VO access to Gaia DR1:

TAP, Cone Search, COOSYS and HiPS

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Trieste Interop, Apps2

CENTRE DE DONNÉES
ASTRONOMIQUES DE STRASBOURG

Gaia DR1

- Released September 14th 2016
- Content
  - **gaia_source**: position and flux (G band)
    for *1 billion sources*
  - **TGAS**: position, flux, proper motions and parallax
    for *2 million sources*
  - light curves for RR Lyrae and Cepheid
  - QSOs

Who distributes the data?

Official archive	**Gaia archive at ESAC**	VOTable	TAP		SAMP
Partner data centers	**AIP**	VOTable			SAMP
	ARI	VOTable	TAP	CS	SAMP
	ASDC	VOTable			
	CDS	VOTable	TAP	CS	SAMP
External data centers	**IRSA**	VOTable	TAP	CS	
	GAVO	VOTable	TAP		

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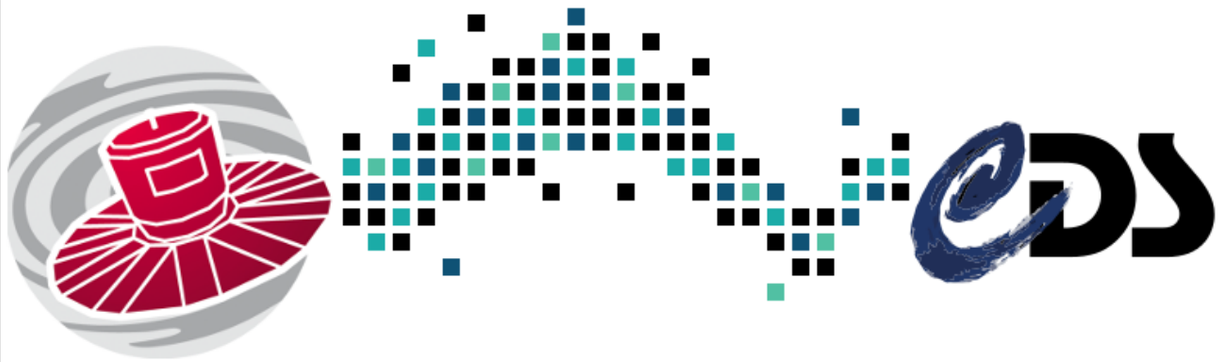
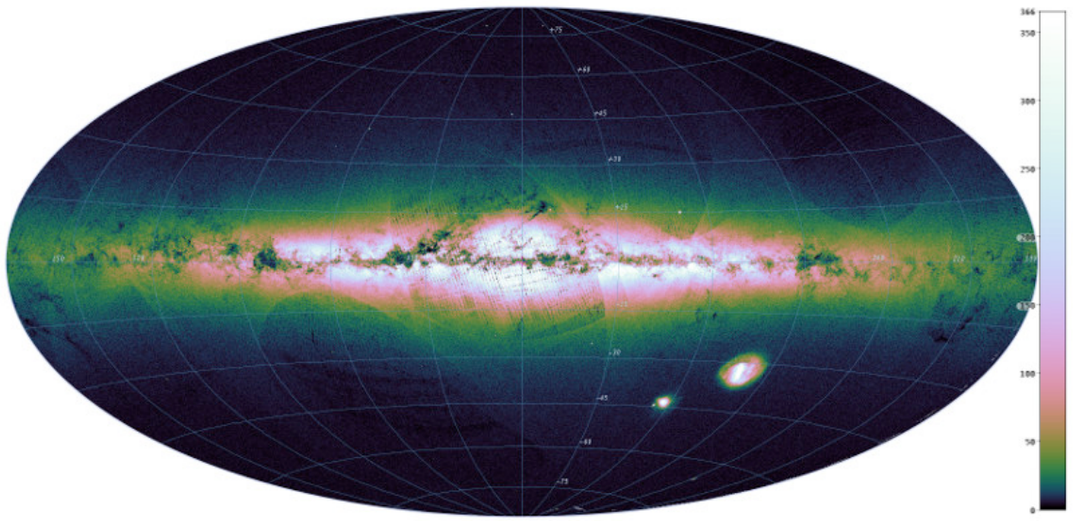
Gaia DR1 at CDS



- VizieR
- TAP VizieR
- Cross-match service
- Aladin
- HiPS catalogue



http://cds.unistra.fr/gaia

Gaia DR1 at CDS: VizieR

- VizieR web interface
- Query by position
  + constraints on fields
- Cone Search interface
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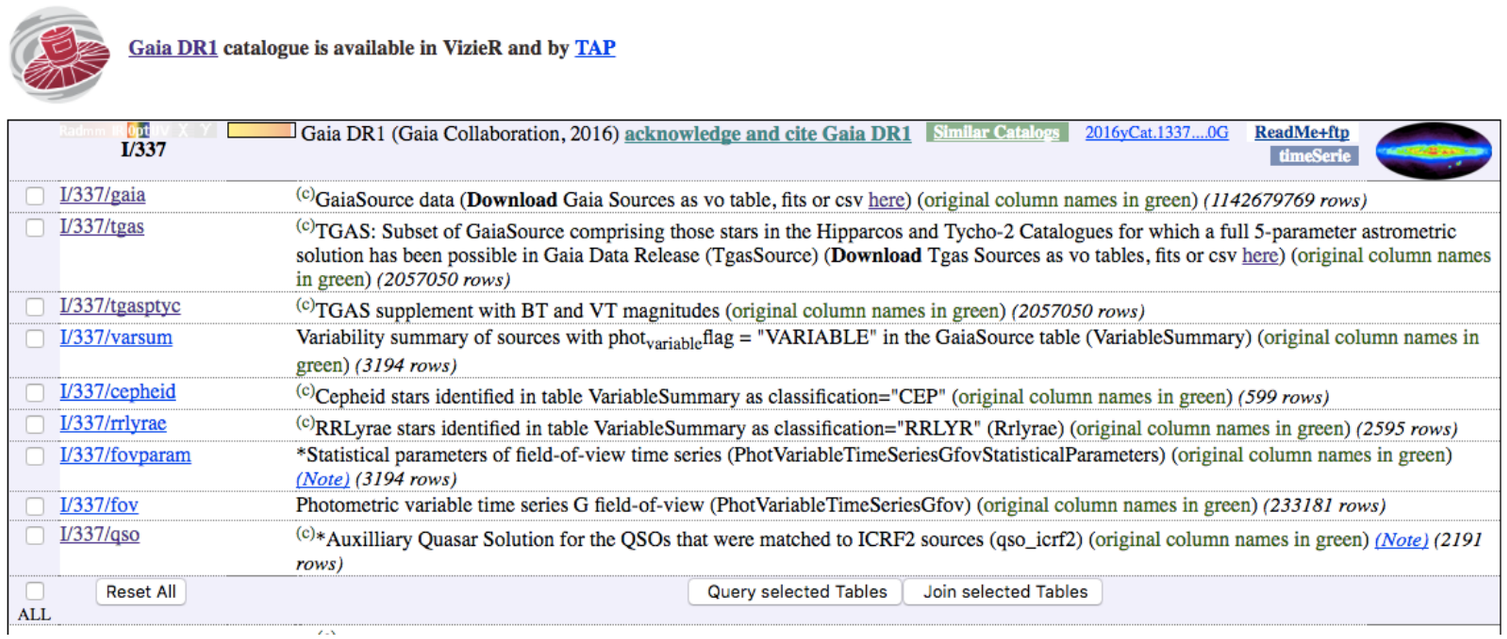

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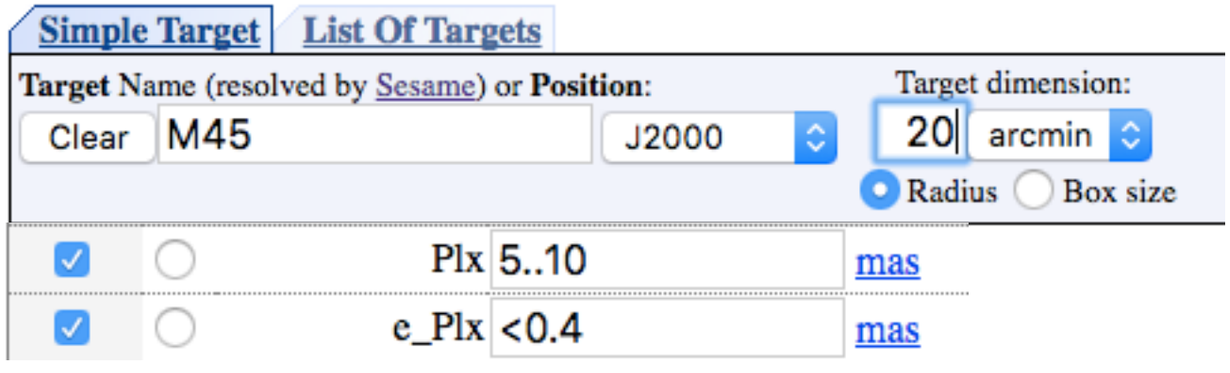

