# Understanding the most Massive Stars in the Universe using Genetic Algorithms

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CESGA, 12-Jun-2008

DAMIR

- *T*
- *L*
- *M*
- *a*

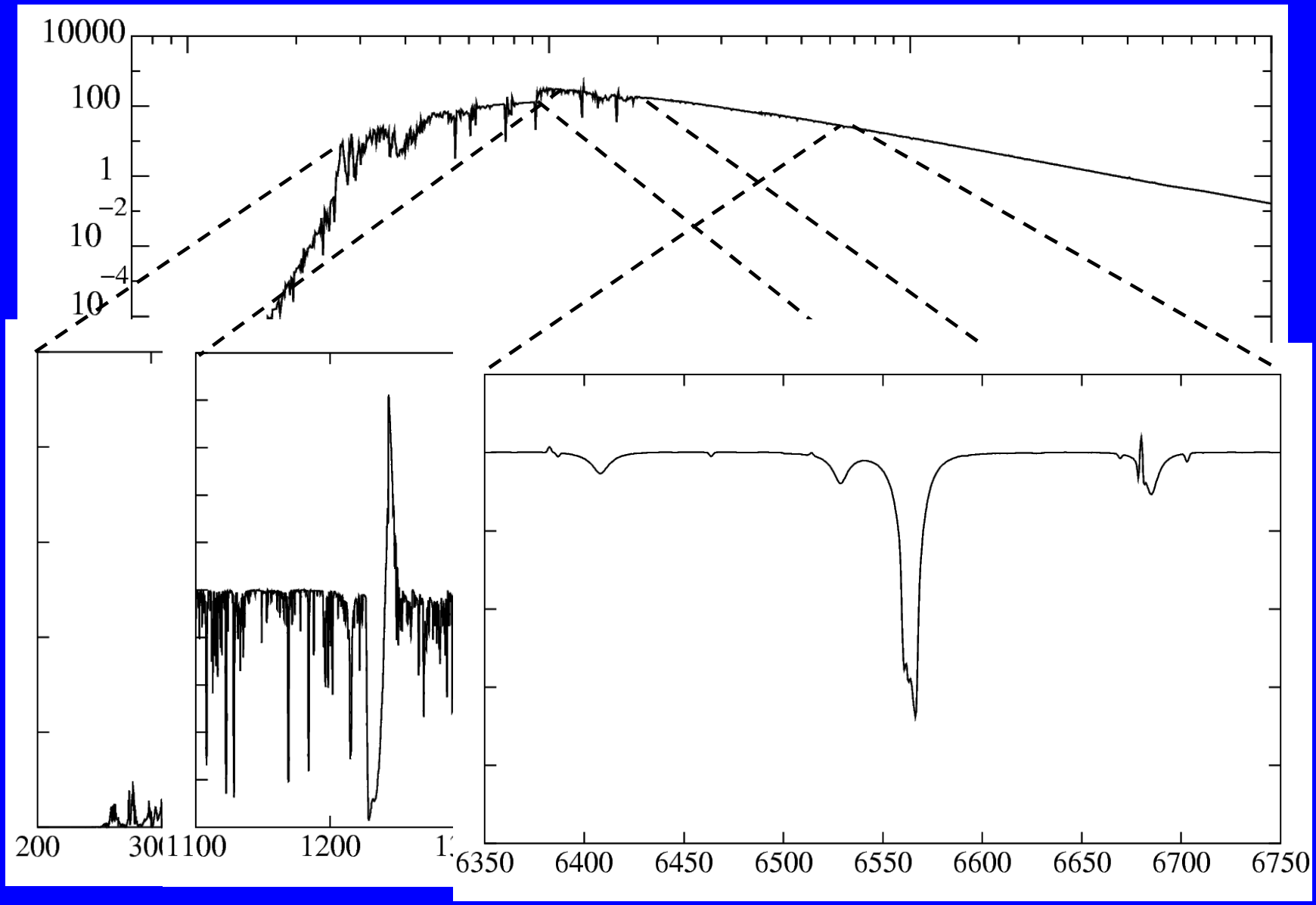
$M_\odot$/yr

# Importance of massive stars

- Evolution of Galaxies
- Super Novae
- Gamma-ray bursts
- Neutron Stars & Black Holes
- Re-ionization of early universe

# Large sample analysis

- ~100 analyzed until now
- Flames Survey
  - ~100 hours VLT time
  - Galactic, SMC and LMC fields
  - will double total number of analyzed stars
  - calibration of fundamental parameters
- Quantitative spectroscopy


