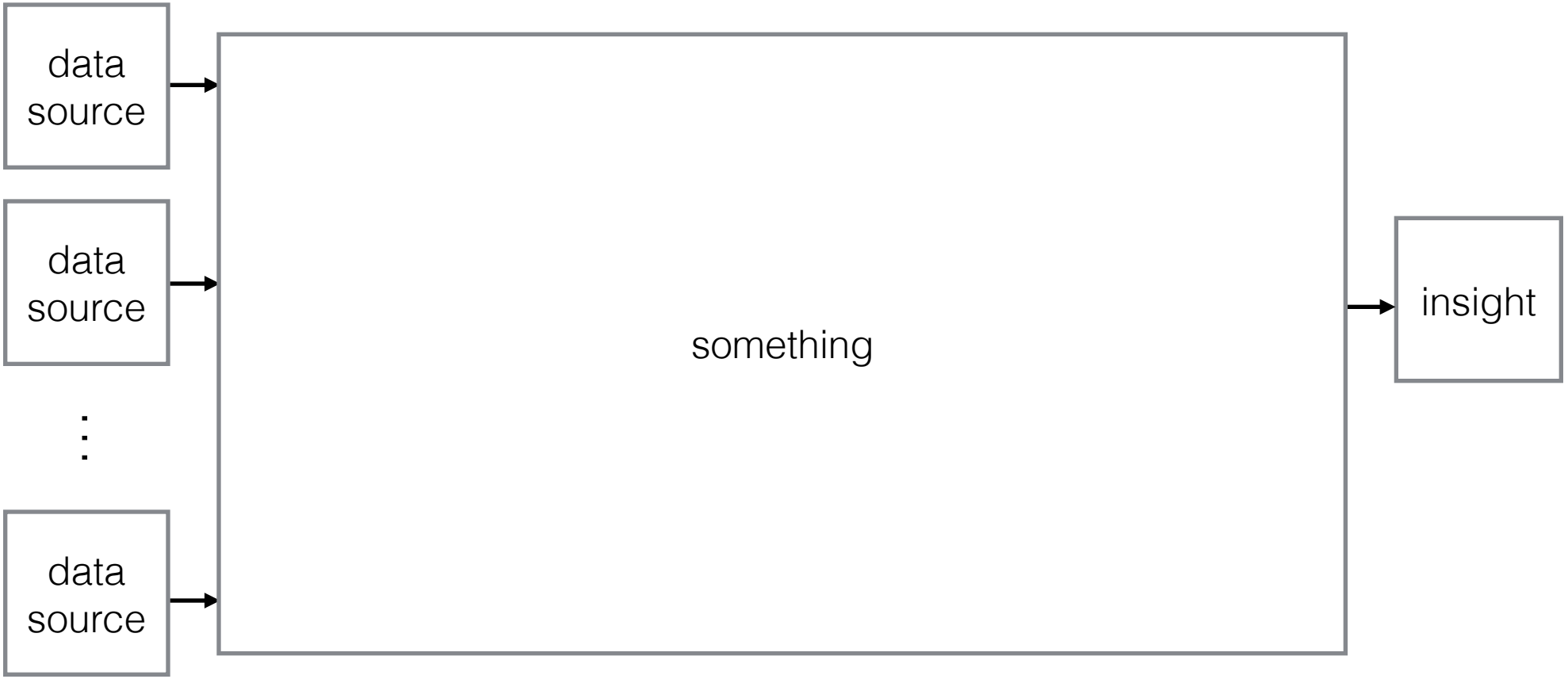
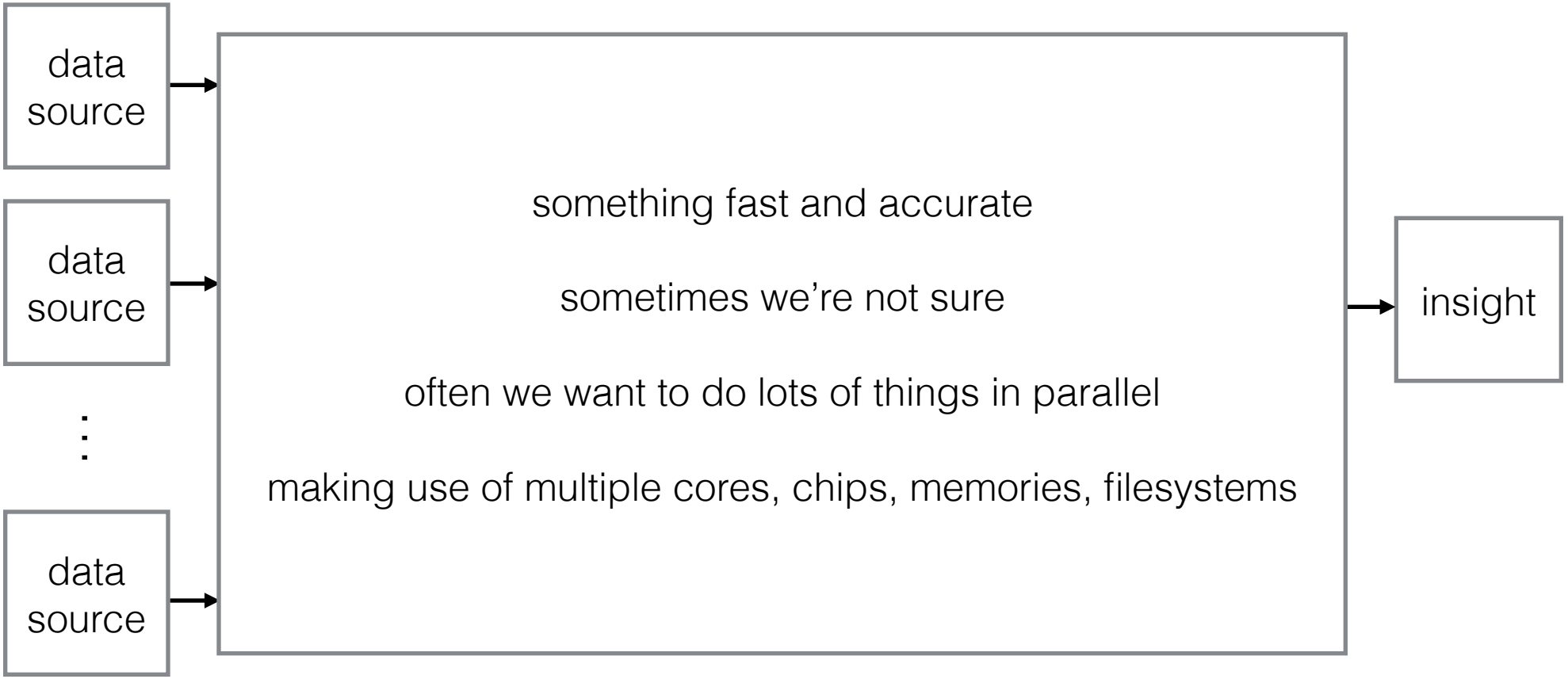
Julia for big data

