An overview of PostgreSQL's backup, archiving and replication

What to do, what not to do, where the pitfalls are

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Agenda

- Logical (aka. SQL-) backup
- Binary backup
- PITR & „replication“ with archiving
- Binary streaming replication

- Classic misconceptions and pitfalls
- What you most probably want to do

Some assertions

- You value your data
  - Otherwise you'd not be here ;-)
- You have (at least) 2 decent servers available
  - ~ same amount of CPU and RAM
  - ECC memory
  - BBU HDD controller / SAN
  - a working UPS
- These should by all means seperated as far as possible (and feasible) from each other
- You know your RTO and RPO requirements

Omnipotent natural laws

- Gravity
- Speed of light
- Murphy's law *
  - Disaster does strike
  - Unlike lightning, disaster tends to strike more than once in a row
  - Ask the Gitlab guys!

And keep Einstein in mind

- „Only two things are infinite, the universe and human stupidity, and I'm not sure about the former.“ **

Evolution

- The options and tools evolved over the years
- Nastily, the docs have mostly been amended
- Usually, you want to do it the way that comes last in the docs...
- Which means you're hopefully ready to go after reading ~ 50 pages of A4 in 2 chapters
- You should still read all of it!

The options you had with 7.0

Logical backup

Sidenote: I especially like this one

Prev

Chapter 33. Database Recovery

This section needs to be written. Volunteers?

Prev
Debugging Messages

Logical aka. „SQL-“ backup

- `pg_dump[all]` connects to your DB just as any other client and provides you with a snapshot of your data
  - You can restore the state of the DB at the moment you *initiated* the backup
- Can dump whole clusters (`pg_dumpall`), databases, single tables
- Can provide textual (SQL) representation or custom („proprietary“) format

Textual format of pg_dump

- Plain SQL
- Uses `COPY` for performance
- Can be used to port DBs….

- Can be read by humans

Custom format of pg_dump

- `pg_dump -Fc`
- Restored using `pg_restore` (into `psql` or straight into a DB)
- Can restore single tables
- Compressed by default

Directory format of pg_dump

- `pg_dump -Fd`
- Can backup (and restore) in parallel (`-j X`)
- Restored using `pg_restore` (into `psql` or straight into a DB)
- Can restore single tables
- Compressed by default

Never forget pg_dumpall!

- `pg_dump` reads from **databases**
- So, global objects are not saved!
  - Roles
  - Tablespaces
- So, whenever you `pg_dump`, do a `pg_dumpall --globals-only` along with it!

RTO & RPO of logical backup

- RTO
  - between minutes and days
  - basically depending on size of DB
- RPO
  - your last backup run
  - in the worst case, the one before*!

Pros and cons

+ backup is readable by humans (or can be made so), schema & roles can go to your VCS
+ can be read by newer versions of PG
+ can backup & restore single entities if need be
+ will reveal issues with the „dark corners“ of your DB (when initialised with data checksums)*

- can only backup and thus restore a single point in time
- rather slow
- RPO & RTO... uhm, well

The way beyond pg_dump

- 7.1 added the WAL
- 8.0 added the ability to do
  - On-line backup
  - PITR (no, that's not Pain In The Rear!)
- 9.1 added `pg_basebackup`
  - „gift-wrapping“ existing backup methods
- 9.2 allowed `pg_basebackup` to also fetch WAL data

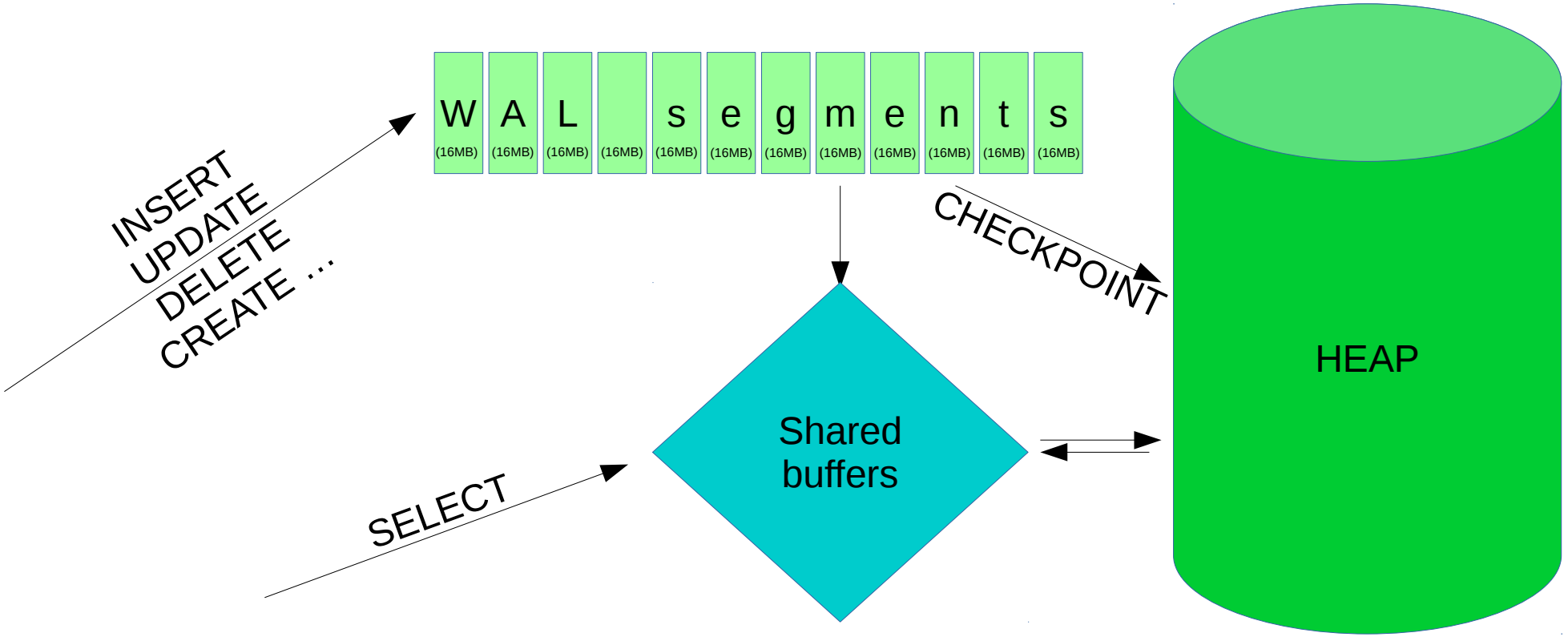
On-line, binary backup

- Erm, we're not there yet ;-)
- We have to discuss some of Postgres' peculiarities first
- Everything binary is centered around the WAL...