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Full	HIP	TYC2	Source	RA_ICRS deg	e_ mas	DE_ICRS deg	e_ mas	Plx mas	e_ mas	pmRA mas/yr	pmD mas/y
1	17692		6501762724415206 4	056.8374571684	0.312	+23.8031539045	0.223	7.17	0.38	19.078	-45.46
2		1800-1567-1	6520770531682675 2	056.8518153901	0.250	+23.9144901927	0.220	7.65	0.30	18.854	-43.75
3		1800-1579-1	6521210336333529 6	056.7676517819	0.318	+23.9950255841	0.180	7.13	0.32	22.722	-44.92
4		1799-79-1	6522148357188812 8	056.4652392295	0.247	+24.0386890228	0.222	7.41	0.25	19.719	-44.88
5		1800-1974-1	6523082942074163 2	056.5573526278	0.276	+24.1965619563	0.172	7.56	0.27	17.724	-12.32
6		1800-1908-1	6523148225577011 2	056.6137540453	0.367	+24.2548128138	0.167	7.74	0.32	19.956	-44.29
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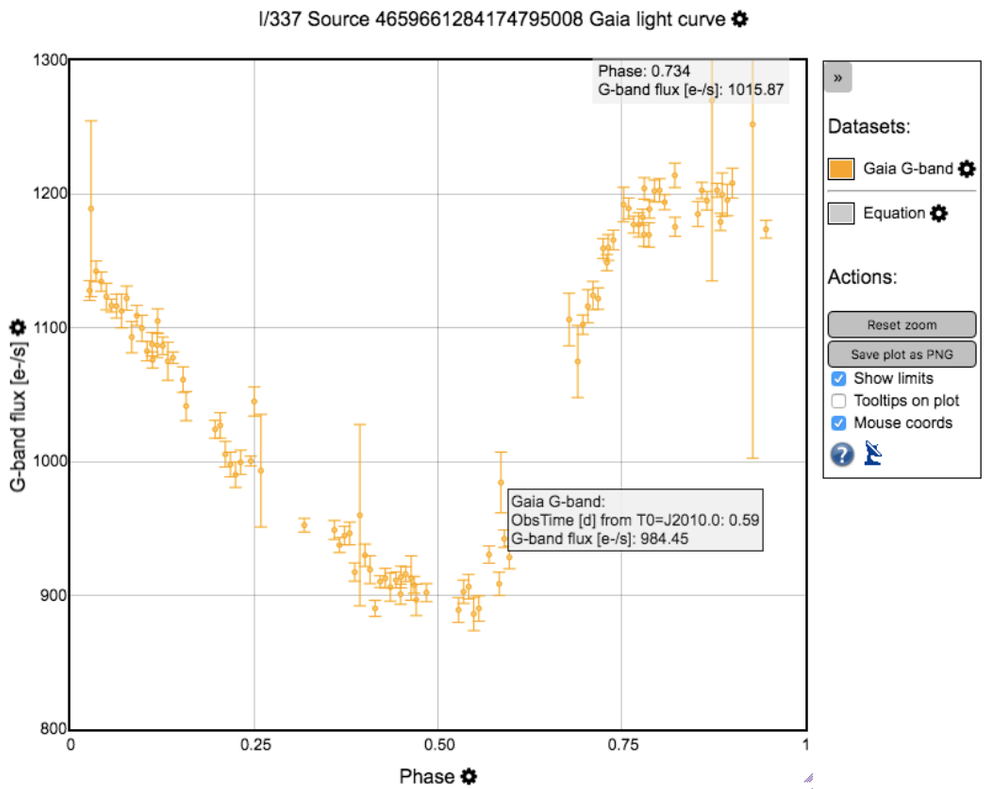

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3+ million queries last month

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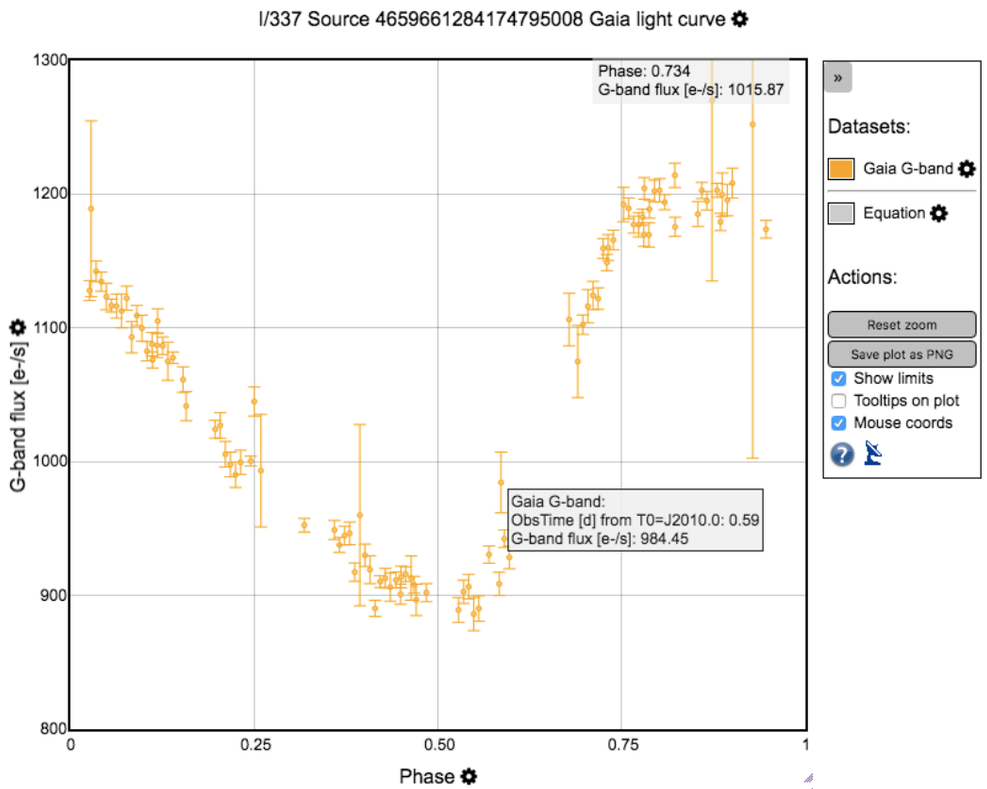

