

CC7220-1

LA WEB DE DATOS

PRIMAVERA 2018

LECTURE 10: RDB2RDF

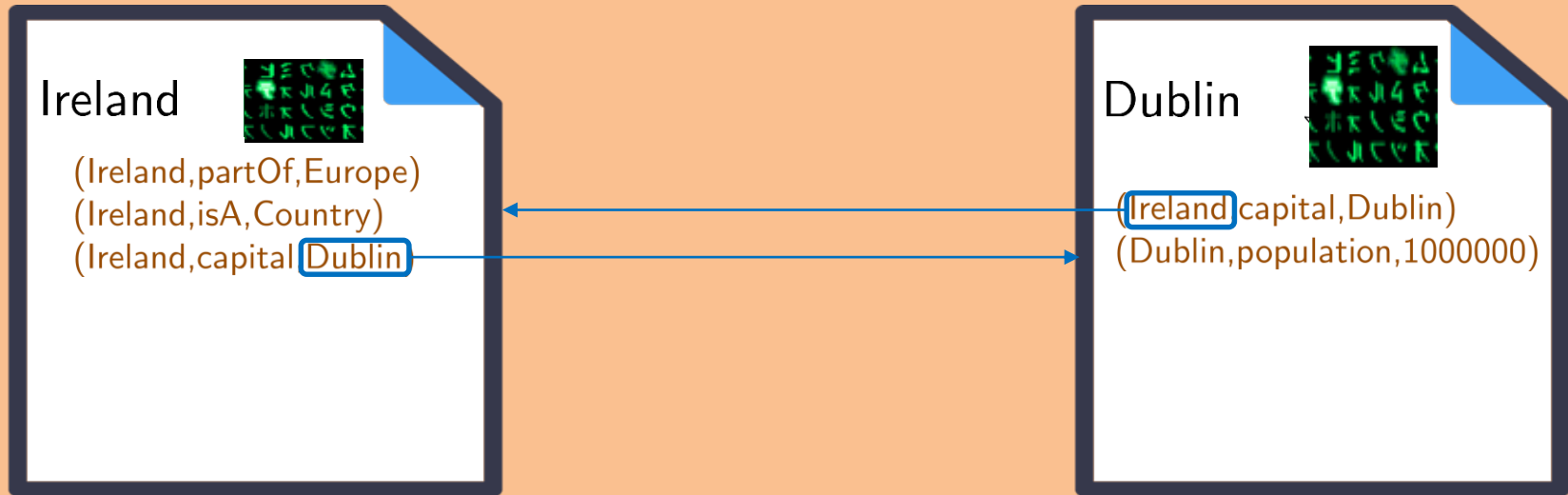
Aidan Hogan

aidhog@gmail.com

PREVIOUSLY ...

SEMANTIC WEB: DATA, LOGIC, QUERY, LINKS

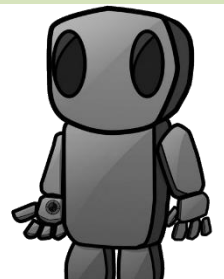
DATA:

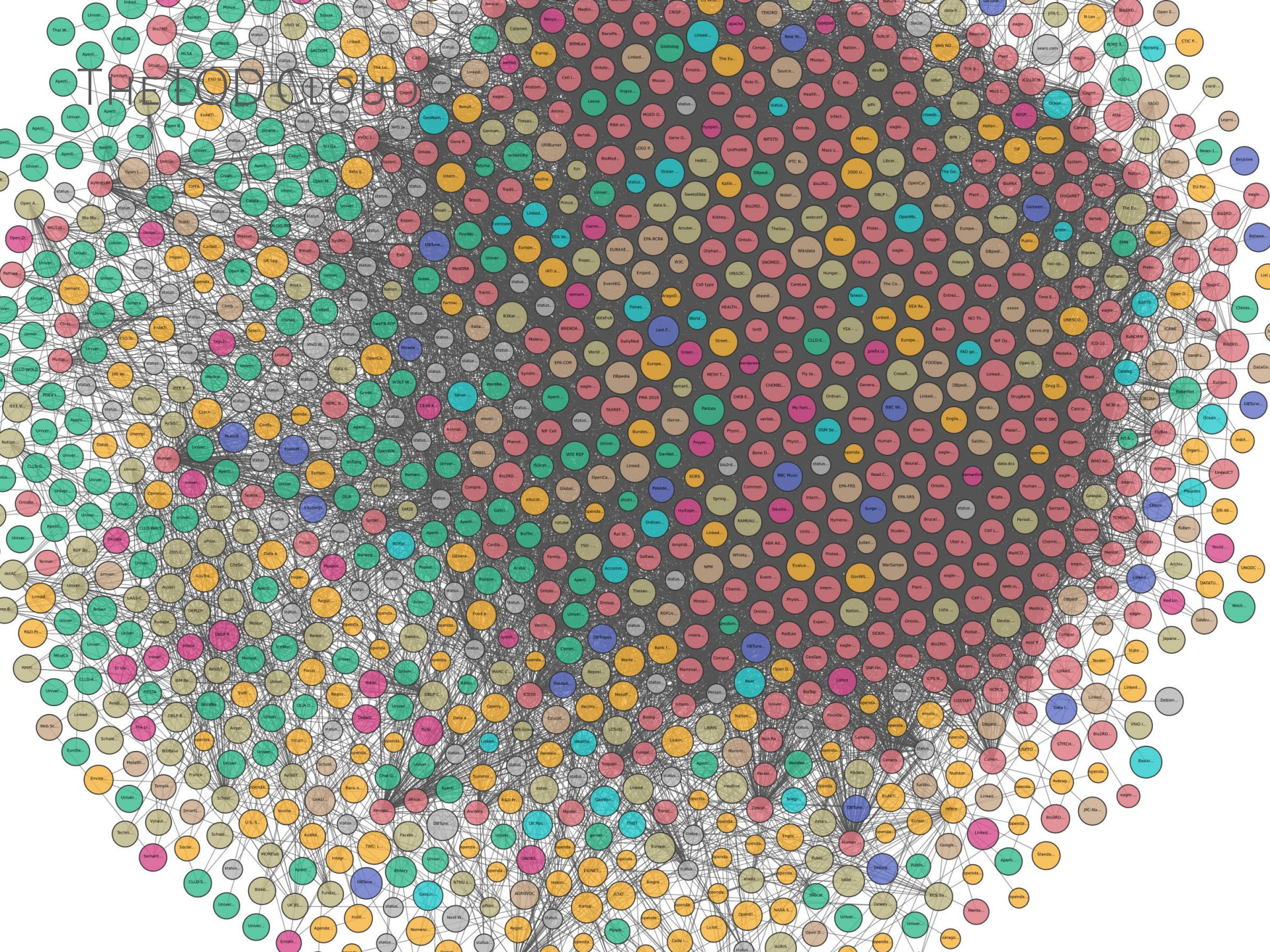


LOGIC: $“(b, \text{capital}, a) \rightarrow (a, \text{partOf}, b)”$
 $“(a, \text{partOf}, b), (b, \text{partOf}, c) \rightarrow (a, \text{partOf}, c)”$

QUERY: $“(x, \text{partOf}, y)?”$

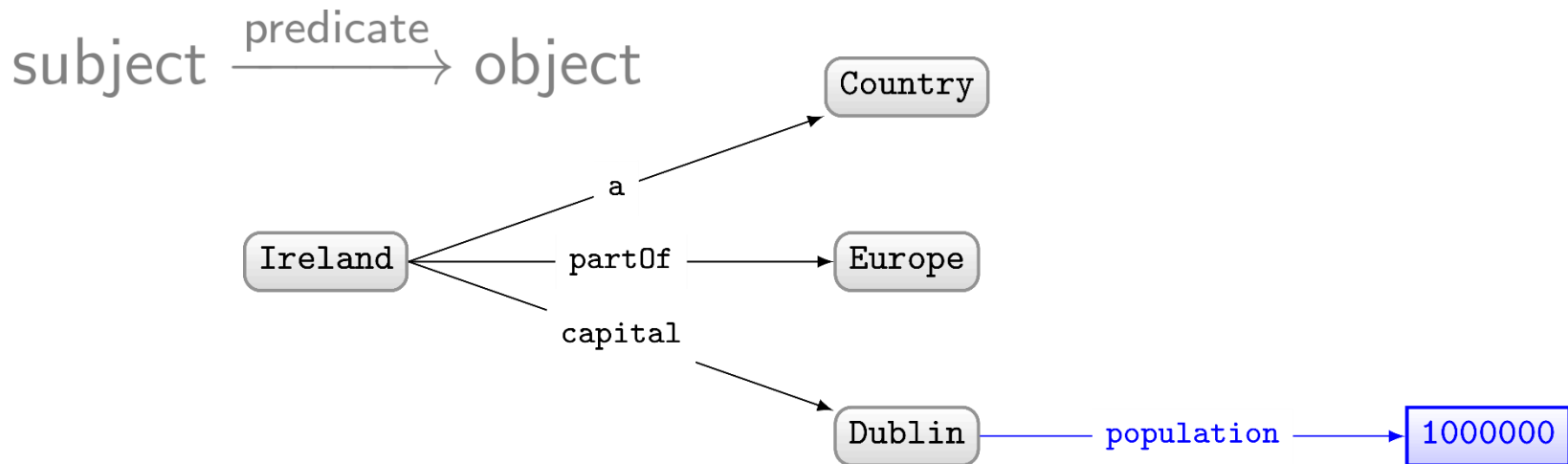
OUTPUT: $\{(x \mapsto \text{Ireland}, y \mapsto \text{Europe}),$
 $(x \mapsto \text{Dublin}, y \mapsto \text{Ireland}),$
 $(x \mapsto \text{Dublin}, y \mapsto \text{Europe})\}$





RDF: PROPOSED MODEL FOR A WEB OF DATA

<i>subject</i>	<i>predicate</i>	<i>object</i>
Ireland	partOf	Europe
Ireland	a	Country
Ireland	capital	Dublin
Dublin	population	1,000,000



RDF: PROPOSED MODEL FOR A WEB OF DATA

<i>subject</i>	<i>predicate</i>	<i>object</i>
Ireland	partOf	Europe
Ireland	capital	Dublin
Dublin	population	1,000,000

But where should this RDF come from?

Most legacy data on the Web not in RDF!

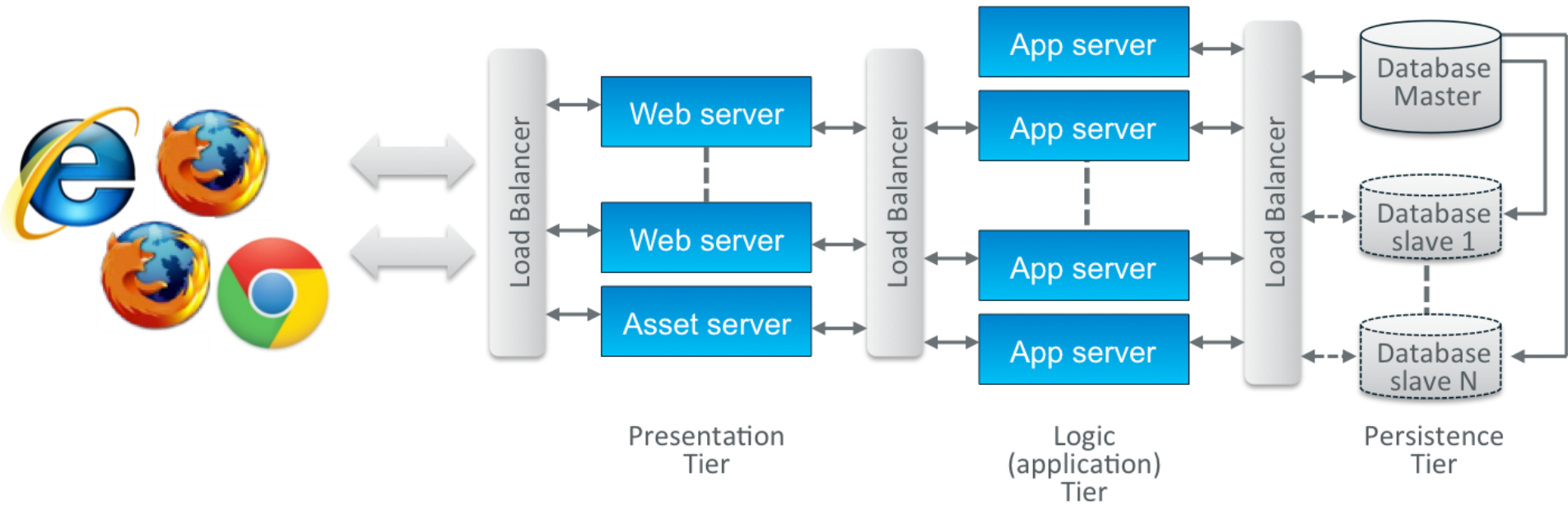


So what legacy formats are common on the Web?

