



# Digitalization in time metrology

Frédéric Meynadier, BIPM Time Department

CCTF Summer school, 09/09/2025



# Digitalization

(in an already highly digital world...)



Digitalizing the Système International d'Unités



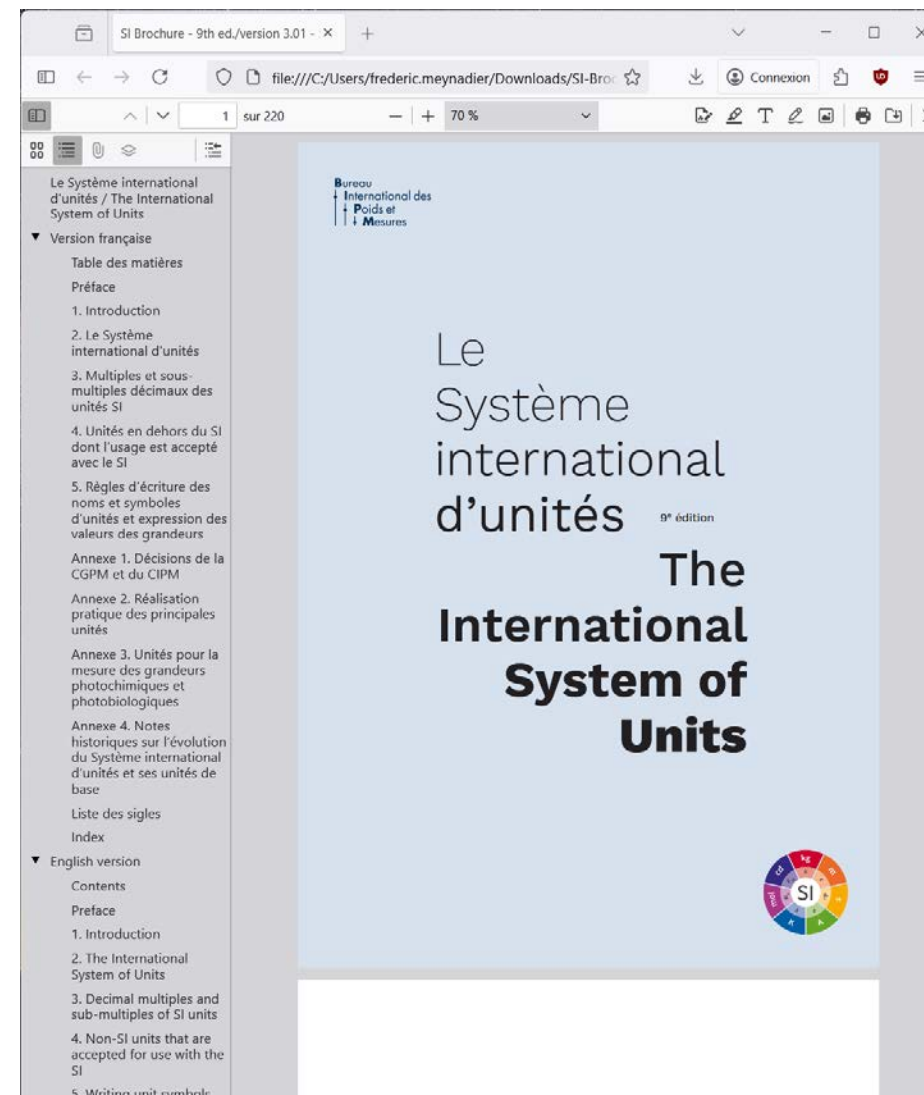
Digitalizing (further) the way we exchange T&F data (TFEX ?)