Gaia DR1 at CDS: VizieR TAP

- Gaia DR1 tables available in TAP VizieR
- Users can query Gaia tables and complement/join them with any available VizieR table (notably *Hipparcos, Tycho*, large surveys like *2MASS, SDSS*, etc)
- Web interface: http://tapvizier.u-strasbg.fr/adql/
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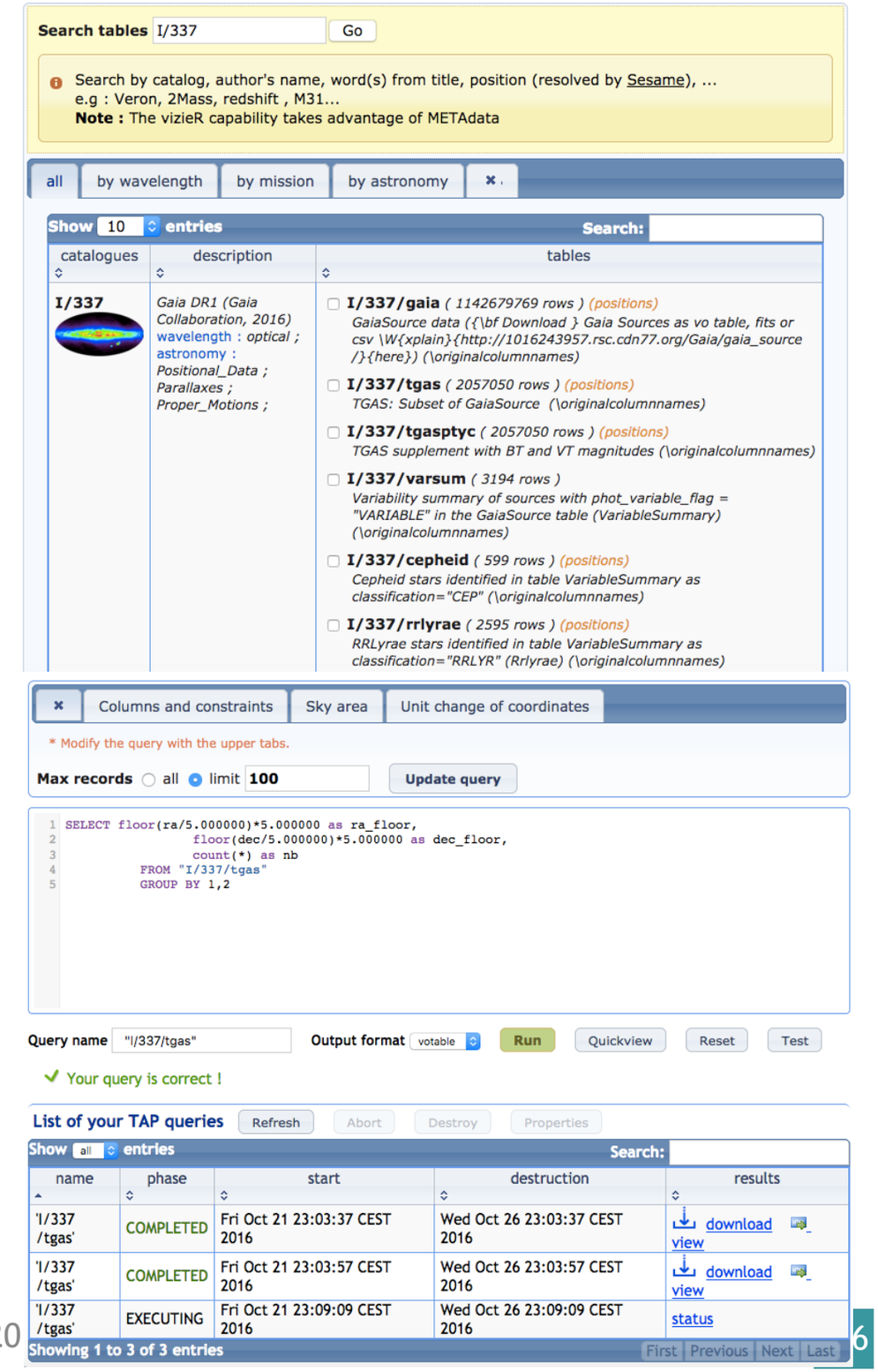

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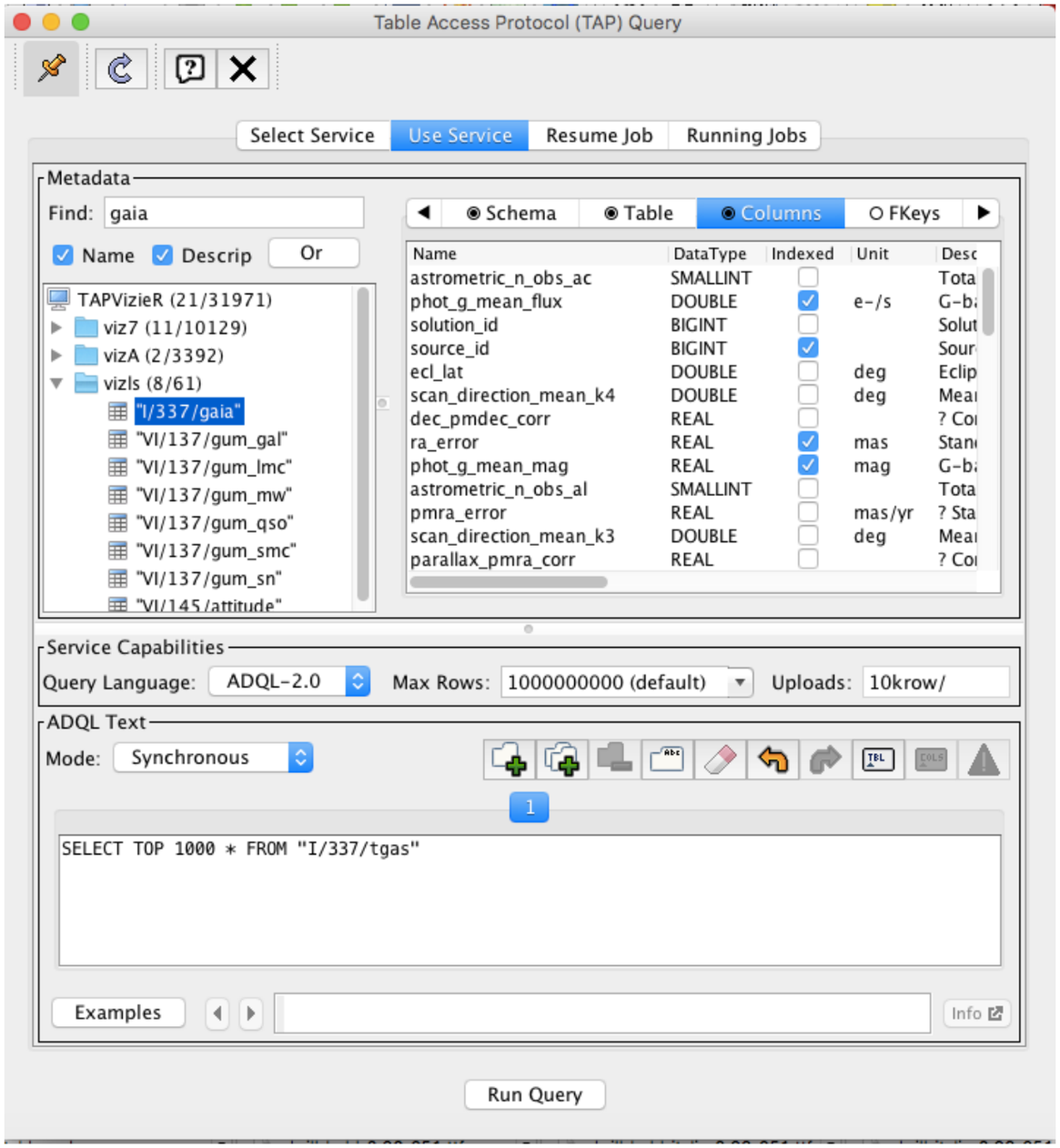

Gaia DR1 at CDS: xmatch service

- Fast positional cross-identification of Gaia sources with any VizieR table with position (or user-uploaded table)
- Web interface: http://cdsxmatch.u-strasbg.fr/xmatch
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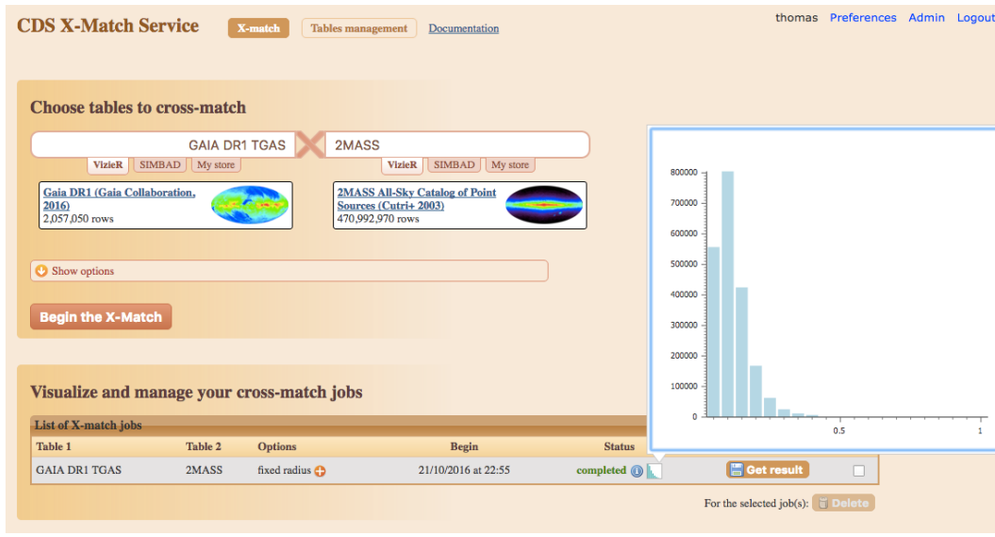

