

# AST5770

Solar and stellar physics

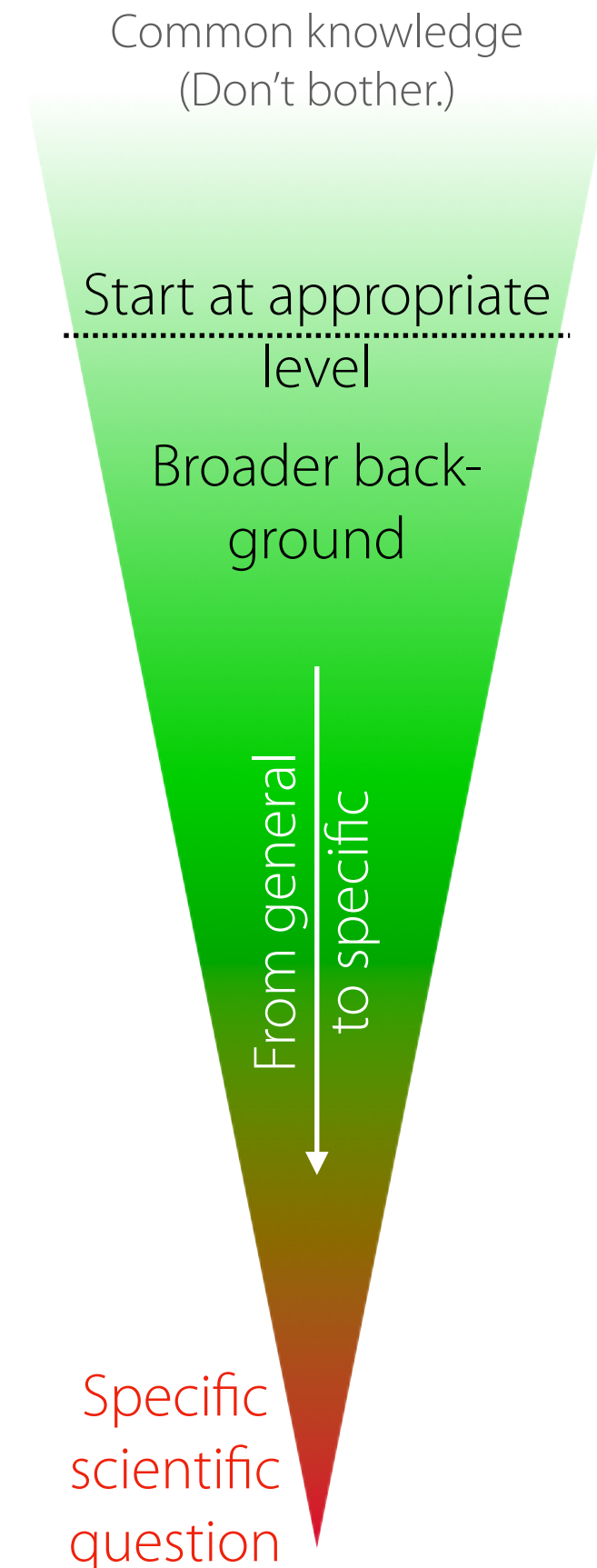
Sven Wedemeyer, University of Oslo, 2026

# Scientific writing

# Introduction and background

## Structure

- **From general to specific — Tell a (logical) “story”.**
  - Start with the general topic and cite papers with general results (finding good review articles may help here)
  - Narrow down towards the specific topic/question of your paper and cite papers that are directly related to your work
- Make sure to mention the following
  - **Motivation:** What is new here and/or why was it necessary to do this study?
    - New method or observational opportunity/better data?
    - Shortcoming in previous research (knowledge gap) that is filled now?
  - Outline your **methodology**/approach including any important (“top level”) assumption that is made (but not all details)
  - Possible restrictions/limitations of the results/conclusions
- Optionally, end with an overview of the different sections, describing each with 1-2 sentences



# Introduction and background

## How to do it?

### Gather information

#### Start reading literature and take notes

- Try to **note** important statements that are **relevant** for your science question and clearly connect them to the source you got them from
- It might be difficult to separate the most relevant from less relevant in the beginning but not get tempted to note all details.
- Look for **references** that are made in these papers that are most relevant for science question.
- Retrieve these new publications and read.

