



# Spatial indexes in PostgreSQL for astronomy

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# Alexander Korotkov, Teodor Sigaev, Oleg Bartunov



- Major contributors to PostgreSQL
- Co-founders of Postgres Professional

## PostgreSQL CORE

- Locale support
- PostgreSQL extendability:
- GiST(KNN), GIN, SP-GiST
- Full Text Search (FTS)
- NoSQL (hstore, jsonb)
- Indexed regexp search
- Custom AM & Generic WAL
- Pluggable table engines (WIP)

## Extensions:

- Intarray
- Pg\_trgm
- Ltree
- Hstore
- plantuner



# Why PostgreSQL?

- Mature DBMS with all necessities
- Open Source product distributed under BSD-like license
- Big and responsible community
- Outstanding extendability
- Rich features to work with



# WSDB Whole Sky DataBase

- Database of astronomic catalogues in Cambridge University
- ~5 dbs, ~ 40 users, up to ~  $10^7$  queries per day, size 40Tb
- pg 9.4 + q3c + hstore
- Example of research:  
[Koposov, S. E., Belokurov, V., Torrealba, G., & Evans, N. W. \(2015\). Beasts of the Southern Wild: Discovery of nine Ultra Faint satellites in the vicinity of the Magellanic Clouds. The Astrophysical Journal, 805\(2\), 130.](#)



# Gaia Alerts Database

- Real time Detection of alerts in the Gaia
- ~10 dbs, 10 users, up to ~  $10^6$  queries per day, size 30Tb
- pg 9.3 + synchronous replication + q3c
- Example of research:

[Campbell, H. C., Marsh, T. R., Fraser, M., Hodgkin, S. T., de Miguel, E., Gänsicke, B. T., ... & Koposov, S. E. \(2015\). Total eclipse of the heart: the AM CVn Gaia14aae/ASSASN-14cn. Monthly Notices of the Royal Astronomical Society, 452\(1\), 1060-1067.](#)

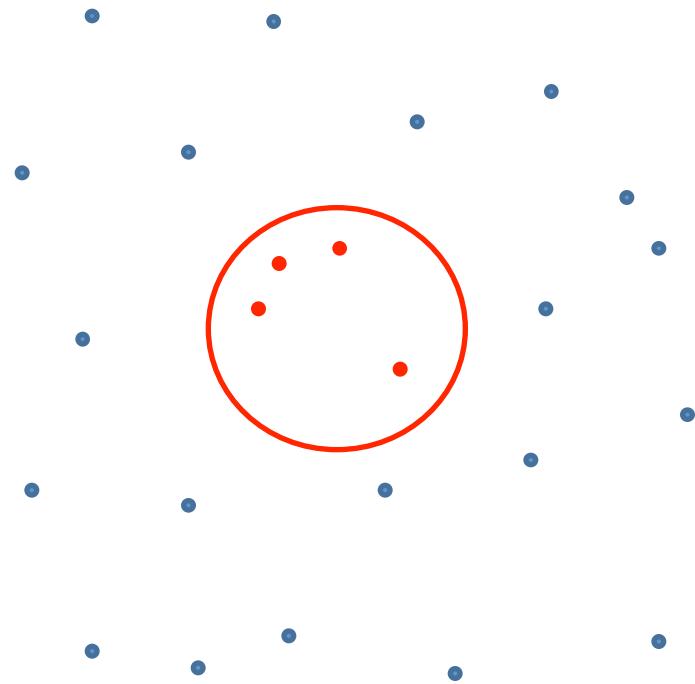


# MASTER database

- Robotic net of telescopes by SAI MSU
- 8 observatories (5 in Russia, 3 outside)
- total size ~100TB
- pg 9.0-9.4 + pgsphere + replication
- See:
  - [Lipunov, Vladimir, et al. "Master robotic net." Advances in Astronomy 2010 \(2010\).](#)
  - [Kornilov, Victor G., et al. "Robotic optical telescopes global network MASTER II. Equipment, structure, algorithms." Experimental Astronomy 33.1 \(2012\): 173-196.](#)

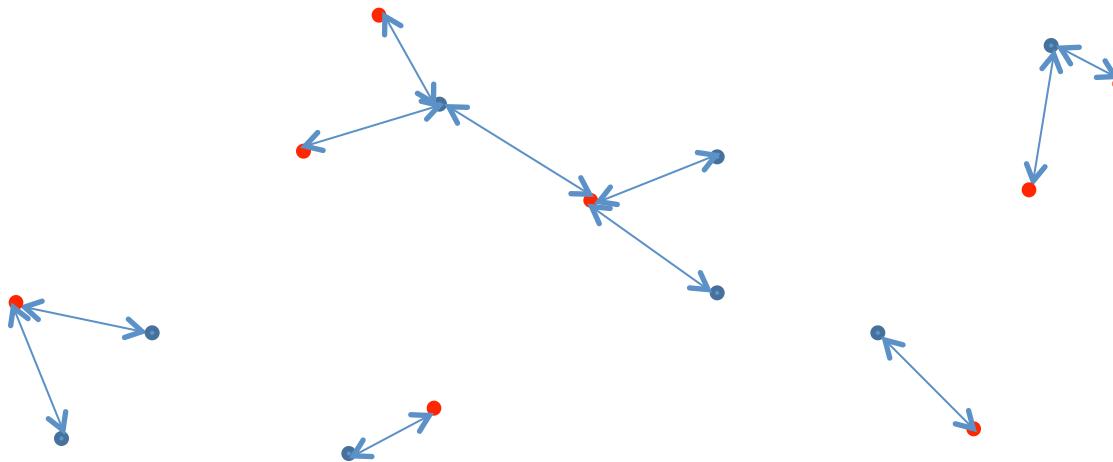


# Radial query





# Crossmatch



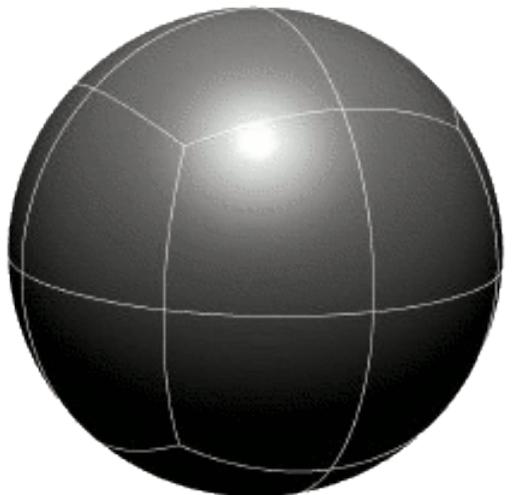


# Indexing methods

- haversine (haive)
- Q3C
- pgSphere
- PostGIS

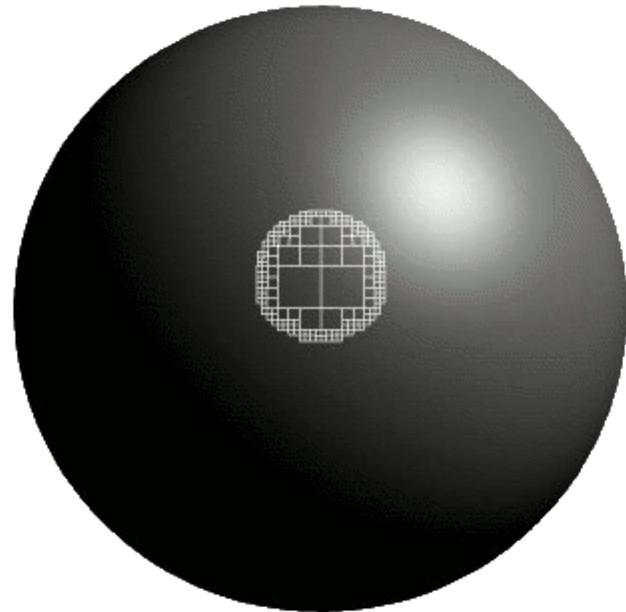
# q3c structure

- Cube is inscribed into sphere
- Central projection of cube into sphere
- Quad-tree on cube faces transforms spherical coordinates into integer (**IPIX**)





