

CC7220-1

LA WEB DE DATOS

PRIMAVERA 2021

LECTURE 11: RDB2RDF

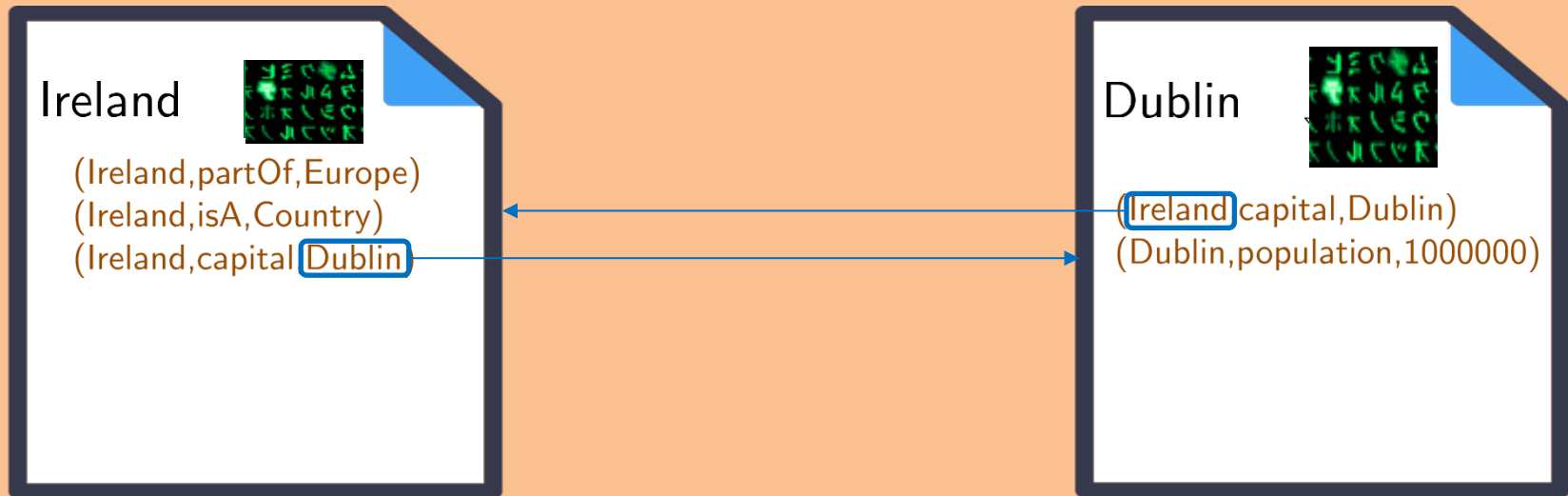
Aidan Hogan

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PREVIOUSLY ...

SEMANTIC WEB: DATA, LOGIC, QUERY, LINKS

DATA:

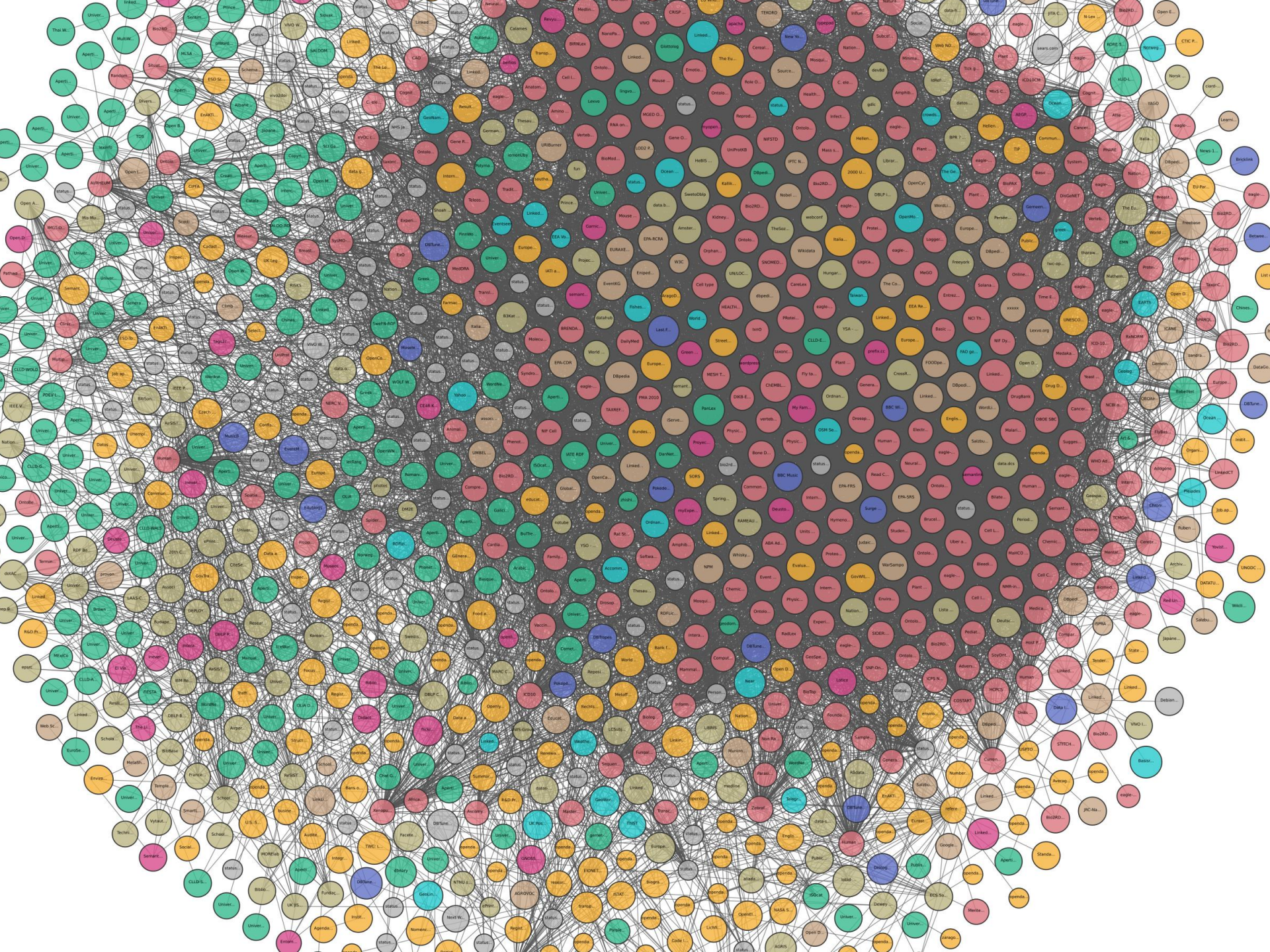


LOGIC:
$$\begin{aligned} &“(b, \text{capital}, a) \rightarrow (a, \text{partOf}, b)” \\ &“(a, \text{partOf}, b), (b, \text{partOf}, c) \rightarrow (a, \text{partOf}, c)” \end{aligned}$$

QUERY: $“(x, \text{partOf}, y)?”$

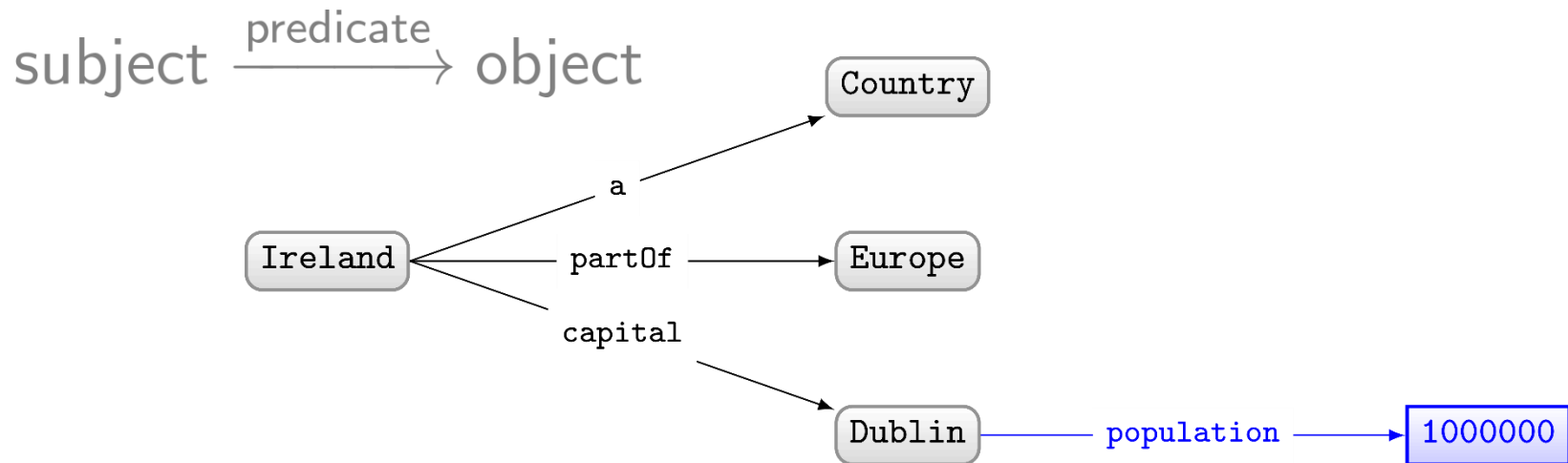
OUTPUT: $\{(x \mapsto \text{Ireland}, y \mapsto \text{Europe}),$
 $(x \mapsto \text{Dublin}, y \mapsto \text{Ireland}),$
 $(x \mapsto \text{Dublin}, y \mapsto \text{Europe})\}$