« Digitalizing » development process



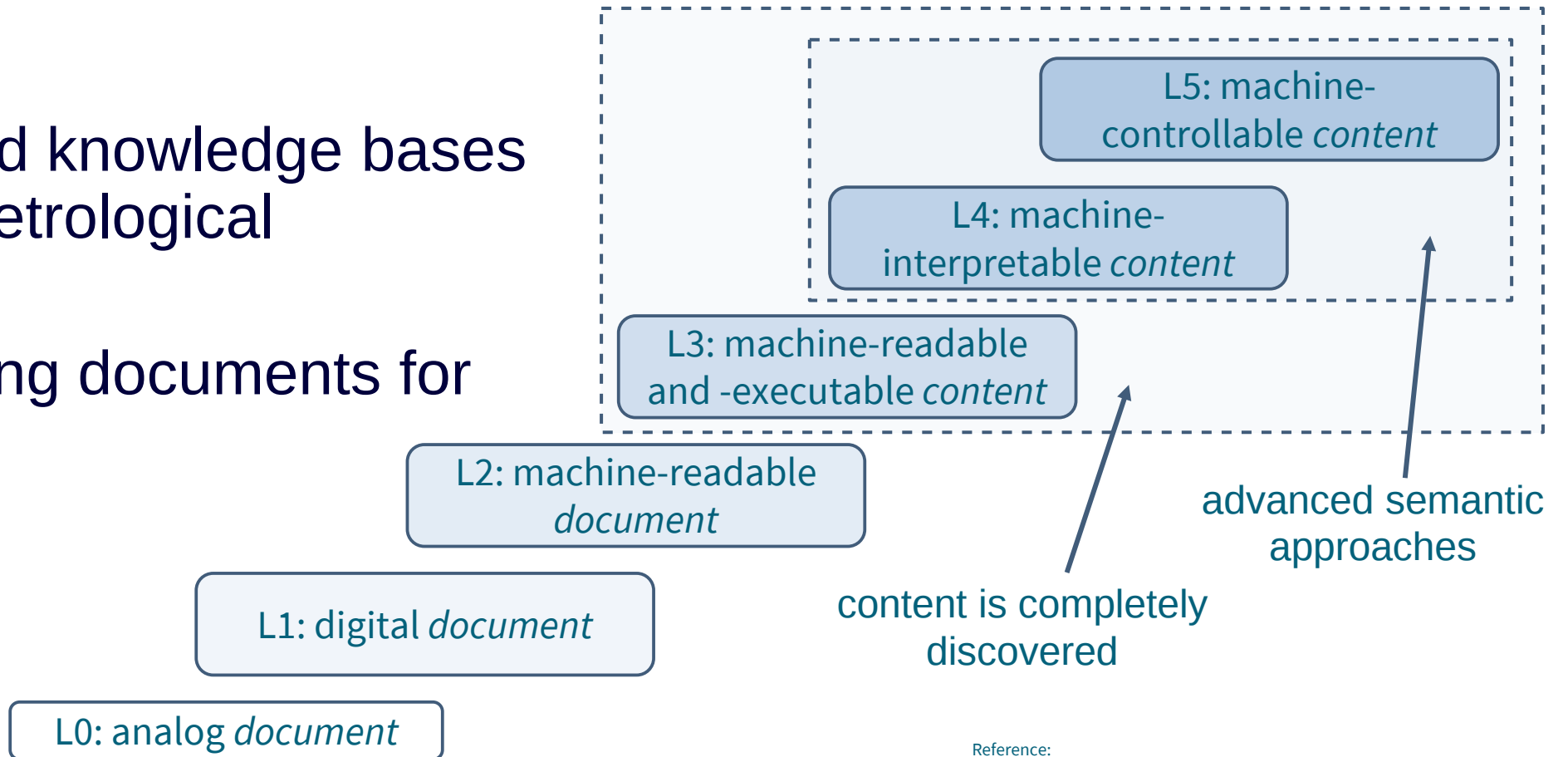


The image shows two copies of the SI brochure. The left copy is the 7th edition (1998) and the right copy is the 8th edition (2006). Both are in French and English.



# Motivation

- provide trusted knowledge bases to describe metrological information
- prepare existing documents for L3+



Reference:  
<https://www.din.de/resource/blob/801106/0251eb1280a9a97e53285d42d3bf1fea/whitepaper-idis-en-data.pdf>

# The principal pillars of SI Reference Point



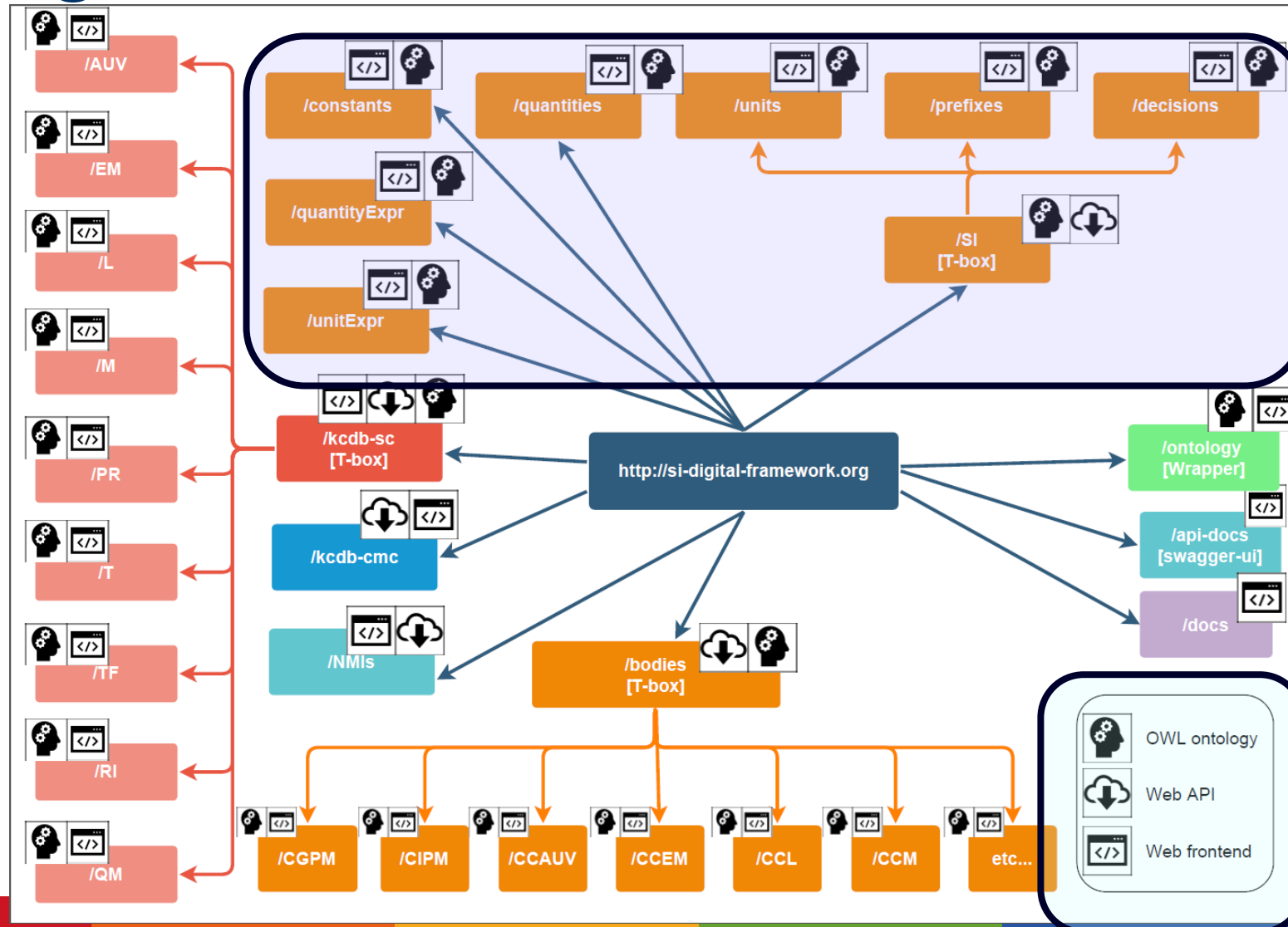
- SI units
- SI prefixes
- Defining constants
- Selected quantities
- Decisions concerning the SI

Information encoded in knowledge graphs (serialized as TTL / JSON-LD)

Usable by both humans and machines.