10000
100
1
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6400
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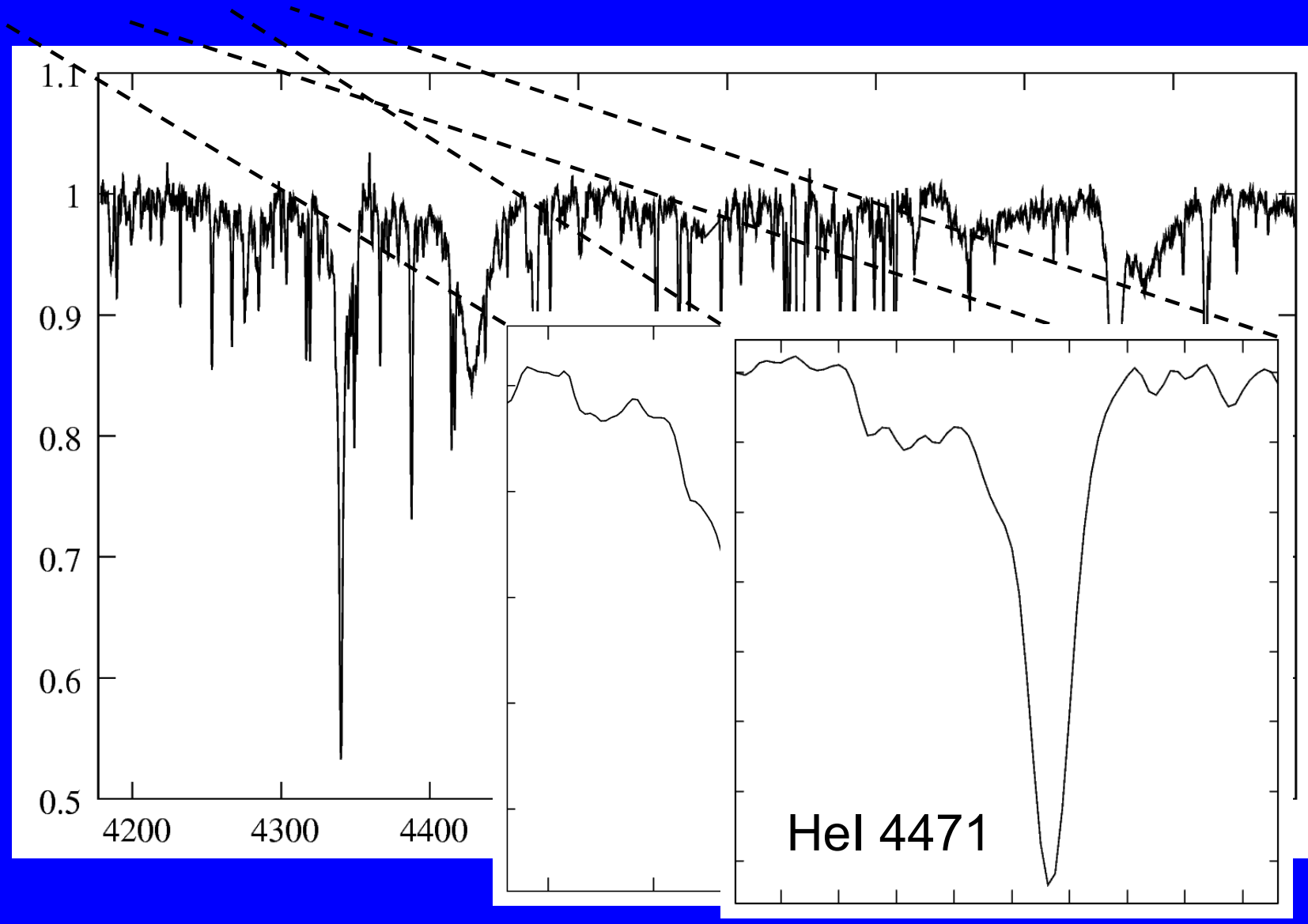
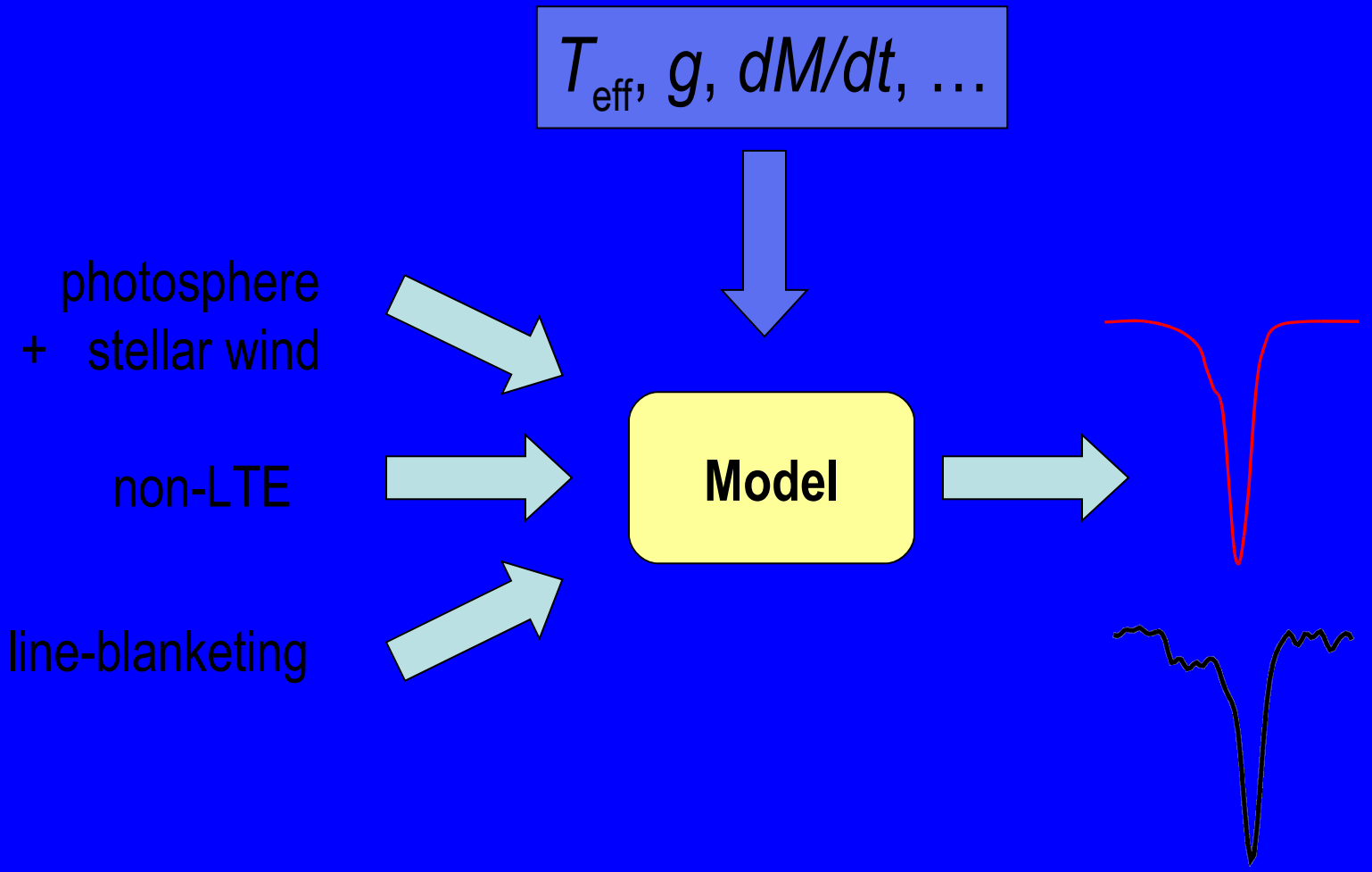
6750

