Breaking PostgreSQL at Scale.

Christophe Pettus
PostgreSQL Experts
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Christophe Pettus

CEO, PostgreSQL Experts, Inc.

christophe.pettus@pgexperts.com

thebuild.com

twitter @xof

So, what is this?

- PostgreSQL can handle databases of any size.
  - Largest community-PostgreSQL DB I’ve worked on was multiple **peta**bytes.
- But how you handle PostgreSQL changes as databases get larger.
- What works for a 1GB database doesn’t for a 10TB database.
- Let’s talk about that!

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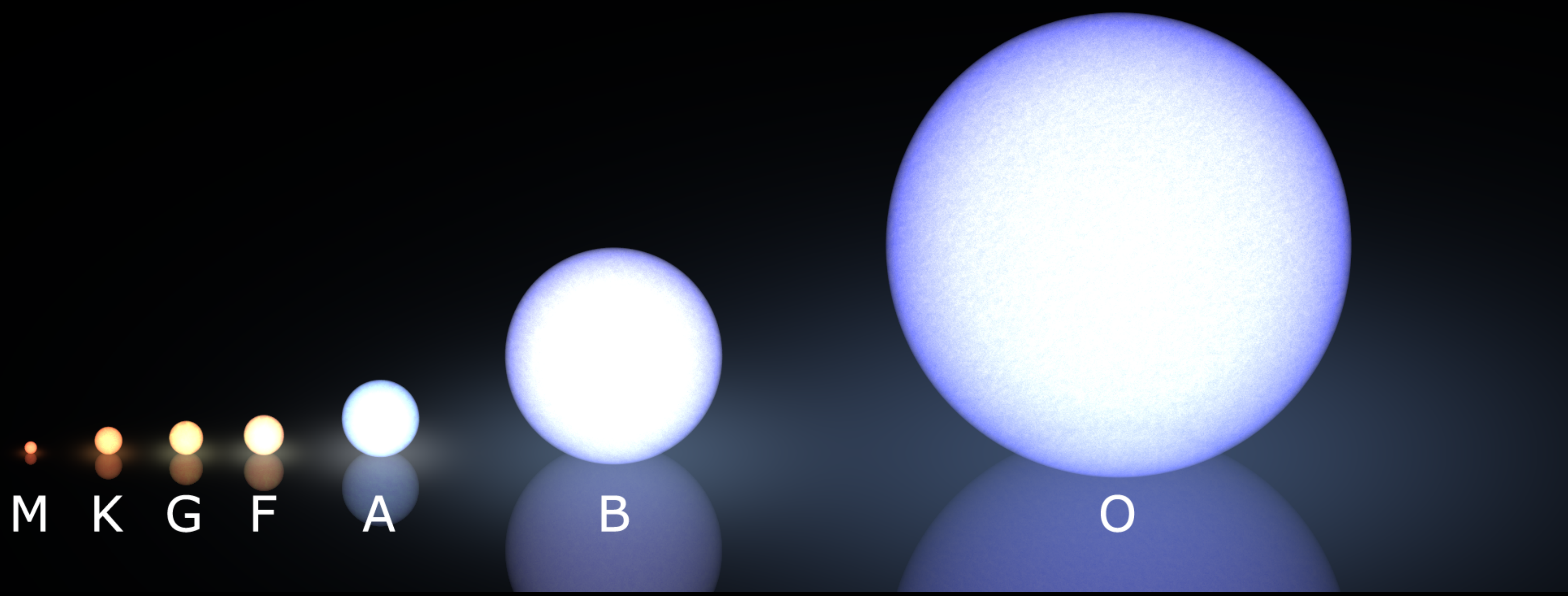
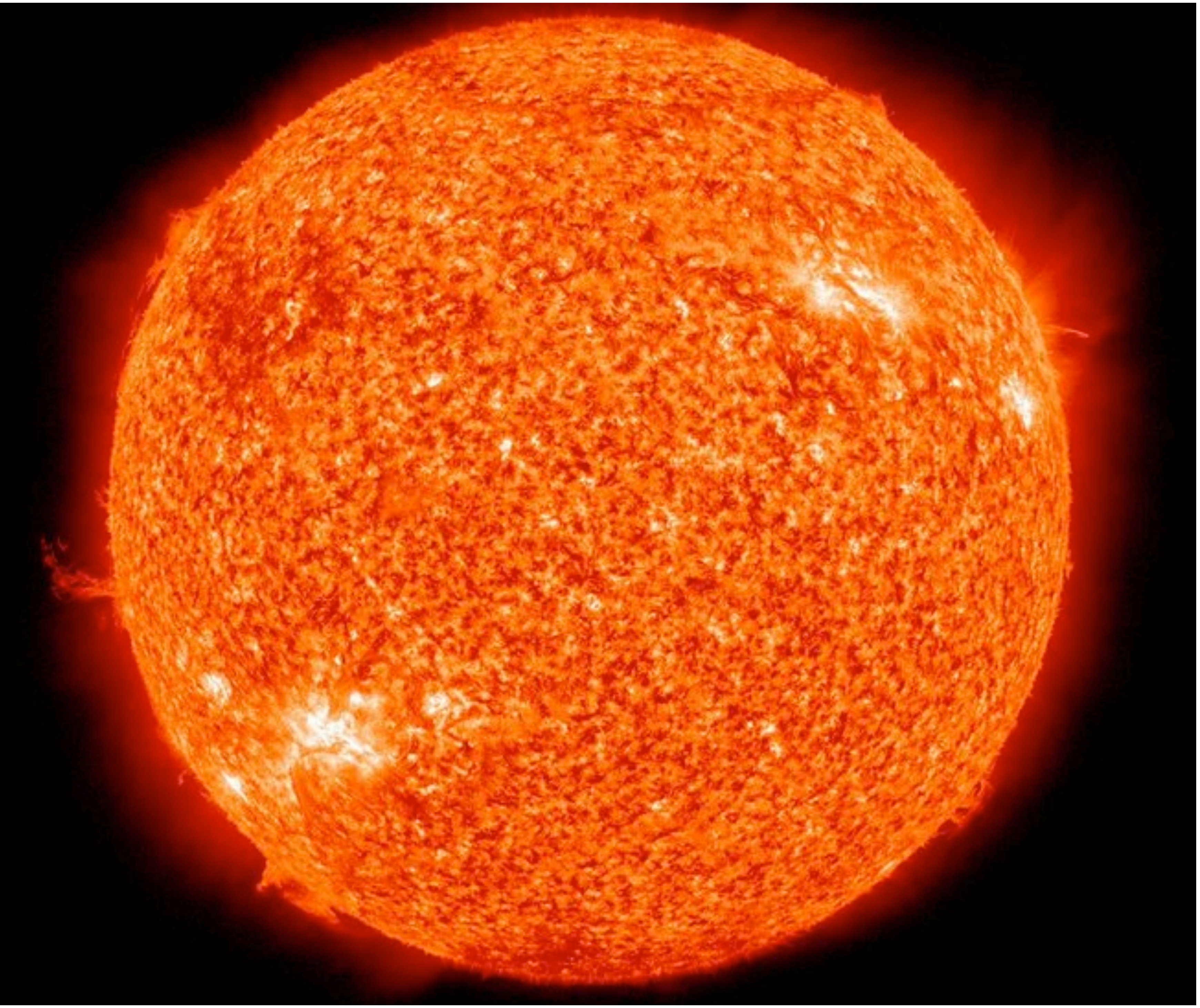
Database Sizes





