An Ontology of Astronomical Object Types for the Virtual Observatory

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Ontology (1)

- Formal representation of a domain
  - concepts
  - properties
  - instances
- Based on Description Logics (math.)
- Common vocabulary for information sharing (between humans, and also machines)

Ontology (2)

- Primitive concepts vs defined concepts
    - Better to have defined concepts: set of necessary and sufficient conditions – requires lot of work, but allows advanced reasoning
- Simple example for object types:
    - AstrObject
        - CompositeObject
            - MultipleStar
                - BinaryStar
    - Astrobject
        - CompositeObject (hasComponent AstrObject)
            - MultipleStar (CompositeObject && hasComponent>=2 Star)
                - BinaryStar (CompositeObject && hasComponent=2 Star)

Ontology (3)

- Make domain implicit knowledge explicit
- Open world assumption
  - Unless you explicitly specify the disjunction of two concepts, the reasoner won't exclude the possibility that they can be equivalent
  - Example:
    - Star (disjoint: Galaxy)
      - VariableStar
      - AGB*
    - Galaxy (disjoint: Star)
      - RadioGalaxy
      - Seyfert

Ontology (4)

- Caution with properties!
  - A star has an effective temperature of 6000K
  - What property do we have for the concept Star ?
  - The property is not the value of the temperature, but rather hasEffectiveTemperature
- Tools and standards:
  - Protégé for edition
  - OWL for storage/exchange
  - Racer, Fact++, ... for reasoning

Concepts and vocabulary

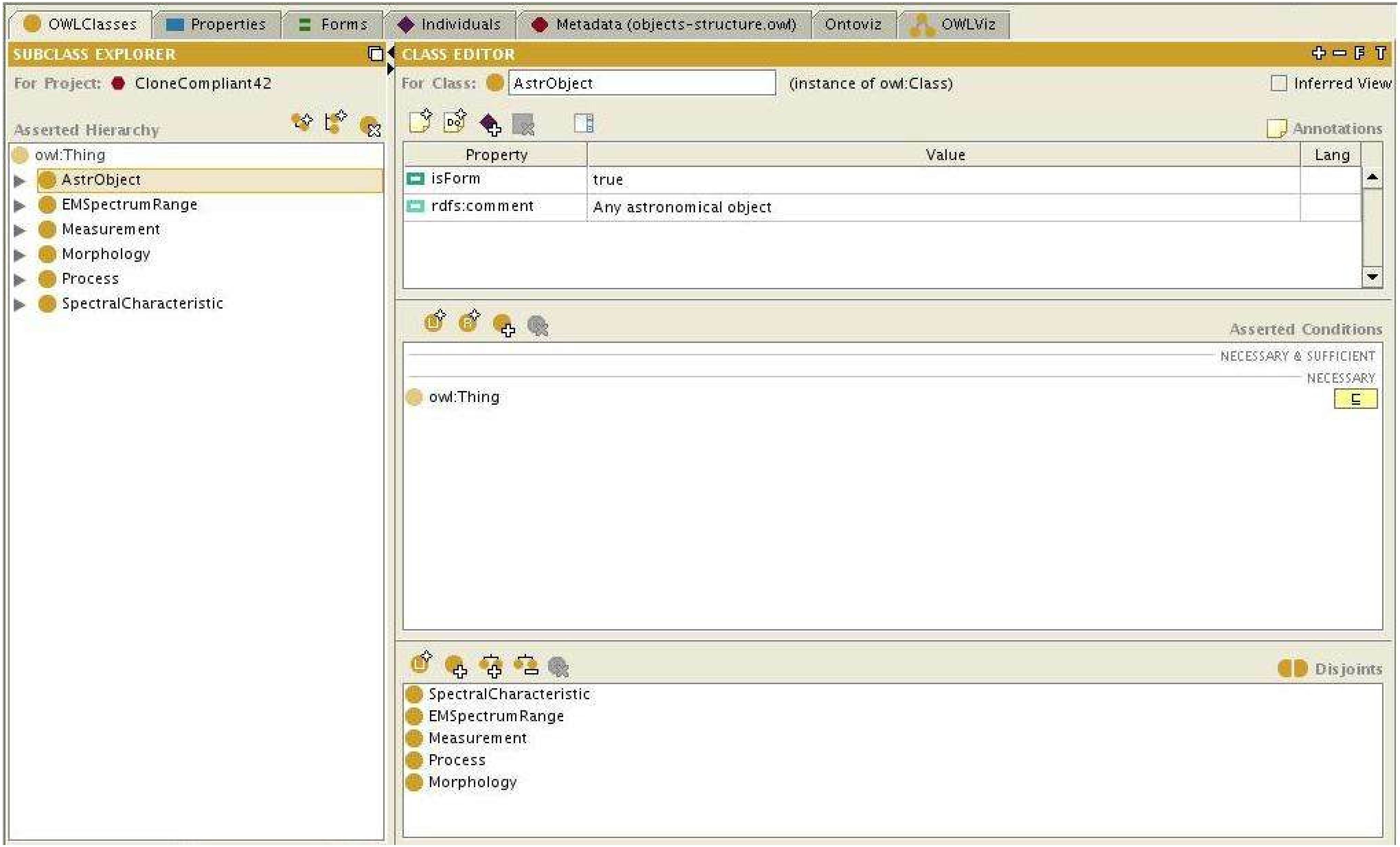
- Concepts can have multiple subsumption relations (not a simple 'tree')
- The naming of the concepts does not carry meaning (only convenient for edition)
- Various text labels can be associated to concepts
  - rdfs:comment   for description
  - Other dedicated labels, e.g. for the concept DoubleStar
    - simbad:hasSimbadNumericCode = "12.13.00.0"
    - ivoa:hasVOConcept = "stars.multiple.binary"