What the WAL is

- The Write Ahead Log (WAL) is basically the logbook of the DB
- Other DBMS call the equivalent „redolog“
  - some also have an „undolog“, PG doesn‘t need that
- Every change is first written to the WAL
- At a `CHECKPOINT` (which can be spread!), the content is written to the HEAP, usually creating new row versions

WAL (vastly simplified)



WAL organisation

- The WAL consists of a chain of files, 16MB each („segments“)
- Or more like a ring, as WAL segments get renamed and overwritten when feasible
- It resides in `$PGDATA/pg_xlog` (10.0 ff: „`pg_wal`“**)
- The size is determined by `wal_min_size` and `wal_max_size` (default: 1GB/2GB)
- These are SOFT limits!

The archiver

- WAL segments are written by the „wal writer“ process
- WAL segments are read and applied to the HEAP by the „checkpointer“ process
- In between, they are handed to the archiver process
  - when `archive_mode != ‚off‘`
  - which is almost certainly what you want!

Binary snapshot

- Prepare your database:
  - `pg_start_backup()`
- Get a snapshot
  - We'll discuss the options later!
- „Release“ the HEAP again
  - `pg_stop_backup()`

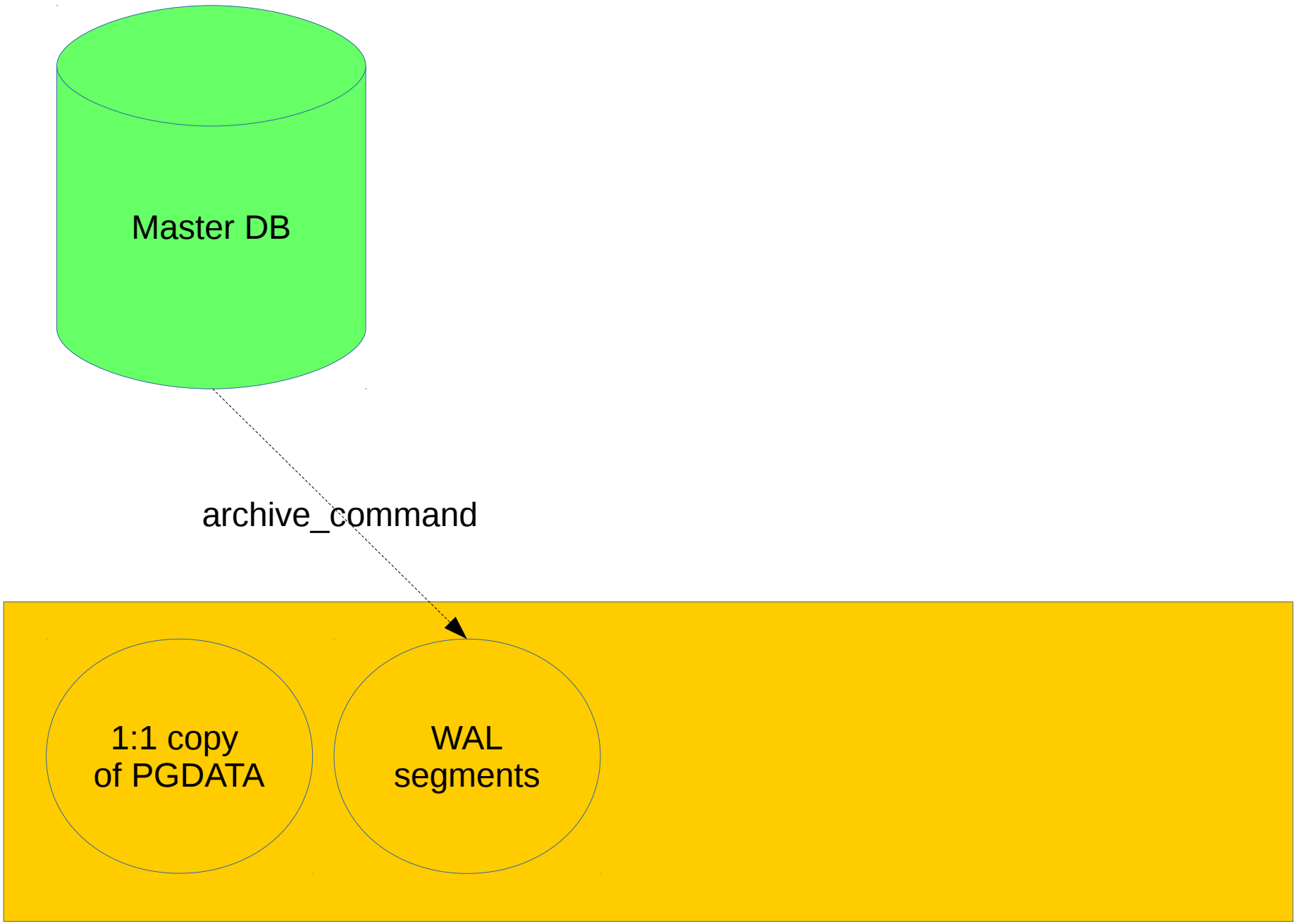
Master DB

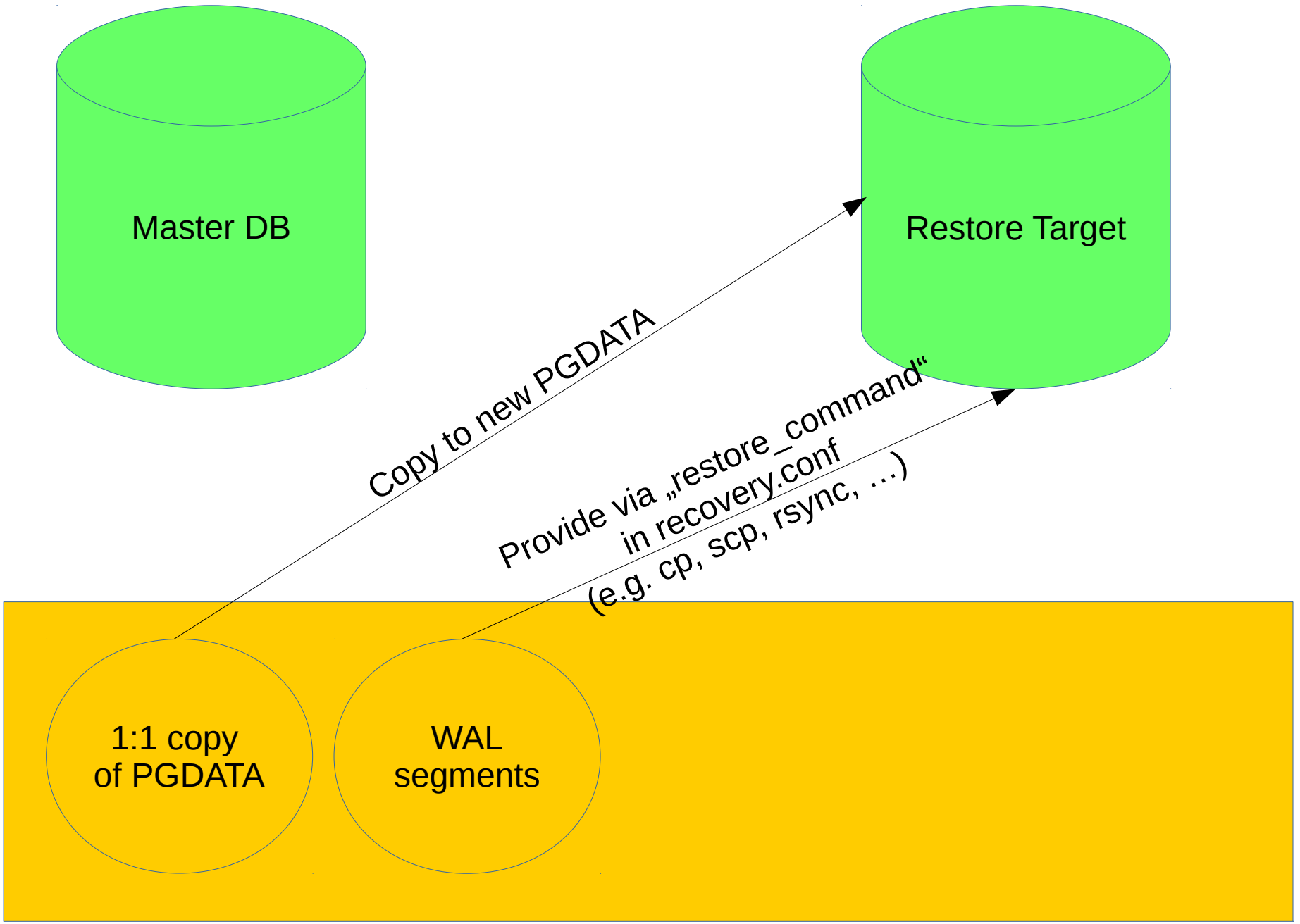
snapshot

1:1 copy
of PGDATA

Ok, anything more that I need?

- Oh yes!
- All the WAL segments since the pg_start_backup()!
- Hopefully, they are still there, eh?
  - If you wrote a lot of data into your DB after pg_start_backup(), they might have been recycled already!*


Master DB
archive_command
1:1 copy
of PGDATA
WAL
segments


Master DB
Restore Target
Copy to new PGDATA
Provide via „restore_command“
in recovery.conf
(e.g. cp, scp, rsync, …)
1:1 copy
of PGDATA
WAL
segments

RTO & RPO

- RTO
  - between minutes & days
  - depending on size & activity during backup
- RPO
  - the end of your backup
  - or the end of the one before!*

Pros and cons

+ 1:1 copy of your DB
+ rather failsafe
+ rather fast
+ RTO fine

- can only back up and thus restore a single point in time
- can only back up and thus restore whole DB clusters
- RPO... still, uhm, well