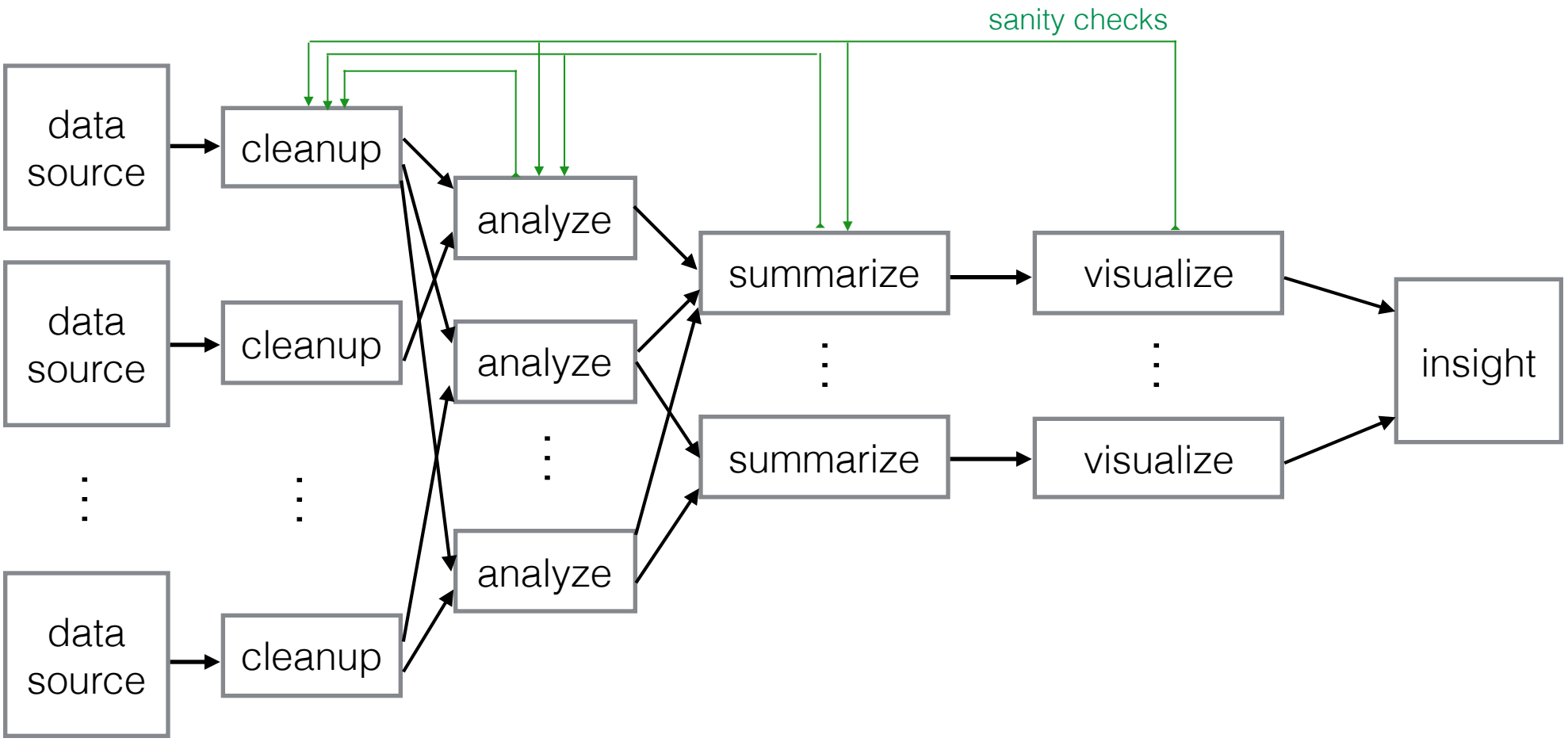
What we want



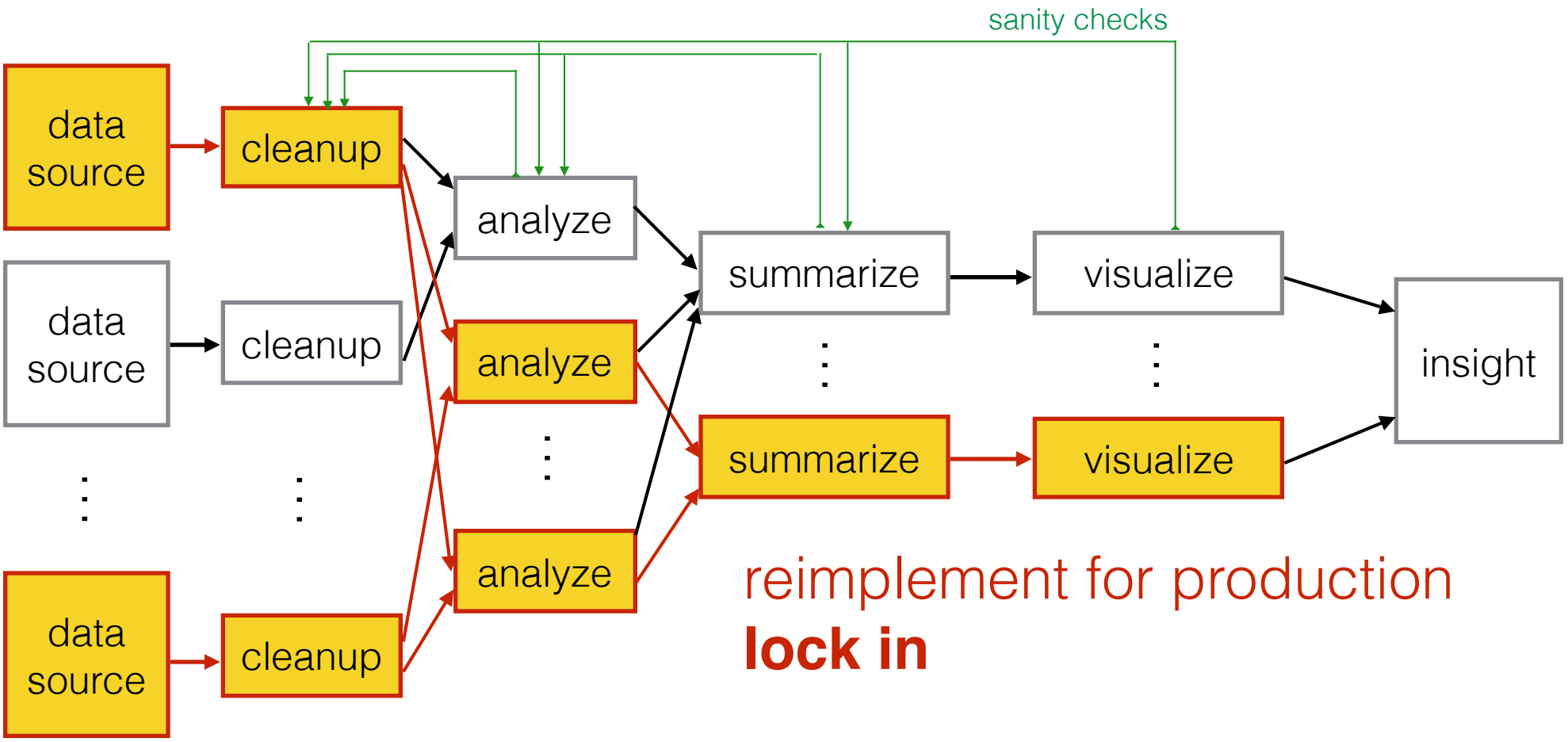
What we want


data source
data source
data source
something fast and accurate
sometimes we're not sure
often we want to do lots of things in parallel
making use of multiple cores, chips, memories, filesystems
insight