Ten Gigabytes.

Your New Database!

- It’s very hard to go wrong with small databases on PostgreSQL.

- Nearly everything will run fast…

  - … even “pathological” joins, unless then are fully N^2.

- The stock postgresql.conf will work.

How much memory?

- If you can’t fit your database in memory…
  - … reconsider your life choices.
- Even small “micro” instances can handle a database this size.
- The entire database can probably fit in memory.
- Even sequential scans will zip right along.

Backups.

- Just use pg_dump.
- A 5GB pg_dump takes 90 seconds on my laptop.
- No need for anything more sophisticated.
- Stick the backup files in cloud storage (S3, B2), and you’re done.

High Availability.

- A primary and a secondary.
- Direct streaming, or basic WAL archiving.
- Manual failover? It’s cheap and easy.

Tuning.

- If you insist.
- The usual memory-related parameters.
- A couple of specialized parameters for all-in-memory databases.
- But at this stage, just keep it simple.

Tuning.

seq_page_cost = 0.1

random_page_cost = 0.1

cpu_tuple_cost = 0.03

shared_buffers = 25% of memory

work_mem = 16MB

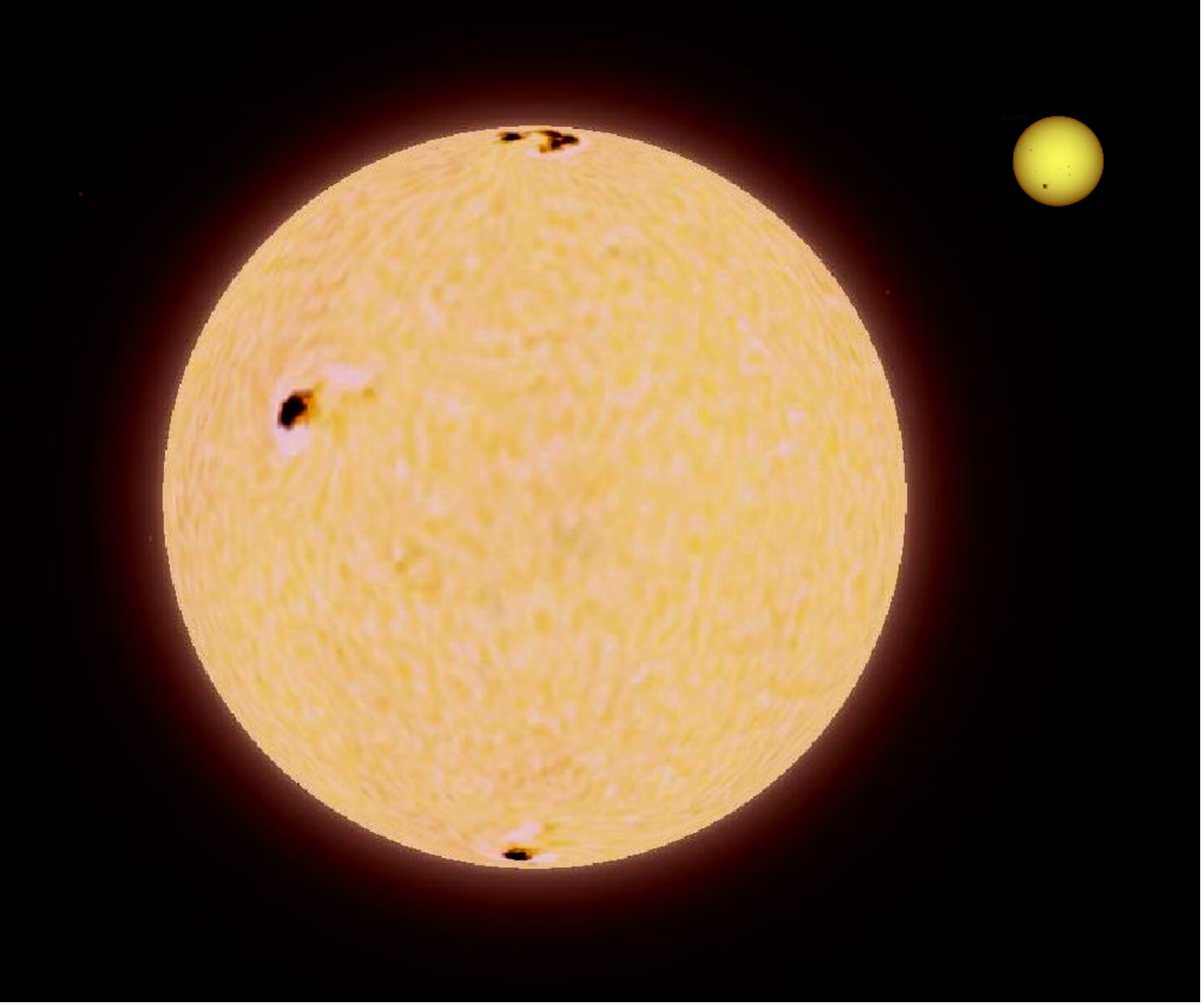
maintenance_work_mem = 128MB

Tuning.

```
log_destination = 'csvlog'
logging_collector = on
log_directory = '/var/log/postgresql'
log_filename = 'postgresql-%Y%m%d-%H%M%S.log'
log_rotation_size = 1GB
log_rotation_age = 1d
log_min_duration_statement = 250ms
log_checkpoints = on
log_connections = on
log_disconnections = on
log_lock_waits = on
log_statement = 'ddl'
log_temp_files = 0
log_autovacuum_min_duration = 1000
```

Upgrades.