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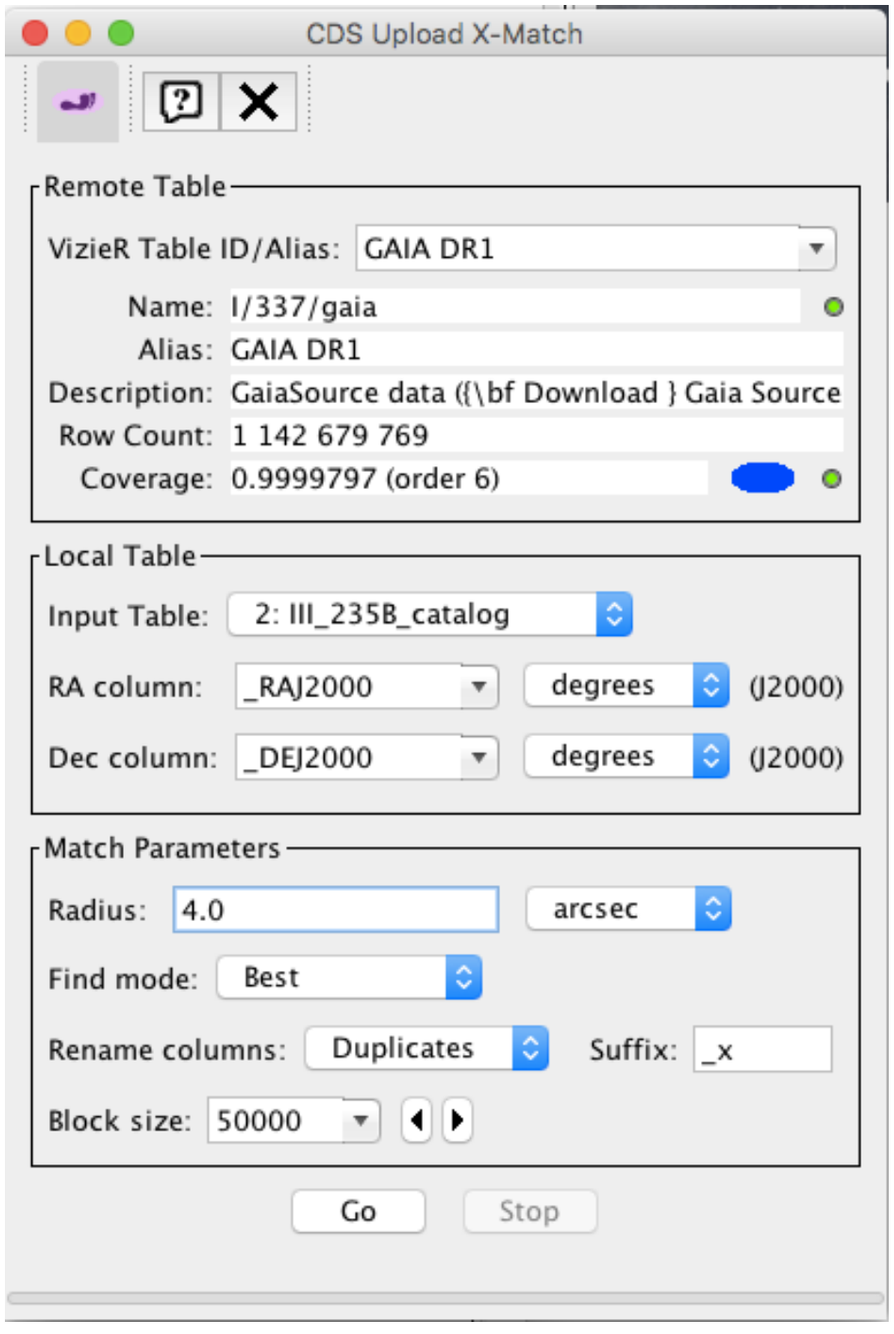

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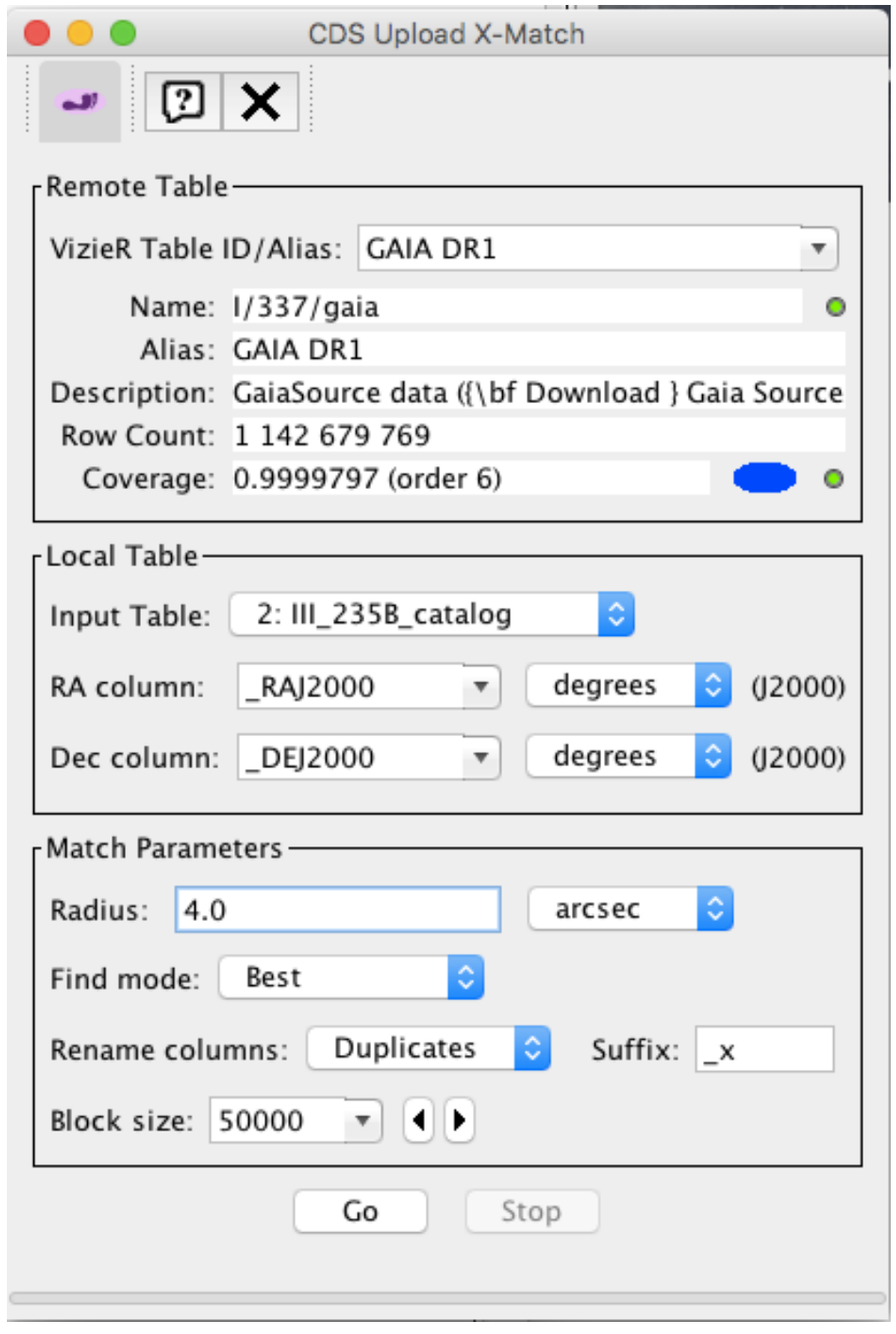
Stats:
130M positions submitted from 200+ different IPs