What we have to do



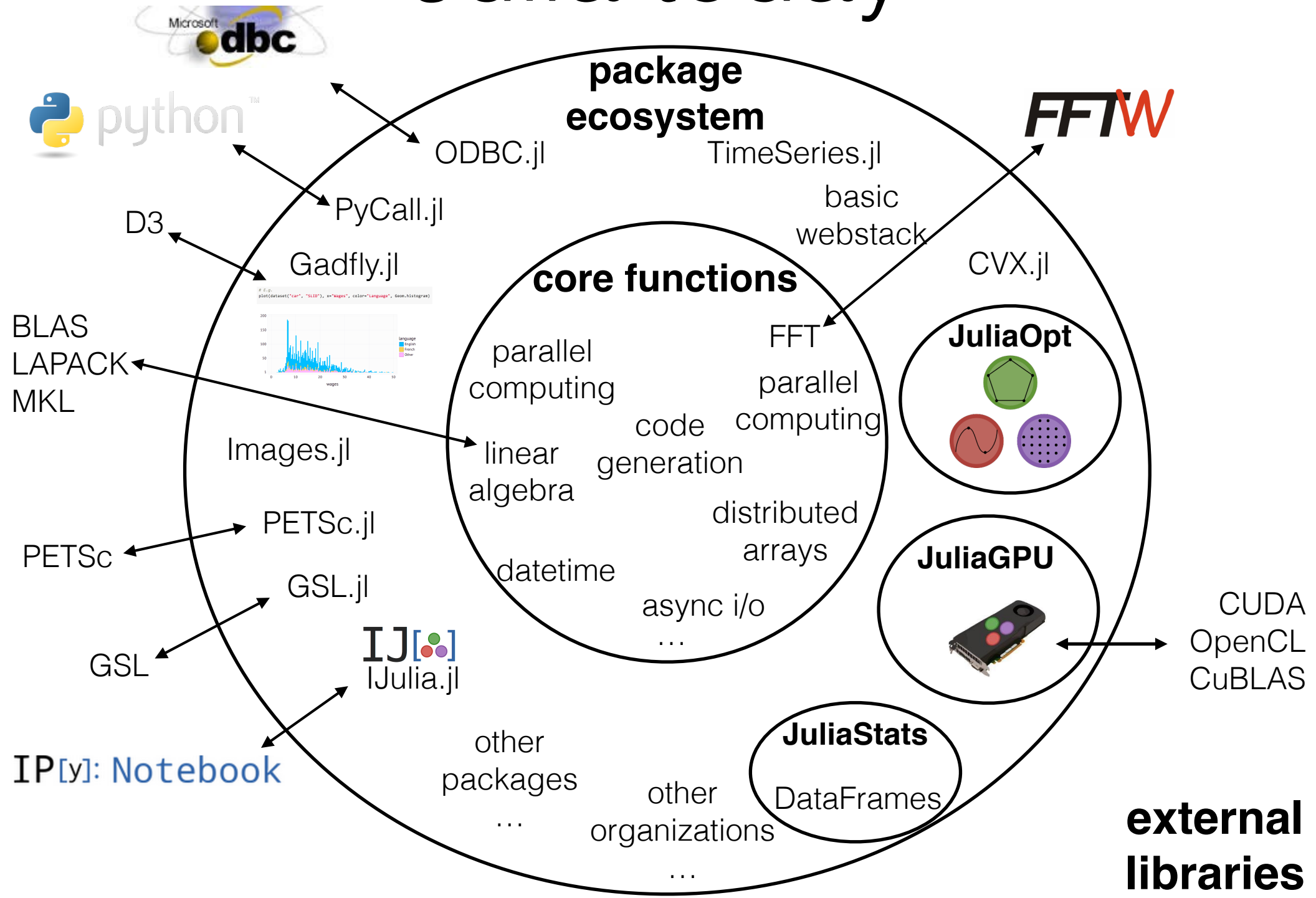
What we have to do