- pg_dump/pg_restore.
- You’re done.
- But do it!
- The farther you fall behind on major versions, the harder it becomes.
- Get into the habit of planning your upgrade strategy.



100 Gigabytes.

Not huge, but…

- … the database is starting to get bigger than will fit in memory.
- Queries might starting performing poorly.
- pg_dump backups take too long to take or restore.

How much memory?

- How much memory does a PostgreSQL database need?
- If you can fit the whole thing in memory, great.
- Otherwise, try to fit at least the top 1-3 largest indexes.
    - Ideally, effective_cache_size > largest index.
- If not, more memory is always better, but…
- … more memory does not help write performance.

Backups.

- pg_dump won’t cut it anymore.
- Time for PITR backups!
- pgBackRest is the new hotness.
- WAL-E is the old warhorse.
- Can roll your own (if you must).

PIT~~A~~R

- Takes an entire filesystem copy, plus WAL archiving.
- More frequent filesystem copies means faster restore…
- … at the cost of doing the large copy.
- Other benefits: Can restore to a point in time, can use backup to prime secondary instances.

Tuning.

seq_page_cost = 0.5-1.0

random_page_cost = 0.5-2.0

shared_buffers = 25% of memory

maintenance_work_mem = 512MB-2GB

work_mem

- Base work_mem on actual temporary files being created in the logs.

- Set to 2-3x the largest temporary file.

- If those are huge? Ideally, fix the query that is creating them.

- If you can’t, accept it for low-frequency queries, or…

- … start thinking about more memory.

Load balancing.

- Consider moving read traffic to streaming secondaries.
- Be aware that replication lag is non-zero.
- Handle the traffic balancing in the app if you can.
- If you can’t, pgpool is there for you (although it’s quirky).

Monitoring.

- Time for real monitoring!
- At a minimum, process logs through pgbadger.
- pg_stat_statements is very valuable.
    - pganalyze is a handy external tool.
- New Relic, Datadog, etc., etc. all have PostgreSQL plugins.

Queries.

