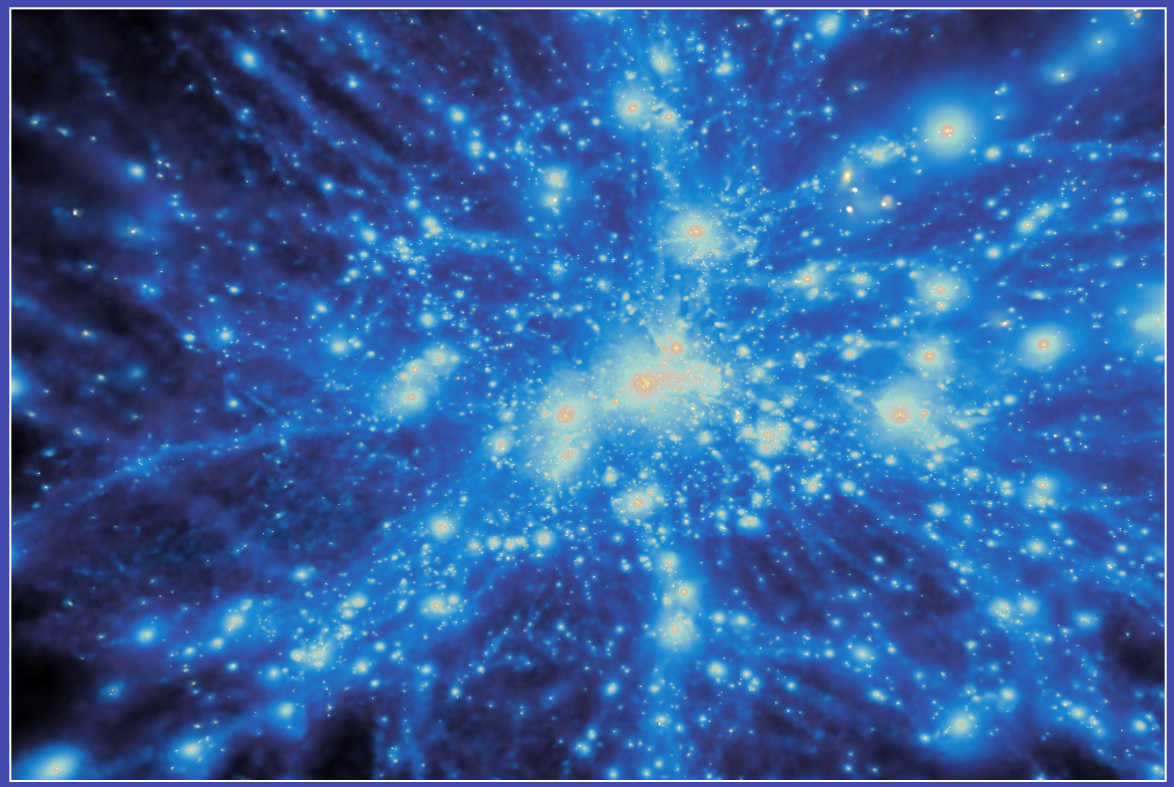
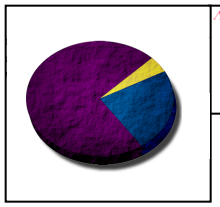
Simulation Databases



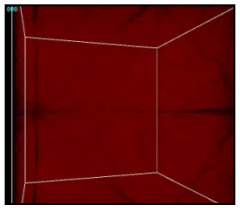
Kristin Riebe
AIP Potsdam

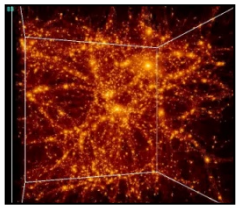
Cosmological Simulations



ΛCDM Modell		
H_0	=	$71 \pm 4\ \mathrm{km\,s^{-1}}$
Ω_0	=	0.29 ± 0.07
Ω_b	=	0.047 ± 0.006
σ_8	=	0.9 ± 0.1
t_0	=	$13.4 \pm 0.3\ \mathrm{Gyr}$

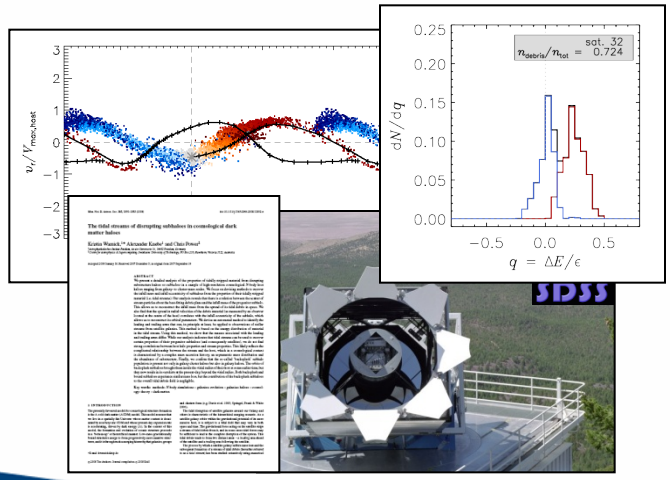
Cosmological Model





simulation snapshots

computer cluster



the model:
initial conditions

run the simulation

store data

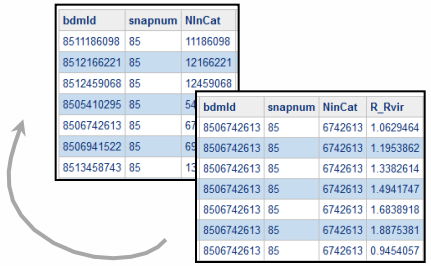
analyse

compare with observations

share results

publish results

Simulation Databases



bdmId	snapnum	NInCat
8511186098	85	11186098
8512166221	85	12166221
8512459068	85	12459068
8505410295	85	54
8506742613	85	67
8506941522	85	69
8513458743	85	13

bdmId	snapnum	NInCat	R_Rvir
8506742613	85	6742613	1.0629464
8506742613	85	6742613	1.1953862
8506742613	85	6742613	1.3382614
8506742613	85	6742613	1.4941747
8506742613	85	6742613	1.6838918
8506742613	85	6742613	1.8875381
8506742613	85	6742613	0.9454057

- store results of simulations in database, as tables and links between them
- Why?
  - simulations produce TB of data => hard to handle and share
  - post-processing results have variety of formats, individual software for reading
  - visibility of data?
  - reproducability of data?

Just get the subset you need, do (basic) calculations directly on the database server

Uniform data format, SQL as standard

Millennium DB: 500 papers!
MultiDark DB: <10

```
select top 20 * from MDR1..FOF
where snapnum=85
order by mass desc
```

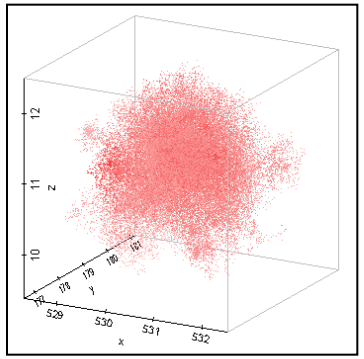
extracts 20 most massive FOF groups at z=0

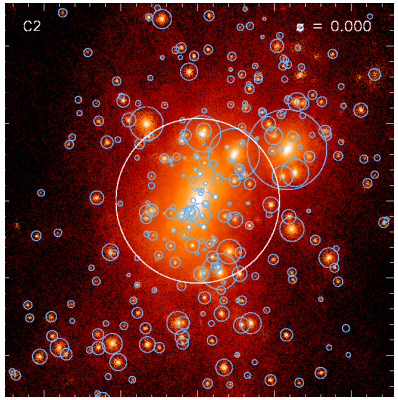
< 1 s

Data sets

- **Halo catalogues:** dark matter halos with their properties
  - position, velocity, mass, spin, concentration
- **Merger trees:** history of halos
- **Substructure trees:** hierarchy of substructures
- **Particles & links with halos:** access raw data
- **Environment:**
  - density field
  - cosmic web

  => study halos in filaments, underdense regions, etc.

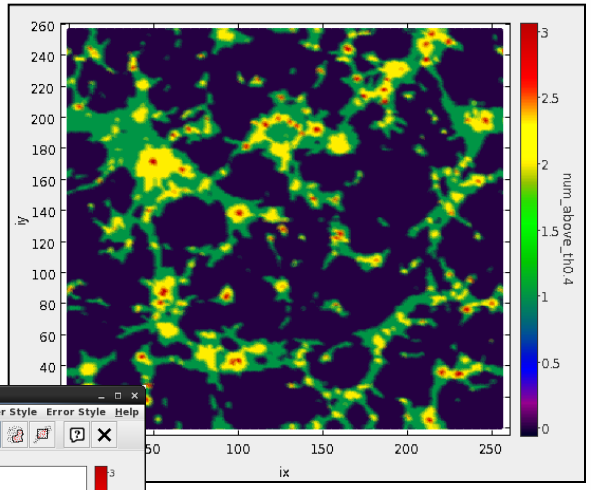


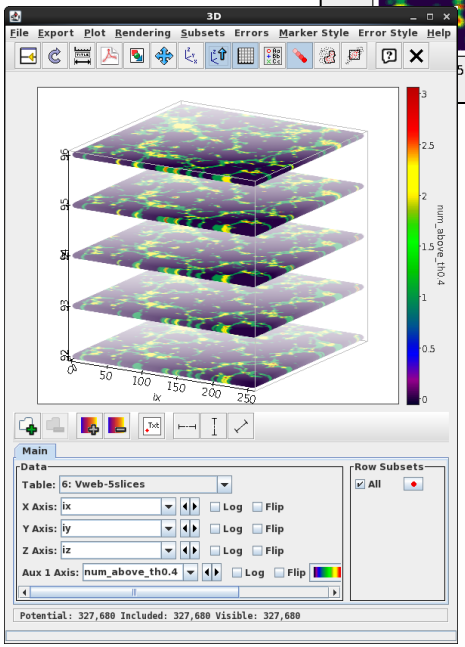


Cosmic web

- Tweb (tidal), Vweb (velocity tensor)
  - eigenvalues + eigenvectors in tables, for each grid cell
  - number of eigenvalues above threshold defines the structure:
    - 0 = void
    - 1 = sheet
    - 2 = filament
    - 3 = knot

=> see tutorial!