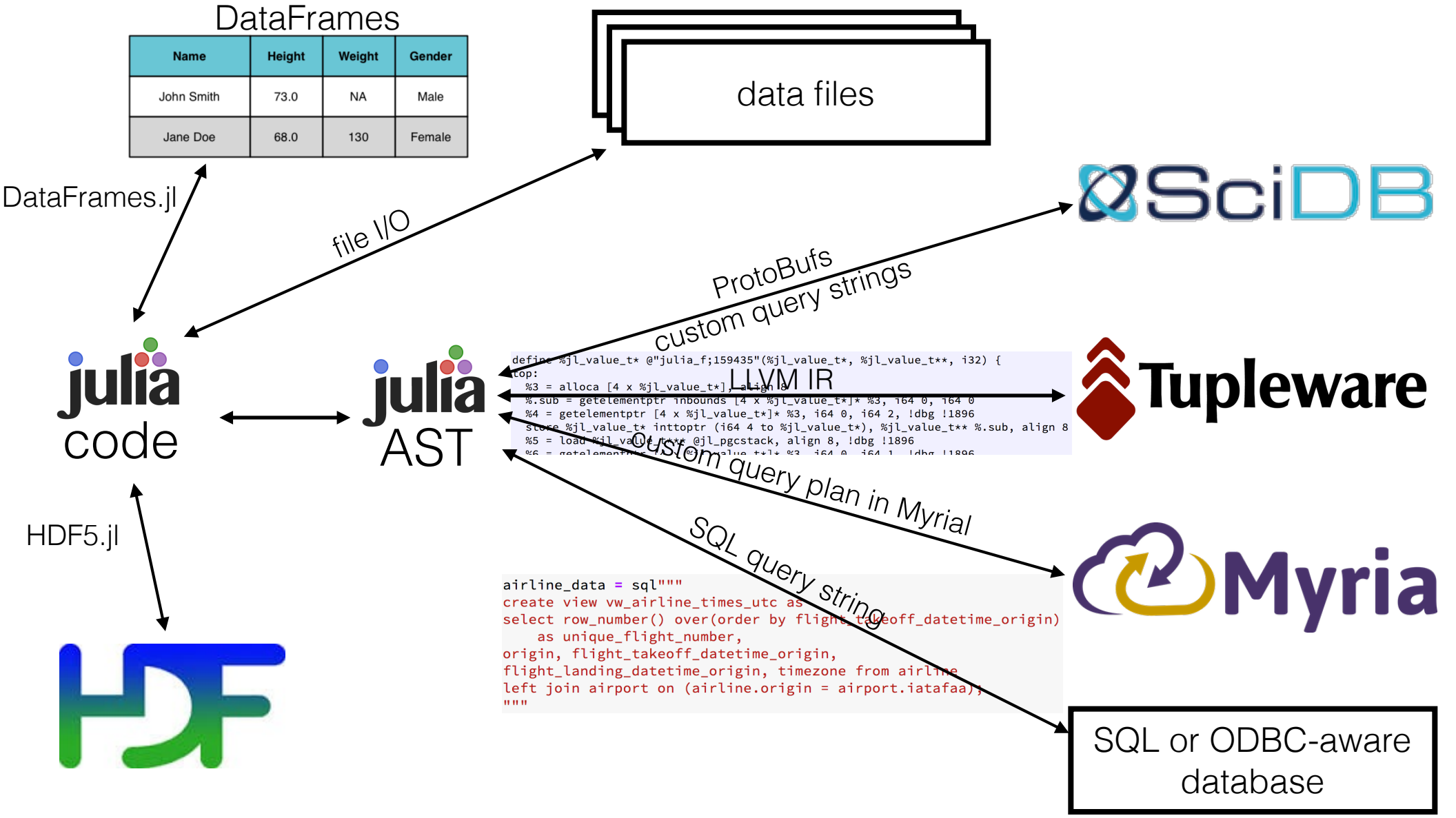
How can programming language design help with big data?

