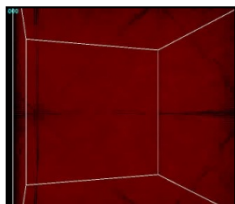
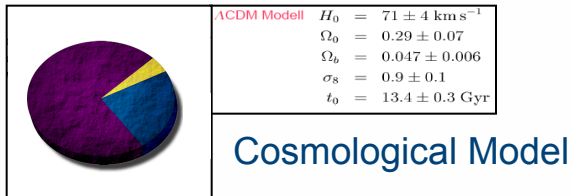


Simulation Databases



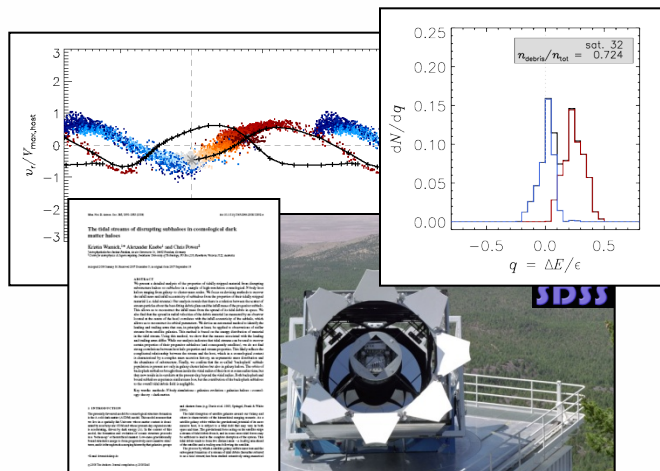
Kristin Riebe
AIP Potsdam

Cosmological Simulations



simulation snapshots

computer cluster



the model:
initial conditions

run the
simulation

store data

analyse

compare with
observations

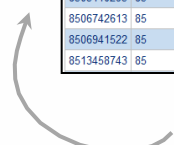
share results

publish results

Simulation Databases

- 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?
- reproducibility of data?



bdmld	snapnum	NinCat
8511186098	85	11186098
8512166221	85	12166221
8512459068	85	12459068

bdmld	snapnum	NinCat	R_Rvir
8505410295	85	54	1.0629464
8506742613	85	67	1.1953862
8506941522	85	69	1.3382614
8513458743	85	13	1.4941747
8506742613	85	67	1.6838918
8506742613	85	67	1.8875381
8506742613	85	67	0.9454057