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

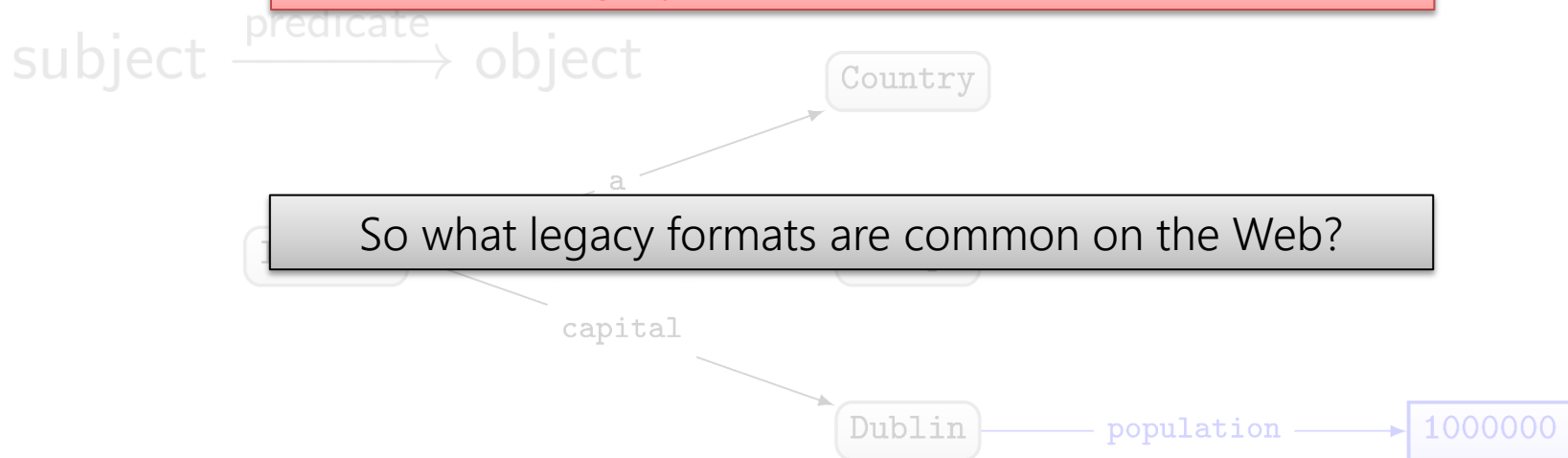


RDF: PROPOSED MODEL FOR A WEB OF DATA

<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?

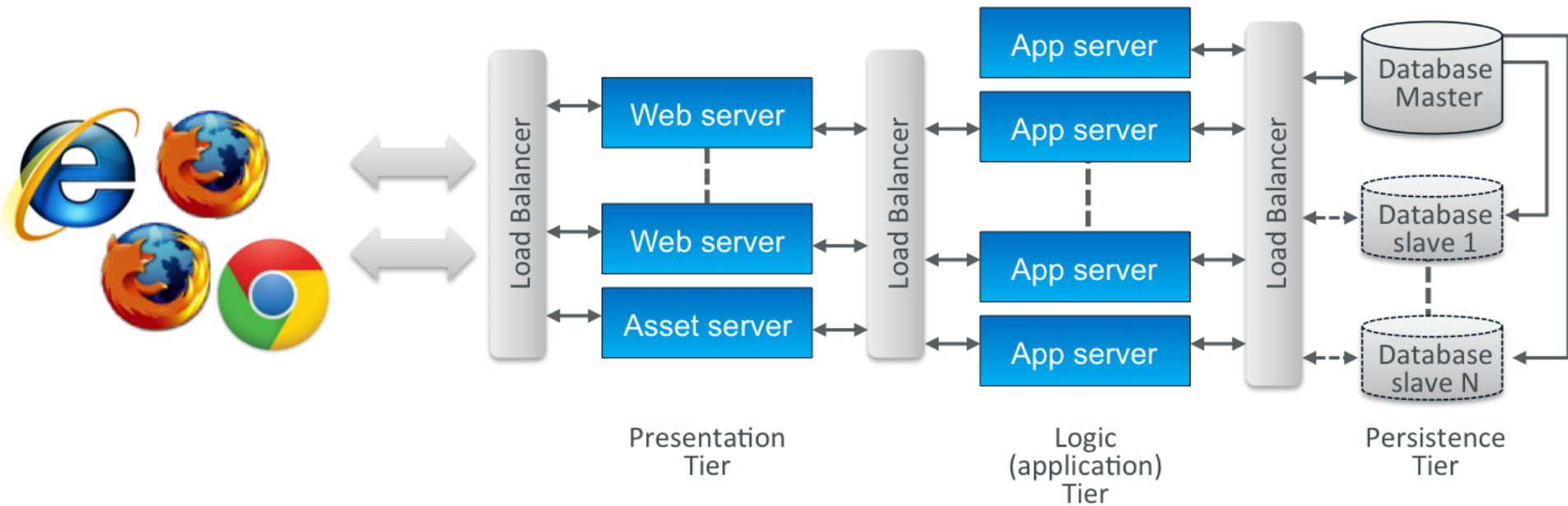
Most legacy data on the Web not in RDF!



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.



363 systems in ranking, December 2020

Rank			DBMS	Database Model	Score		
Dec 2020	Nov 2020	Dec 2019			Dec 2020	Nov 2020	Dec 2019
1.	1.	1.	Oracle +	Relational, Multi-model i	1325.60	-19.40	-20.80
2.	2.	2.	MySQL +	Relational, Multi-model i	1255.45	+13.81	-20.21
3.	3.	3.	Microsoft SQL Server +	Relational, Multi-model i	1038.09	+0.45	-58.11
4.	4.	4.	PostgreSQL +	Relational, Multi-model i	547.57	-7.49	+44.20
5.	5.	5.	MongoDB +	Document, Multi-model i	457.73	+3.90	+36.61
6.	6.	6.	IBM Db2 +	Relational, Multi-model i	160.43	-1.19	-10.91
7.	7.	↑ 8.	Redis +	Key-value, Multi-model i	153.63	-1.79	+7.39
8.	8.	↓ 7.	Elasticsearch +	Search engine, Multi-model i	152.49	+0.94	+2.24
9.	9.	↑ 11.	SQLite +	Relational	121.68	-1.63	+1.32
10.	10.	10.	Cassandra +	Wide column	118.84	+0.09	-1.87

<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.

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



Out of top 10 databases, 6 are relational databases.

Rank			DBMS	Database Model	Score		
Dec 2020	Nov 2020	Dec 2019			Dec 2020	Nov 2020	Dec 2019
1.	1.	1.	Oracle +	Relational, Multi-model i	1325.60	-19.40	-20.80
2.	2.	2.	MySQL +	Relational, Multi-model i	1255.45	+13.81	-20.21
3.	3.	3.	Microsoft SQL Server +	Relational, Multi-model i	1038.09	+0.45	-58.11
4.	4.	4.	PostgreSQL +	Relational, Multi-model i	547.57	-7.49	+44.20
5.	5.	5.	MongoDB +	Document, Multi-model i	457.73	+3.90	+36.61
6.	6.				.43	-1.19	-10.91
7.	7.	↑			.63	-1.79	+7.39
8.	8.	↓			.49	+0.94	+2.24
9.	9.	↑			.68	-1.63	+1.32
10.	10.	10.	Cassandra +	Wide column	118.84	+0.09	-1.87

Out of 363 databases, any idea in what position the first SPARQL engine would be?

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

TOP SPARQL ENGINE IS ...