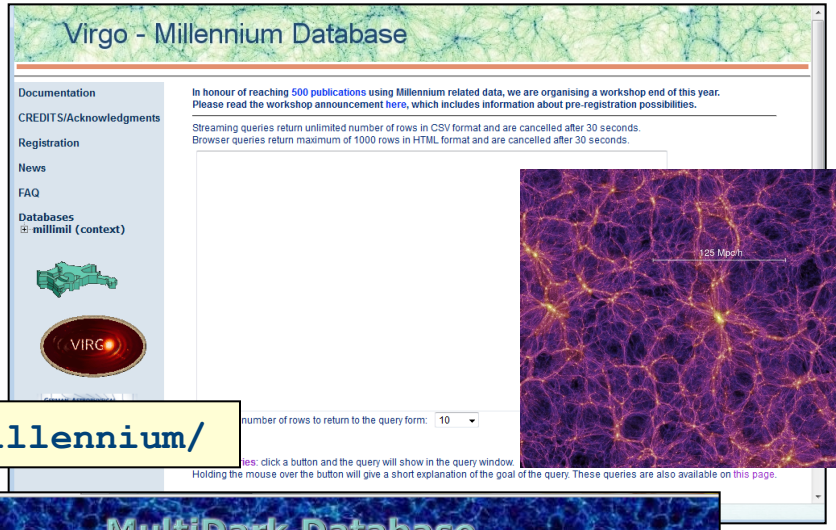




Simulation Databases

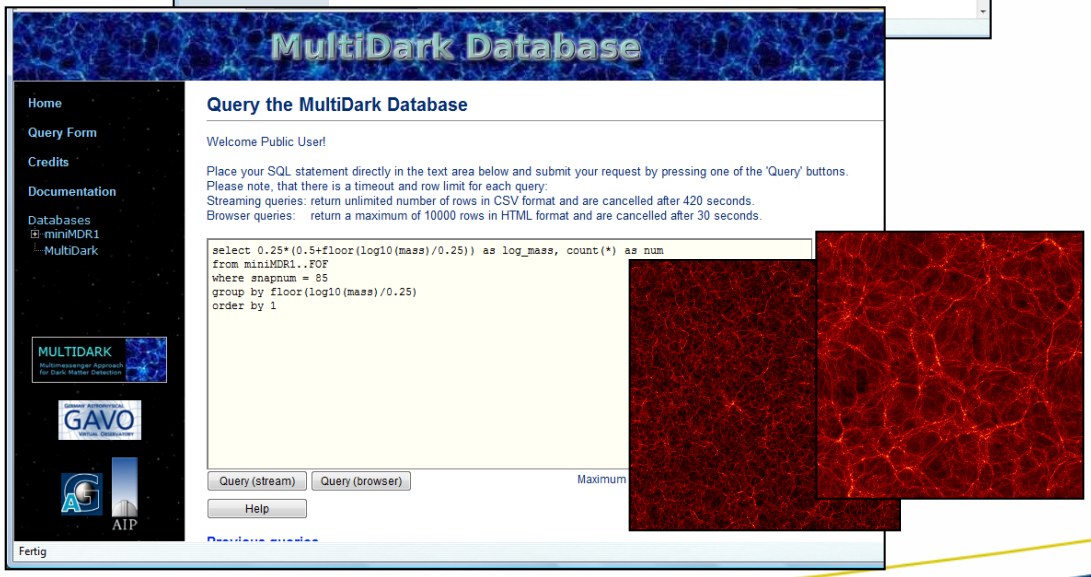
- Millennium DB
  - Millennium Simulation
  - Millennium II
  - WMAP 1

`http://gavo.mpa-garching.mpg.de/Millennium/`



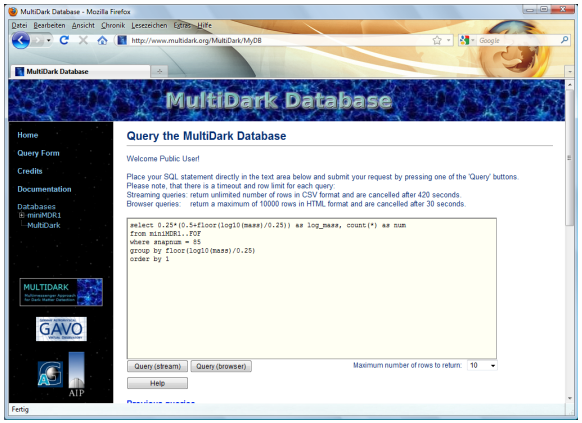
- MultiDark (AIP)
  - Bolshoi
  - BigBolshoi (MDR1)
  - WMAP 5

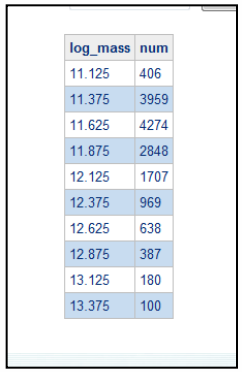
`http://www.multidark.org/`



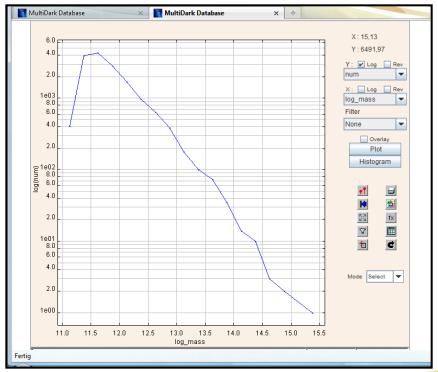
MultiDark Database Webinterface

- Interactive access: http://www.multidark.org
- Scripted access: IDL, R, Topcat: wget.multidark.org/MyDB
- Retrieve data via SQL queries
- History of previous queries
- Extensive documentation, demo & useful queries
- Private db space (registered users)

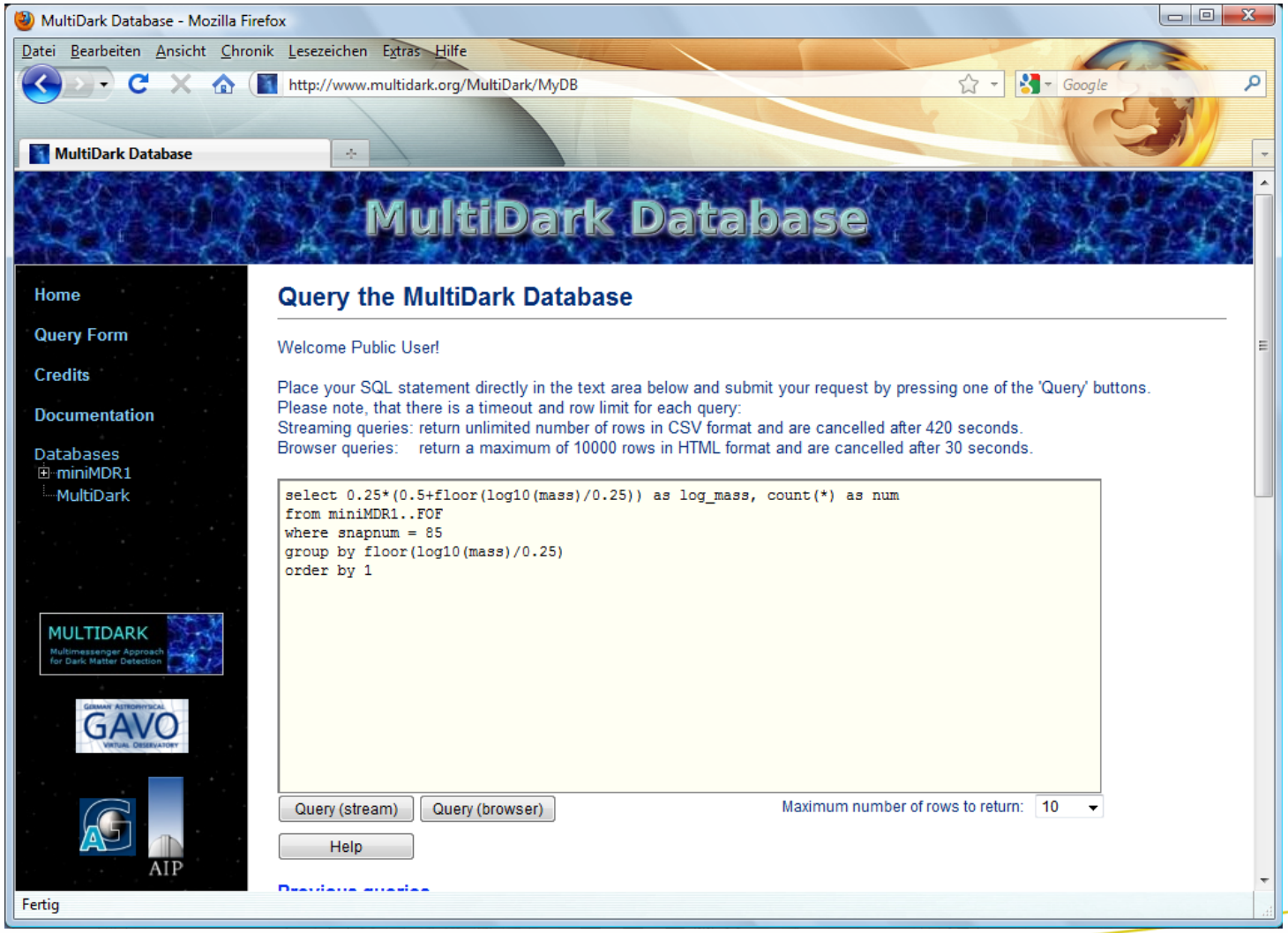




log_mass	num
11.125	406
11.375	3959
11.625	4274
11.875	2848
12.125	1707
12.375	969
12.625	638
12.875	387
13.125	180
13.375	100