Options to get that snapshot

- LVM / filesystem snapshot
- rsync
- pg_basebackup

Options to get that snapshot

- ~~LVM / filesystem snapshot~~
- ~~rsync~~
- pg_basebackup

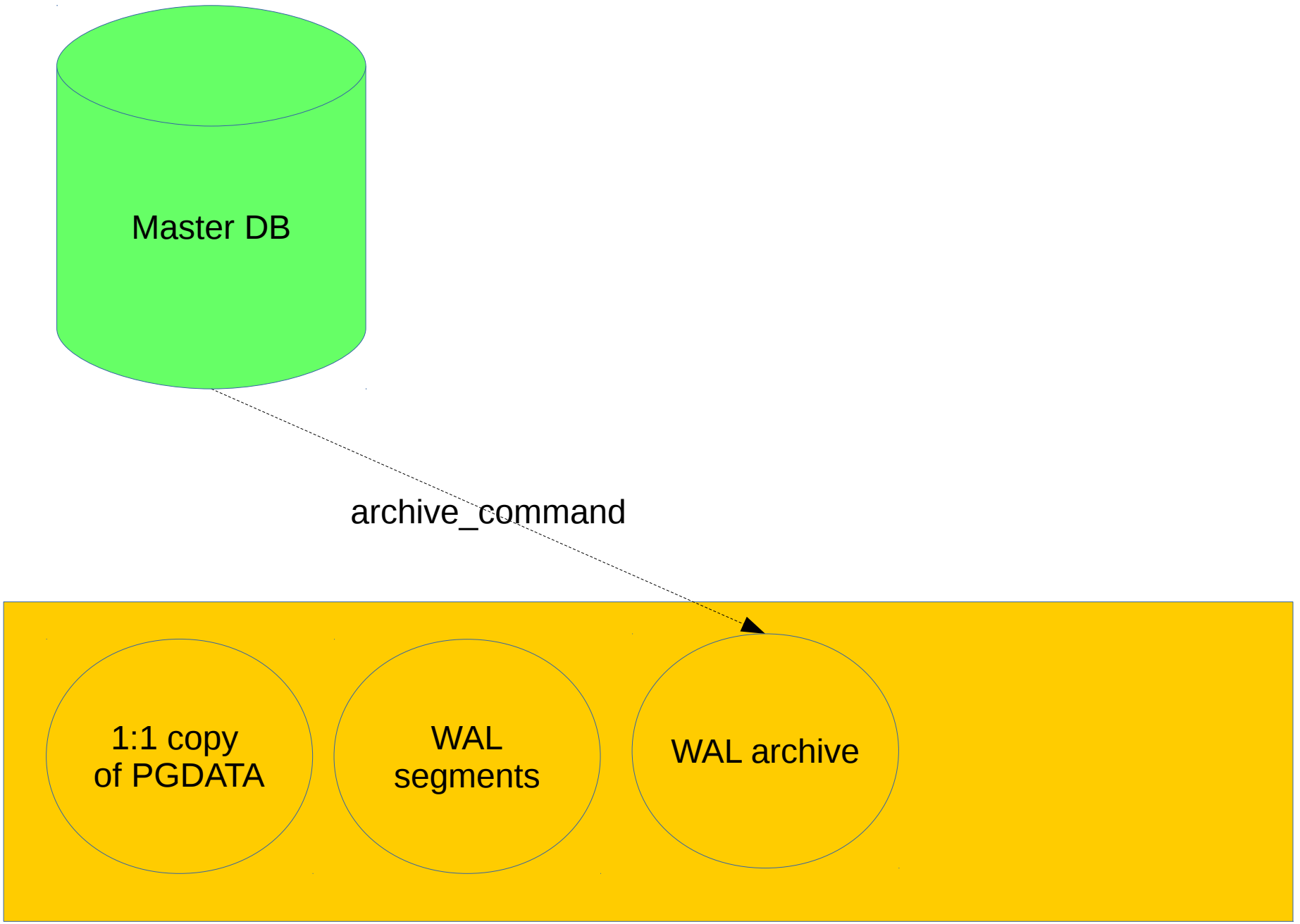
Options to get the WAL segments

- archive_command (postgresql.conf)
- pg_basebackup
  - With --xlog-method=[fetch|stream]
  - -X [s|f]

USE BOTH!

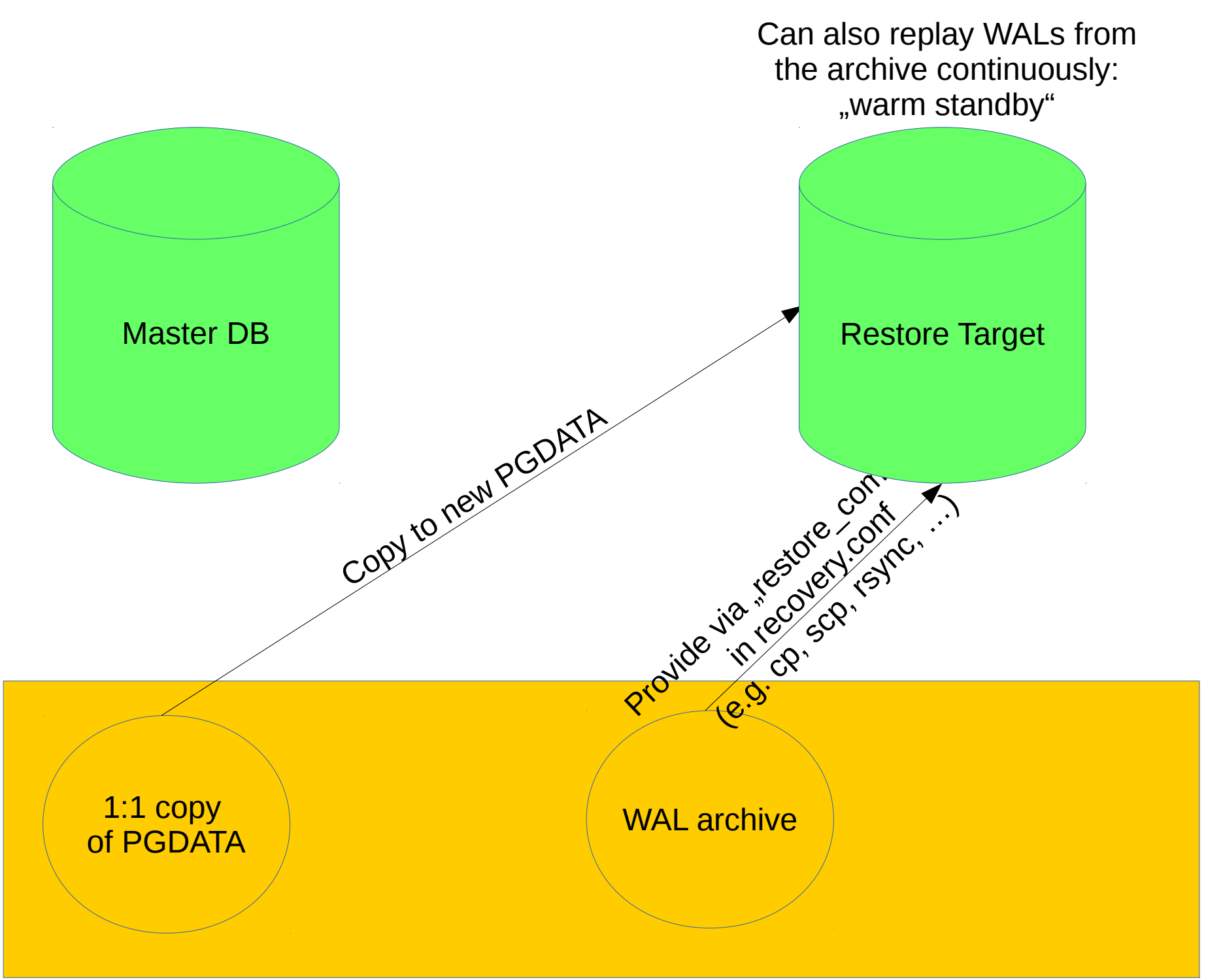
Why use both?