Work with multiple data sources	API for large scale data, distributed, data source objects
Create multiple visualizations	API for visualization objects
Iterate through many different workflows	High level language constructs for rapid development
Interoperate with existing tools/libraries	Easy foreign function interface: C, Fortran, LLVM,…
Reproducible science automatable analysis	Consistent cross-platform interop
Fast throughput	Native language constructs for multithreading, parallel computing

Julia today


Microsoft
dbc
python
package
ecosystem
ODBC.jl
TimeSeries.jl
FFTW
PyCall.jl
basic
webstack
D3
Gadfly.jl
CVX.jl
core functions
BLAS
LAPACK
MKL
FFT
parallel
computing
parallel
computing
JuliaOpt
code
generation
Images.jl
linear
algebra
distributed
arrays
PETSc.jl
PETSc
datetime
JuliaGPU
GSL.jl
async i/o
…
CUDA
OpenCL
CuBLAS
GSL
IJ[ ]
IJulia.jl
JuliaStats
other
packages
…
DataFrames
IP[y]: Notebook
other
organizations
…
external
libraries

Unifying in-core and out-of-core algorithms



Multiple dispatch + metaprogramming (code generation)

Linear algebra

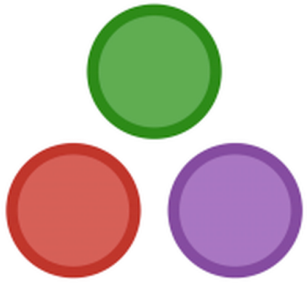
Today:

- Wrappers to OpenBLAS, LAPACK, SuiteSparse, ARPACK
- Generic routines for LU, Cholesky, QR, etc. over arbitrary fields (rationals, quaternions, arbitrary precision arithmetic, etc.)

Planned:

- new abstractions for iterative methods [IterativeSolvers.jl#28, #29]
- randomized algorithms efficient on huge data sets: for least squares, SVD,…
- Native scalable solvers that are faster than LAPACK in serial, yet parallelizable to arbitrarily many cores
- record breaking sparse matrix solvers for size and speed

Community-driven statistics and machine learning in Julia



JuliaStats

Statistics and **Machine Learning** made easy in Julia.

- Easy to use tools for statistics and machine learning.
- Extensible and reusable models and algorithms
- Efficient and scalable implementation
- Community driven, and open source

StatsBase

Basic functionalities for statistics

- Descriptive statistics and moments
- sampling with/without replacement
- Counting and ranking
- Autocorrelation and cross-correlation
- Weighted statistics

DataArrays

Arrays that allow missing data

- Data arrays with missing values
- Optimized representation of arrays comprised of repetitive values
- Computational routines that work with missing values

DataFrames

Essential tools for tabular data

- DataFrames to represent tabular datasets
- Database-style joins and indexing
- Split-apply-combine operations, pivoting
- Formula and model frames

Distributions

Probability distributions

- A large collection of univariate, multivariate distributions
- descriptive stats, pdf/pmf, and mgf
- Efficient sampling
- Maximum likelihood estimation

MultivariateStats

Multivariate statistical analysis

- Linear regression (LSQ and Ridge)
- Dimensionality reduction (PCA,CCA,ICA,...)
- Multidimensional scaling
- Linear discriminant analysis

HypothesisTests

Hypothesis tests

- Parametric tests: t-tests
- Nonparametric tests: binomial tests, sign tests, exact tests, U tests, rank tests, etc

Packages

We bring together a number of great packages

MLBase

Swiss knife for machine learning

- Data preprocessing
- Score-based classification
- Performance evaluation
- Model selection, cross validation

Distance

Various distances between vectors

- A large variety of metrics
- Efficient column-wise and pairwise computation
- Support weighted distances

KernelDensity

Kernel density estimation

- Kernel density estimation for univariate and bivariate data
- User customization of interpolation points, kernel, and bandwidth

Clustering

Algorithms for data clustering

- K-means
- K-medoids
- Affinity propagation
- Evaluation of clustering performance

GLM

Generalized linear models

- Friendly API for fitting GLM to data
- Work with data frames and formulas
- A variety of link types
- Optimized implementation