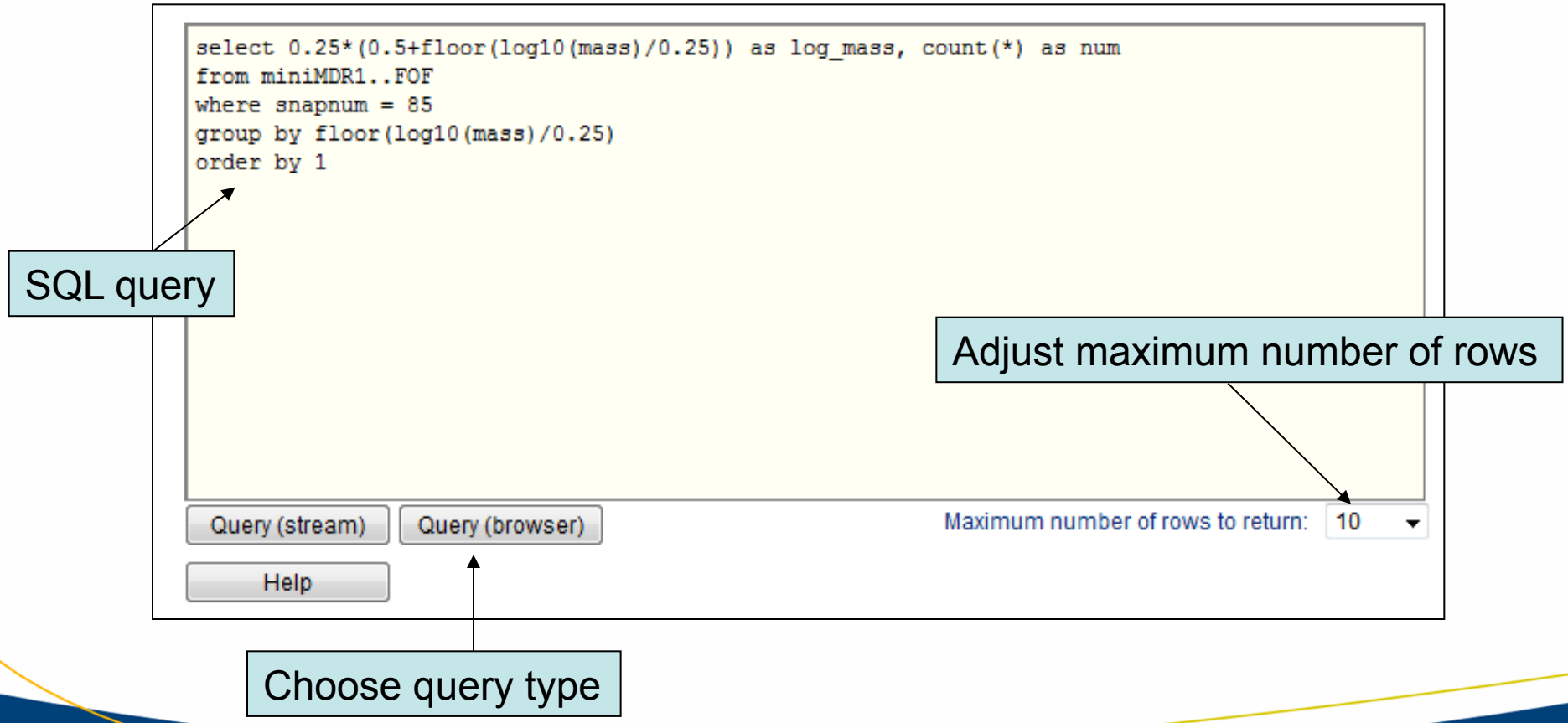


Demo: Mass function of halos

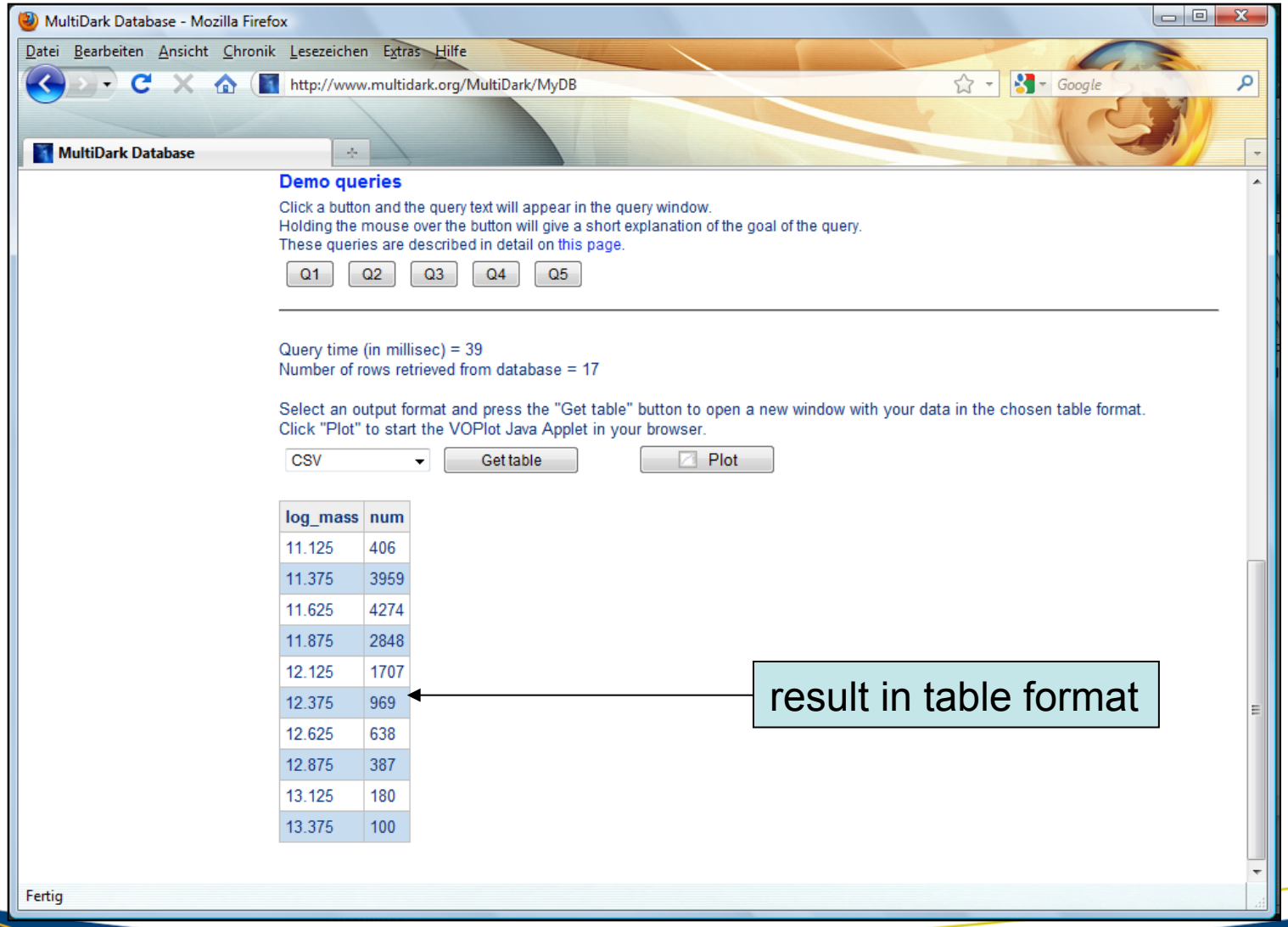


Enter SQL query & submit

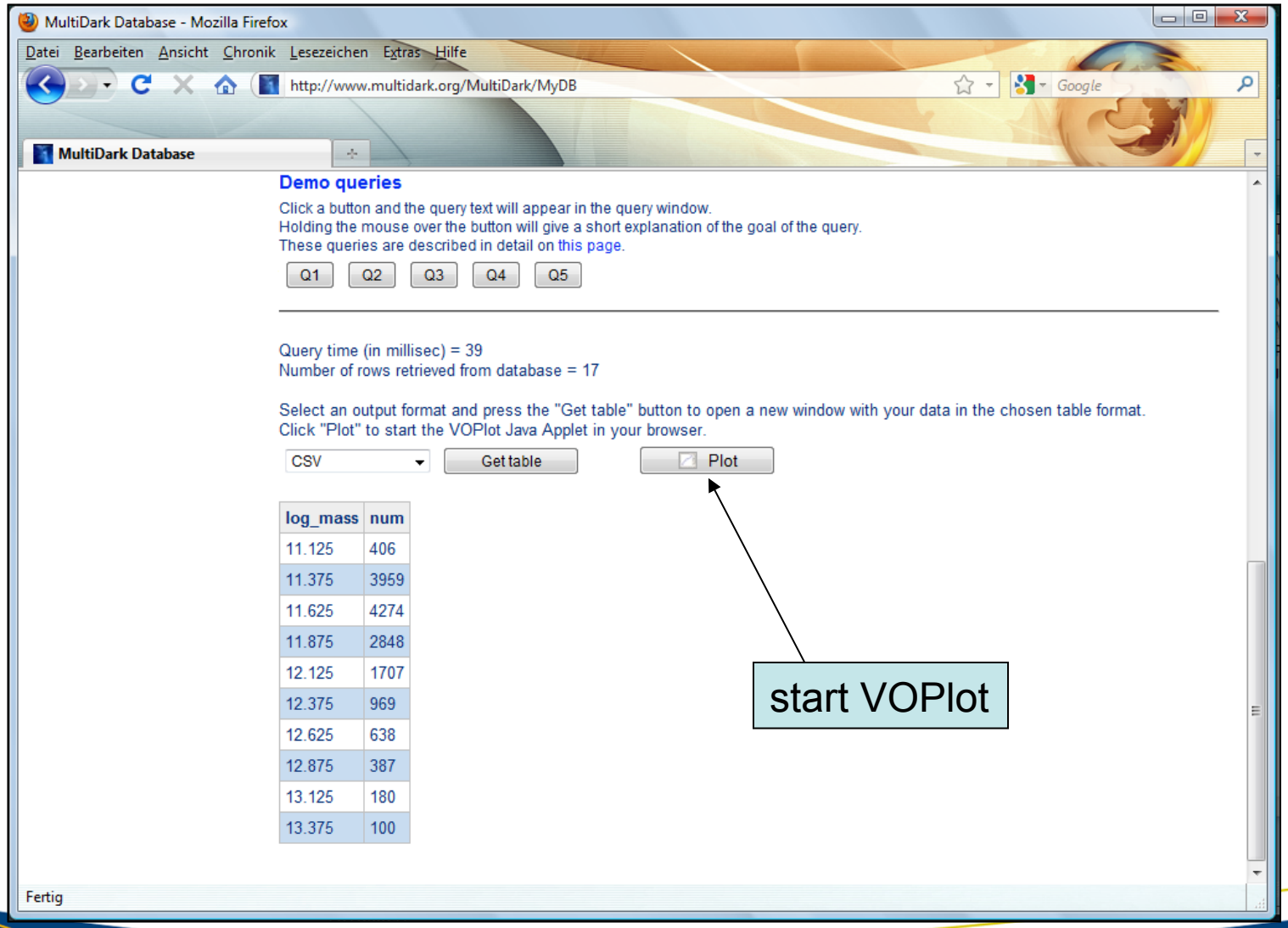
- Example: get mass function in logarithmic bins for redshift 0