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
```

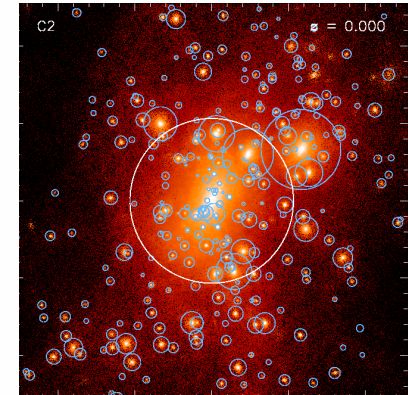
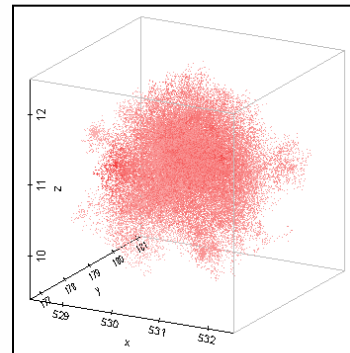
extracts 20 most massive
FOF groups at z=0

< 1 s

Data sets

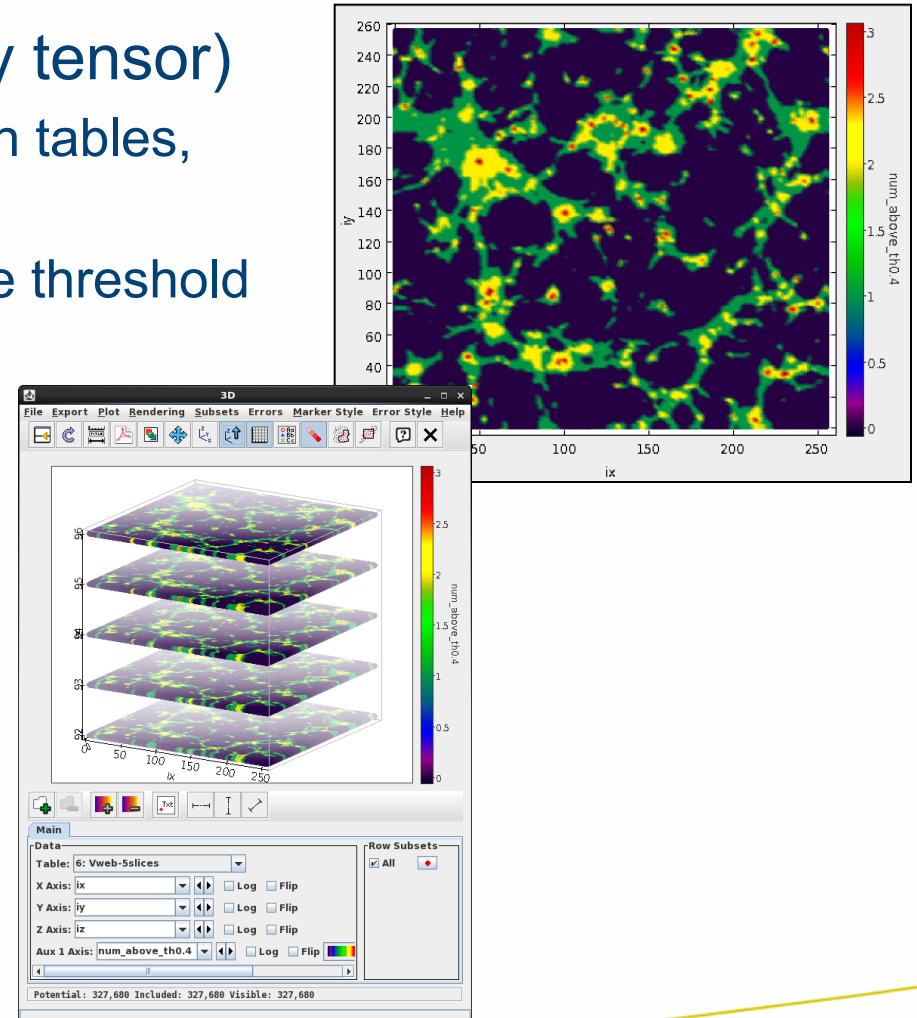
- **Halo catalogues:** dark matter halos with their properties
 - position, velocity, mass, spin, concentration
- **Merger trees:** history of halos
- **Substructure trees:** hierarchy of substructures
- **Particles & links with halos:** access raw data
- **Environment:**
 - density field
 - cosmic web

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



Cosmic web

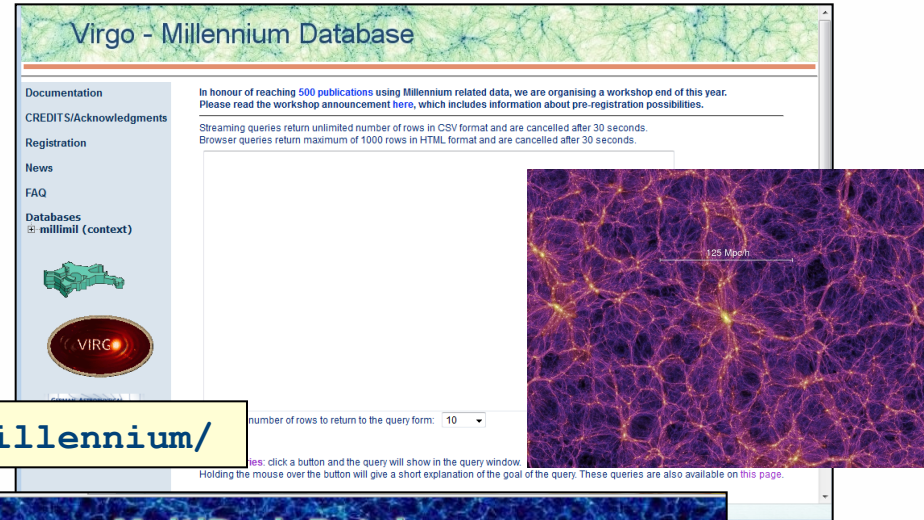
- Tweb (tidal), Vweb (velocity tensor)
 - eigenvalues + eigenvectors in tables, for each grid cell
 - number of eigenvalues above threshold defines the structure:
 - 0 = void
 - 1 = sheet
 - 2 = filament
 - 3 = knot
- => see tutorial!



Simulation Databases

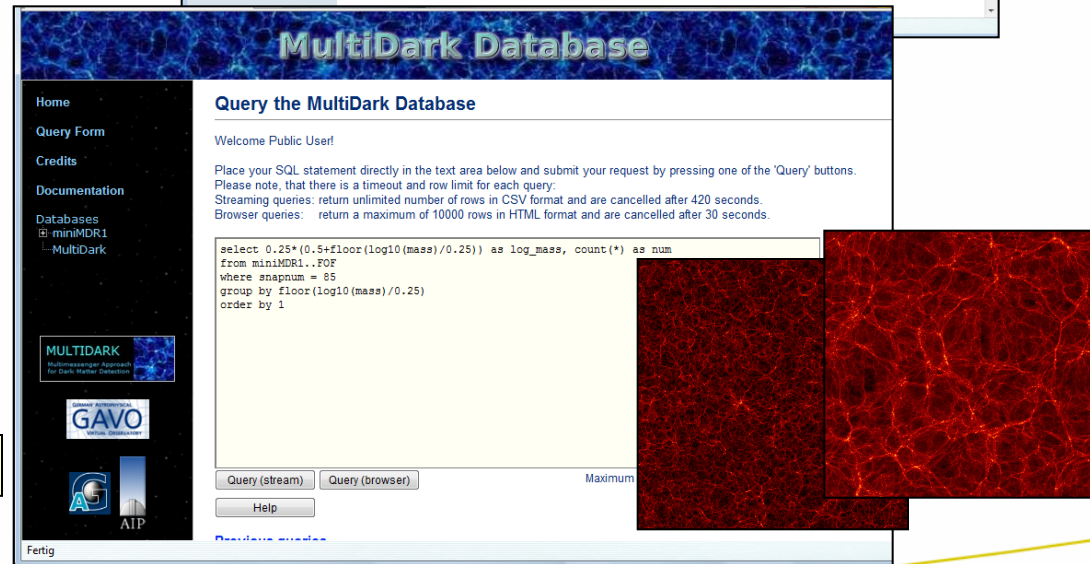
- Millennium DB
 - Millennium Simulation
 - Millennium II
 - WMAP 1

<http://gavo.mpa-garching.mpg.de/Millennium/>



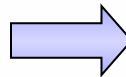
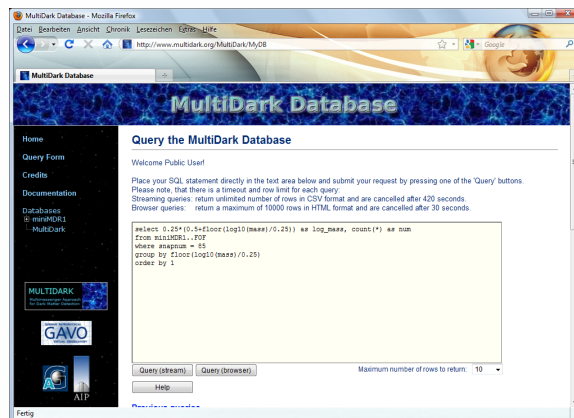
- MultiDark (AIP)
 - Bolshoi
 - BigBolshoi (MDR1)
 - WMAP 5

<http://www.multidark.org/>

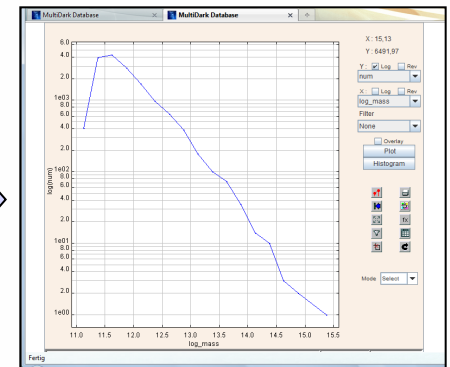


MultiDark Database Webinterface

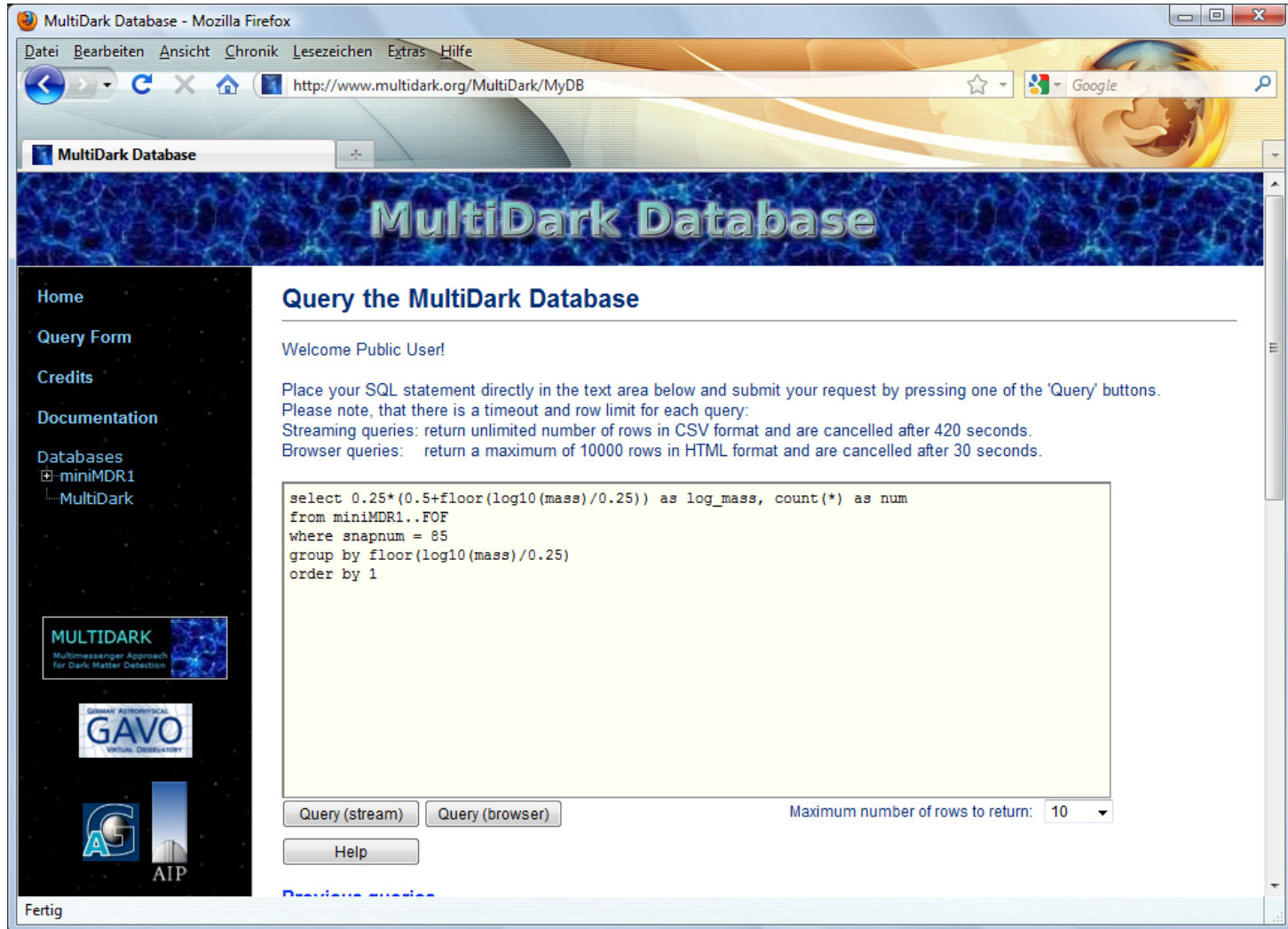
- Interactive access: <http://www.multidark.org>
- Scripted access: IDL, R, Topcat: www.multidark.org/MyDB
- Retrieve data via SQL queries
- History of previous queries
- Extensive documentation, demo & useful queries
- Private db space (registered users)



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



MultiDark Database - Mozilla Firefox

http://www.multidark.org/MultiDark/MyDB

MultiDark Database

Home
Query Form
Credits
Documentation
Databases
miniMDR1
MultiDark

MULTIDARK
Multimessenger Approach
for Dark Matter Detection

GERMAN ASTRONOMICAL
GAVO
VIRTUAL OBSERVATORY

AG
AIP

Query the MultiDark Database

Welcome Public User!

Place your SQL statement directly in the text area below and submit your request by pressing one of the 'Query' buttons.
Please note, that there is a timeout and row limit for each query:
Streaming queries: return unlimited number of rows in CSV format and are cancelled after 420 seconds.
Browser queries: return a maximum of 10000 rows in HTML format and are cancelled after 30 seconds.