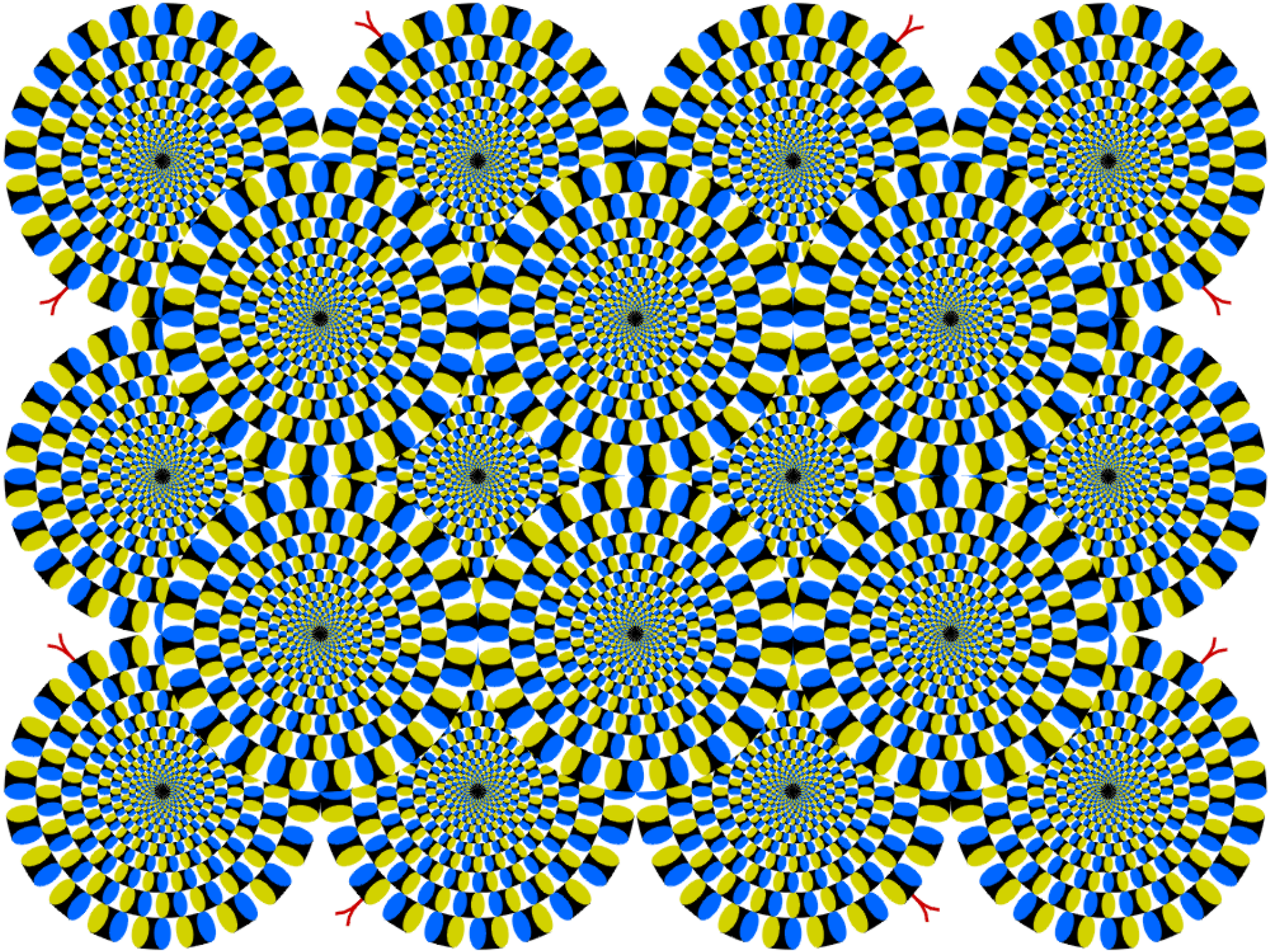

1.1
1
0.9
0.8
0.7
0.6
0.5
4200
4300
4400
HeI 4471

# Quantitative spectroscopy



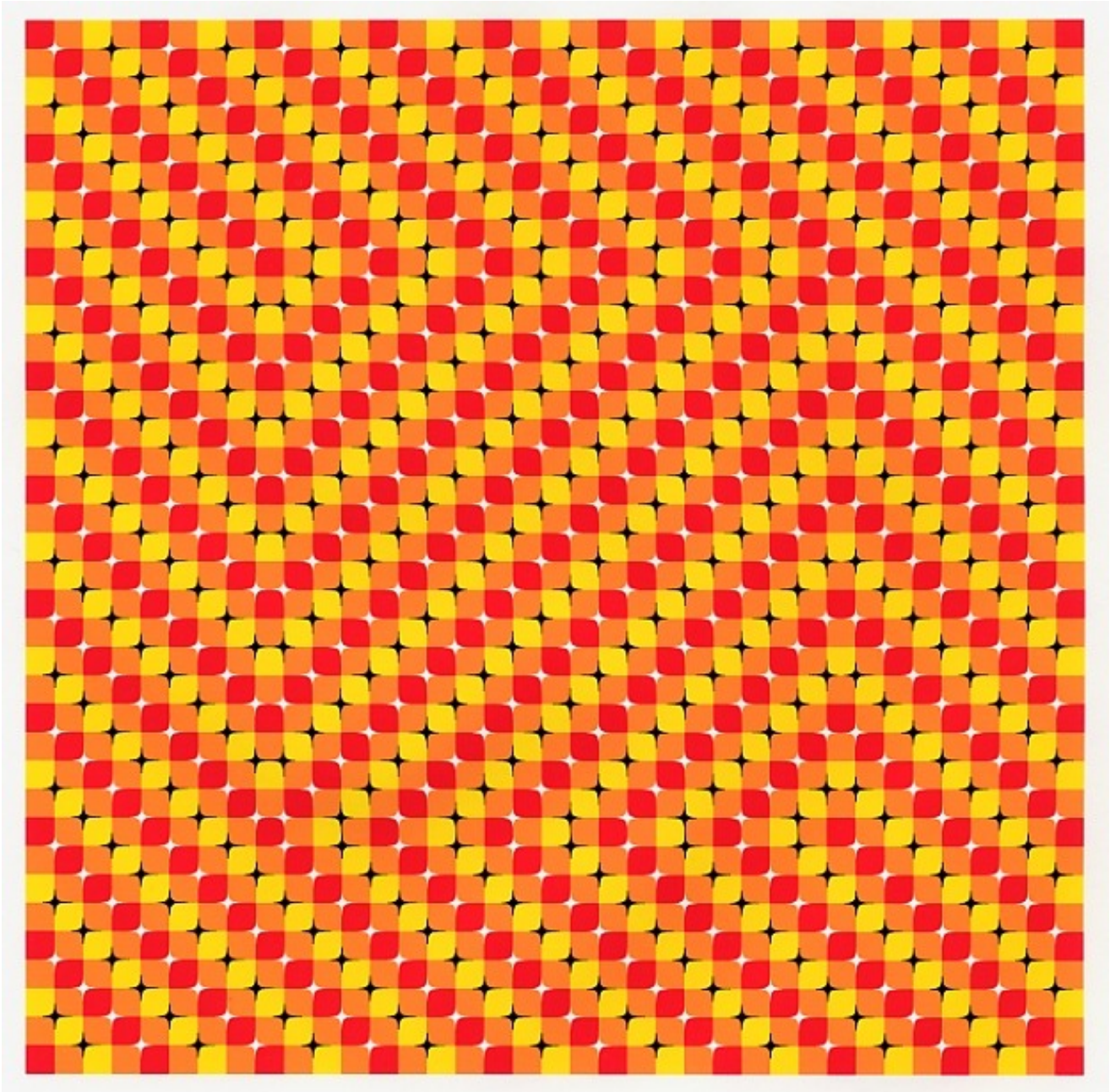
# “by eye”

