**PyaR (Python and Research) tutorial – Fall 2018 through 2022**

[**Registration Google Form**](https://docs.google.com/forms/d/e/1FAIpQLSdWPTYFW-h42NRpIV-O4mS-zi05z-89G4vd9OPp71t6kinSgg/viewform)

***General information: Answers to frequently asked questions (FAQs)—***

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* *What is the PyaR tutorial?*

PyaR is a Python tutorial that covers the basics of Python computer programming via a series of 6 Jupyter notebooks that are derived from the data analysis software tools used in the 2015 scientific journal article led by Claire Dorman (Raja GuhaThakurta’s former PhD student at the University of California Santa Cruz) on the stellar disk kinematics and the satellite bombardment history of the Andromeda galaxy. Claire and Raja, with help from UCSC PhD students Emily Cunningham and Amanda Quirk, developed the tutorial by replacing key lines of code in the Jupyter notebooks with coding instructions. Participants are expected to recreate these lines of code as they work through the tutorial. Students can go through the tutorial at their own pace without instruction. However, we would also be happy to provide remote mentoring sessions for interested students via Zoom videoconferencing. The sessions will include Q&A on Python issues and will cover the key astrophysical concepts that are relevant for the tutorial. Research students Antara Bhattacharya, Maddy Broome, Douglas Grion Filho, Kevin McKinnon, César Rojas-Bravo, and Asher Wasserman have served as mentors over the years.

* *What are the main learning goals of the PyaR tutorial?*
  + Basics of **Python programming** via Jupyter notebooks
  + Structure of a **scientific journal article**
  + Some basic **astrophysics concepts**: e.g., stellar evolution, H-R diagrams/color-magnitude diagrams, spectra, Doppler shift, galaxies: disk dynamics, formation, evolution, and mergers
  + Some relevant **mathematical and statistical concepts** (e.g., logarithms, standard deviation)
  + Explanations (via Zoom, Slack, and/or video) from **people** who are involved in this research
* *Which students should consider participating in the PyaR tutorial?*

Any student who is interested in one or more of the above five learning goals should consider participating. In the past, students ranging from high school through post-graduate levels have participated in the PyaR tutorial and have learned from it.

* *How much time and other resources is a student expected to commit to the PyaR tutorial?*

Beyond the time and effort associated with the Anaconda Python software installation, each student should ideally expect to spend about 6 hours working through the six Jupyter notebooks on their own (approximately 1 hour per notebook; approximately 2 hours of work before each of the three mentored sessions). This is **in addition to** the 6 hours associated with the student’s participation in the (3 x 2-hour) mentored sessions. There is **no monetary cost** associated with participation in the PyaR tutorial.

* *Can a student participate even if they cannot attend any of the mentored sessions?*

Yes, students are welcome to work through the six Jupyter notebooks on their own and post their questions on the Slack channel before each of the three mentored sessions. The mentors will do their best to answer students’ questions via the Slack channel and during the mentored session Zoom videoconferences. Videos of these Zoom sessions will be made available afterwards (videos of past Zoom sessions and completed Jupyter notebooks are linked below).

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***Key links***

* [***Registration Google form***](https://docs.google.com/forms/d/e/1FAIpQLSdWPTYFW-h42NRpIV-O4mS-zi05z-89G4vd9OPp71t6kinSgg/viewform)
* ***Zoom (changes each time):*** [***https://ucsc.zoom.us/j/96783319260?pwd=Mkc0bVQzakVaOGNxeHBBYTcyWXRpQT09***](https://ucsc.zoom.us/j/96783319260?pwd=Mkc0bVQzakVaOGNxeHBBYTcyWXRpQT09)
* ***Slack #general channel:***

[**https://join.slack.com/t/pyar-workshop/shared\_invite/zt-7uj8rrdu-~awfeULJfnIhn7zy7aztcA**](https://ucsc.us20.list-manage.com/track/click?u=53edd08fba9a940e360b888d8&id=812af22364&e=eb181660ce)

* ***Anaconda Python installation instructions:*** [**http://tinyurl.com/pyar-conda-setup**](http://tinyurl.com/pyar-conda-setup)

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***Schedule of the June 2022 (2022B) PyaR Zoom sessions***

Session 2022B1 (Mon, Jun 6, 2022: 9:30 AM–12 noon PST / 1630–1900 GMT / 2200–0030 IST)