NMF

Nonnegative matrix factorization

- A variety of NMF algorithms, including Lee & Seung's, Projected ALS and projected gradient, with optimized implementation.
- NNDSVD initialization

RegERMs

Regularized empirical risk minimization

- Foundational framework for regression analysis
- Support ridge regression, logistic regression, and many more (e.g. user-provided loss)
- Solvers: L-BFGS and SGD
- Highly configurable and

MCMC

Markov Chain Monte Carlo

- A generic engine for Bayesian inference
- A variety of samplers, using latest techniques
- User-friendly syntax for model specification
- Use auto-differentiation
- ability to suspend and resume

TimeSeries

Time series analysis

- Tools to represent, manipulate, and apply computation to time series data
- Based on data frames

Hardware accelerators and Julia

Today:

JuliaGPU organization for GPU-based computing

Wrappers for CUDA [CUDA.jl] and OpenCL [OpenCL.jl]

Planned and in progress:

LLVM code generation targeting Intel Xeon Phi (KNC, KNL architectures)

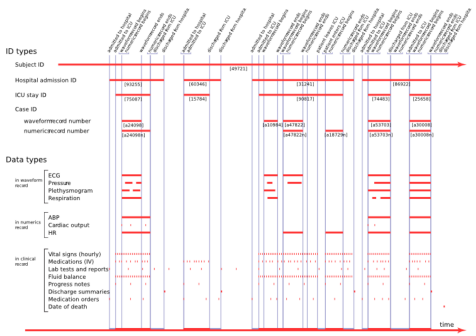
Unified model for heterogeneous hardware threads

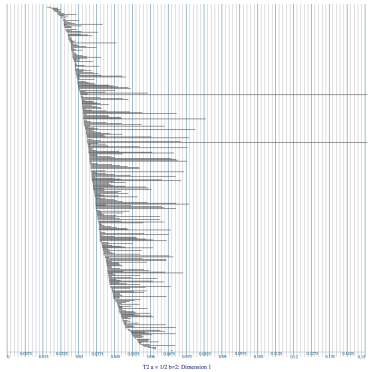
Some recent big data-related Julia improvements

Better I/O	>20x faster HDF5 I/O [HDF5.jl#132]
Better data handling	comprehensive handling of dates and times [#7654] array views [#7941] and Cartesian iteration [#6437] string handling
Better parallel computing	faster interprocess communication with 10x faster serialization [#7893] multithreading support [#1790, #6741, threads]
Better foreign code interop	llvmcall [#5046], C++ [CXX.jl], Java [JavaCall.jl] staged functions [#7474] C struct interoperability [#7906]
Interactive visualization support	reactive programming framework [React.jl] interactive IPython widgets [IJuliaWidgets.jl]
Other speedups	better garbage collection [#5227]

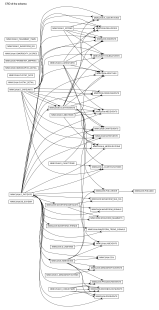
…and many more planned [0.4-projects]

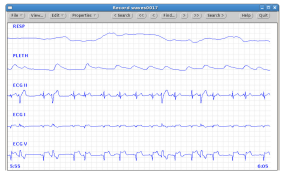
Stretch goal: To break the record on the largest data set that's ever been analyzed





data source → cleanup → analyze → summarize → visualization

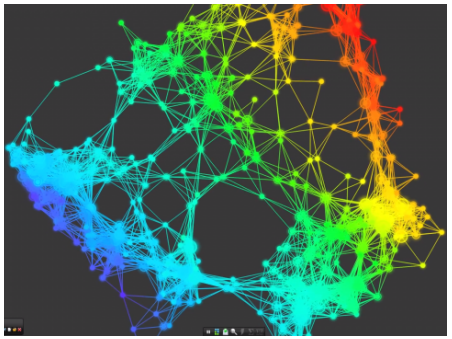




Definition 2.1. An *abstract simplicial complex* is a pair (V, Σ), where V is a finite set, and Σ is a family of non-empty subsets of V such that $\sigma \in \Sigma$ and $\tau \subseteq \sigma$ implies that $\tau \in \Sigma$.