LAMP: LINUX, APACHE, MYSQL, PHP



3-TIER WEB APPLICATIONS



DEEP WEB

Surface Web



Deep Web



LOTS OF DATA IN RELATIONAL DATABASES ...

[Ranking](#) > Complete Ranking

[RSS](#) [RSS Feed](#)

DB-Engines Ranking

The DB-Engines Ranking ranks database management systems according to their popularity. The ranking is updated monthly.

Read more about the [method](#) of calculating the scores.



348 systems in ranking, November 2018

Rank			DBMS	Database Model	Score		
Nov 2018	Oct 2018	Nov 2017			Nov 2018	Oct 2018	Nov 2017
1.	1.	1.	Oracle +	Relational DBMS	1301.11	-18.16	-58.94
2.	2.	2.	MySQL +	Relational DBMS	1159.89	-18.22	-162.14
3.	3.	3.	Microsoft SQL Server +	Relational DBMS	1051.55	-6.78	-163.53
4.	4.	4.	PostgreSQL +	Relational DBMS	440.24	+20.85	+60.33
5.	5.	5.	MongoDB +	Document store	369.48	+6.30	+39.01
6.	6.	6.	IBM Db2 +	Relational DBMS	179.87	+0.19	-14.19
7.	7.	↑ 9.	Redis +	Key-value store	144.17	-1.12	+22.99
8.	8.	↑ 10.	Elasticsearch +	Search engine	143.46	+1.13	+24.05
9.	9.	↓ 7.	Microsoft Access	Relational DBMS	138.44	+1.64	+5.12
10.	↑ 11.	↑ 11.	SQLite +	Relational DBMS	122.71	+5.96	+9.95

<http://db-engines.com/en/ranking>

LOTS OF DATA IN RELATIONAL DATABASES ...

Ranking > Complete Ranking

[RSS](#) [RSS Feed](#)

DB-Engines Ranking

The DB-Engines Ranking ranks database management systems according to their popularity. The ranking is updated monthly.

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Out of top 10 databases, 7 are relational databases.

November 2018

Rank			DBMS	Database Model	Score		
Nov 2018	Oct 2018	Nov 2017			Nov 2018	Oct 2018	Nov 2017
1.	1.	1.	Oracle +	Relational DBMS	1301.11	-18.16	-58.94
2.	2.	2.	MySQL +	Relational DBMS	1159.89	-18.22	-162.14
3.	3.	3.	Microsoft SQL Server +	Relational DBMS	1051.55	-6.78	-163.53
4.	4.	4.	PostgreSQL +	Relational DBMS	440.24	+20.85	+60.33
5.	5.	5.	MongoDB +	Document store	369.48	+6.30	+39.01
6.	6.	6.	Microsoft Access	Relational DBMS	130.44	+0.19	-14.19
7.	7.	7.	Microsoft Access	Relational DBMS	130.44	-1.12	+22.99
8.	8.	8.	Microsoft Access	Relational DBMS	130.44	+1.13	+24.05
9.	9.	9.	Microsoft Access	Relational DBMS	130.44	+1.64	+5.12
10.	↑ 11.	↑ 11.	SQLite +	Relational DBMS	122.71	+5.96	+9.95

Out of 348 databases, any idea in what position the first SPARQL engine would be?

<http://db-engines.com/en/ranking>

TOP SPARQL ENGINE IS ...

81.	↓ 79.	↓ 73.	Apache Drill	Multi-model ⓘ	2.85	-0.07	-0.07
82.	↑ 84.	↓ 75.	Graphite	Time Series DBMS	2.85	+0.04	-0.01
83.	↓ 74.	↑ 86.	Amazon CloudSearch	Search engine	2.75	-0.33	+0.39
84.	↓ 83.	↓ 74.	PouchDB	Document store	2.75	-0.06	-0.16
85.	85.	↓ 69.	RRDtool	Time Series DBMS	2.73	+0.05	-0.47
86.	↑ 95.	↓ 84.	TimesTen ⓘ	Relational DBMS	2.62	+0.35	+0.04
87.	↓ 86.	↑ 95.	LevelDB	Key-value store	2.59	+0.01	+0.57
88.	88.	88.	Apache Jena - TDB	RDF store	2.45	-0.05	+0.16
89.	↑ 92.	↓ 81.	SAP Advantage Database Server	Relational DBMS	2.40	+0.07	-0.27
90.	↓ 89.	90.	OmniSci ⓘ	Relational DBMS	2.40	-0.04	+0.17
91.	↑ 97.	↑ 97.	Virtuoso ⓘ	Multi-model ⓘ	2.37	+0.18	+0.49
92.	↓ 87.	↓ 87.	Infinispan	Key-value store	2.36	-0.20	+0.04
93.	↓ 90						
94.	94						
95.	↓ 91						
96.	↓ 93						
97.	↓ 96						
98.	↑ 100						
99.	99						
100.	↑ 104						



RDB₂RDF:

RELATIONAL DATABASES TO RDF

SOME RELATIONAL TABLES ABOUT PLANETS ...

Planet							
<u>name</u>	dist	radius	grav	day	year	temp	ring
Mercury	0.39	0.38	2.8	58.646	0.241	440	false
Venus	0.72	0.95	8.9	-243.019	0.615	730	false
Earth	1.00	1.00	9.8	0.997	1.000	288	false
Mars	1.52	0.53	3.7	1.026	1.880	186	false
Jupiter	5.20	10.97	22.9	0.414	11.862	152	true
Saturn	9.54	9.14	9.1	0.444	29.447	134	true
Uranus	19.19	3.98	7.8	-0.719	84.017	76	true
Neptune	30.07	3.86	11.0	0.671	164.791	53	true

Moon			
<u>name</u>	pname	discoverer	year
Luna	Earth	⊥	⊥
Ganymedes	Jupiter	Galileo Galilei	1610
Calisto	Jupiter	Galileo Galilei	1610
Europa	Jupiter	Galileo Galilei	1610
Io	Jupiter	Galileo Galilei	1610
Titan	Saturn	Christiaan Huygens	1655
Triton	Neptune	William Lassell	1846

Landing			
<u>ship</u>	pname	country	year
Messenger	Mercury	US	2015
Venera 3	Venus	USSR	1966
Pioneer	Venus	US	1978
Mars 2 lander	Ma	USSR	1971
Viking 1	Mars	US	1976
Beagle 2	Mars	EU	2003
Galileo	Jupiter	US	2003

MEANWHILE ON PLUTO ...



RDB₂RDF?

Planet							
<u>name</u>	dist	radius	grav	day	year	temp	ring
Mercury	0.39	0.38	2.8	58.646	0.241	440	false
Venus	0.72	0.95	8.9	-243.019	0.615	730	false
Earth	1.00	1.00	9.8	0.997	1.000	288	false
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Neptune	30.07	3.86	11.0	0.671	164.791	53	true

How might we automatically convert this table to RDF?

DIRECT MAPPING:

AUTOMATIC RDB2RDF MAPPING



A Direct Mapping of Relational Data to RDF

W3C Recommendation 27 September 2012

This version:

<http://www.w3.org/TR/2012/REC-rdb-direct-mapping-20120927/>

Latest version:

<http://www.w3.org/TR/rdb-direct-mapping/>

Previous version:

<http://www.w3.org/TR/2012/PR-rdb-direct-mapping-20120814/>

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Eric Prud'hommeaux, W3C [<eric@w3.org>](mailto:eric@w3.org)

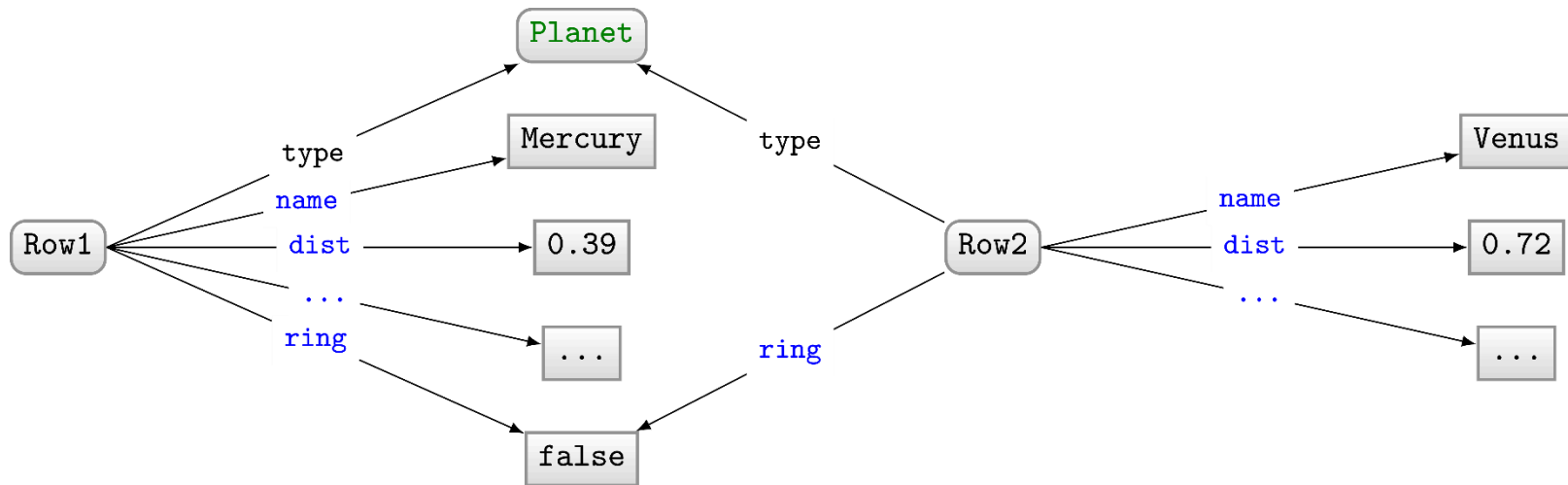
Juan Sequeda, University of Texas at Austin [<jsequeda@cs.utexas.edu>](mailto:jsequeda@cs.utexas.edu)

Please refer to the [errata](#) for this document, which may include some normative corrections.

See also [translations](#).

