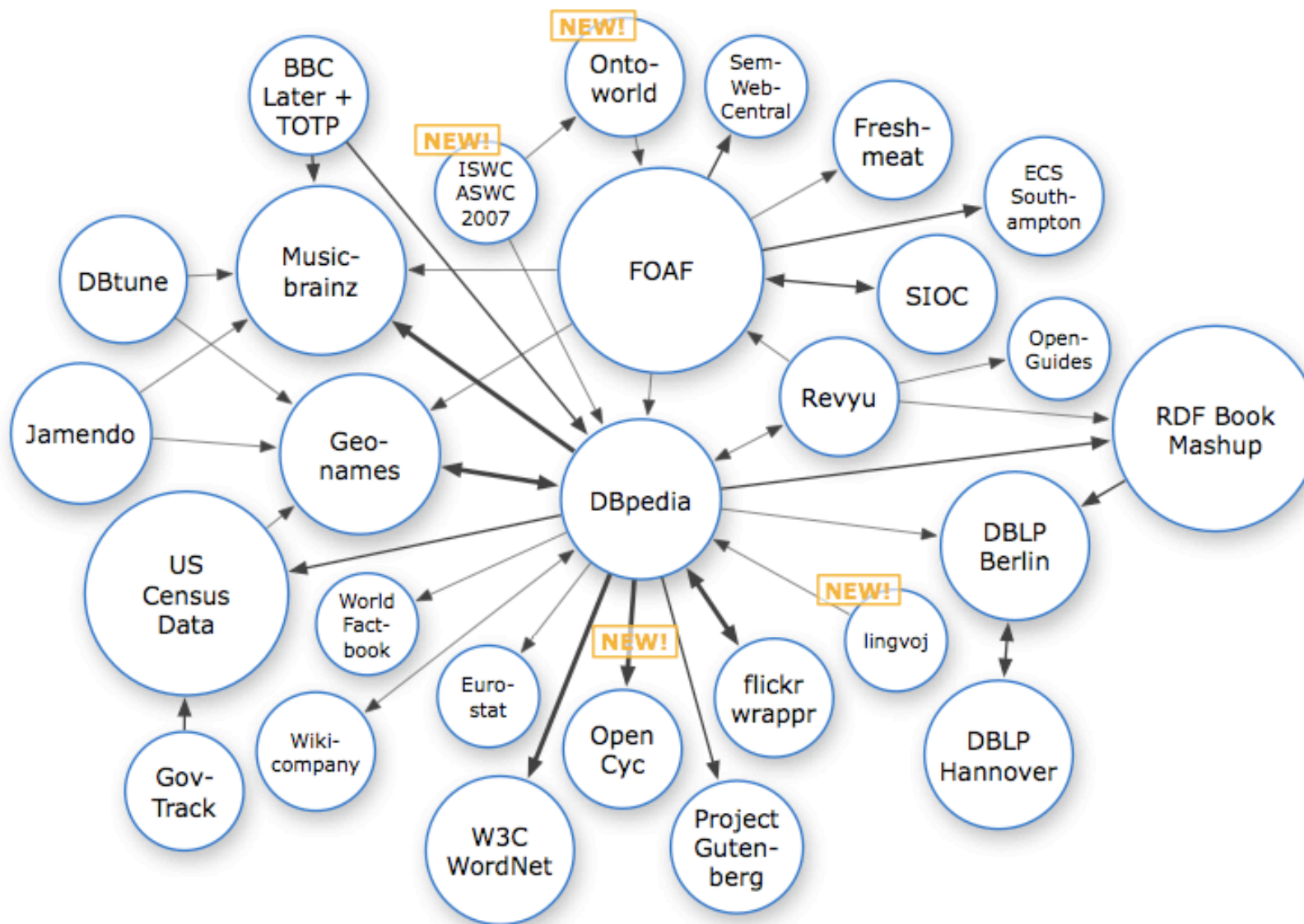
Large Graphs



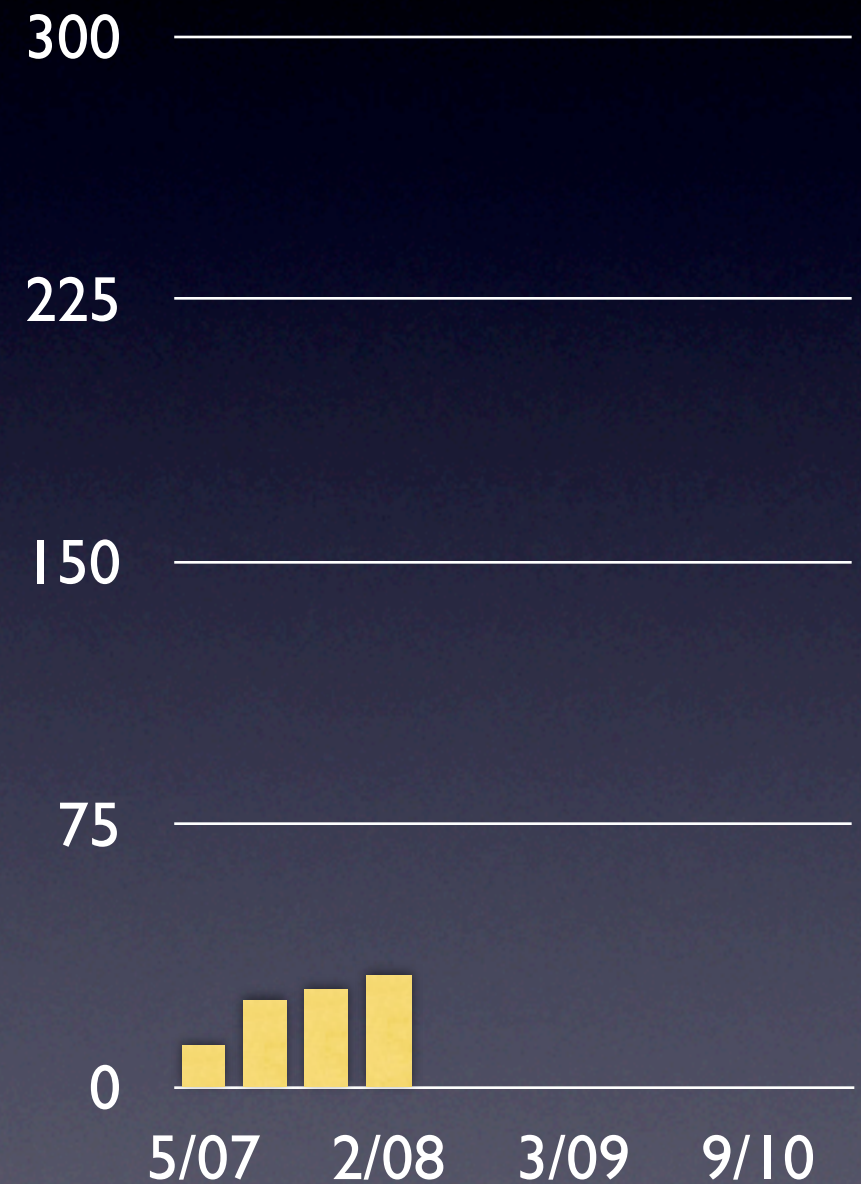
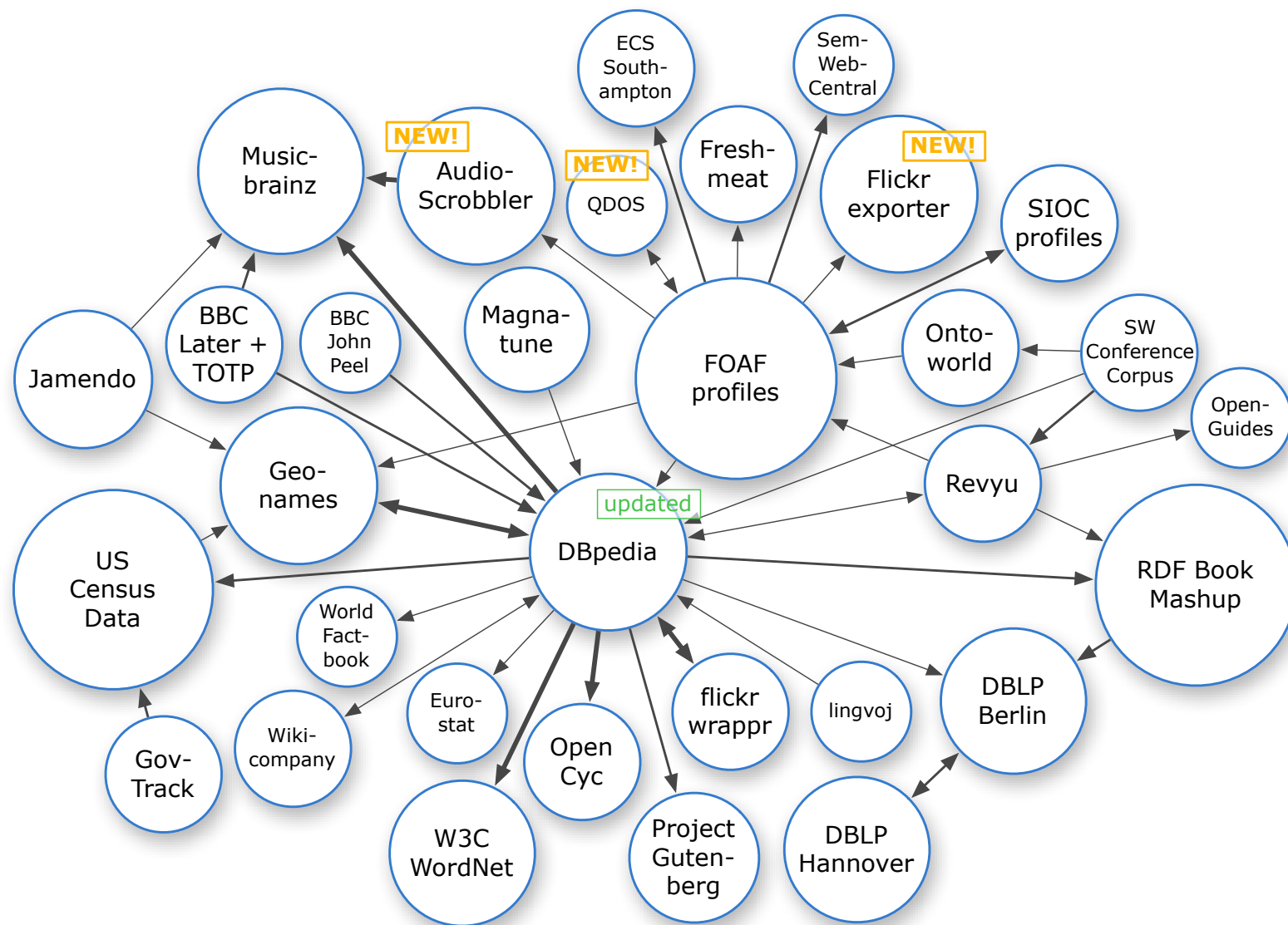
Large Graphs



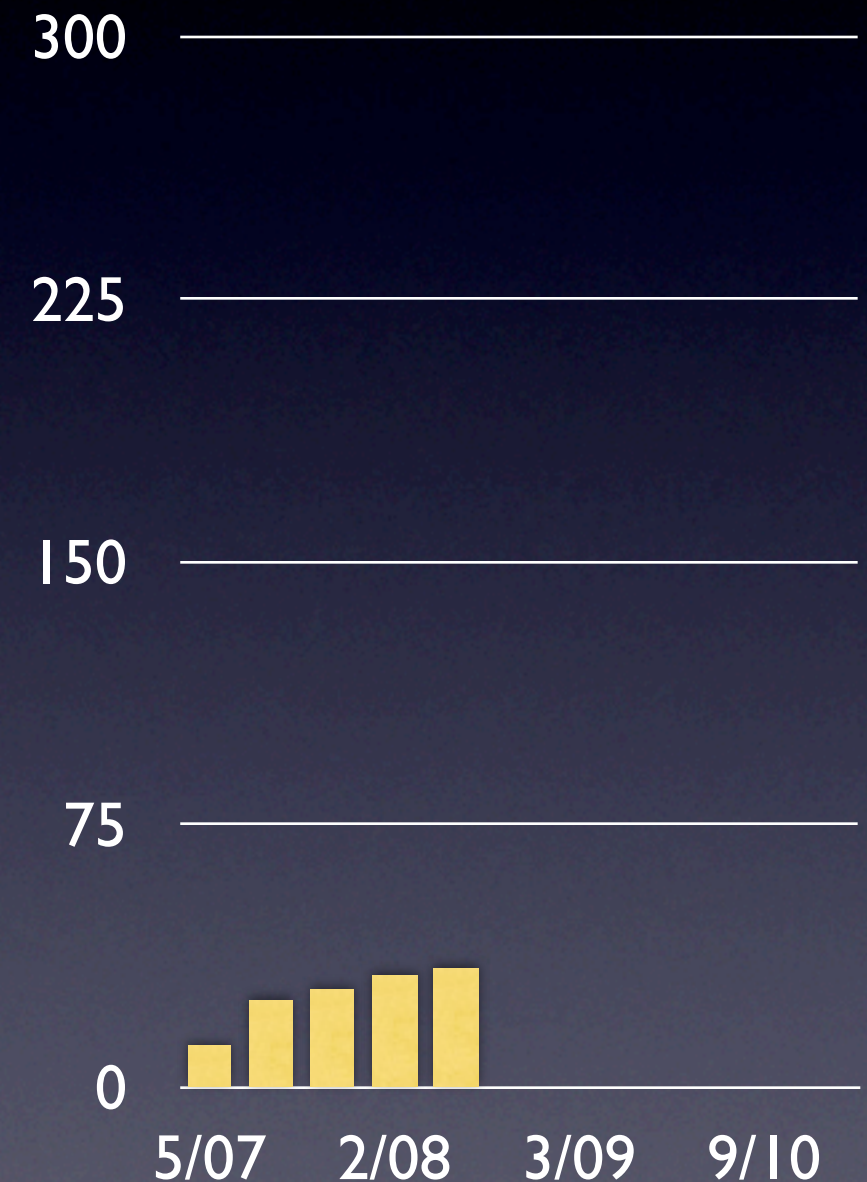
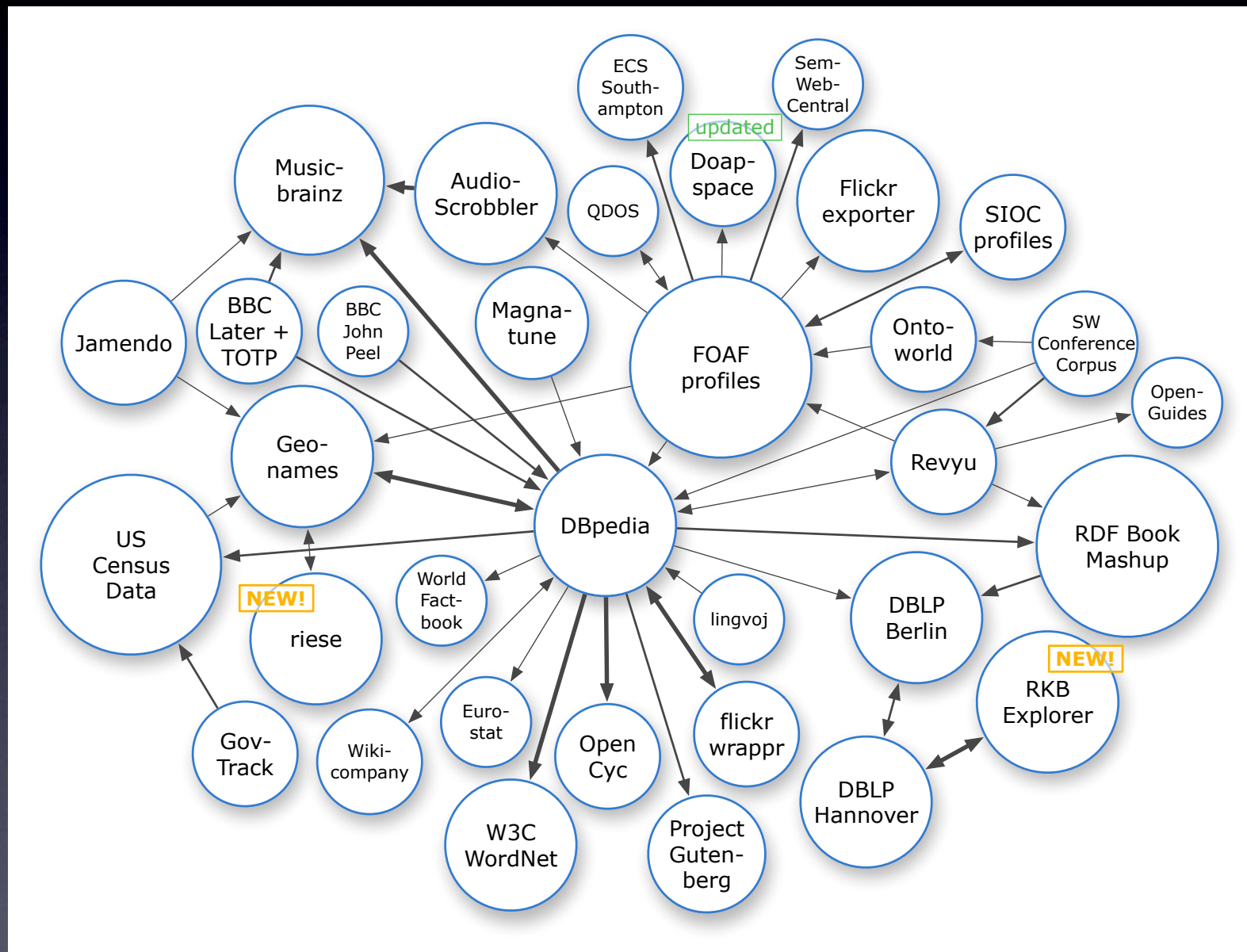
Large Graphs