# Querying using q3c





# R-tree



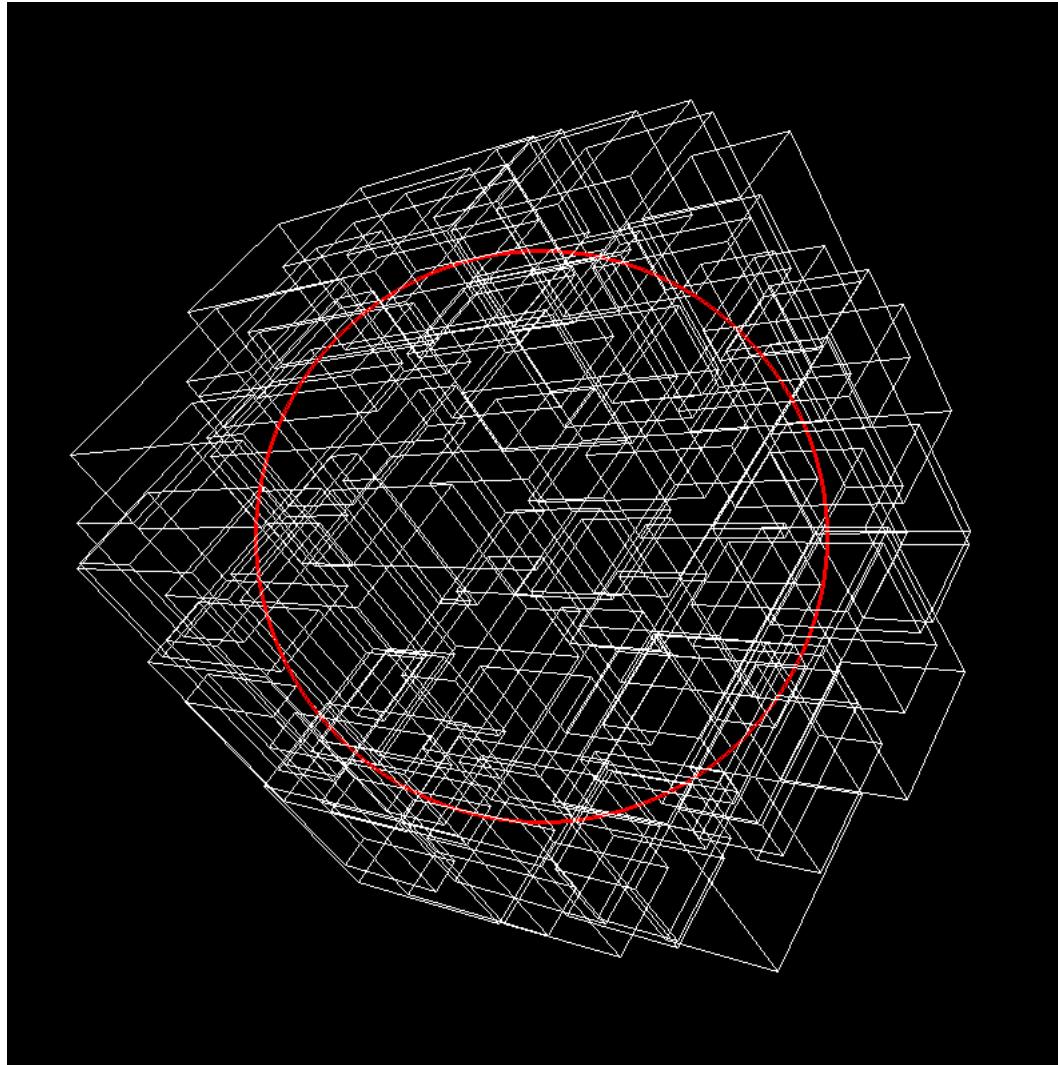


# Generalized search tree (GiST)

- Generalization over R-tree and its variances
- PostgreSQL GiST is the only full featured implementation of GiST
- A lot of applications (operator classes) to various tasks



