

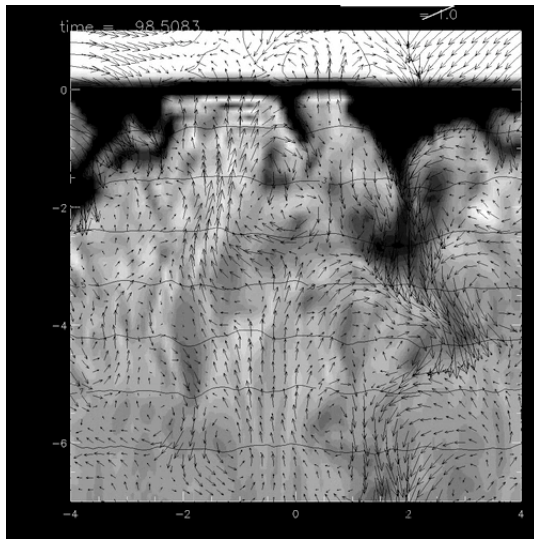
Numerical Simulation

What is numerical simulation?

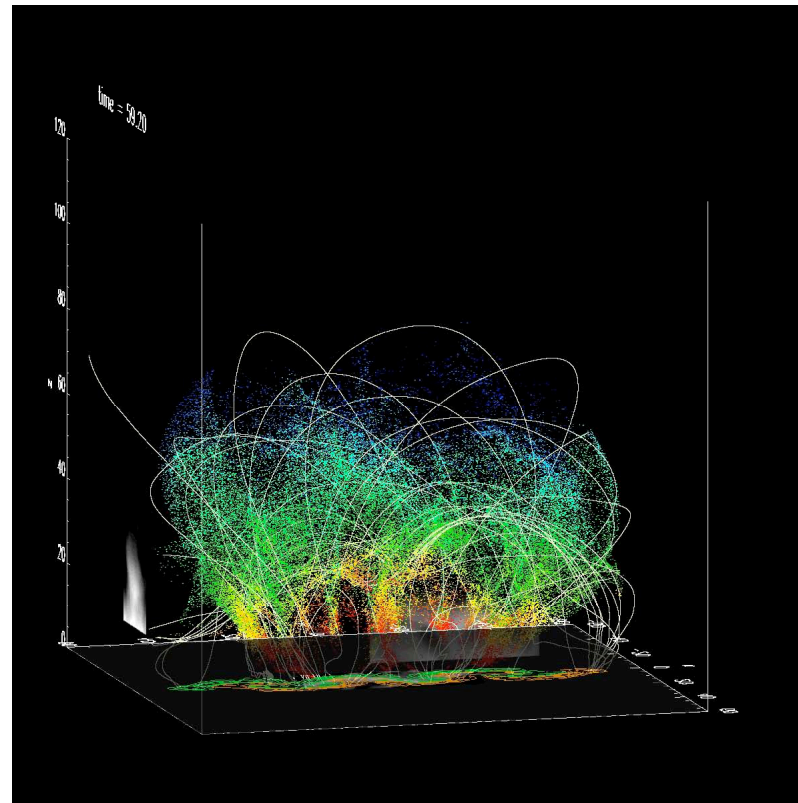
Three key features of the numerical simulation discussed here...

1. Numerical simulation **reproduces physical phenomena evolving in time and space**.
2. Numerical simulation **is performed** in a **computer** according to a **numerical code** written in a **programming language** (e.g. *fortran, c*).
3. Numerical simulation **is based** on **partial differential equations (PDEs)** that **describe temporal & spatial variations** of **physical quantities** such as *density, velocity, pressure, and magnetic field*.

1. Numerical simulation *reproduces physical phenomena evolving in time and space.*



convective motion in solar interior



solar prominence (filament)

2. Numerical simulation *is performed* in a **computer** according to a **numerical code** written in a **programming language** (e.g. *fortran*, *c*).