- Actually, get used to both
- When you have a WAL archive anyway, you can (probably) rely on that
- But pg_basebackup with -X is also handy to clone new slaves (we'll get there)


Master DB
archive_command
1:1 copy
of PGDATA
WAL
segments
WAL archive

Why do I want to have a WAL archive?

- The WAL segments, together with the snapshot of your HEAP, allow you to restore your database to any point in time
  - e.g., the moment right before you forgot the WHERE in your „DELETE FROM customers“ statement ;-) **
- That‘s Point In Time Recovery („PITR“)
- Obviously, you need two things for that:
  - a binary snapshot of your HEAP
  - all WAL segments between your snapshot and your mistake


Can also replay WALs from
the archive continuously:
„warm standby“
Master DB
Restore Target
Copy to new PGDATA
Provide via „restore_com
in recovery.conf
(e.g. cp, scp, rsync, …)
1:1 copy
of PGDATA
WAL archive

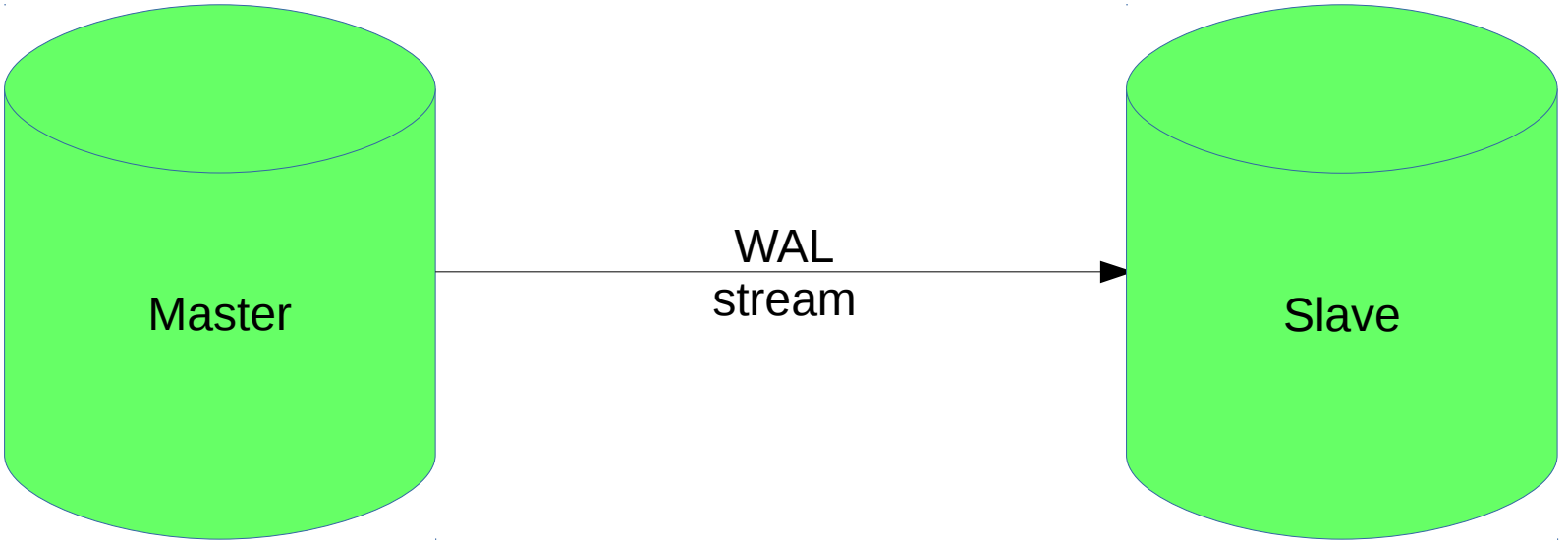
RTO & RPO

- RTO
  - minutes to hours (cold standby)
  - seconds (warm standby)
- RPO
  - your last archived WAL segment