# pgsphere

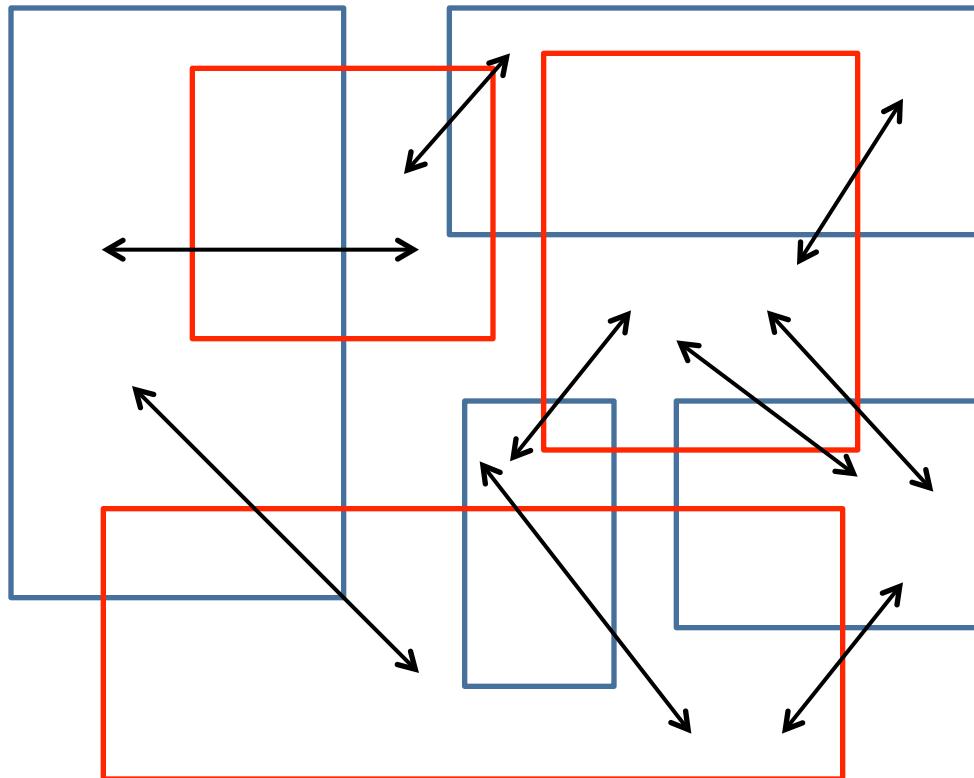




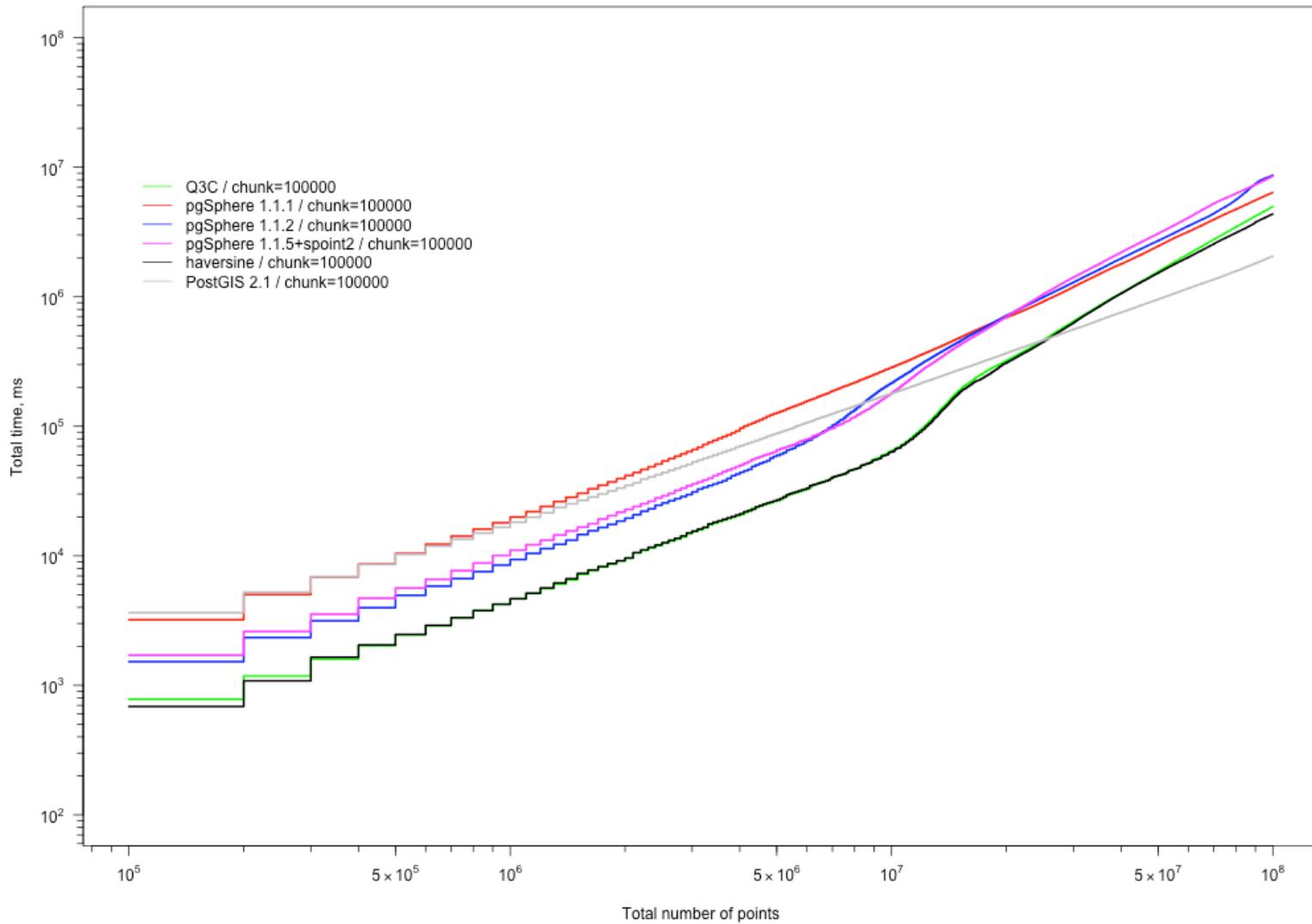
# pgsphere versions

- pgSphere 1.1.1 – last version before this research
- pgSphere 1.1.2 – bug fixes, new node splitting algorithm
- pgSphere 1.1.5 – new operator class spoint2, which able to store source points in index leafs