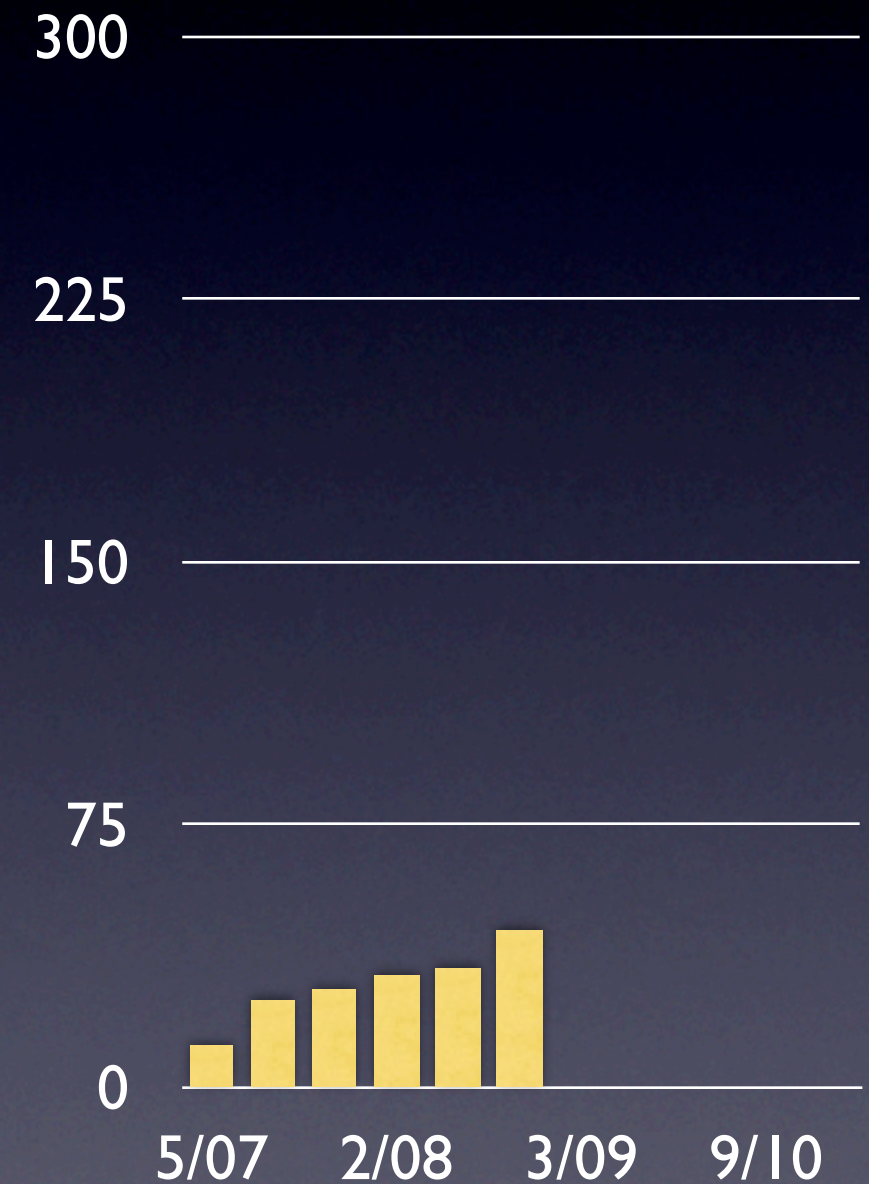
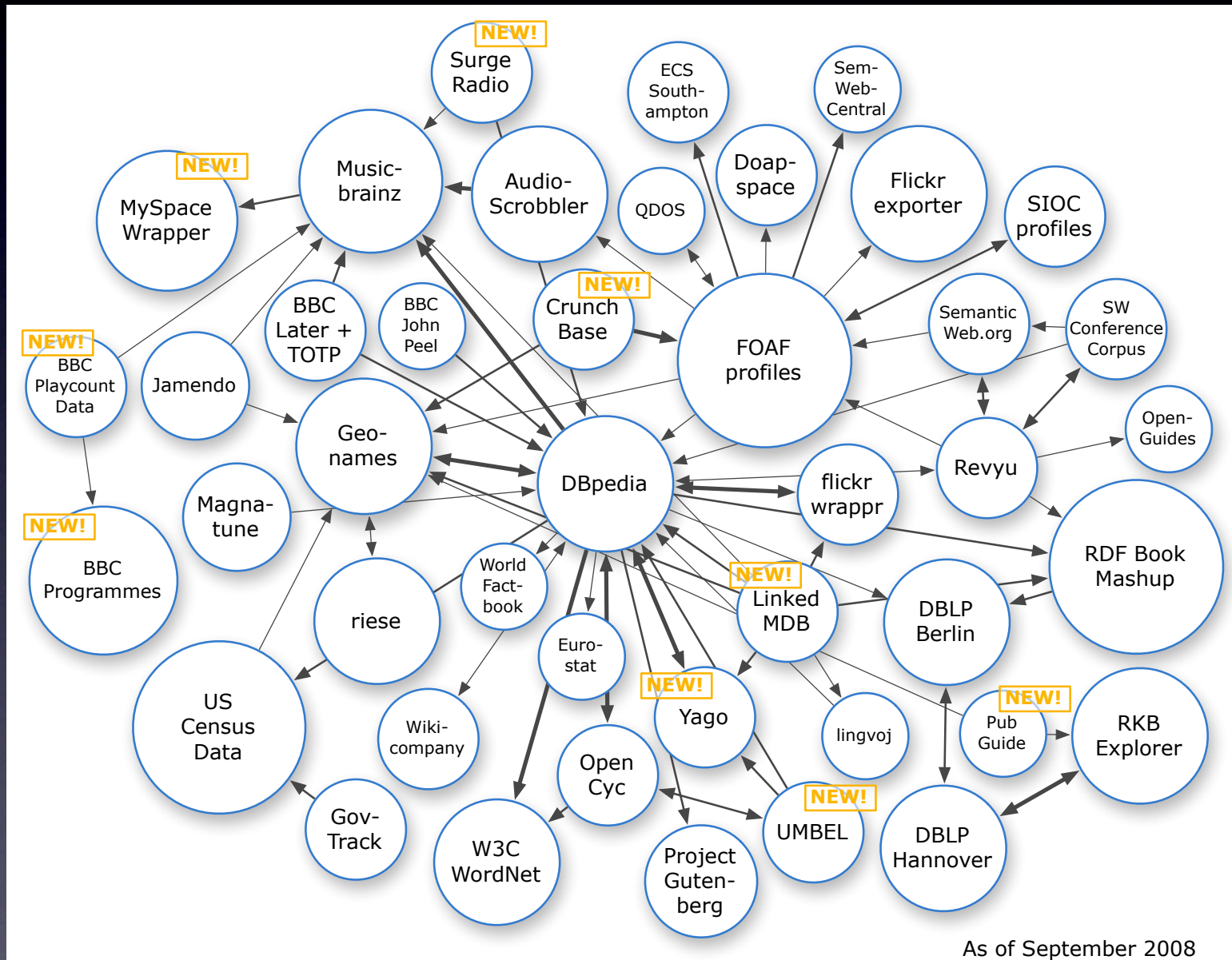
Large Graphs



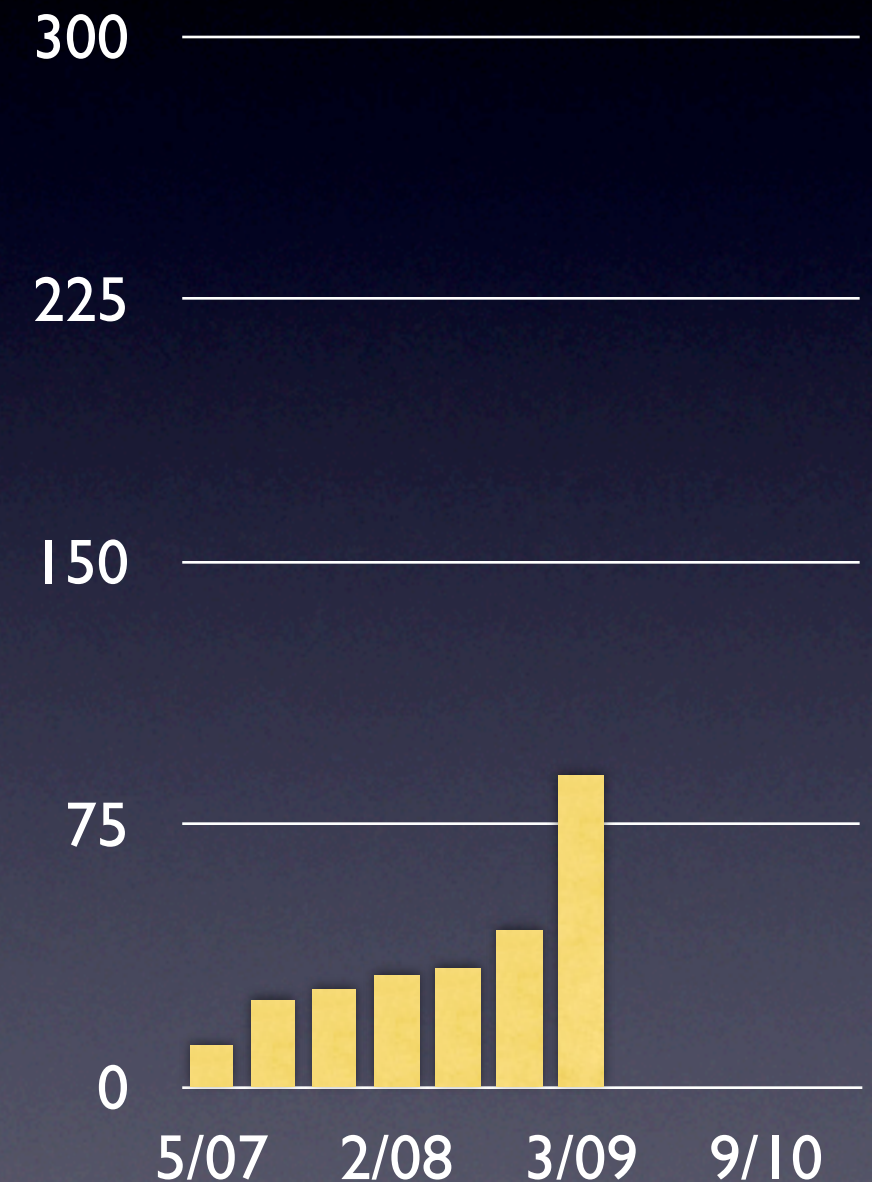
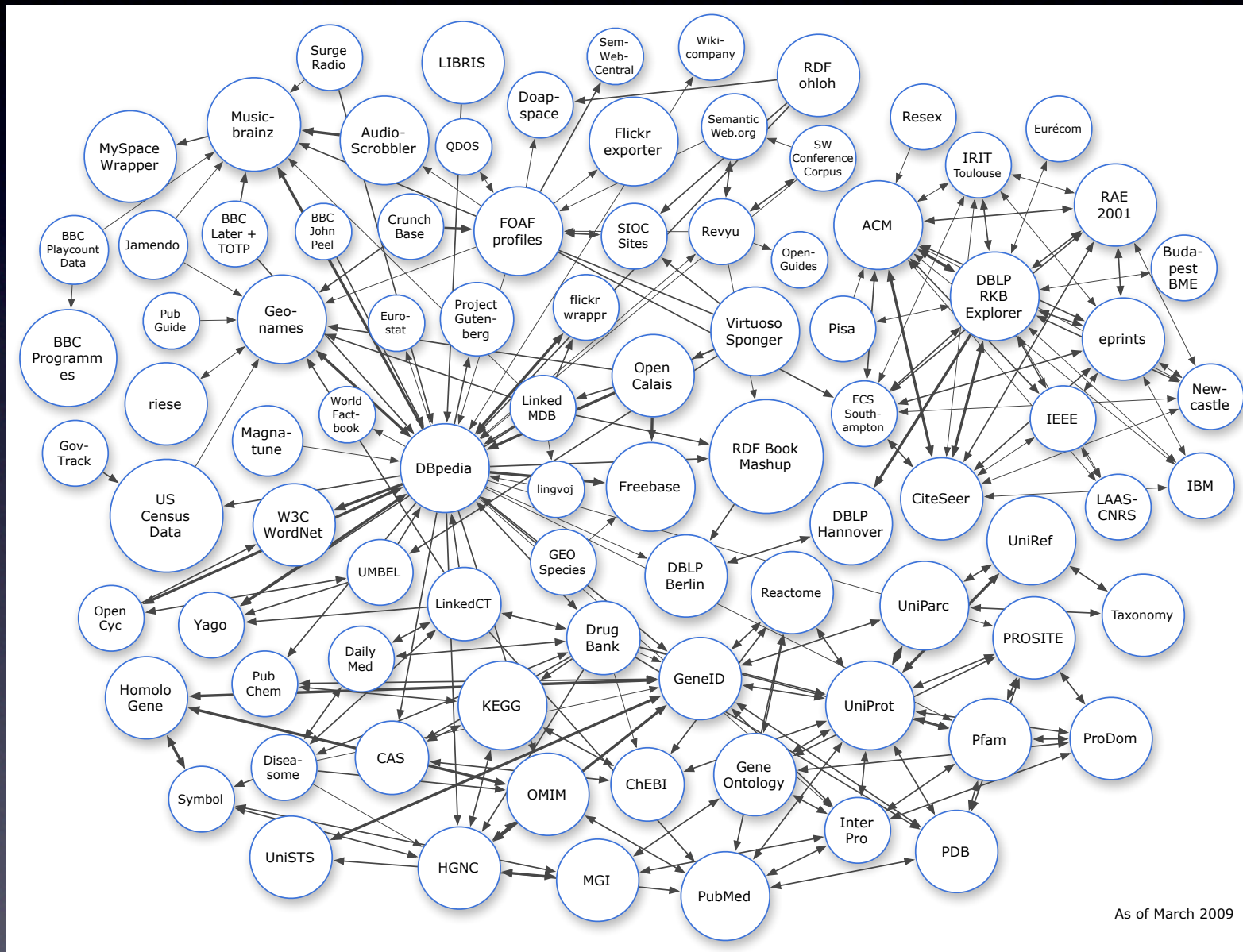
Large Graphs