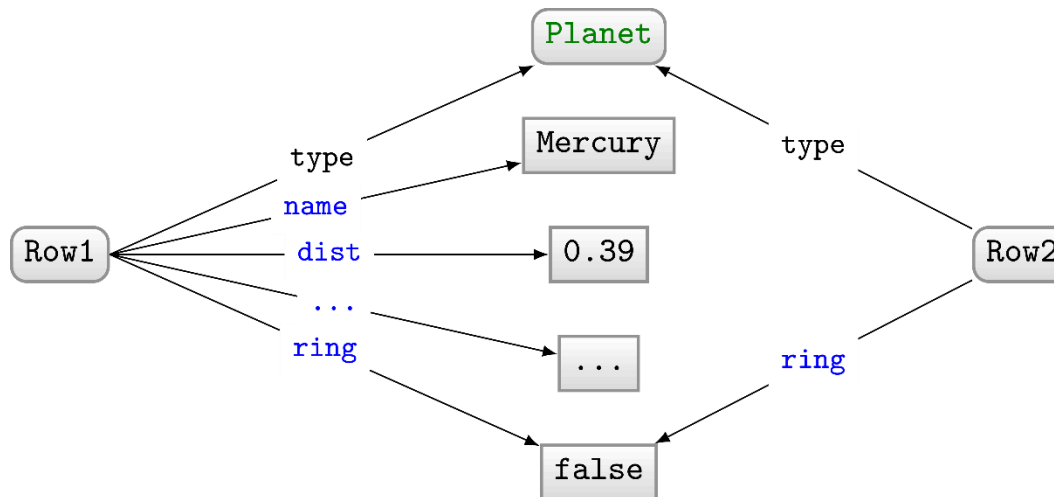
DIRECT MAPPING

Planet							
<u>name</u>	dist	radius	grav	day	year	temp	ring
Mercury	0.39	0.38	2.8	58.646	0.241	440	false
Venus	0.72	0.95	8.9	-243.019	0.615	730	false
Earth	1.00	1.00	9.8	0.997	1.000	288	false
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DIRECT MAPPING

Planet							
<u>name</u>	dist	radius	grav	day	year	temp	ring
Mercury	0.39	0.38	2.8	58.646	0.241	440	false
Venus	0.72	0.95	8.9	-243.019	0.615	730	false
Earth	1.00	1.00	9.8	0.997	1.000	288	false
Mars	1.52	0.53	3.7	1.026	1.880	186	false
Jupiter	5.20	10.97	22.9	0.414	11.862	152	true
Saturn	9.54	9.14	9.1	0.444	29.447	134	true
Uranus	19.19	3.98	7.8	-0.719	84.017	76	true
Neptune	30.07	3.86	11.0	0.671	164.791	53	true



Each table name is a **type**
Each row is a subject
Each attribute a **predicate**
Each value an object

But what about RDF terms
(IRIs/literals/blank nodes)?

DIRECT MAPPING: IDENTIFYING ROWS

Planet							
name	dist	radius	grav	day	year	temp	ring
Mercury	0.39	0.38	2.8	58.646	0.241	440	false
Venus	0.72	0.95	8.9	-243.019	0.615	730	false
Earth	1.00	1.00	9.8	0.997	1.000	288	false
Mars	1.52	0.53	3.7	1.026	1.880	186	false
Jupiter	5.20	10.97	22.9	0.414	11.862	152	true
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Neptune	30.07	3.86	11.0	0.671	164.791	53	true

How can we identify Row1?

- If the table has a **primary key** (pk_1, \dots, pk_n):
 - <http://ex.org/TableName/pk1=v1;...;pkn=vn>
 - (Base IRI <http://ex.org/> given as input)
- If not: use a fresh blank node.

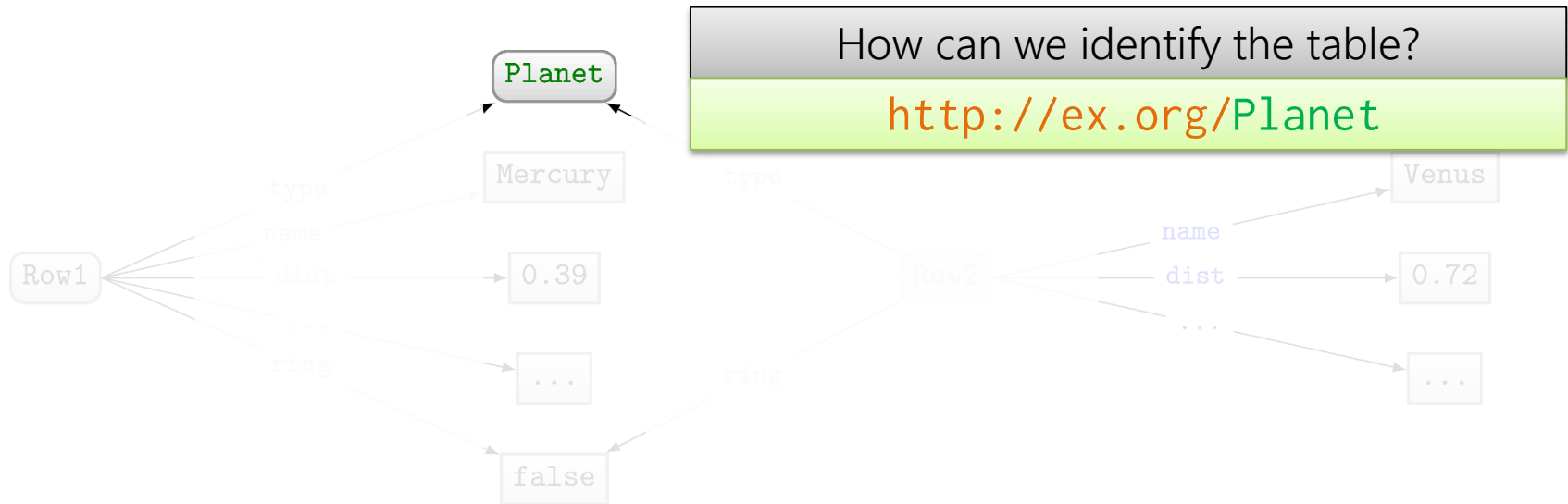
Row1

So Row1 would be ...?

<http://ex.org/Planet/name=Mercury>

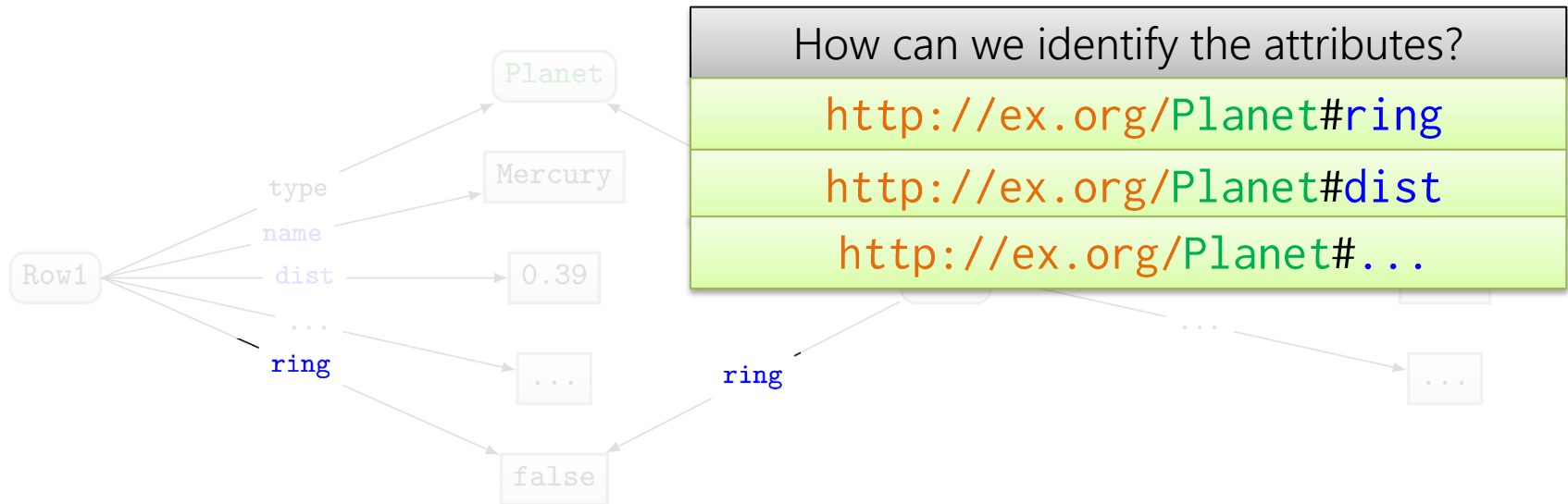
DIRECT MAPPING: IDENTIFYING TABLES

Planet							
name	dist	radius	grav	day	year	temp	ring
Mercury	0.39	0.38	2.8	58.646	0.241	440	false
Venus	0.72	0.95	8.9	-243.019	0.615	730	false
Earth	1.00	1.00	9.8	0.997	1.000	288	false
Mars	1.52	0.53	3.7	1.026	1.880	186	false
Jupiter	5.20	10.97	22.9	0.414	11.862	152	true
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Uranus	19.19	3.98	7.8	-0.719	84.017	76	true
Neptune	30.07	3.86	11.0	0.671	164.791	53	true



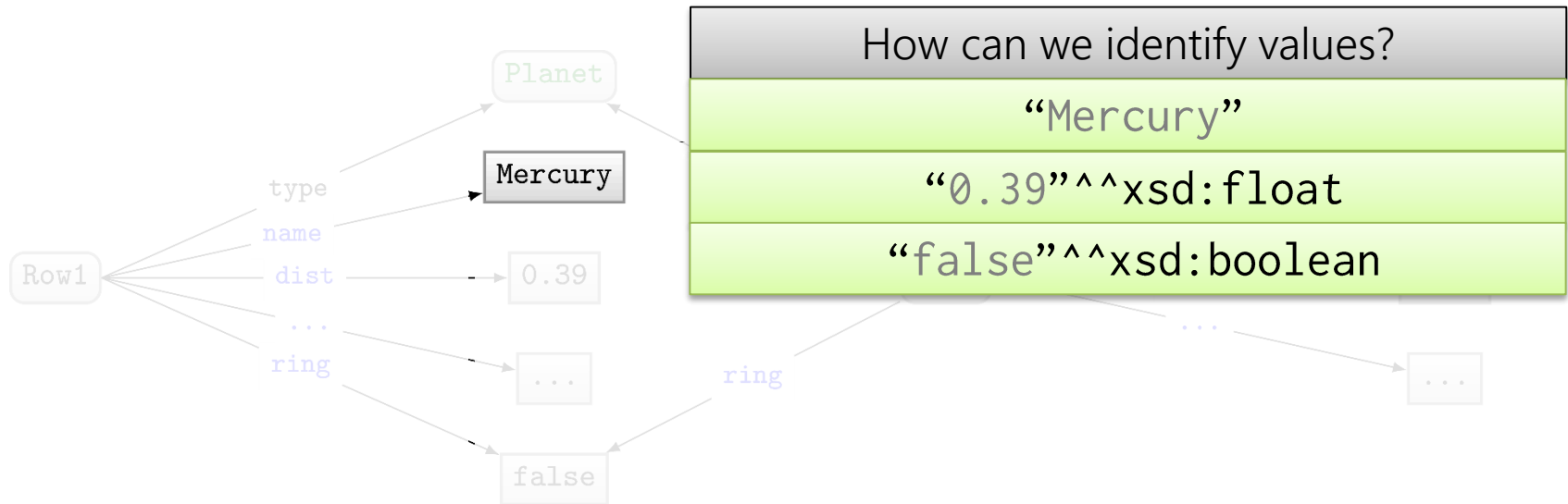
DIRECT MAPPING: IDENTIFYING COLUMNS

Planet							
<u>name</u>	dist	radius	grav	day	year	temp	ring
Mercury	0.39	0.38	2.8	58.646	0.241	440	false
Venus	0.72	0.95	8.9	-243.019	0.615	730	false
Earth	1.00	1.00	9.8	0.997	1.000	288	false
Mars	1.52	0.53	3.7	1.026	1.880	186	false
Jupiter	5.20	10.97	22.9	0.414	11.862	152	true
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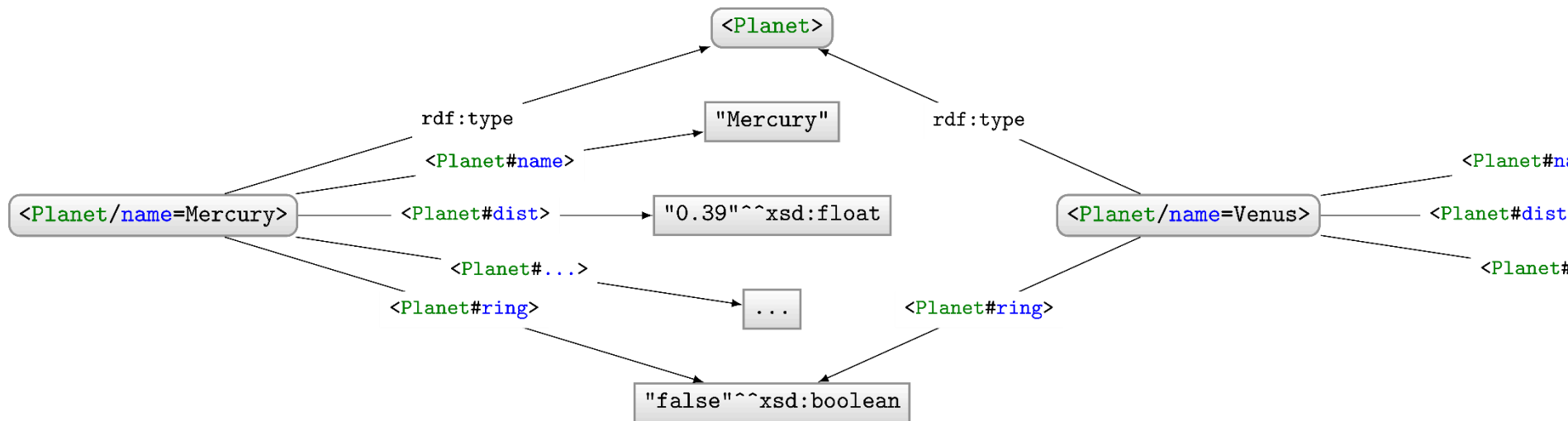
DIRECT MAPPING: IDENTIFYING VALUES