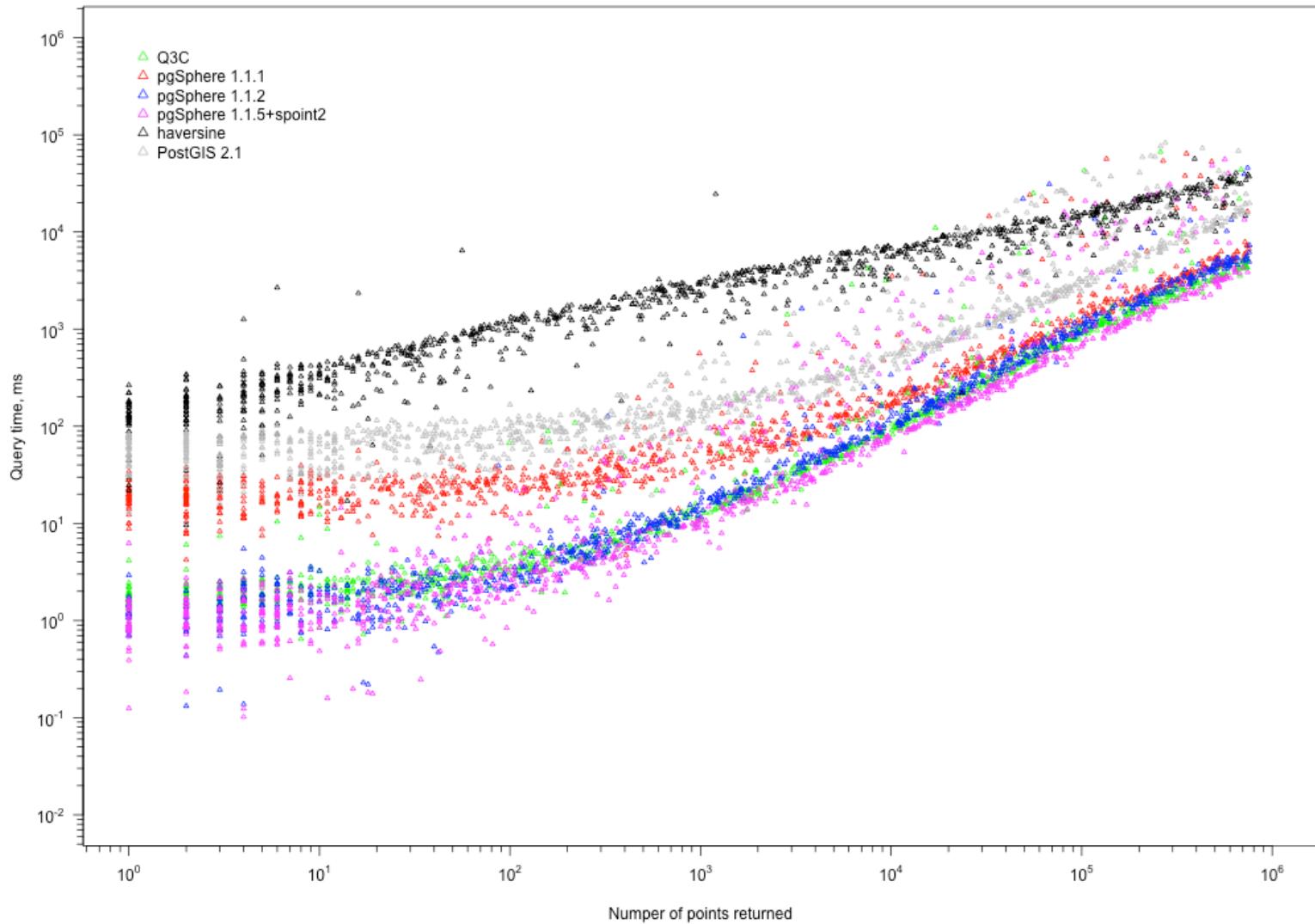
# Crossmatch by two indexes



# Time required for insertion

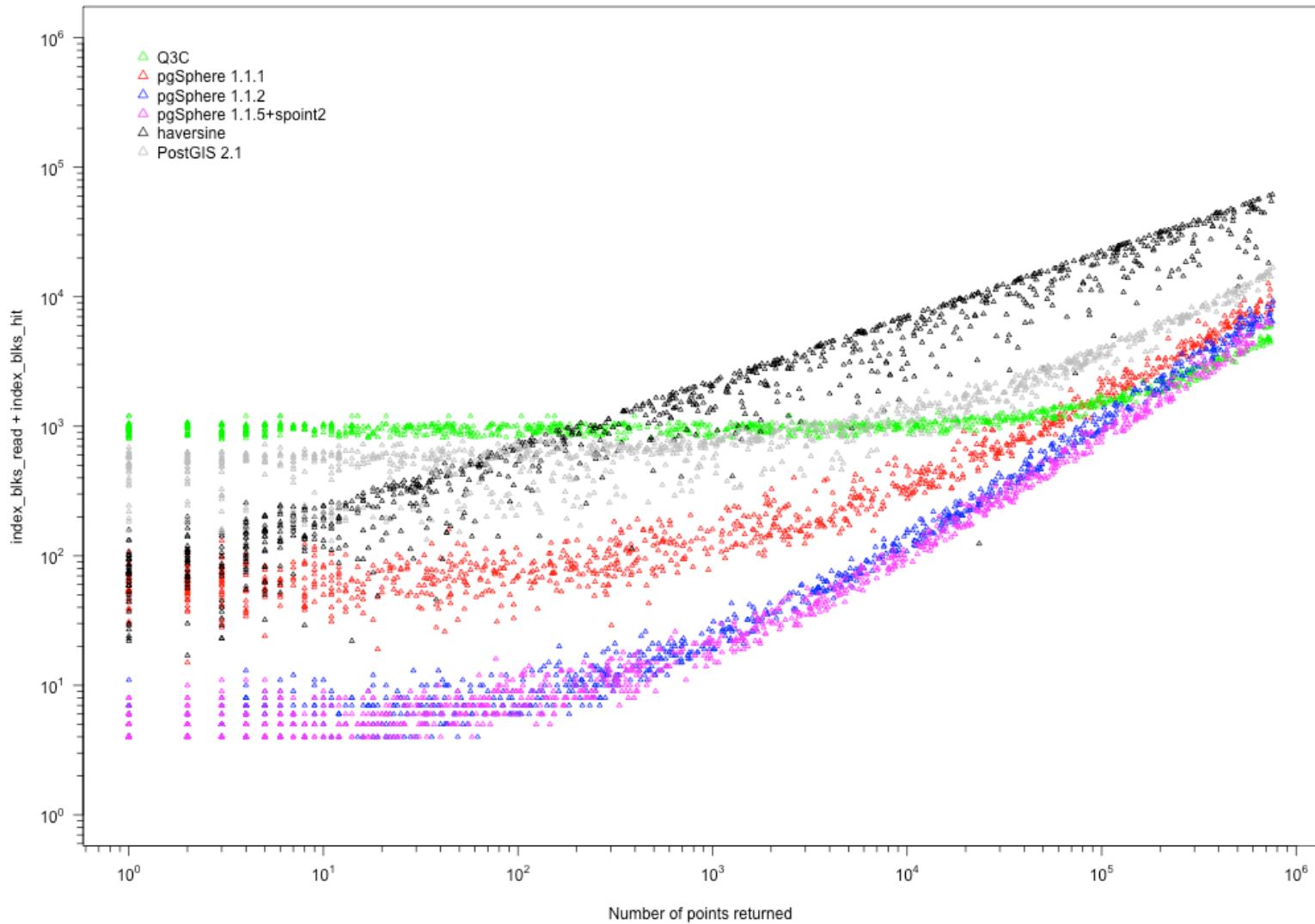


# Time required for radial queries



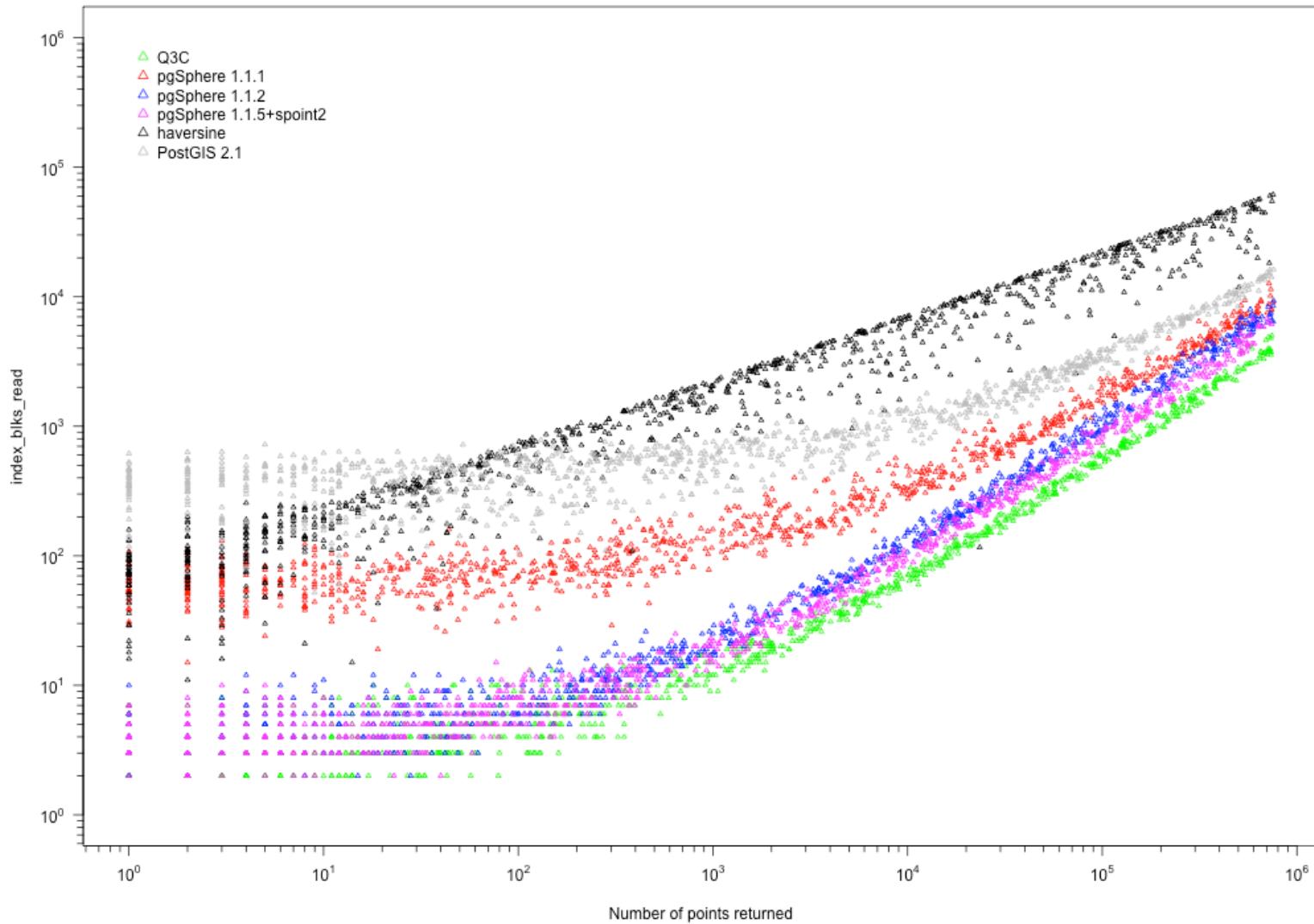