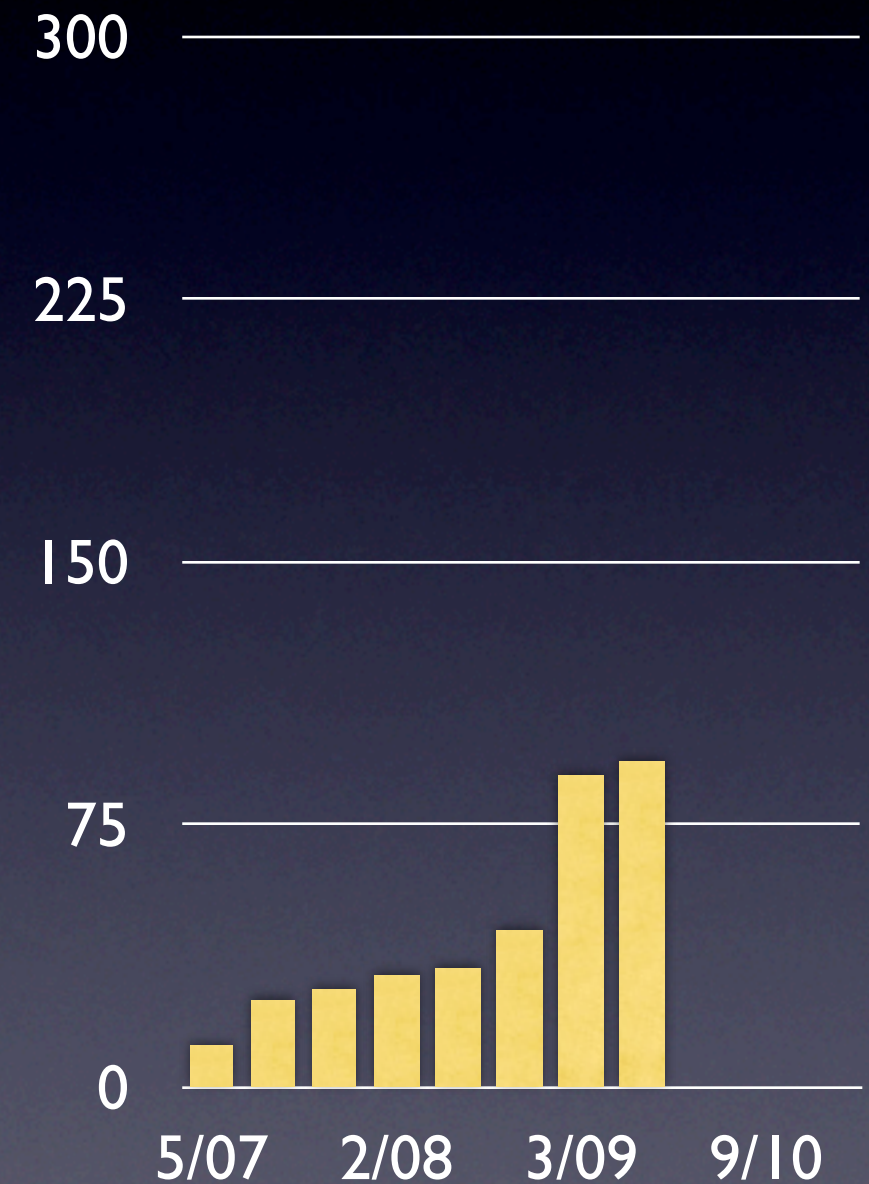
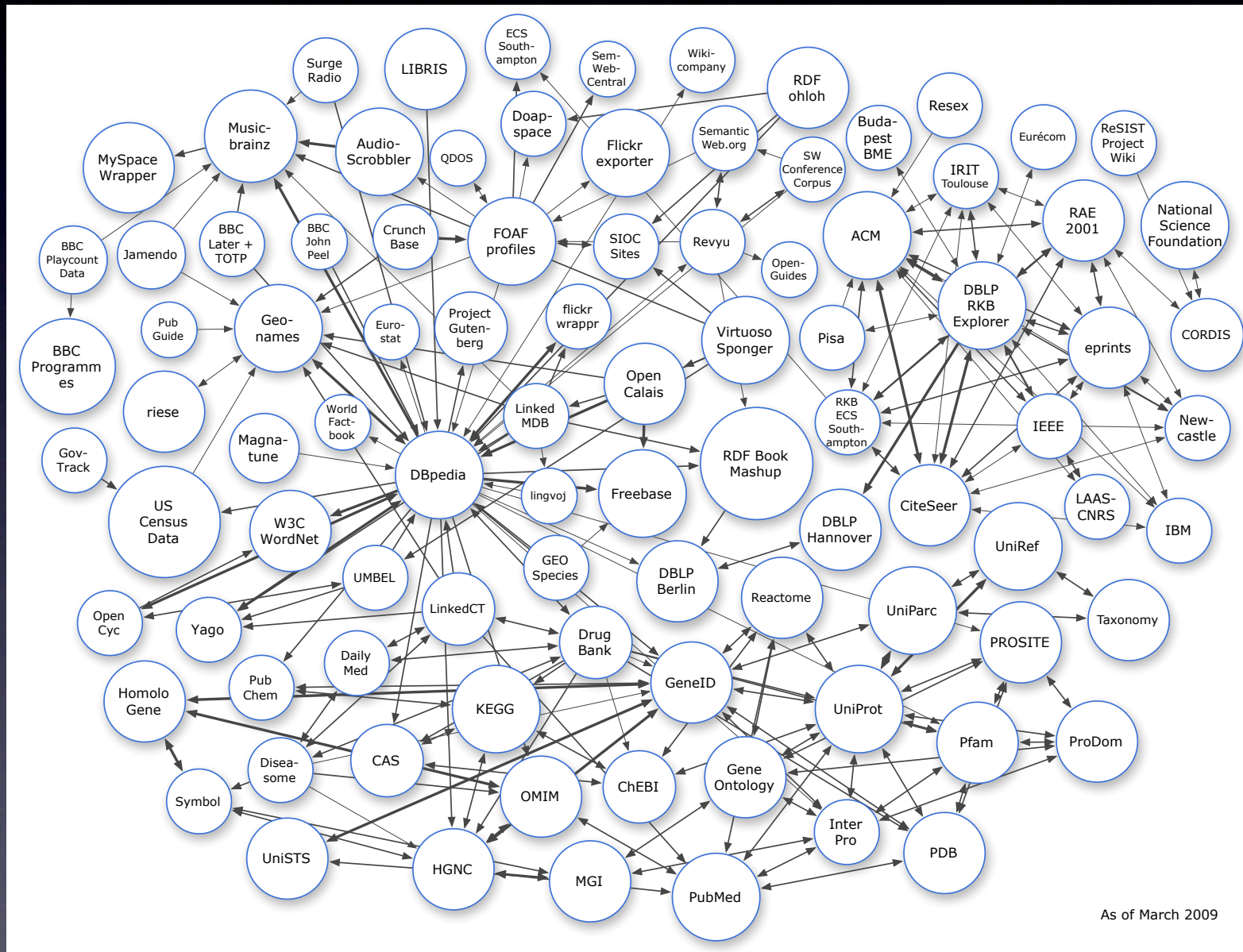
Large Graphs



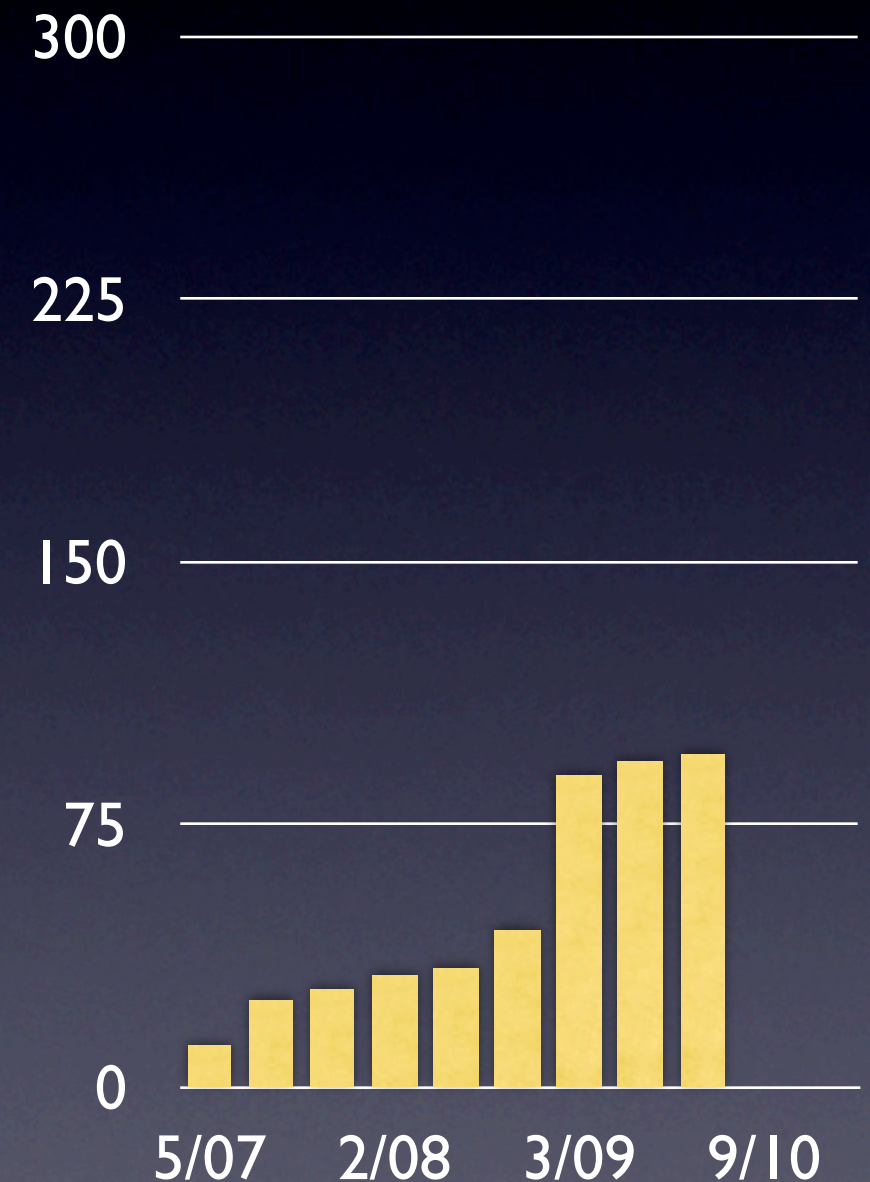
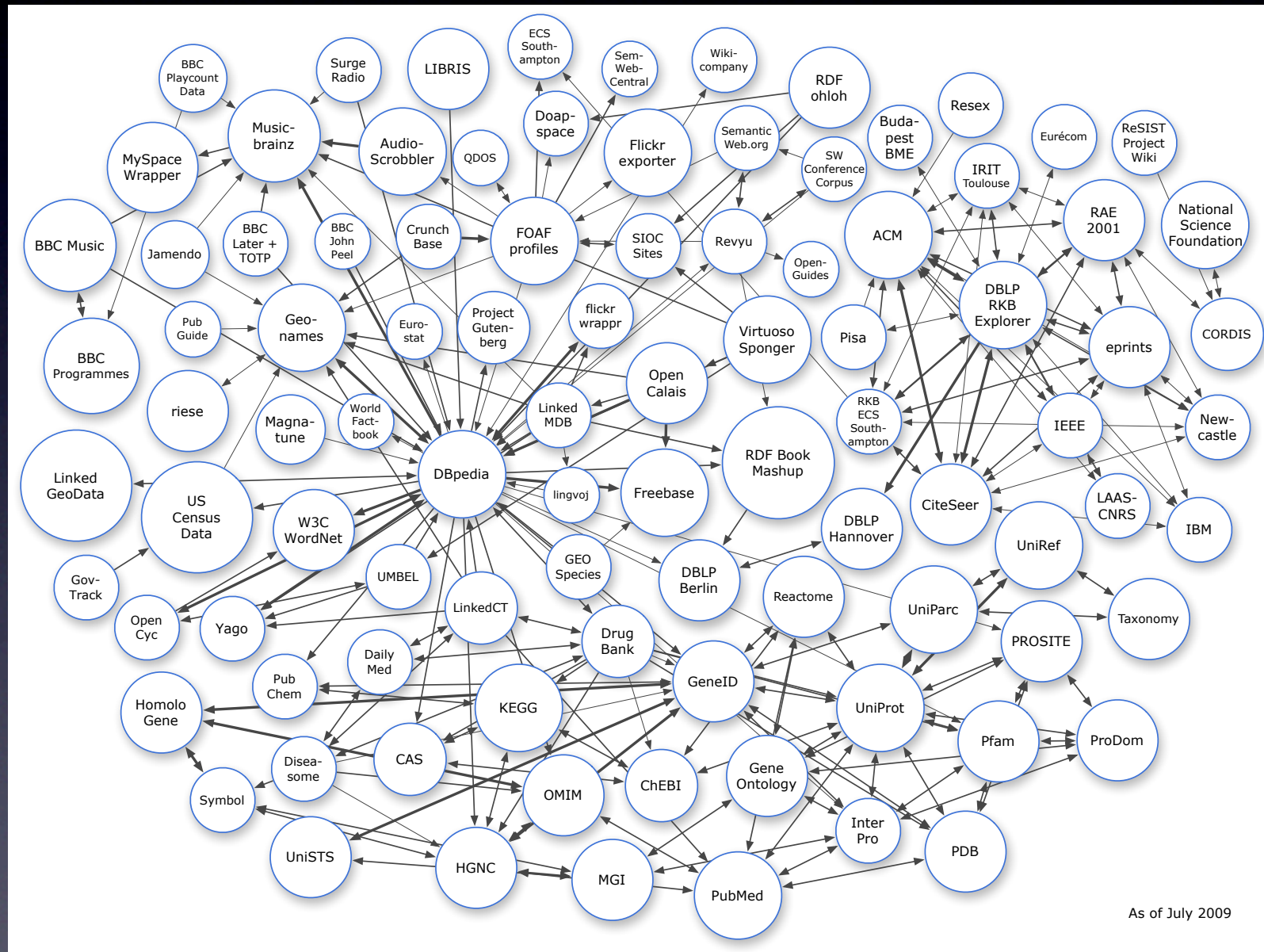
Large Graphs