### Connect & filter

Make a **mind map** (or some other helpful way) to organise the retrieved information

Try to create a **“red thread”** that connects the most relevant information starting from the general background to your specific science question  
(You can start by ordering keywords in your latex doc).

Now fill in the relevant information bits in more **detail** in your own words with **references**

- Do not care about language yet. Do not stop if you don't remember the English word, just use the Norwegian one for now.

### Write

**Order the content:** First, work on the individual passages and move them around until they match your wanted “red thread”. Remove text that seems to be irrelevant/does not fit.

**Language editing:** Start from the beginning of the text and rewrite in a consistent way, sentence by sentence. Repeat as often as needed.

# Results and beyond

## Figures

- **Readability:** Make sure that all graphical elements and text are clearly visible/readable.
  - Line thickness, image resolution, labels
  - Font size not too small, best about the same as in the figure caption (must be clearly readable) — Careful: Check this once it is in your document as the figure might be scaled.
  - Number and size of major and minor ticks
- Meaningful axis ranges (round numbers, fill the frame), linear/log scale
- **Do not overload figures** (do not plot too many different quantities)
  - Consider splitting figures into panels or repeating them on a linear or log/log scale or different axis ranges or different subsets — Whatever makes most sense when describing the results in the text.
- Make sure **all quantities can be distinguished**.
  - If two lines are essentially identical so that only one is visible, try different line styles (one solid, one dashed?), colors, etc. to make both visible
  - Provide a legend if you use many symbols (either in plot and/or in caption)

# Results and beyond

## Tables

- **When to use a table?**

- Many numbers that cannot be presented in a meaningful figure.
- Exact numbers are needed (which is difficult to infer from a figure).  
Can be in addition to figure.
- Overview over data properties, especially when several sets are used.

- **Note:**

- Figures are easier to interpret than tables.
- Tables need a caption that explains all content.
- The table must be referred to in the text (in the order of them being first referred to in the text).

**Table 3.** Average contrast  $\delta I_{\text{rms}}$  and standard deviation of the original and the deconvolved disc-centre observations in comparison with the synthetic images.

| $\delta I_{\text{rms}}$ | $\lambda$   |           |           |           |           |           |
|-------------------------|-------------|-----------|-----------|-----------|-----------|-----------|
| [%]                     | 450.45 nm   |           | 555.00 nm |           | 668.40 nm |           |
|                         | observation |           |           |           |           |           |
| original                | 12.8        | $\pm 0.5$ | 8.3       | $\pm 0.4$ | 6.2       | $\pm 0.2$ |
| ideal PSF               | 18.0        | $\pm 0.8$ | 12.3      | $\pm 0.8$ | 9.9       | $\pm 0.4$ |
| full PSF                | 26.7        | $\pm 1.3$ | 19.4      | $\pm 1.4$ | 16.6      | $\pm 0.7$ |

# **Discussion + Conclusions (Assignment V)**

# Assignment #5

## Discussion — Conclusion

*Sometimes discussion & conclusions are combined in one section.  
Not for you here! ;-)*

| Results                                                                                                                                                                                                                                                                                             | Discussion                                                                                                                                                                                                                                       | Conclusion                                                                                                                                                              |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"> <li>Detailed but yet focused <b>description</b> of the <b>new results</b> found in this study</li> <li>Thorough analysis of the introduced data, using the introduced methods</li> <li>Results presented with good figures (and tables if applicable)</li> </ul> | <ul style="list-style-type: none"> <li><b>Interpretation</b> of the new results (described in the previous section), setting them into <b>context</b> / comparing them to results in the literature (and possibly complementary data)</li> </ul> | <ul style="list-style-type: none"> <li>The <b>essence</b> and take-away message</li> <li><b>Brief</b> summary of the most important results and conclusions!</li> </ul> |
| <b>Avoid details and repetitions!</b>                                                                                                                                                                           |                                                                                                                                                                                                                                                  |                                                                                                                                                                         |