Ontology of Object Types

- Ontology of SIMBAD astronomical object types (INAF+CDS in VOTech DS5)
  - Relies on SIMBAD object types
  - ~ 150 terms to classify objects

```
...
14.09.08.0 |     SN          |SN*  |SuperNova
14.09.09.0 |     Symbiotic*  |Sy*  |Symbiotic Star
14.14.00.0 |    Sub-stellar  |su*  |Sub-stellar object
14.14.02.0 |     Planet?     |Pl?  |Extra-solar Planet Candidate
15.00.00.0 |  Galaxy         |G    |Galaxy
15.01.00.0 |    PartofG      |PoG  |Part of a Galaxy
15.02.00.0 |    GinCl        |GiC  |Galaxy in Cluster of Galaxies
15.03.00.0 |    GinGroup     |GiG  |Galaxy in Group of Galaxies
15.04.00.0 |    GinPair      |GiP  |Galaxy in Pair of Galaxies
...
```

Top-level concepts



For Project: CloneCompliant42

- owl:Thing
  - AstrObject
  - EMSpectrumRange
  - Measurement
  - Morphology
  - Process
  - SpectralCharacteristic

For Class: AstrObject (instance of owl:Class)

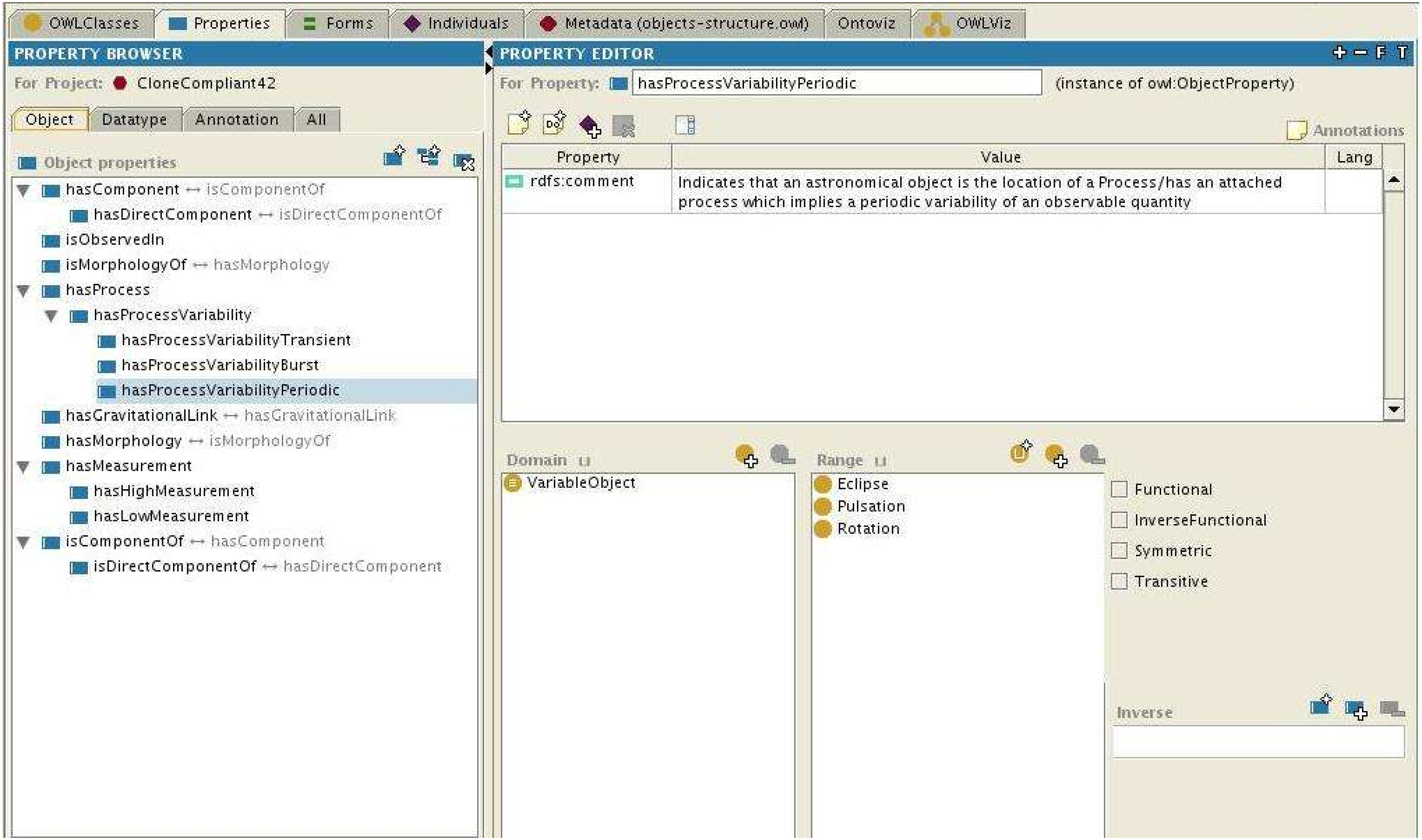
Property	Value	Lang
isForm	true	
rdfs:comment	Any astronomical object	

Asserted Conditions — NECESSARY: owl:Thing

Disjoints:

- SpectralCharacteristic
- EMSpectrumRange
- Measurement
- Process
- Morphology

Properties



PROPERTY BROWSER

For Project: CloneCompliant42

Object properties

- hasComponent ↔ isComponentOf
  - hasDirectComponent ↔ isDirectComponentOf
- isObservedIn
- isMorphologyOf ↔ hasMorphology
- hasProcess
  - hasProcessVariability
    - hasProcessVariabilityTransient
    - hasProcessVariabilityBurst
    - hasProcessVariabilityPeriodic
- hasGravitationalLink ↔ hasGravitationalLink
- hasMorphology ↔ isMorphologyOf
- hasMeasurement
  - hasHighMeasurement
  - hasLowMeasurement
- isComponentOf ↔ hasComponent
  - isDirectComponentOf ↔ hasDirectComponent

PROPERTY EDITOR

For Property: hasProcessVariabilityPeriodic (instance of owl:ObjectProperty)