Planet							
<u>name</u>	<u>dist</u>	<u>radius</u>	<u>grav</u>	<u>day</u>	<u>year</u>	<u>temp</u>	<u>ring</u>
Mercury	0.39	0.38	2.8	58.646	0.241	440	false
Venus	0.72	0.95	8.9	-243.019	0.615	730	false
Earth	1.00	1.00	9.8	0.997	1.000	288	false
Mars	1.52	0.53	3.7	1.026	1.880	186	false
Jupiter	5.20	10.97	22.9	0.414	11.862	152	true
Saturn	9.54	9.14	9.1	0.444	29.447	134	true
Uranus	19.19	3.98	7.8	-0.719	84.017	76	true
Neptune	30.07	3.86	11.0	0.671	164.791	53	true



DIRECT MAPPING: FINAL RDF

Planet							
name	dist	radius	grav	day	year	temp	ring
Mercury	0.39	0.38	2.8	58.646	0.241	440	false
Venus	0.72	0.95	8.9	-243.019	0.615	730	false
Earth	1.00	1.00	9.8	0.997	1.000	288	false
Mars	1.52	0.53	3.7	1.026	1.880	186	false
Jupiter	5.20	10.97	22.9	0.414	11.862	152	true
Saturn	9.54	9.14	9.1	0.444	29.447	134	true
Uranus	19.19	3.98	7.8	-0.719	84.017	76	true
Neptune	30.07	3.86	11.0	0.671	164.791	53	true



```

@base : <http://ex.org/>.
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>.
@prefix xsd: <http://www.w3.org/2001/XMLSchema#>.
    
```

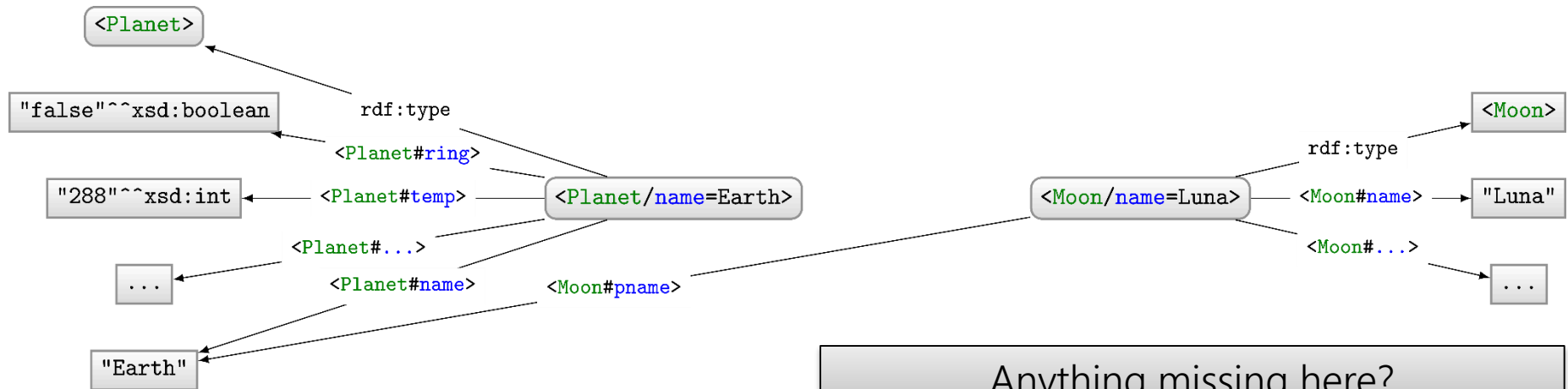
DIRECT MAPPING: MULTIPLE TABLES

Planet

name	dist	radius	grav	day	year	temp	ring
Mercury	0.39	0.38	2.8	58.646	0.241	440	false
Venus	0.72	0.95	8.9	-243.019	0.615	730	false
Earth	1.00	1.00	9.8	0.997	1.000	288	false
Mars	1.52	0.53	3.7	1.026	1.880	186	false
Jupiter	5.20	10.97	22.9	0.414	11.862	152	true
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Uranus	19.19	3.98	7.8	-0.719	84.017	76	true
Neptune	30.07	3.86	11.0	0.671	164.791	53	true

Moon

name	pname	discoverer	year
Luna	Earth	⊥	⊥
Ganymedes	Jupiter	Galileo Galilei	1610
Calisto	Jupiter	Galileo Galilei	1610
Europa	Jupiter	Galileo Galilei	1610
Io	Jupiter	Galileo Galilei	1610
Titan	Saturn	Christiaan Huygens	1655
Triton	Neptune	William Lassell	1846



Anything missing here?

If we assume that `pname` is a foreign key for `Planet.name`, then ...

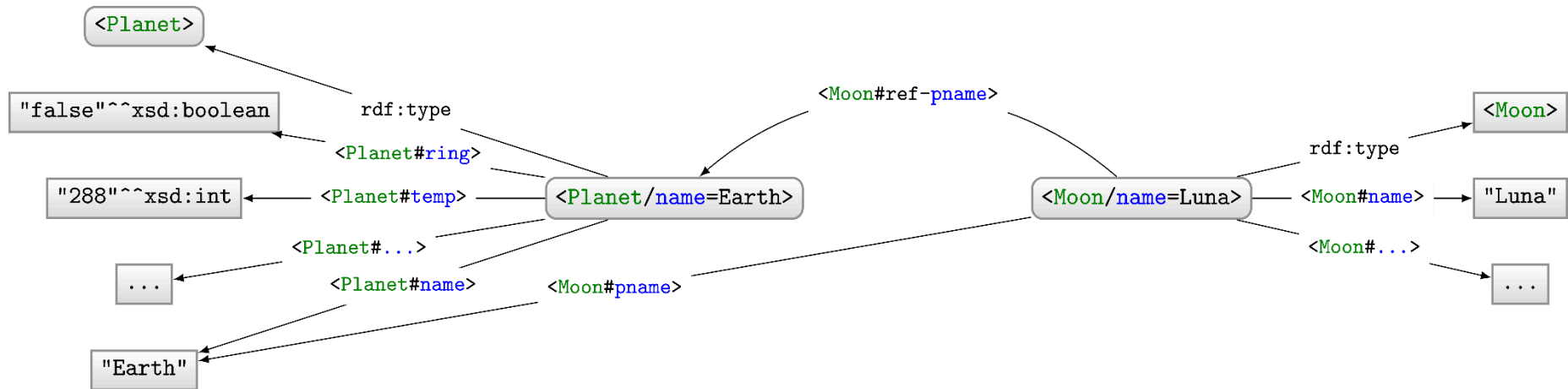
DIRECT MAPPING: FOREIGN KEY REFERENCES

Planet

name	dist	radius	grav	day	year	temp	ring
Mercury	0.39	0.38	2.8	58.646	0.241	440	false
Venus	0.72	0.95	8.9	-243.019	0.615	730	false
Earth	1.00	1.00	9.8	0.997	1.000	288	false
Mars	1.52	0.53	3.7	1.026	1.880	186	false
Jupiter	5.20	10.97	22.9	0.414	11.862	152	true
Saturn	9.54	9.14	9.1	0.444	29.447	134	true
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Moon

name	pname	discoverer	year
Luna	Earth	⊥	⊥
Ganymedes	Jupiter	Galileo Galilei	1610
Calisto	Jupiter	Galileo Galilei	1610
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Io	Jupiter	Galileo Galilei	1610
Titan	Saturn	Christiaan Huygens	1655
Triton	Neptune	William Lassell	1846



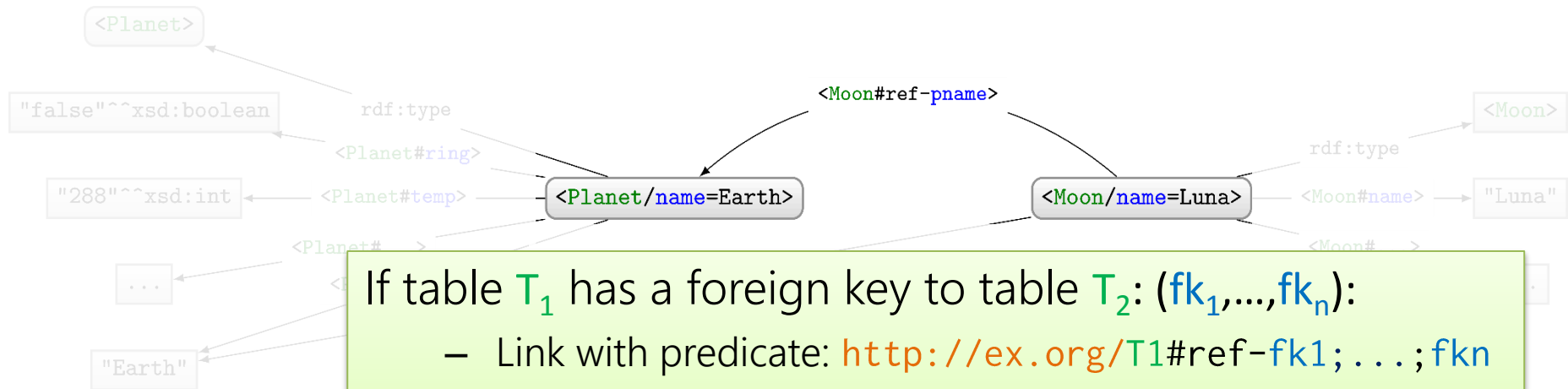
DIRECT MAPPING: FOREIGN KEY REFERENCES

Planet

name	dist	radius	grav	day	year	temp	ring
Mercury	0.39	0.38	2.8	58.646	0.241	440	false
Venus	0.72	0.95	8.9	-243.019	0.615	730	false
Earth	1.00	1.00	9.8	0.997	1.000	288	false
Mars	1.52	0.53	3.7	1.026	1.880	186	false
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Neptune	30.07	3.86	11.0	0.671	164.791	53	true

Moon

name	pname	discoverer	year
Luna	Earth	⊥	⊥
Ganymedes	Jupiter	Galileo Galilei	1610
Calisto	Jupiter	Galileo Galilei	1610
Europa	Jupiter	Galileo Galilei	1610
Io	Jupiter	Galileo Galilei	1610
Titan	Saturn	Christiaan Huygens	1655
Triton	Neptune	William Lassell	1846



If table T_1 has a foreign key to table T_2 : (fk_1, \dots, fk_n) :

- Link with predicate: `http://ex.org/T1#ref-fk1; ... ; fkn`
- (Base IRI `http://ex.org/` given as input)