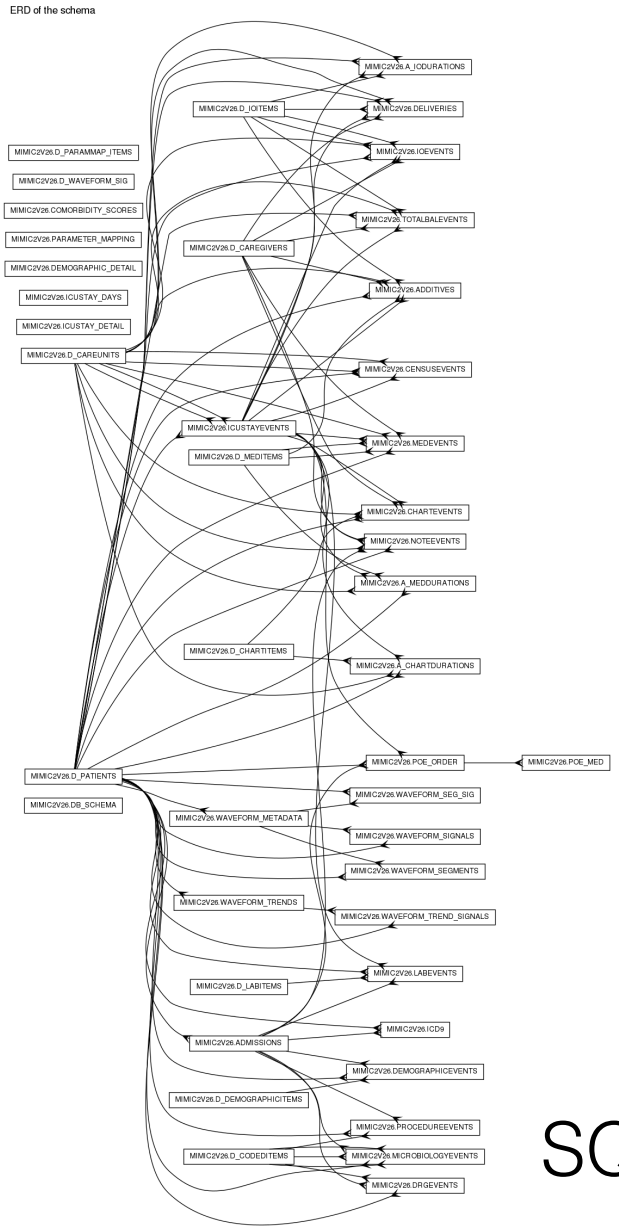
In [ ]:
```
type AbstractSimplicialComplex{T}
    V :: Vector{T} #Vertex set with total ordering imposed
    Σ :: Set{Vector{T}} #Set of Vs

    function AbstractSimplicialComplex{T}(V::Vector{T}, Σ)
        Σ'=Set{Vector{T}}()
        for σ in Σ
            σ ⊆ V || error("σ=$σ ∈ Σ is not a subset of V")
            push!(Σ', σ)
        end
        #Check that σ∈Σ and τ⊆σ implies that τ∈Σ
        for σ in Σ, τ in ℘(σ)
            τ ∈ Σ || error("τ=$τ ⊆ σ=$σ but τ∉Σ")
        end
        new(V, Σ')
    end
end
```



The MIMIC II dataset

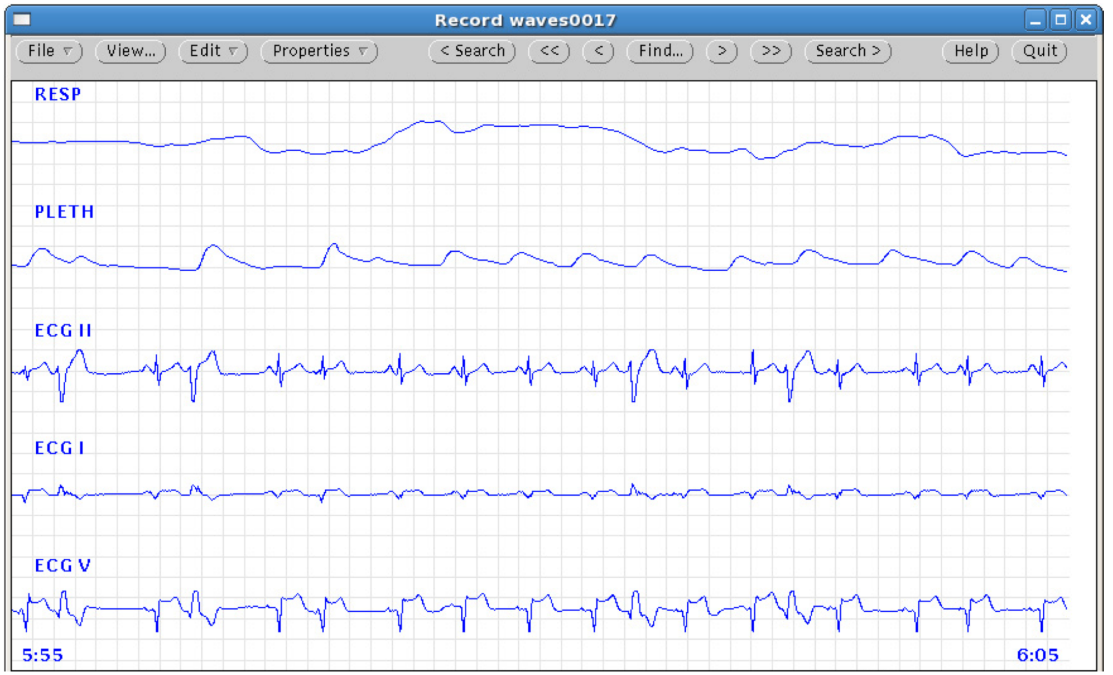
(with S. Madden & group)



SQL database

+

raw waveform data



mimic.physionet.org

The MIMIC II dataset

(with S. Madden & group)