99.	↓ 97.	↓ 94.	Apache Drill	Multi-model ⓘ	3.14	-0.19	+0.49
100.	↑ 103.	↑ 102.	Percona Server for MySQL	Relational	3.12	+0.18	+0.73
101.	↑ 106.	↓ 85.	Amazon CloudSearch	Search engine	3.06	+0.29	-0.15
102.	102.	↓ 96.	Apache Jena - TDB	RDF	3.05	+0.11	+0.42
103.	↑ 104.	↑ 105.	Oracle Coherence	Key-value	3.03	+0.14	+0.79
104.	↓ 100.	↑ 117.	TimescaleDB ⚡	Time Series, Multi-model ⓘ	2.98	+0.02	+1.19
105.	↓ 101.	↑ 111.	Datomic	Relational	2.92	-0.03	+0.89
106.	↓ 105.	↑ 112.	Google Cloud Spanner	Relational	2.89	+0.10	+0.87
107.	↑ 108.	↓ 103.	CloudKit	Document	2.80	+0.05	+0.42
108.	↑ 112.	↓ 100.	Amazon SimpleDB	Key-value	2.75	+0.27	+0.34
109.	↑ 115.	↑ 118.	JanusGraph	Graph	2.65	+0.28	+0.90
110.	↓ 107.	↓ 92.	4D	Relational	2.64	-0.13	-0.12
111.	111.	↑ 115.	Apache Druid	Multi-model ⓘ	2.59	+0.09	+0.76
112.	↓ 110.	↓ 95.	Virtuoso ⚡	Multi-model ⓘ	2.58	+0.05	-0.05
113.	↑ 116.	↓ 109.	TimesTen ⚡	Relational	2.54	+0.19	+0.44
114.	↓ 113.	↑ 125.	Amazon Neptune	Multi-model ⓘ	2.51	+0.08	+0.94
115.	↓ 109.	↓ 110.	ScyllaDB ⚡	Multi-model ⓘ	2.51	-0.12	+0.48
116.	↑ 118.	↓ 98.	EDB Postgres ⚡	Relational, Multi-model ⓘ	2.45	+0.13	+0.02
117.	↑ 119.	↓ 113.	OpenTSDB	Time Series	2.44	+0.17	+0.46
118.	↓ 117.	↑ 123.	TiDB ⚡				
119.	↑ 120.	↑ 124.	GridGain				
120.	↑ 123.	120.	jBASE				
121.	↑ 122.	↓ 114.	IBM DB2				
122.	↓ 121.	↑ 127.	Tibero				
123.	↑ 126.	↓ 119.	MonetDB				
124.	↑ 125.	↓ 104.	OmniSQL				
125.	↓ 124.	↑ 138.	GraphDB				
126.	↑ 128.	↑ 180.	Fauna				



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	└	└
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

Landing			
<u>ship</u>	<u>pname</u>	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
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

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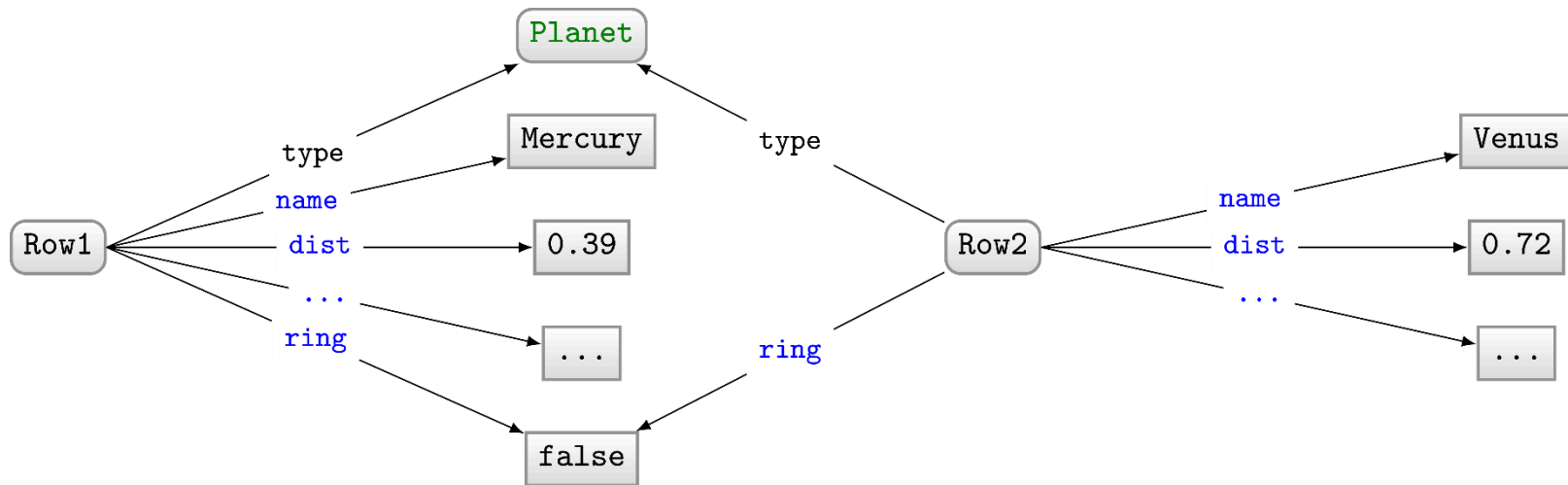
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Please refer to the [errata](#) for this document, which may include some normative corrections.

See also [translations](#).

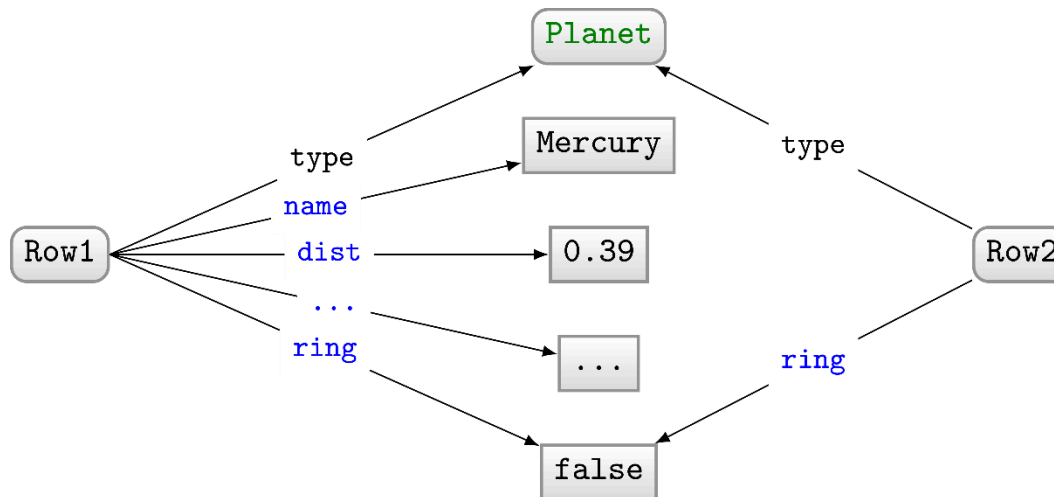
DIRECT MAPPING

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



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



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
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

How can we identify Row1?

- If the table has a **primary key** (pk₁, ..., 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.

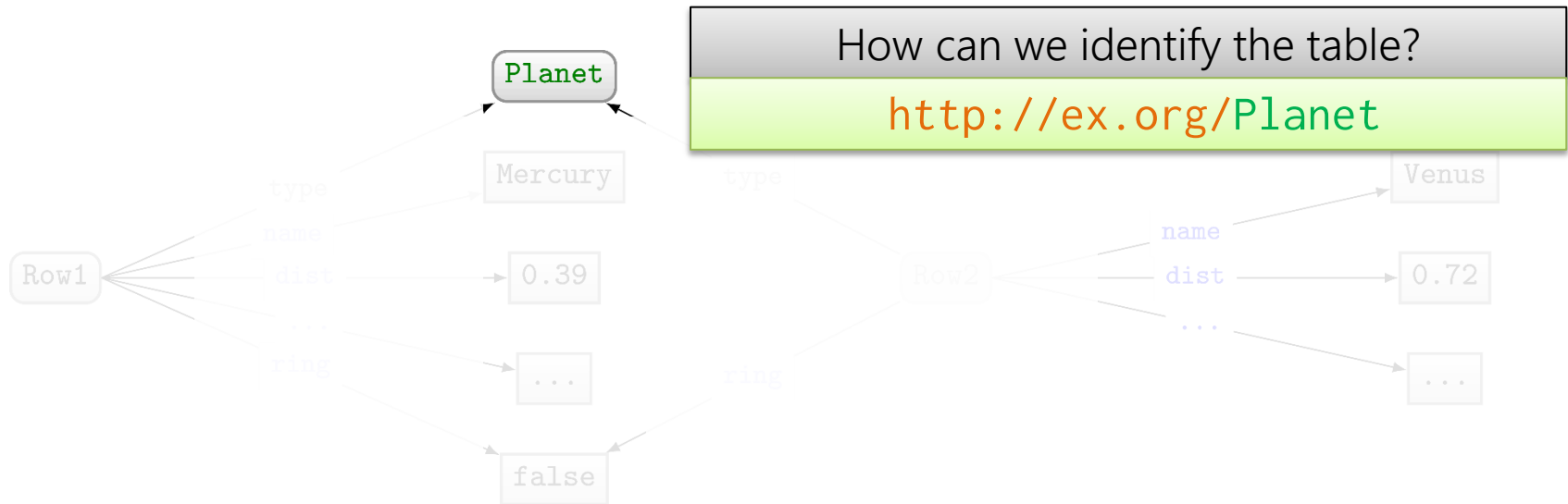
Row1

So Row1 would be ...?