# The SI Reference point within the (wider) SI Digital framework



SI Reference Point

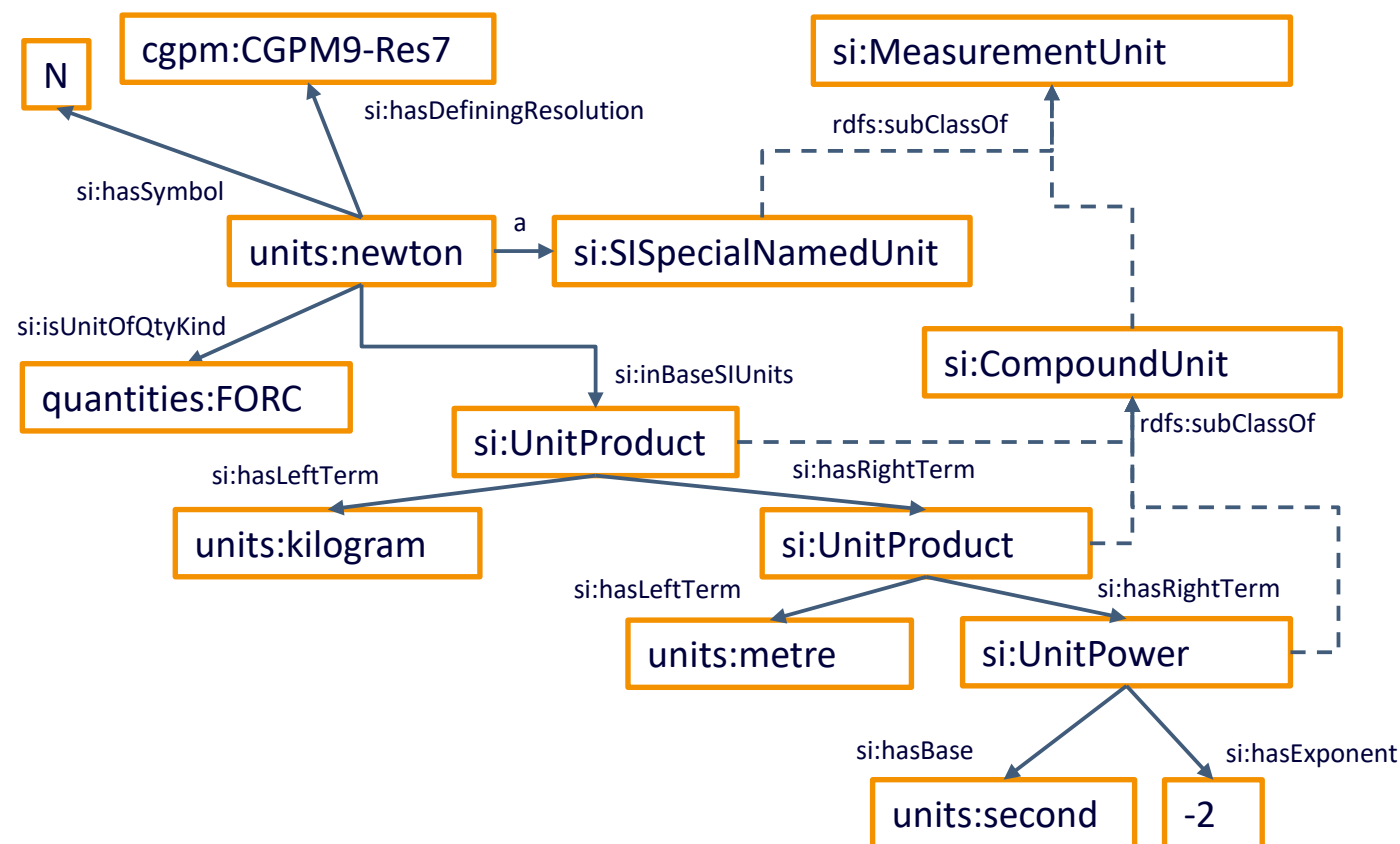
# Construct Units from expressions

$$\text{Unit Equation: } N = \text{kg m} / \text{s}^2$$

## Turtle Syntax:

```
units:newton a si:SISpecialNamedUnit ;
  si:hasDefiningResolution cgpm:CGPM9-Res7 ;
  si:hasSymbol "N"^^xsd:string ;
  si:hasUnitTypeAsString "Named SI derived unit"@en,
    "Unité SI dérivée ayant un nom spécial"@fr ;
  si:inBaseSIUnits [ a si:UnitProduct ;
    si:hasLeftUnitTerm units:kilogram ;
    si:hasRightUnitTerm [ a si:UnitProduct ;
      si:hasLeftUnitTerm units:metre ;
      si:hasRightUnitTerm [ a si:UnitPower ;
        si:hasNumericExponent "-2"^^xsd:short ;
        si:hasUnitBase units:second ] ] ] ;
  si:isUnitOfQtyKind quantities:FORC ;
  si:prefixRestriction false ;
  skos:prefLabel "newton"@en,
    "newton"@fr .
```