Real-world problems

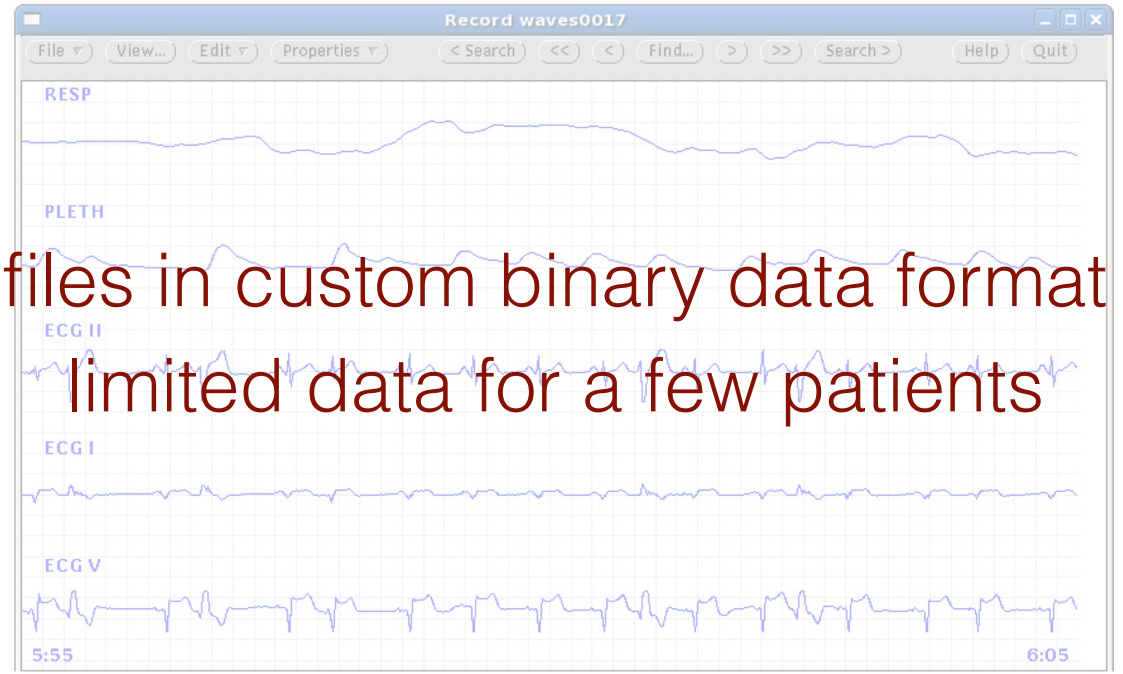
missing data

corrupt data (purposely anonymized)

free-form data (doctors' notes, prescriptions, …)

+

raw waveform data



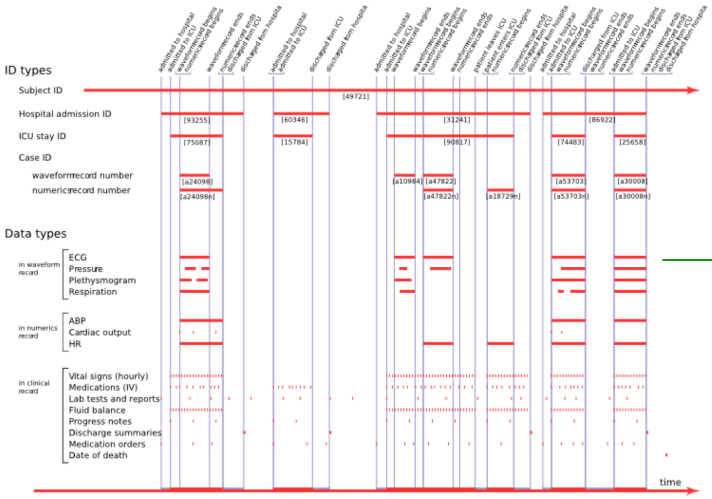
files in custom binary data format

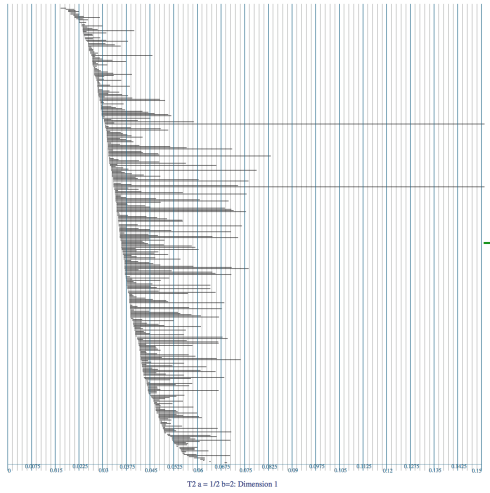
limited data for a few patients

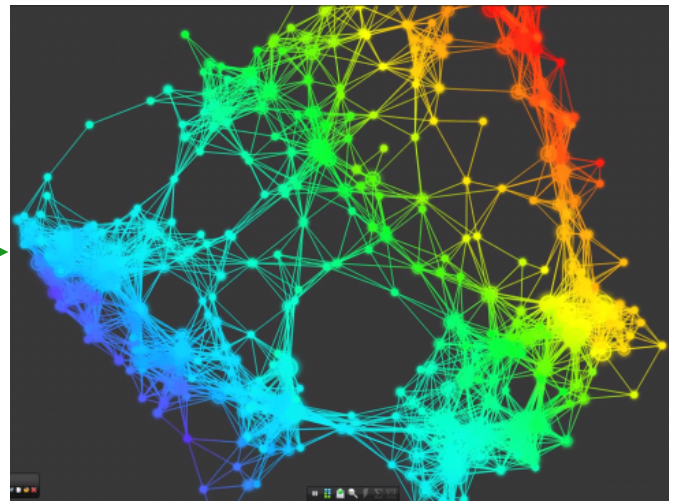
SQL database

mimic.physionet.org

Topological data analysis







raw data

persistent homology

visualizations

From paper to Julia code

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