Gaia DR1 at CDS: Aladin

- Dedicated form to access Gaia data in Aladin Desktop

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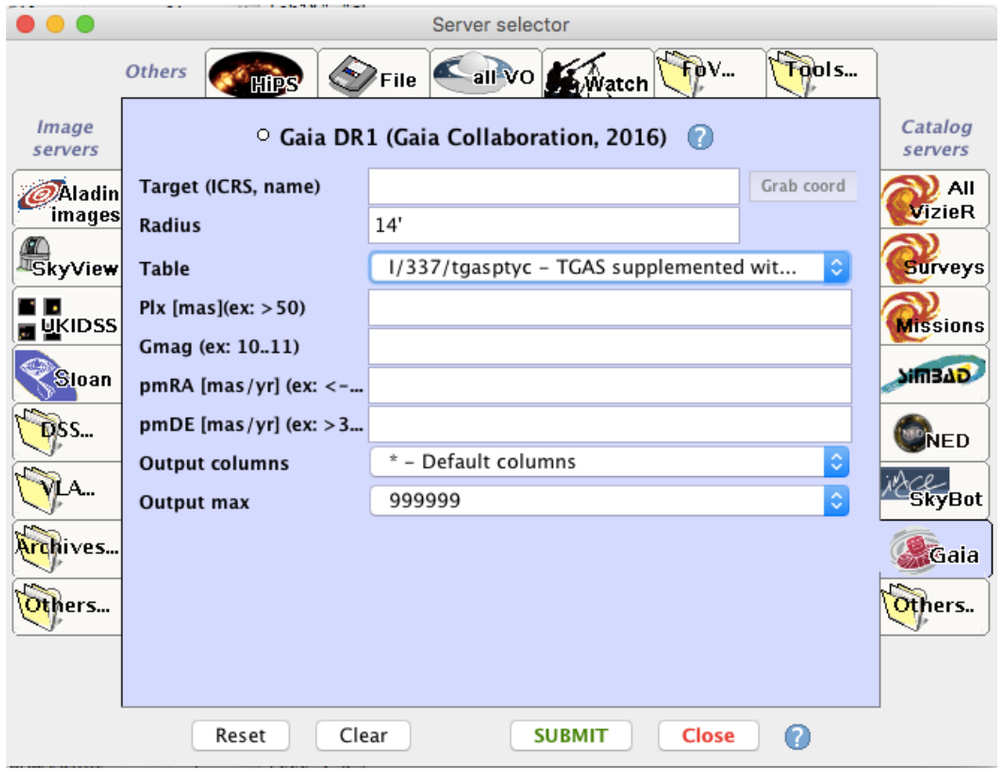

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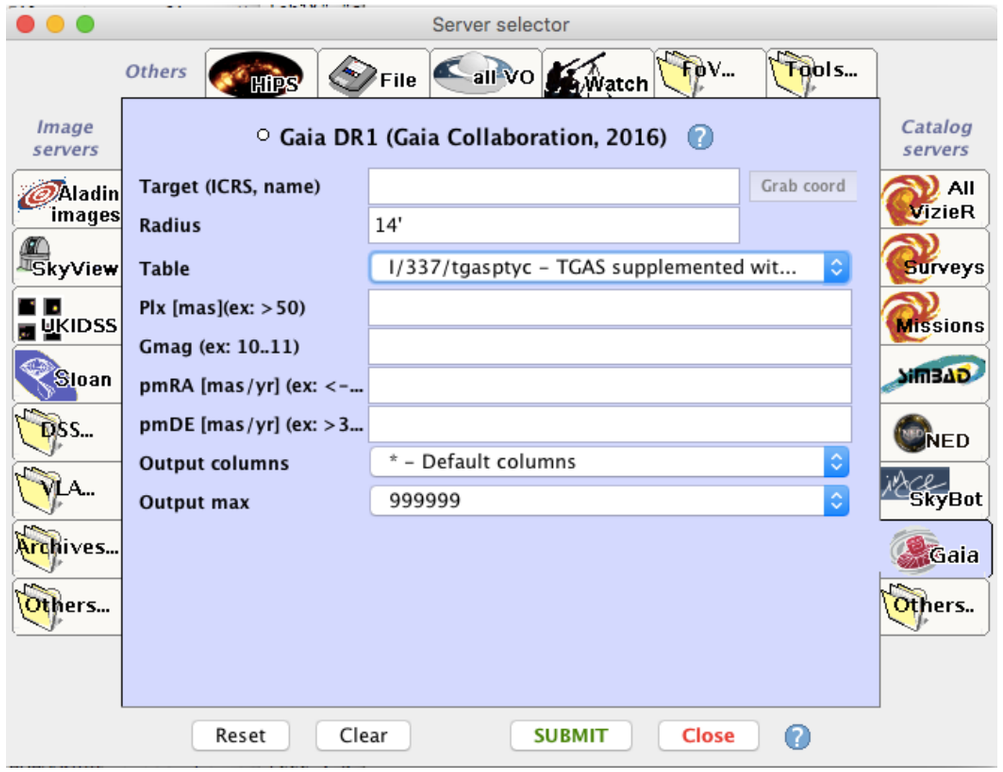

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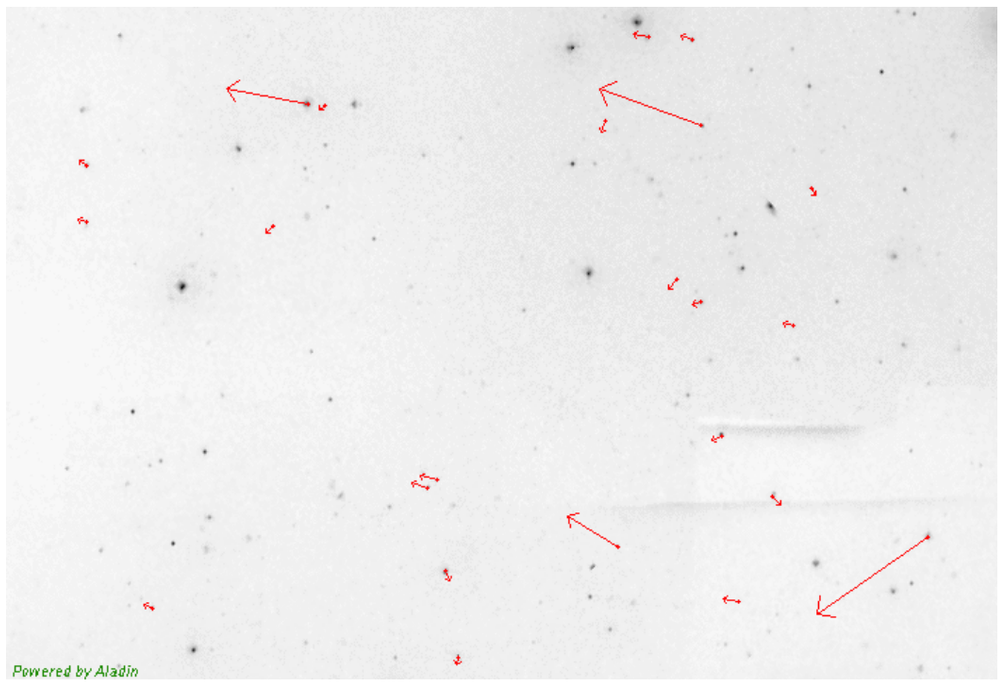
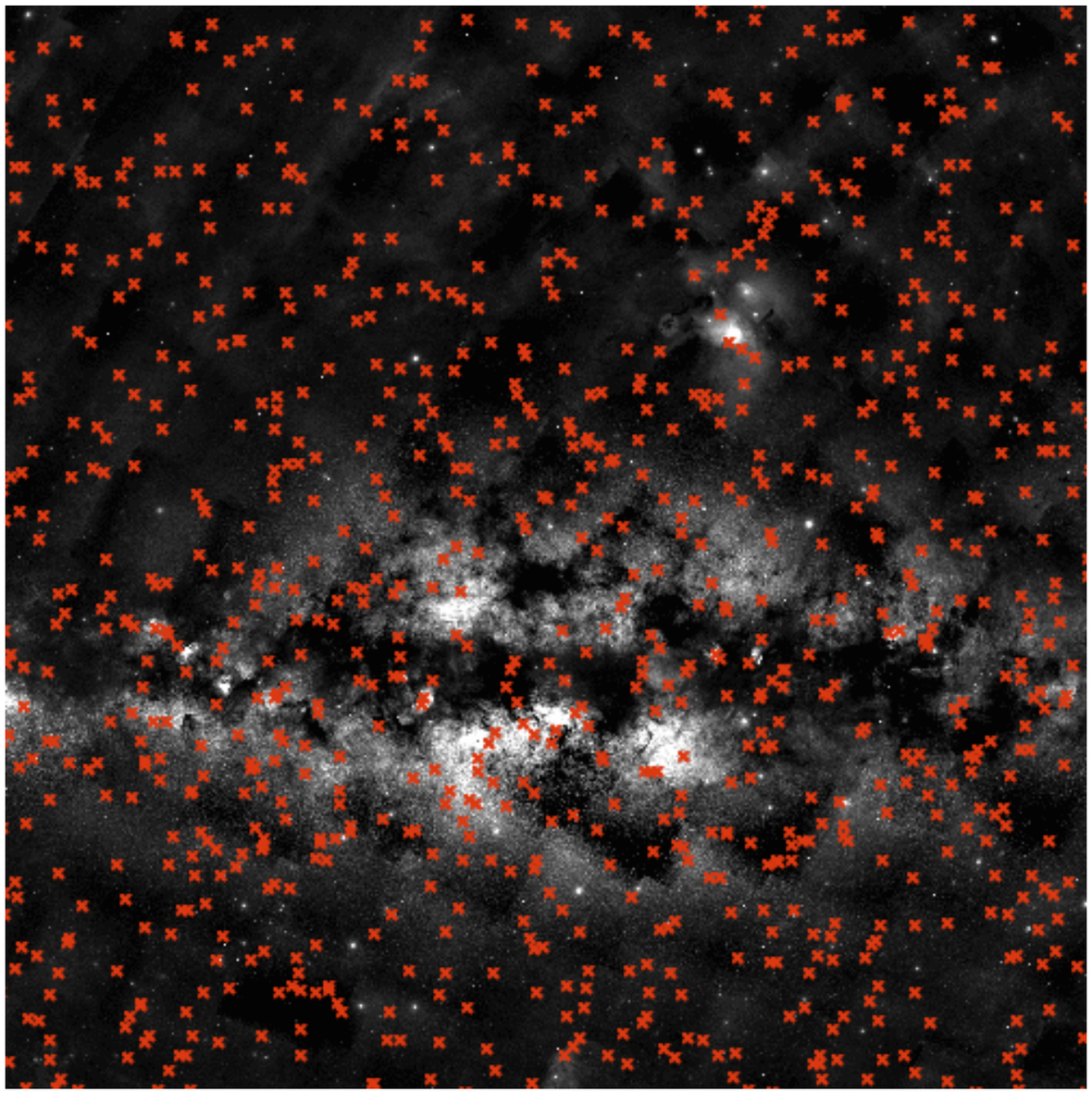