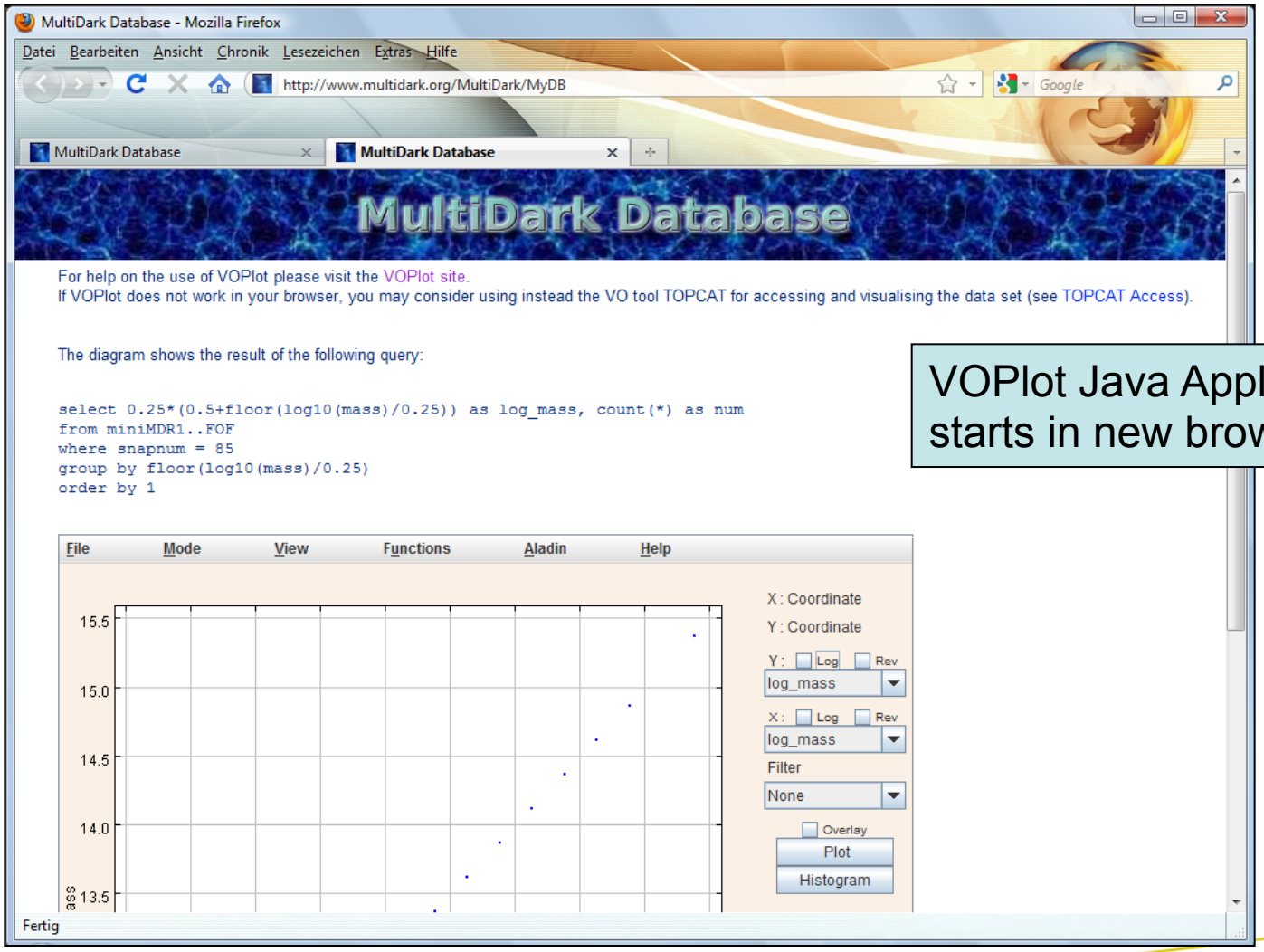
Result returned in browser



VOPlot

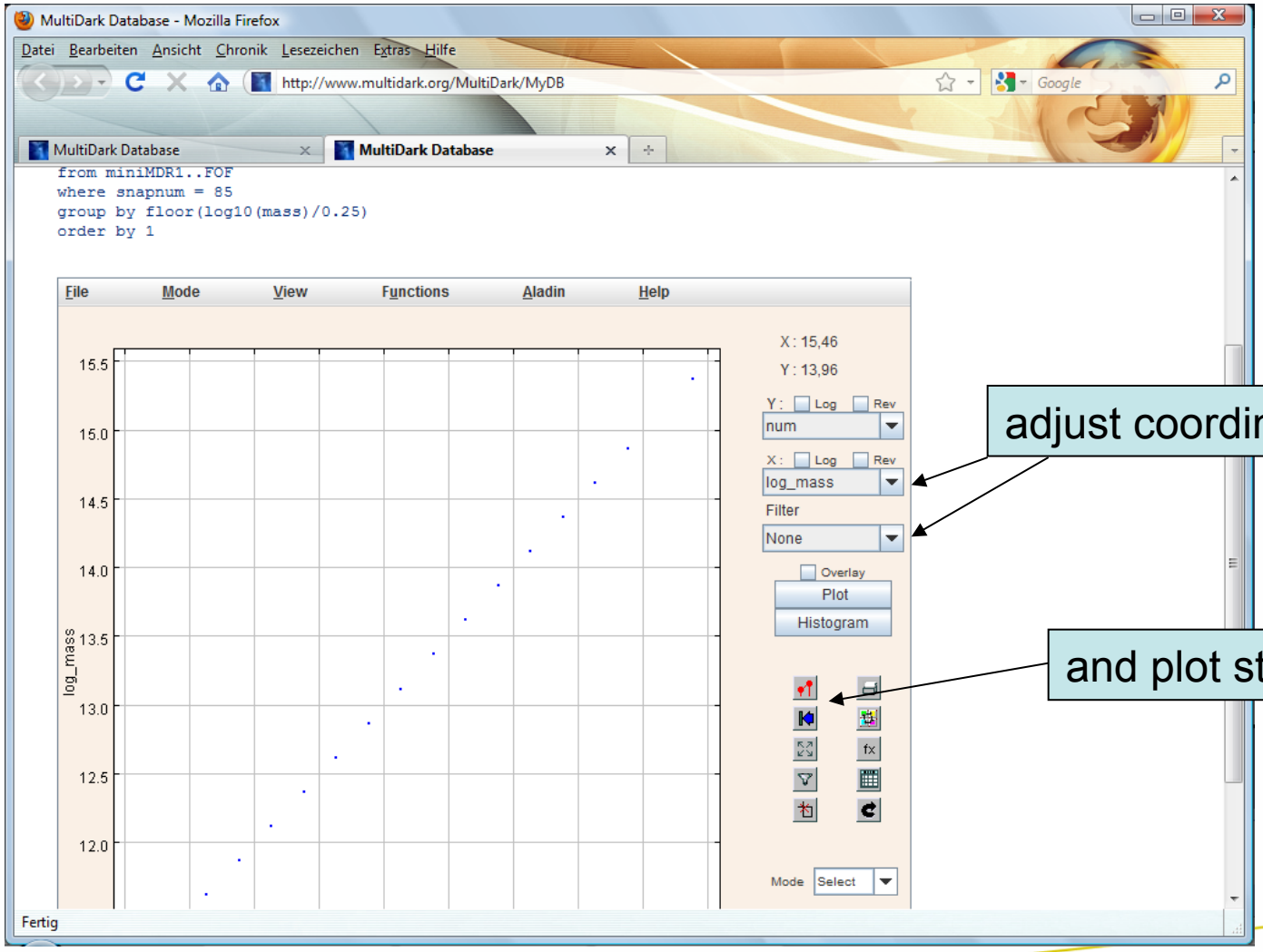

MultiDark Database - Mozilla Firefox
Datei Bearbeiten Ansicht Chronik Lesezeichen Extras Hilfe
http://www.multidark.org/MultiDark/MyDB
MultiDark Database
Demo queries
Click a button and the query text will appear in the query window.
Holding the mouse over the button will give a short explanation of the goal of the query.
These queries are described in detail on this page.
Q1 Q2 Q3 Q4 Q5
Query time (in millisec) = 39
Number of rows retrieved from database = 17
Select an output format and press the "Get table" button to open a new window with your data in the chosen table format.
Click "Plot" to start the VOPlot Java Applet in your browser.
CSV
Get table
Plot
log_mass num
11.125 406
11.375 3959
11.625 4274
11.875 2848
12.125 1707
12.375 969
12.625 638
12.875 387
13.125 180
13.375 100
start VOPlot
Fertig