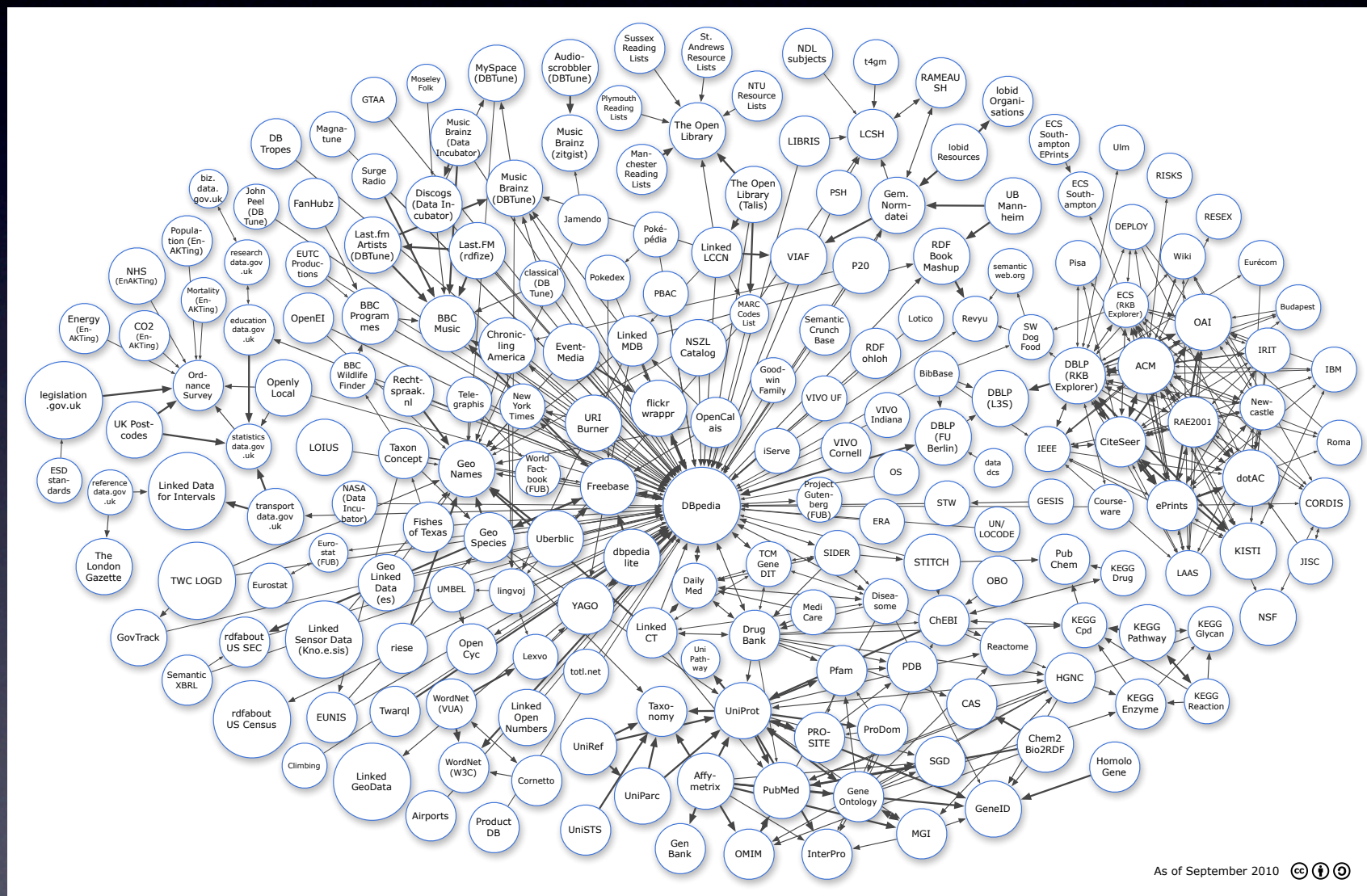
Large Graphs



Large Graphs



Large Graphs



300

225

150

75

0

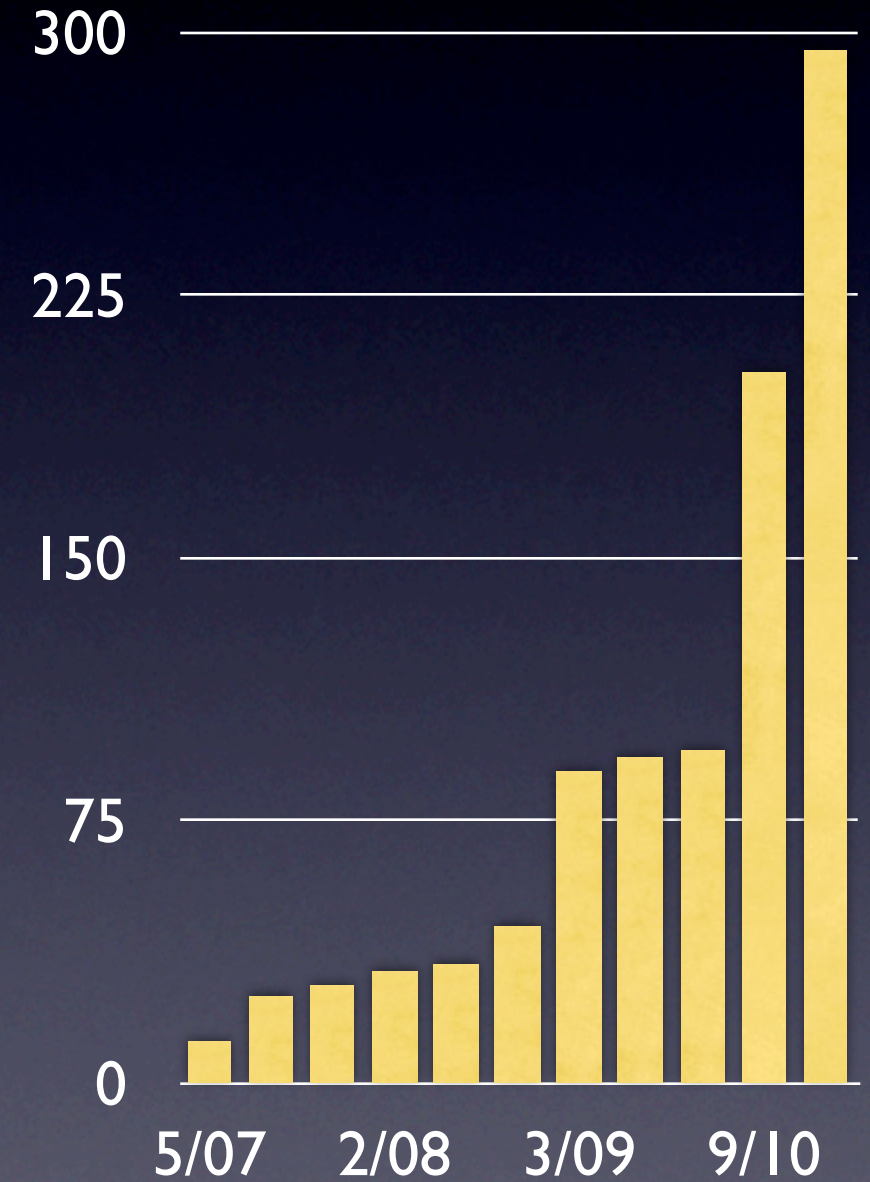
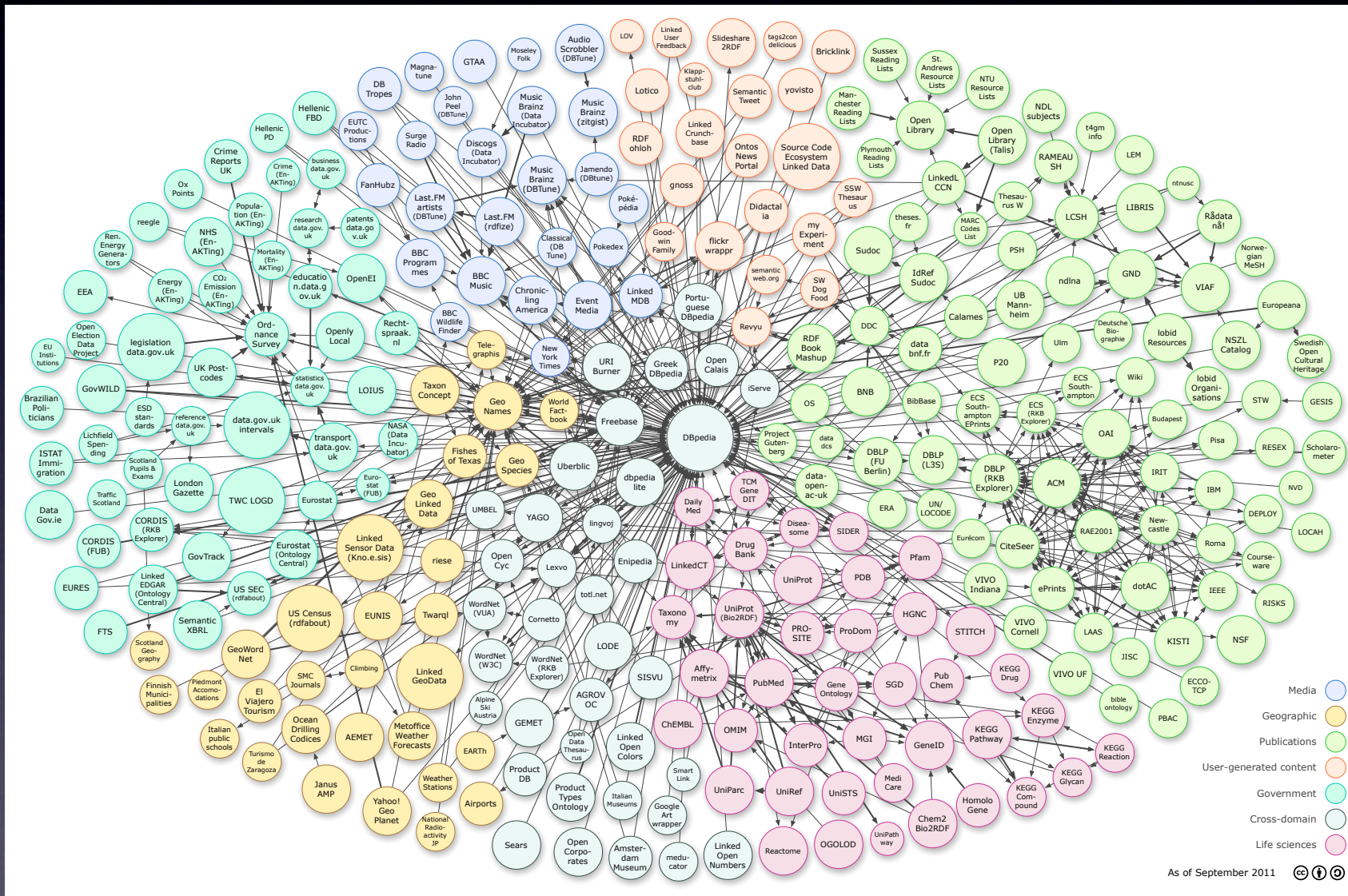
5/07

2/08

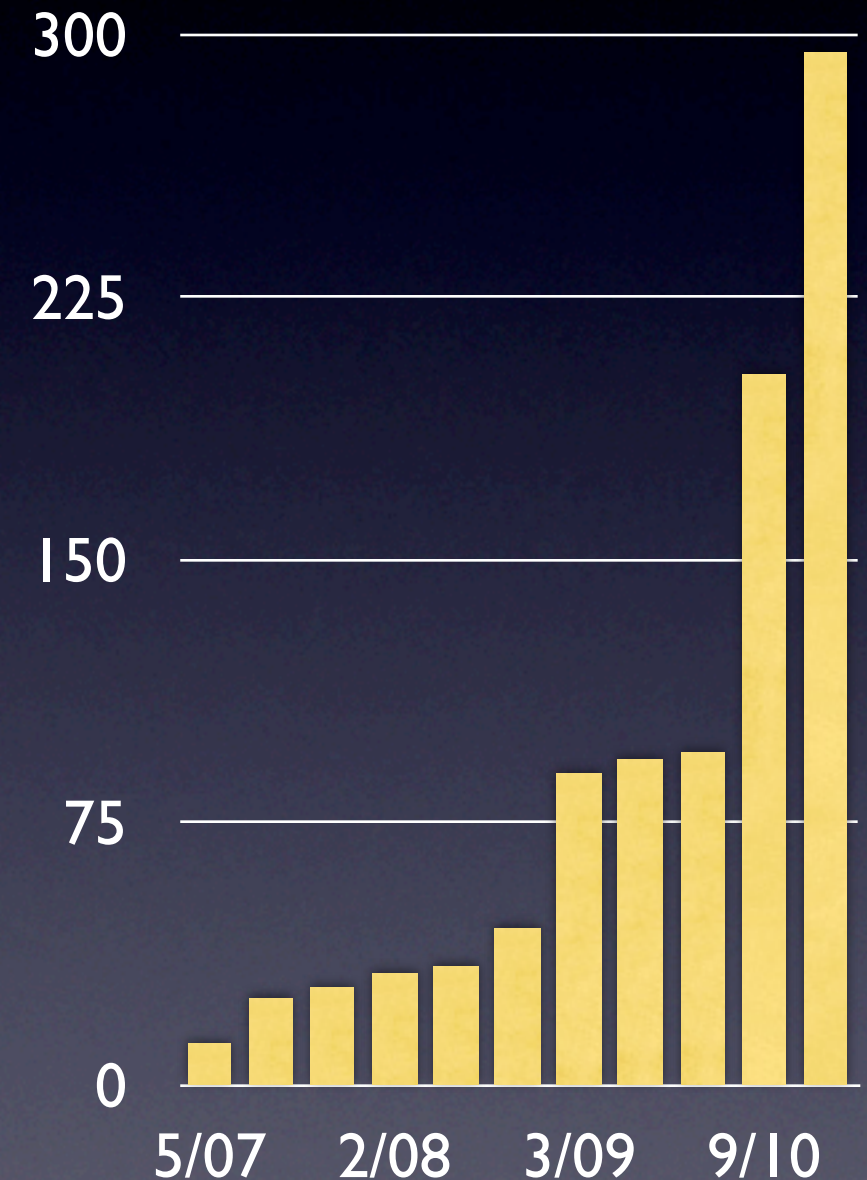
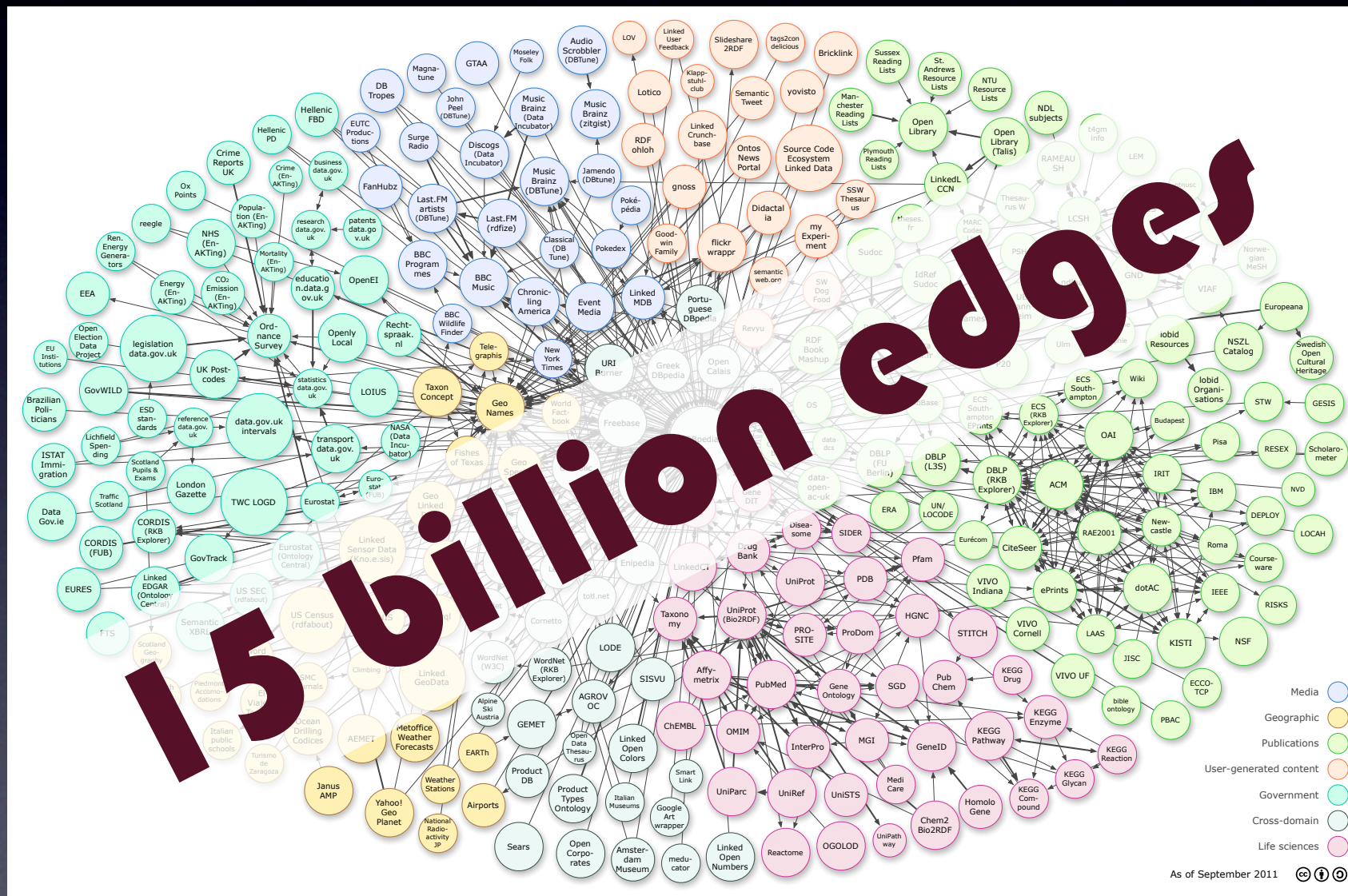
3/09