Example: `http://ex.org/Moon#ref-pname`

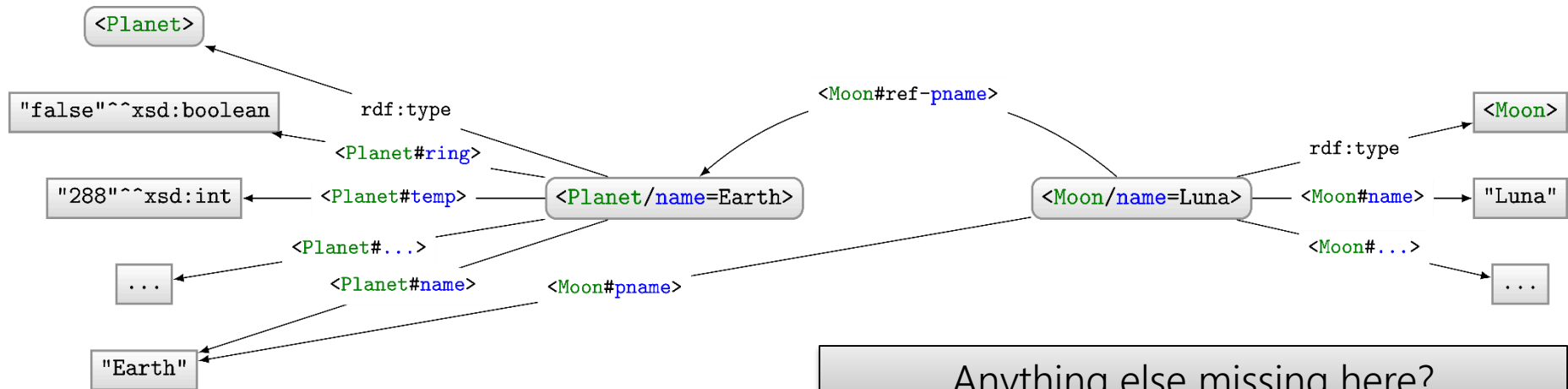
DIRECT MAPPING

Planet

name	dist	radius	grav	day	year	temp	ring
Mercury	0.39	0.38	2.8	58.646	0.241	440	false
Venus	0.72	0.95	8.9	-243.019	0.615	730	false
Earth	1.00	1.00	9.8	0.997	1.000	288	false
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Moon

name	pname	discoverer	year
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Ganimesdes	Jupiter	Galileo Galilei	1610
Calisto	Jupiter	Galileo Galilei	1610
Europa	Jupiter	Galileo Galilei	1610
Io	Jupiter	Galileo Galilei	1610
Titan	Saturn	Christiaan Huygens	1655
Triton	Neptune	William Lassell	1846



Anything else missing here?
 What should we do with NULL (⊥)??

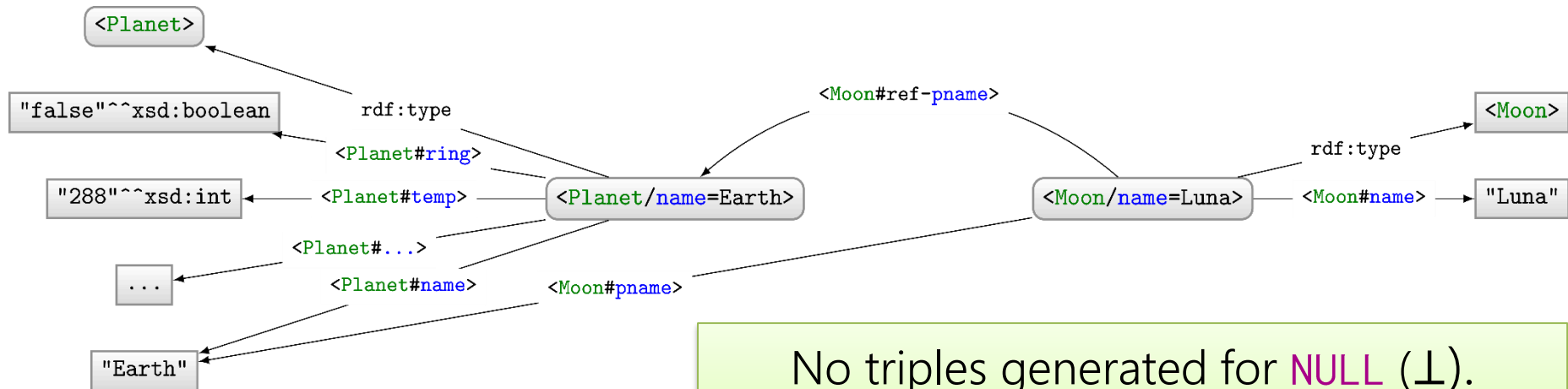
DIRECT MAPPING: NULL (\perp)

Planet

name	dist	radius	grav	day	year	temp	ring
Mercury	0.39	0.38	2.8	58.646	0.241	440	false
Venus	0.72	0.95	8.9	-243.019	0.615	730	false
Earth	1.00	1.00	9.8	0.997	1.000	288	false
Mars	1.52	0.53	3.7	1.026	1.880	186	false
Jupiter	5.20	10.97	22.9	0.414	11.862	152	true
Saturn	9.54	9.14	9.1	0.444	29.447	134	true
Uranus	19.19	3.98	7.8	-0.719	84.017	76	true
Neptune	30.07	3.86	11.0	0.671	164.791	53	true

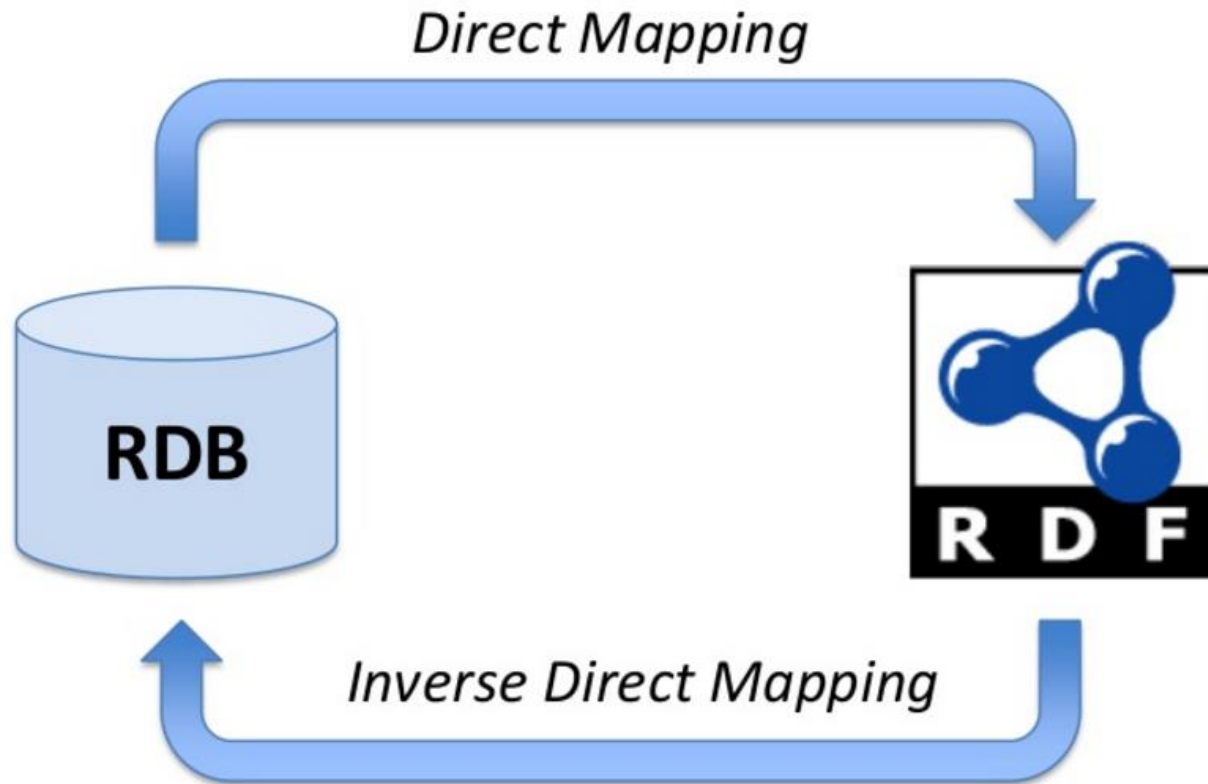
Moon

name	pname	discoverer	year
Luna	Earth	\perp	\perp
Ganimesdes	Jupiter	Galileo Galilei	1610
Calisto	Jupiter	Galileo Galilei	1610
Europa	Jupiter	Galileo Galilei	1610
Io	Jupiter	Galileo Galilei	1610
Titan	Saturn	Christiaan Huygens	1655
Triton	Neptune	William Lassell	1846

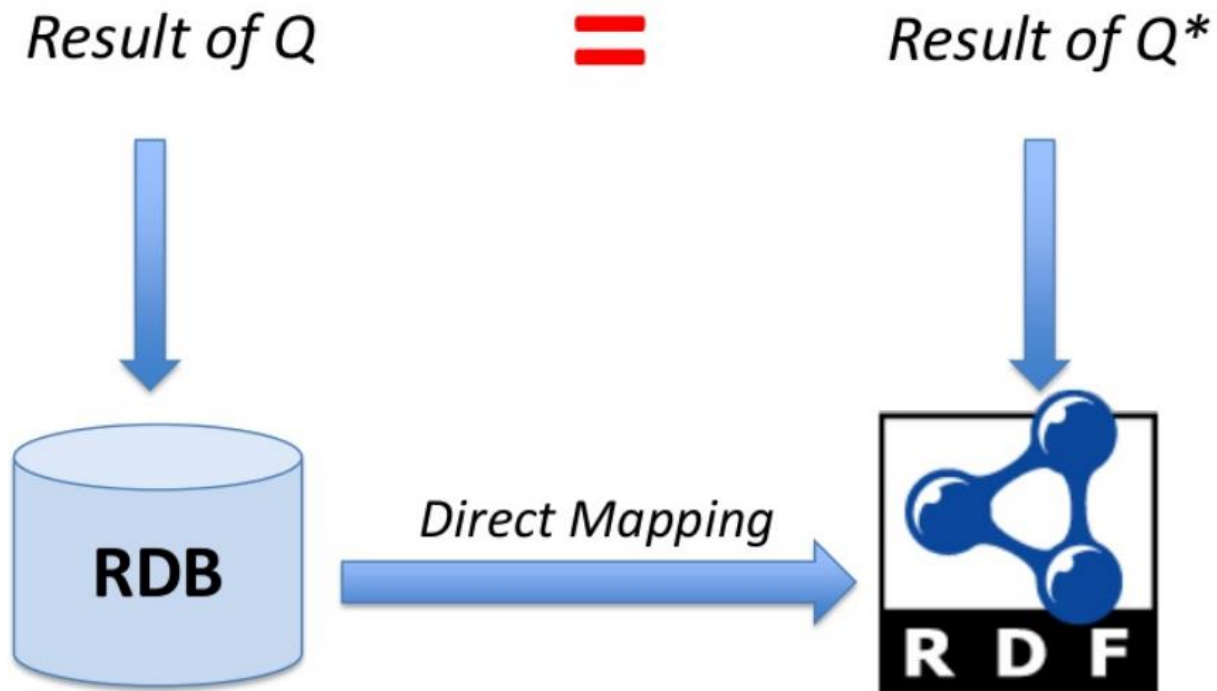


No triples generated for NULL (\perp).
(Semantics of NULL often not clear)

DIRECT MAPPING: INFORMATION PRESERVATION



DIRECT MAPPING: QUERY PRESERVATION



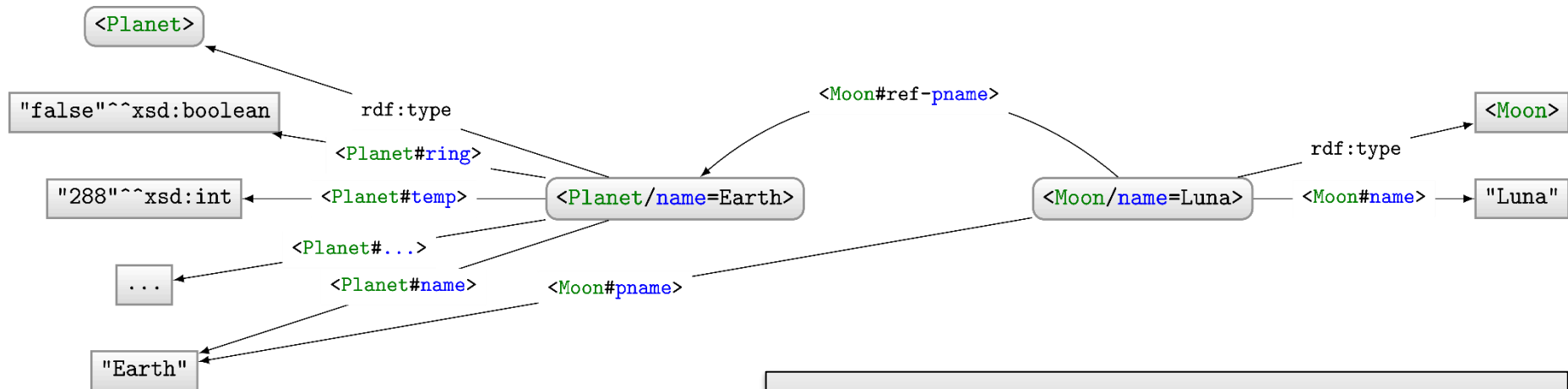
DIRECT MAPPING: CUSTOMISATION?