VOPlot

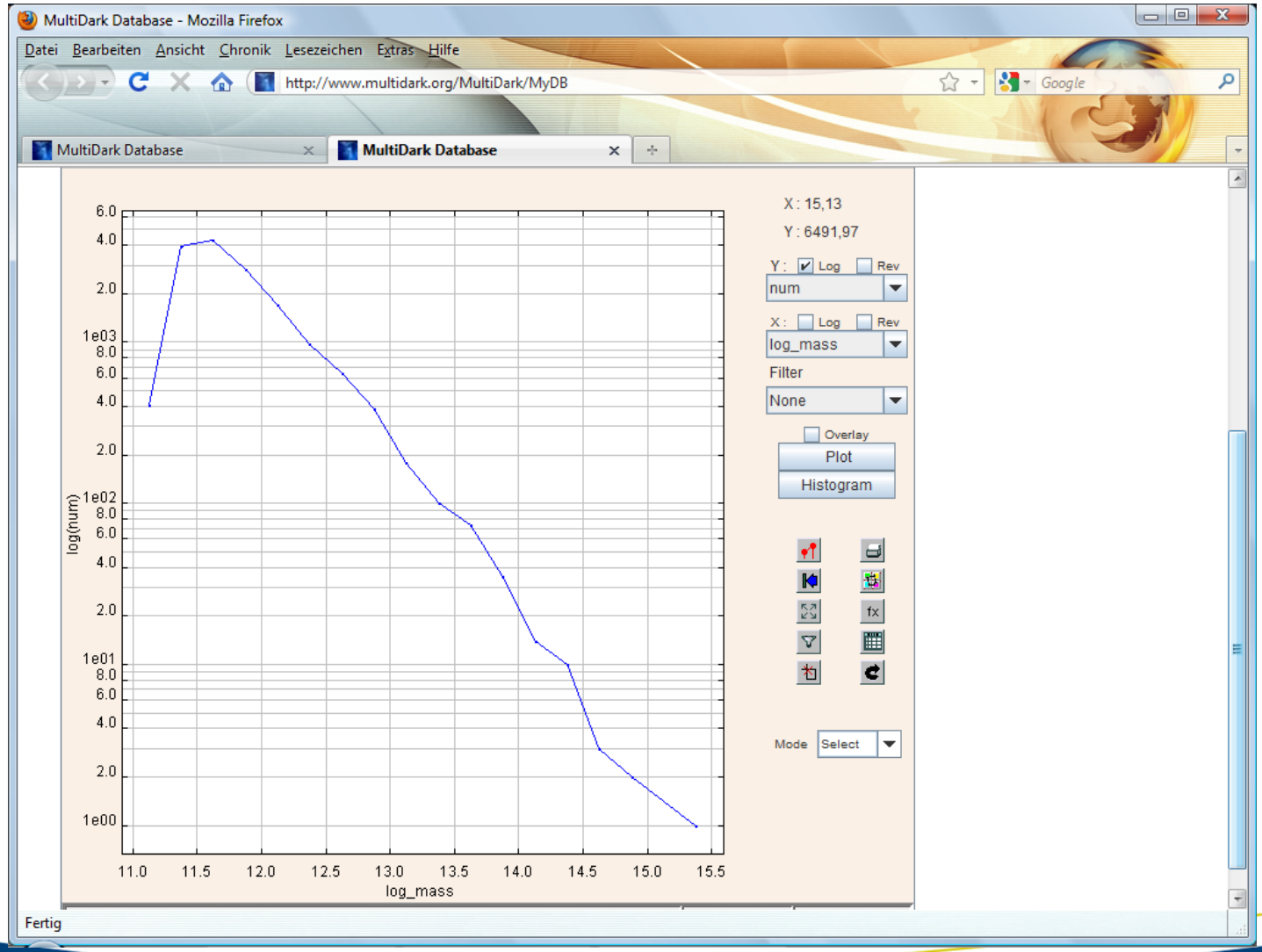


VOPlot Java Applet starts in new browser tab

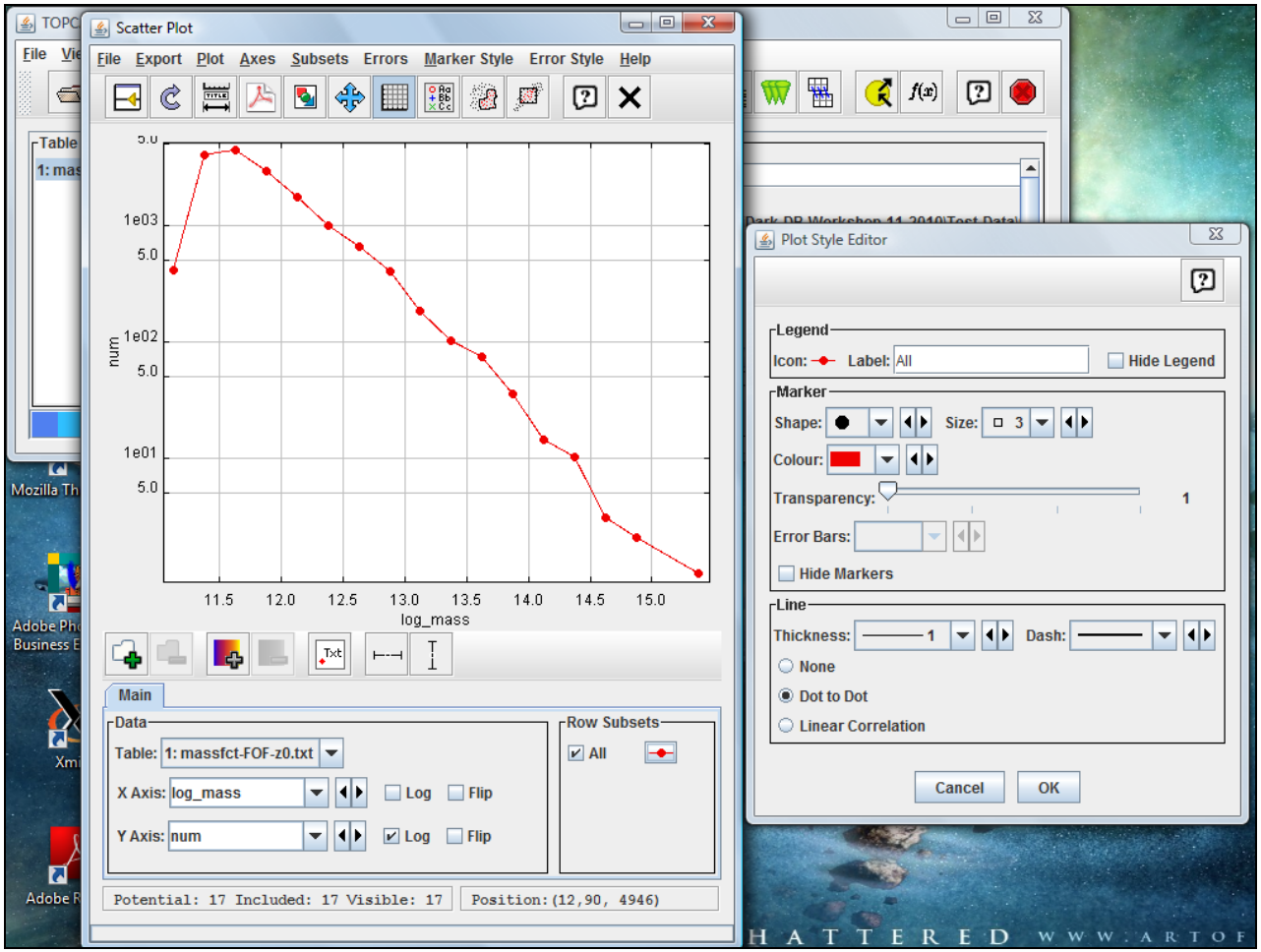
Adjust plot parameters



Mass function of halos at z=0



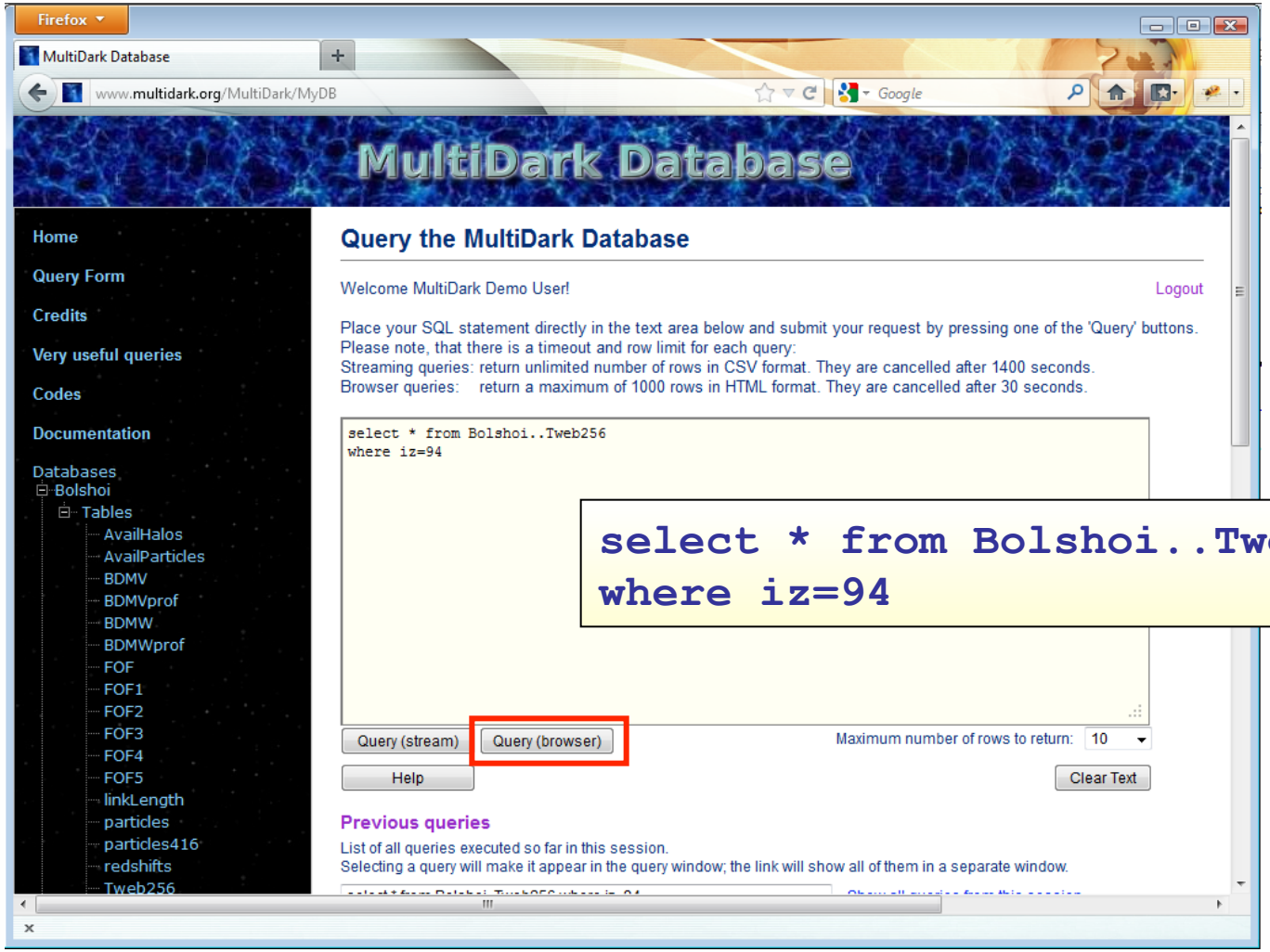
Other tools: Topcat



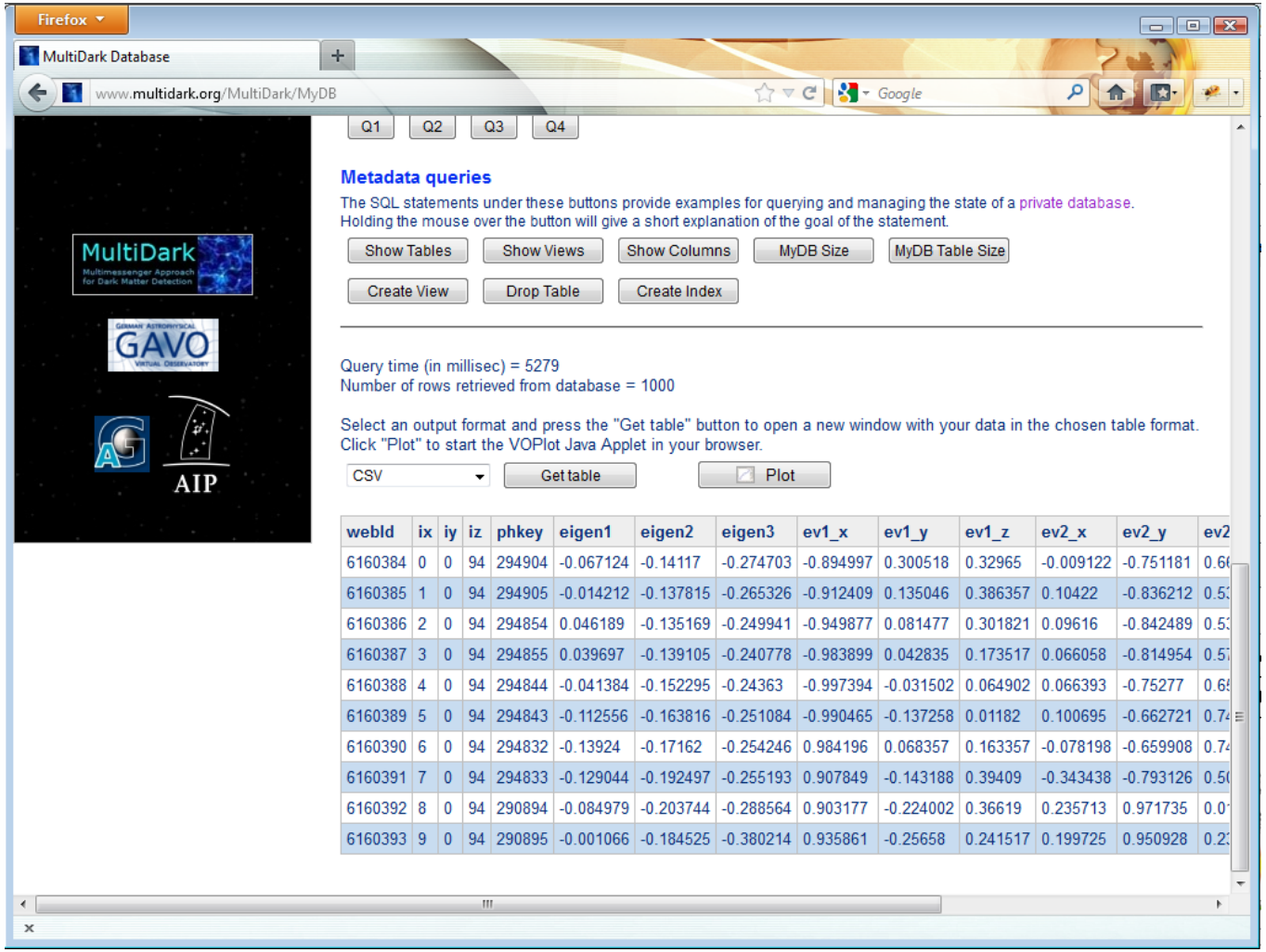
....
or load data directly into R, IDL, ...

=> offers many possibilities!