9/10

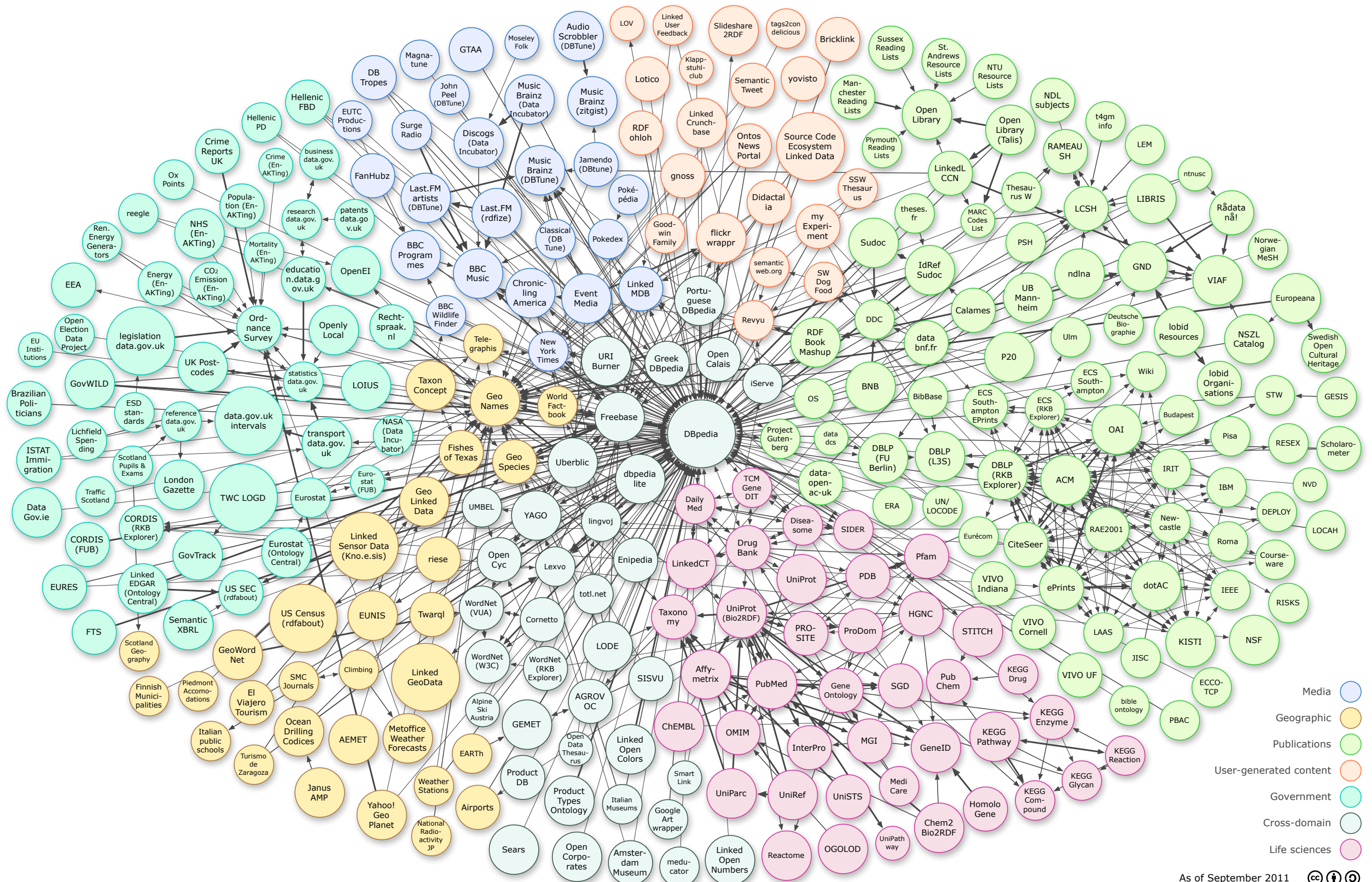
Large Graphs



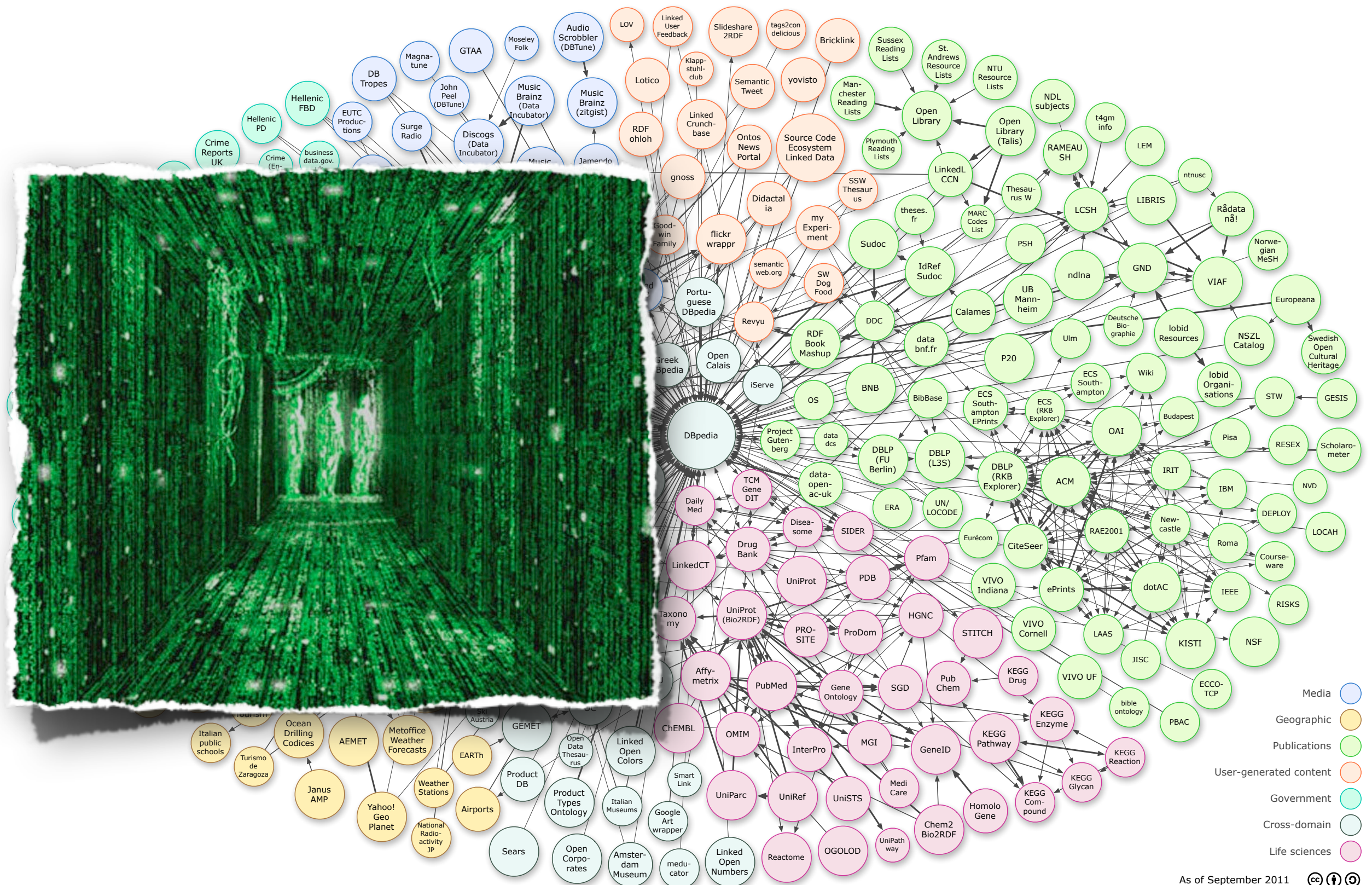
Large Graphs



Large Graphs



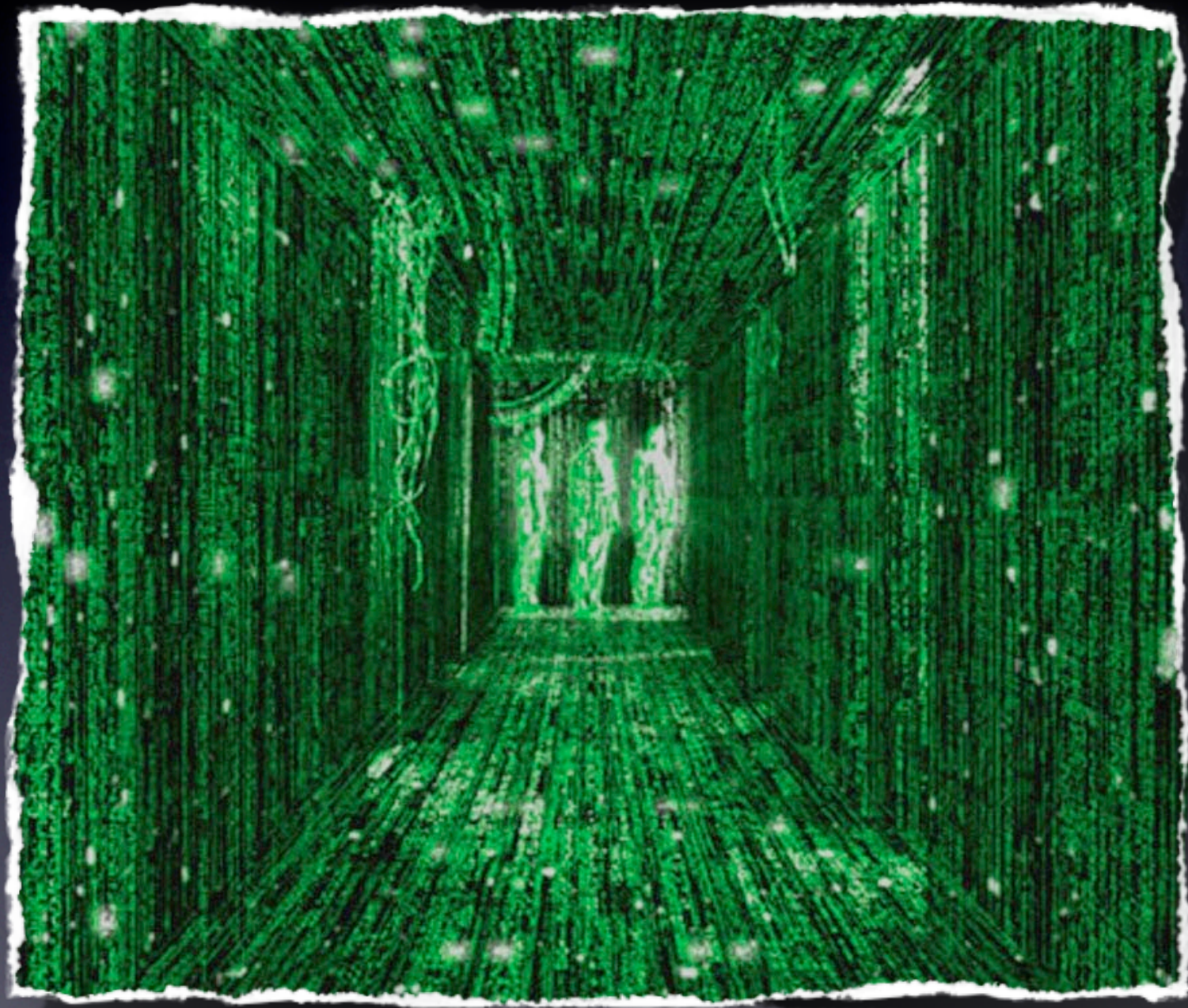
Large Graphs



Large Graphs



Large Graph Processing



Large Graph Processing

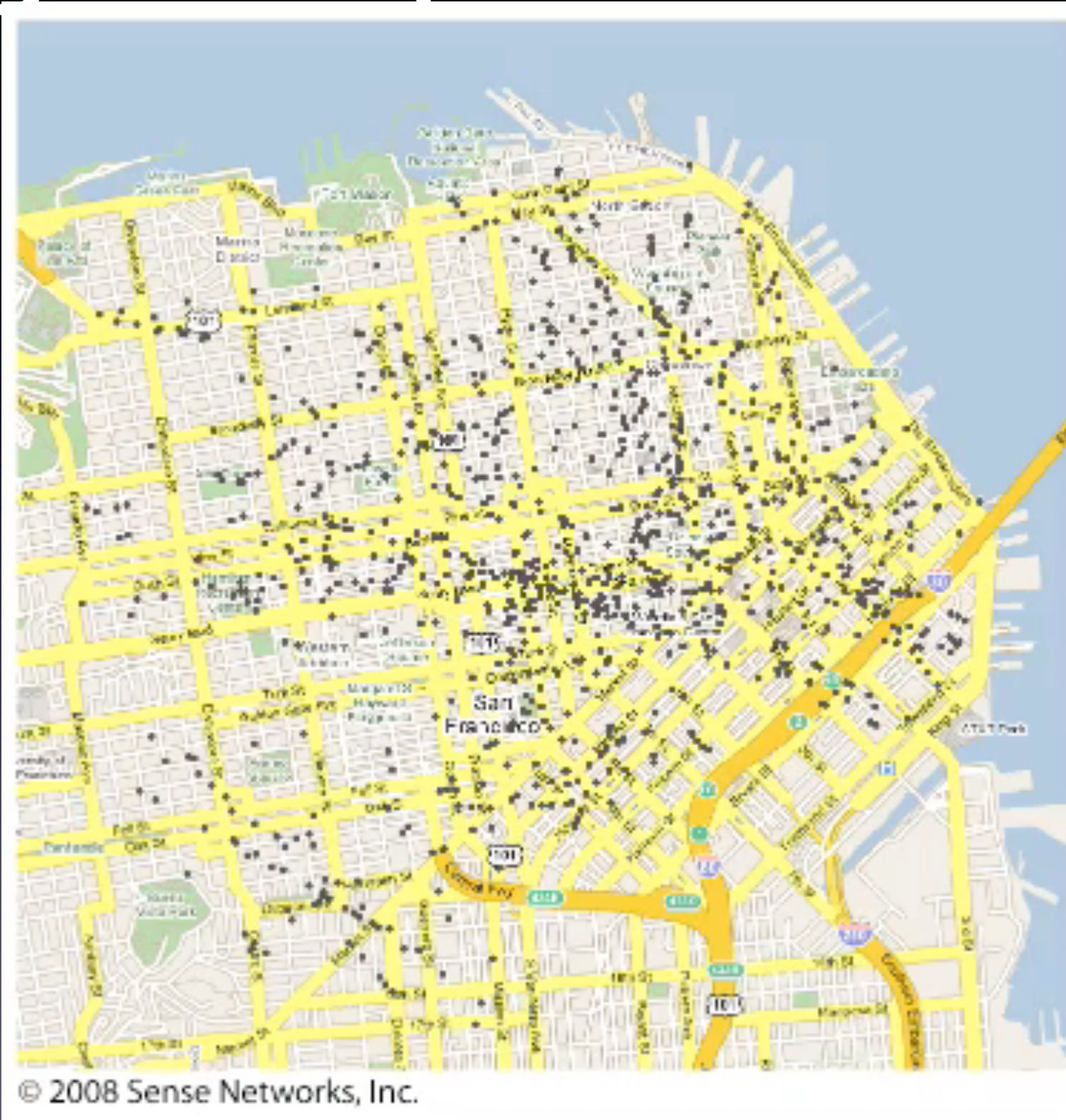


**DB-Languages
SQL/SPARQL?**

**Custom Solution
(Jena, MPI)?**

MapReduce?

Large Graph Processing

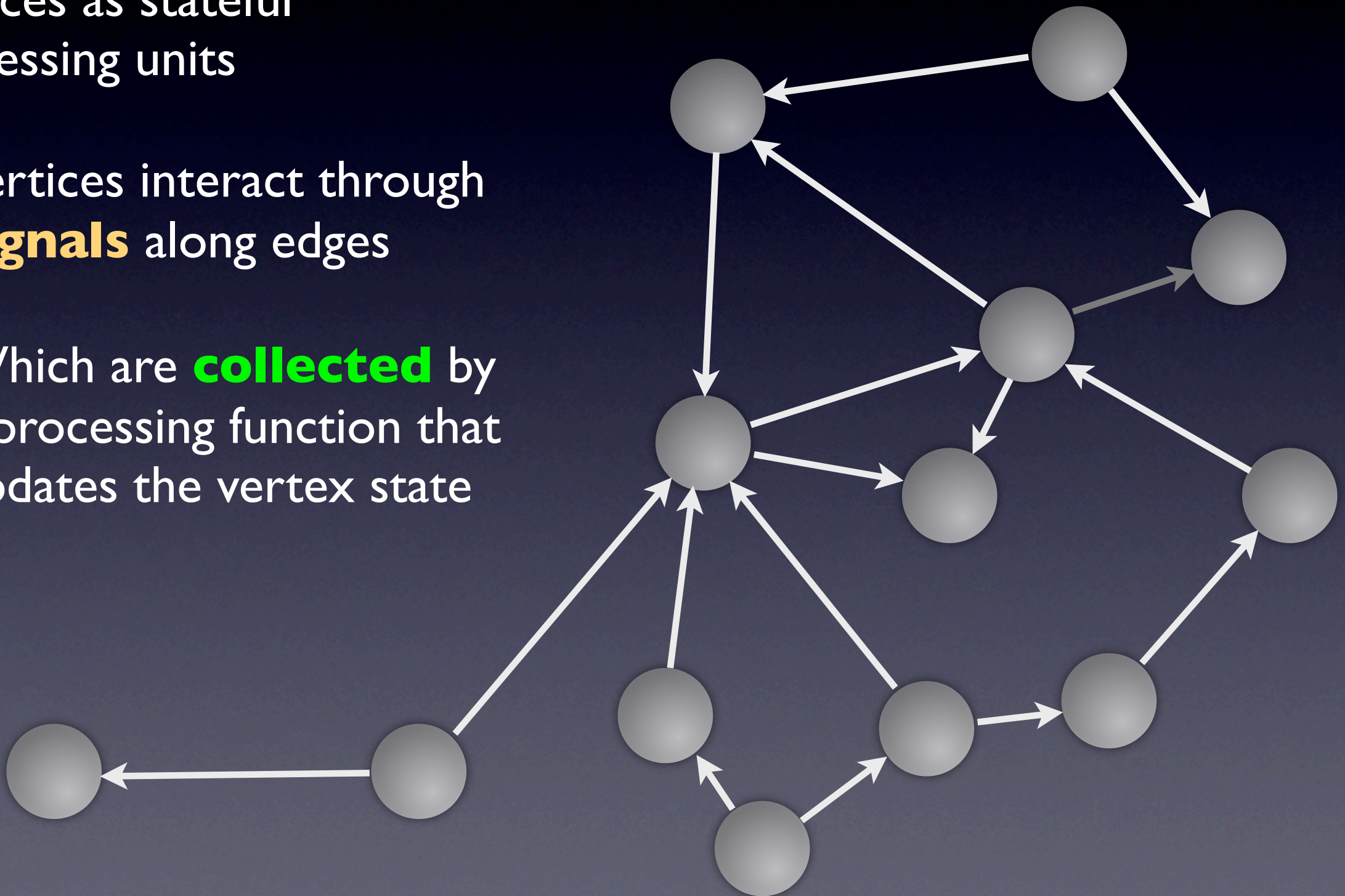


Processing Graphs Naturally

- Vertices as stateful processing units
- Vertices interact through **signals** along edges
- Which are **collected** by a processing function that updates the vertex state