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

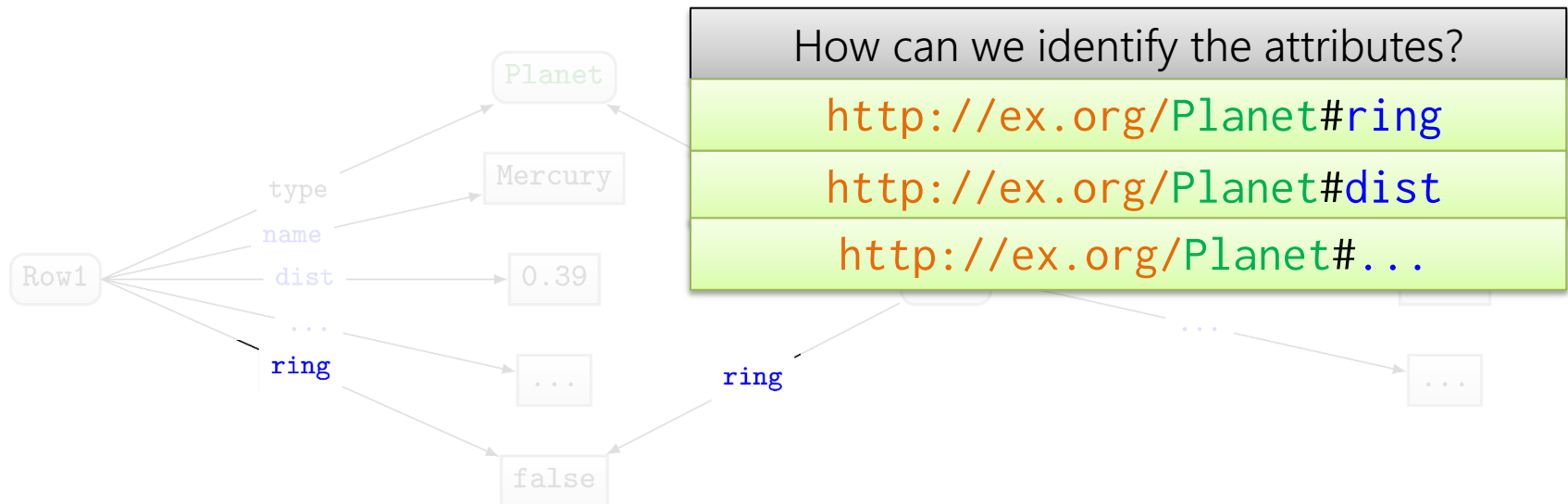
DIRECT MAPPING: IDENTIFYING TABLES

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
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



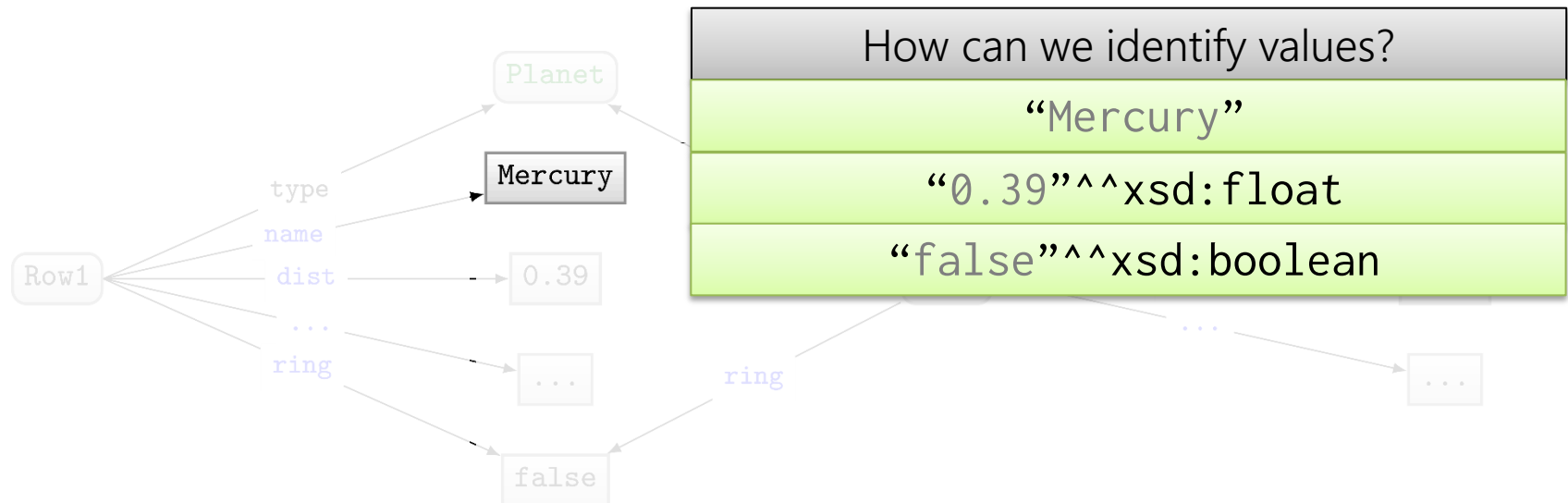
DIRECT MAPPING: IDENTIFYING COLUMNS

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



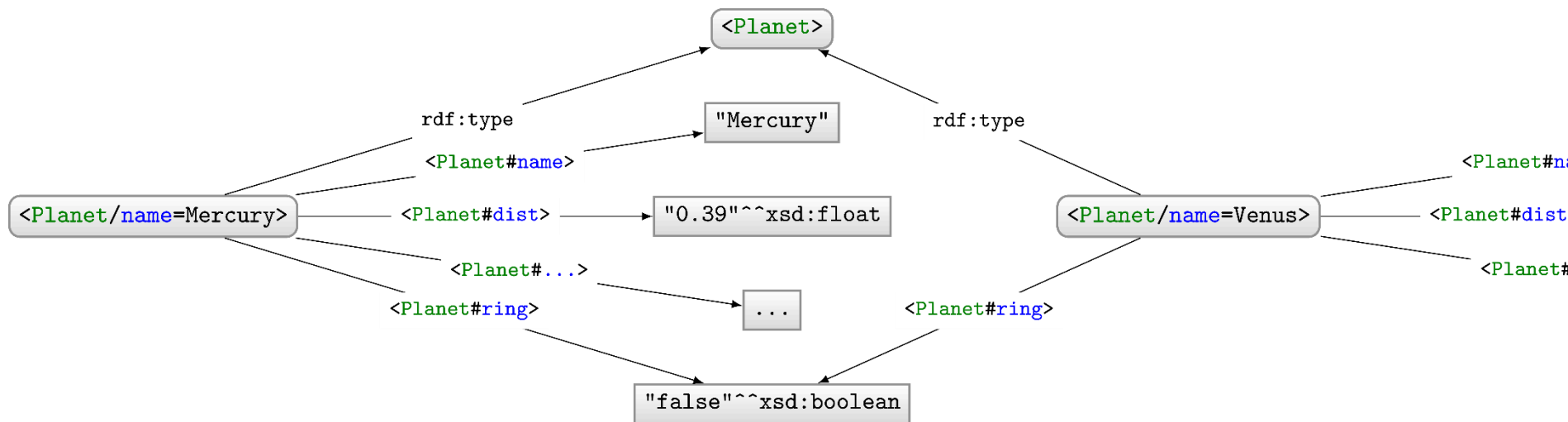
DIRECT MAPPING: IDENTIFYING VALUES

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



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#>.

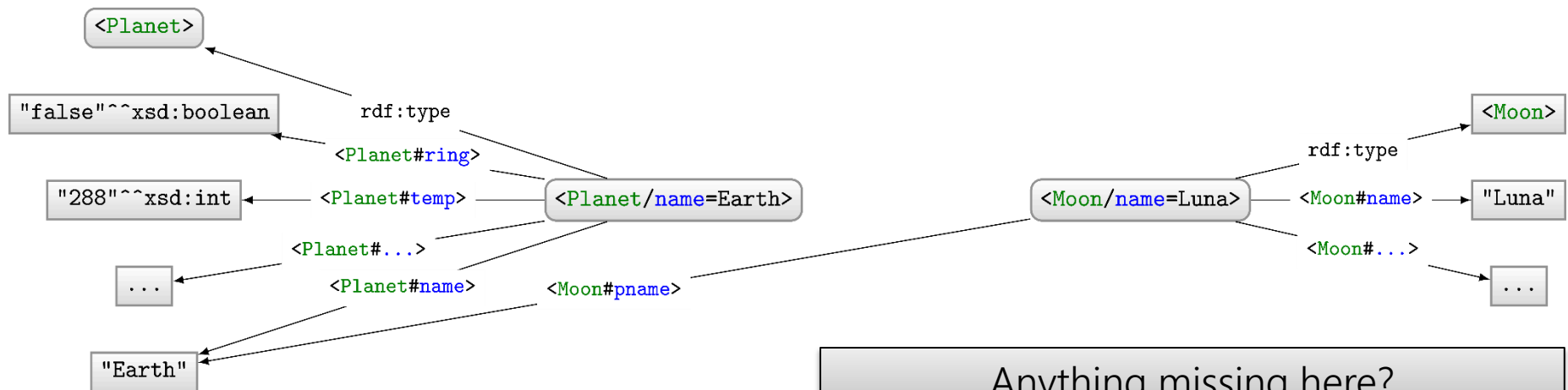
DIRECT MAPPING: MULTIPLE TABLES

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
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



Anything missing here?