Planet

name	dist	radius	grav	day	year	temp	ring
Mercury	0.39	0.38	2.8	58.646	0.241	440	false
Venus	0.72	0.95	8.9	-243.019	0.615	730	false
Earth	1.00	1.00	9.8	0.997	1.000	288	false
Mars	1.52	0.53	3.7	1.026	1.880	186	false
Jupiter	5.20	10.97	22.9	0.414	11.862	152	true
Saturn	9.54	9.14	9.1	0.444	29.447	134	true
Uranus	19.19	3.98	7.8	-0.719	84.017	76	true
Neptune	30.07	3.86	11.0	0.671	164.791	53	true

Moon

name	pname	discoverer	year
Luna	Earth	⊥	⊥
Ganymedes	Jupiter	Galileo Galilei	1610
Calisto	Jupiter	Galileo Galilei	1610
Europa	Jupiter	Galileo Galilei	1610
Io	Jupiter	Galileo Galilei	1610
Titan	Saturn	Christiaan Huygens	1655
Triton	Neptune	William Lassell	1846



What if we want to customise the mapping, e.g., to create a node for people?

R2RML:

CUSTOM RDB2RDF MAPPINGS



R2RML: RDB to RDF Mapping Language

W3C Recommendation 27 September 2012

This version:

<http://www.w3.org/TR/2012/REC-r2rml-20120927/>

Latest version:

<http://www.w3.org/TR/r2rml/>

Previous version:

<http://www.w3.org/TR/2012/PR-r2rml-20120814/>

Editors:

Souripriya Das, Oracle

Seema Sundara, Oracle

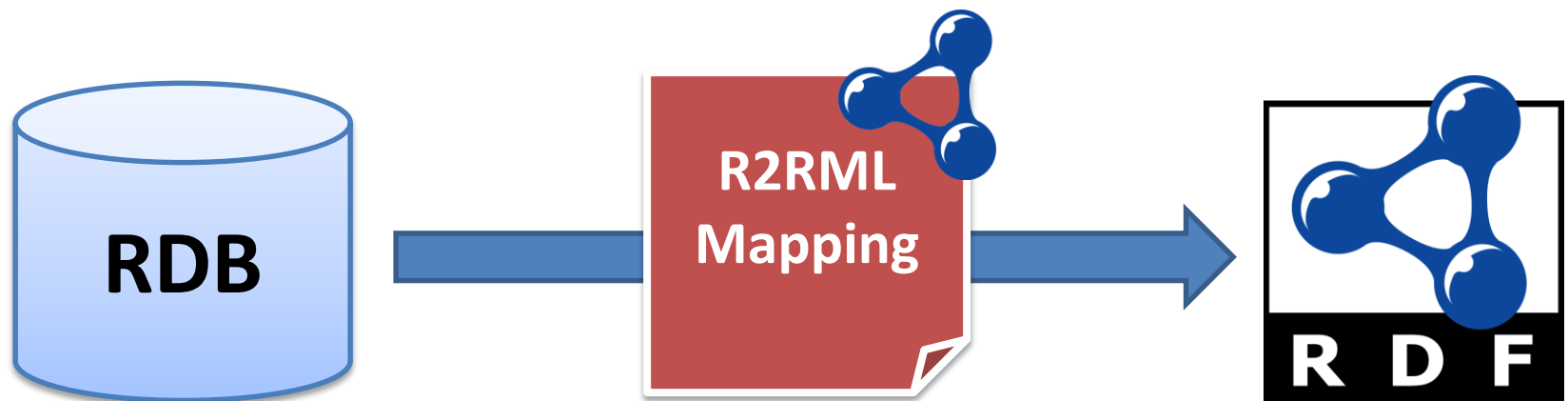
Richard Cyganiak, DERI, National University of Ireland, Galway

Please refer to the [errata](#) for this document, which may include some normative corrections.

See also [translations](#).

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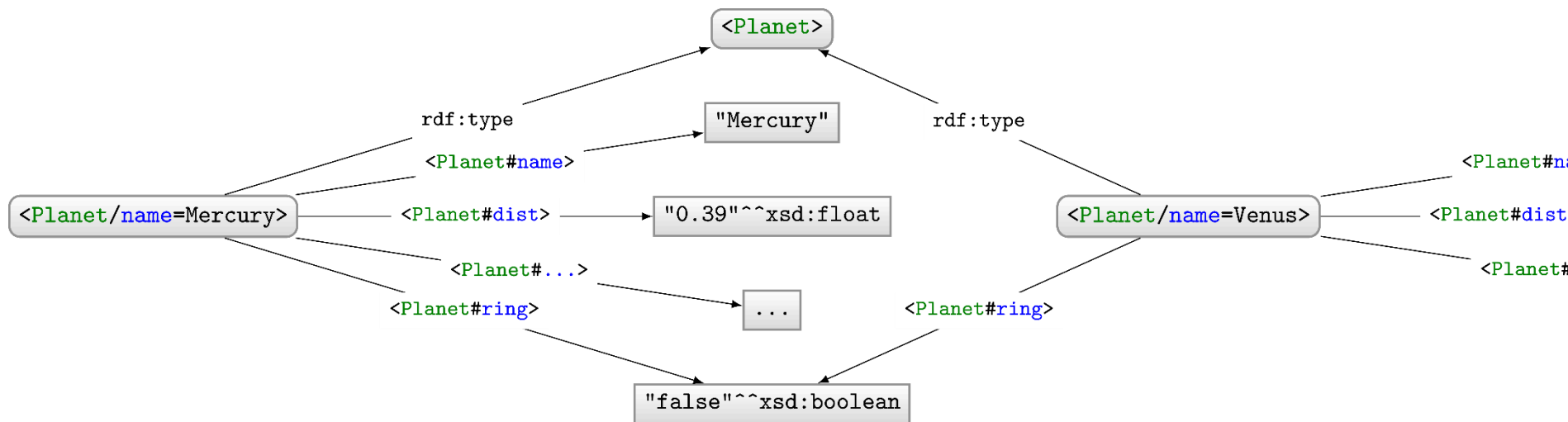
R2RML: IN A NUTSHELL



What should we use to specify this R2RML mapping?

R2RML EXAMPLE: THE DIRECT MAPPING

Planet							
name	dist	radius	grav	day	year	temp	ring
Mercury	0.39	0.38	2.8	58.646	0.241	440	false
Venus	0.72	0.95	8.9	-243.019	0.615	730	false
Earth	1.00	1.00	9.8	0.997	1.000	288	false
Mars	1.52	0.53	3.7	1.026	1.880	186	false
Jupiter	5.20	10.97	22.9	0.414	11.862	152	true
Saturn	9.54	9.14	9.1	0.444	29.447	134	true
Uranus	19.19	3.98	7.8	-0.719	84.017	76	true
Neptune	30.07	3.86	11.0	0.671	164.791	53	true



```

@base : <http://ex.org/>.
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>.
@prefix xsd: <http://www.w3.org/2001/XMLSchema#>.
    
```

R2RML EXAMPLE: THE DIRECT MAPPING

```
@prefix rr: <http://www.w3.org/ns/r2rml#>.
```

```
@prefix xsd: <http://www.w3.org/2001/XMLSchema#>.
```

```
@base <http://rr.org/astro#>.
```

```
<PlanetMap> a rr:TriplesMap ;
```

```
  rr:logicalTable [ rr:tableName "Planet" ] ;
```

```
  rr:subjectMap [
    rr:template "http://ex.org/Planet/name={name}" ;
    rr:class <http://ex.org/Planet>
  ] ;
```

```
  rr:predicateObjectMap [
    rr:predicate <http://ex.org/Planet#name> ;
    rr:objectMap [ rr:column "name" ]
  ] ;
```

```
  rr:predicateObjectMap [
    rr:predicate <http://ex.org/Planet#dist> ;
    rr:objectMap [ rr:column "dist" ; rr:datatype xsd:float ]
  ] ;
```

```
  ...
```

Triple Mapping

Source Table

Subject Mapping

Predicate-Object Mapping

Predicate-Object Mapping

```
@base : <http://ex.org/>.
```

```
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>.
```

```
@prefix xsd: <http://www.w3.org/2001/XMLSchema#>.
```

R2RML: SELECTING A LOGICAL TABLE

```
@prefix rr: <http://www.w3.org/ns/r2rml#>.
```

```
@prefix xsd: <http://www.w3.org/2001/XMLSchema#>.
```

```
@base <http://rr.org/astro#>.
```

```
<PlanetMap> a rr:TriplesMap ;
```

```
  rr:logicalTable [ rr:tableName "Planet" ] ;
```

OPTION 1: Specify table name:

```
  rr:logicalTable [ rr:tableName "Planet" ] ;
```

OPTION 2: Specify SQL query:

```
  rr:logicalTable [
    rr:sqlQuery "SELECT * FROM Planet WHERE dist>1" ;
    rr:sqlVersion rr:SQL2008
  ] ;
```

(rr:sqlVersion is optional)

Triple Mapping

Source Table

Subject Mapping

Predicate-Object
Mapping

Predicate-Object
Mapping

R2RML: EXAMPLE WITH SQL QUERY

```
@prefix ...

<OuterPlanetMap> a rr:TriplesMap ;

rr:logicalTable [
  rr:sqlQuery "SELECT * FROM Planet WHERE dist>1" ;
  rr:sqlVersion rr:SQL2008
] ;

rr:subjectMap [
  rr:template "http://ex.org/Planet/name={name}" ;
  rr:class <http://ex.org/OuterPlanet>
] .
```

Planet

name	dist	radius	grav	day	year	temp	ring
Mercury	0.39	0.38	2.8	58.646	0.241	440	false
Venus	0.72	0.95	8.9	-243.019	0.615	730	false
Earth	1.00	1.00	9.8	0.997	1.000	288	false
Mars	1.52	0.53	3.7	1.026	1.880	186	false
Jupiter	5.20	10.97	22.9	0.414	11.862	152	true
Saturn	9.54	9.14	9.1	0.444	29.447	134	true
Uranus	19.19	3.98	7.8	-0.719	84.017	76	true
Neptune	30.07	3.86	11.0	0.671	164.791	53	true

```
@base <http://ex.org/>
@prefix ...
```

```
<Planet/name=Mars> a <OuterPlanet> .
<Planet/name=Jupiter> a <OuterPlanet> .
<Planet/name=Saturn> a <OuterPlanet> .
<Planet/name=Neptune> a <OuterPlanet> .
```


R2RML TERM MAPS: CREATING RDF TERMS

```
@prefix rr: <http://www.w3.org/ns/r2rml#>.
@prefix xsd: <http://www.w3.org/2001/XMLSchema#>.
@base <http://rr.org/astro#>.
```

```
<PlanetMap> a rr:TriplesMap ;
```

```
  rr:logicalTable [ rr:tableName "Planet" ] ;
```

```
  rr:subjectMap [
    rr:template "http://ex.org/Planet/name={name}" ;
    rr:class <http://ex.org/Planet>
  ] ;
```

```
  rr:predicateObjectMap [
    rr:predicate <http://ex.org/Planet#name> ;
    rr:objectMap [ rr:column "name" ]
  ] ;
```

```
  rr:predicateObjectMap [
    rr:predicate <http://ex.org/Planet#dist> ;
    rr:objectMap [ rr:column "dist" ; rr:datatype xsd:float ]
  ] ;
```

```
  ...
```

Triple Mapping

Source Table

Subject Mapping

Predicate-Object
Mapping

Predicate-Object
Mapping

...