- The conventional method
- However, …



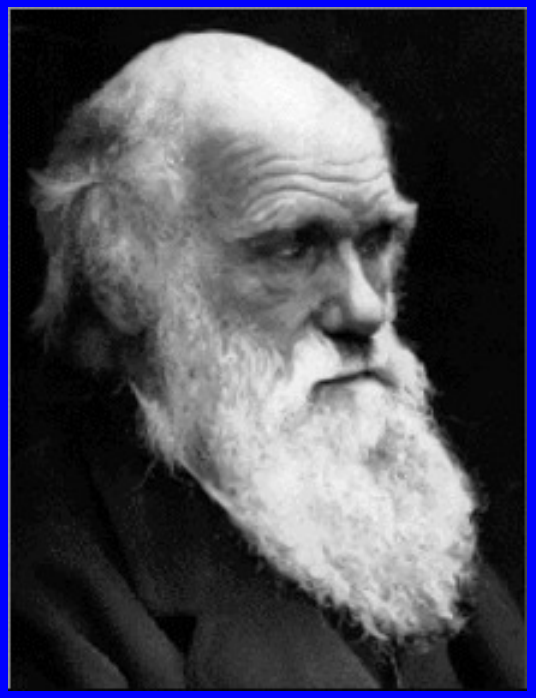
# Drawbacks of fitting “by eye”

- Laborious
- Limited number of physical parameters
- Not reproducible
  - biases
  - best fit?
- No large sample, and …



It gives you a headache

# Natural selection



Charles Darwin
1809 -1882

“I have called this principle, by which each slight variation, if useful, is preserved, by the term Natural Selection.”

# Genetic Algorithms

Adaptative heuristic search method using Darwinian principles

**Applications:**

Scheduling, Data fitting,Trend spotting, Budgeting, ...

Any search for which all solutions cannot be tested.

**Scheme:**

1.Initialization: compute solutions for random parameters

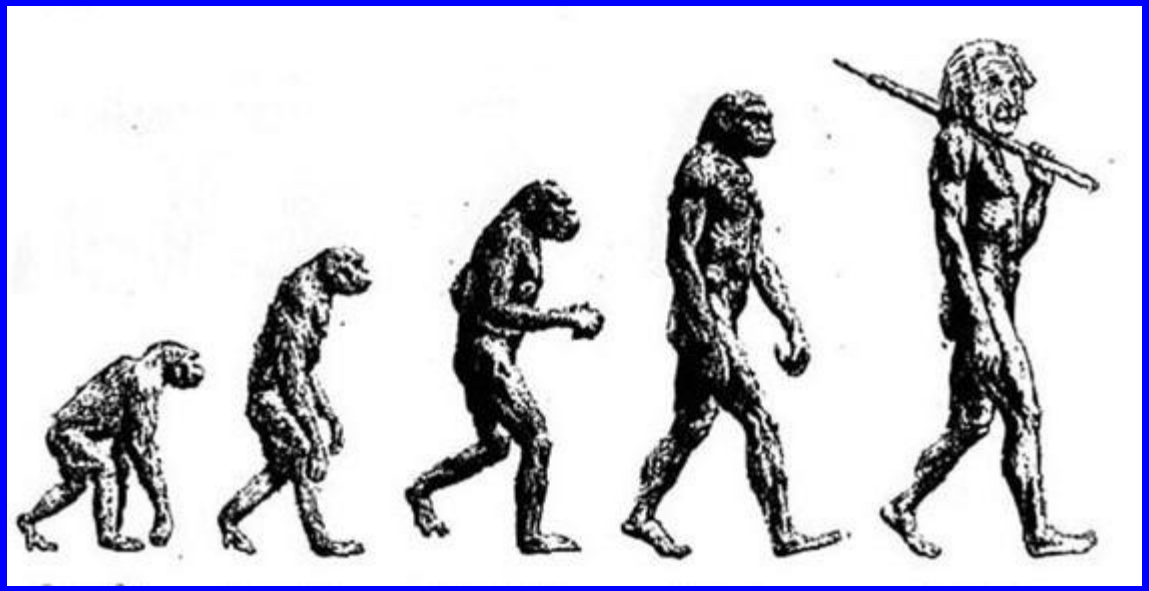
2.Selection: retain successful solutions

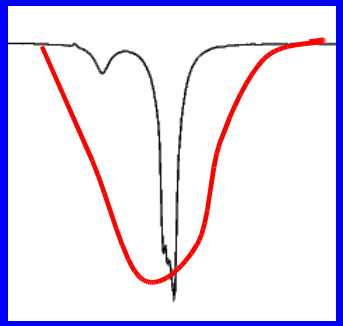
3.Reproduction: deduce potentially better model parameters

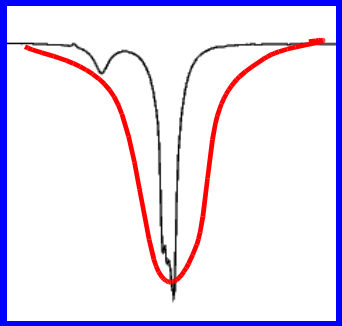
4.Evaluation: compute and evaluate solutions

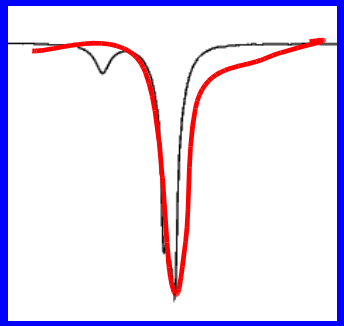
5.Termination: the best solution is satisfactory