# Number of used index blocks



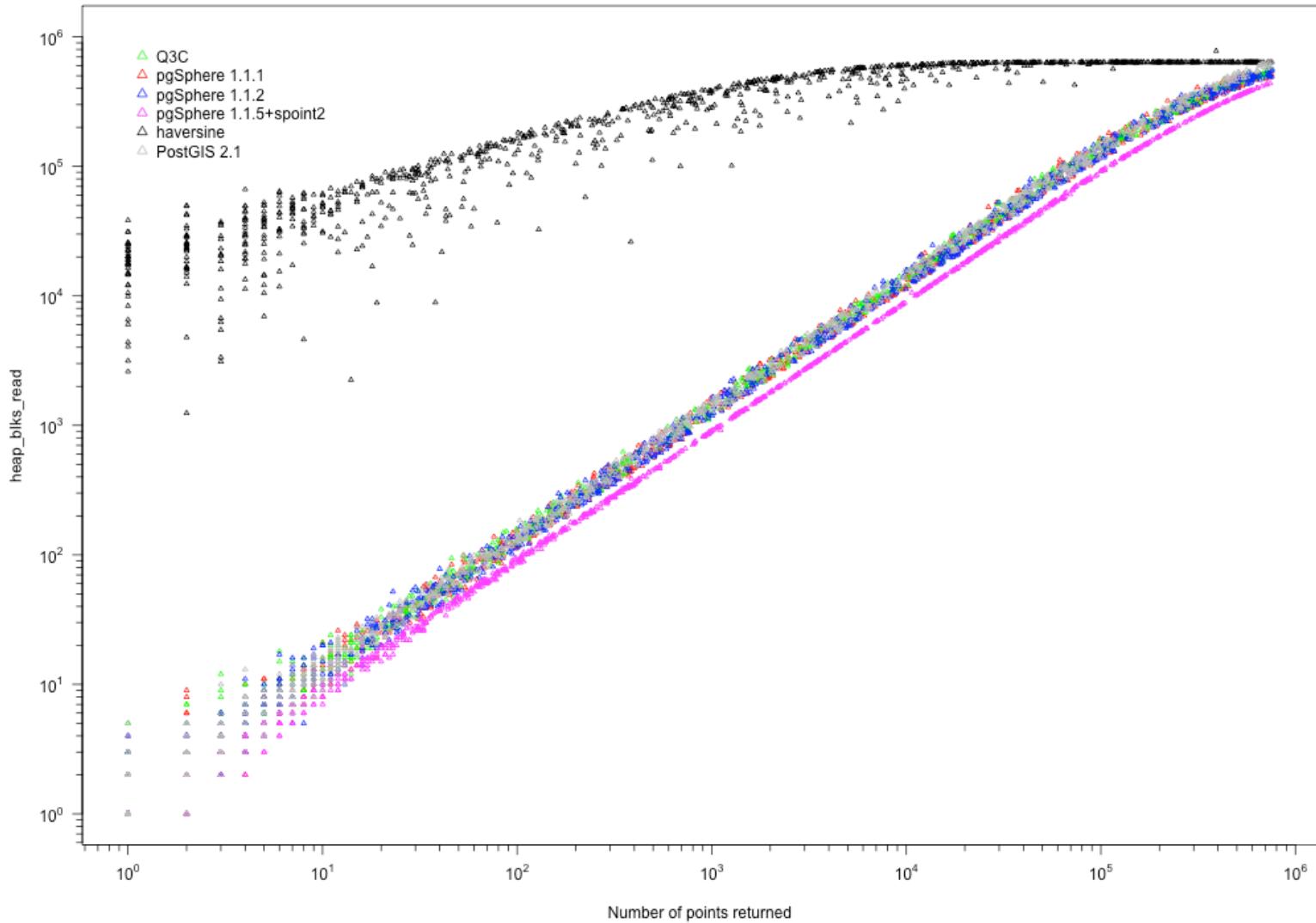


# Number of read index blocks with shared\_buffers = 512 МБ

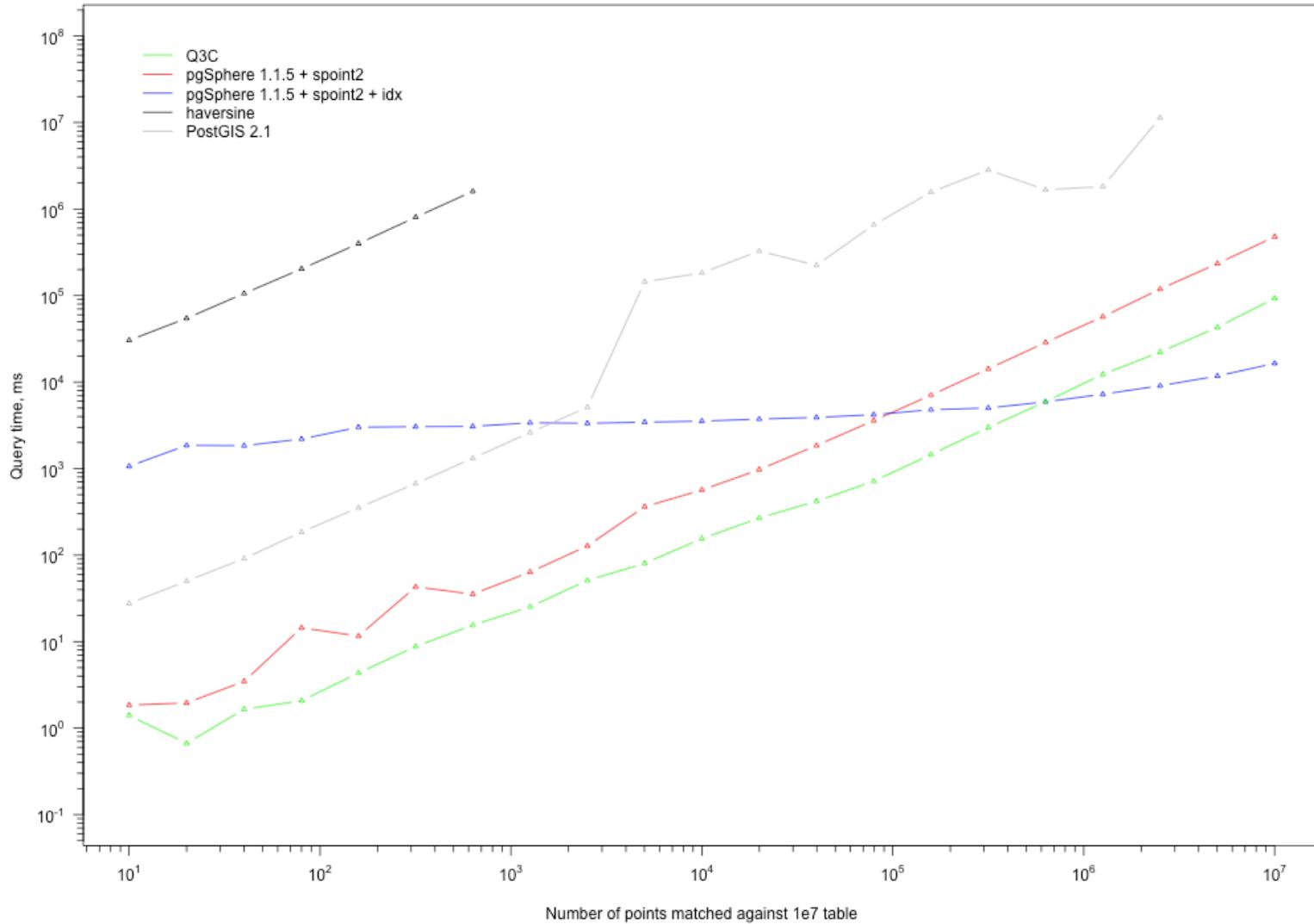