— Recording of 2022B1 Zoom session: [**video**](https://drive.google.com/file/d/1T9rkekcAntKTchuw-XCzkyi6IHrCjJps/view), [**chat**](https://drive.google.com/file/d/1Qc-dewev_aN9eozkRz_911yty7oAkUAq/view)

* Introduction: value proposition and structure/format of the PyaR tutorial **— Raja**
* Jupyter notebook 1 **— Doug/Raja**
* Structure of an astrophysics journal article (Dorman et al. 2015) **— Raja**

Session 2022B2 (Tue, Jun 7, 2022: 9:30 AM–12 noon PST / 1630–1900 GMT / 2200–0030 IST)

— Recording of 2022B2 Zoom session: [**video**](https://drive.google.com/file/d/1K1vG_6t6EkNaJbZM-mArvhmQ3Xs54T3T/view), [**chat**](https://drive.google.com/file/d/12u2X8RlM2LUo_Y868IVMoe5tnB2YYOL_/view), [**live transcript**](https://drive.google.com/file/d/1NKwdEA2uVRhIWOYTQQd8t8Z0GpyRrqF6/view)

* Astrophysics background: Andromeda galaxy, PHAT dataset **— Raja**
* Jupyter notebook 3 **— Amanda**
* Astrophysics background: magnitudes, colors, stellar evolution, color-magnitude or Hertzsprung-Russell diagrams, mass-luminosity relation ([**slides**](https://docs.google.com/presentation/d/1Pi7UiwYRw22z-G8IxM8HUIFLkOcCdOHcgM-72zOGE1s/edit?usp=sharing)); stellar spectra and Doppler shift **— Maddy/Raja**
* Jupyter notebook 4 **— Maddy**

Session 2022B3 (Wed, Jun 8, 2022: 9:30 AM–12 noon PST / 1630–1900 GMT / 2200–0030 IST)

— Recording of 2022B3 Zoom session: [**video**](https://drive.google.com/file/d/1rsUVa7A_Xivk9cNaVDRIZpe5gccqjXDT/view), [**chat**](https://drive.google.com/file/d/1s6D9oQhJQqaME0lT2LO-fD9OMuKBa_gJ/view), [**live transcript**](https://drive.google.com/file/d/1rzx-ayoFI9Pb3L2SLBqvIM-O9vSTTk2K/view)

* Astrophysics background: galaxy mergers **— Raja**
* Jupyter notebook 5 **— Amanda**
* Astrophysics background: galaxy disk kinematics, viewing geometry, statistical concept of standard deviation **— Maddy/Raja**
* Jupyter notebook 6 **— Maddy/Amanda**

Slack channel and Zoom chat Q&A moderation **— Aparajito**

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***Schedule of the January 2022 (2022A) PyaR Zoom sessions***

Session 2022A1 (Sat, Jan 22, 2022: 9 AM–12 noon PST / 1700–2000 GMT / 2230–0130 IST)

— Recording of 2022A1 Zoom session: [**video**](https://drive.google.com/file/d/1mnltTPmr-PdcQuY_ua_srQkMX4cJtszu/view?usp=drive_web), [**chat**](https://drive.google.com/file/d/107llFu60_MhQYa6P1rW7nzW9kA4jaT8r/view?usp=drive_web), [**live transcript**](https://drive.google.com/file/d/181tTXdk1dlN2YaxVDPVBX7F9ntPEXnW1/view?usp=drive_web)

* Introduction: value proposition and structure/format of the PyaR tutorial **— Raja**
* Jupyter notebook 1 **— Antara**
* Structure of an astrophysics journal article (Dorman et al. 2015); astrophysics background: Andromeda galaxy, PHAT dataset **— Maddy**
* Jupyter notebook 2 **— Antara**
* Astrophysics background: magnitudes, colors, stellar evolution, color-magnitude or Hertzsprung-Russell diagrams, mass-luminosity relation ([**slides**](https://docs.google.com/presentation/d/1Pi7UiwYRw22z-G8IxM8HUIFLkOcCdOHcgM-72zOGE1s/edit?usp=sharing)) **— Raja/Maddy**

Session 2022A2 (Sat, Jan 29, 2022: 9 AM–12 noon PST / 1700–2000 GMT / 2230–0130 IST)