Demo: Cosmic Web in browser



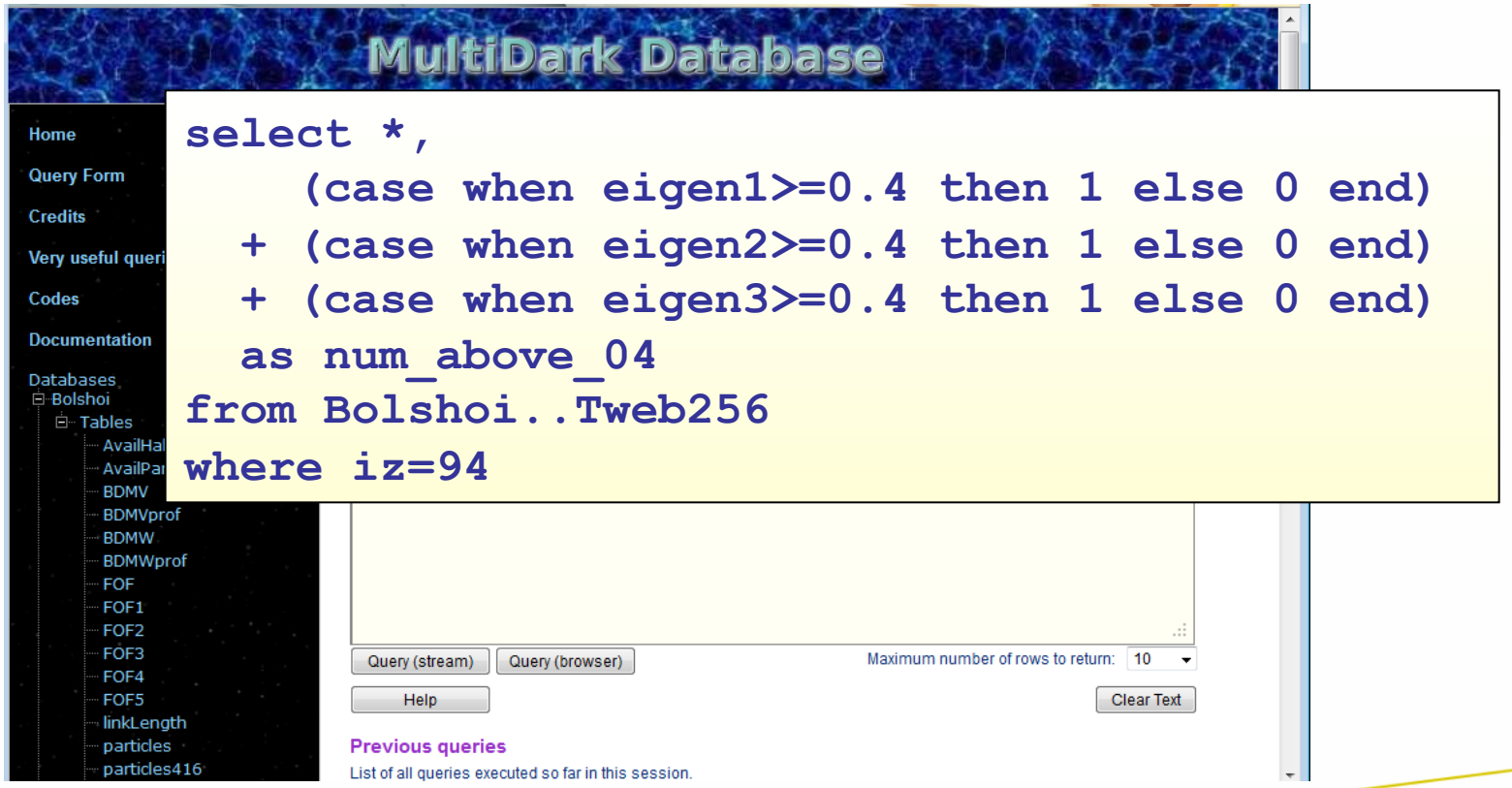
Demo: Cosmic Web in browser



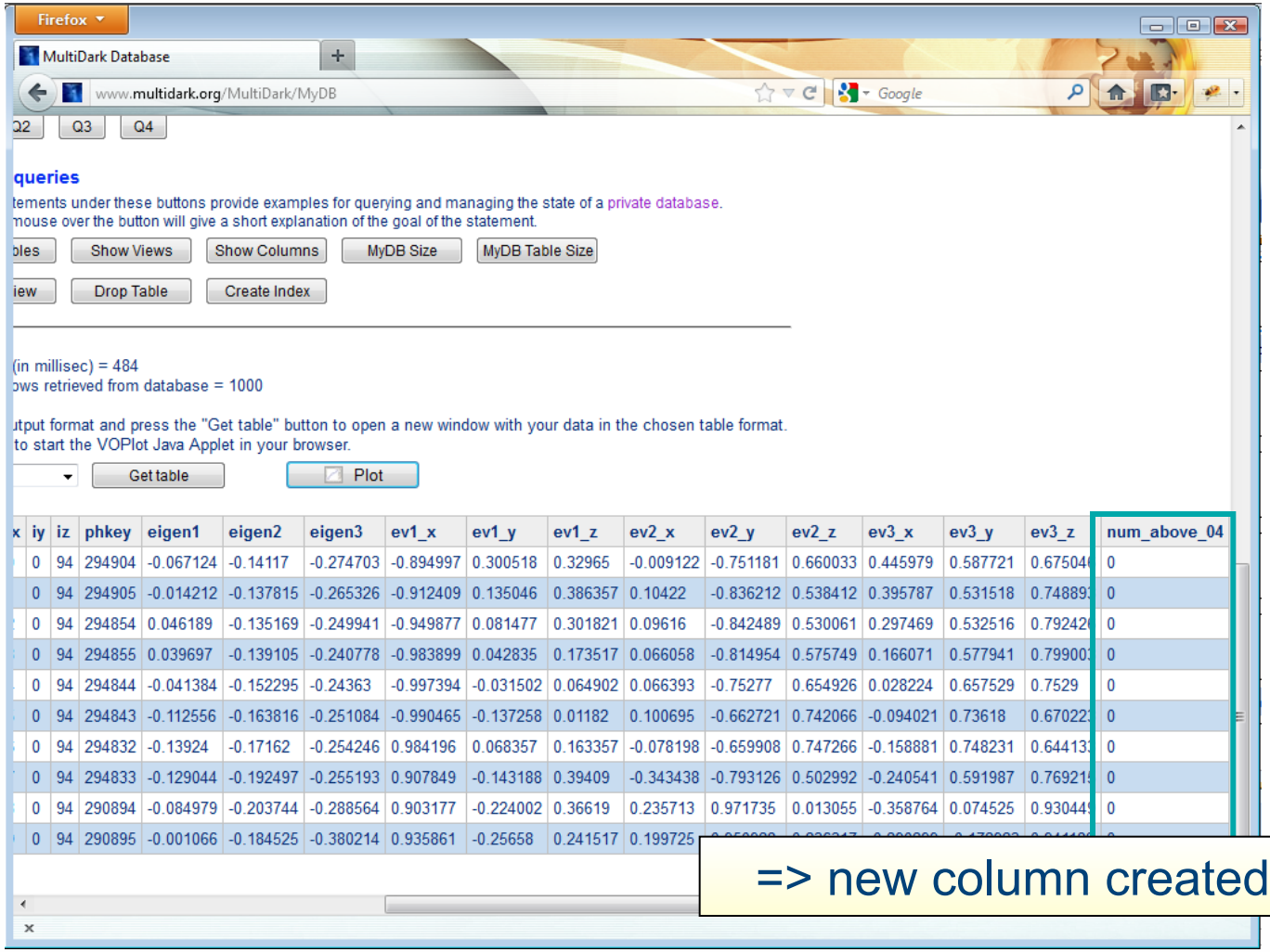
webId	ix	iy	iz	phkey	eigen1	eigen2	eigen3	ev1_x	ev1_y	ev1_z	ev2_x	ev2_y	ev2
6160384	0	0	94	294904	-0.067124	-0.14117	-0.274703	-0.894997	0.300518	0.32965	-0.009122	-0.751181	0.6
6160385	1	0	94	294905	-0.014212	-0.137815	-0.265326	-0.912409	0.135046	0.386357	0.10422	-0.836212	0.5
6160386	2	0	94	294854	0.046189	-0.135169	-0.249941	-0.949877	0.081477	0.301821	0.09616	-0.842489	0.5
6160387	3	0	94	294855	0.039697	-0.139105	-0.240778	-0.983899	0.042835	0.173517	0.066058	-0.814954	0.5
6160388	4	0	94	294844	-0.041384	-0.152295	-0.24363	-0.997394	-0.031502	0.064902	0.066393	-0.75277	0.6
6160389	5	0	94	294843	-0.112556	-0.163816	-0.251084	-0.990465	-0.137258	0.01182	0.100695	-0.662721	0.7
6160390	6	0	94	294832	-0.13924	-0.17162	-0.254246	0.984196	0.068357	0.163357	-0.078198	-0.659908	0.7
6160391	7	0	94	294833	-0.129044	-0.192497	-0.255193	0.907849	-0.143188	0.39409	-0.343438	-0.793126	0.5
6160392	8	0	94	290894	-0.084979	-0.203744	-0.288564	0.903177	-0.224002	0.36619	0.235713	0.971735	0.0
6160393	9	0	94	290895	-0.001066	-0.184525	-0.380214	0.935861	-0.25658	0.241517	0.199725	0.950928	0.2

Demo: Cosmic Web in browser

- number of eigenvalues above certain threshold:
  0 = void, 1 = sheet, 2 = filament, 3 = knot