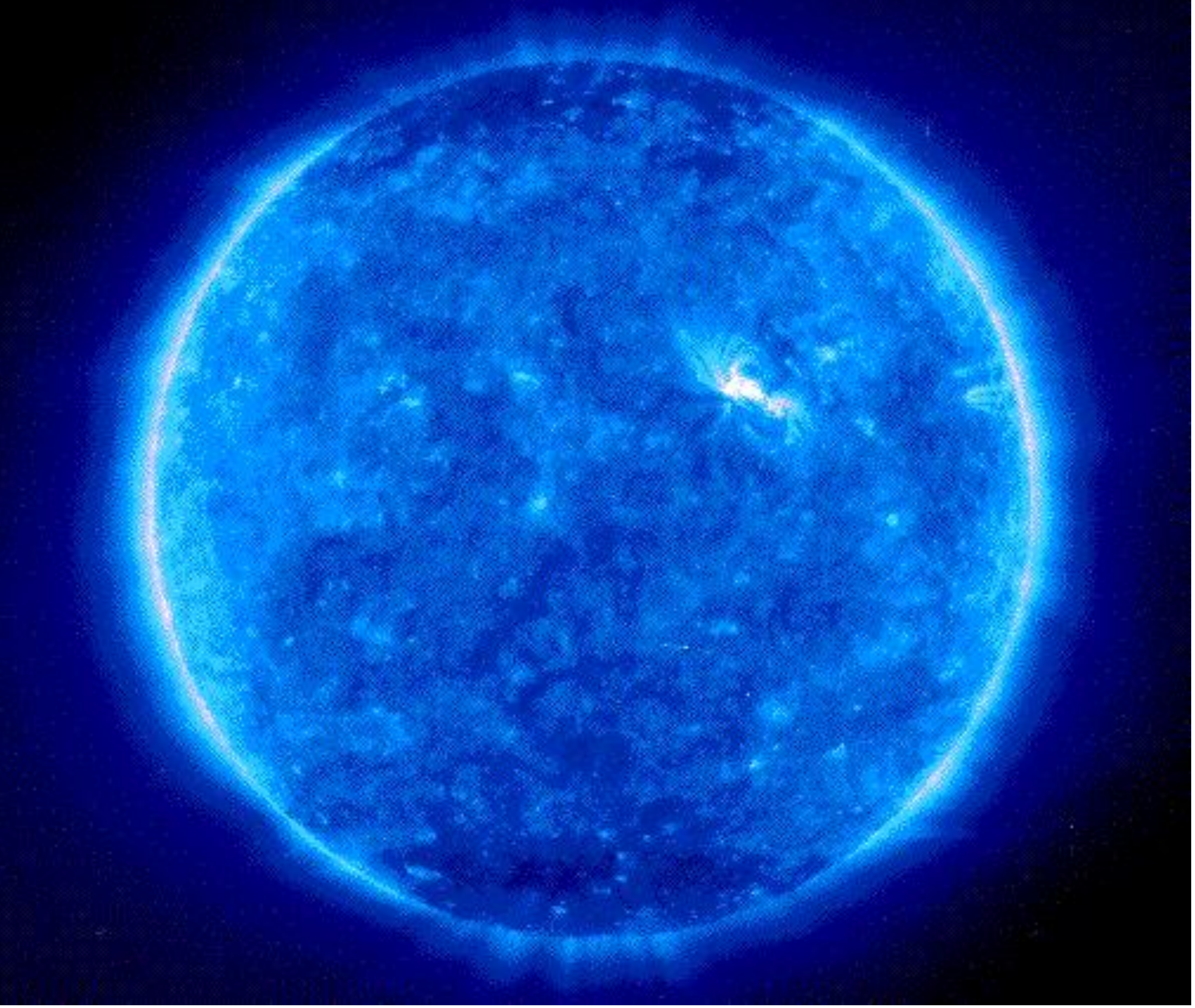
- Check pgbadger / pg_stat_statements regularly for slower queries.
- Missing indexes will start becoming very apparent here.
- Create as required, but…
- … don’t just start slapping indexes on everything!
- Base index creation on specific query needs.

High Availability.

- Probably don’t want to fix it manually anymore.
- Look at tooling for failover:
  - pgpool2
  - Patroni
  - Hosted solutions (Amazon RDS, etc.)

Upgrades.

- pgupgrade.
- In-place, low downtime.
- Very reliable and well-tested.
- Some extensions are not a comfortable fit, especially for large major version jumps.
    - We’re looking at you, PostGIS.



One Terabyte.

Things Get Real.

- Just can’t get enough memory anymore.
- Queries are starting to fall apart more regularly.
- Running out of read capacity.
- Doing full PITR backups is taking too long.

Resources

- As much memory as you can afford.
- Data warehouses need much more than transactional databases.
- I/O throughput becomes much more important.
- Consider moving to fast local storage from slower SAN-based solutions (such as EBS, etc.).

Backups

- Start doing incremental backups.
- pgBackRest does them out of the box.
- You can roll your own with rsync, but…
    - … this is very much extra for experts!

Checkpoints/WAL.

```
min_wal_size = 2GB+
max_wal_size = 8GB+
checkpoint_timeout = 15min
checkpoint_completion_target = 0.9
wal_compression = on
```

Restrain yourself.

- Keep shared_buffers to 16-32GB.
    - Larger will increase checkpoint activity without much actual performance benefit.
- Don’t go crazy with maintenance_work_mem.
    - If most indexes are larger than 2GB, it is often better to decrease it to 256-512MB.

Load balancing.

- Read replicas become very important.
- Distinguish between the failover candidate (that stays close to the primary) and read replicas (that can accept delays due to queries).
- Have scripted / config-as-code ways of spinning up new secondaries.

Off-Load Services.

- Move analytic queries off of the primary database.
    - Consider creating a logical replica for analytics and data warehousing.
- Move job queues and similar high-update-rate, low-retention-period data items out of the database and into other datastores (Redis, etc.).

VACUUM.