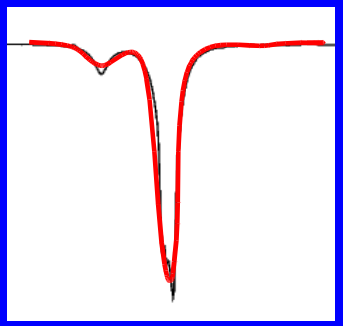
# Optimization technique







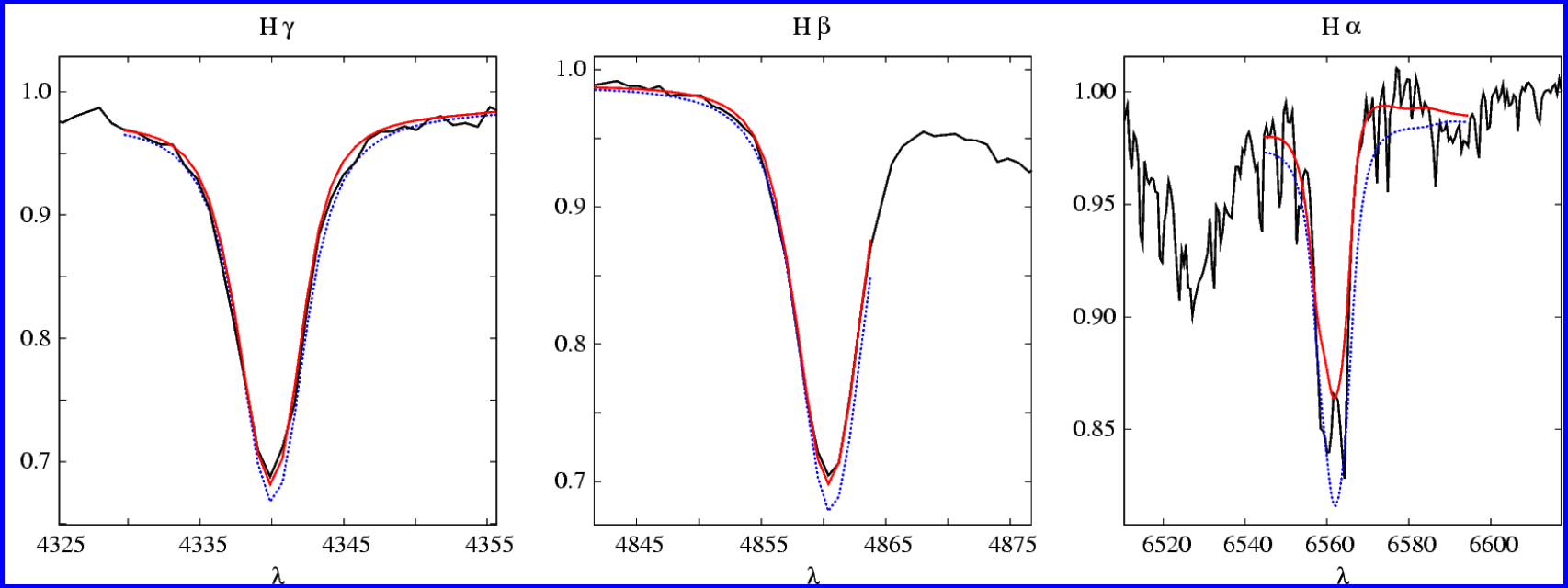




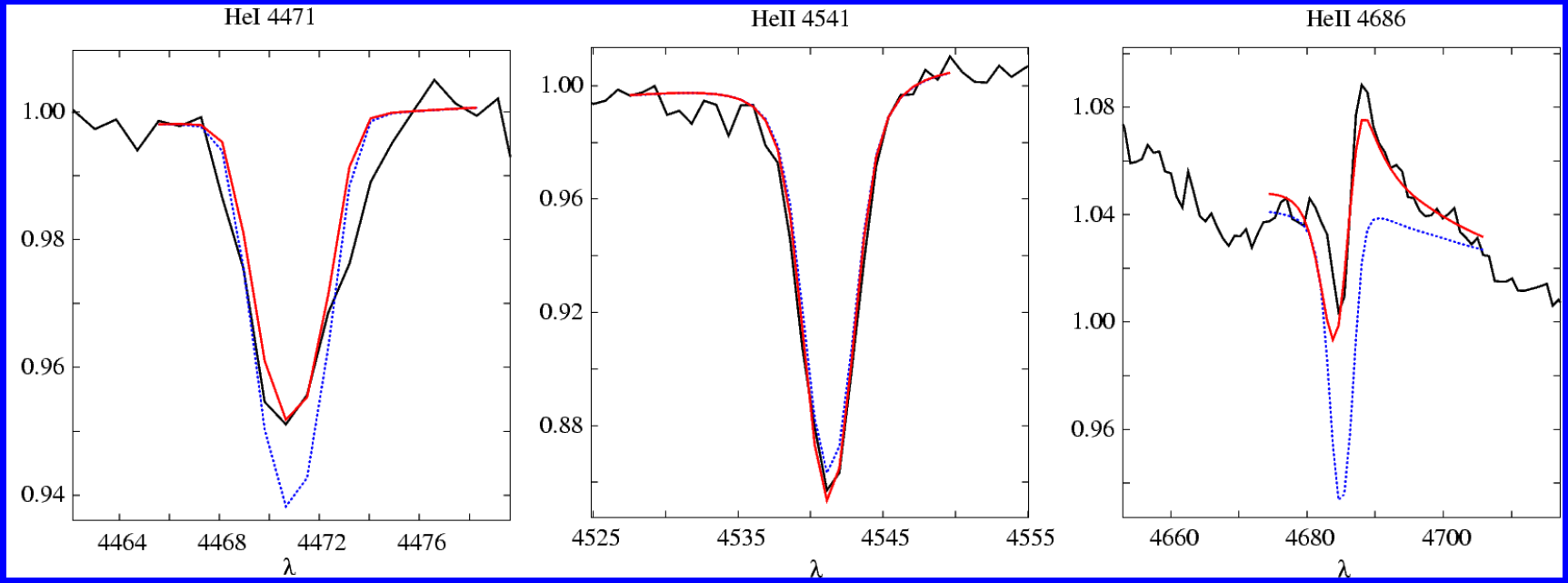
# Basic genetic algorithm

- S

# Cyg OB2 8C O5 If
# Hydrogen lines



# Helium lines



# Encoding: from parameters to gene

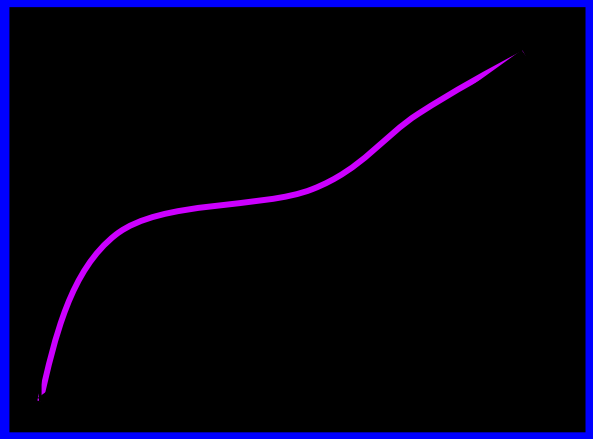
**Bounds of parameters search domain:**

$P_{imin} < P_i < P_{imax}$

**Coding Function:**

$F(P_i)=ph_i$

F(31000K)=0.274396



**Precision required:**

$ph_i$=0.27 (2 digits)

**Choice of gene base:**

2 (computers), 4 (life), 10 (physics)...