- Be **thorough but still focused on the main results of your analysis**
- **Discussion based on the material you presented in the previous sections!**
- Possible questions to address:
  - Are these results expected in comparison of published results? Or do they contradict? If so, why? And what are the implications? How do your results change the field?
  - How could your results inform future observations/models?
  - What are the limitations of your study (due to data accuracy, methods, assumptions)? And how could they impact your results?

# Assignment #5

## Discussion — Conclusion

- **Discussing and drawing conclusions**
  - Use logic! Think of a court case:
    - ➡ How do you present and defend your results?
    - ➡ You need robust evidence for any statement you make (e.g., in form of a supporting reference) or a solid result of your analysis
    - ➡ No handwaving or vague statements!
- **Conclusion section:**
  - NOT a detailed summary but only a very **brief** presentation of the **essence**
  - Only repeat the main aspects of your main results but not in all detail.
  - Avoid too many details and focus on the main message(s)!
- **Note:** You may find this difficult to write as it requires some knowledge of the literature and experience. That's why it is important to practise! ;-)

# Assignment #5

## Abstract

- **Purpose**

- The abstract is a brief summary of the paper (usually one paragraph).
- Contains the essence !

- **Length**

- Usually: ~ 5% of total length of the whole paper but max. 200 words
- *Some journals may have specific limits.*

- **Format**

- The abstract stands for itself.
  - ➡ No figures, no tables, no footnotes, no references to other places in the paper!
  - ➡ Avoid if possible references to other papers (*some journals do not allow them at all*).  
Exception: if paper mainly checks results of another paper
- Keep abbreviations, equations and symbols to a minimum
- As always: Write concise and clear sentences. (Split too long sentences!)
- *Some journals (e.g., Astronomy & Astrophysics) offer structured abstracts (with headings like context, aim, method, ...)*

# Assignment #5

## Abstract

- **Structure**

- Follows the structure of the paper and summarises the most important parts at each step.
- Typical structure:
  - **Context** (wider scientific topic/question), typically 1-2 sentences, sometimes dropped.
  - **Aim:** What is the intention of your paper? What scientific question do you address? What does this paper try to prove/disprove?
  - **Method:** x A brief summary of the most important data and methods used in this study. What observatories/instruments? Which spectral line? But not too many details, essence only!
  - **Results:** What are the most important results of your analysis? Brief summary!
  - **Conclusion:** What do you conclude? The major message of the paper! Can also point out limitations, need for further studies. May contain an outlook if meaningful.

- **For assignment #5:** First draft of abstract in form of bullet points is sufficient  
*(but write full sentences if you like and want to receive early feedback.)*

# Assignment #5

## Consistency check

- **Once written** — check that discussion, conclusion and abstract are consistent
  - Is there any important information in the conclusion that is missing in the abstract?
  - Any information given in the conclusion and abstract must stem/connect to other parts in the paper. (You must not add new/additional information only in the abstract!)
  - Have you mentioned the main results and conclusions in the abstract?
- **For the final assignment:** Apply such a consistency check to the whole paper.

# Language and style

# Language and style

## Useful words and phrases

### Contrasts and alternatives:

|                           |              |                       |                |
|---------------------------|--------------|-----------------------|----------------|
| all the same              | surprisingly | <i>even though</i>    | nonetheless    |
| alternatively             | even though  | however               | rather (than)  |
| <i>although</i>           | but          | in comparison         | still (infml)  |
| apart from that           | still        | in contrast to + noun | <i>though</i>  |
| by contrast               | in spite of  | instead (of ...)      | though (infml) |
| conversely                | whereas      | on the contrary       | <i>while</i>   |
| despite the fact that ... |              | on the other hand     | yet            |
| even so                   |              | nevertheless          |                |