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

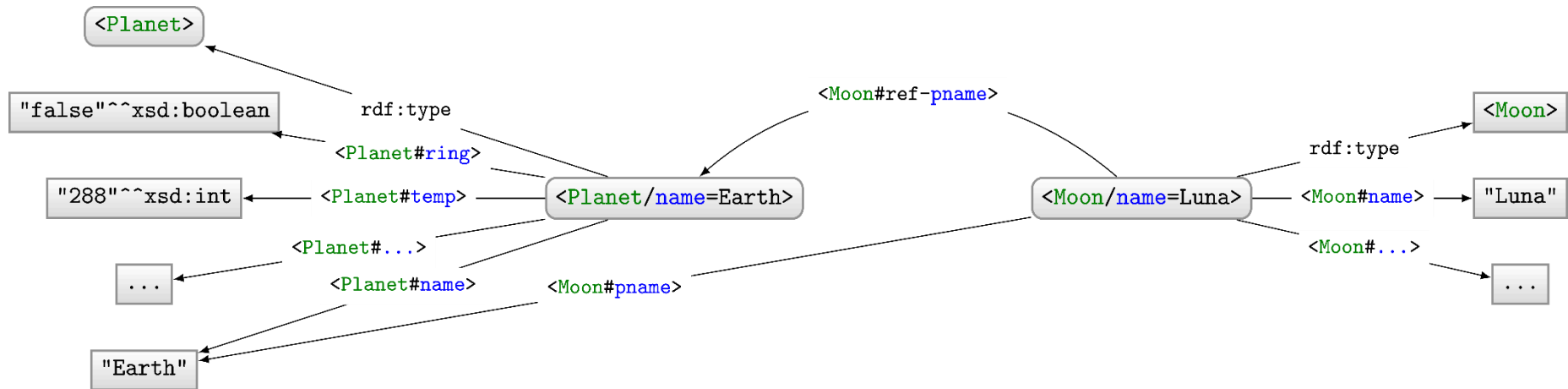
DIRECT MAPPING: FOREIGN KEY REFERENCES

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
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



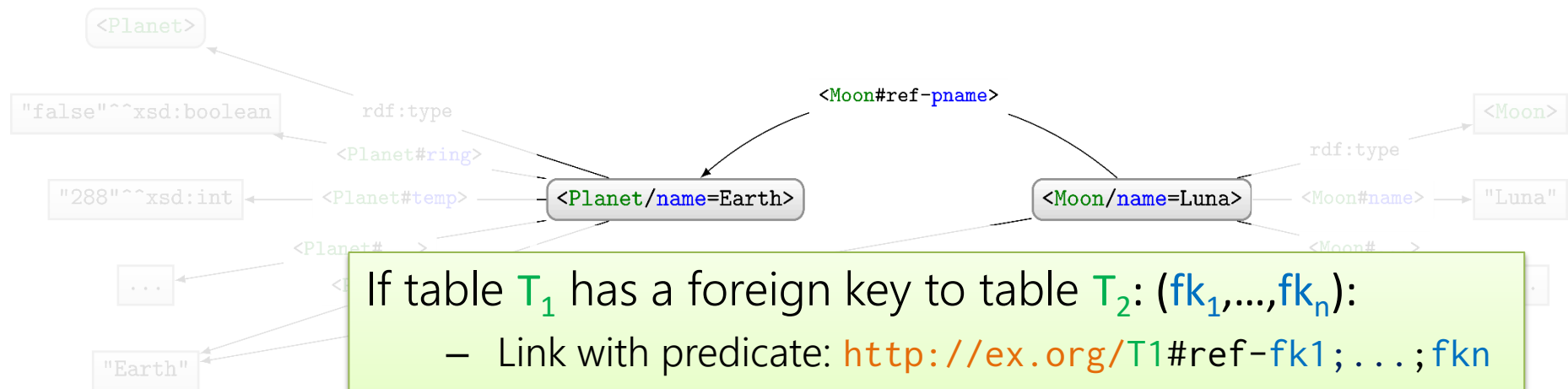
DIRECT MAPPING: FOREIGN KEY REFERENCES

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
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



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`

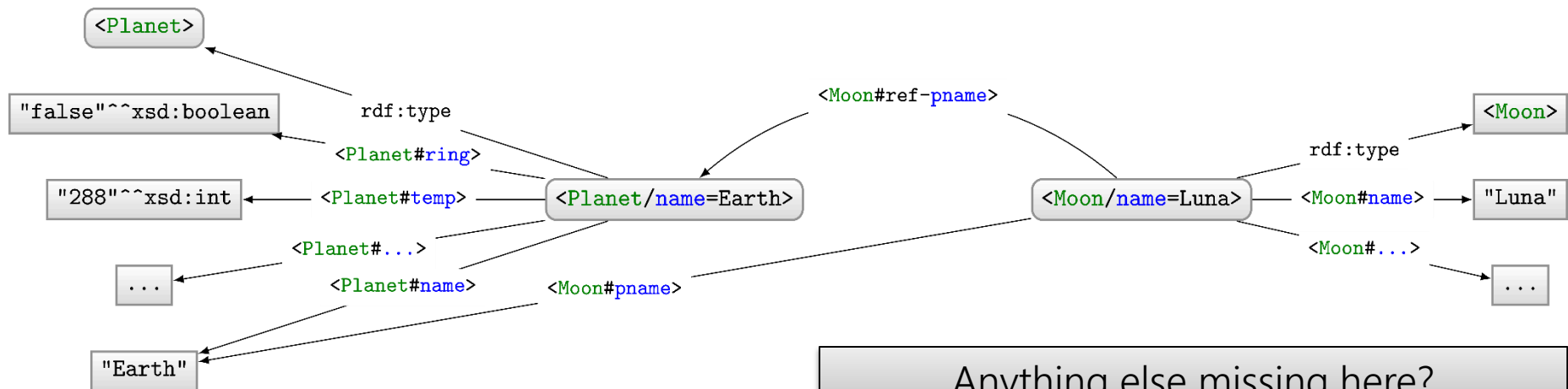
DIRECT MAPPING

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
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



Anything else missing here?

What should we do with **NULL** ($\perp$)??

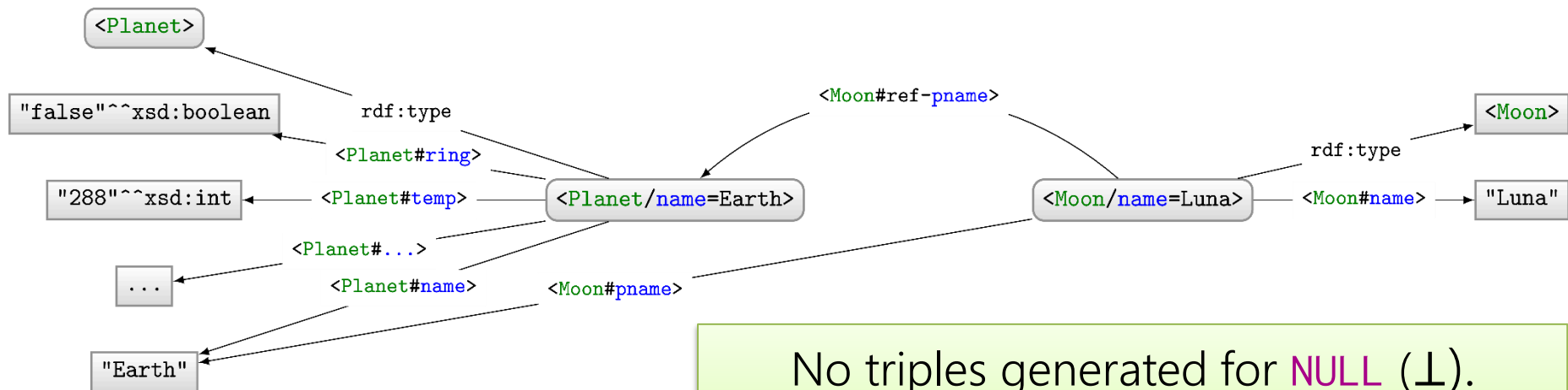
DIRECT MAPPING: NULL ($\perp$)