Gaia DR1 at CDS: HiPS catalogue

- HiPS progressive catalogue built from Gaia data
  http://cds.unistra.fr/Gaia/DR1/AL-visualisation.gml



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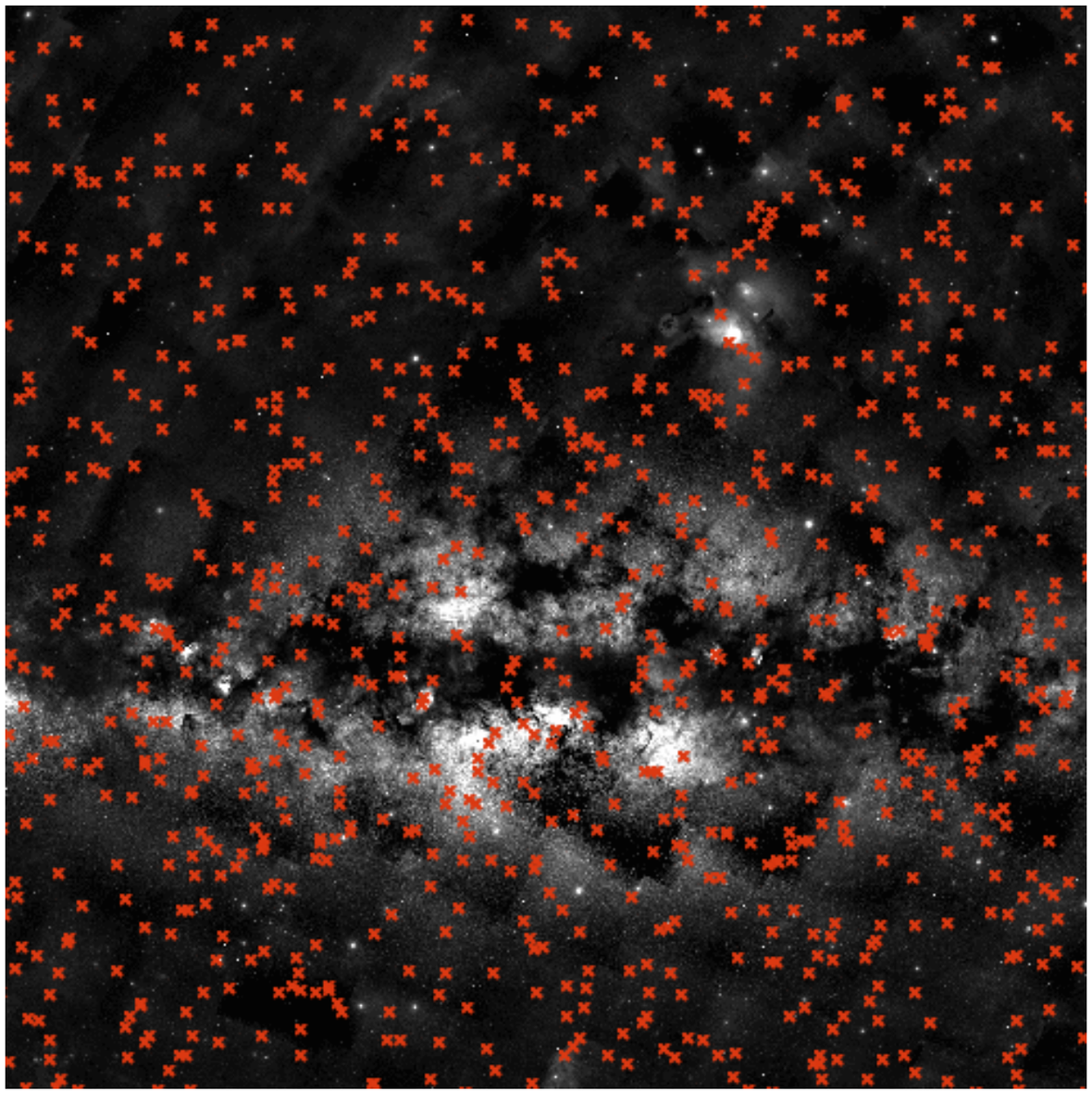

VO access to Gaia data: the good, the bad, the ugly

VO access to Gaia: the good

- Data available through numerous services
- Services do work fine
- Same column names in all TAP services
  - user-friendly
  - allows for easy re-launch of the same query on different services

VO access to Gaia: the ugly

- Poor metadata describing output FIELDs
  - no UCD
  - no unit
  - non-standard non-parseable units

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- Unit parser/validator: http://www.astro.gla.ac.uk/users/norman/ivoa/unity/
- UCD tools: http://cds.unistra.fr/UCD/tools.htx

VO access to Gaia: the bad

- (Lack of) definition of coordinate system in VOTable output
- examples
  - no description at all
  - inaccurate description
  - accurate description

No description

```
▼<RESOURCE type="results">
   <INFO name="QUERY_STATUS" value="OK"/>
  ▼<TABLE>
     <FIELD name="ra" datatype="double" unit="deg"/>
     <FIELD name="dec" datatype="double" unit="deg"/>
     <FIELD name="solution_id" datatype="long"/>
     <FIELD name="source_id" datatype="long"/>
     <FIELD name="random_index" datatype="long"/>
<FIELD name="ref_epoch" datatype="double" unit="Julian Years"/>
<FIELD name="ra_error" datatype="double" unit="mas"/>
<FIELD name="dec_error" datatype="double" unit="mas"/>
<FIELD name="parallax" datatype="double" unit="mas"/>
<FIELD name="parallax_error" datatype="double" unit="mas"/>
<FIELD name="pmra" datatype="double" unit="mas/year"/>
<FIELD name="pmra_error" datatype="double" unit="mas/year"/>
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Epoch?

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Inaccurate description

```
▼<RESOURCE type="results">
  <INFO name="QUERY_STATUS" value="OK"/>
  <COOSYS ID="coosys_FK5_2015.0" system="eq_FK5" equinox="2000.0" epoch="2015.0"/>
 ▼<TABLE>
  ▼<FIELD ID="ra" name="ra" datatype="double" arraysize="1" ucd="pos.eq.ra;meta.main" unit="deg"
   ref="coosys_FK5_2015.0">
   ▼<DESCRIPTION>
      Right ascension (ICRS) at epoch Epoch (ra)
    </DESCRIPTION>
   </FIELD>
  ▼<FIELD ID="dec" name="dec" datatype="double" arraysize="1" ucd="pos.eq.dec;meta.main" unit="deg"
   ref="coosys_FK5_2015.0">
    <DESCRIPTION>Declination (ICRS) at epoch Epoch (dec)</DESCRIPTION>
  </FIELD>
▼<FIELD ID="solution_id" name="solution_id" datatype="long" arraysize="1" ucd="meta.id;meta.version">
    <DESCRIPTION>Solution ID (solution_id)</DESCRIPTION>
  </FIELD>
▼<FIELD ID="source_id" name="source_id" datatype="long" arraysize="1" ucd="meta.id;meta.main">
    <DESCRIPTION>Source ID (source_id)</DESCRIPTION>
  </FIELD>
▼<FIELD ID="random_index" name="random_index" datatype="int" arraysize="1" ucd="meta.code">
  ▶<DESCRIPTION>...</DESCRIPTION>
  </FIELD>
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    <DESCRIPTION>Solution ID (solution_id)</DESCRIPTION>
  </FIELD>
▼<FIELD ID="source_id" name="source_id" datatype="long" arraysize="1" ucd="meta.id;meta.main">
    <DESCRIPTION>Source ID (source_id)</DESCRIPTION>
  </FIELD>
▼<FIELD ID="random_index" name="random_index" datatype="int" arraysize="1" ucd="meta.code">
  ▶<DESCRIPTION>...</DESCRIPTION>
  </FIELD>
▼<FIELD ID="ref_epoch" name="ref_epoch" datatype="double" arraysize="1" ucd="meta.ref;time.epoch" unit
  ▶<DESCRIPTION>...</DESCRIPTION>
  </FIELD>
```

Inaccurate description