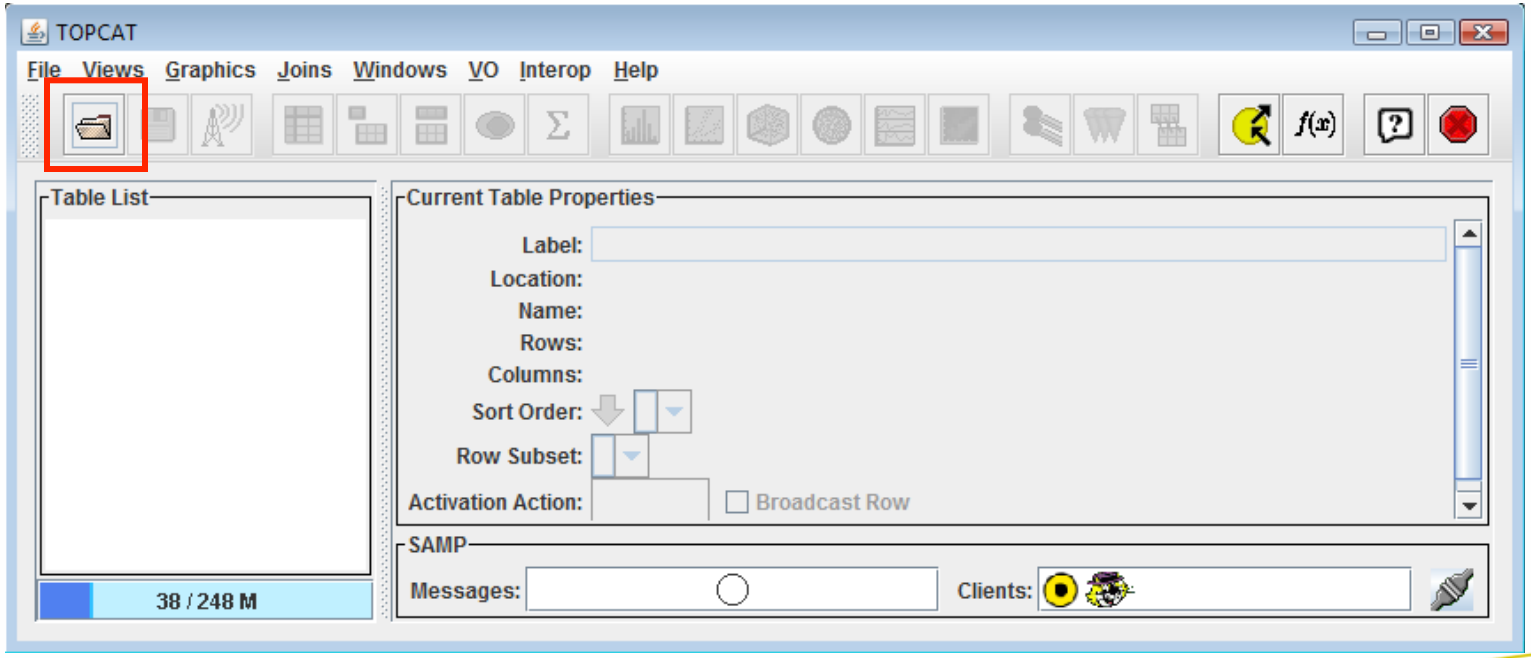


Demo: Cosmic Web in browser

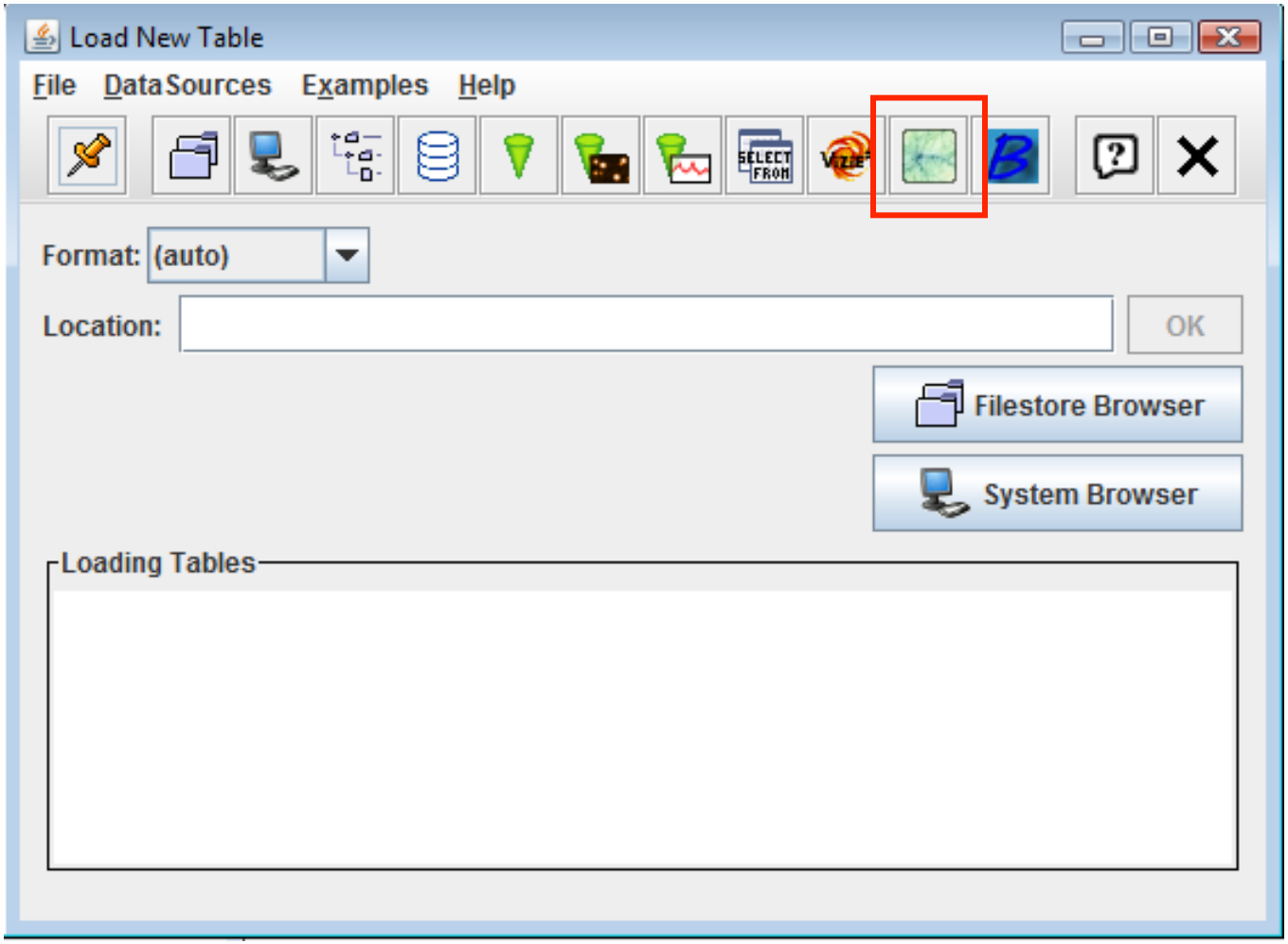


Plot with Topcat

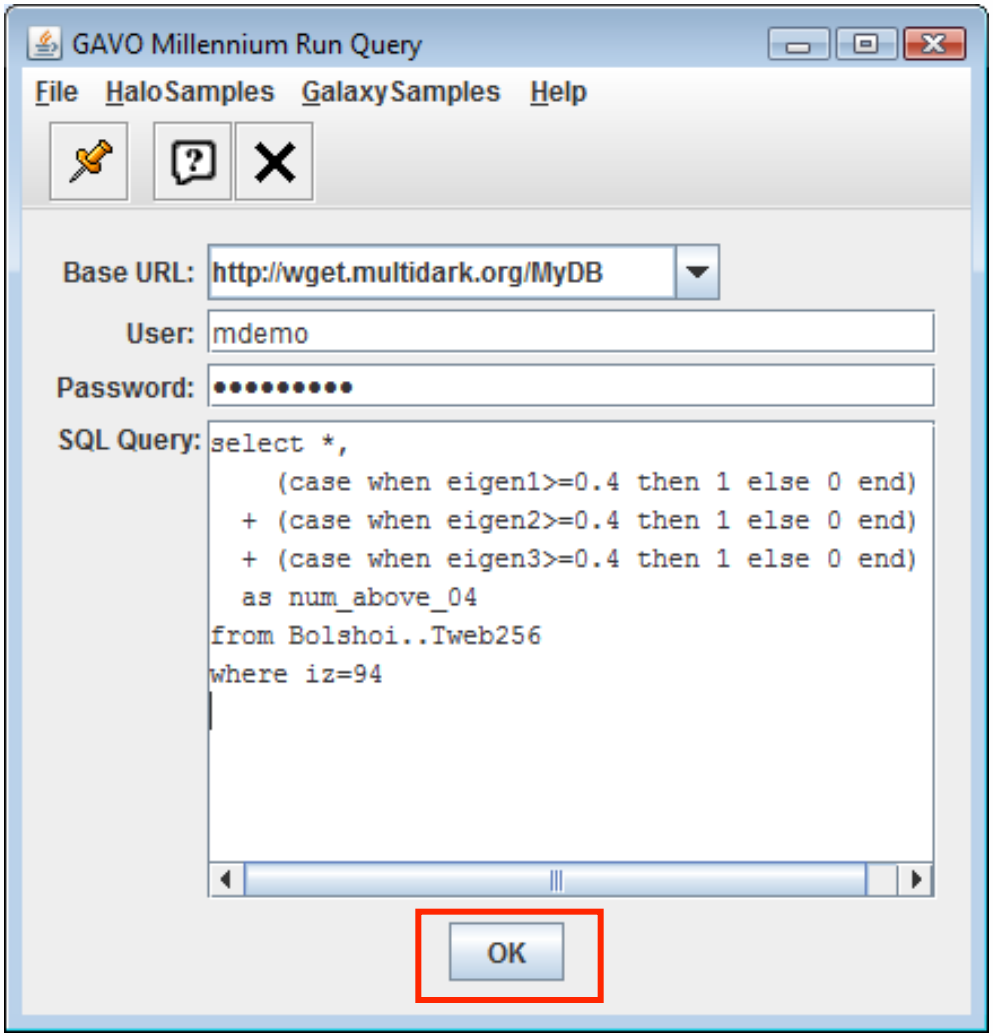
- Download topcat-full.jar from http://www.star.bris.ac.uk/~mbt/topcat/
- start: `java -jar topcat-full.jar`
  (or just double-click)