- warm standby = „poor man's replication“

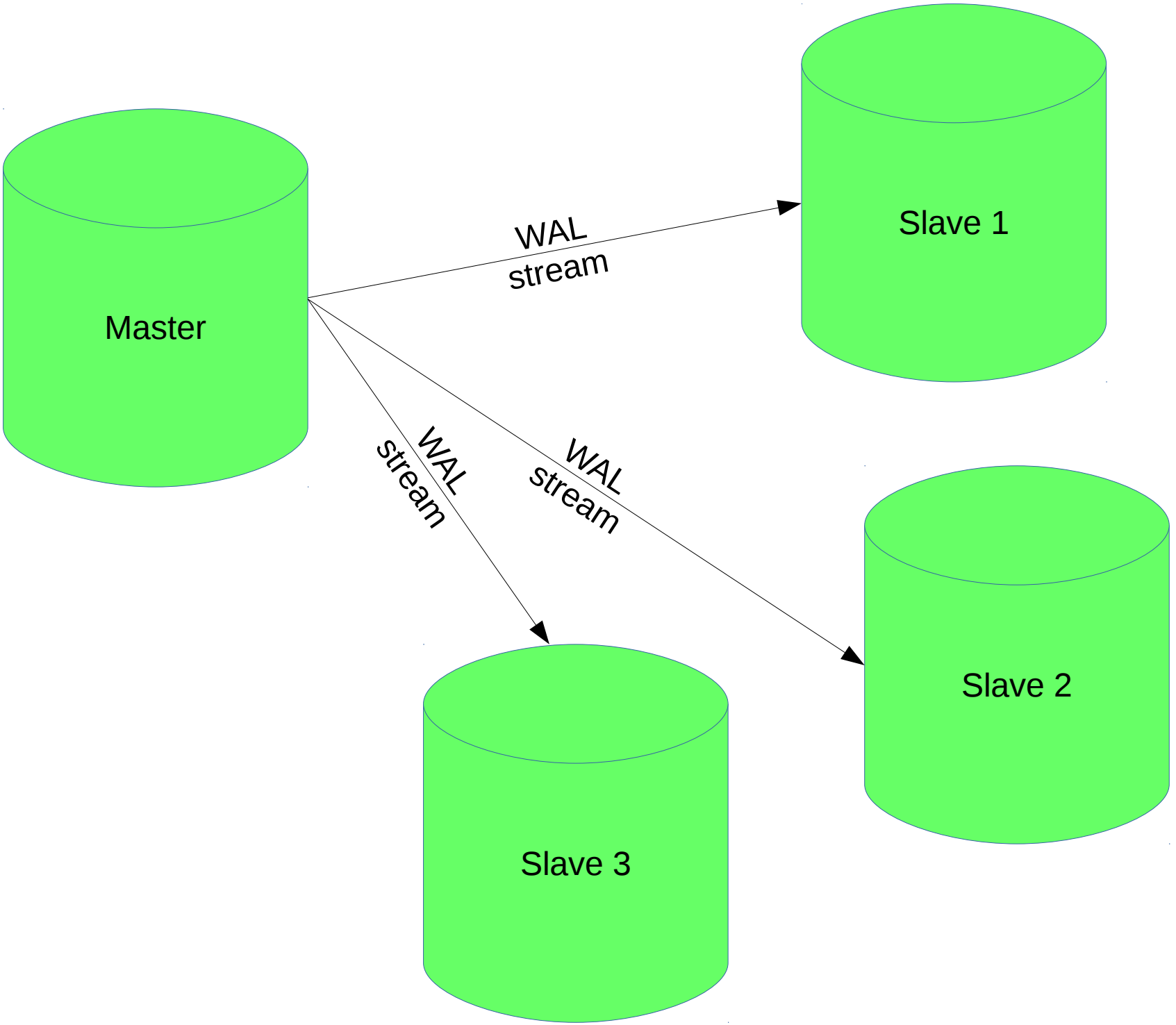
Binary streaming replication

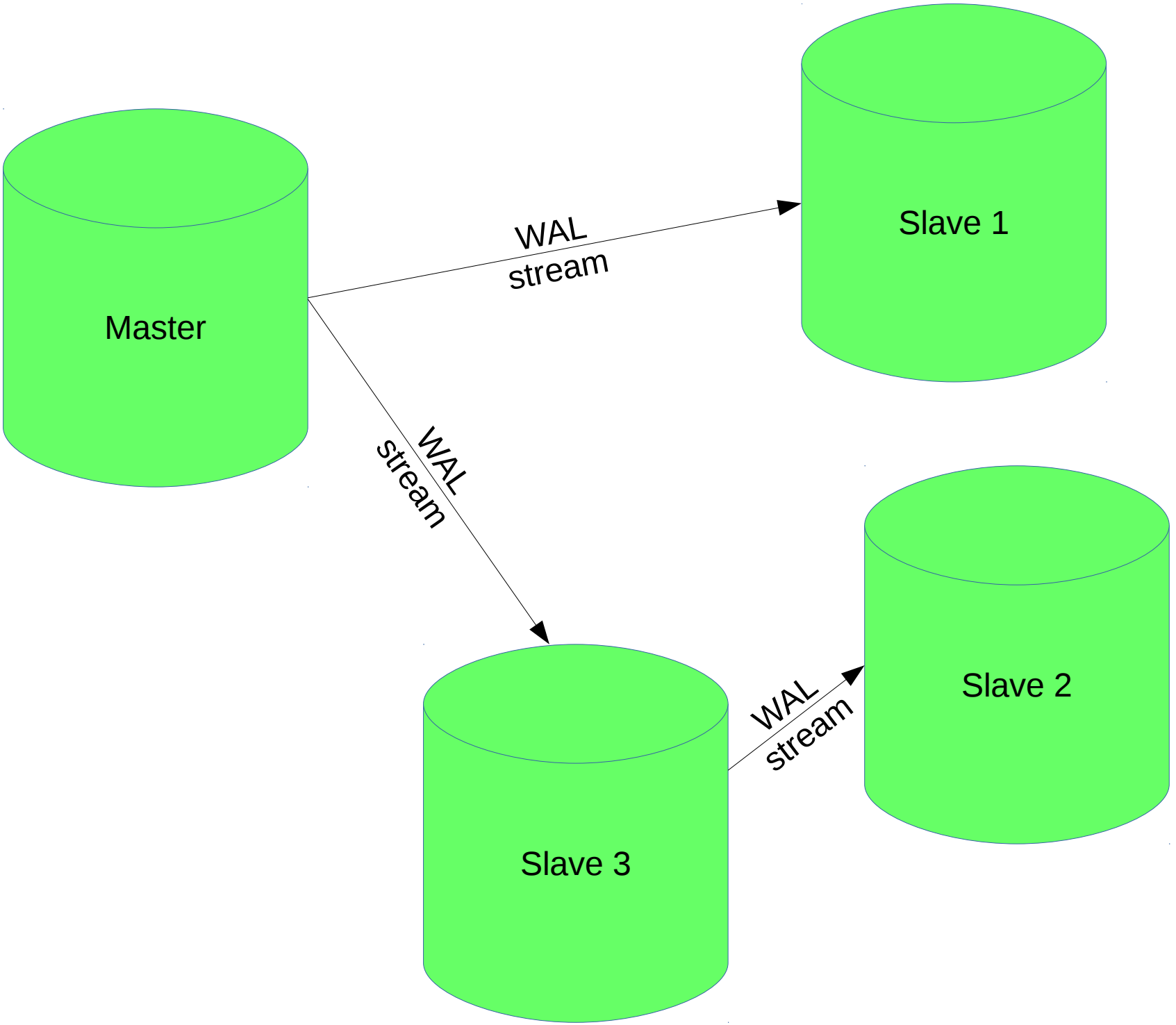
- Binary streaming is like a warm standby server as seen before
- But the WAL segments get sent over the network directly
- Transactions are replayed immediately
  - i.e., „ASAP“


Master
WAL
stream
Slave

Let's talk about options!

- Streaming replication can be synchronous or asynchronous
  - choose per transaction!
  - choose between remote_write & remote_apply
- *can* use replication slots
- *can* be cascaded
- slaves *can* serve RO queries
  - you *can* take your backup from a slave (
- Streaming slave can be delayed (so you can still press the big red button) **


Master
Slave 1
Slave 2
Slave 3
WAL
stream
WAL
stream
WAL
stream


Master
Slave 1
WAL
stream
WAL
stream
Slave 3
WAL
stream
Slave 2

Sync replication pitfalls

- You can now have N sync slaves
- Make sure you always have N+1 slaves in total
  - If you go to N-1, your DB will still work
  - but not finish any transactions before you get back to N! *
- Network latency / roundtrip time becomes an issue!
  - so choose wisely (you can!) which transactions should by sync
  - and where to put your sync slave

Pros and cons

+ 1:1 copy of your DB, online
+ Reliable & battle proven
+ RTO & RPO very good
+ very flexible

- works on whole DB clusters only
- implications on network connection loss

So, with replication,...