The **computer** (or a **cluster of computers**) conducts calculations according to the **code**.

submit the **code** to a **computer**

```

hwa4 = 2.*(ah(i-1,j,k,4) - ah(i-1,j,k,4))
+ uz1(j)*uy1(k)*(yah(i,j,k,4) - yah(i-1,j,k,4))
+ uz2(j)*uy1(k)*(yah(i,j,k,4) - yah(i-1,j,k,4))
+ uy2(k)*uz1(j)*(yah(i,j,k,4) - yah(i-1,j,k,4))
+ uz2(j)*uy2(k)*(yah(i,j,k,4) - yah(i-1,j,k,4))

hwa5 = 2.*(ah(i-1,j,k,5) - ah(i-1,j,k,5))
+ uz1(j)*uy1(k)*(yah(i,j,k,5) - yah(i-1,j,k,5))
+ uz2(j)*uy1(k)*(yah(i,j,k,5) - yah(i-1,j,k,5))
+ uy2(k)*uz1(j)*(yah(i,j,k,5) - yah(i-1,j,k,5))
+ uz2(j)*uy2(k)*(yah(i,j,k,5) - yah(i-1,j,k,5))

hwa6 = 2.*(ah(i-1,j,k,6) - ah(i-1,j,k,6))
+ uz1(j)*uy1(k)*(yah(i,j,k,6) - yah(i-1,j,k,6))
+ uz2(j)*uy1(k)*(yah(i,j,k,6) - yah(i-1,j,k,6))
+ uy2(k)*uz1(j)*(yah(i,j,k,6) - yah(i-1,j,k,6))
+ uz2(j)*uy2(k)*(yah(i,j,k,6) - yah(i-1,j,k,6))

hwa7 = 2.*(ah(i-1,j,k,7) - ah(i-1,j,k,7))
+ uz1(j)*uy1(k)*(yah(i,j,k,7) - yah(i-1,j,k,7))
+ uz2(j)*uy1(k)*(yah(i,j,k,7) - yah(i-1,j,k,7))
+ uy2(k)*uz1(j)*(yah(i,j,k,7) - yah(i-1,j,k,7))
+ uz2(j)*uy2(k)*(yah(i,j,k,7) - yah(i-1,j,k,7))

hwa8 = 2.*(ah(i-1,j,k,8) - ah(i-1,j,k,8))
+ uz1(j)*uy1(k)*(yah(i,j,k,8) - yah(i-1,j,k,8))
+ uz2(j)*uy1(k)*(yah(i,j,k,8) - yah(i-1,j,k,8))
+ uy2(k)*uz1(j)*(yah(i,j,k,8) - yah(i-1,j,k,8))
+ uz2(j)*uy2(k)*(yah(i,j,k,8) - yah(i-1,j,k,8))

gwa1 = 2.*(ag(i,j-1,k,1) - ag(i,j-1,k,1))
+ ur1(i)*uy1(k)*(yag(i,j,k,1) - yag(i,j-1,k,1))
+ ur2(i)*uy1(k)*(yag(i,j,k,1) - yag(i,j-1,k,1))
+ ur1(i)*uy2(k)*(yag(i,j,k,1) - yag(i,j-1,k,1))
+ ur2(i)*uy2(k)*(yag(i,j,k,1) - yag(i,j-1,k,1))

gwa2 = 2.*(ag(i,j-1,k,2) - ag(i,j-1,k,2))
+ ur1(i)*uy1(k)*(yag(i,j,k,2) - yag(i,j-1,k,2))
+ ur2(i)*uy1(k)*(yag(i,j,k,2) - yag(i,j-1,k,2))
+ ur1(i)*uy2(k)*(yag(i,j,k,2) - yag(i,j-1,k,2))
+ ur2(i)*uy2(k)*(yag(i,j,k,2) - yag(i,j-1,k,2))

```

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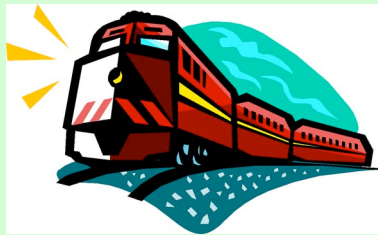
numerical code written in fortran

Why fortran?

Among various programing languages, **fortran** (**f**ormula **t**ranslation) is relatively old.
Then *why do we use it for numerical simulations?*

In fact, fortran is like the **train**, compared to other modern programing languages like the **car**.

fortran



Long history (train: since 16th century)

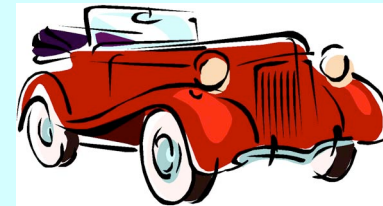
Disadvantages: **less flexible, less controllable, less interactive**

Advantage: **very fast** (for arithmetic operations)



numerical simulation, any program based on arithmetic operations

c, c++, Python, etc.



Short history (car: since 18th century)

Advantages: **more flexible, more controllable, more interactive**

Disadvantage: **relatively slow**



data analysis, instrument control, application program, OS