```
▼<RESOURCE type="results">
  <INFO name="QUERY_STATUS" value="OK"/>
  <COOSYS ID="coosys_FK5_2015.0" system="eq_FK5" equinox="2000.0" epoch="2015.0"/>
 ▼<TABLE>
  ▼<FIELD ID="ra" name="ra" datatype="double" arraysize="1" ucd="pos.eq.ra;meta.main" unit="deg"
   ref="coosys_FK5_2015.0">
    ▼<DESCRIPTION>
       Right ascension (ICRS) at epoch Epoch (ra)
     </DESCRIPTION>
   </FIELD>
▼<FIELD ID="dec" name="dec" datatype="double" arraysize="1" ucd="pos.eq.dec;meta.main" unit="deg"
 ref="coosys_FK5_2015.0">
   <DESCRIPTION>Declination (ICRS) at epoch Epoch (dec)</DESCRIPTION>
 </FIELD>
▼<FIELD ID="solution_id" name="solution_id" datatype="long" arraysize="1" ucd="meta.id;meta.version">
   <DESCRIPTION>Solution ID (solution_id)</DESCRIPTION>
 </FIELD>
▼<FIELD ID="source_id" name="source_id" datatype="long" arraysize="1" ucd="meta.id;meta.main">
   <DESCRIPTION>Source ID (source_id)</DESCRIPTION>
 </FIELD>
▼<FIELD ID="random_index" name="random_index" datatype="int" arraysize="1" ucd="meta.code">
 ▶<DESCRIPTION>...</DESCRIPTION>
 </FIELD>
▼<FIELD ID="ref_epoch" name="ref_epoch" datatype="double" arraysize="1" ucd="meta.ref;time.epoch" unit
 ▶<DESCRIPTION>...</DESCRIPTION>
 </FIELD>
```

Inaccurate description

```
▼<RESOURCE type="results">
  <INFO name="QUERY_STATUS" value="OK"/>
  <COOSYS ID="coosys_FK5_2015.0" system="eq_FK5" equinox="2000.0" epoch="2015.0"/>
 ▼<TABLE>
  ▼<FIELD ID="ra" name="ra" datatype="double" arraysize="1" ucd="pos.eq.ra;meta.main" unit="deg"
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       Right ascension (ICRS) at epoch Epoch (ra)
     </DESCRIPTION>
   </FIELD>
▼<FIELD ID="dec" name="dec" datatype="double" arraysize="1" ucd="pos.eq.dec;meta.main" unit="deg"
 ref="coosys_FK5_2015.0">
   <DESCRIPTION>Declination (ICRS) at epoch Epoch (dec)</DESCRIPTION>
 </FIELD>
▼<FIELD ID="solution_id" name="solution_id" datatype="long" arraysize="1" ucd="meta.id;meta.version">
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 </FIELD>
▼<FIELD ID="source_id" name="source_id" datatype="long" arraysize="1" ucd="meta.id;meta.main">
   <DESCRIPTION>Source ID (source_id)</DESCRIPTION>
 </FIELD>
▼<FIELD ID="random_index" name="random_index" datatype="int" arraysize="1" ucd="meta.code">
 ▶<DESCRIPTION>...</DESCRIPTION>
 </FIELD>
▼<FIELD ID="ref_epoch" name="ref_epoch" datatype="double" arraysize="1" ucd="meta.ref;time.epoch" unit
 ▶<DESCRIPTION>...</DESCRIPTION>
 </FIELD>
```

Inaccurate description

But Gaia positions are in ICRS!

```
▼<RESOURCE type="results">
   <INFO name="QUERY_STATUS" value="OK"/>
   <COOSYS ID="coosys_FK5_2015.0" system="eq_FK5" equinox="2000.0" epoch="2015.0"/>
  ▼<TABLE>
   ▼<FIELD ID="ra" name="ra" datatype="double" arraysize="1" ucd="pos.eq.ra;meta.main" unit="deg"
    ref="coosys_FK5_2015.0">
     ▼<DESCRIPTION>
        Right ascension (ICRS) at epoch Epoch (ra)
      </DESCRIPTION>
    </FIELD>
▼<FIELD ID="dec" name="dec" datatype="double" arraysize="1" ucd="pos.eq.dec;meta.main" unit="deg"
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    <DESCRIPTION>Declination (ICRS) at epoch Epoch (dec)</DESCRIPTION>
  </FIELD>
▼<FIELD ID="solution_id" name="solution_id" datatype="long" arraysize="1" ucd="meta.id;meta.version">
    <DESCRIPTION>Solution ID (solution_id)</DESCRIPTION>
  </FIELD>
▼<FIELD ID="source_id" name="source_id" datatype="long" arraysize="1" ucd="meta.id;meta.main">
    <DESCRIPTION>Source ID (source_id)</DESCRIPTION>
  </FIELD>
▼<FIELD ID="random_index" name="random_index" datatype="int" arraysize="1" ucd="meta.code">
  ▶<DESCRIPTION>...</DESCRIPTION>
  </FIELD>
▼<FIELD ID="ref_epoch" name="ref_epoch" datatype="double" arraysize="1" ucd="meta.ref;time.epoch" unit
  ▶<DESCRIPTION>...</DESCRIPTION>
  </FIELD>
```

Accurate description

```
▼<GROUP utype="stc:CatalogEntryLocation">
    <PARAM arraysize="*" datatype="char" name="CoordFlavor" utype="stc:AstroCoordSystem.SpaceFrame.CoordFlavor" value="SPHERICAL"/>
    <PARAM arraysize="*" datatype="char" name="coord_naxes" utype="stc:AstroCoordSystem.SpaceFrame.CoordFlavor.coord_naxes" value="3"/>
    <PARAM arraysize="*" datatype="char" name="CoordRefFrame" utype="stc:AstroCoordSystem.SpaceFrame.CoordRefFrame" value="ICRS"/>
    <PARAM arraysize="*" datatype="char" name="ReferencePosition" utype="stc:AstroCoordSystem.SpaceFrame.ReferencePosition"
    value="BARYCENTER"/>
    <PARAM arraysize="*" datatype="char" name="TimeScale" utype="stc:AstroCoordSystem.TimeFrame.TimeScale" value="TCB"/>
    <PARAM arraysize="*" datatype="char" name="C3" utype="stc:AstroCoords.Velocity3D.Value3.C3" value="0.0"/>
    <PARAM arraysize="*" datatype="char" name="URI" utype="stc:DataModel.URI" value="http://www.ivoa.net/xml/STC/stc-v1.30.xsd"/>
    <FIELDref ref="raj2000" utype="stc:AstroCoords.Position3D.Value3.C1"/>
    <FIELDref ref="dej2000" utype="stc:AstroCoords.Position3D.Value3.C2"/>
    <FIELDref ref="parallax" utype="stc:AstroCoords.Position3D.Value3.C3"/>
    <FIELDref ref="ref_epoch" utype="stc:AstroCoords.Time.TimeInstant"/>
    <FIELDref ref="pmra" utype="stc:AstroCoords.Velocity3D.Value3.C1"/>
    <FIELDref ref="pmdec" utype="stc:AstroCoords.Velocity3D.Value3.C2"/>
  </GROUP>
▼<FIELD ID="source_id" datatype="long" name="source_id" ucd="meta.id;meta.main">
    <DESCRIPTION>Unique source identifier</DESCRIPTION>
    <VALUES null="-1"/>
  </FIELD>
▼<FIELD ID="raj2000" datatype="double" name="raj2000" ucd="pos.eq.ra;meta.main" unit="deg">
    <DESCRIPTION>Barycentric Right Ascension in ICRS at ref_epoch</DESCRIPTION>
  </FIELD>
▼<FIELD ID="dej2000" datatype="double" name="dej2000" ucd="pos.eq.dec;meta.main" unit="deg">
    <DESCRIPTION>Barycentric Declination in ICRS at ref_epoch</DESCRIPTION>
  </FIELD>
```

Accurate description