$g_i$=27

**PARAMETERS TO GENE**

**(31000K,3.65,10E-8,0.8) ≈ 27421809**

# Reproduction

**Cross parents:**

1, 2 or more cross points

Include complementary kid (base 2)

P1(7395725439)

P2(9243872374)

K1(7393872339)

K2(9245725474)

**Mutate kids:**

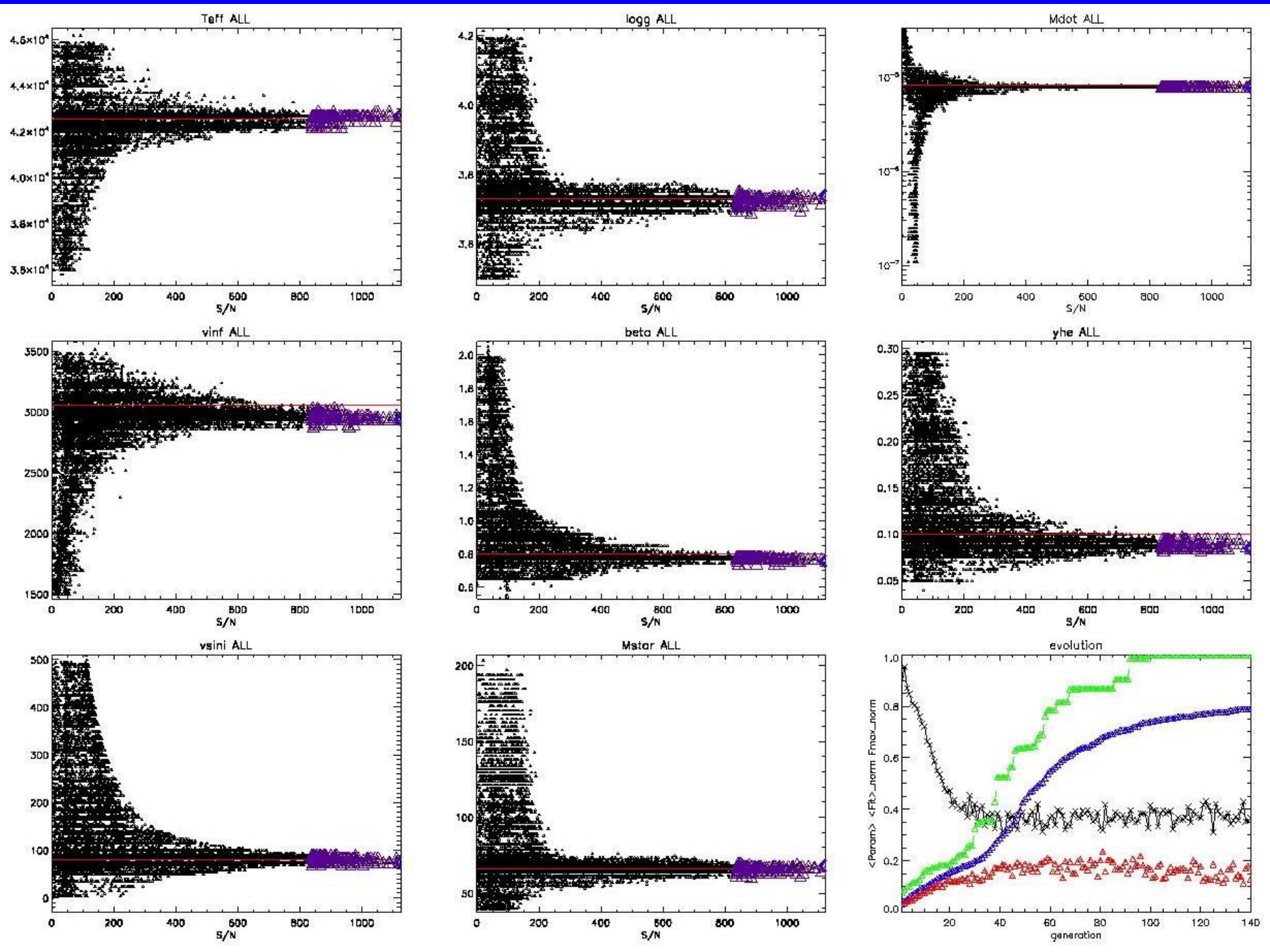
Normal mutation, creep mutation or both

Constant or varying mutation rate

Same or different for each gene locus

K1(7393972340)