R2RML TERM MAPS: CREATING RDF TERMS

OPTION 1: Specify a constant:

```
...  
rr:objectMap [ rr:constant "Solar System" ] ;  
...
```

OPTION 2: Select from a table column:

```
...  
rr:objectMap [ rr:column "dist" ] ;  
...
```

OPTION 3: Template using table columns:

```
...  
rr:objectMap [ rr:template "http://ex.org/Moon/{name}_{pname}" ] ;  
...
```

R2RML TERM MAPS: CONSTANTS

OPTION 1: Specify a constant:

```
...  
rr:objectMap [ rr:constant "Solar System" ] ;  
...
```

Or use the shortcut form:

```
...  
rr:object "Solar System" ;  
...
```

Can also use for IRIs:

```
...  
rr:object <http://ex.org/Solar_System> ;  
...
```

R2RML TERM MAPS: COLUMNS

OPTION 2: Select from a table column:

```
...  
rr:objectMap [ rr:column "dist" ] ;  
...
```

By default generates ...

... literals for obj. (datatype based on RDB), IRIs for sub. or pred.

... but can use `rr:termType` to override:

`rr:IRI`, `rr:BlankNode` or `rr:Literal`

```
...  
rr:objectMap [ rr:column "homepage" ; rr:termType rr:IRI ] ;  
...
```

If a literal, can specify `rr:datatype` or `rr:language`

```
...  
rr:objectMap [ rr:column "dist" ; rr:datatype xsd:float ] ;  
...
```

```
...  
rr:objectMap [ rr:column "name" ; rr:language "en" ] ;  
...
```

R2RML TERM MAPS: TEMPLATES

OPTION 3: Template using table columns:

```
...  
rr:objectMap [ rr:column "http://ex.org/Moon/{name}_{pname}" ] ;  
...
```

By default generates IRIs ...

... but can use `rr:termType` to specify:

`rr:IRI`, `rr:BlankNode` or `rr:Literal`

```
...  
rr:objectMap [  
  rr:template "{name}_{pname}" ;  
  rr:termType rr:Literal  
] ;  
...
```

If a literal, can (again) specify `rr:datatype` or `rr:language`

R2RML TERM MAPS

Term map should not break restrictions on positions:

<i>subject</i>	<i>predicate</i>	<i>object</i>
[IRI, Blank Node]	[IRI]	[IRI, Blank Node, Literal]

R2RML TERM MAPS: EXAMPLE

```
@prefix ...
<PlanetMap> a rr:TriplesMap ;
  rr:logicalTable [ rr:tableName "Planet" ] ;

  rr:subjectMap [
    rr:template "http://ex.org/p/{name}"
  ] .

  rr:predicateObjectMap [
    rr:predicate <http://ex.org/v/dist> ;
    rr:objectMap [ rr:column "dist" ; rr:datatype xsd:float ]
  ] .
```

Planet

<u>name</u>	<u>dist</u>	<u>radius</u>	<u>grav</u>	<u>day</u>	<u>year</u>	<u>temp</u>	<u>ring</u>
Mercury	0.39	0.38	2.8	58.646	0.241	440	false
Venus	0.72	0.95	8.9	-243.019	0.615	730	false
Earth	1.00	1.00	9.8	0.997	1.000	288	false
Mars	1.52	0.53	3.7	1.026	1.880	186	false
Jupiter	5.20	10.97	22.9	0.414	11.862	152	true
Saturn	9.54	9.14	9.1	0.444	29.447	134	true
Uranus	19.19	3.98	7.8	-0.719	84.017	76	true
Neptune	30.07	3.86	11.0	0.671	164.791	53	true

```
@base <http://ex.org/>
```

```
@prefix ...
```

```
<p/Mercury> <v/dist> "0.39"^^xsd:float
```

```
<p/Venus> <v/dist> "0.72"^^xsd:float .
```

```
<p/Earth> <v/dist> "1.00"^^xsd:float .
```

```
...
```

R2RML: SUBJECT MAP

```
@prefix rr: <http://www.w3.org/ns/r2rml#>.
@prefix xsd: <http://www.w3.org/2001/XMLSchema#>.
@base <http://rr.org/astro#>.
```

```
<PlanetMap> a rr:TriplesMap ;
```

```
  rr:logicalTable [ rr:tableName "Planet" ] ;
```

```
  rr:subjectMap [
    rr:template "http://ex.org/Planet/name={name}" ;
    rr:class <http://ex.org/Planet>
  ] ;
```

Triple Mapping

Source Table

Subject Mapping

```
rr:predicateObjectMap [
  rr:predicate <http://ex.org/Planet#name> ;
  rr:objectMap [ rr:column "name" ]
] ;
```

One per triple map
Specifies one term map (IRI/Blank Node)

Predicate-Object
Mapping

```
rr:predicateObjectMap [
  rr:predicate <http://ex.org/Planet#dist> ;
  rr:objectMap [ rr:column "dist" rdfs:type xsd:float ]
] ;
```

Specifies zero or many types (rr:class)

Predicate-Object
Mapping

...

...

R2RML: EXAMPLE WITH MULTIPLE TYPES

```
@prefix ...

<OuterPlanetMap> a rr:TriplesMap ;

  rr:logicalTable [
    rr:sqlQuery "SELECT * FROM Planet WHERE dist>1" ;
    rr:sqlVersion rr:SQL2008
  ] ;

  rr:subjectMap [
    rr:template "http://ex.org/Planet/name={name}" ;
    rr:class <OuterPlanet> , <Planet>
  ] .
```

Planet

<u>name</u>	<u>dist</u>	<u>radius</u>	<u>grav</u>	<u>day</u>	<u>year</u>	<u>temp</u>	<u>ring</u>
Mercury	0.39	0.38	2.8	58.646	0.241	440	false
Venus	0.72	0.95	8.9	-243.019	0.615	730	false
Earth	1.00	1.00	9.8	0.997	1.000	288	false
Mars	1.52	0.53	3.7	1.026	1.880	186	false
Jupiter	5.20	10.97	22.9	0.414	11.862	152	true
Saturn	9.54	9.14	9.1	0.444	29.447	134	true
Uranus	19.19	3.98	7.8	-0.719	84.017	76	true
Neptune	30.07	3.86	11.0	0.671	164.791	53	true

```
@base <http://ex.org/>
@prefix ...
```

```
<Planet/name=Mars> a
  <OuterPlanet> , <Planet>
```

```
<Planet/name=Jupiter> a
  <OuterPlanet> , <Planet>
```

```
...
```

R2RML: PREDICATE-OBJECT MAP

```
@prefix rr: <http://www.w3.org/ns/r2rml#>.
@prefix xsd: <http://www.w3.org/2001/XMLSchema#>.
@base <http://rr.org/astro#>.
```

```
<PlanetMap> a rr:TriplesMap ;
```

```
  rr:logicalTable [ rr:tableName "Planet" ] ;
```

```
  rr:subjectMap [
    rr:template "http://ex.org/Planet/name={name}" ;
    rr:class <http://ex.org/Planet>
  ] ;
```

```
  rr:predicateObjectMap [
    rr:predicate <http://ex.org/Planet#name> ;
    rr:objectMap [ rr:column "name" ]
  ] ;
```

```
  rr:predicateObjectMap [
    rr:predicate <http://ex.org/Planet#dist> ;
    rr:objectMap [ rr:column "dist" ; rr:datatype xsd:float ]
  ] ;
```

...

Triple Mapping

Source Table

Subject Mapping

Predicate-Object Mapping

Predicate-Object Mapping

...

R2RML: PREDICATE-OBJECT MAP

```
@prefix rr: <http://www.w3.org/ns/r2rml#>.
@prefix xsd: <http://www.w3.org/2001/XMLSchema#>.
@base <http://rr.org/astro#>.
```

```
<Planet [ rr:logicalTable [ rr:tableName "Planet" ] ;
```

Each has one or more predicate term map, one or more object term map

```
  rr:subjectMap [
    rr:template "http://ex.org/Planet/name={name}" ;
    rr:class <http://ex.org/Planet>
  ] ;
```

```
rr:predicateObjectMap [
  rr:predicate <http://ex.org/Planet#name> ;
  rr:objectMap [ rr:column "name" ]
] ;
```

```
rr:predicateObjectMap [
  rr:predicate <http://ex.org/Planet#dist> ;
  rr:objectMap [ rr:column "dist" ; rr:datatype xsd:float ]
] ;
```

...

Triple Mapping

Source Table

Subject Mapping

Predicate-Object Mapping

Predicate-Object Mapping

...

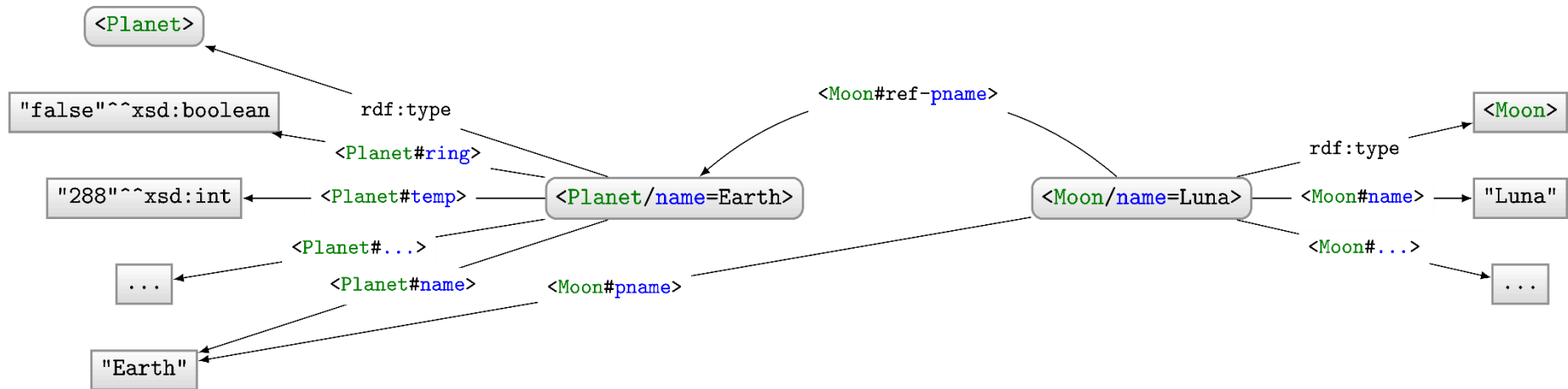
R2RML: REFERENCE OBJECT MAP

Planet

name	dist	radius	grav	day	year	temp	ring
Mercury	0.39	0.38	2.8	58.646	0.241	440	false
Venus	0.72	0.95	8.9	-243.019	0.615	730	false
Earth	1.00	1.00	9.8	0.997	1.000	288	false
Mars	1.52	0.53	3.7	1.026	1.880	186	false
Jupiter	5.20	10.97	22.9	0.414	11.862	152	true
Saturn	9.54	9.14	9.1	0.444	29.447	134	true
Uranus	19.19	3.98	7.8	-0.719	84.017	76	true
Neptune	30.07	3.86	11.0	0.671	164.791	53	true