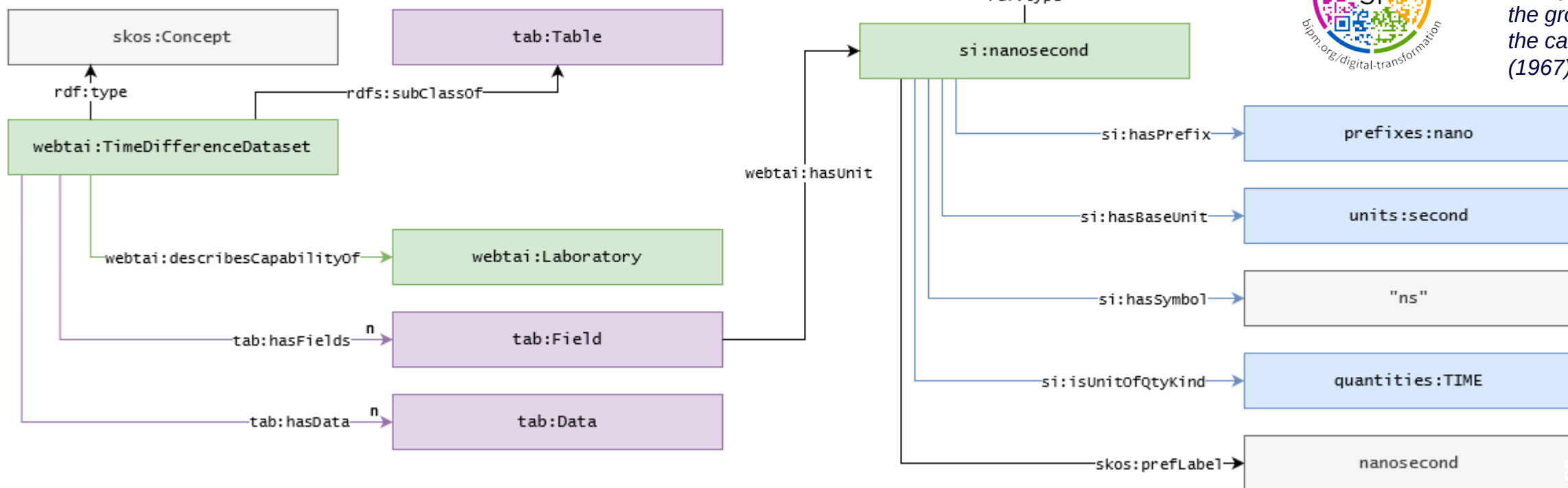
## Implied Graph (excerpt):



# How to link data to units ?

What is “ns”?

“The second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium 133 atom (1967)”



# Links



<https://si-digital-framework.org/> : the root URI and web endpoint

[https://github.com/TheBIPM/SI\\_Digital\\_Framework](https://github.com/TheBIPM/SI_Digital_Framework) : public github repository where files and documentation are available, and issues can be raised.

Current version : 1.0beta, **comments and feedback welcome.**

Collaboration between BIPM and external collaborators (secondees, contractors), headed by BIPM ILC department, steered by task group from CIPM Forum on Metrology and Digitalization.



# Digitalizing (further) T&F data exchange



- The T&F community is already highly « digitized » (out of necessity !)
  - Standard data exchange formats exist, but are technique dependant (CGGTTS, ITU TWSTFT, experiment-specific)
  - BIPM Time Department already handles internally this variety
- *Would a standard T&F data exchange format help the community ?*

# Designing a standard format

## Desiderata :

- Human readable
- Easy to parse
- Technique independent
- Metadata should be included in the files
- Suitable for BIPM Time department use
- Suitable to the time and frequency community

## Design choices :

- Fixed width column-based format: Easy to read, easy to parse
- Flexible description of column content (similar to VOTable): Suitable for all major techniques
- TOML based header: Machine and human readable, libraries already exist to parse and generate
- “Composable delays”

# Example of a simple TFEX file



```
# TFEXVER = 0.3
# PREFIX = { si = 'https://si-digital-framework.org/SI/units/' }
# AUTHOR = 'BIPM'
# REFPOINTS = [
#   {id = 'A', ts = 'UTC(k1)', dev = 'K101', type = 'GNSS'},
#   {id = 'B', ts = 'UTC(k2)', dev = 'K202', type = 'GNSS'},
# ]
# COLUMNS = [
#   {timetag = true, label = 'MJD', scale = 'utc', unit = 'si:day', format = '5d'},
#   {timetag = true, label = 'SoD', scale = 'utc', unit = 'si:second', format = '5d'},
#   {label = 'link', trip = ['B-A'], unit = 'si:nanosecond', format = '8.3f'},
# ]
# COMMENT =
60547    281    -1.421
60547    582    -1.434
60547    882    -1.465
60547   1181    -1.508
60547   1481    -1.530
60547   1781    -1.530
60547   2082    -1.539
```