- I don't need the WAL archive anymore, right?

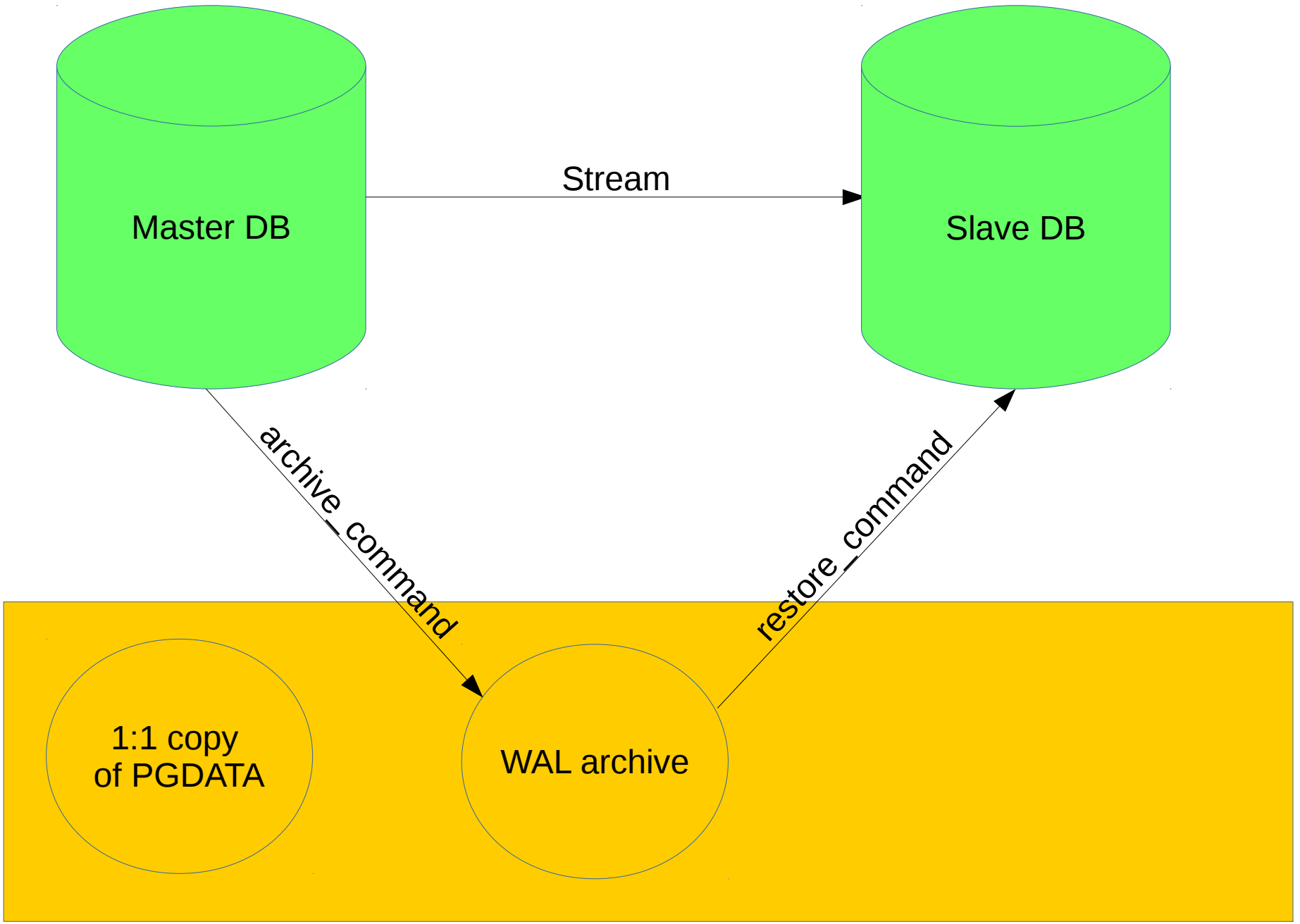
R U effing kidding me?!?

We need to talk...

- Replication does not replace backup
- And, while we're on it: **
- RAID does not replace backups
- SAN does not replace backups
- „The Cloud“ does not replace backups **

Putting it all together

- You want to have a WAL archive
- You want to have (a) replication slaves
  - maybe more than one
  - maybe a sync one
  - maybe a delayed one
  - maybe cascaded
- RTO: minimal
- RPO:
  - closest possible (sync slave)
  - closest feasible (async slave)
- Protection against human errors (RTO obviously rises...)
- Allow read only queries on slave(s)


Master DB
Stream
Slave DB
archive_command
restore_command
1:1 copy
of PGDATA
WAL archive

Pros and cons

+ all of replication
+ all of WAL archive

- major version still has to be the same

Configure postgresql.conf

- `wal_level = replica # or logical already`
- `archive_mode = on   # always to cascade`
- `archive_command = /your/archive_script.sh %p %f`
- `max_wal_senders = 10 # or more`
- `max_replication_slots = 10 # or more`
- `synchronous_commit = local # for now`
- `synchronous_standby_names = '' | <set>`
- `hot_standby = on`
- `log_collector = on`

Set up your WAL archive

- Don't roll your own! **
  - Use pgbarman, pgbackrest, WAL-E, …
  - Follow their instructions
- Invest the saved time in thinking about redundancy, persistance and data safety
- Your DB server is not a good place to keep your archive **
- Even the same datacenter is a bad choice (unless you mirror)

/your/archive_script.sh

- Only slightly complex functionality will not fit in archive_command
- A script can be changed w/out HUPing the DB
- Purpose of the script: somehow get %p ($1) to your WAL archive as %f ($2)
- rsync is not a bad choice, however:
  - make sure %f does not exist in the archive yet before you start sending
  - call sync remotely (or mount your archive sync) after sending
  - rsync tends to give RCs > 127, filter these
- Make sure it never, ever returns RC=0 w/out having done the job
  - Unless you're still setting everything up
  - „set -e“ etc.
  - Errors will end up in PG's log (as we turned log_collector on)