### Indicating a cause: (cause and effect)

|                  |              |            |              |
|------------------|--------------|------------|--------------|
| accordingly      | consequently | thereby    | <i>since</i> |
| as a consequence | <i>for</i>   | due to     | so (infml)   |
| as a result      | hence        | owing to   | therefore    |
| <i>because</i>   | owing to ... | leading to | thus         |

### Ordering points:

|          |            |         |                  |               |
|----------|------------|---------|------------------|---------------|
| first    | next       | thirdly | as the next step | in conclusion |
| second   | now        | then    | after            | in summary    |
| secondly | continuing | finally | before           | to summarise  |
| third    | further    | lastly  |                  | to sum up     |

# Language and style

## Useful words and phrases

### Emphasis:

above all  
actually  
as a matter of fact  
in actuality  
in fact

essentially  
Primarily  
indeed  
in particular  
let alone  
naturally (infml)  
of course

interestingly  
Most important  
specifically  
surely  
to put it mildly  
to say the least  
without exception

### Modifying a statement: (some: confirming a statement)

according to ...  
as a rule  
by all accounts  
for the most part  
generally  
in general  
in most cases  
in practice

in principle  
in theory  
theoretically  
to some degree  
to some extent  
to the best of my  
knowledge  
in accordance with

typically  
usually  
traditionally  
normally  
naturally  
clearly  
ideally  
confirms

### Continuation of explanation

In this context  
In this perspective

In this connection  
In connection with

In this respect  
Here

# Language and style

## Useful words and phrases

### Examples

|                   |                   |                    |         |
|-------------------|-------------------|--------------------|---------|
| for example       | for instance      | as shown by        | like    |
| as exemplified by | as illustrated by | as an illustration | such as |
| e.g.              | shown by          |                    |         |

### Reintroducing and comparing

|                    |                 |               |
|--------------------|-----------------|---------------|
| in connection with | regarding       | for           |
| focusing on        | with respect to | compared with |
| in comparison with | with regard to  | relative to   |

### Conditional

|              |               |          |          |
|--------------|---------------|----------|----------|
| In that case | otherwise     | given    | until    |
| given that   | provided that | now that | if       |
| once that    | as long as    | while    | now that |

### Generalisation

|            |                      |                    |
|------------|----------------------|--------------------|
| In general | in a broader context | generally speaking |
|------------|----------------------|--------------------|

# Language and style

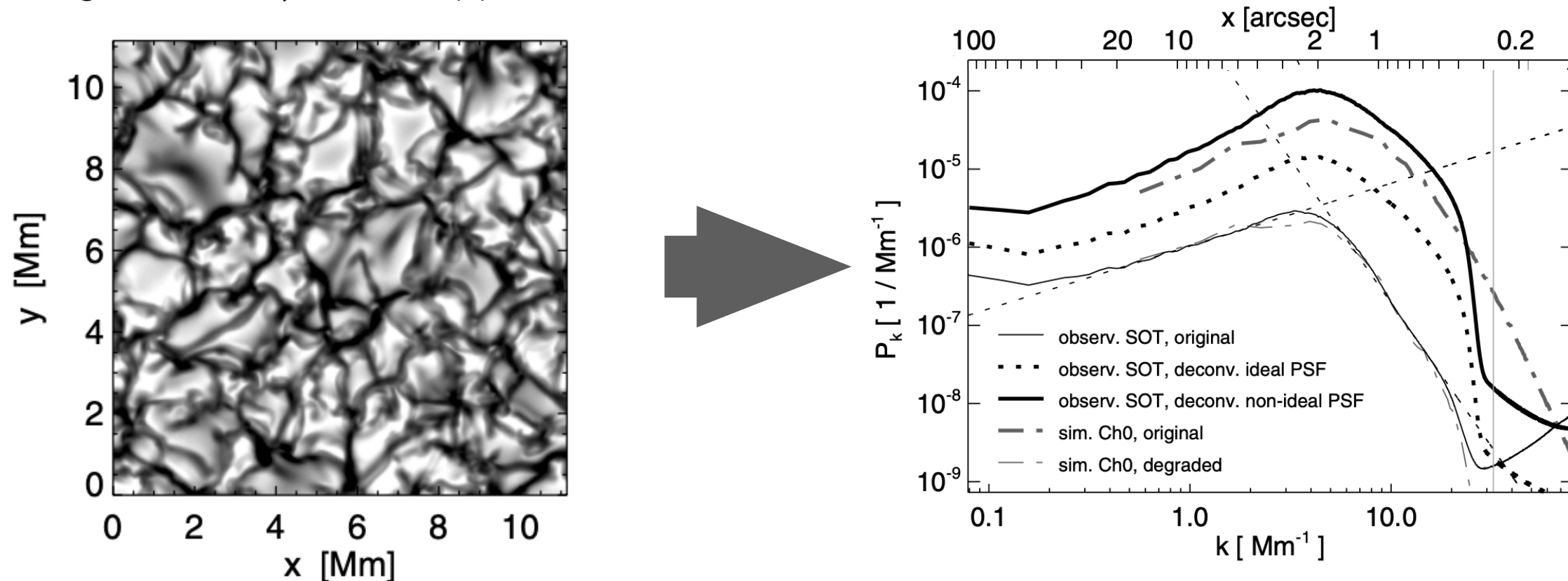
## BUT...