- Vacuum can start taking a long time here.
- Only increase autovacuum_workers if you have a large number of database tables (500+).
- Let vacuum jobs complete!
    - Be careful with long-running transactions.
- Consider automated “manual” vacuums for tables that are very high update rate.

VACUUM.

- If autovacuum is taking too long, consider making it more “aggressive” by reducing autovacuum_vacuum_cost_delay.

- If autovacuum is causing capacity issues, consider increasing autovacuum_vacuum_cost_delay.

- But let autovacuum run! You can get yourself into serious (like, database-shutdown-serious) trouble without it.

Indexes

- Indexes are getting pretty huge now.

- Consider partial indexes for specific queries.

- Analyze which indexes are really being used, and drop those that aren’t necessary (pg_stat_user_indexes is your friend here).

Queries.

- Queries can start becoming problematic here.
- Even the “best” query can take a long time to run against the much larger dataset.
- “Index Scan” queries turning into “Bitmap Index Scan / Bitmap Heap Scan” queries, and taking much longer.

Partitioning.

- Look for tables than can benefit from partitioning.
- Time-based, hash-based, etc.
- PostgreSQL 10+ has **greatly** improved partitioning functionality.
- Just be sure that the table has a strong partitioning key.

Parallel Query Execution.

- Increase the number of query workers, and the per-query parallelism.
- Very powerful for queries that handle large result sets.
- Make sure your I/O capacity can keep up!

Statistics Targets.

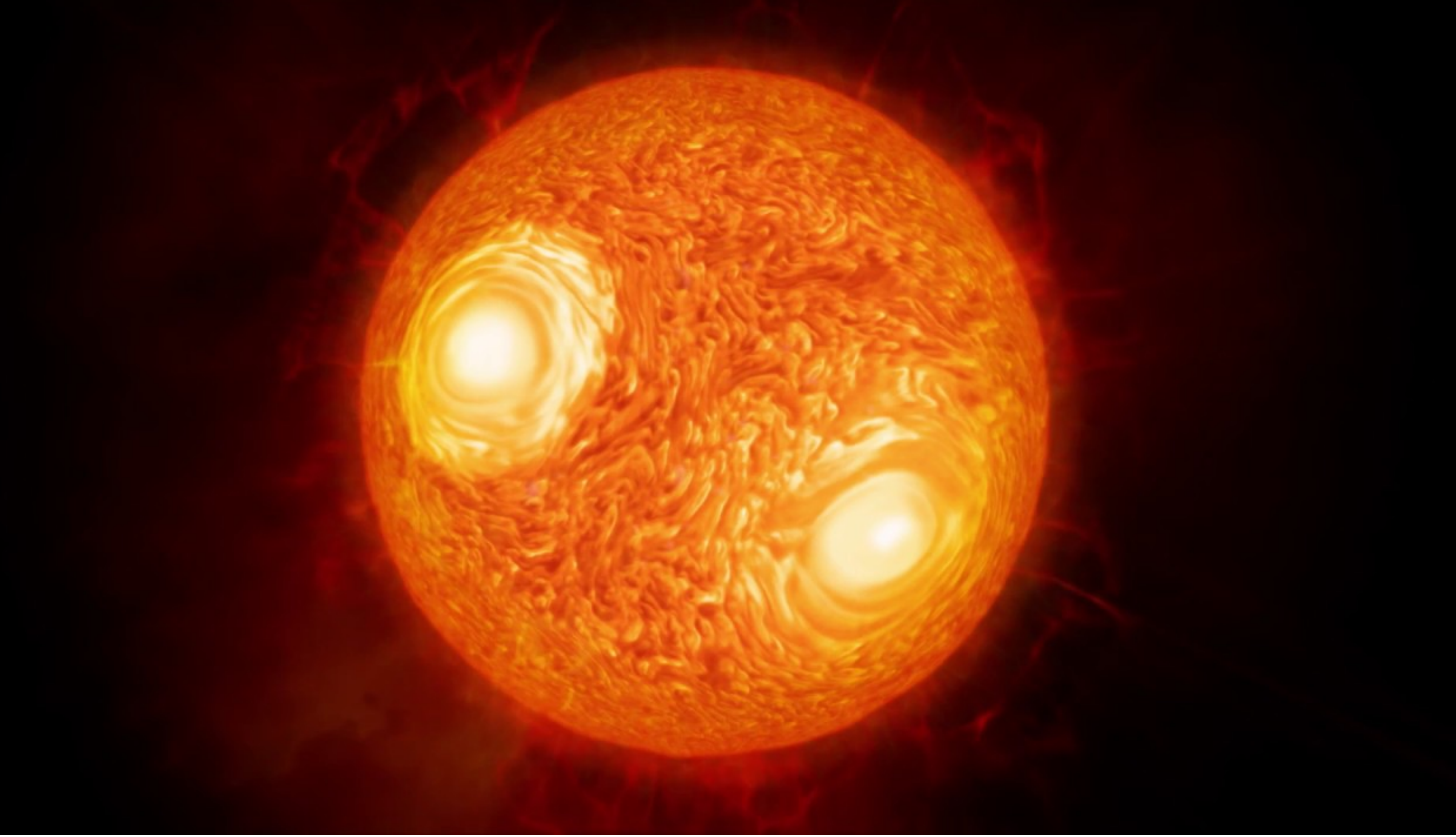
- For fields with a large number of values, the default statistic target can be too low.
- Especially for longer values.
  - Strings, UUIDs, etc.
- Look for queries where a highly specific query is planned to return a large number of rows.
- Don’t go crazy! Increasing statistics targets slows ANALYZE time.