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

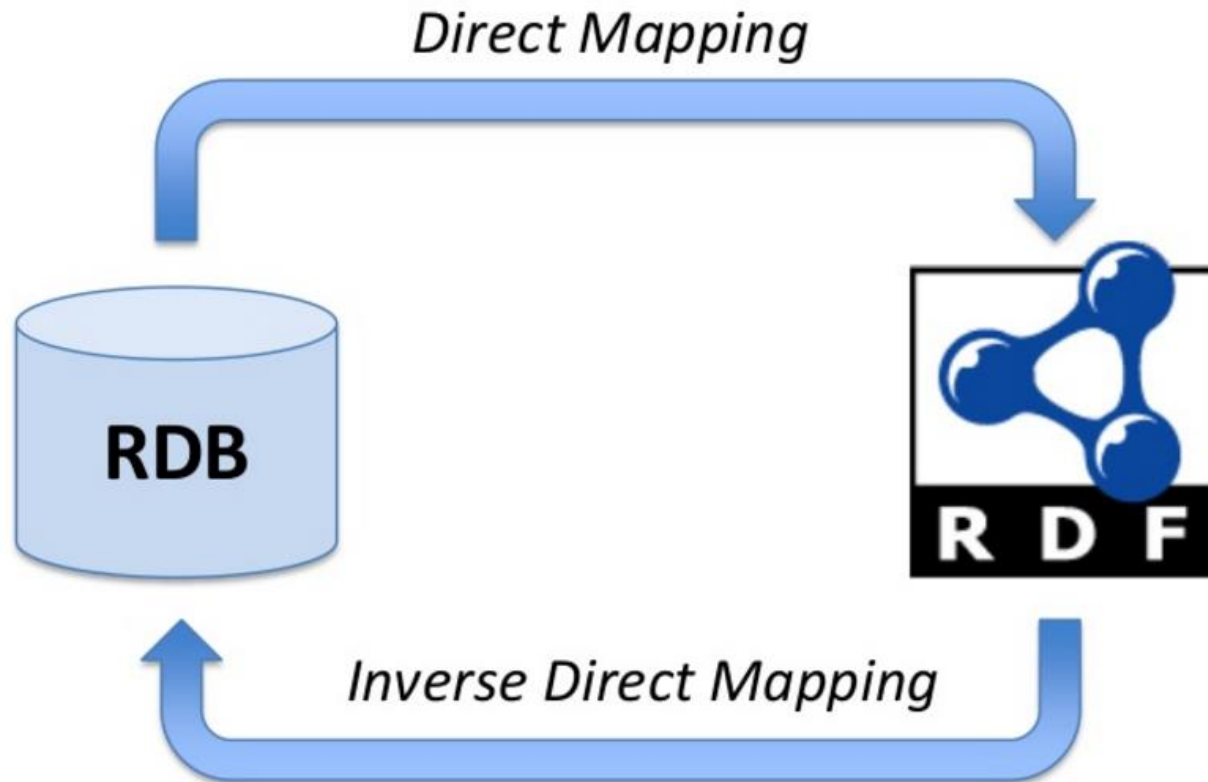
Moon

name	pname	discoverer	year
Luna	Earth	$\perp$	$\perp$
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

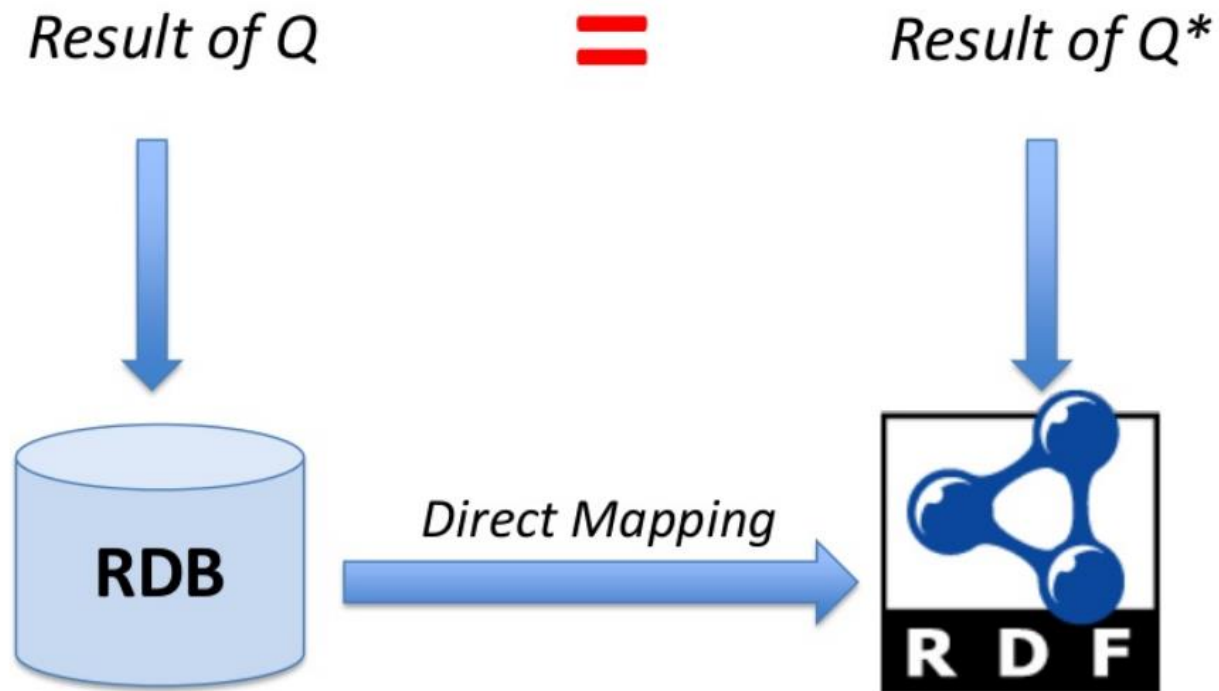


No triples generated for NULL ($\perp$).
(Semantics of NULL often not clear)

DIRECT MAPPING: INFORMATION PRESERVATION



DIRECT MAPPING: QUERY PRESERVATION



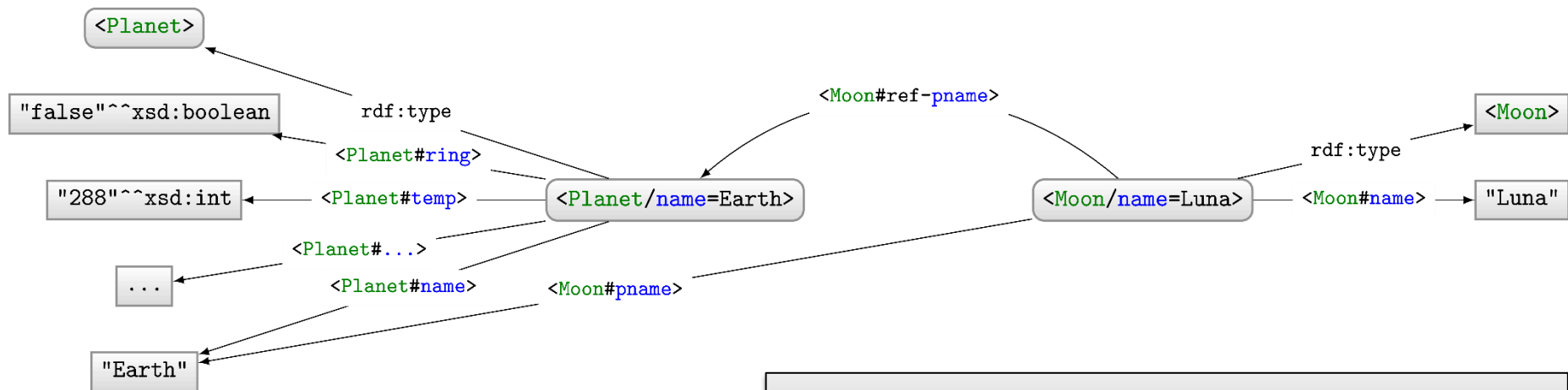
DIRECT MAPPING: CUSTOMISATION?