Let me repeat that

- You are most probably writing into some OS pagecache, and potentially async on top (NFS)!
- Your backup is not safe until it has been flushed to persistent storage in a safe location *
- Your archived WAL segments are not safe until they have been flushed to persistent storage in a safe location *
- You'll probably make some compromises, but keep the implications on the RCO in mind **

Now, activate archiving

- And watch it
- PG will not throw away WAL segments it could not archive
  - your PGDATA can run out of disk space!
- Replication slots have the same implication, so keep that in mind

Now, try a full backup

- Since you're using a tool anyway**, you're hopefully ready to go already (rights, replication permission, preparation, ...)
- E.g., do
  - `barman backup all`

Doing your first slave

- Add a „replication“ line to your master's `pg_hba.conf`
- Prepare the new PGDATA
  - e.g. on Debian/Ubuntu do a `pg_createcluster` and `rm -rf` the result (no, really)
  - Make sure the `postgresql.conf` etc. match your master's
- Run
- `pg_basebackup -X stream -h <master> -U <user> -R -D <new_pgdata>`
- Add a restore_command to the resulting `recovery.conf`
  - Which gets the segment from your archive
- Start the slave, enjoy, rinse, repeat

Now, start looking for software

- E.g.
  - repmgr
  - PAF
  - pglookout
  - ...

Logical replication

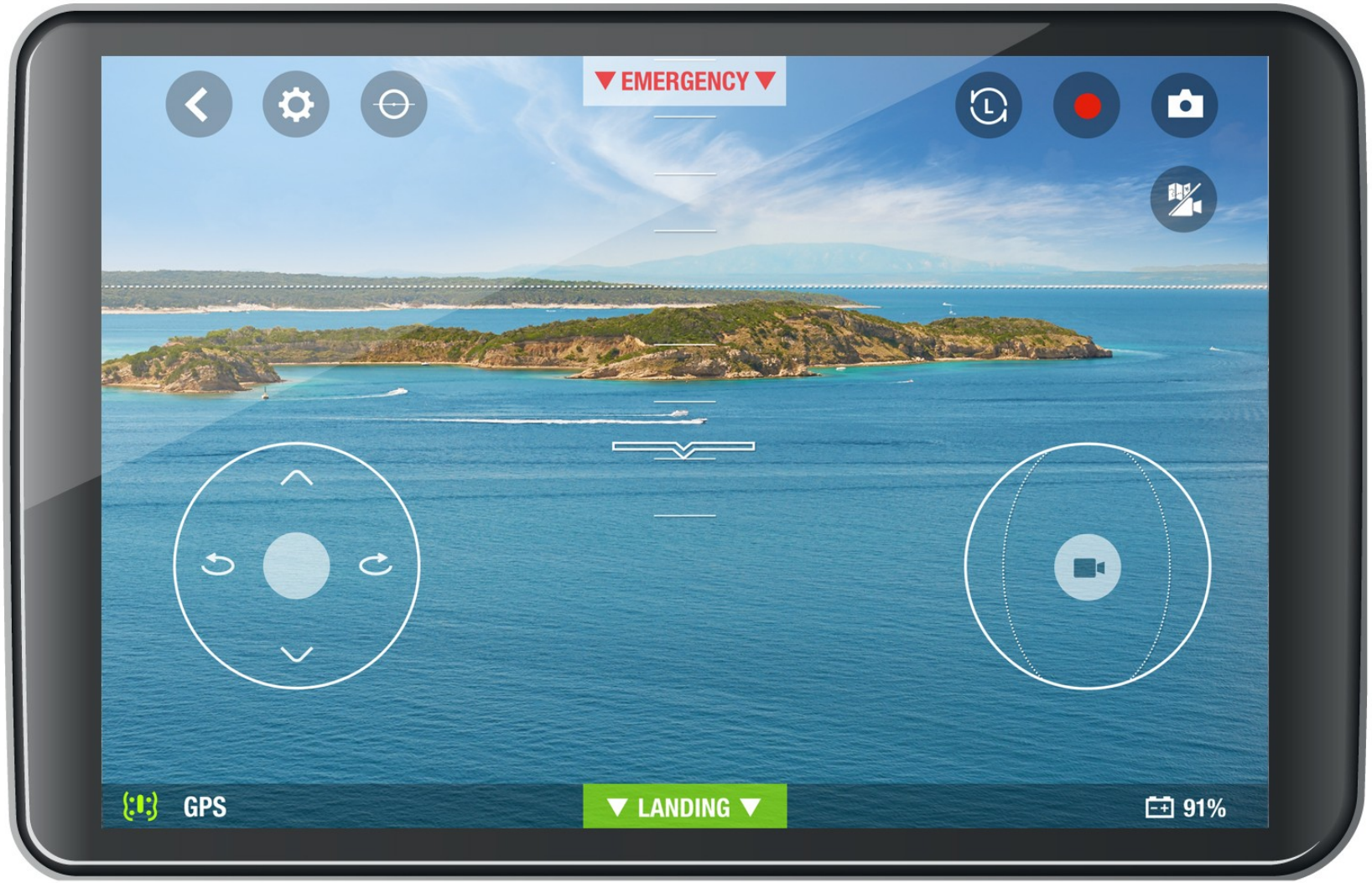
- In the not so recent past...
-

Logical replication

- Coming into core with 10.0
- Already available with e.g. pglogical
- If you can afford a few MB extra backup volume, already set
  - `wal_level = logical`
- Allows for e.g.
  - painless, low-downtime version upgrades
  - sharding
  - collecting data from different DBs in a DWH
  - multi-master
  - ...

When in core

- Somewhat moving target yet, but will be more like



Famous last words

- Don't reinvent the wheel!
- Test your backup procedure!
- Test your restore procedure!!! **
- Monitor your logs and your lags!
- Make sure your configs are in sync!
- Make sure everybody in your team understands your backup and restore procedures! **
- In case of disaster *
  - keep calm and follow your procedures **

Thank you for your attention!