Alternative Indexes.

- Some fields are not good matches for B-tree indexes.
- Long strings, range types, etc.
- Use indexes appropriate for the type.
- Hash indexes are very good for strings, especially those with most of the entropy later in the string (URLs, etc.).

Upgrades.

- pgupgrade still works fine.
- Time is proportional to the number of database objects, not database size.
- If downtime is unacceptable, logical replication / rehoming works as well.
- Be sure to plan for major version upgrades…
  - … lest you be the 1PB database still on 8.3.



Ten Terabytes.

Big.

- Congratulations! You’re definitely in the big leagues now.
- Some hard decisions will need to be made.

Backups

- Anything involving copying is going to start being very slow and impractical.
- Consider moving to file system snapshots for the base backup in PITR.
  - ZFS, SAN-based snapshots, etc.

Tablespaces.

- Tablespaces are a pain.
- Only use them if you have a specific reason.
- Fast/slow storage, reaching limits of a single volume, etc.
- Understand that they will complicated backups and replication.

Index Bloat.

- Index bloat can be a significant problem at this size.
- Space in indexes is harder to reclaim that space in the heap.
- Reindex / replace scripts can be helpful here.

Index Contention.

- High write rates against a UNIQUE index can create locking issues.

- Especially with closely clustered keys, such as SERIAL, Snowflake-generated primary keys, etc.

- If generated keys are guaranteed to be unique, consider dropping the UNIQUE constraint.

- Consider using non-sequential keys, such as UUIDs.

Write Capacity.

- Write capacity might start being constrained.
- Time to consider sharding.
- Many options: Citus, Postgres-XL, custom application-based sharding.
- Also can significantly accelerate large-dataset reads.
- Be prepared for the increase in administration complexity.

Huge.

Wow.

- PostgreSQL can handle really huge databases.
- But you need to be prepared to make some complex choices.
- Each large installation is unique, but…

What’s the working set?

- If most of the data is just archival, performance will be more manageable.
- But if it’s archival, why not archive it?
- Separate the system into a transactional system and a data warehouse.
- Logical replication is great for this.

Large-Scale Sharding.

- Instead of one gigantic database, or closely connected nodes.
- Geographic, enterprise, etc.
- Multi-master tools, if necessary, to handle synchonization.
  - Bucardo, 2nd Quadrant’s BDR.

Data Federation.

- Move archival data to alternative datastores.
  - Or even into cold storage if it’s not required for analytics.
- Use Foreign Data Wrappers to federate multiple databases.
- Or just run big/small databases on the same PostgreSQL instance.

In Sum.

PostgreSQL is amazing.

- It can handle everything from your laptop to world-spanning database environments.
- It will grow with you.
- Don’t over-tool your installation at each phase, but…
- … keep one eye out for how to handle the next step.

Thank you!

Questions?

thebuild.com

Christophe Pettus

CEO, PostgreSQL Experts, Inc.

christophe.pettus@pgexperts.com

thebuild.com

twitter @xof