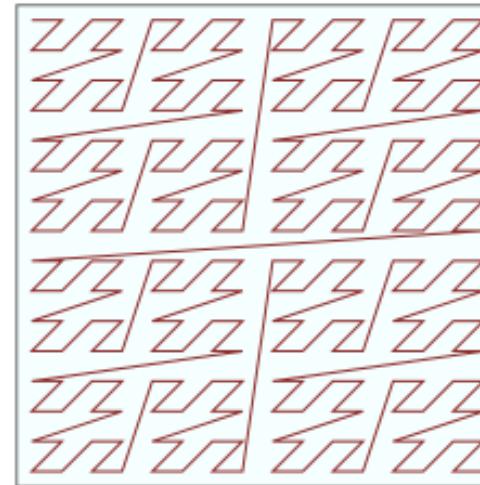
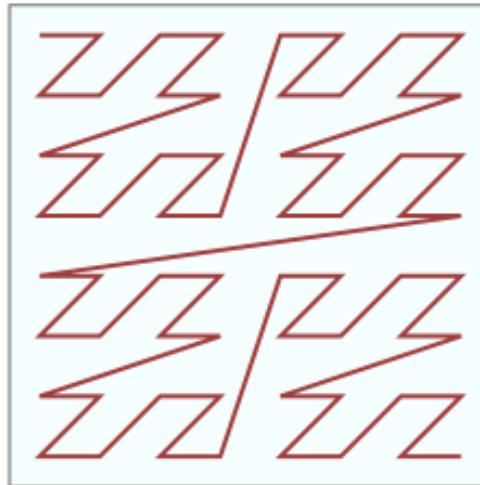
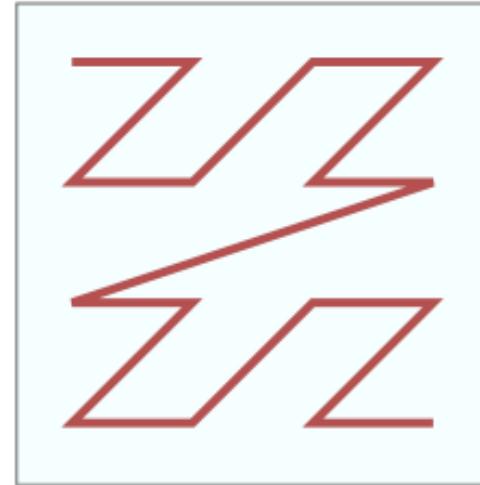
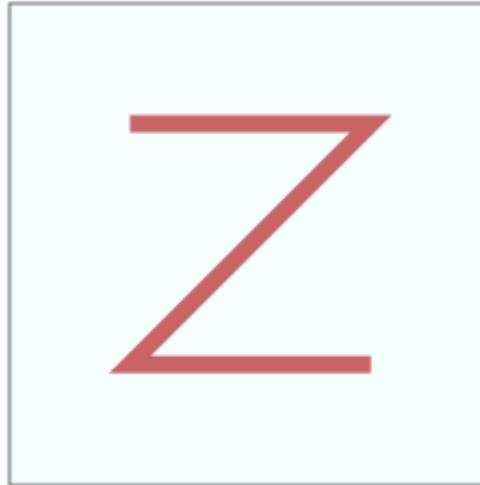
# Number of read heap blocks