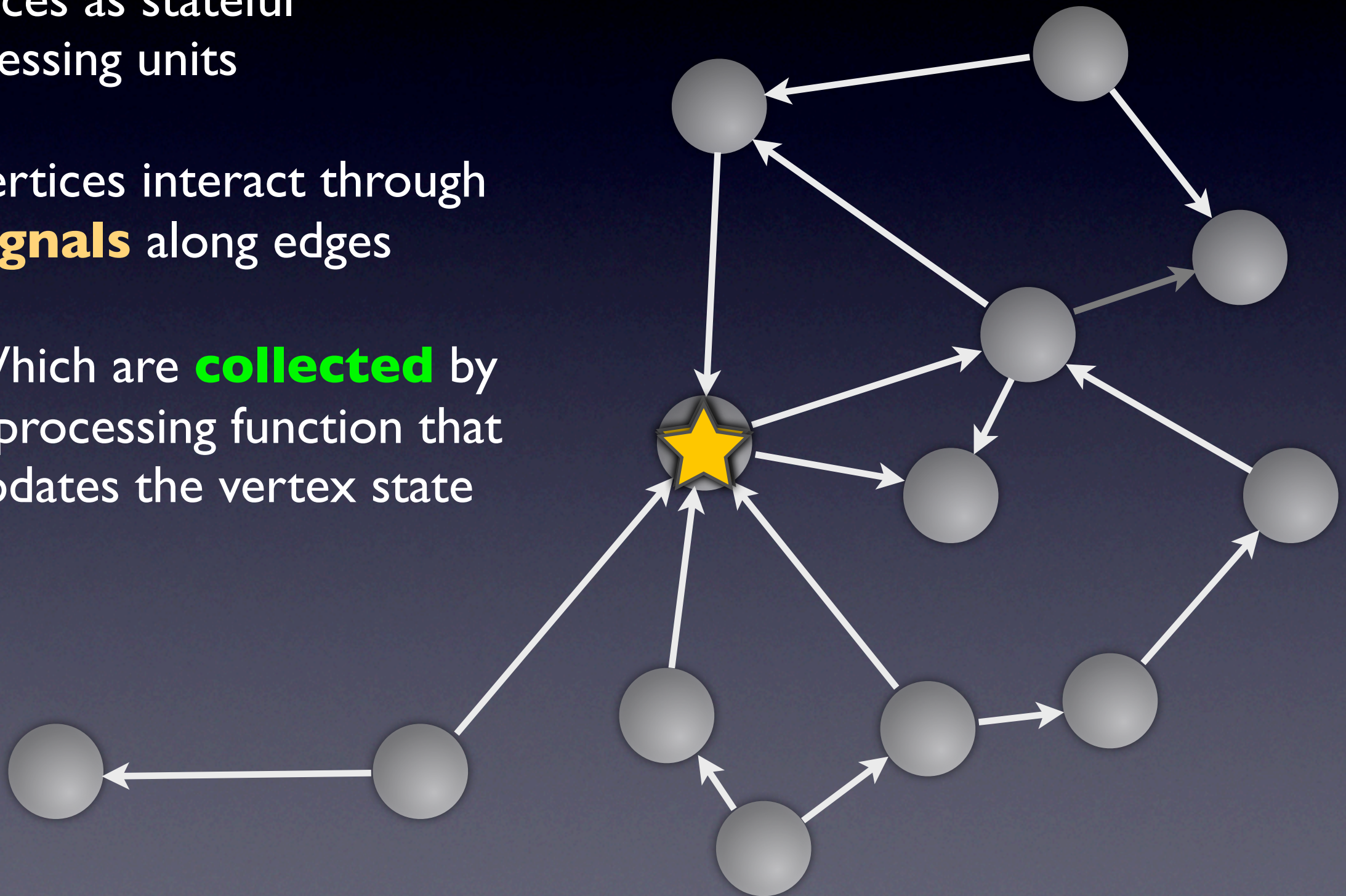
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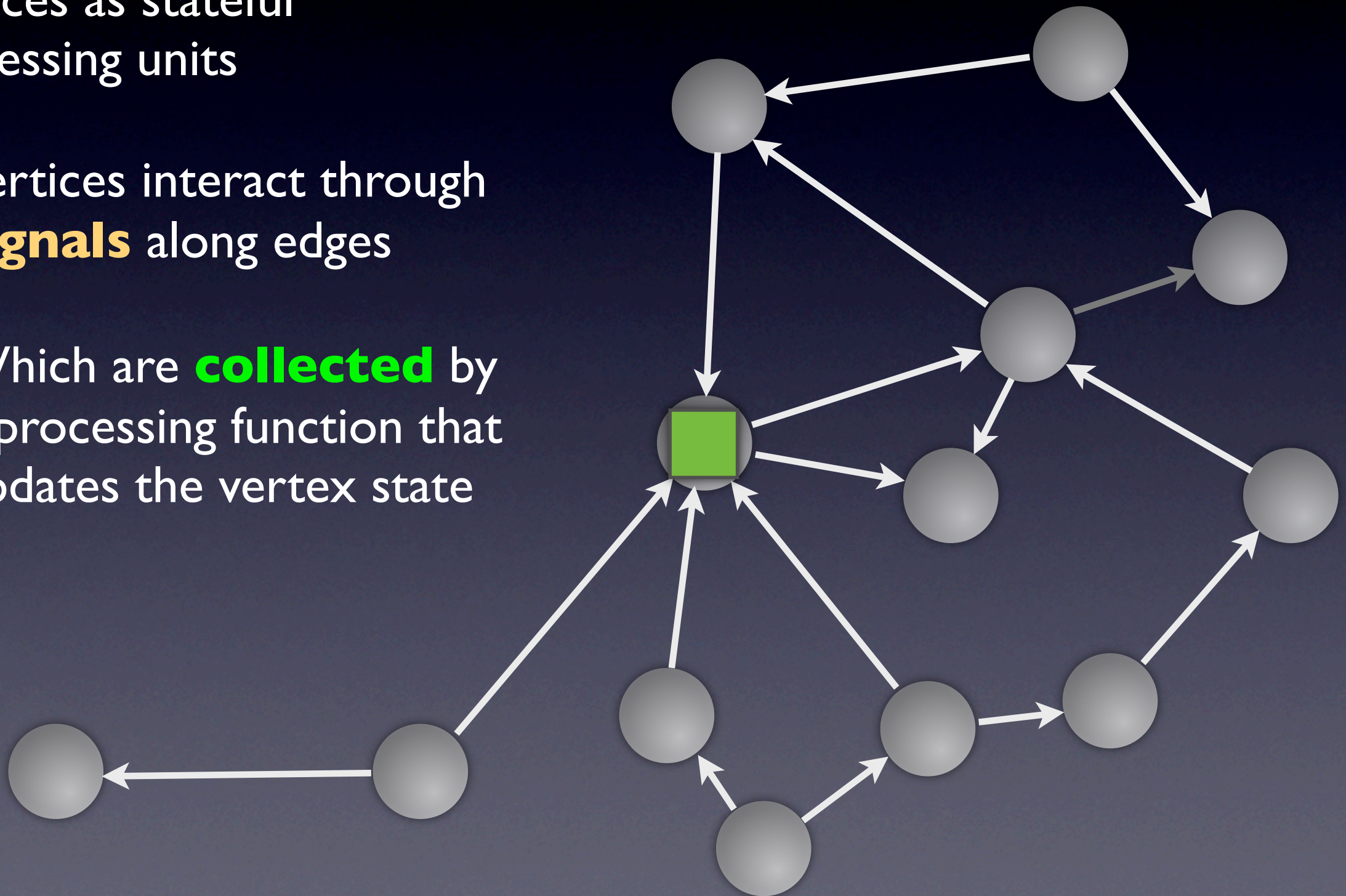
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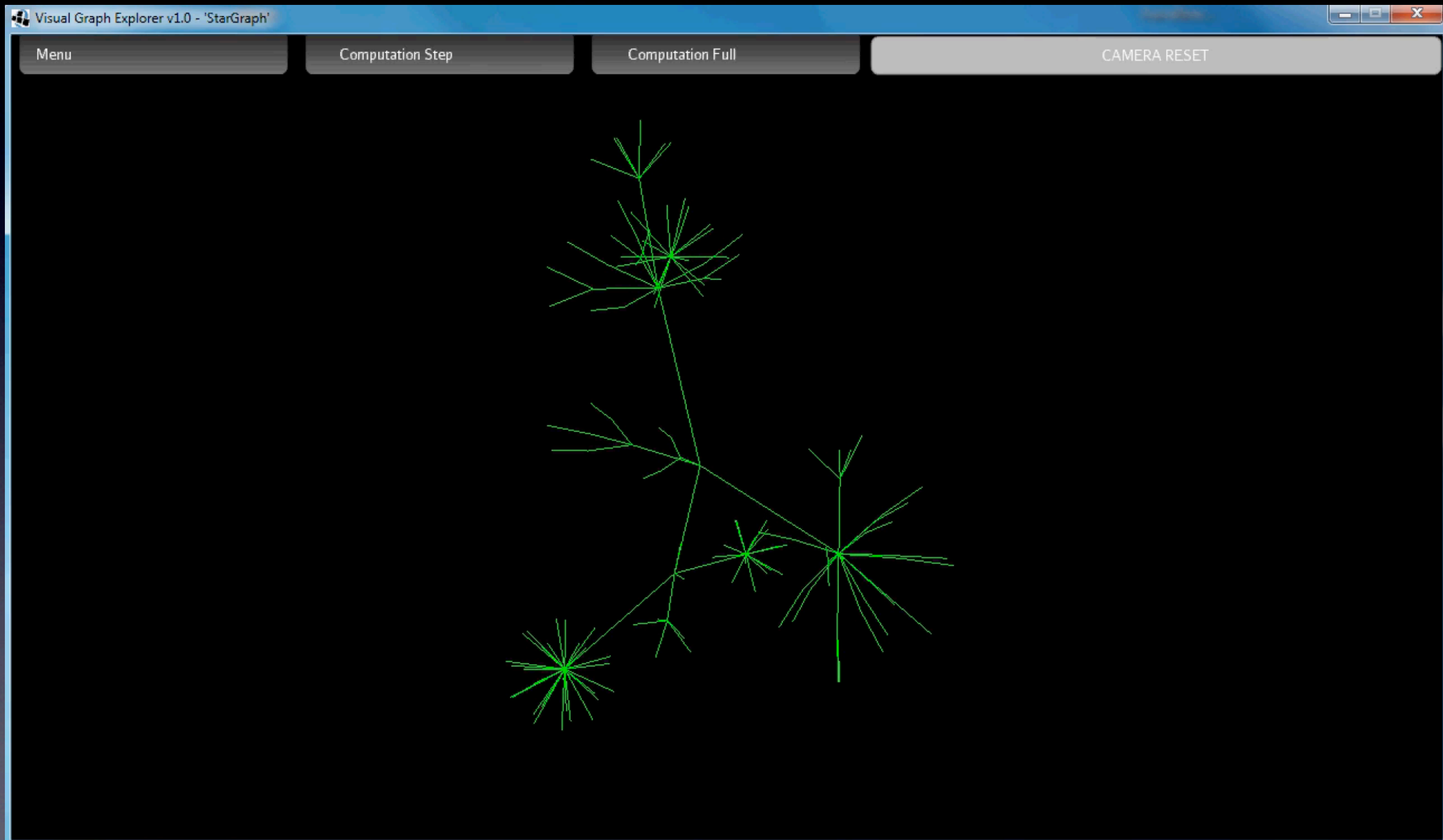
Processing Graphs Naturally

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PageRank Running

PageRank Running



PageRank in Code

PageRank in Code

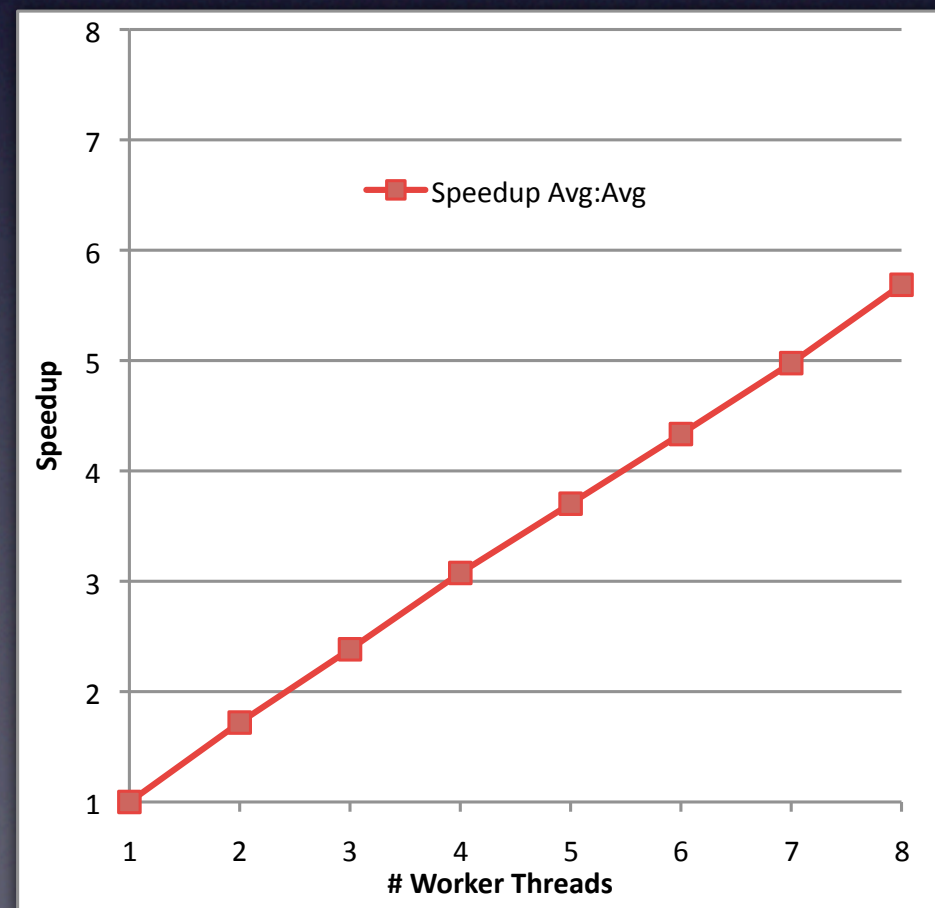
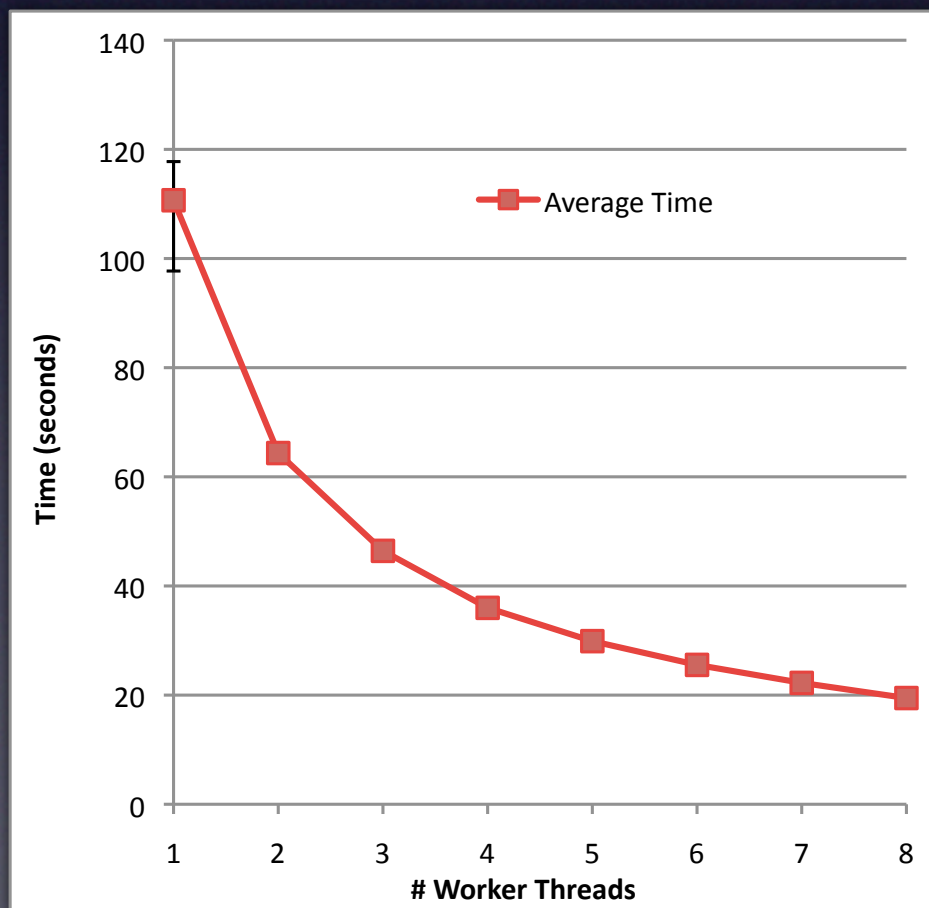
Algorithm

```
class Document(id: Any) extends Vertex(id, 0.15) {  
  def collect = 0.15 + 0.85 * signals[Double].foldLeft(0.0)(_ + _)  
}  
  
class Citation(citer: Any, cited: Any) extends Edge(citer, cited) {  
  def signal = source.state.asInstanceOf[Double] * weight / source.sumOfOutWeights  
}
```


