The surface of the Sun is hot!
(~ 6000 K)
The surface of the Sun is hot!
(\(\sim 6000 \text{ K}\))

The atmosphere of the Sun is even hotter!
(\(\sim 1,000,000 \text{ K}\))

Why?
<table>
<thead>
<tr>
<th>Question</th>
<th>Hypothesis</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>Why is the Sun’s atmosphere so hot?</td>
<td>Is heating correlated with magnetic field strength?</td>
<td>Model the magnetic field</td>
</tr>
</tbody>
</table>

As a scientist, I’m paid to do these
Why is the Sun’s atmosphere so hot?

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Model the magnetic field using Python converted to byte code run on a C virtual machine compiled to machine code that runs on transistors made from atoms that obey quantum mechanics...

Question

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that obey quantum mechanics

...

Layers

The layer below what we’re doing are tools

They layer above what we’re doing is motivation
Layers

Is heating correlated with magnetic field strength?

Model the magnetic field

Research software goes here

using Python

• When is it worth adding another layer?
• It takes time/effort to make software
• Key question: Will adding a layer be a net time saving in the future?

• Take into account time taken to write, maintain
• Take into account how widely it will be used
The state in 2017

- 816 citations for original method paper (published 1969)
- A Python implementation is released in 2017 🎉
- 1 function, ~250 line script
- Well documented
- But, no
  - Examples, tests, input data cleaning, integration w/ other packages

https://github.com/antyeates1983/pfss
The state in 2021

- A full blown python package
- 11 files, 3039 lines of code
- 11 examples
- 1 paper in Journal of Open Source Software
- Full integration with astropy, sunpy
- An excellent distraction from my thesis

pfsspy.readthedocs.io

So, what did I add, and why?
Versioning + changelog

0.5.0

Changes to outputted maps

This release largely sees a transition to leveraging Sunpy Map objects. As such, the following changes have been made:

```python
pfspp.Input now must take a sunpy.map.GenericMap as an input boundary condition (as opposed to a numpy array). To convert a numpy array to a GenericMap, the helper function
pfspp.carr_cea WCS header can be used:
```

```python
map_date = datetime(...) br = np.array(...) header = pfspp.carr_cea_wcs_header(map_date, br.shape)
```

```python
n = sunpy.map.Map(br, header)
pfspp_input = pfspp.Input[n, ...]
```

```python
pfspp.Output.source_surface.br now returns a GenericMap instead of an array. To get the data array use source_surface_br.data.
```

The new pfspp.Output.source_surface.plis returns the coordinates of the polarity inversion lines on the source surface.

In favour of directly using the plotting functionality built into SunPy, the following plotting functionality has been removed:

- pfspp.Input.plot_input. Instead Input has a new map property, which returns a SunPy map, which can easily be plotted using sunpy.map.GenericMap.plot
- pfspp.Output.plot source_surface. A map of Bz, on the source surface can now be obtained using pfspp.Output.source_surface.br, which again returns a SunPy map.


Allows users to stick to one version for reproducibility

Tell users exactly why to update, how to update
Examples

Using pfsspy

Reduces barrier to use

Gives a recipe that users can adapt for their situation

The best introduction to a package

Gives you confidence that your package is doing what you expect!

Package

Gives users a common method to install and use code

Aids reproducibility

pfsspy 0.6.6

pip install pfsspy

Released: Jan 31, 2021

"Potential field source surface modelling"
### Documented API

**Input**

```python
class pfsspy.Input(br, nr, rss)

Bases: object

Input to PFSS modelling.
```

- **Warning**
  
  The input must be on a regularly spaced grid in $\phi$ and $s = \cos(\theta)$. See `pfsspy.grid` for more information on the coordinate system.

**Parameters:**

- `br (sunpy.map.GenericMap)` – Boundary condition of radial magnetic field at the inner surface. Note that the data must have a cylindrical equal area projection.
- `nr (int) ` – Number of cells in the radial direction to calculate the PFSS solution on.
- `rss (float)` – Radius of the source surface, as a fraction of the solar radius.

**Attributes Summary**

```python
<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>map</td>
<td>sunpy.map.GenericMap</td>
<td>representation of the input.</td>
</tr>
</tbody>
</table>
```

**Attributes Documentation**

```python
map

sunpy.map.GenericMap representation of the input.
```
Ensures package is working as intended

Makes sure you don’t break your API...

...or if you do, it is intended and understood
Components of a research package

In order of importance:

- Exists
- Versioned
- Changelog
- Examples
- Package
- API docs
- Tests

These aid both **usability** and **reproducibility**

What skills do you need to do this, and how to develop them?
Back to layers

Answer science question  Motivation

Test a hypothesis

Using domain specific software  Tool

Scientist is paid to

• Too add a layer, you have to know about layer above (motivation) and layer below (tools)

• Move towards Research Software Engineers (RSEs), who are experts in tools

• …but scientists are experts in motivation

› Teach scientists about tools

› Teach RSEs about motivation
So was pfsspy successful?

• Used in 18 papers (and counting!)

• Critical for interpreting results from Parker Solar Probe, NASA’s $2bn mission to “Touch the Sun”

• It took a lot of unfunded work to get here; I was lucky to have time and flexibility

• I think unique position as both scientist and software engineer helped make package useable for a wide community
Successful research software

- Performs a specific task (not one hypothesis or question)
- Performs a widely used task

In order of importance:
- Exists
- Versioned
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- Need to nurture (and ideally teach) these practices at PhD level
- Recognise that s/w development improves research efficiency
- Good steps being taken by NASA in US and UKRI/EPSRC in UK