Topcat: open query window

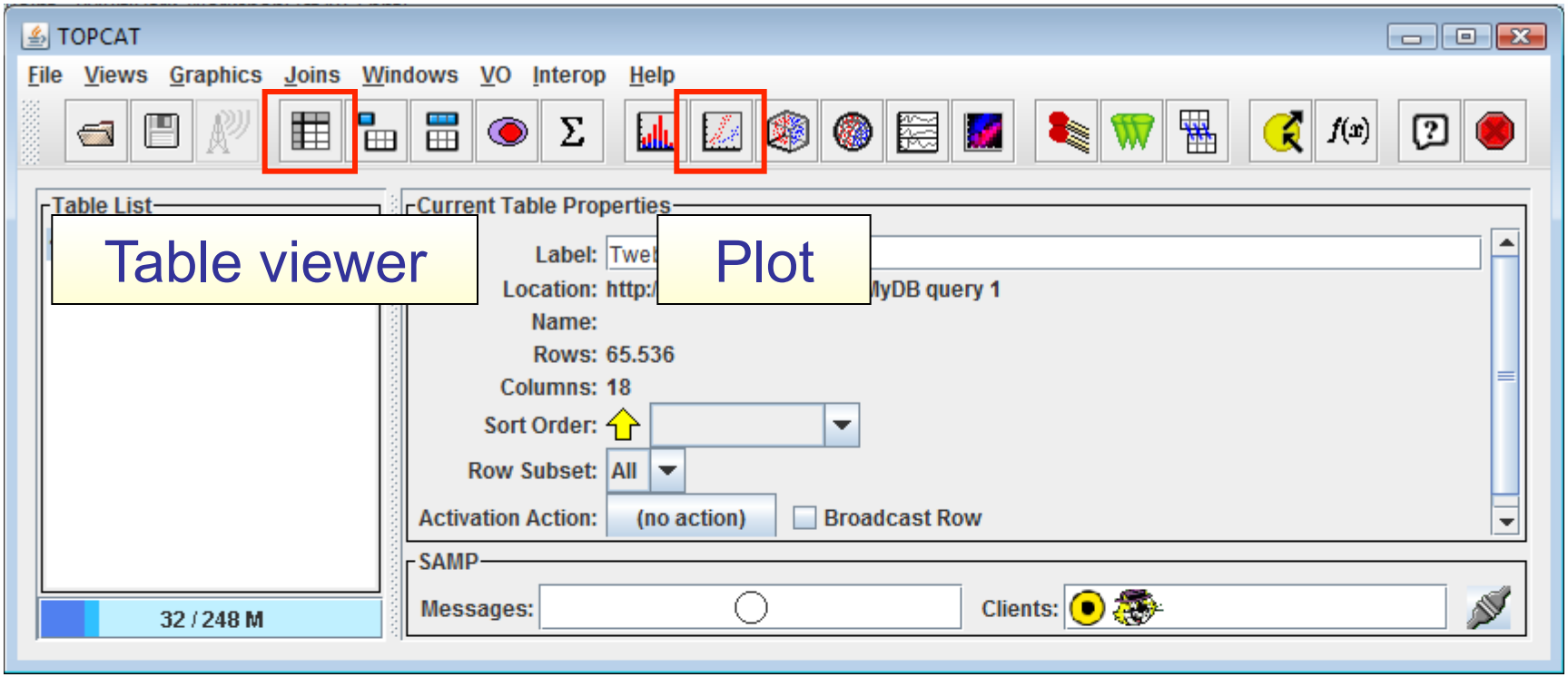


Enter SQL query

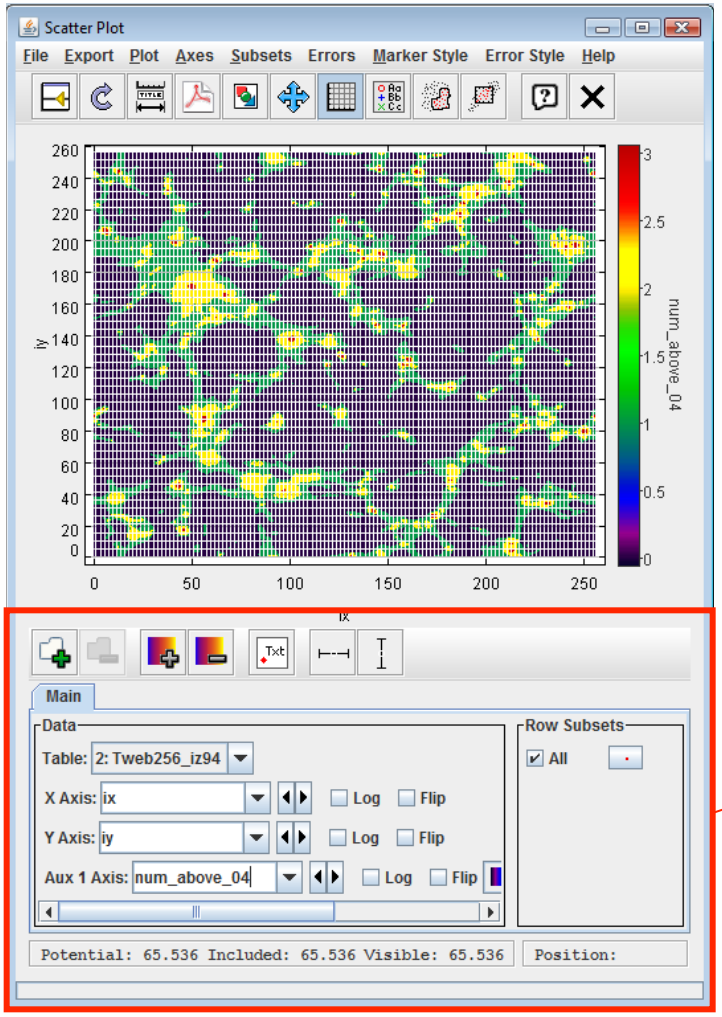


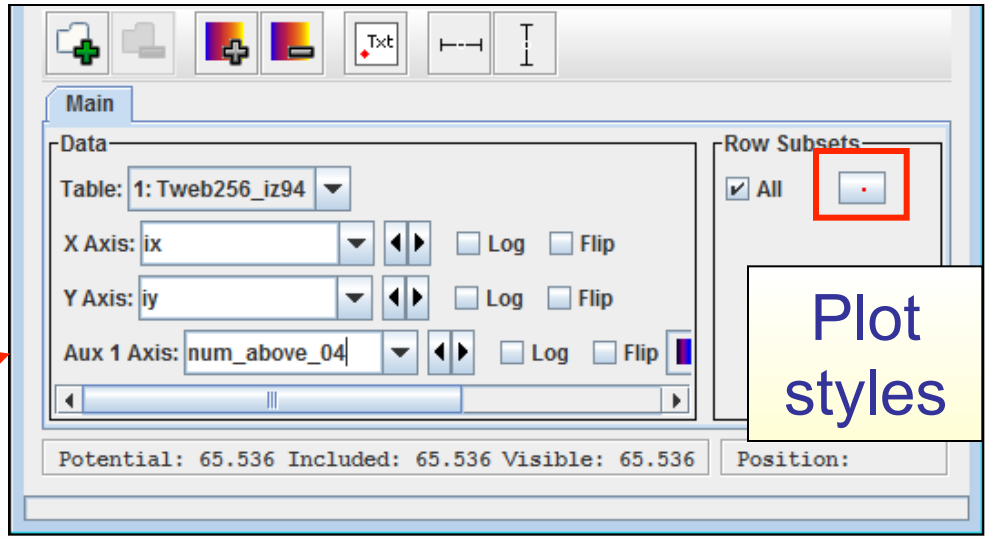
Press OK
and wait …

Topcat: rename & view table



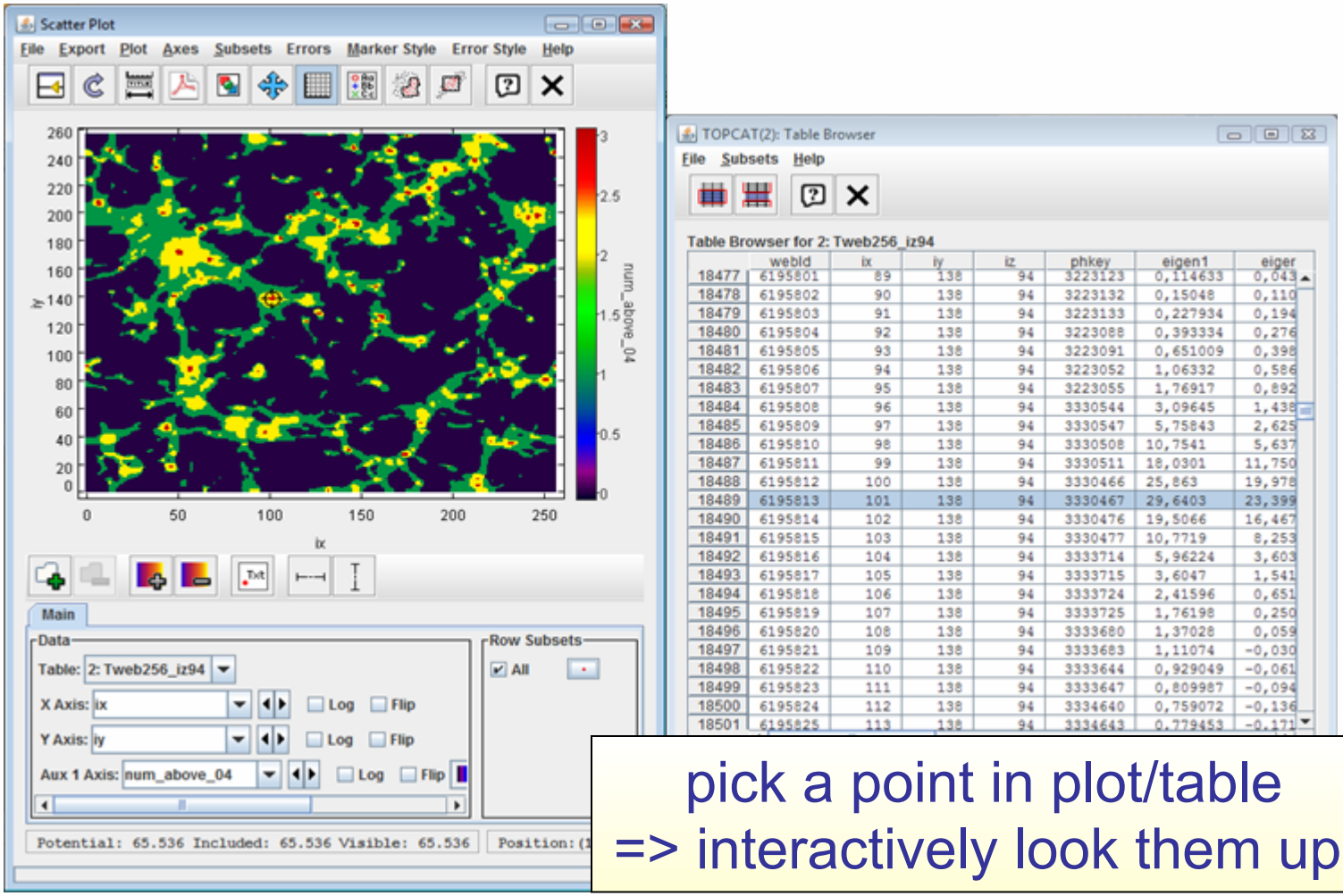
Topcat: plot





- Adjust axes: ix, iy
- Add „Auxiliary axis“: num_above_04

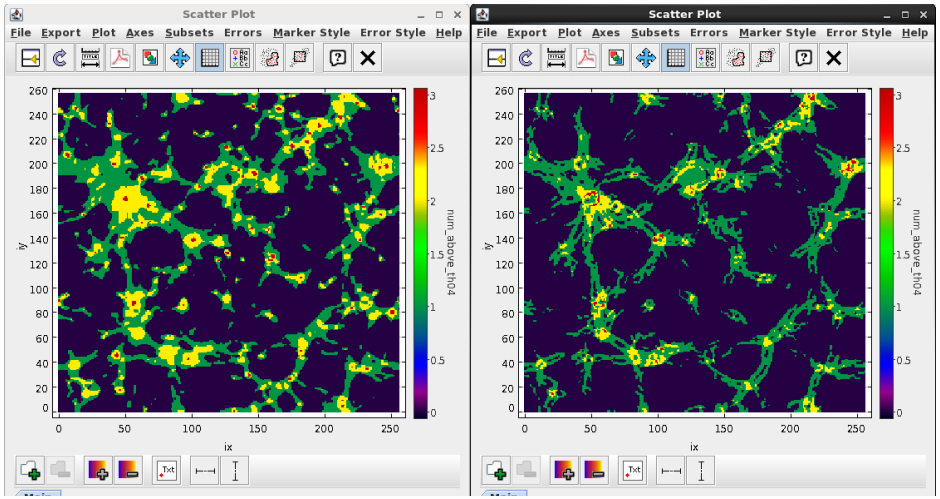
Topcat: Plot and table interaction



pick a point in plot/table
=> interactively look them up!

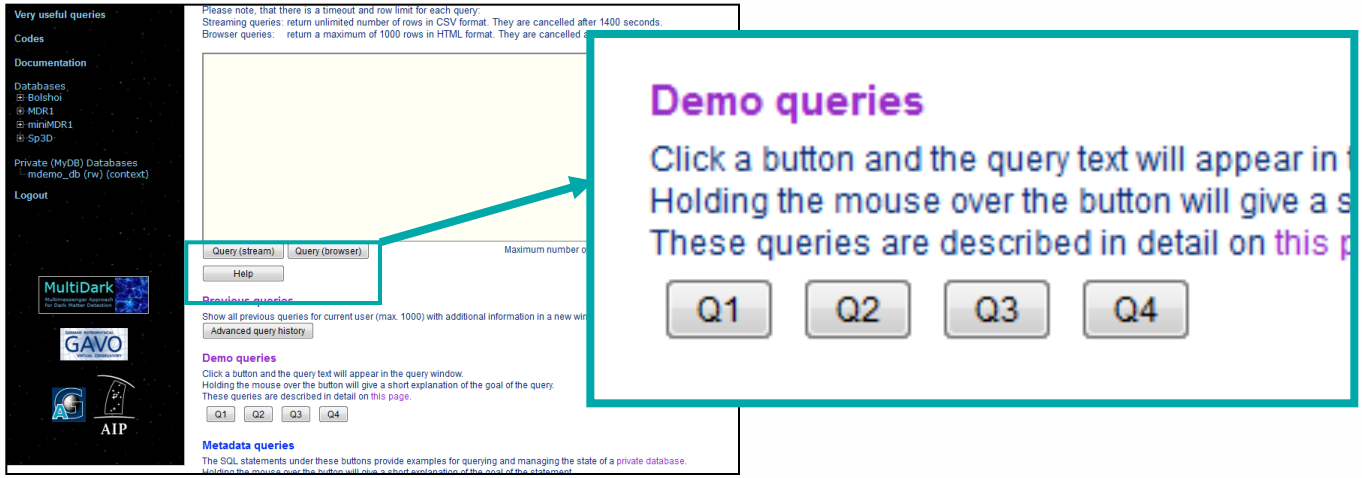
Cosmic Web

- play around with Tweb/Vweb comparison
- load multiple slices, order rows by num_above_04
- add different thresholds using Topcat by creating additional computed columns
- look up halos in grid cells using join of web-table and BDM
- …



Hands-on Session

- Interactive access: www.multidark.org
- Scripted access: IDL, R, Topcat: wget.multidark.org/MyDB
- Login: **mdemo**, password: **voday** (only today!)
- Try demo queries:



- Look at very useful queries: www.multidark.org/MultiDark/Help?page=vuq

Example: Profile of a halo

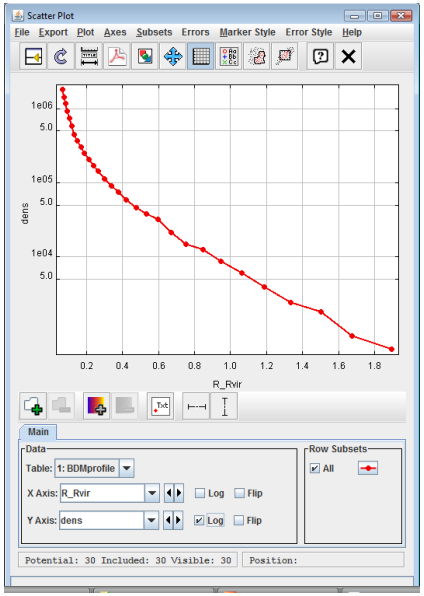
- Profile of most massive BDMV halo

```
select * from MDR1..BDMVprof
where bdmId =
(select top 1 bdmId from MDR1..BDMV
where snapnum=85 order by Mvir desc)
order by Rbin
```

- or:

```
set @mostmassive = (select top 1 bdmId
from MDR1..BDMV where snapnum=85
order by Mvir desc)

select * from MDR1..BDMVprof
where bdmId = @mostmassive
from MDR1..BDMV
where snapnum=85 order by Mvir desc)
order by Rbin
```



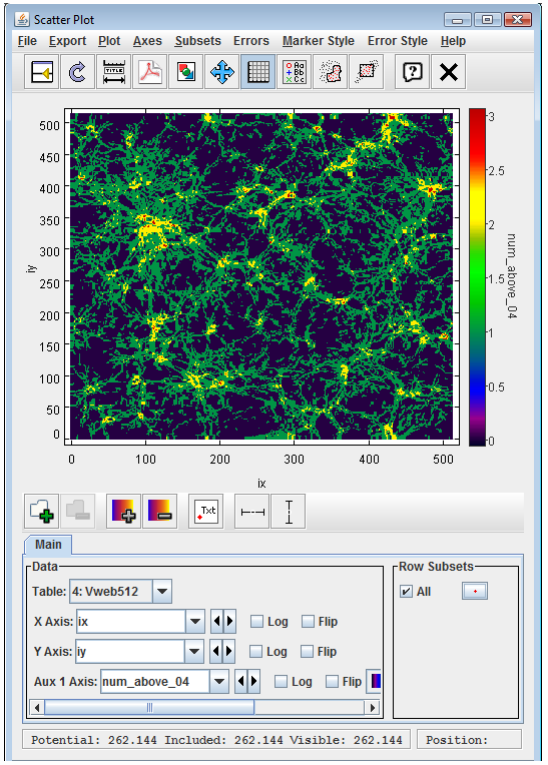
density profile (log)

Example: Cosmic web, for 512 grid

- Retrieve slice in xy-plane, use z-cell with most mass. halo
- count eigenvalues above a threshold, faster than with case-when-then construct

```
declare @th float
declare @iz_1024 int
set @th = 0.4
set @iz_1024 = (
select top 1 iz from Bolshoi..BDMV
where snapnum=416 order by Mvir desc)

select *,
     sign(sign(eigen1-@th)+1)
   + sign(sign(eigen2-@th)+1)
   + sign(sign(eigen3-@th)+1)
   as num_above_04
from Bolshoi..Vweb512
where iz = floor(0.5*@iz_1024)
```



Example: Halos in knots of cosmic web

- Halos in knots, i.e.
  halos in grid cells with all eigenvalues > 0.4;
- use faster version with phkey-lookup, need phkey divided by 8^2 because of different grid resolutions

```
select *
from Bolshoi..Vweb256 w, Bolshoi..BDMV h
where h.snapnum=416 and h.Mvir>1.e12
and (case when w.eigen1>=0.4 then 1 else 0 end)
  + (case when w.eigen2>=0.4 then 1 else 0 end)
  + (case when w.eigen3>=0.4 then 1 else 0 end)
  = 3
and h.phkey/64 = w.phkey
order by h.ix,h.iy,h.iz, h.Mvir desc
```

=> can be used to check halo alignment etc.,
could use private MyDB to store results in between