Moon

name	pname	discoverer	year
Luna	Earth	⊥	⊥
Ganymedes	Jupiter	Galileo Galilei	1610
Calisto	Jupiter	Galileo Galilei	1610
Europa	Jupiter	Galileo Galilei	1610
Io	Jupiter	Galileo Galilei	1610
Titan	Saturn	Christiaan Huygens	1655
Triton	Neptune	William Lassell	1846



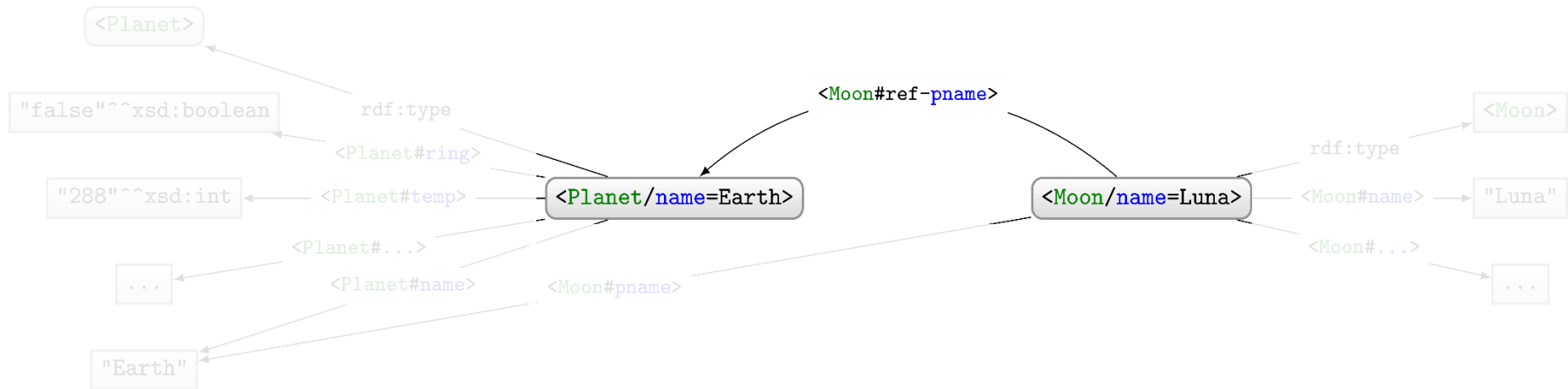
R2RML: REFERENCE OBJECT MAP

Planet

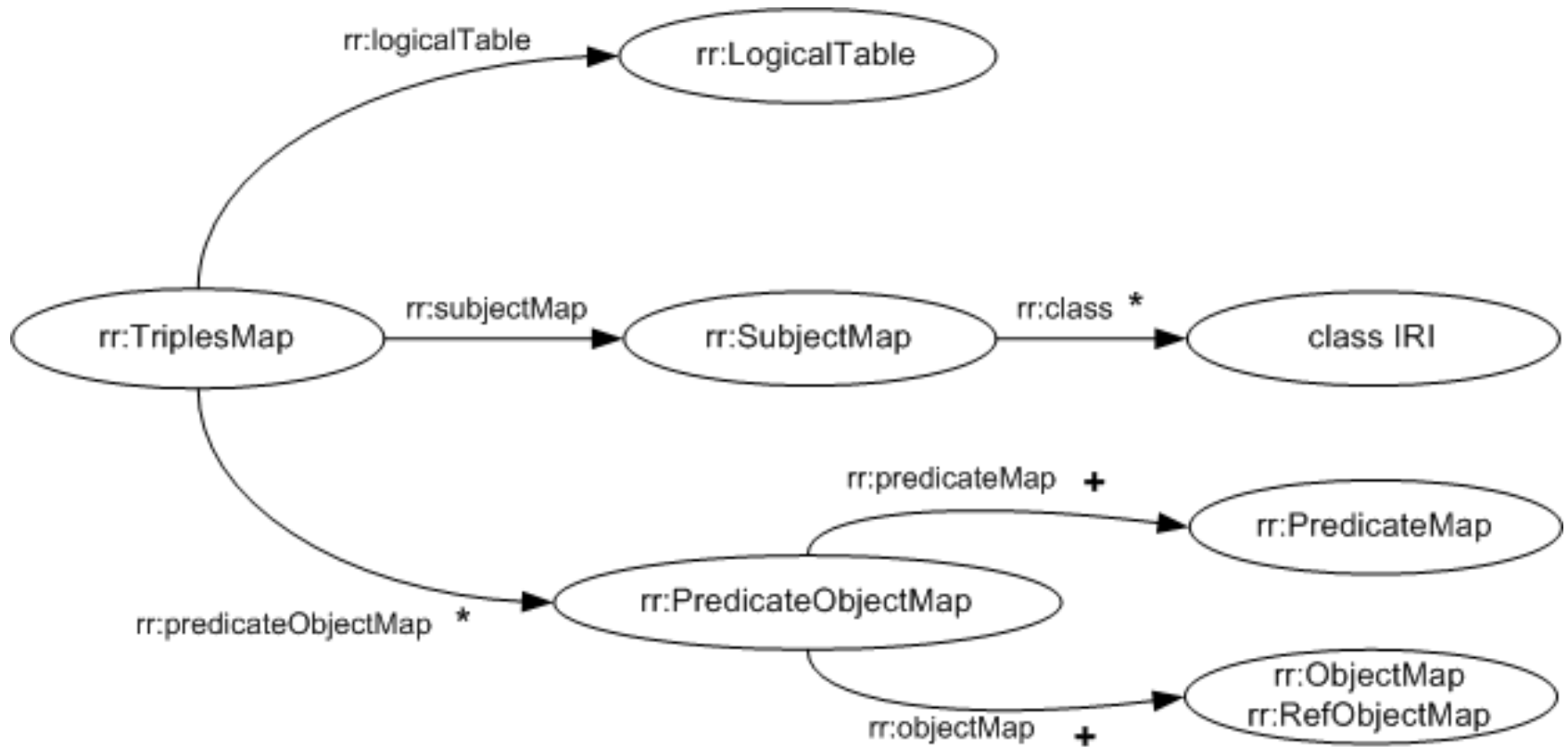
name	dist	radius	grav	day	year	temp	ring
Mercury	0.39	0.38	2.8	58.646	0.241	440	false
Venus	0.72	0.95	8.9	-243.019	0.615	730	false
Earth	1.00	1.00	9.8	0.997	1.000	288	false
Mars	1.52	0.53	3.7	1.026	1.880	186	false
Jupiter	5.20	10.97	22.9	0.414	11.862	152	true
Saturn	9.54	9.14	9.1	0.444	29.447	134	true
Uranus	19.19	3.98	7.8	-0.719	84.017	76	true
Neptune	30.07	3.86	11.0	0.671	164.791	53	true

Moon

name	pname	discoverer	year
Luna	Earth	⊥	⊥
Ganimesdes	Jupiter	Galileo Galilei	1610
Calisto	Jupiter	Galileo Galilei	1610
Europa	Jupiter	Galileo Galilei	1610
Io	Jupiter	Galileo Galilei	1610
Titan	Saturn	Christiaan Huygens	1655
Triton	Neptune	William Lassell	1846



SUMMARY OF TRIPLE MAP STRUCTURE



* zero or more
+ one or more
(otherwise, precisely one)

R2RML: GRAPH MAPS

```
@prefix ...
<MoonMap> a rr:TriplesMap ;
  rr:logicalTable [ rr:tableName "Moon" ] ;
  rr:subjectMap [
    rr:template "http://ex.org/Moon/name={name}" ;
    rr:class <http://ex.org/Moon> ;
    rr:graph <http://ex.org/graph/SolarSystem>
  ] ;
  rr:predicateObjectMap [
    rr:predicate <http://ex.org/Moon/ref-pname> ;
    rr:objectMap [
      rr:parentTriplesMap <PlanetMap> ;
      rr:joinCondition [
        rr:child "pname" ; rr:parent "name"
      ]
    ] ;
    rr:graphMap [
      rr:template "http://ex.org/graph/{pname}"
    ] ;
    rr:graph rr:defaultGraph
  ] ;
  rr:predicateObjectMap [
    rr:predicate <http://ex.org/discoveryYear> ;
    rr:objectMap [ rr:column "year" ] ;
    rr:graphMap [
      rr:template "http://ex.org/graph/{year}"
    ]
  ]
]
```

Triples added to named graph(s)

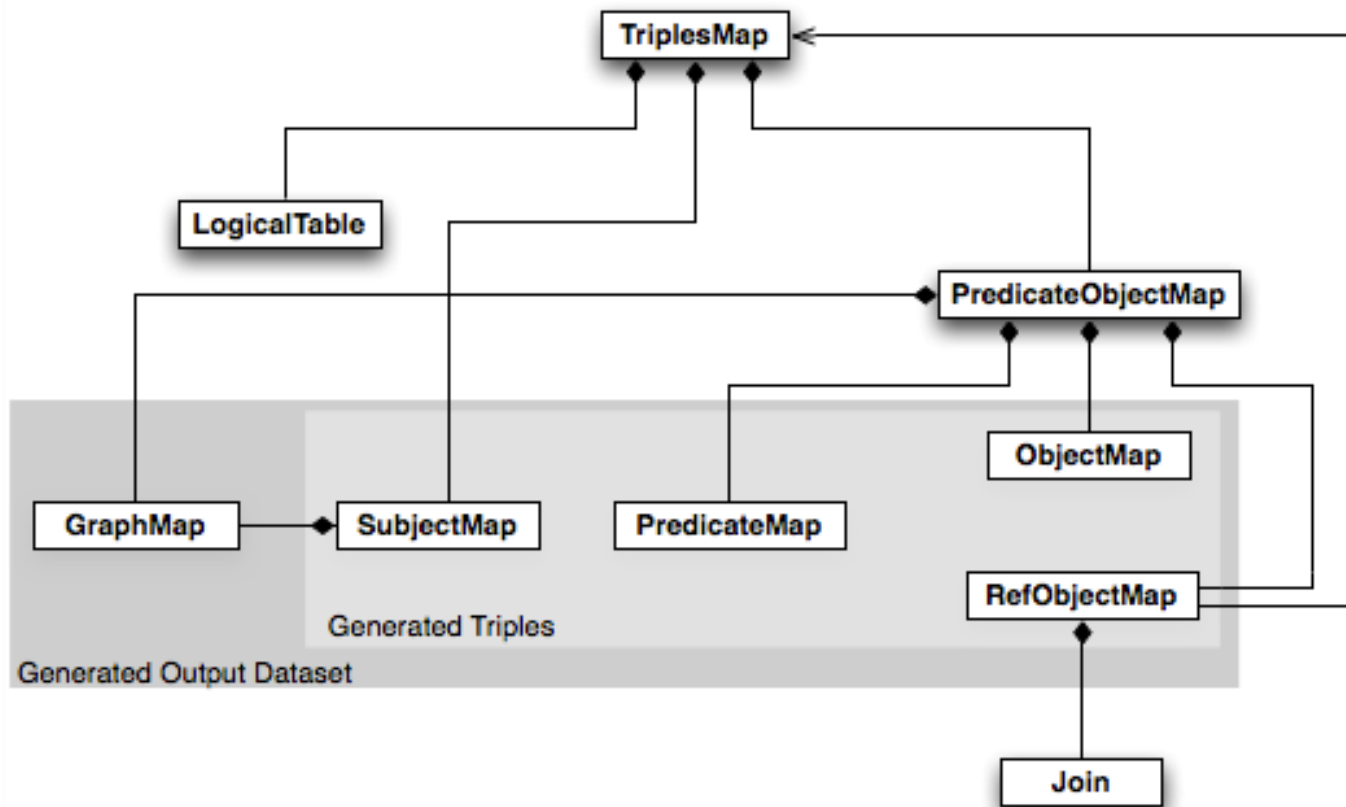
Graphs specified by term maps

`rr:defaultGraph` for default graph

Zero or many graph maps
on subject or predicate-object map

Predicate-object maps “inherit”
from subject map

R2RML ...



RDB₂RDF

RDB2RDF: SURFACING (SOME OF) THE DEEP WEB

Surface Web



Deep Web



QUESTIONS?