- Be careful and do not add too many words that do not mean anything and have no purpose.
- Ok to use connectors when it improves the “reading flow”.
- Takes practice and repetition ...
- **Scientific articles must be concise and precise!**

# Data analysis — Power spectrum

# Power spectrum

- Useful for analysing temporal and spatial scales
- Example: Spatial power spectrum to quantify the dominant spatial scale (due to granulation)
- See (e.g.) Wedemeyer & Rouppe van der Voort, A&A 503, 225–239 (2009)



- How to collapse two spatial dimensions into one?
- $[x, y] \rightarrow [k_x, k_y] \rightarrow k$  (radial wavenumber)

$$k = \sqrt{k_x^2 + k_y^2} = 2\pi \sqrt{L_x^{-2} + L_y^{-2}},$$

$L_x$  and  $L_y$ : spatial wavelengths in x- and y- direction.

# Power spectrum

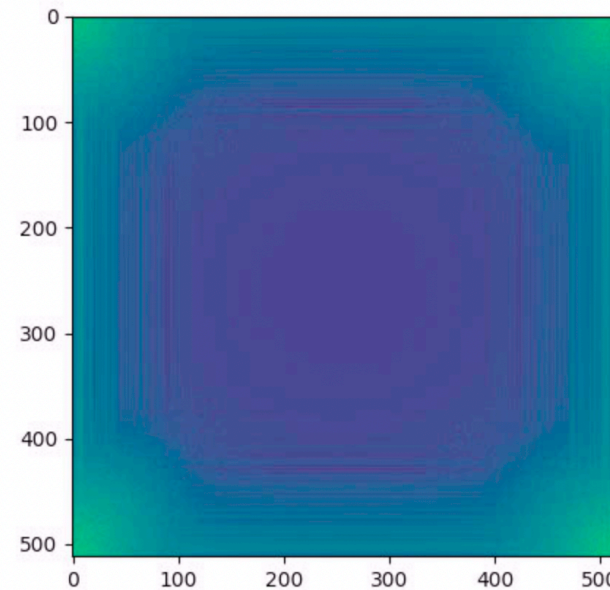
```
datafile='/mn/stornext/d19/RoCS/svenwe/lecture/AST5770/data/obssun_sst1/obssun_sst1.h5'
```

```
obssun = h5py.File(datafile, 'r')
intens = hf['intensity'][:]
```

```
x = hf['x'][:]  
y = hf['y'][:]
```