```
select 0.25*(0.5+floor(log10(mass)/0.25)) as log_mass, count(*) as num
from miniMDR1..FOF
where snapnum = 85
group by floor(log10(mass)/0.25)
order by 1
```

Query (stream) Query (browser) Maximum number of rows to return: 10

Help

Fertig

Enter SQL query & submit

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

```
select 0.25*(0.5+floor(log10(mass)/0.25)) as log_mass, count(*) as num  
from miniMDR1..FOF  
where snapnum = 85  
group by floor(log10(mass)/0.25)  
order by 1
```

SQL query

Adjust maximum number of rows

Query (stream)

Query (browser)

Help

Maximum number of rows to return:

10

Choose query type

Result returned in browser

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

Fertig

result in table format

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.
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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

Fertig

start VOPlot

VOPlot

MultiDark Database - Mozilla Firefox

http://www.multidark.org/MultiDark/MyDB

MultiDark Database

For help on the use of VOPlot please visit the [VOPlot site](#).
If VOPlot does not work in your browser, you may consider using instead the VO tool TOPCAT for accessing and visualising the data set (see [TOPCAT Access](#)).

The diagram shows the result of the following query:

```
select 0.25*(0.5+floor(log10(mass)/0.25)) as log_mass, count(*) as num
from miniMDR1..FOF
where snapnum = 85
group by floor(log10(mass)/0.25)