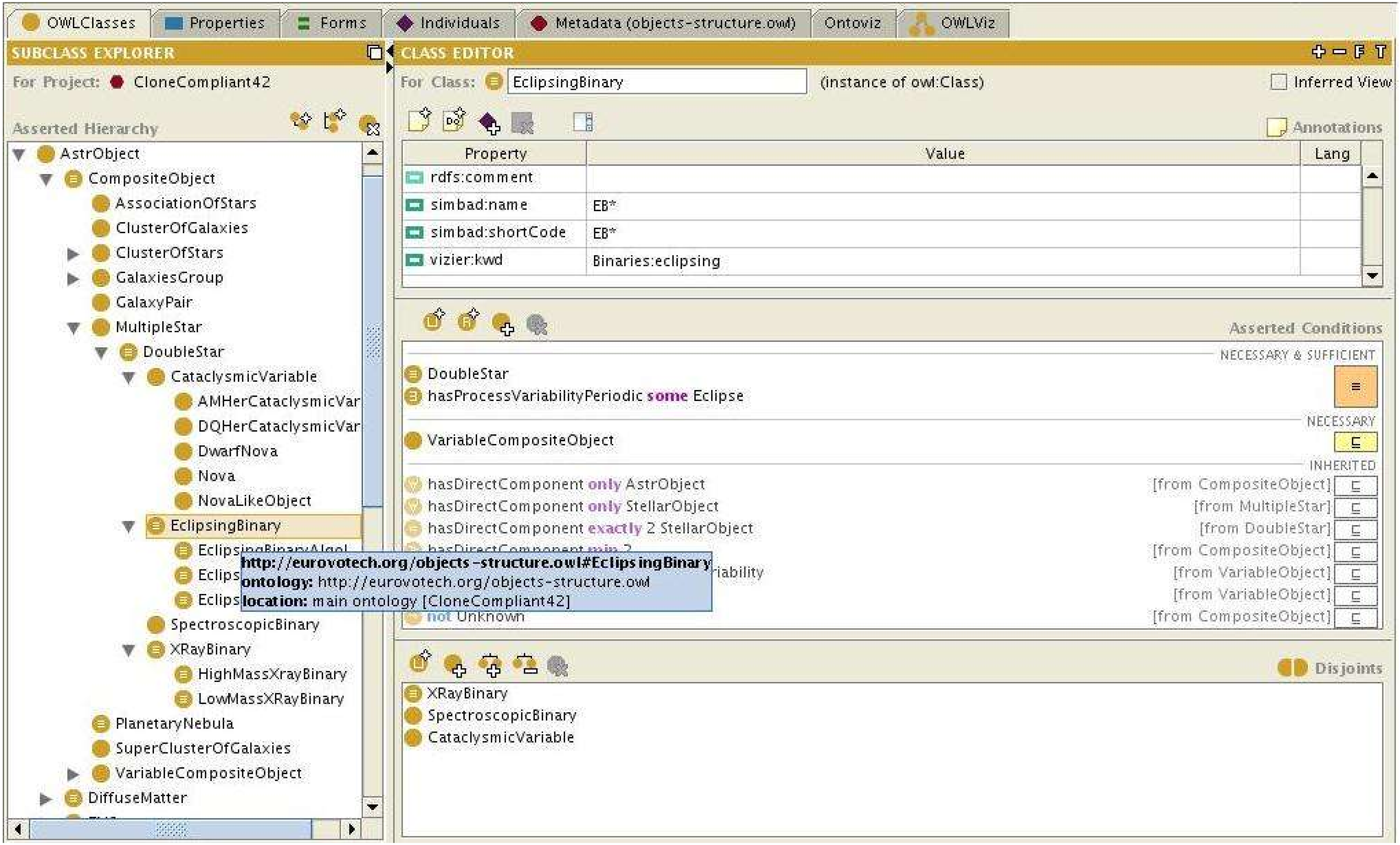
Property	Value	Lang
rdfs:comment	Indicates that an astronomical object is the location of a Process/has an attached process which implies a periodic variability of an observable quantity	

Domain: VariableObject

Range: Eclipse, Pulsation, Rotation

☐ Functional
☐ InverseFunctional
☐ Symmetric
☐ Transitive

AstrObject



For Project: CloneCompliant42

- AstrObject
  - CompositeObject
    - AssociationOfStars
    - ClusterOfGalaxies
    - ClusterOfStars
    - GalaxiesGroup
    - GalaxyPair
    - MultipleStar
      - DoubleStar
        - CataclysmicVariable
          - AMHerCataclysmicVar
          - DQHerCataclysmicVar
          - DwarfNova
          - Nova
          - NovaLikeObject
        - EclipsingBinary
          - EclipsingBinaryAlgol
          - Eclips
          - Eclips
        - SpectroscopicBinary
        - XRayBinary
          - HighMassXrayBinary
          - LowMassXRayBinary
    - PlanetaryNebula
    - SuperClusterOfGalaxies
    - VariableCompositeObject
  - DiffuseMatter

For Class: EclipsingBinary (instance of owl:Class) □ Inferred View

Property	Value	Lang
rdfs:comment		
simbad:name	EB*	
simbad:shortCode	EB*	
vizier:kwd	Binaries:eclipsing	

NECESSARY & SUFFICIENT ≡

DoubleStar
hasProcessVariabilityPeriodic **some** Eclipse

NECESSARY ⊑

VariableCompositeObject

INHERITED

hasDirectComponent **only** AstrObject	[from CompositeObject] ⊑
hasDirectComponent **only** StellarObject	[from MultipleStar] ⊑
hasDirectComponent **exactly** 2 StellarObject	[from DoubleStar] ⊑
hasDirectComponent **min** 2	[from CompositeObject] ⊑
riability	[from VariableObject] ⊑
	[from VariableObject] ⊑
not Unknown	[from CompositeObject] ⊑

http://eurovotech.org/objects-structure.owl#EclipsingBinary
ontology: http://eurovotech.org/objects-structure.owl
location: main ontology [CloneCompliant42]