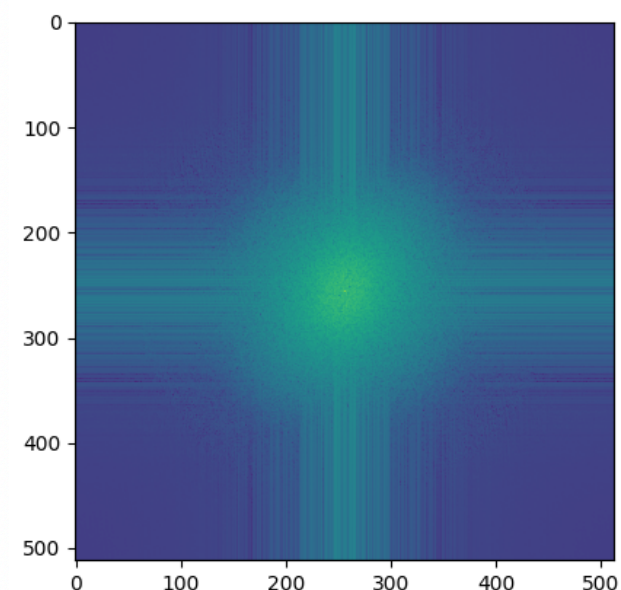
```
image=intens[0,0,:,:]
```

```
ftsq = np.abs(np.fft.fft2(image))**2  
plt.imshow(np.log10(ftsq))  
plt.show()
```



Needs to be shifted by half the array size.

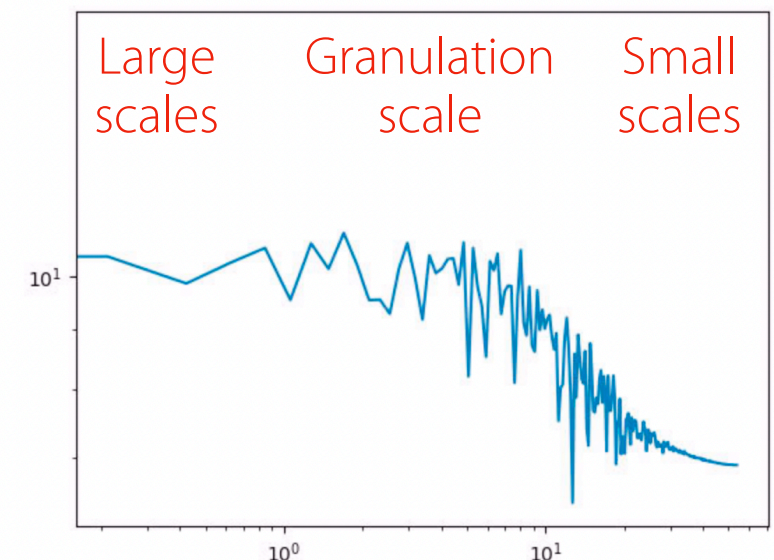
```
ftsq = np.abs(np.fft.fftshift(np.fft.fft2(image))**2  
plt.imshow(np.log10(ftsq))  
plt.show()
```



Test: Plotting only the central horizontal row (half)

```
nx = np.shape(intens)[2]  
kx = np.fft.fftfreq(nx, d=(x[1]-x[0]))*(2*np.pi)  
kx = np.fft.fftshift(kx)
```

```
plt.loglog(kx[256:], np.log10(ftsq[256:, 256]))  
plt.show()
```



