**Schedule for the PyaR (Python and Research) tutorial – India, Fall 2018**

Google drive link containing a compilation of PyaR tutorial materials

(courtesy of Philip Cherian, Ashoka University teaching fellow):

[**https://drive.google.com/open?id=1XaxSQ\_2\_lNgaTxlwC8si9PQ93d35RERa**](https://drive.google.com/open?id=1XaxSQ_2_lNgaTxlwC8si9PQ93d35RERa)

PyaR tutorial website: [**http://www.ucolick.org/~raja/rm4/Astro/**](http://www.ucolick.org/~raja/rm4/Astro/)

Zoom conference link: [**https://ucsc.zoom.us/j/985270755**](https://ucsc.zoom.us/j/985270755) (same link for all four sessions)

PyaR Slack #general channel link: [**https://pyar-workshop.slack.com/messages/CDMR8FZAQ/**](https://pyar-workshop.slack.com/messages/CDMR8FZAQ/)

Session details:

* Session 0: **Friday, November 9, 2018; 8–10 PM IST (6:30–8:30 AM PST)**
  + This is a *pre-tutorial* session (mostly for Ashoka University students, but others are welcome to call in) for participants to: (1) check in about installing Anaconda Python 3.6 or 3.7 on their computers, and (2) test the use of Zoom and Slack.

Summary of Session 0 (courtesy of Philip Cherian, Ashoka University teaching fellow):

[**https://drive.google.com/open?id=13O\_K943llhgoTA4Puo32s4xAPtA2NL3kCpl4pHoTobI**](https://drive.google.com/open?id=13O_K943llhgoTA4Puo32s4xAPtA2NL3kCpl4pHoTobI)

* Session 1: **Friday, November 16, 2018; 8–10 PM IST (6:30–8:30 AM PST)**
  + Before the start of Mentored Session 1, participants are expected to have: (1) installed Anaconda Python 3.6 on their computers, and (2) run Jupyter notebooks 1 and 2 of the PyaR tutorial and tried to edit lines of code in them.

[**https://drive.google.com/file/d/12mrA0PjO2Vsjo9O5fVJzZUVOf51r0\_i5/view**](https://drive.google.com/file/d/12mrA0PjO2Vsjo9O5fVJzZUVOf51r0_i5/view)

* Session 2: **Friday, November 23, 2018; 8–10 PM IST (6:30–8:30 AM PST)**
  + Before the start of Mentored Session 2, participants are expected to have completed (or at least attempted to complete) Jupyter notebooks 3 and 4 of the PyaR tutorial.

[**https://drive.google.com/file/d/1zUZRZmO0kykOBMFDgp8-Z5dgpqfbfmUr/view**](https://drive.google.com/file/d/1zUZRZmO0kykOBMFDgp8-Z5dgpqfbfmUr/view)

* Session 3: **Friday, November 30, 2018; 8–10 PM IST (6:30–8:30 AM PST)**
  + Before the start of Mentored Session 3, participants are expected to have completed (or at least attempted to complete) Jupyter notebooks 5 and 6 of the PyaR tutoria

[**https://drive.google.com/file/d/1IvE8CWFg9eqP3a88fnlUCU5DzWNFg\_J8/view**](https://drive.google.com/file/d/1IvE8CWFg9eqP3a88fnlUCU5DzWNFg_J8/view)

***Explanation of the cross-correlation technique***

A standard data analysis technique known as “cross correlation” is used to automate the measurement of Doppler shifts of stellar absorption line spectra. Here's how it works:

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(1) A smoothly varying analytical function (e.g., a low-order polynomial or spline) is fit to the continuum portion of the science spectrum, the non-absorption line parts which is the majority of the spectrum. The science spectrum is ***normalized*** by dividing the flux value at each wavelength of the raw spectrum by the corresponding value of the best-fit analytic function at the same wavelength. The continuum value of the normalized science spectrum should be approximately 1, except at the absorption lines of course where the flux values are smaller than 1 (by definition). A constant value of 1 is subtracted from all flux values in the normalized science spectrum. The continuum parts should now be approximately 0 and the absorption line fluxes are now negative. Let's call this the ***modified*** science spectrum.

(2) The above operations are also applied to a library of ***template*** stellar spectra – i.e., high fidelity spectra of stars of known velocity whose spectra have been corrected to the rest frame. Let's call these modified template spectra.

(3) For each modified science spectrum, a modified template spectrum is Doppler shifted by a specific amount by dividing all wavelengths by a factor of (1 + ***v***/***c***), where ***v*** is an arbitrary velocity and ***c*** is the speed of light. The two spectra – modified science spectrum and Doppler shifted modified template spectrum – are multiplied together pixel by pixel. This multiplication involves taking a product of the two sets of corresponding fluxes, one from each spectrum, at each wavelength. These products are then summed over the full spectrum. The sum is called the cross-correlation function ***C*** which is a function of ***v*** of course: ***C***(***v***).

(4) The cross-correlation function is expected to show a peak when the correct value of ***v\_corr*** is chosen. At the correct velocity, the negative dips corresponding to absorption lines in the modified science spectrum are at the same wavelengths as the dips in the Doppler shifted modified template spectrum. The products at these wavelengths are therefore non-zero positive values.

(5) Typically, one tries a bunch of different template spectra for each science spectrum and uses the ***v\_corr*** value that is based on the Doppler shifted template spectrum that is best matched to the science spectrum.

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