# Time of crossmatch execution

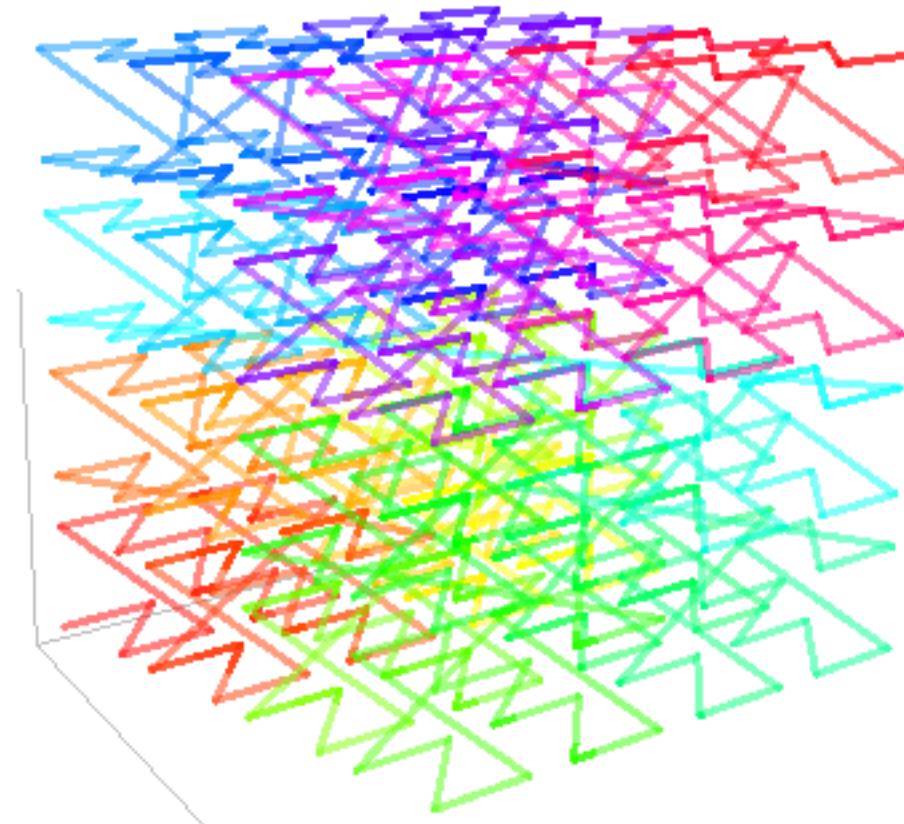


# Z-curve





# 3d-zcurve



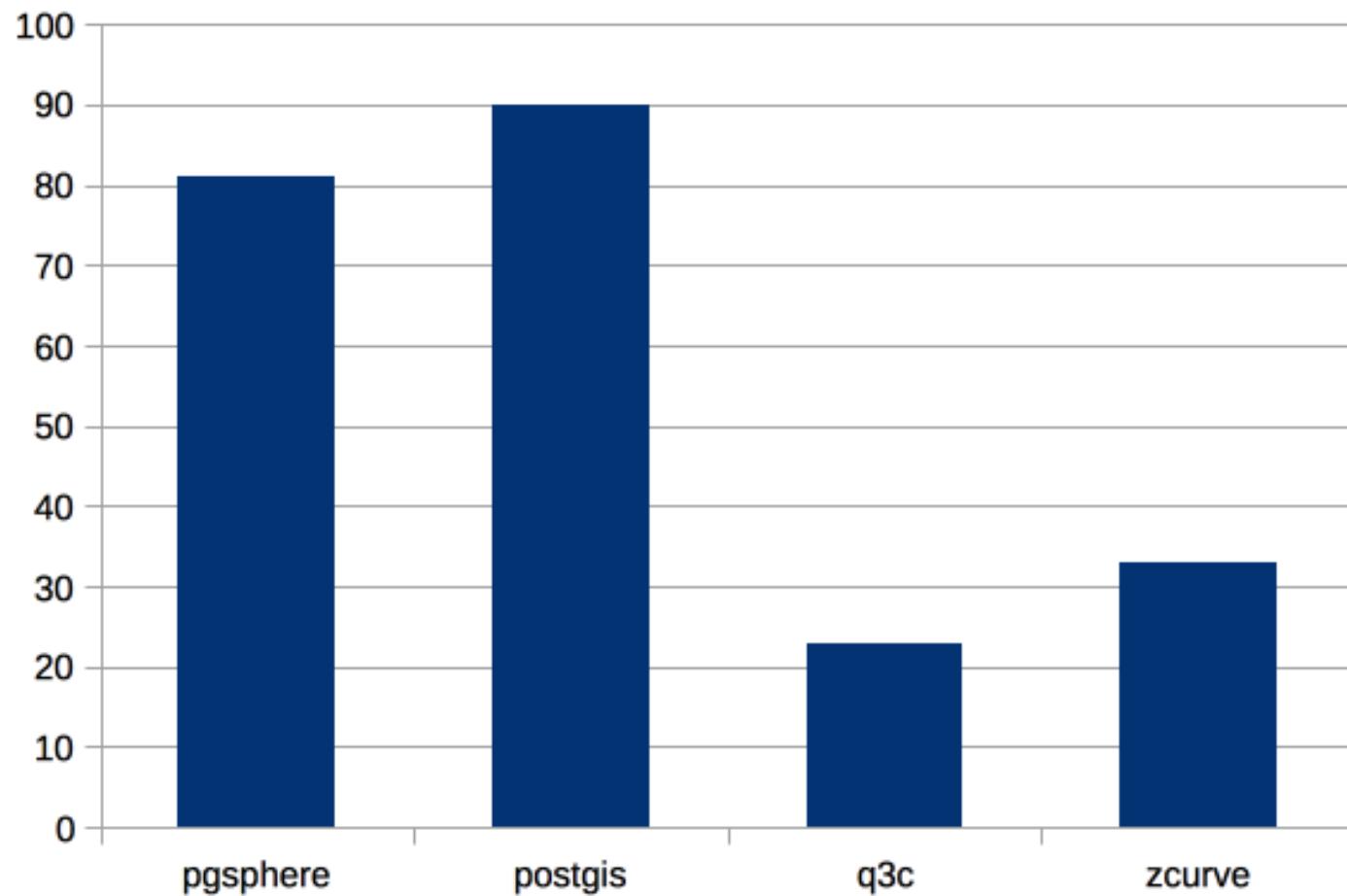


# Experiments on real-life dataset

- Nomad catalogue
- $10^9$  points
- Size of table without indexes = 182 GB

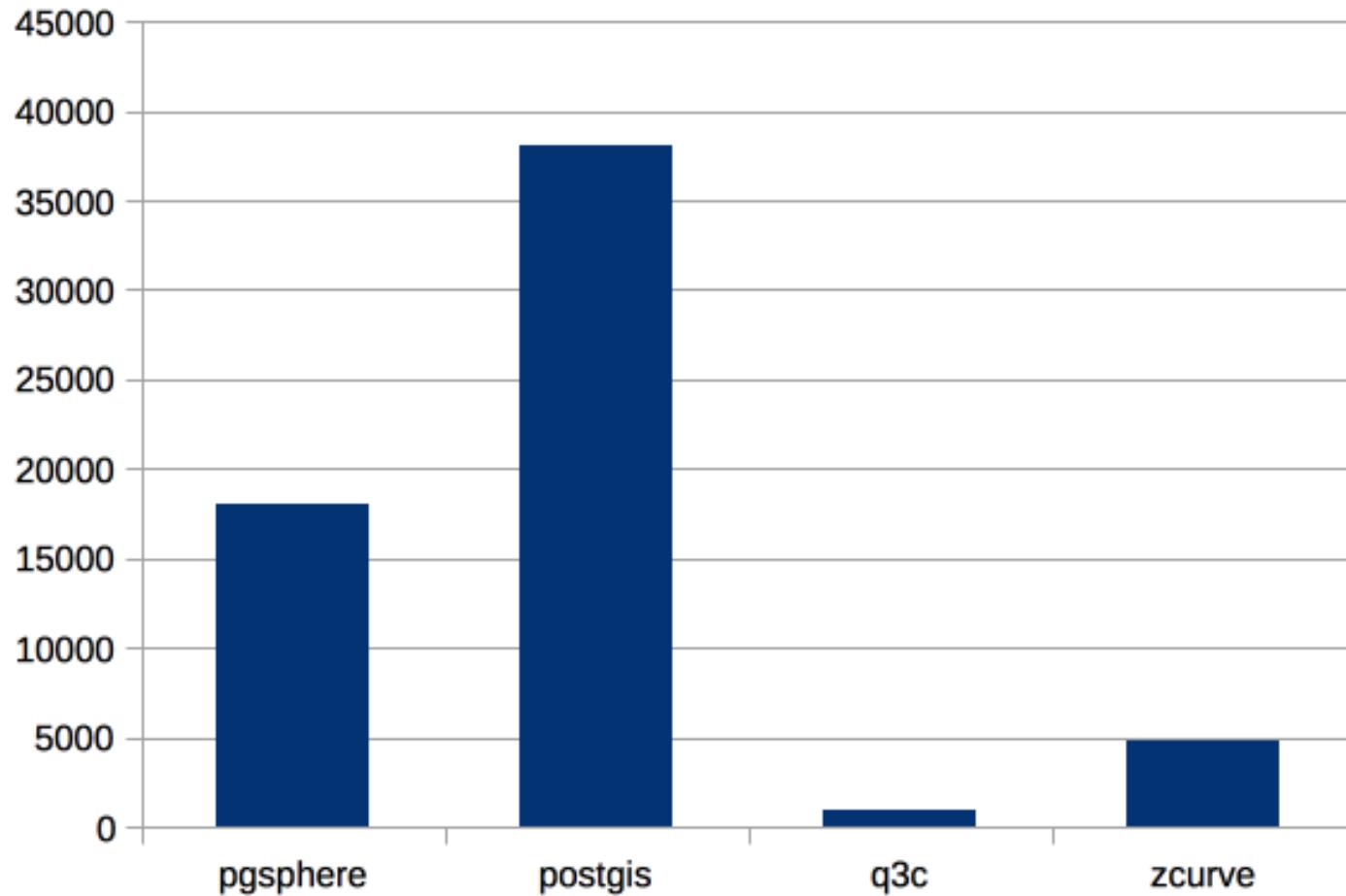


# Index size, GB



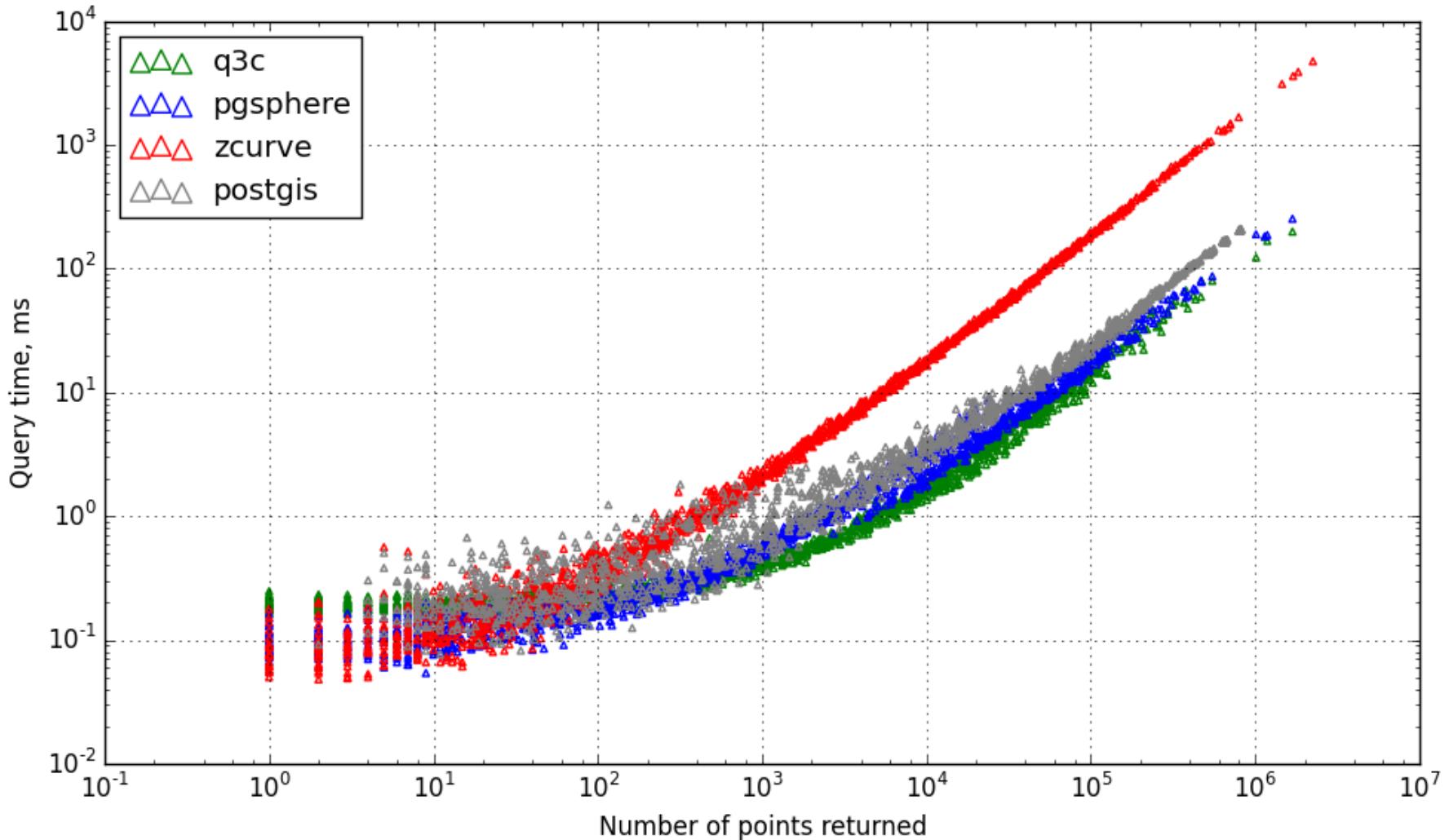


# Build time, sec



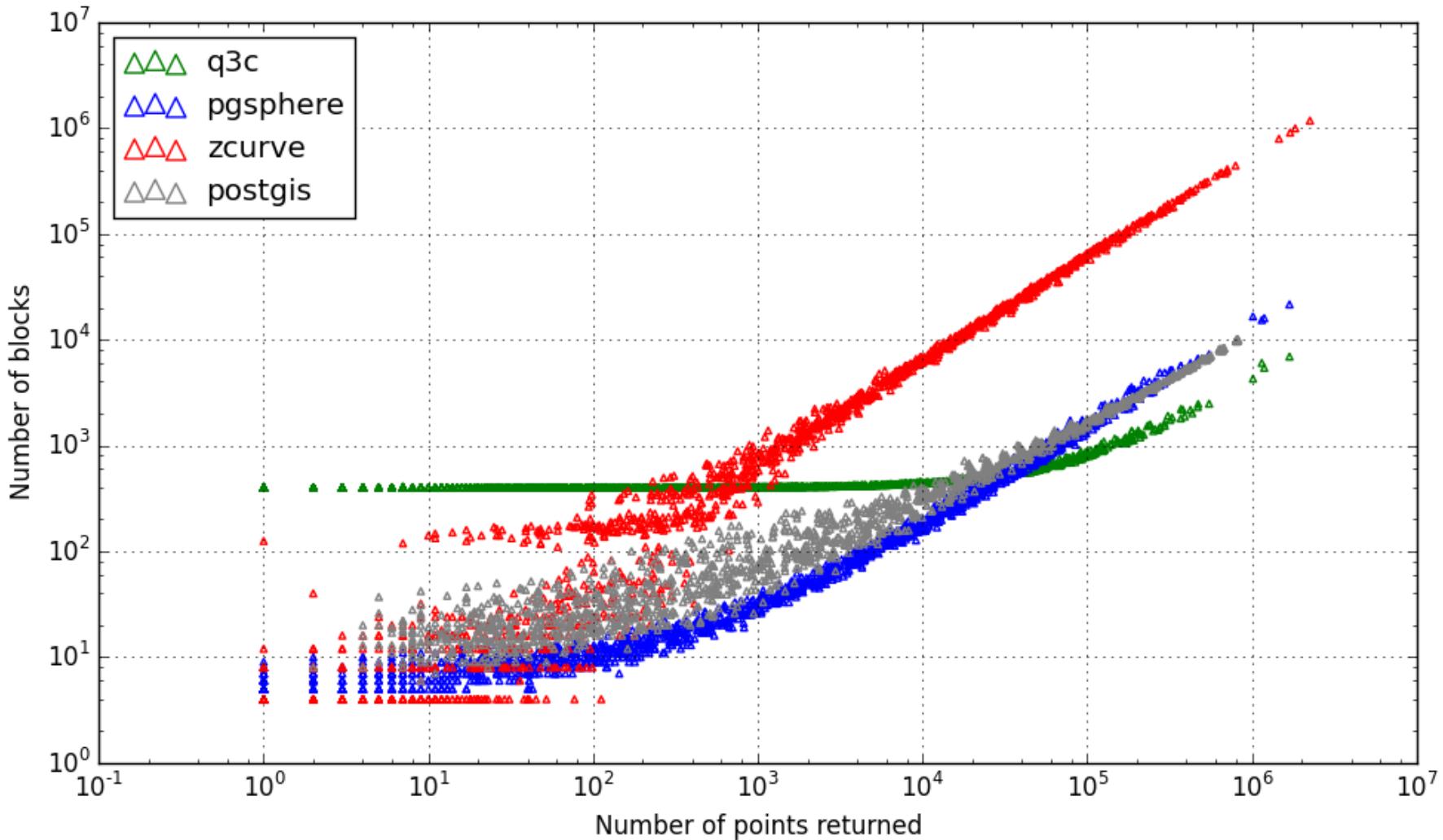


# Radial query time





# Radial query blocks used





# Conclusion

СУБД PostgreSQL provides rich set of features for working with spatial data including spatial objects in spherical system of coordinates. It allows to effectively process various types of search among them.



# Future work

- Improve z-curve
- Index using GiST and z-curve in spherical coordinates
- Implement HTM using SP-GiST



**Thank you for attention!**  
**Any questions?**