# Power spectrum

Now: Integrate over rings — Define a function for this purpose

```
def azavg(image, center=None):
    """
    Calculate the azimuthally averaged radial profile.

    image - The 2D image
    center - The [x,y] pixel coordinates used as the center.

    """
    # Calculate the indices from the image
    y, x = np.indices(image.shape)

    if not center:
        center = np.array([(x.max()-x.min())/2.0, (x.max()-x.min())/2.0])

    r = np.hypot(x - center[0], y - center[1])

    # Get sorted radii
    # r.flat is the 1d indexed r-matrix
    ind = np.argsort(r.flat) # This returns the indexes of the flat, sorted r-array
    r_sorted = r.flat[ind] # This makes a sorted and flat version of r
    i_sorted = image.flat[ind] # This makes the r-sorted image (flat)

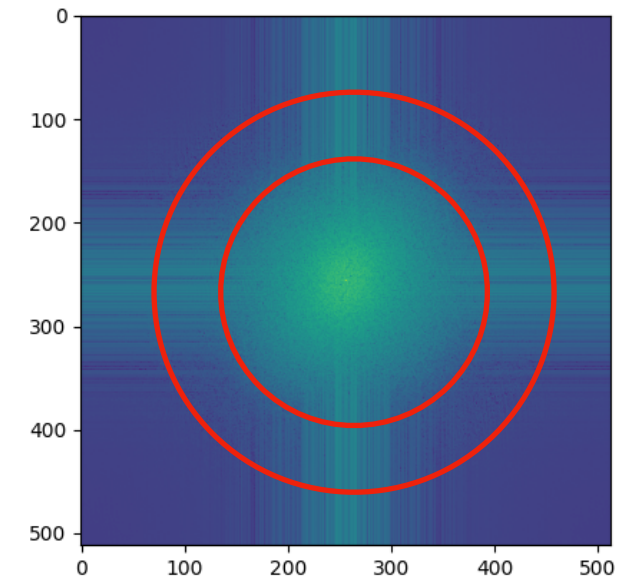
    # Now we have two 1d arrays of the values and corresponding radii, sorted after the radii

    # Get the integer part of the radii (bin size = 1)
    r_int = r_sorted.astype(int)

    # Find all pixels that fall within each radial bin.
    deltar = r_int[1:] - r_int[:-1] # Assumes all radii represented
    rind = np.where(deltar)[0] # location of changed radius
    nr = rind[1:] - rind[:-1] # number of radius bin
    #('number of radii bin', nr)

    # Cumulative sum to figure out sums for each radius bin
    csim = np.cumsum(i_sorted, dtype=float)
    tbin = csim[rind[1:]] - csim[rind[:-1]]

    radial_prof = tbin / nr
    return radial_prof
```