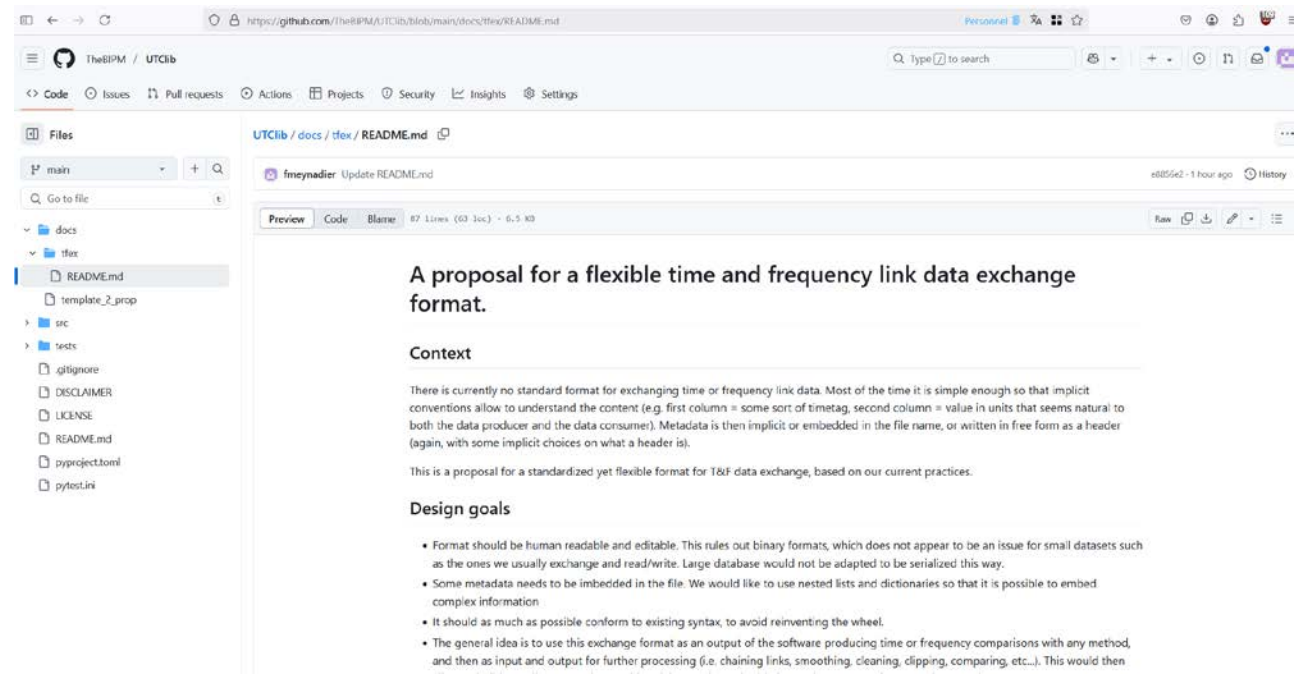
# Development of the TFEX proposal



Design choices are tested by developing a library showcasing the features of the format, and providing basic useful tools

The library is distributed under [GPL 3](https://www.gnu.org/licenses/gpl-3.0.html) license as a python package

Feedback and contributions are welcome !



<https://github.com/TheBIPM/UTCLib>

# A word about « git »

- Git is an extremely popular *version control software*, to the point of being a de-facto standard (although other ones exist).
- Git ≠ Github. Github is a (huge) additional layer, using git as its version control system, adding features like issue trackers, wiki / discussion hosting, graphical interface, etc... Lots of other layers exist (gitlab, codeberg, ...)
- A 1h seminar on « git for metrology » has been recorded in 2022 and is available on the BIPM youtube channel at <https://www.youtube.com/watch?v=0OFRAadYsd4>