K2(9145725874)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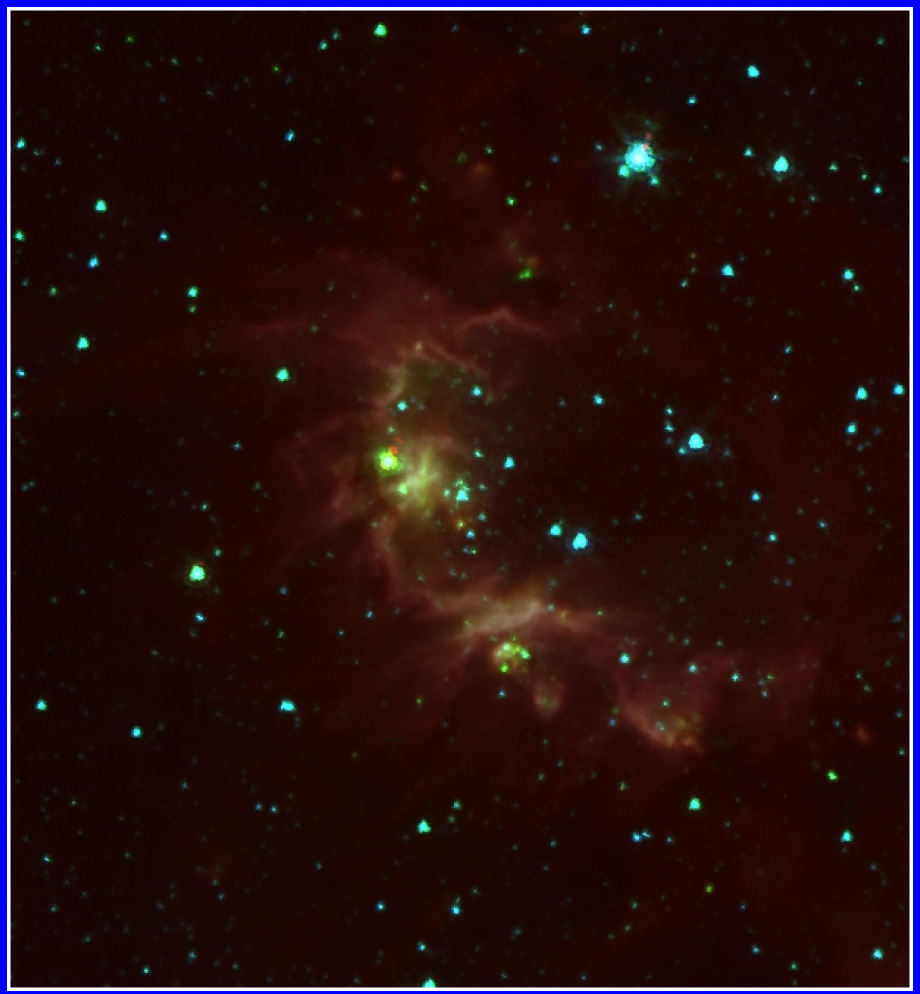
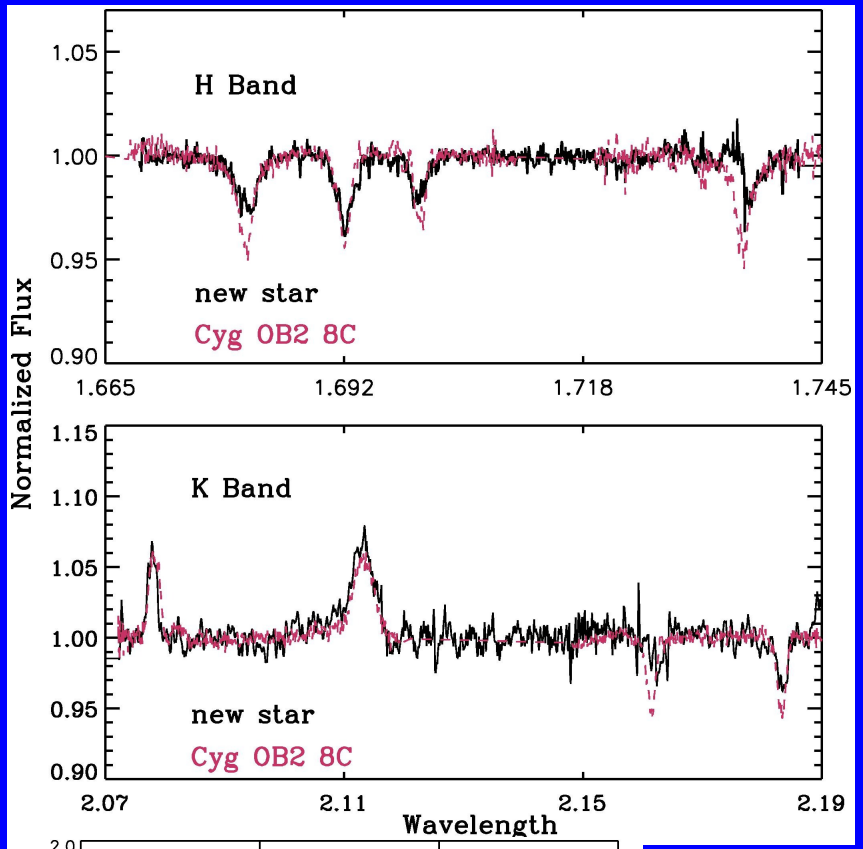
logg ALL
Mdot ALL
vinf ALL
beta ALL
yhe ALL
vsini ALL
Mstar ALL
evolution
S/N
generation
<Param> <Fit>_norm Fmax_norm

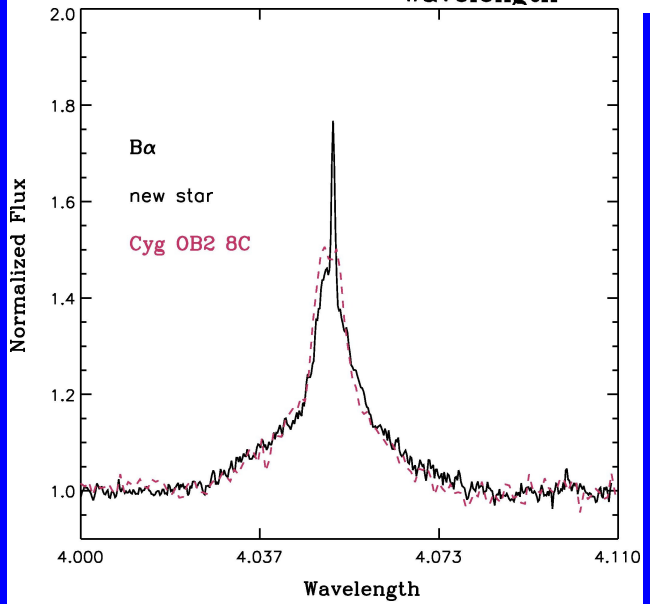
# CESGA PROJECT:

## New Obscured clusters in the Milky Way

Lenorzer et al 2008





# OUR CASE

About 10 parameters coded on 2 digits each: gene length ≈ 20
Model running in 30 min, 50 processors: population size ≈ 100