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	⊥	⊥
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



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

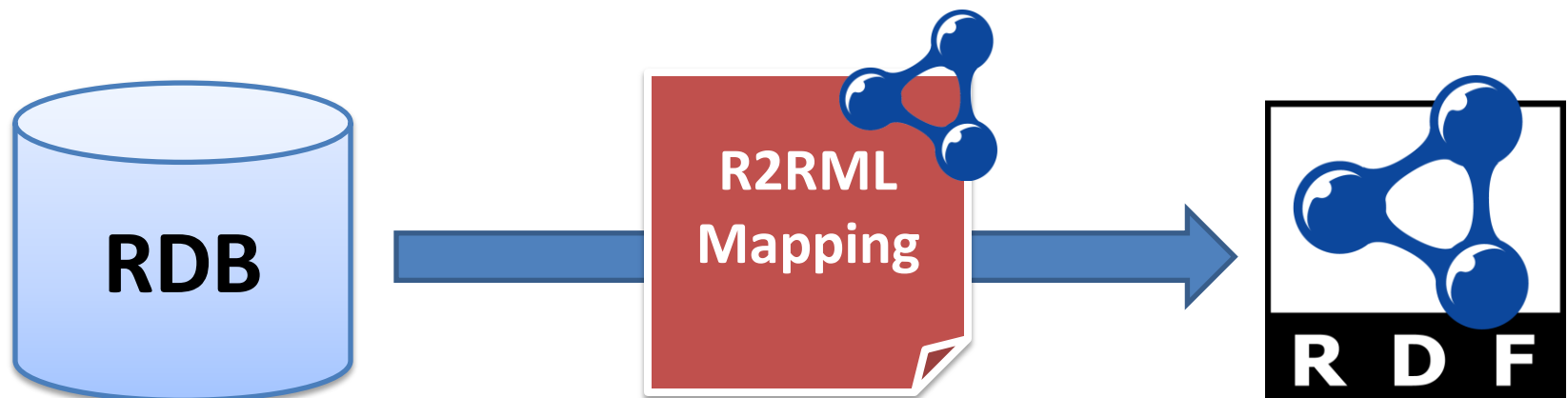
Richard Cyganiak, DERI, National University of Ireland, Galway

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

See also [translations](#).

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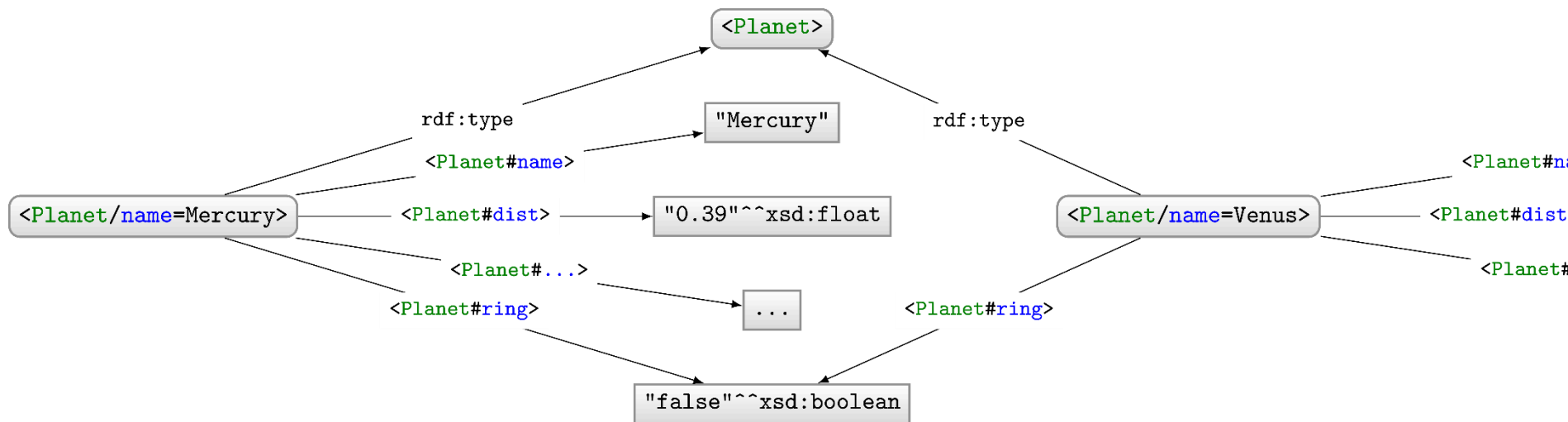
R2RML: IN A NUTSHELL



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 ;
```

Triple Mapping

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

Source Table

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

Subject Mapping

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

Predicate-Object Mapping

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

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 ;
```

Triple Mapping

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

Source Table

OPTION 1: Specify table name:

Subject Mapping

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

OPTION 2: Specify SQL query:

Predicate-Object Mapping

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

Predicate-Object Mapping

(rr:sqlVersion is optional)

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 ;
```

Triple Mapping

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

Source Table

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

Subject Mapping

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

Predicate-Object Mapping

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

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

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 ...
```

```
<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" ; rr:datatype 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							
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> .
<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>
Zero or more per triple map
```

```
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>
] ;
```

Triple Mapping

Source Table

Subject Mapping

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

Predicate—Object
Mapping

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

Predicate—Object
Mapping

...

...

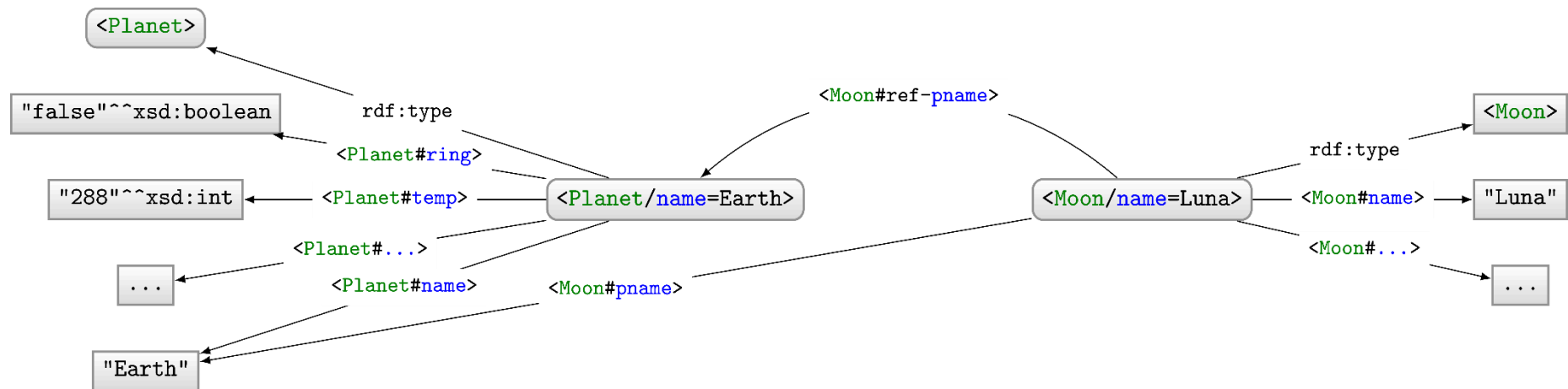
R2RML: REFERENCE OBJECT MAP

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	⊥	⊥
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



R2RML: REFERENCE OBJECT MAP

```
@prefix ... radius grav day year temp ring
<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>
  ] ; ...
```

```
<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:predicateObjectMap [
    rr:predicate <http://ex.org/Moon#ref-pname> ;
    rr:objectMap [
      rr:parentTriplesMap <PlanetMap> ;
      rr:joinCondition [
        rr:child "pname" ; rr:parent "name"
      ]
    ]
  ] ; ...
```

Moon			
name	pname	discoverer	year
Luna	Earth	1	1
Ganymedes	Jupiter	Galileo Galilei	1610
Calisto	Jupiter	Galileo Galilei	1610
Io	Jupiter	Galileo Galilei	1610
Titan	Saturn	Christiaan Huygens	1655
Phobos	Mars	Asaph Hall	1877
Deimos	Mars	Asaph Hall	1877
Charon	Pluto	James Christy	1978
Hyperion	Saturn	William Herschel	1789
Phaethon	Asteroid	Augustine Le Moine	1802
Eros	Asteroid	Karl Ludwig Heine	1898
Ceres	Asteroid	Piazzi	1801
Pallas	Asteroid	Piazzi	1802
Juno	Asteroid	Carlo Lodovico Bode	1804
Vesta	Asteroid	Oltrapp	1807
Neptune	Planet	Urbain Le Verrier	1846

Zero or more join conditions
(zero when parent and child share logical table)

Child object will be parent subject ...