```
<GROUP utype="stc:CatalogEntryLocation">
  <PARAM arraysize="*" datatype="char" name="CoordFlavor" utype="stc:AstroCoordSystem.SpaceFrame.CoordFlavor" value="SPHERICAL"/>
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  <PARAM arraysize="*" datatype="char" name="CoordRefFrame" utype="stc:AstroCoordSystem.SpaceFrame.CoordRefFrame" value="ICRS"/>
  <PARAM arraysize="*" datatype="char" name="ReferencePosition" utype="stc:AstroCoordSystem.SpaceFrame.ReferencePosition"
  value="BARYCENTER"/>
  <PARAM arraysize="*" datatype="char" name="TimeScale" utype="stc:AstroCoordSystem.TimeFrame.TimeScale" value="TCB"/>
  <PARAM arraysize="*" datatype="char" name="C3" utype="stc:AstroCoords.Velocity3D.Value3.C3" value="0.0"/>
  <PARAM arraysize="*" datatype="char" name="URI" utype="stc:DataModel.URI" value="http://www.ivoa.net/xml/STC/stc-v1.30.xsd"/>
  <FIELDref ref="raj2000" utype="stc:AstroCoords.Position3D.Value3.C1"/>
  <FIELDref ref="dej2000" utype="stc:AstroCoords.Position3D.Value3.C2"/>
  <FIELDref ref="parallax" utype="stc:AstroCoords.Position3D.Value3.C3"/>
  <FIELDref ref="ref_epoch" utype="stc:AstroCoords.Time.TimeInstant"/>
  <FIELDref ref="pmra" utype="stc:AstroCoords.Velocity3D.Value3.C1"/>
  <FIELDref ref="pmdec" utype="stc:AstroCoords.Velocity3D.Value3.C2"/>
</GROUP>
<FIELD ID="source_id" datatype="long" name="source_id" ucd="meta.id;meta.main">
  <DESCRIPTION>Unique source identifier</DESCRIPTION>
  <VALUES null="-1"/>
</FIELD>
<FIELD ID="raj2000" datatype="double" name="raj2000" ucd="pos.eq.ra;meta.main" unit="deg">
  <DESCRIPTION>Barycentric Right Ascension in ICRS at ref_epoch</DESCRIPTION>
</FIELD>
<FIELD ID="dej2000" datatype="double" name="dej2000" ucd="pos.eq.dec;meta.main" unit="deg">
  <DESCRIPTION>Barycentric Declination in ICRS at ref_epoch</DESCRIPTION>
</FIELD>
```

Accurate description

```
▼<GROUP utype="stc:CatalogEntryLocation">
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    <FIELDref ref="raj2000" utype="stc:AstroCoords.Position3D.Value3.C1"/>
    <FIELDref ref="dej2000" utype="stc:AstroCoords.Position3D.Value3.C2"/>
    <FIELDref ref="parallax" utype="stc:AstroCoords.Position3D.Value3.C3"/>
    <FIELDref ref="ref_epoch" utype="stc:AstroCoords.Time.TimeInstant"/>
    <FIELDref ref="pmra" utype="stc:AstroCoords.Velocity3D.Value3.C1"/>
    <FIELDref ref="pmdec" utype="stc:AstroCoords.Velocity3D.Value3.C2"/>
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▼<FIELD ID="raj2000" datatype="double" name="raj2000" ucd="pos.eq.ra;meta.main" unit="deg">
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  </FIELD>
▼<FIELD ID="dej2000" datatype="double" name="dej2000" ucd="pos.eq.dec;meta.main" unit="deg">
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  </FIELD>
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Accurate description

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    value="BARYCENTER"/>
    <PARAM arraysize="*" datatype="char" name="TimeScale" utype="stc:AstroCoordSystem.TimeFrame.TimeScale" value="TCB"/>
    <PARAM arraysize="*" datatype="char" name="C3" utype="stc:AstroCoords.Velocity3D.Value3.C3" value="0.0"/>
    <PARAM arraysize="*" datatype="char" name="URI" utype="stc:DataModel.URI" value="http://www.ivoa.net/xml/STC/stc-v1.30.xsd"/>
    <FIELDref ref="raj2000" utype="stc:AstroCoords.Position3D.Value3.C1"/>
    <FIELDref ref="dej2000" utype="stc:AstroCoords.Position3D.Value3.C2"/>
    <FIELDref ref="parallax" utype="stc:AstroCoords.Position3D.Value3.C3"/>
    <FIELDref ref="ref_epoch" utype="stc:AstroCoords.Time.TimeInstant"/>
    <FIELDref ref="pmra" utype="stc:AstroCoords.Velocity3D.Value3.C1"/>
    <FIELDref ref="pmdec" utype="stc:AstroCoords.Velocity3D.Value3.C2"/>
  </GROUP>
▼<FIELD ID="source_id" datatype="long" name="source_id" ucd="meta.id;meta.main">
    <DESCRIPTION>Unique source identifier</DESCRIPTION>
    <VALUES null="-1"/>
  </FIELD>
▼<FIELD ID="raj2000" datatype="double" name="raj2000" ucd="pos.eq.ra;meta.main" unit="deg">
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  </FIELD>
▼<FIELD ID="dej2000" datatype="double" name="dej2000" ucd="pos.eq.dec;meta.main" unit="deg">
    <DESCRIPTION>Barycentric Declination in ICRS at ref_epoch</DESCRIPTION>
  </FIELD>
```

Accurate description

Based on *Referencing STC in VOTable* note v2.0

```
▼<GROUP utype="stc:CatalogEntryLocation">
    <PARAM arraysize="*" datatype="char" name="CoordFlavor" utype="stc:AstroCoordSystem.SpaceFrame.CoordFlavor" value="SPHERICAL"/>
    <PARAM arraysize="*" datatype="char" name="coord_naxes" utype="stc:AstroCoordSystem.SpaceFrame.CoordFlavor.coord_naxes" value="3"/>
    <PARAM arraysize="*" datatype="char" name="CoordRefFrame" utype="stc:AstroCoordSystem.SpaceFrame.CoordRefFrame" value="ICRS"/>
    <PARAM arraysize="*" datatype="char" name="ReferencePosition" utype="stc:AstroCoordSystem.SpaceFrame.ReferencePosition"
    value="BARYCENTER"/>
    <PARAM arraysize="*" datatype="char" name="TimeScale" utype="stc:AstroCoordSystem.TimeFrame.TimeScale" value="TCB"/>
    <PARAM arraysize="*" datatype="char" name="C3" utype="stc:AstroCoords.Velocity3D.Value3.C3" value="0.0"/>
    <PARAM arraysize="*" datatype="char" name="URI" utype="stc:DataModel.URI" value="http://www.ivoa.net/xml/STC/stc-v1.30.xsd"/>
    <FIELDref ref="raj2000" utype="stc:AstroCoords.Position3D.Value3.C1"/>
    <FIELDref ref="dej2000" utype="stc:AstroCoords.Position3D.Value3.C2"/>
    <FIELDref ref="parallax" utype="stc:AstroCoords.Position3D.Value3.C3"/>
    <FIELDref ref="ref_epoch" utype="stc:AstroCoords.Time.TimeInstant"/>
    <FIELDref ref="pmra" utype="stc:AstroCoords.Velocity3D.Value3.C1"/>
    <FIELDref ref="pmdec" utype="stc:AstroCoords.Velocity3D.Value3.C2"/>
  </GROUP>
▼<FIELD ID="source_id" datatype="long" name="source_id" ucd="meta.id;meta.main">
    <DESCRIPTION>Unique source identifier</DESCRIPTION>
    <VALUES null="-1"/>
  </FIELD>
▼<FIELD ID="raj2000" datatype="double" name="raj2000" ucd="pos.eq.ra;meta.main" unit="deg">
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  </FIELD>
▼<FIELD ID="dej2000" datatype="double" name="dej2000" ucd="pos.eq.dec;meta.main" unit="deg">
    <DESCRIPTION>Barycentric Declination in ICRS at ref_epoch</DESCRIPTION>
  </FIELD>
```

How to improve description of coordinates?

- In Banff (nov 2014):
  - only 1 service provider (out of 20 tested) was describing coordinates according to the *Referencing STC in VOTable* note
  - only 1 client was parsing the description as expected
    - suggestion to un-deprecate COOSYS
      as a temporary solution to increase number of services
      and clients supporting coordinates description/parsing
- COOSYS not enough, can't describe everything
  (eg: different epoch for each source)
- How shall we go on?