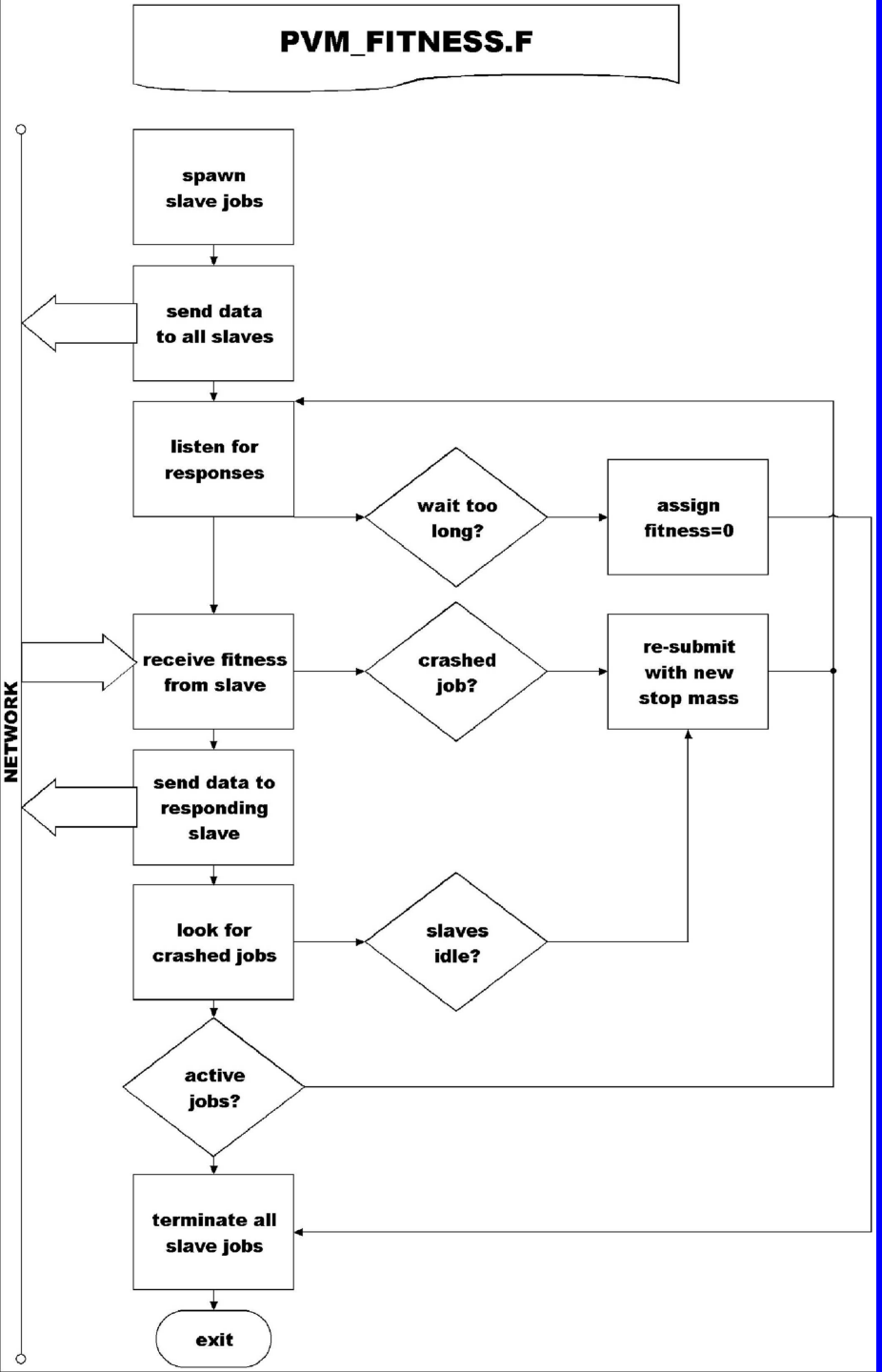
Random search would take <1.E8 generations> for 1 digit accuracy
Need a high selection pressure to be “fast”

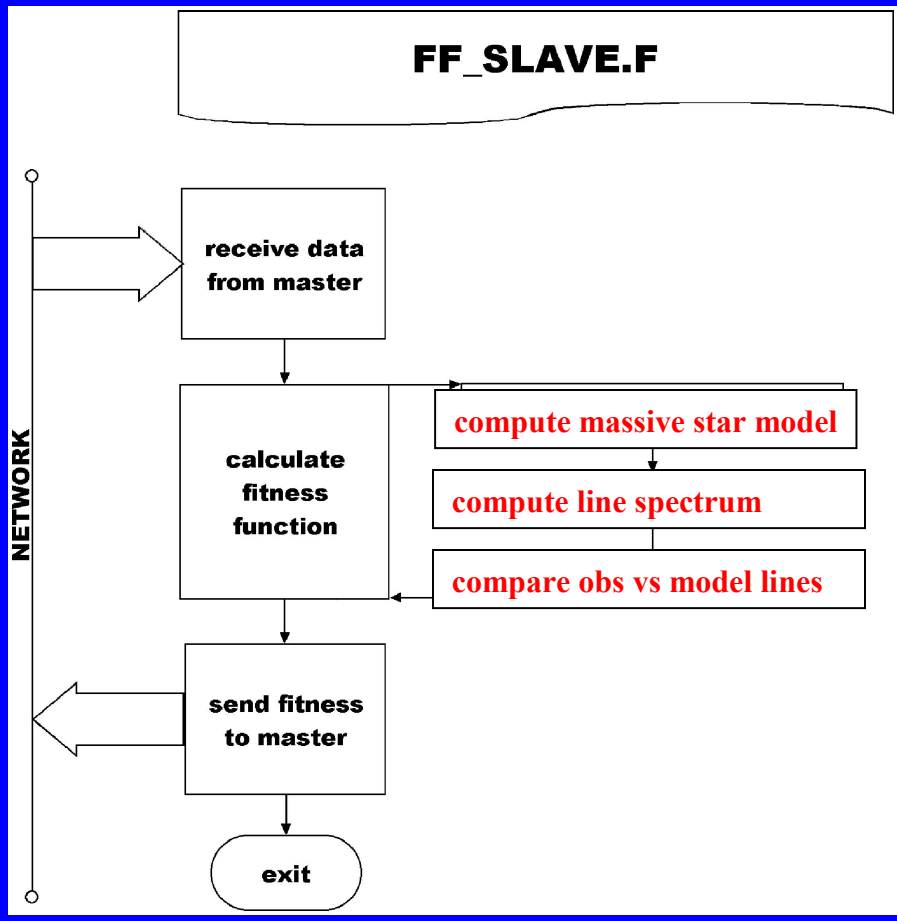
Initial population: each gene value present <pop/base=10 times>
Without mutation all genes are the same after ≈ 50 generations

Mutation needs to be high enough to keep gene diversity
Mutation rate needs to be low enough to allow gene convergence
Uniform mutation ⇨ genetic based adaptative mutation

Mutation rate needs to be low enough to maintain evolution
Full generation replacement ⇨ Steady state replace worst

$$Fgn = Fgn\text{-}1 \times Psel \times (1-Pmut) + Pmut \times pop/base$$


PVM_FITNESS.F
spawn slave jobs
send data to all slaves
listen for responses
wait too long?
assign fitness=0
receive fitness from slave
crashed job?
re-submit with new stop mass
send data to responding slave
look for crashed jobs
slaves idle?
active jobs?
terminate all slave jobs
exit
NETWORK


FF_SLAVE.F
receive data from master
calculate fitness function
compute massive star model
compute line spectrum
compare obs vs model lines
send fitness to master
exit
NETWORK

# Scalability on parallel computers