order by 1
```

File Mode View Functions Aladin Help

X: Coordinate
Y: Coordinate

Y: ☐ Log ☐ Rev
log_mass

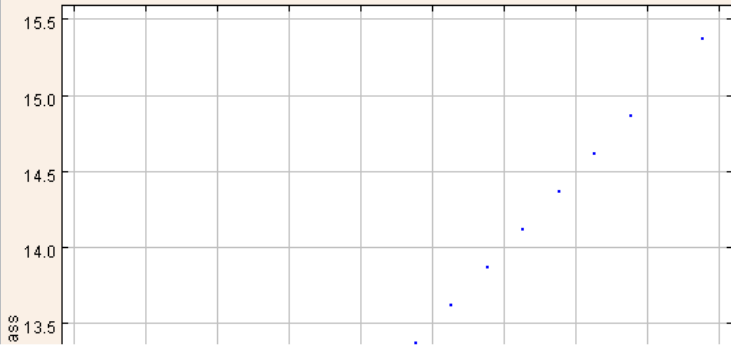
X: ☐ Log ☐ Rev
log_mass

Filter
None

☐ Overlay

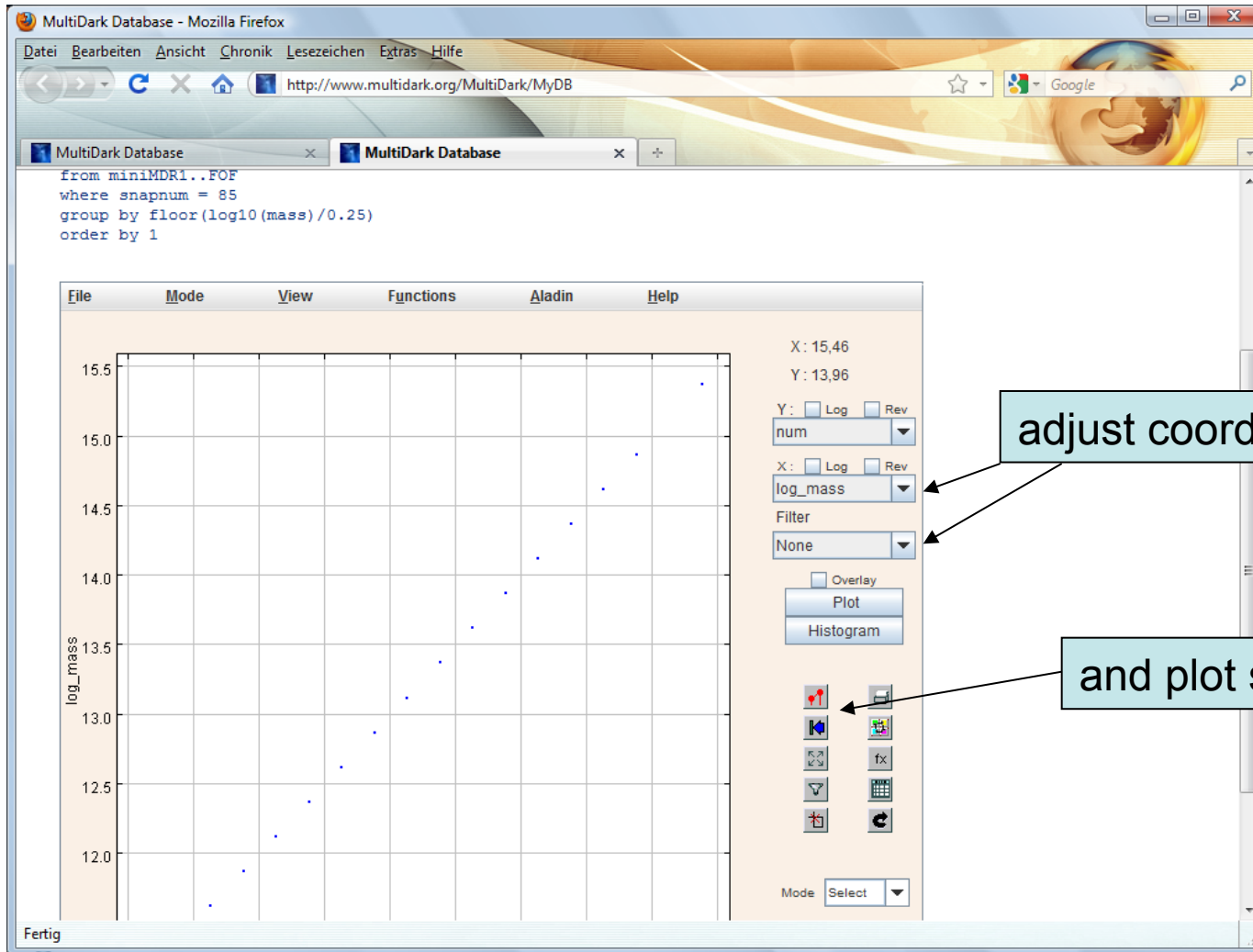
Plot
Histogram

Fertig

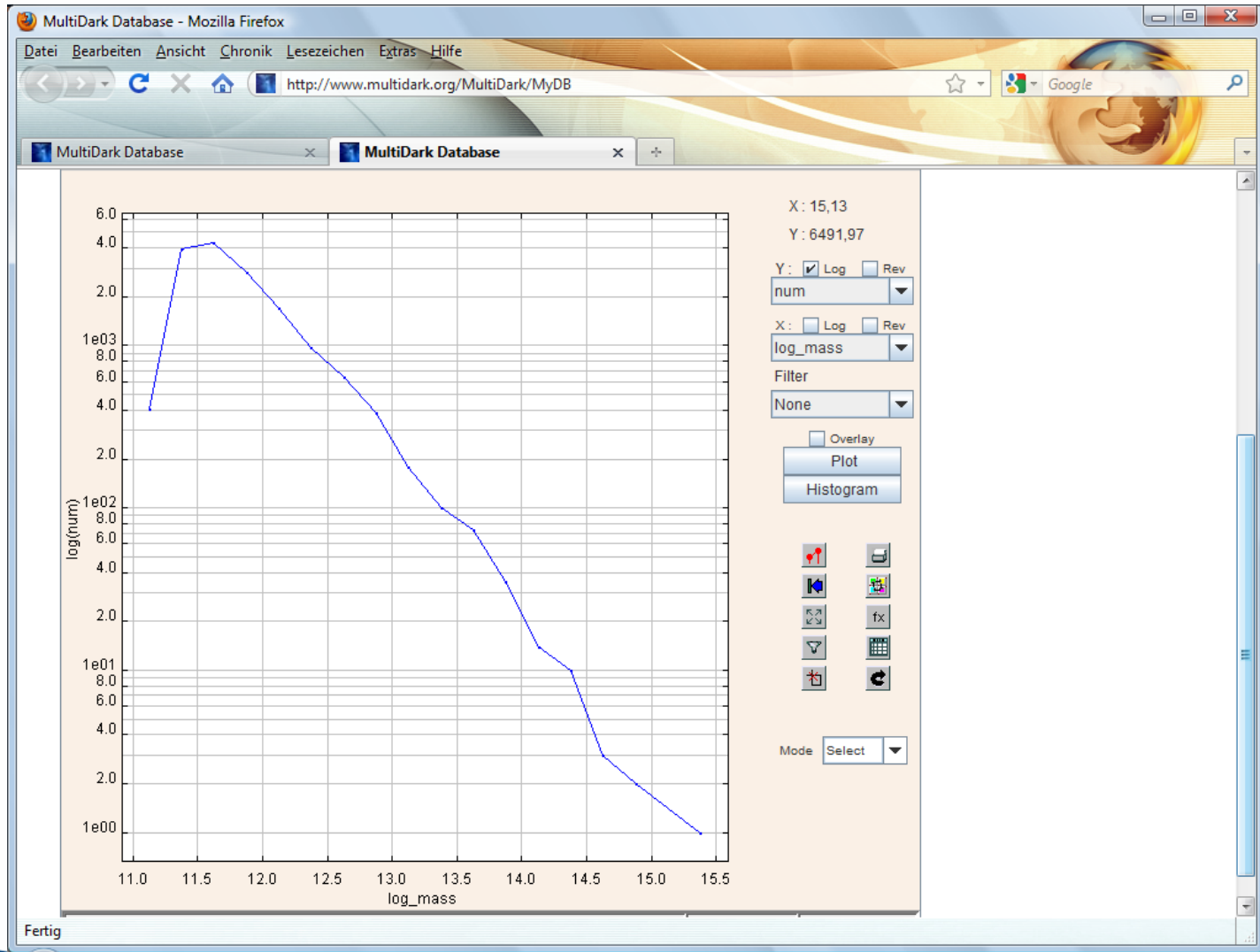


VOPlot Java Applet
starts in new browser tab

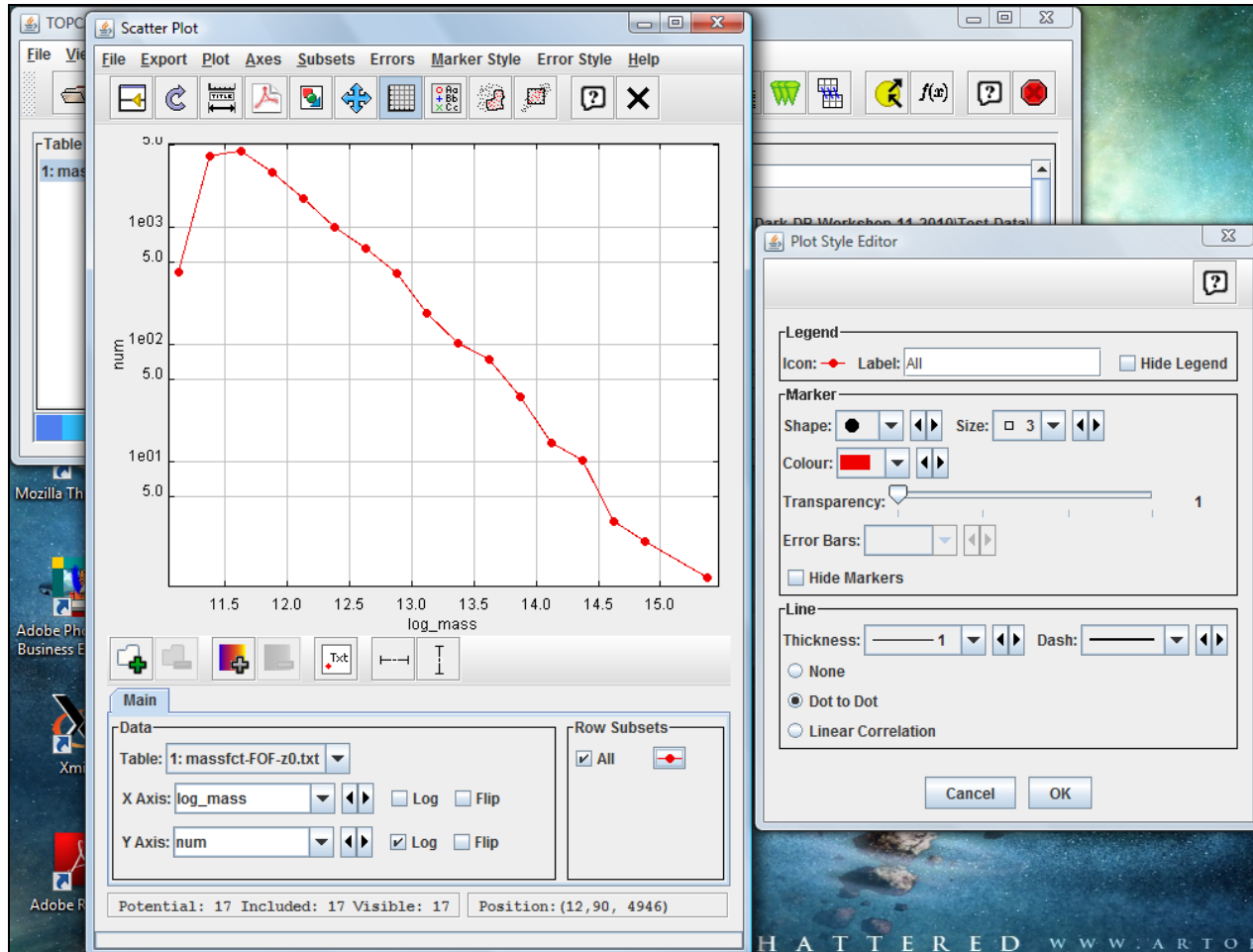
Adjust plot parameters



Mass function of halos at $z=0$



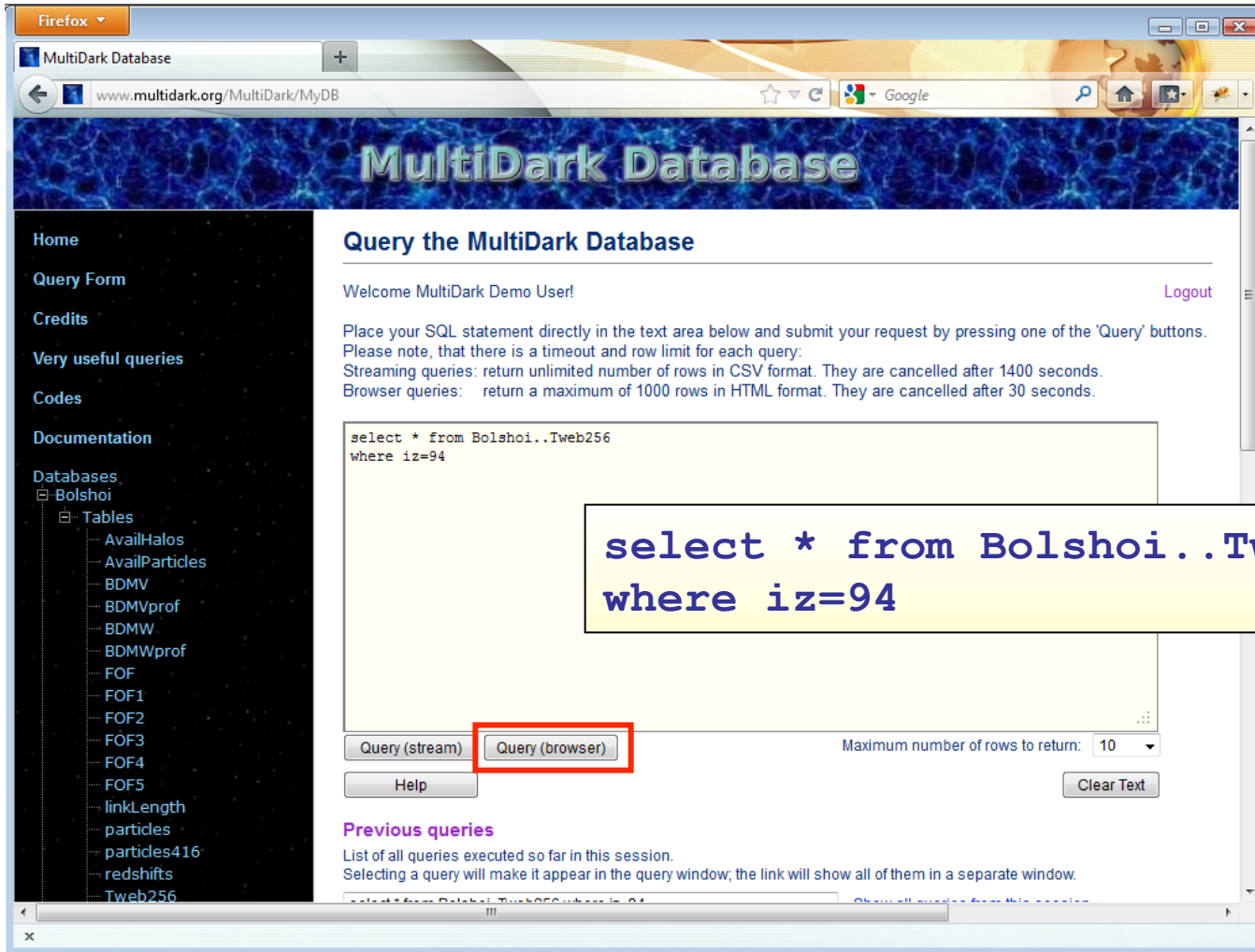
Other tools: Topcat



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

=> offers
many
possibilities!

Demo: Cosmic Web in browser



Firefox

MultiDark Database

www.multidark.org/MultiDark/MyDB

MultiDark Database

Home

Query Form

Credits

Very useful queries

Codes

Documentation

Databases

- Bolshoi
 - Tables
 - AvailHalos
 - AvailParticles
 - BDMV
 - BDMVprof
 - BDMW
 - BDMWprof
 - FOF
 - FOF1
 - FOF2
 - FOF3
 - FOF4
 - FOF5
 - linkLength
 - particles
 - particles416
 - redshifts
 - Tweb256

Query the MultiDark Database

Welcome MultiDark Demo User! [Logout](#)

Place your SQL statement directly in the text area below and submit your request by pressing one of the 'Query' buttons.
Please note, that there is a timeout and row limit for each query:
Streaming queries: return unlimited number of rows in CSV format. They are cancelled after 1400 seconds.
Browser queries: return a maximum of 1000 rows in HTML format. They are cancelled after 30 seconds.