# Why bother using version control ?

Version control saves you from a “Save as...” fiasco

trying to make  
sense from the  
**filename**

Location: C:\user\research\data

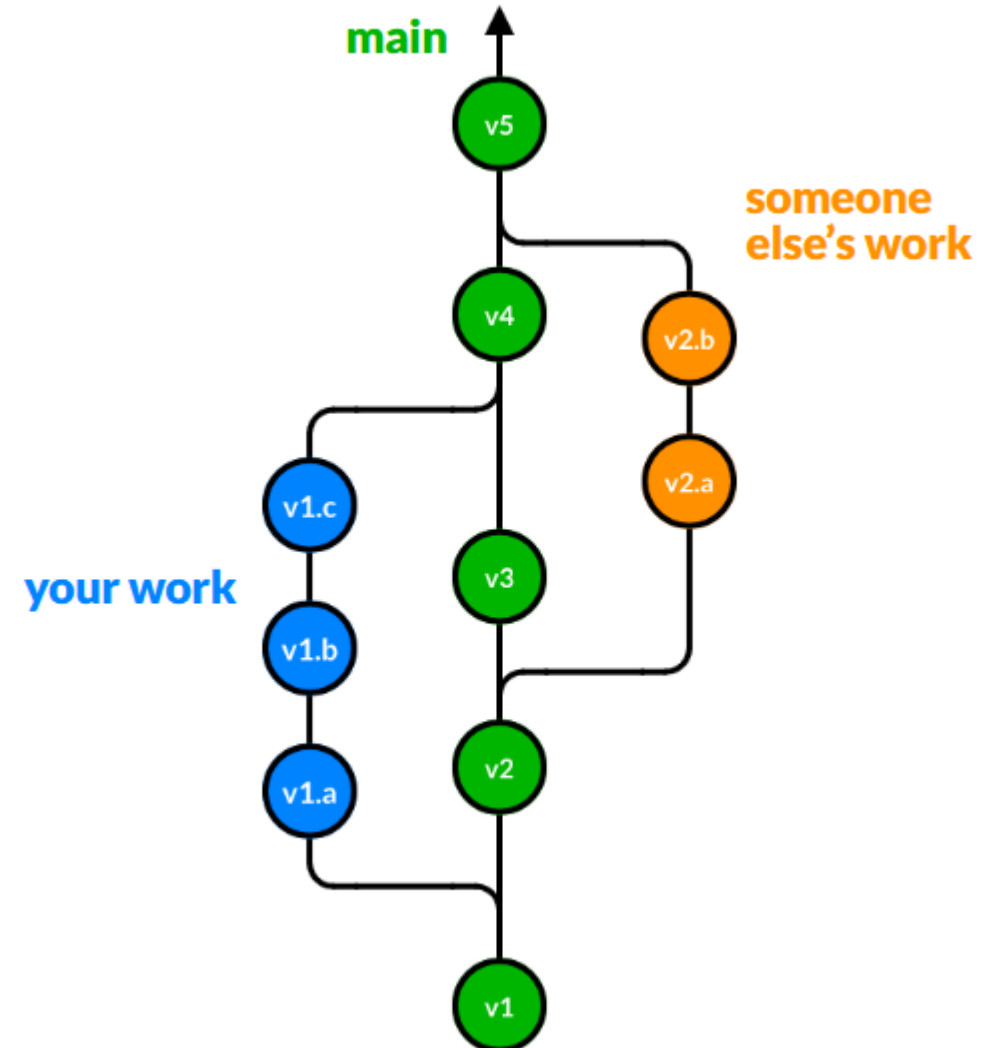
| Filename                         | Date Modified      | Size     | Type     |
|----------------------------------|--------------------|----------|----------|
| data_2010.05.28_test.dat         | 3:37 PM 5/28/2010  | 420 KB   | DAT file |
| data_2010.05.28_re-test.dat      | 4:29 PM 5/28/2010  | 421 KB   | DAT file |
| data_2010.05.28_re-re-test.dat   | 5:43 PM 5/28/2010  | 420 KB   | DAT file |
| data_2010.05.28_calibrate.dat    | 7:17 PM 5/28/2010  | 1,256 KB | DAT file |
| data_2010.05.28_huh??.dat        | 7:20 PM 5/28/2010  | 30 KB    | DAT file |
| data_2010.05.28_WTF.dat          | 9:58 PM 5/28/2010  | 30 KB    | DAT file |
| data_2010.05.29_aaarrgh.dat      | 12:37 AM 5/29/2010 | 30 KB    | DAT file |
| data_2010.05.29_#\$@*!l.dat      | 2:40 AM 5/29/2010  | 0 KB     | DAT file |
| data_2010.05.29_crap.dat         | 3:22 AM 5/29/2010  | 437 KB   | DAT file |
| data_2010.05.29_notbad.dat       | 4:16 AM 5/29/2010  | 670 KB   | DAT file |
| data_2010.05.29_woohoo!!l.dat    | 4:47 AM 5/29/2010  | 1,349 KB | DAT file |
| data_2010.05.29_USETHISONE.dat   | 5:08 AM 5/29/2010  | 2,894 KB | DAT file |
| analysis_graphs.xls              | 7:13 AM 5/29/2010  | 455 KB   | XLS file |
| ThesisOutline.doc                | 7:26 AM 5/29/2010  | 38 KB    | DOC file |
| Notes_Meeting_with_ProfSmith.txt | 11:38 AM 5/29/2010 | 1,673 KB | TXT file |
| JUNK...                          | 2:45 PM 5/29/2010  |          | Folder   |
| data_2010.05.30_startingover.dat | 8:37 AM 5/30/2010  | 420 KB   | DAT file |

Type: Ph.D Thesis Modified: too many times Copyright: Jorge Cham www.phdcomics.com

trying to make  
sense from the  
**timestamp**

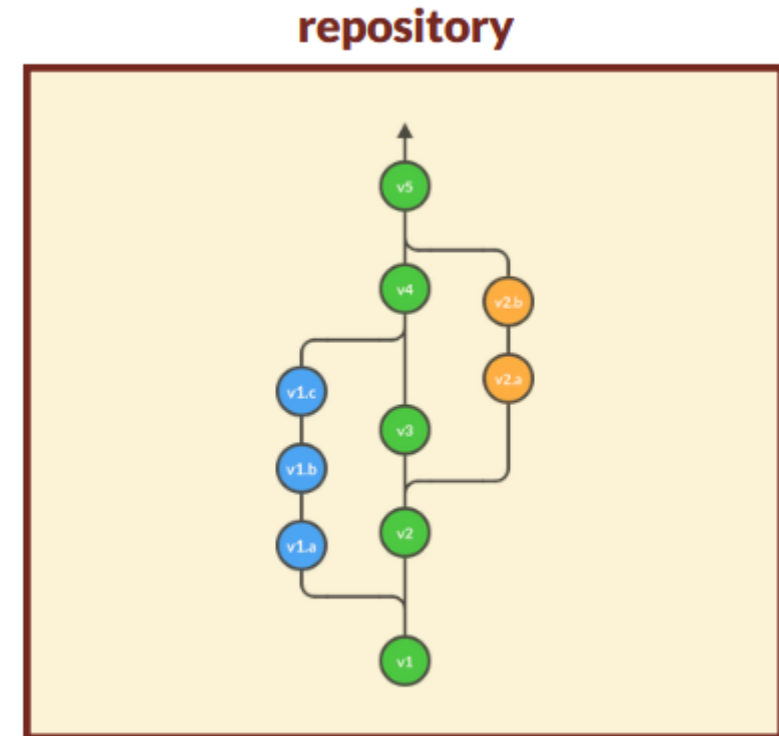
# Why bother using version control ?

- Git gives you the tools to handle multiple versions of your work, but also incorporate (as smoothly as possible) collaborators work.