PageRank in Code

Algorithm

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PageRank in Code

Algorithm

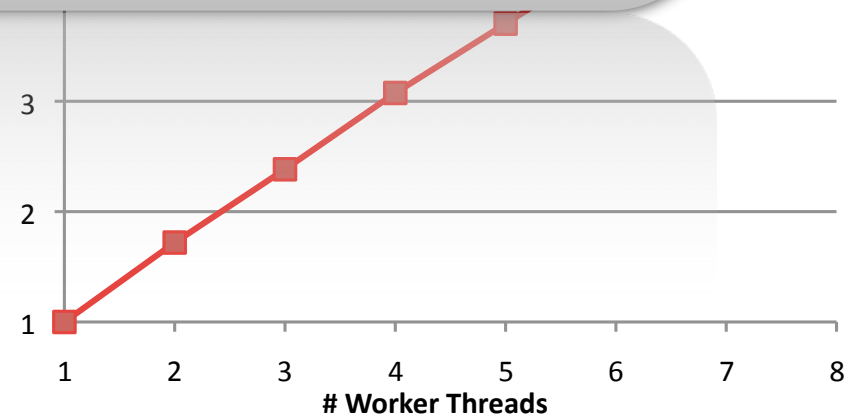
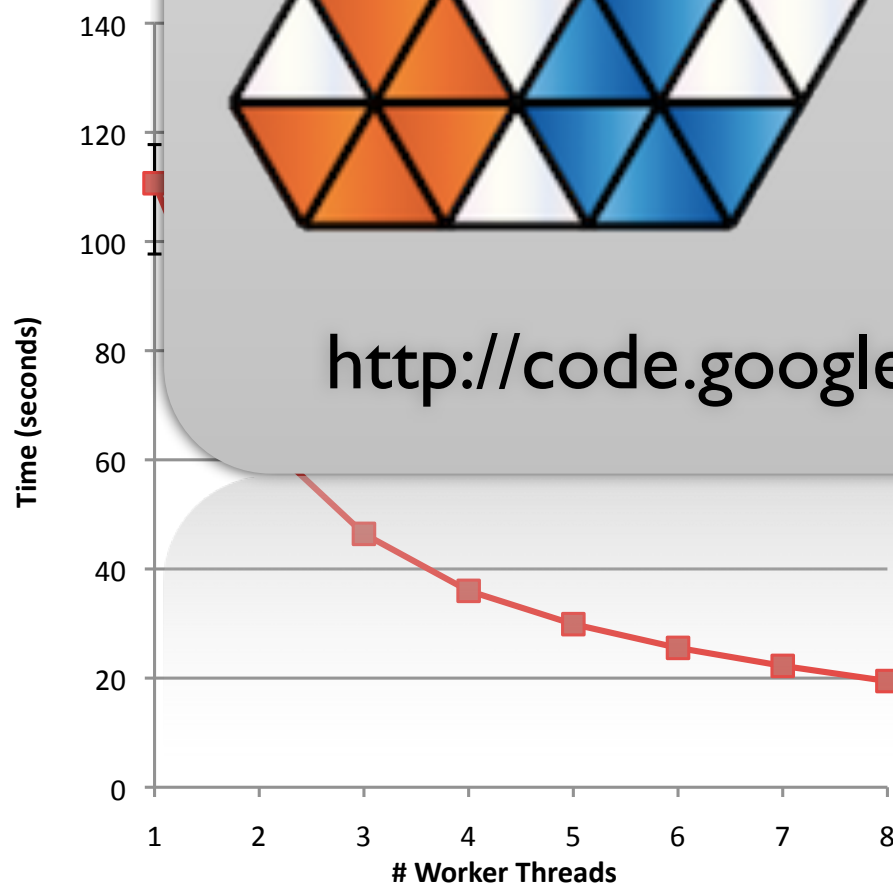
```
class Document(id: Any) extends Vertex(id, 0.15) {  
  def collect = 0.15 + 0.85 * signals[Double].foldLeft(0.0)(_ + _)  
}
```

```
class Citation(citer: Any, cited: Any) extends Edge(citer, cited) {  
  def signal = ... .sumOfOutWeights  
}
```



signal collect

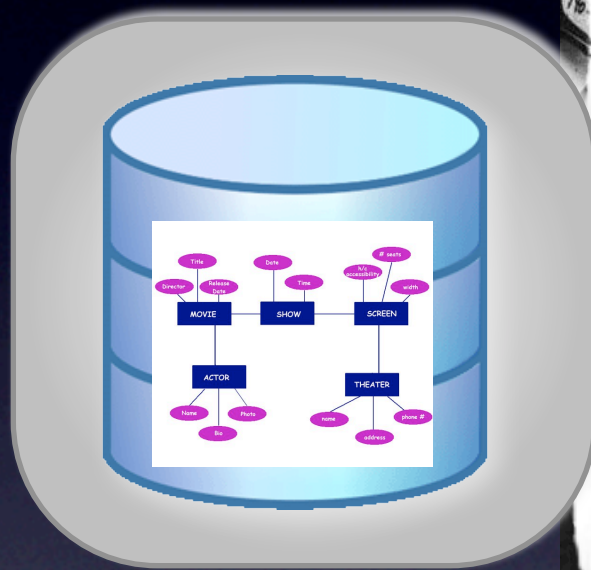
<http://code.google.com/p/signal-collect/>



Large Graph Storage

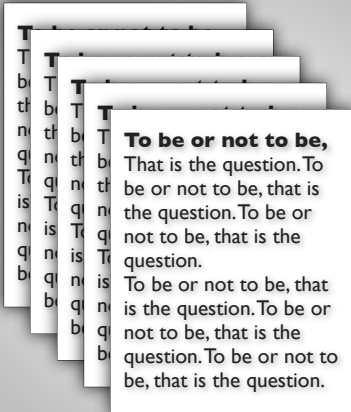


Large Graph Storage



The diagram illustrates a database system for a movie theater. The database is represented by a blue cylinder. Inside the cylinder is an Entity-Relationship (ER) diagram with the following components:

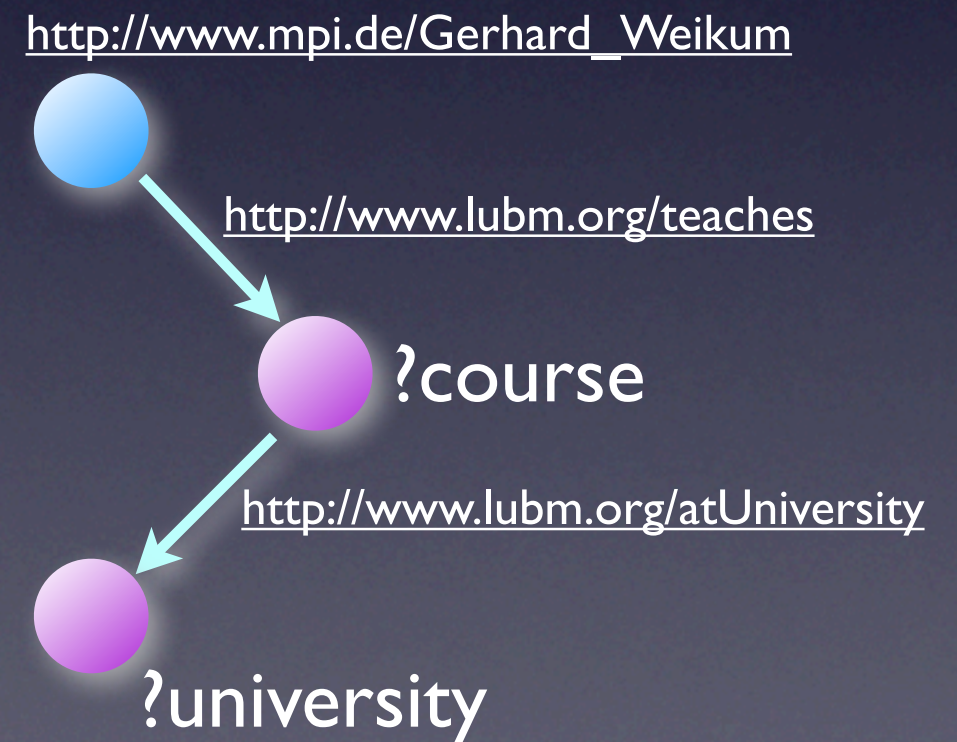
- Entities (Blue Rectangles):**
 - MOVIE**: Attributes include Title, Director, Release Date, and Genre.
 - SHOW**: Attributes include Date and Time.
 - SCREEN**: Attributes include Location, Room, and Show.
 - ACTOR**: Attributes include Name, Photo, and Bio.
 - THEATER**: Attributes include Name, Address, and Phone #.
- Relationships (Lines):**
 - A line connects **MOVIE** and **SHOW**.
 - A line connects **SHOW** and **SCREEN**.
 - A line connects **SCREEN** and **THEATER**.
 - A line connects **ACTOR** and **MOVIE**.



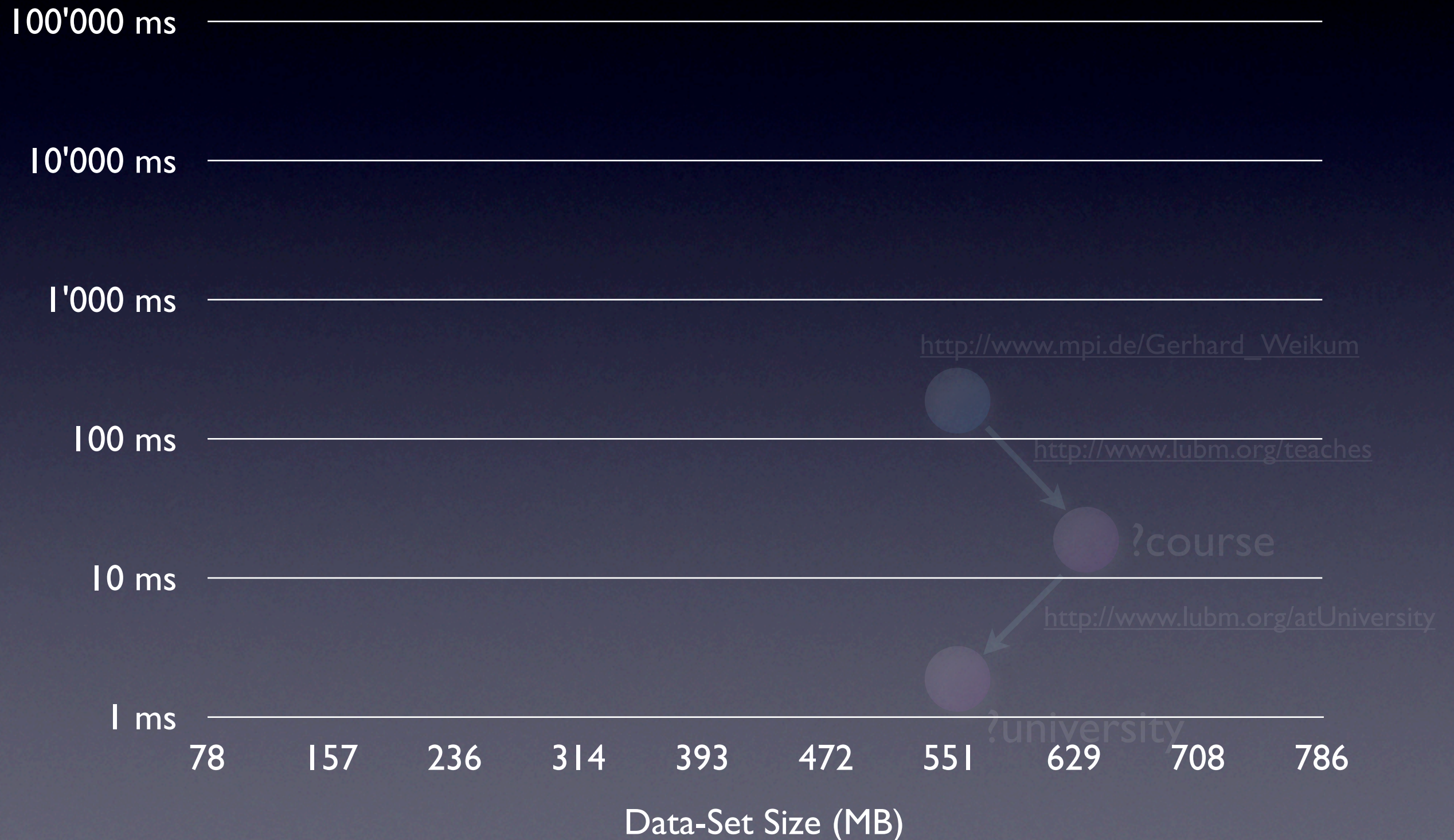
To be or not to be,
That is the question. To
be or not to be, that is
the question. To be or
not to be, that is the
question.

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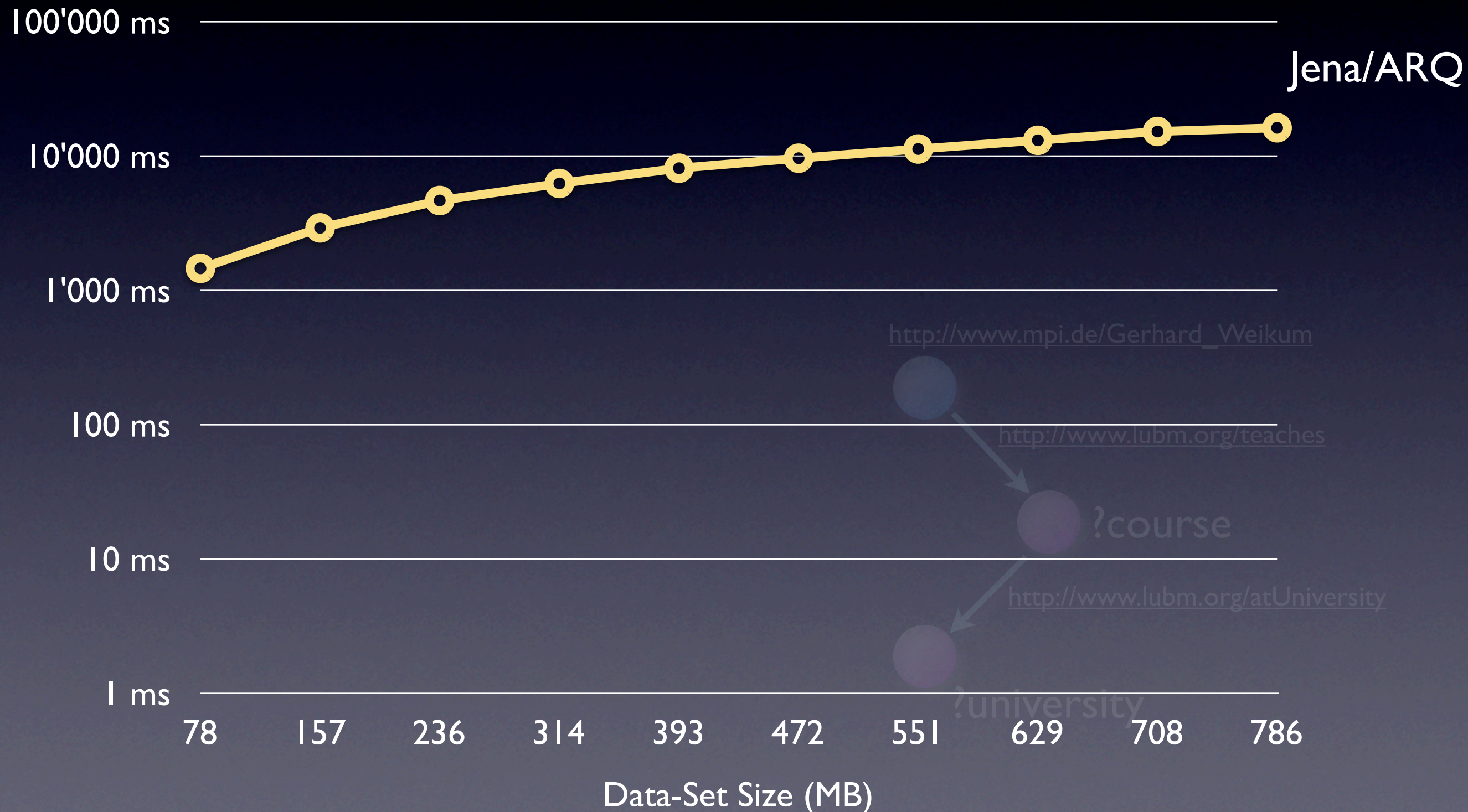
Querying Large Graphs (2007)