```
select * from Bolshoi..Tweb256
where iz=94
```

[Query \(stream\)](#) [Query \(browser\)](#) [Help](#)




Maximum number of rows to return: 10 [Clear Text](#)

Previous queries

List of all queries executed so far in this session.
Selecting a query will make it appear in the query window; the link will show all of them in a separate window.

[select * from Bolshoi..Tweb256 where iz=94](#) [Show all queries from this session](#)

Demo: Cosmic Web in browser

Metadata queries

The SQL statements under these buttons provide examples for querying and managing the state of a *private* database. Holding the mouse over the button will give a short explanation of the goal of the statement.

Show Tables
Show Views
Show Columns
MyDB Size
MyDB Table Size

Create View
Drop Table
Create Index

Query time (in millisec) = 5279
Number of rows retrieved from database = 1000

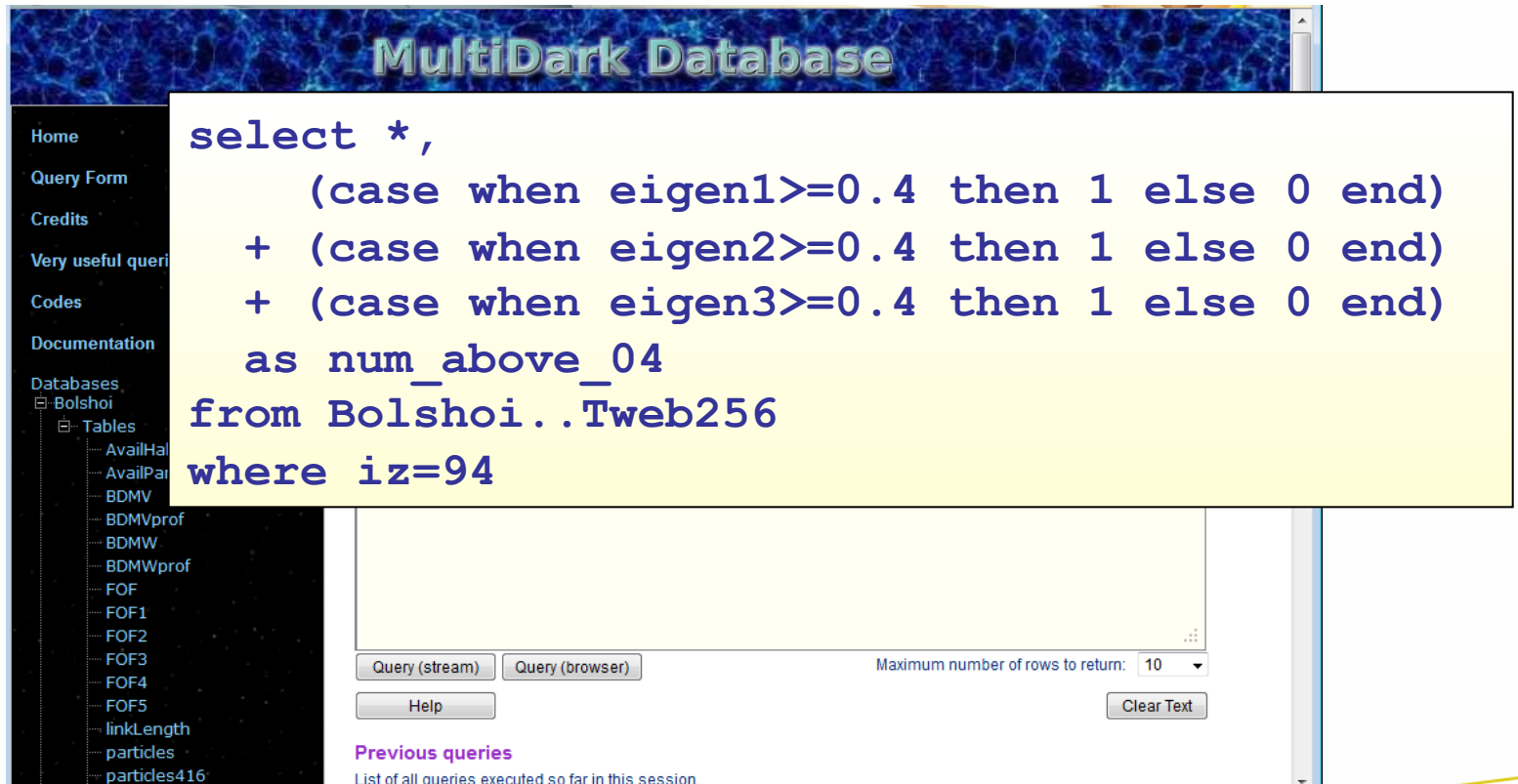
Select an output format and press the "Get table" button to open a new window with your data in the chosen table format. Click "Plot" to start the VOPlot Java Applet in your browser.

CSV
Get table
Plot

webld	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



The screenshot shows the MultiDark Database web interface. On the left is a navigation menu with links: Home, Query Form, Credits, Very useful queries, Codes, Documentation, Databases, and a tree view for Bolshoi tables including AvailHal, AvailPar, BDMV, BDMVprof, BDMW, BDMWprof, FOF, FOF1, FOF2, FOF3, FOF4, FOF5, linkLength, particles, and particles416. The main area displays a SQL query in a text box:

```
select *,
    (case when eigen1>=0.4 then 1 else 0 end)
  + (case when eigen2>=0.4 then 1 else 0 end)
  + (case when eigen3>=0.4 then 1 else 0 end)
  as num_above_04
from Bolshoi..Tweb256
where iz=94
```

Below the query box are buttons for "Query (stream)", "Query (browser)", and "Help". To the right of these buttons is a dropdown menu for "Maximum number of rows to return:" set to 10, and a "Clear Text" button. At the bottom, there is a section titled "Previous queries" with the text "List of all queries executed so far in this session."

Demo: Cosmic Web in browser

Firefox

MultiDark Database

www.multidark.org/MultiDark/MyDB

Q2 Q3 Q4

queries

Statements under these buttons provide examples for querying and managing the state of a *private* database. Mouse over the button will give a short explanation of the goal of the statement.

ables Show Views Show Columns MyDB Size MyDB Table Size

iew Drop Table Create Index

(in millisec) = 484
Rows retrieved from database = 1000

Output format and press the "Get table" button to open a new window with your data in the chosen table format. To start the VOPlot Java Applet in your browser.

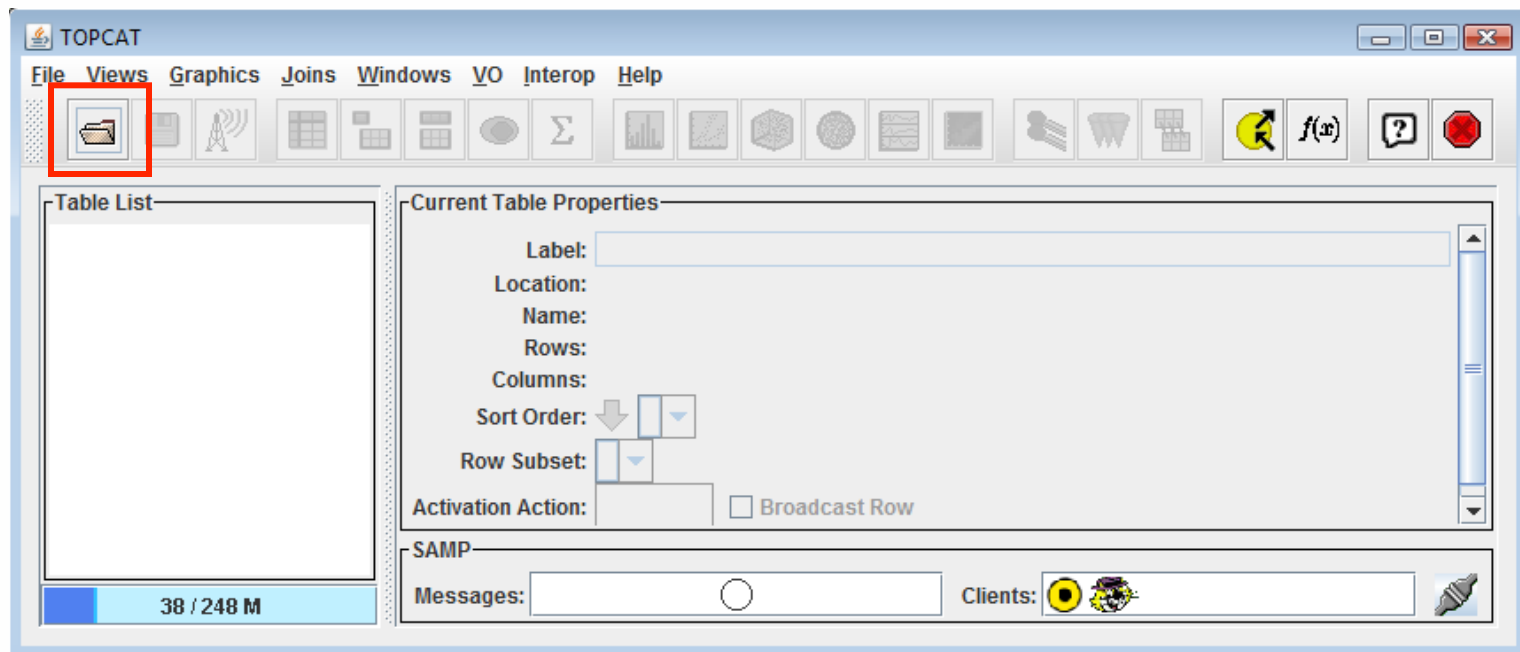
Get table Plot

x	iy	iz	phkey	eigen1	eigen2	eigen3	ev1_x	ev1_y	ev1_z	ev2_x	ev2_y	ev2_z	ev3_x	ev3_y	ev3_z	num_above_04
0	94	294904	-0.067124	-0.14117	-0.274703	-0.894997	0.300518	0.32965	-0.009122	-0.751181	0.660033	0.445979	0.587721	0.67504	0	
0	94	294905	-0.014212	-0.137815	-0.265326	-0.912409	0.135046	0.386357	0.10422	-0.836212	0.538412	0.395787	0.531518	0.74889	0	
0	94	294854	0.046189	-0.135169	-0.249941	-0.949877	0.081477	0.301821	0.09616	-0.842489	0.530061	0.297469	0.532516	0.79242	0	
0	94	294855	0.039697	-0.139105	-0.240778	-0.983899	0.042835	0.173517	0.066058	-0.814954	0.575749	0.166071	0.577941	0.79900	0	
0	94	294844	-0.041384	-0.152295	-0.24363	-0.997394	-0.031502	0.064902	0.066393	-0.75277	0.654926	0.028224	0.657529	0.7529	0	
0	94	294843	-0.112556	-0.163816	-0.251084	-0.990465	-0.137258	0.01182	0.100695	-0.662721	0.742066	-0.094021	0.73618	0.67022	0	
0	94	294832	-0.13924	-0.17162	-0.254246	0.984196	0.068357	0.163357	-0.078198	-0.659908	0.747266	-0.158881	0.748231	0.64413	0	
0	94	294833	-0.129044	-0.192497	-0.255193	0.907849	-0.143188	0.39409	-0.343438	-0.793126	0.502992	-0.240541	0.591987	0.76921	0	
0	94	290894	-0.084979	-0.203744	-0.288564	0.903177	-0.224002	0.36619	0.235713	0.971735	0.013055	-0.358764	0.074525	0.93044	0	
0	94	290895	-0.001066	-0.184525	-0.380214	0.935861	-0.25658	0.241517	0.199725	0.050888	0.026817	0.000888	0.438888	0.01118	0	

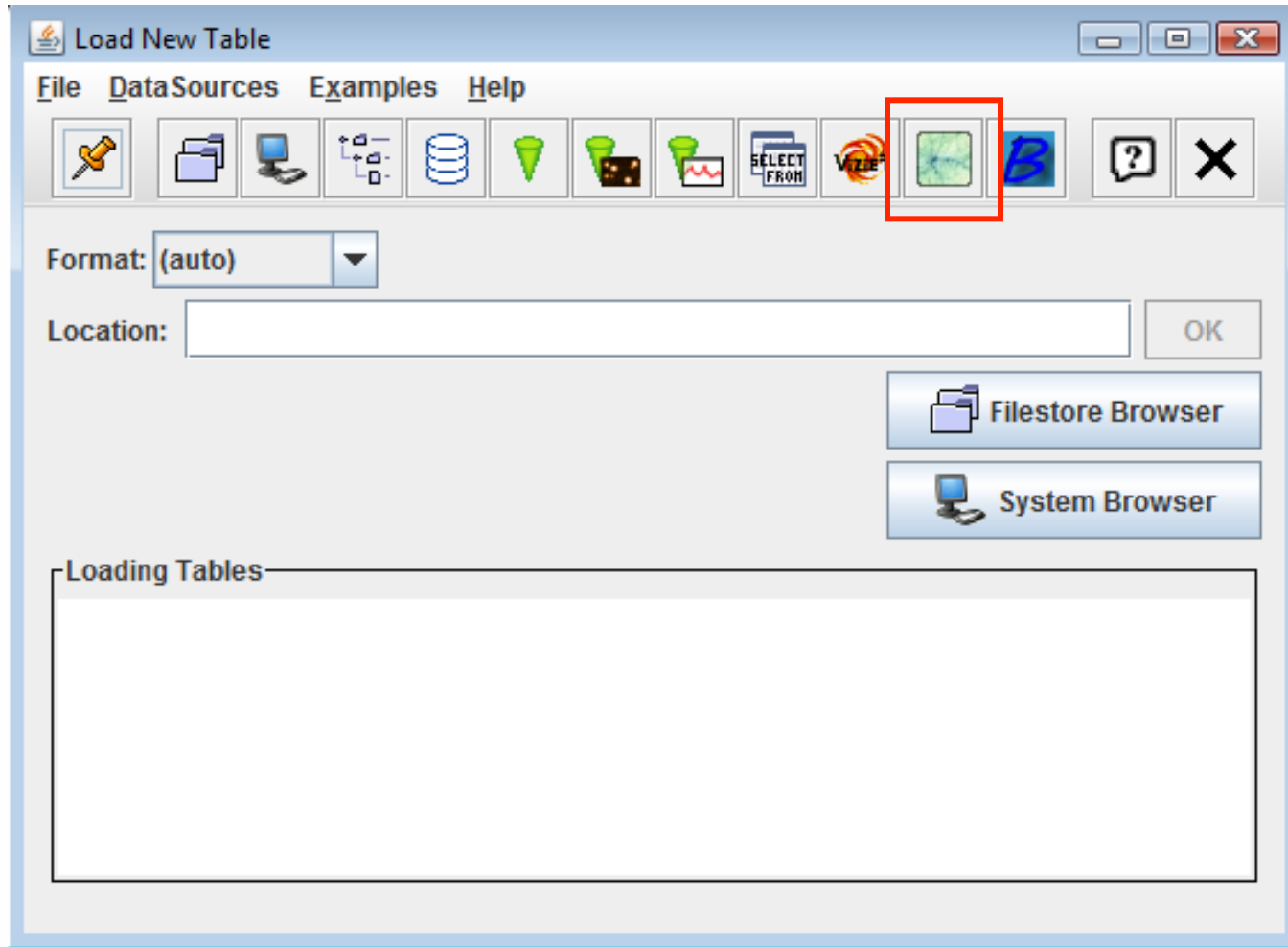
=> new column created!

Plot with Topcat

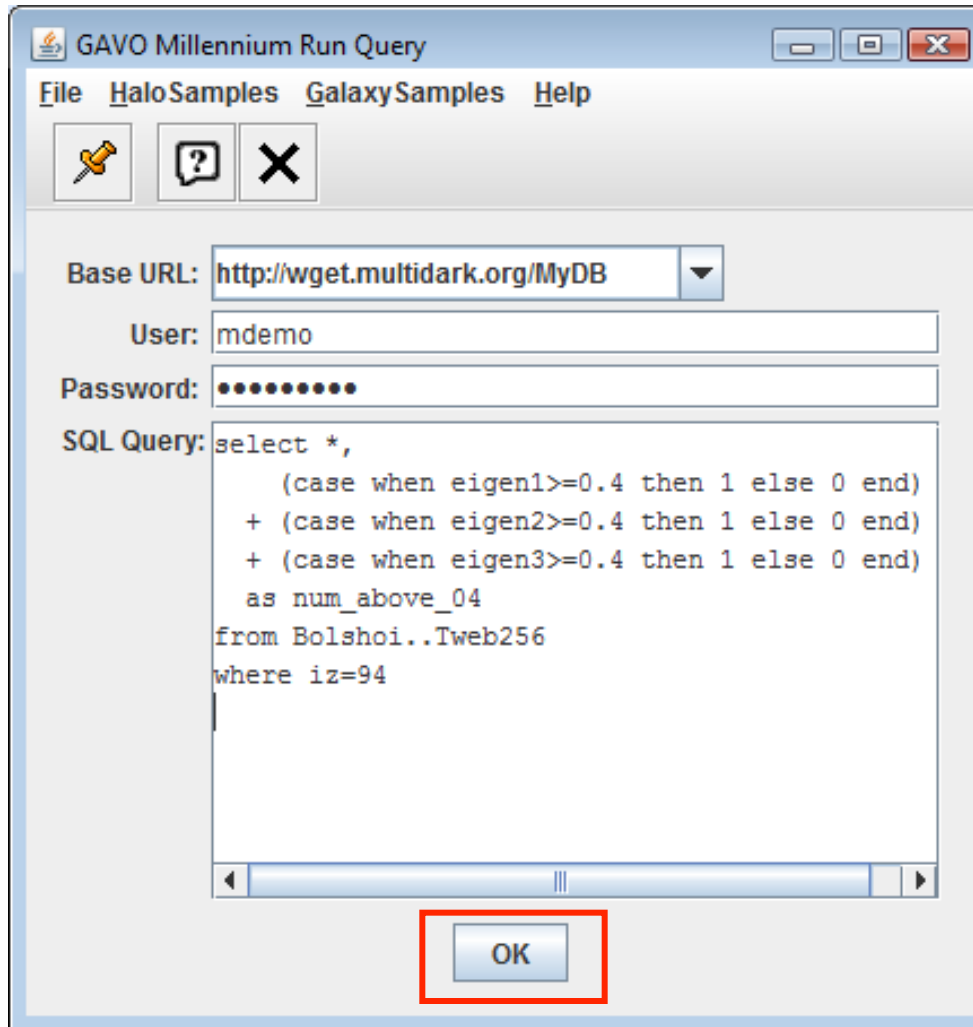
- Download topcat-full.jar from <http://www.star.bris.ac.uk/~mbt/topcat/>
- start: `java -jar topcat-full.jar`
(or just double-click)



Topcat: open query window



Enter SQL query



GAVO Millennium Run Query

File HaloSamples GalaxySamples Help

Base URL:

User:

Password:

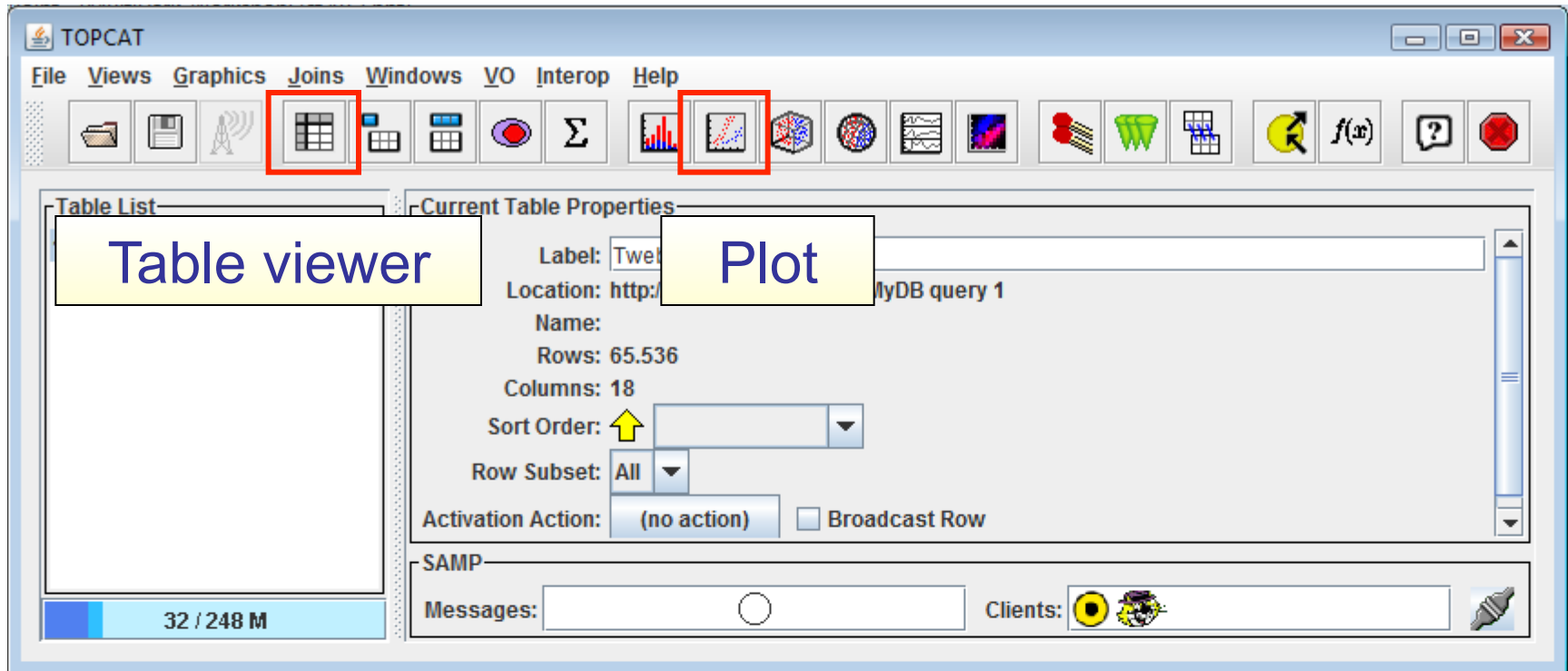
SQL Query:

```
select *,  
    (case when eigen1>=0.4 then 1 else 0 end)  
+ (case when eigen2>=0.4 then 1 else 0 end)  
+ (case when eigen3>=0.4 then 1 else 0 end)  
as num_above_04  
from Bolshoi..Tweb256  
where iz=94
```

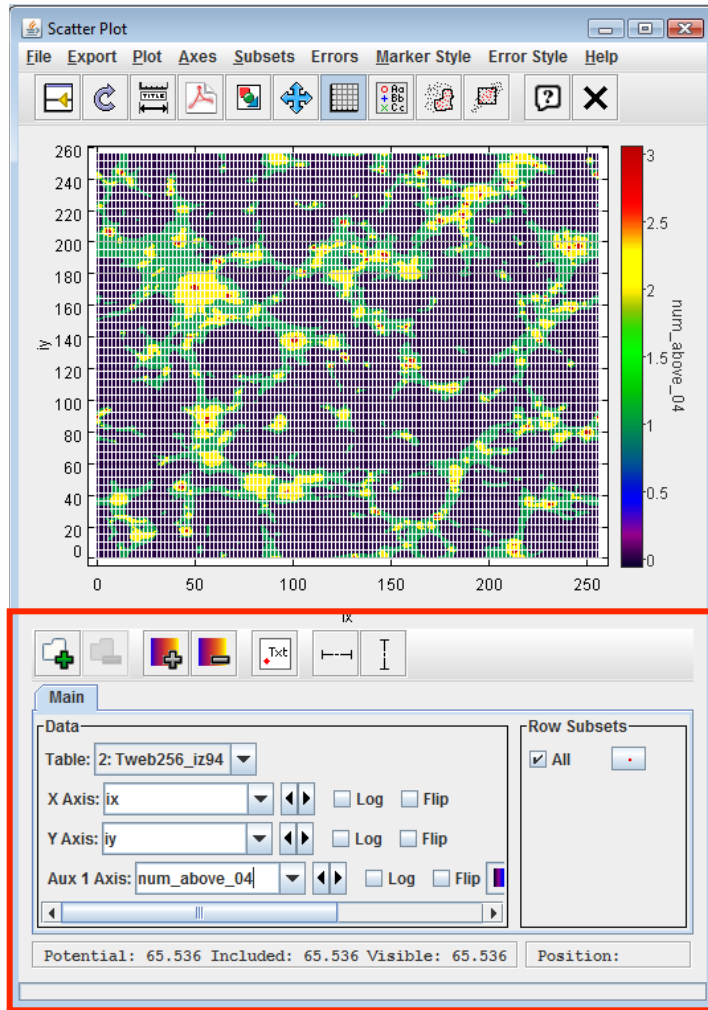
OK

Press OK
and wait ...

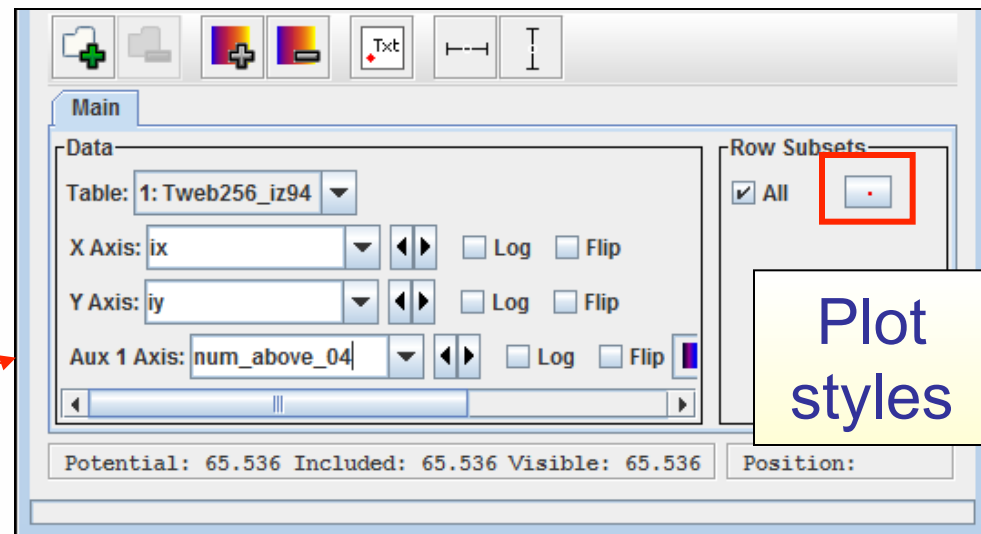
Topcat: rename & view table



Topcat: plot

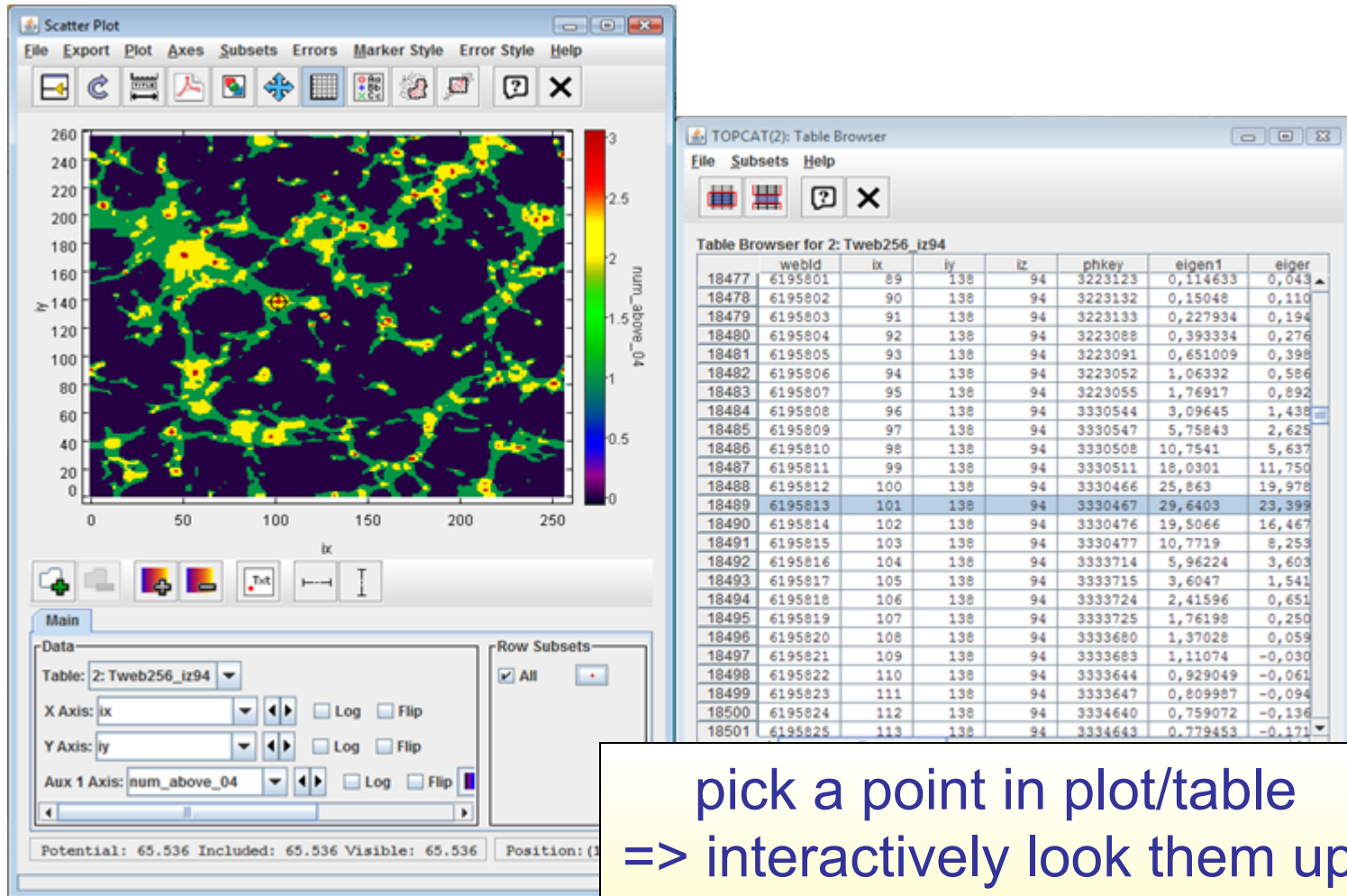


- Adjust axes: ix, iy
- Add „Auxiliary axis“: num_above_04



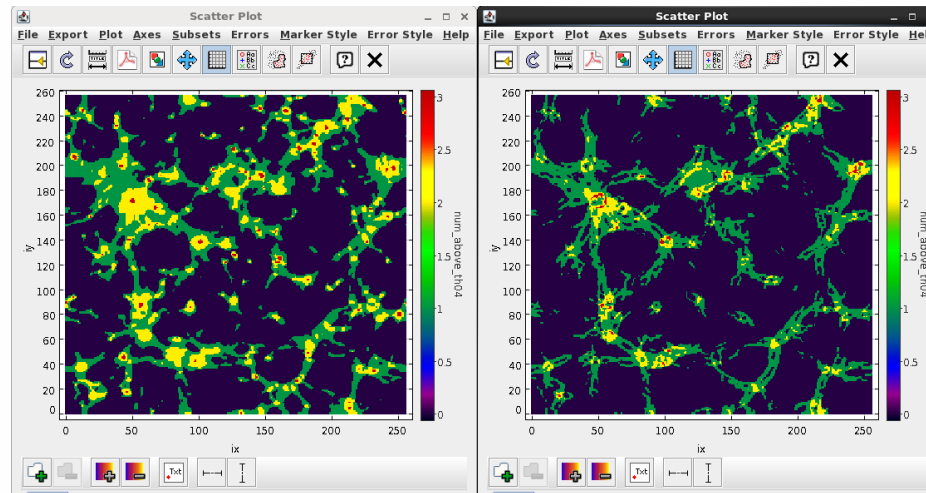
Plot styles

Topcat: Plot and table interaction



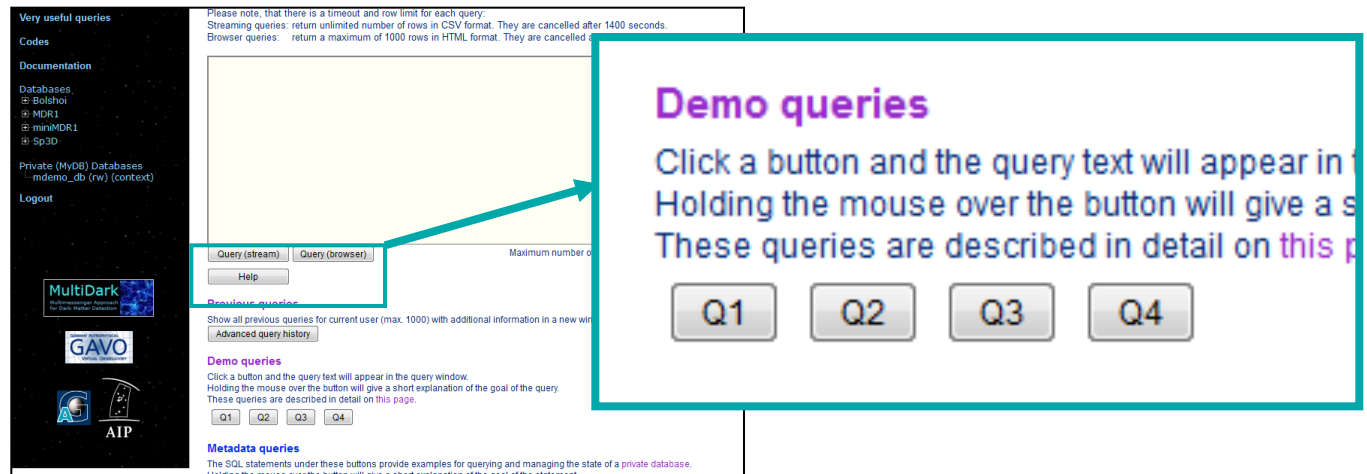
Cosmic Web

- 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:



The screenshot shows the MultiDark web interface. On the left is a dark sidebar with navigation links: 'Very useful queries', 'Codes', 'Documentation', 'Databases' (listing Bolshoi, MDR1, miniMDR1, Sp3D), 'Private (MySQL) Databases' (listing mdemo_db), and 'Logout'. The main content area has a yellow background and contains a 'Query (stream)' and 'Query (browser)' button, a 'Help' button, and a 'Previous queries' section. A callout box with a red border and an arrow pointing to the 'Query (browser)' button contains the text: '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.', and four buttons labeled 'Q1', 'Q2', 'Q3', and 'Q4'.

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

Example: Profile of a halo

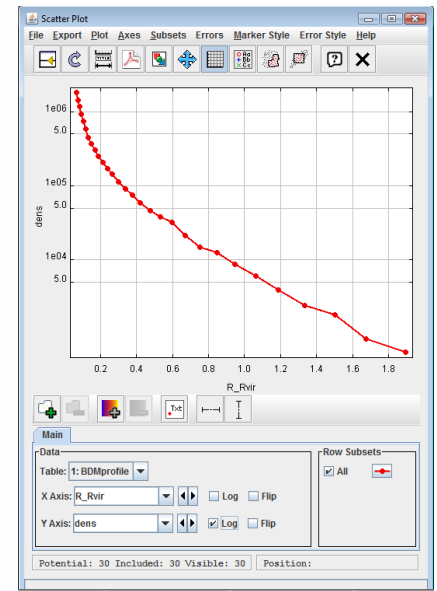
- Profile of most massive BDMV halo