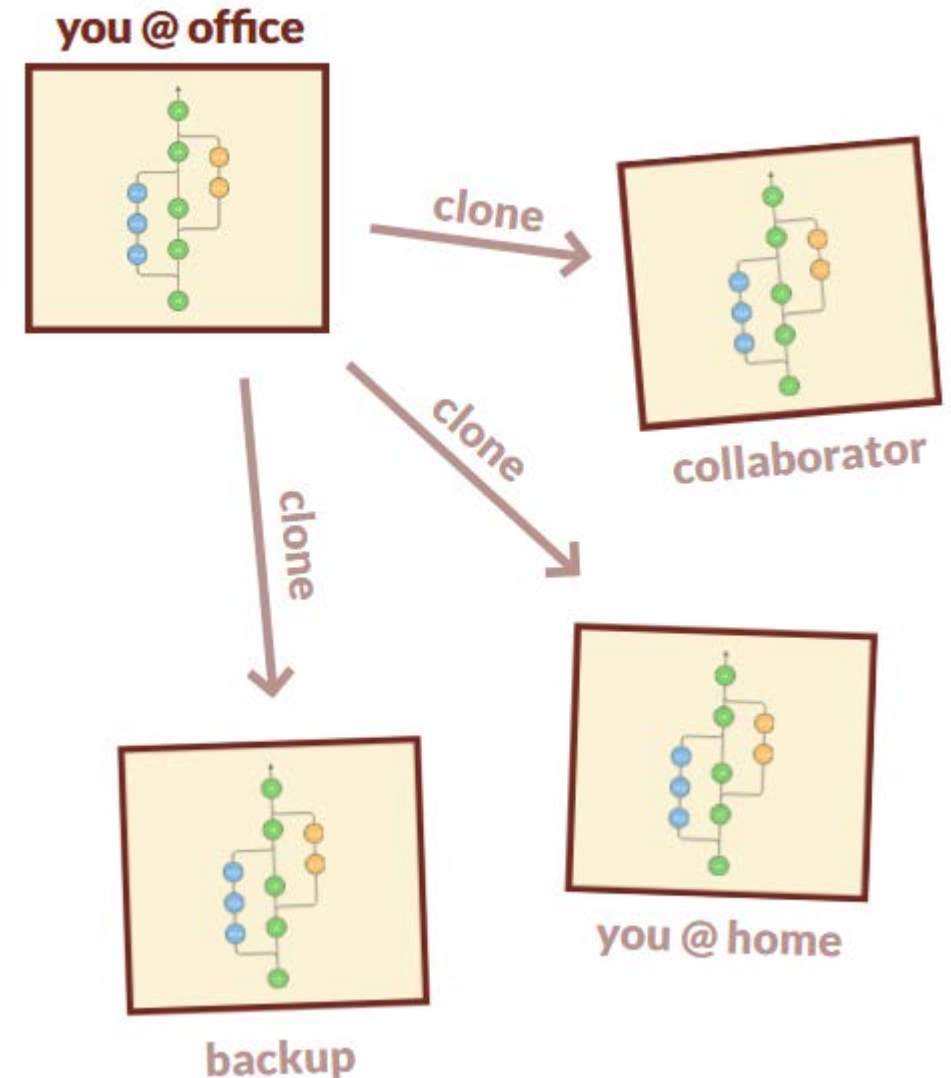
# Why bother using version control ?

- Git gives you the tools to handle multiple versions of your work, but also incorporate (as smoothly as possible) collaborators work.
- Each repository contains the whole history



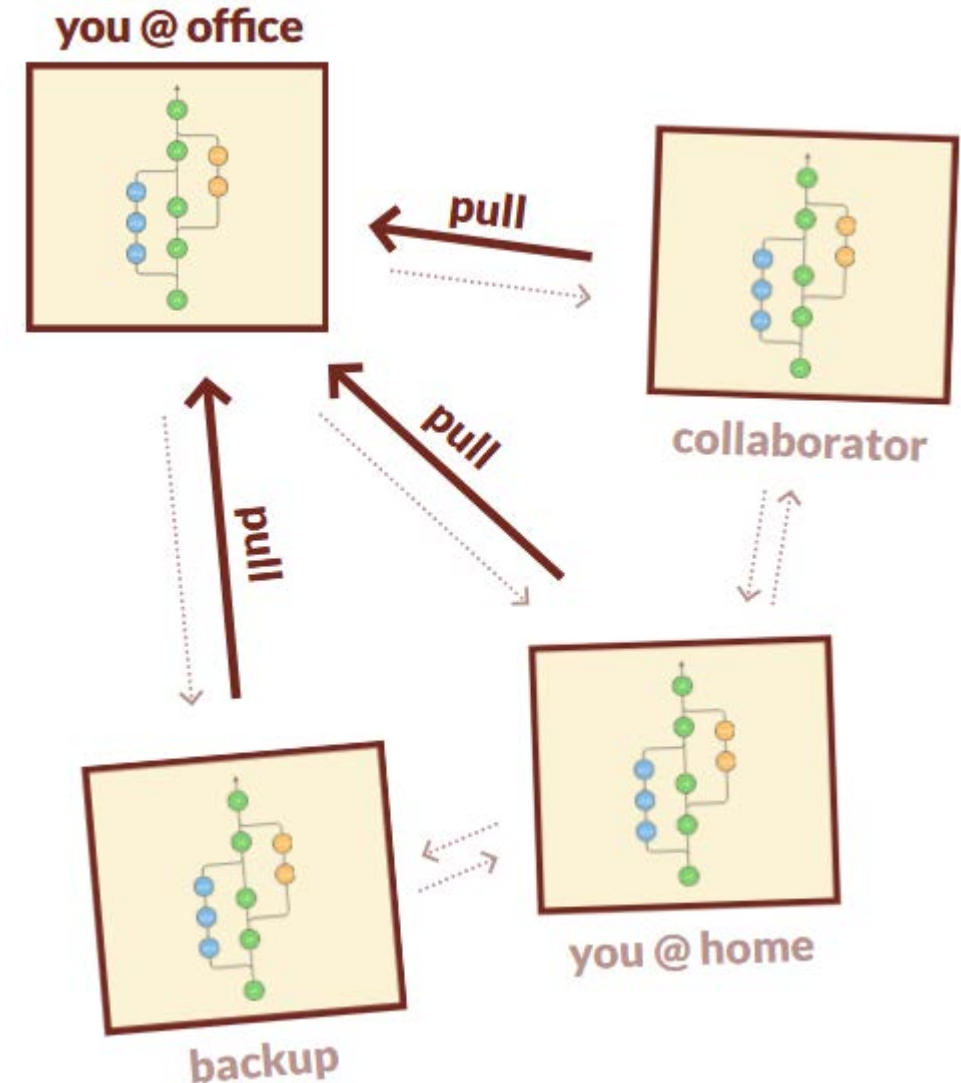
# Why bother using version control ?