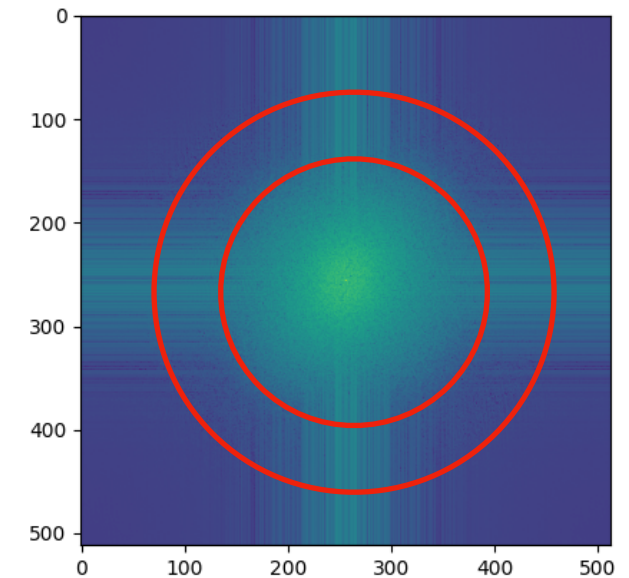
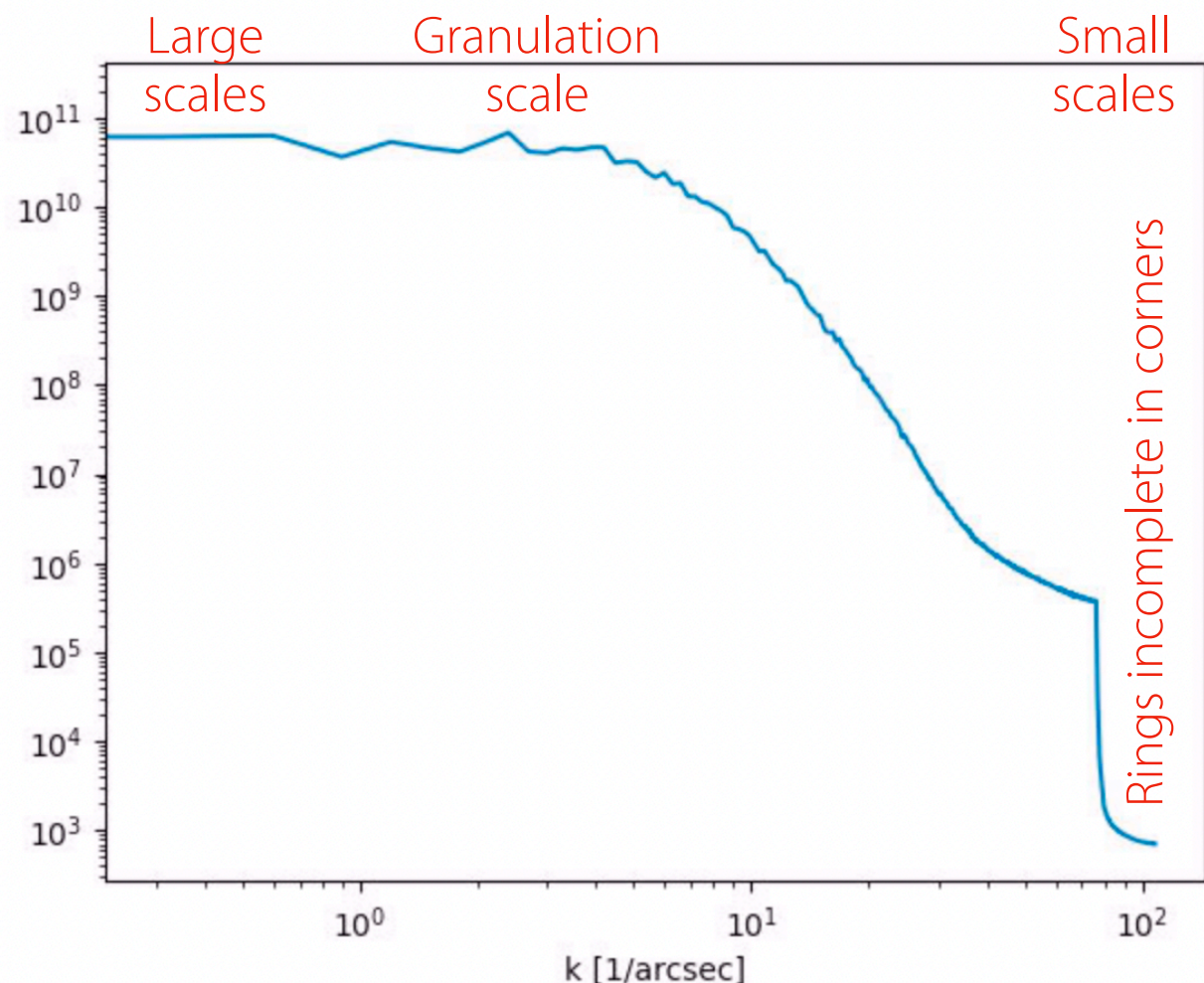


# Power spectrum

Now: Integrate

```
ft_az = azavg(ftsqr)
dx = (x[-1]-x[0])
dy = (y[-1]-y[0])
k = np.arange(len(ft_az))*2*np.pi*np.sqrt(1/dx**2 + 1/dy**2)
```

```
plt.plot(k, ft_az)
plt.xscale('log')
plt.yscale('log')
plt.xlabel('k [1/arcsec]')
plt.show()
```



- Power spectral density often shown in arbitrary units (often sufficient)
- More meaningful normalisation via Parseval theorem:

$$\int P_k dk' = (\delta I_{\text{rms}})^2$$