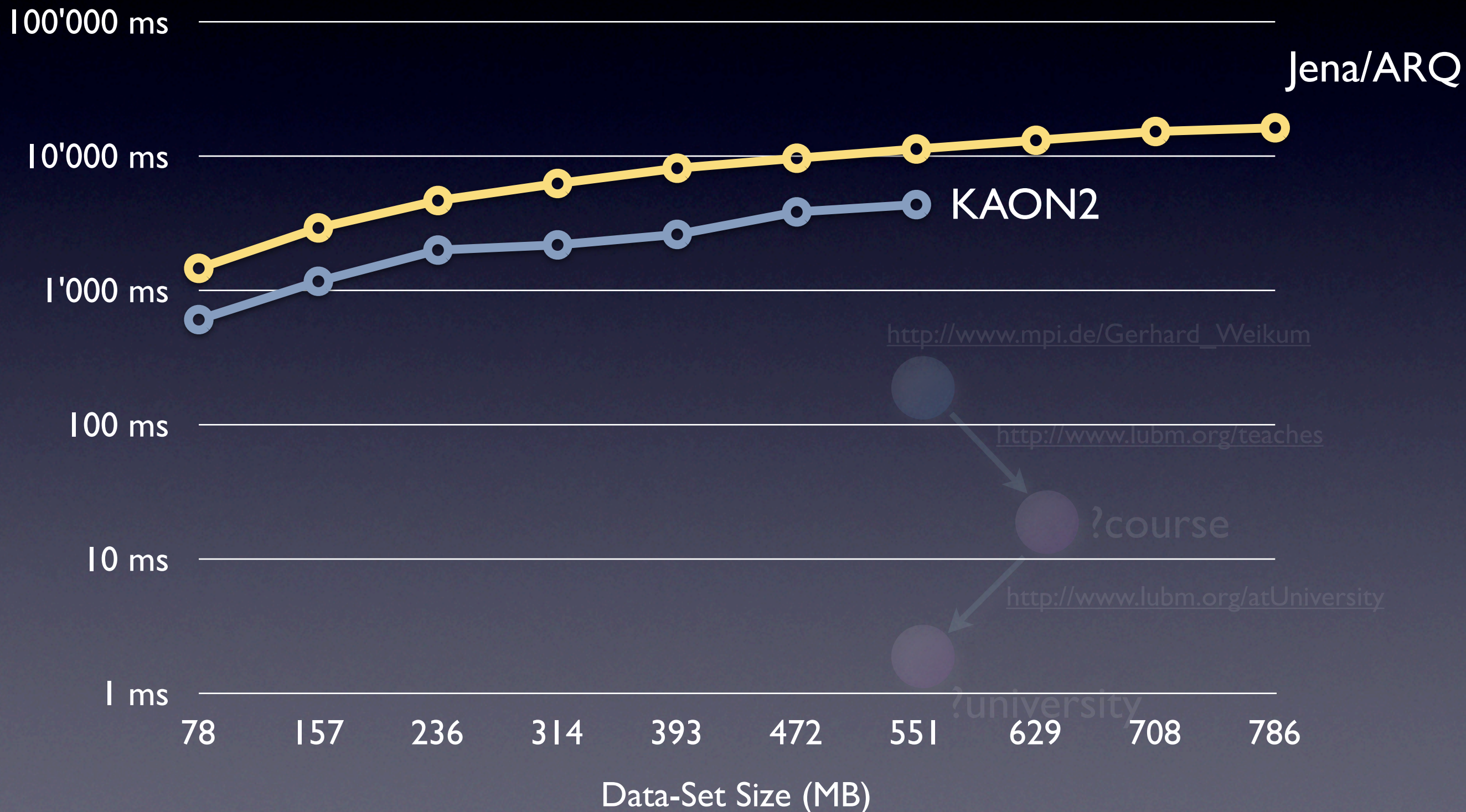
Querying Large Graphs (2007)



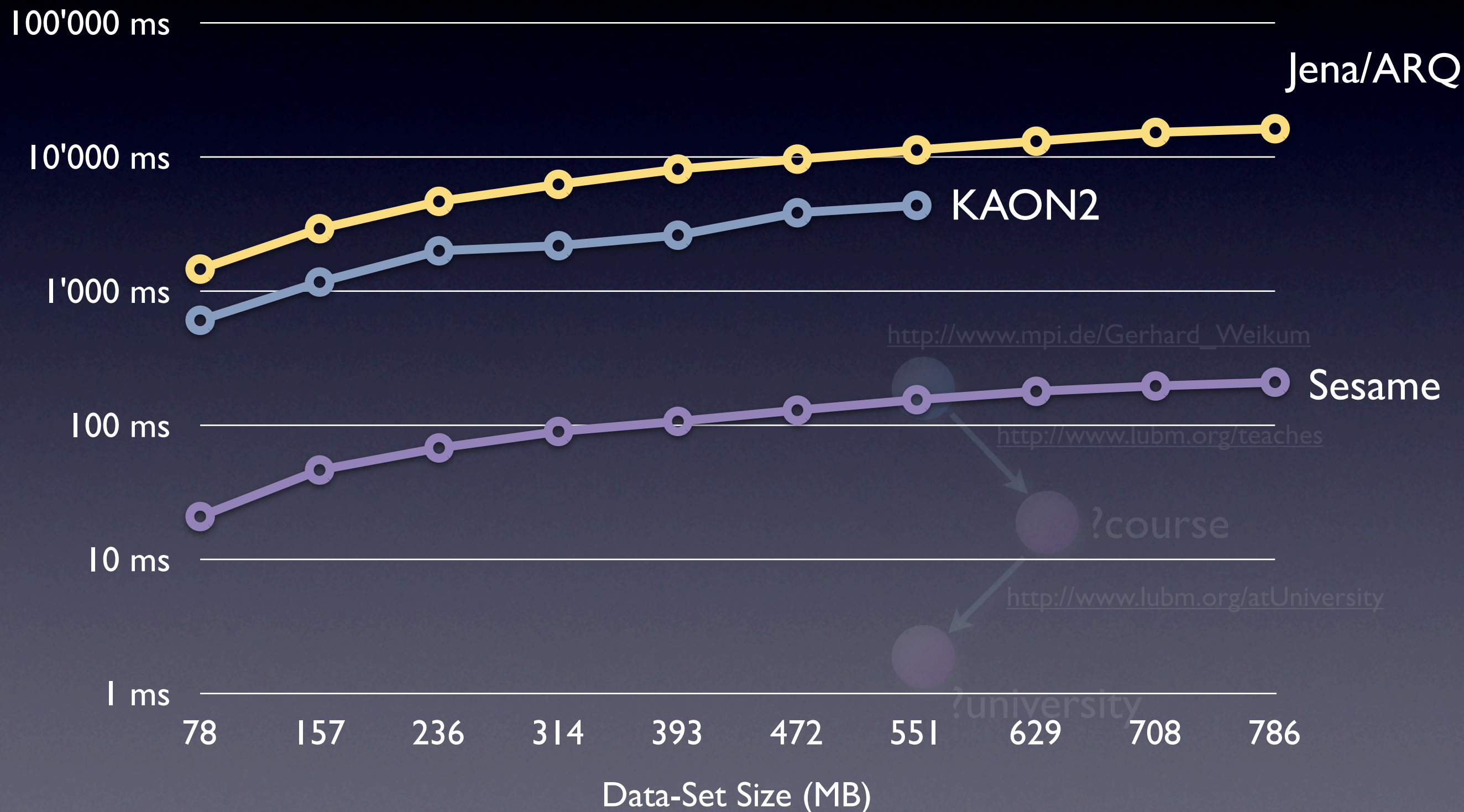
Querying Large Graphs (2007)



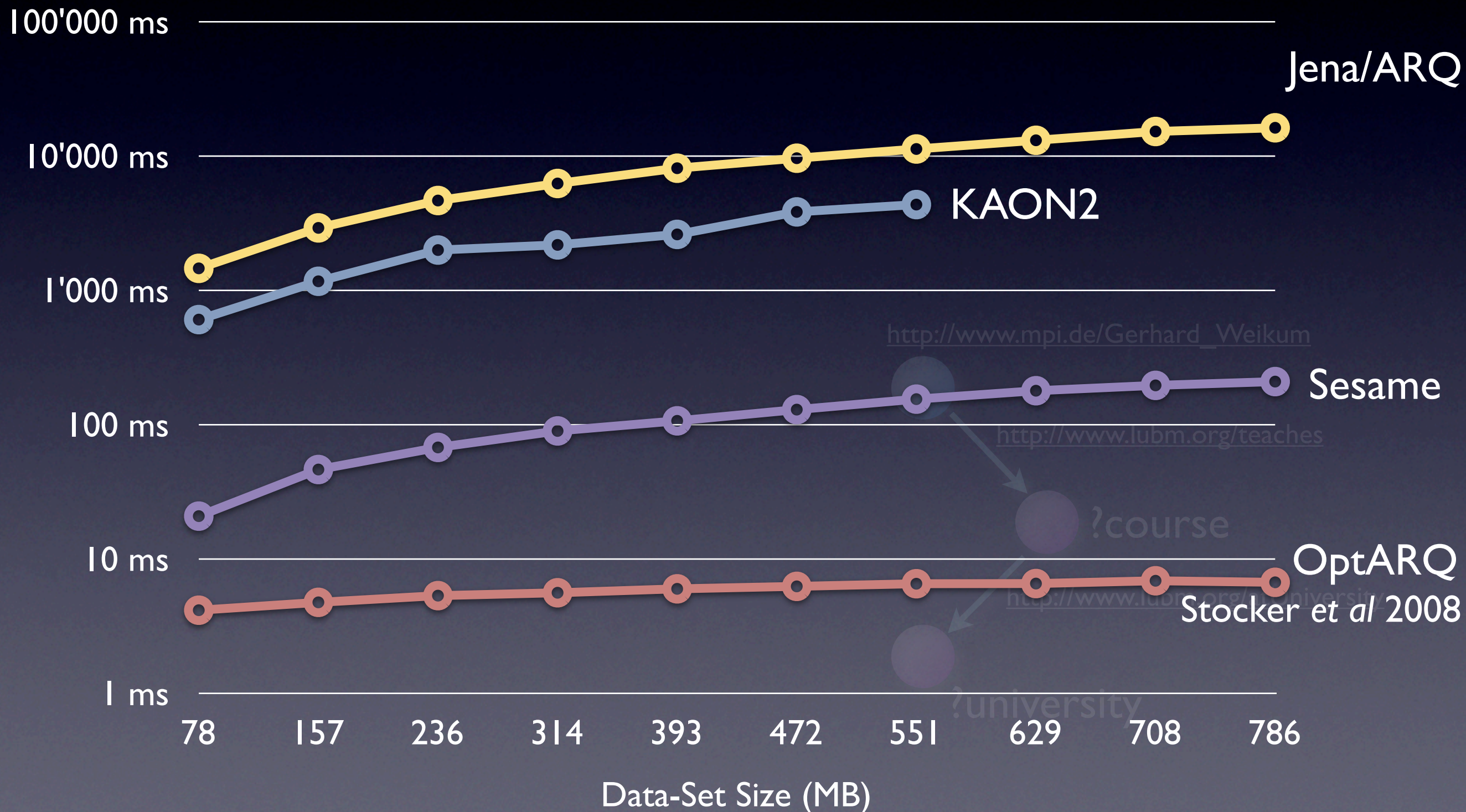
Querying Large Graphs (2007)



Querying Large Graphs (2007)



Querying Large Graphs (2007)



Querying Large Graphs on a first-generation iPhone



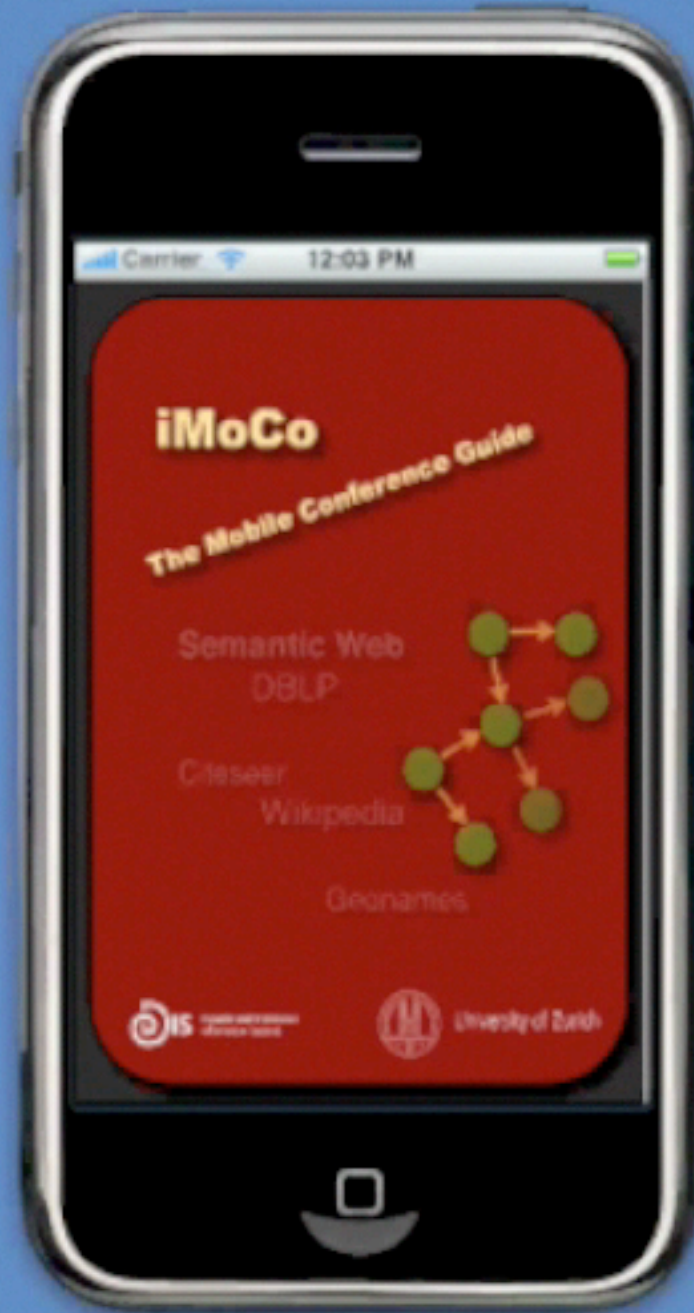
Querying Large Graphs on a first-generation iPhone

8 GB iPhone

9 GB raw data

~250 million triples

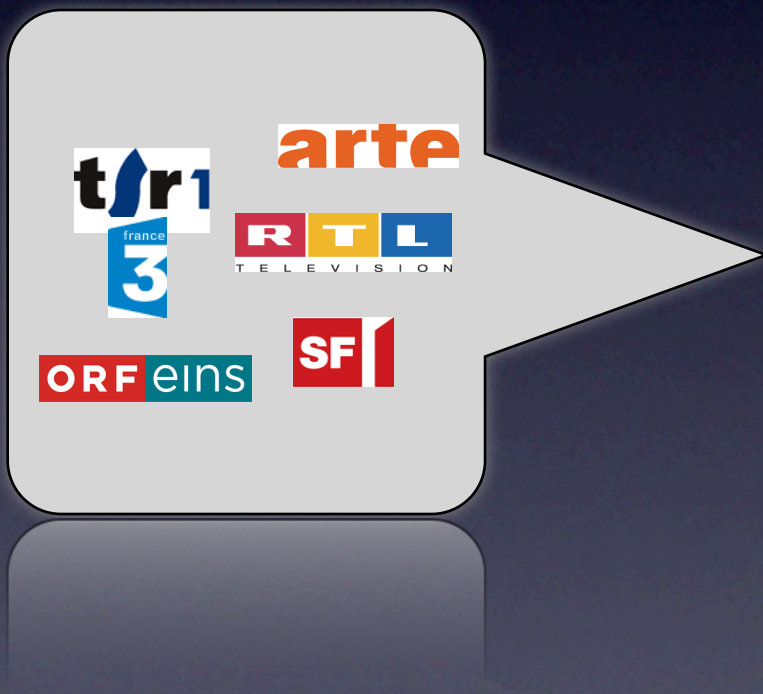
Real-time querying



Make Open **vista** Data

vista-tv.eu

Make Open **vistaTV** Data



vista-tv.eu

Make Open **vistaTV** Data



**signal
collect**

<http://code.google.com/p/signal-collect/>

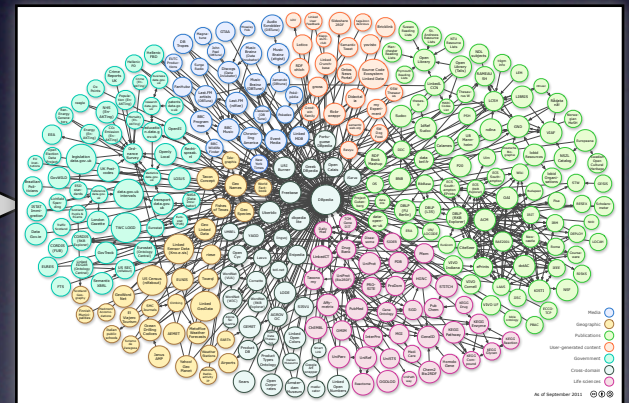
vista-tv.eu

Make Open **vistaTV** Data



**signal
collect**

<http://code.google.com/p/signal-collect/>



vista-tv.eu

So what do you need?



So what do you need?



RDF Processing

- Jena, Surf, ...
- BGL, ...
- Signal/Collect

So what do you need?



RDF Processing

- Jena, Surf, ...
- BGL, ...
- Signal/Collect



RDF Stores

- Sesame, Virtuoso, ...
- HBase, Cassandra, ...
- RDF Box



**University of
Zurich^{UZH}**



**Dynamic and Distributed
Information Systems**