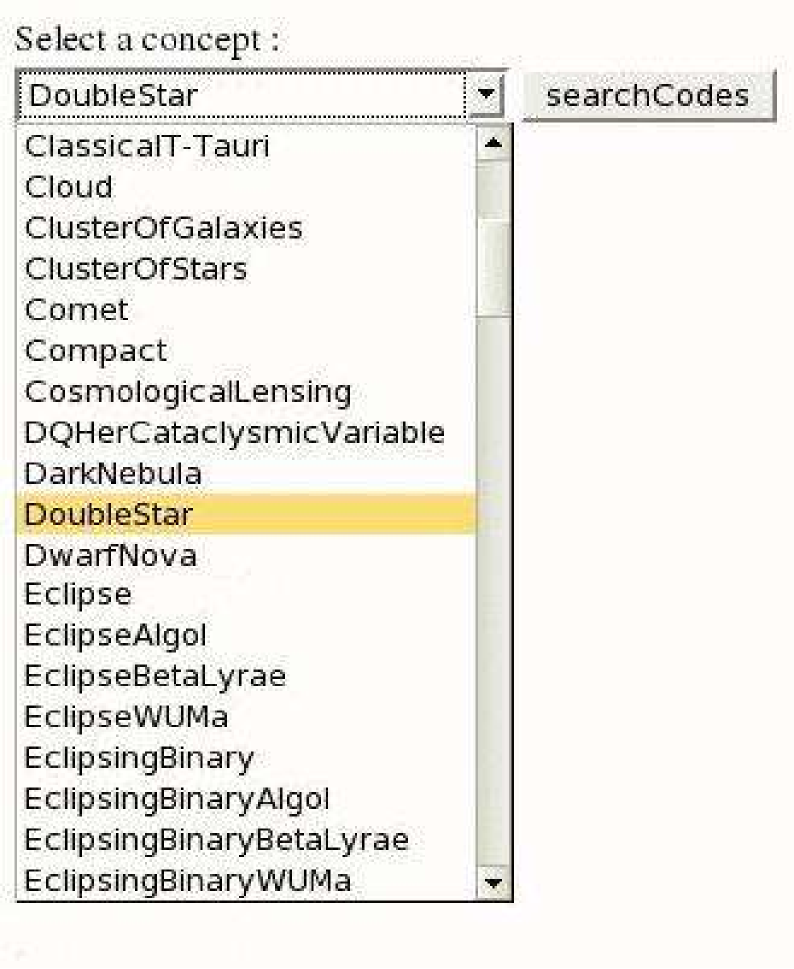
XRayBinary
SpectroscopicBinary
CataclysmicVariable

Use cases

- Advanced queries in the VO registry
  - Queries on <subject> relative to astronomical object types (label registry entries with ontology concepts)
  - Broaden or refine queries by finding subsuming or subsumed concepts
- Applications to SIMBAD
  - Validate cross-identifications in SIMBAD, by checking the consistency of the object types associated to various identifiers
  - Refine objects classification during updates
    - e.g. adding a stellar component to an instance of DoubleStar yields inconsistency -> MultipleStar

Registry Query (1)

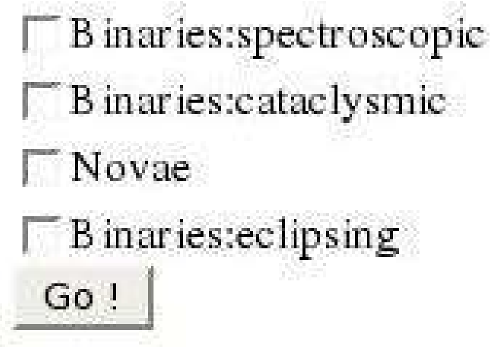
- Select one concept in the ontology



Select a concept : DoubleStar

Registry Query (2)

- The ontology is used to search labels of:
  - Equivalent and more specific concepts
  - More generic concepts if none were found



□ Binaries:spectroscopic

□ Binaries:cataclysmic

□ Novae

□ Binaries:eclipsing

- A query for these labels is sent to the VO registry (AstroGrid)

Conclusions and perspectives

- Ontology of astronomical object types under development (VOTech)
- First prototype to query the VO registry
- Other applications should follow
- Link with the IVOA Semantics working group
- Visit the CDS booth for more information