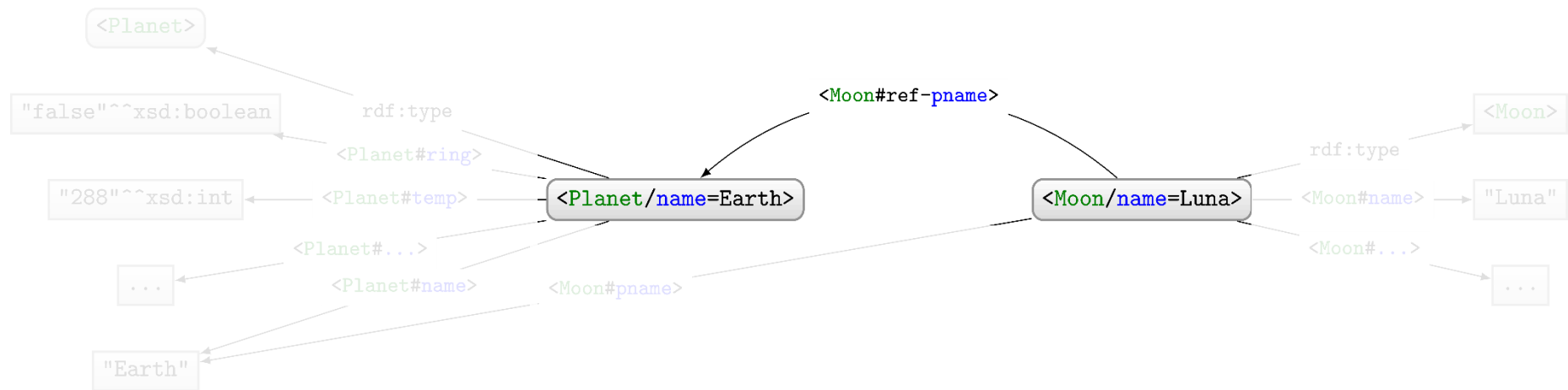
R2RML: REFERENCE OBJECT MAP

Planet

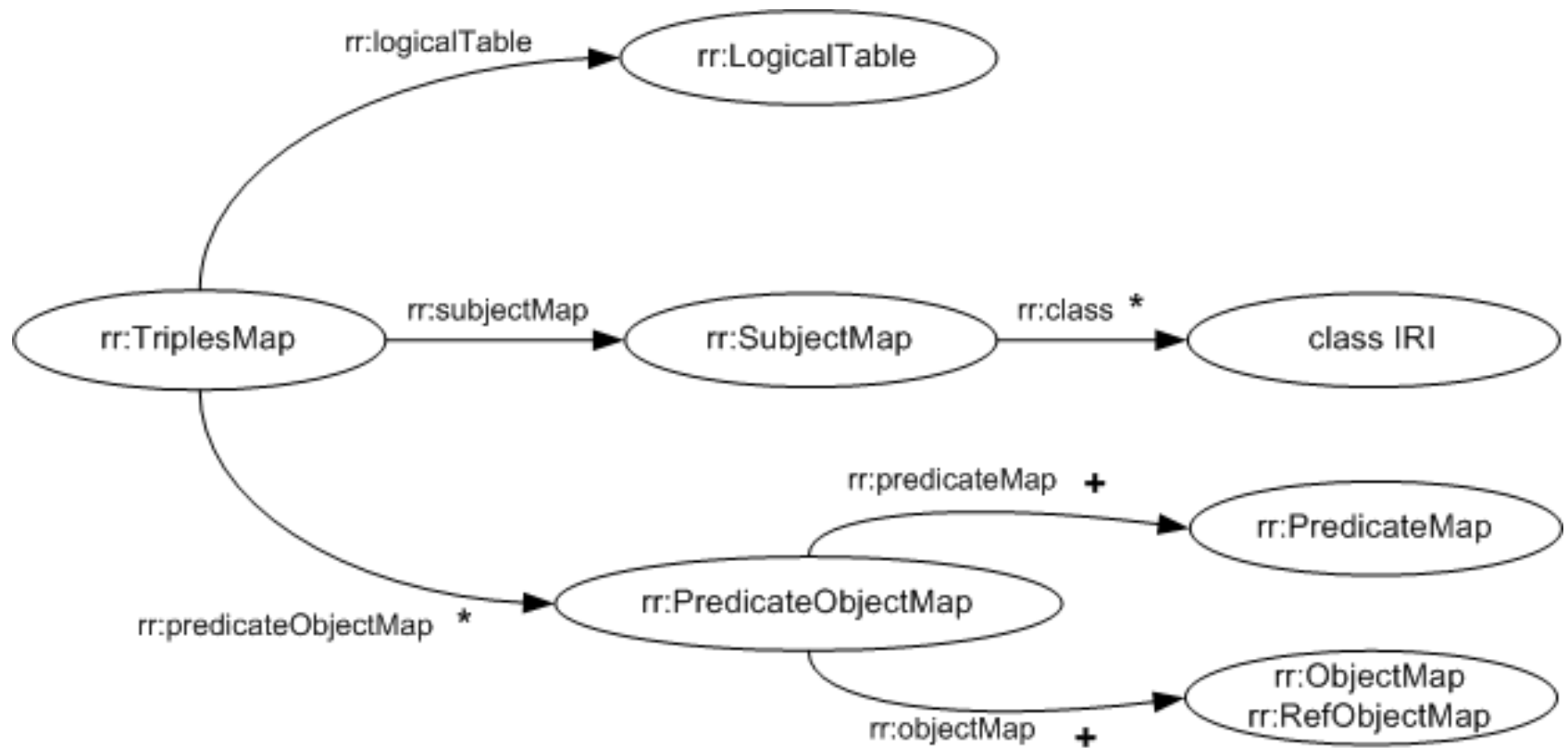
name	dist	radius	grav	day	year	temp	ring
Mercury	0.39	0.38	2.8	58.646	0.241	440	false
Venus	0.72	0.95	8.9	-243.019	0.615	730	false
Earth	1.00	1.00	9.8	0.997	1.000	288	false
Mars	1.52	0.53	3.7	1.026	1.880	186	false
Jupiter	5.20	10.97	22.9	0.414	11.862	152	true
Saturn	9.54	9.14	9.1	0.444	29.447	134	true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



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)

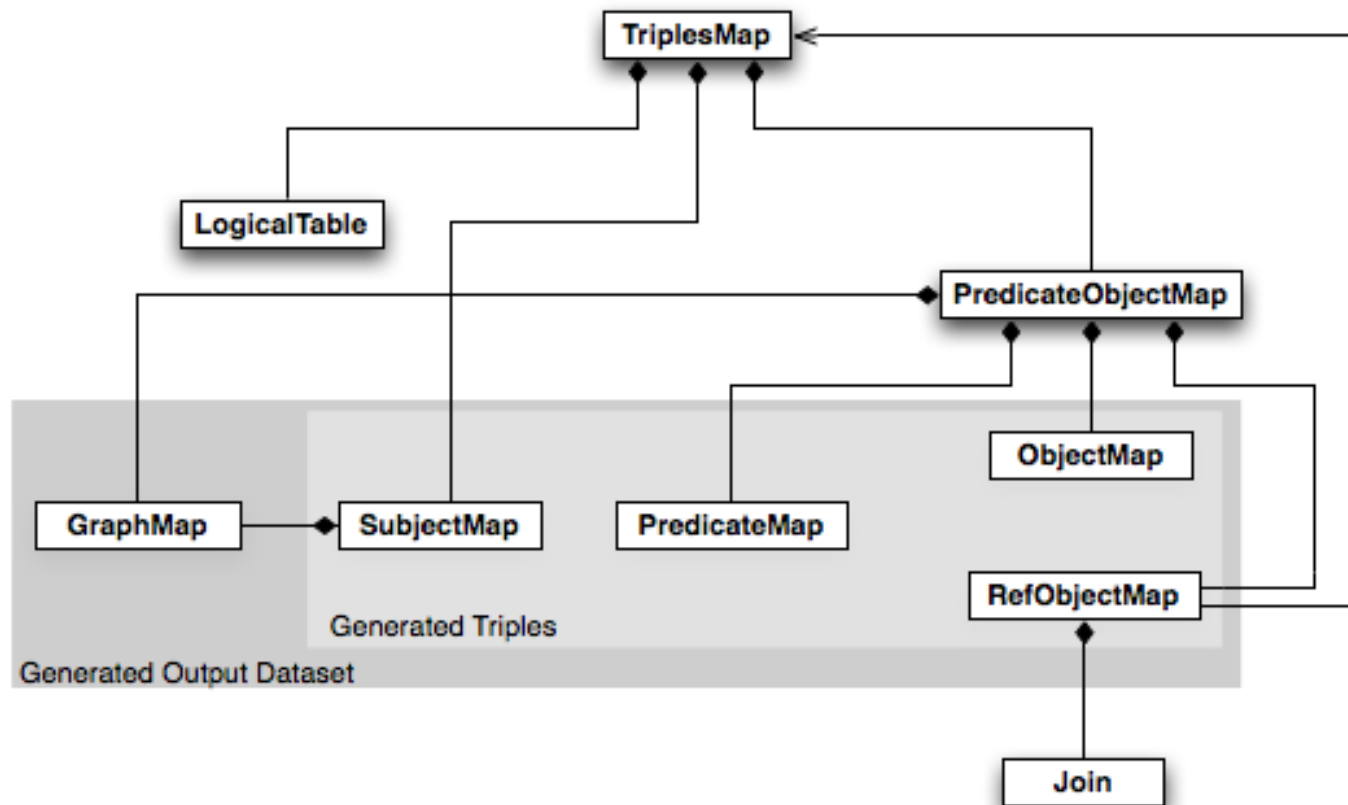
Graphs specified by term maps

`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?