- Git gives you the tools to handle multiple versions of your work, but also incorporate (as smoothly as possible) collaborators work.
- Each repository contains the whole history
- The « clone » command allows to disseminate the whole history



# Why bother using version control ?

- Git gives you the tools to handle multiple versions of your work, but also incorporate (as smoothly as possible) collaborators work.
- Each repository contains the whole history
- The « clone » command allows to disseminate the whole history
- Other commands handle the exchanges between repositories



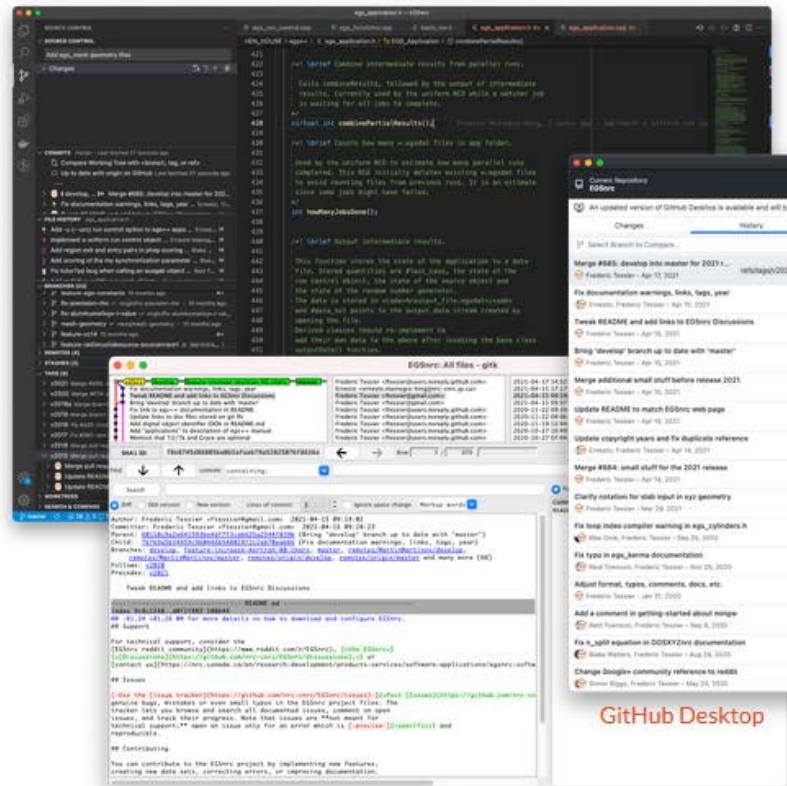
# In practice



Git works great in command line, but many GUIs are available

<https://git-scm.com/downloads/guis>

Visual Studio Code

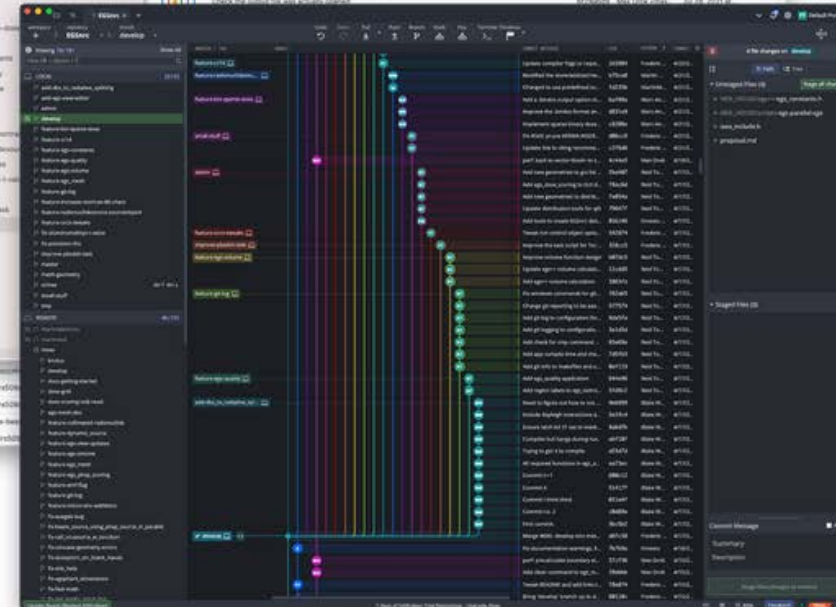


gitk

Sourcetree



GitHub Desktop



GitKraken

# In conclusion...

- Digitalization is a continuous process, with multiple aspects
- It takes time and work, but this is an investment : this usually pays off quite quickly
- Collaboration is the key : lots of resources already available + need to adapt the output to other's needs.
- AI : related but distinct



[frederic.meynadier@bipm.org](mailto:frederic.meynadier@bipm.org)