```
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

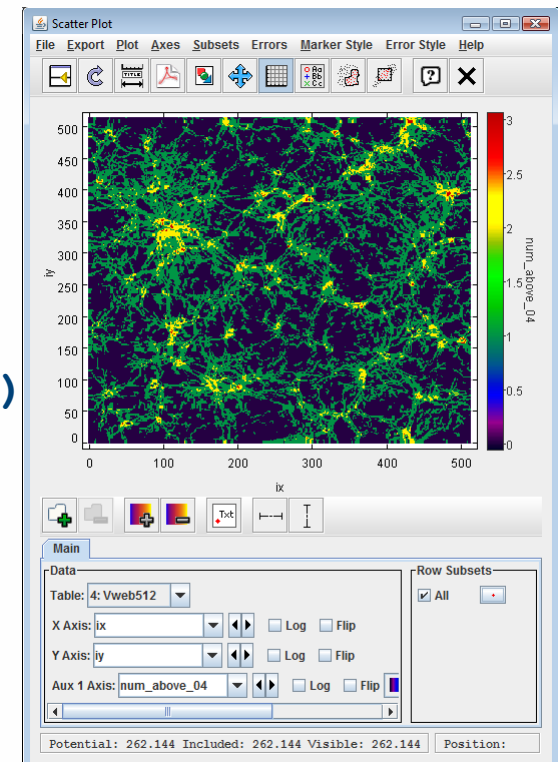
- Retrieve slice in xy-plane, use z-cell with most mass. halo
- count eigenvalues above a threshold, faster than with case-when-then construct

```

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