— Recording of 2022A2 Zoom session: [**video**](https://drive.google.com/file/d/1L0OtcNCuom_z-rzh8Ew8zTrXWaxYsknH/view?usp=sharing), [**chat**](https://drive.google.com/file/d/1yS9h2DOovu2uHMZVv1NA__e34mzwmFSM/view?usp=sharing), [**live transcript**](https://drive.google.com/file/d/1rtZp0LKn8r5GItdi5ONTqJ1DSXvvNaqr/view?usp=sharing)

* Jupyter notebook 3 **— Amanda**
* Astrophysics background: Stellar spectra and Doppler shift **— Raja**
* Jupyter notebook 4 **— Doug**
* Astrophysics background: galaxy mergers **— Doug**
* Jupyter notebook 5 **— Amanda**
* Q&A about notebook 4 and 5 (Slack+Zoom) **— Doug**
* Astrophysics background: galaxy disk kinematics, viewing geometry, statistical concept of standard deviation **— Raja**
* Jupyter notebook 6 **— Amanda**
* Closing the loop: conclusions of the Dorman et al. (2015) article **— Raja**

Slack channel and Zoom chat Q&A moderation **— Kevin**

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***Recordings and schedule for the 2021C offering of PyaR***

Session 2021C1 (Thu, July 29, 2021: 6–8 AM PDT / 1300–1500 GMT / 1830–2030 IST)

[**Zoom video recording**](https://drive.google.com/file/d/1GHDicGFu_MstVySIDibfCLNNvs4v6PWH/view)

[**Zoom chat recording**](https://drive.google.com/file/d/1glXkCIwlh-N47nvnJ654BcEuPGXz1JKU/view)

* Introduction: value proposition and structure/format of the PyaR tutorial **— Raja**
* Jupyter notebook 1 **— Amanda**
* Structure of an astrophysics journal article (Dorman et al. 2015); astrophysics background: Andromeda galaxy, PHAT dataset **— Raja**
* Jupyter notebook 2 **— Antara**

Session 2021C2 (Fri, July 30, 2021: 6–8 AM PDT / 1300–1500 GMT / 1830–2030 IST)

[**Zoom video recording**](https://drive.google.com/file/d/1h8PTSUW-K_WB9QlJf8hGWtDwUrR4Rvcz/view?usp=sharing)

[**Zoom chat recording**](https://drive.google.com/file/d/10KOqKv9_2v14JU2pEIifmcMHrfA_em5D/view?usp=sharing)

* Astrophysics background: magnitudes, colors, stellar evolution, color-magnitude or Hertzsprung-Russell diagrams, mass-luminosity relation **— Raja/Maddy**
* Jupyter notebook 3 **— Philip**
* Astrophysics background: Stellar spectra and Doppler shift **— Maddy**
* Jupyter notebook 4 **— Antara**

Session 2021C3 (Sat, July 31, 2021: 6–8 AM PDT / 1300–1500 GMT / 1830–2030 IST)

[**Zoom video recording**](https://drive.google.com/file/d/1lR11xpwMQS0zfwPRYkI0FN8jXNrFKB9T/view)

[**Zoom chat recording**](https://drive.google.com/file/d/1_T_5ocyWmveCJNH4a_Fo5AVNMeOED6Xw/view)

* Jupyter notebook 4 (continued) **— Philip**
* Astrophysics background: galaxy mergers **— Raja**
* Jupyter notebook 5 **— Antara/Raja**
* Q&A about notebook 4 and 5 (Slack+Zoom) **— Antara/Philip**
* Astrophysics background: galaxy disk kinematics, viewing geometry, statistical concept of standard deviation **— Raja**
* Jupyter notebook 6 **— Antara/Raja**
* Closing the loop: conclusions of the Dorman et al. (2015) article **— Raja**

Mentors: Antara Bhattacharya, Aparajito Bhattacharya, Madelyn Broome, Philip Cherian, Raja GuhaThakurta, Amanda Quirk, Vishaka Ranjan, Preksha Sethia

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***Recordings and schedule of the June 2021 (2021B) PyaR Zoom sessions***

Session 2021B1 (Tue, June 8, 2021: 9 AM–12 noon PDT / 1600–1900 GMT / 2130–0030 IST)

[**Zoom video recording**](https://drive.google.com/file/d/1KrTowFIFQfEkpPVaVim63EvavA_tI3T2/view)

[**Zoom chat recording**](https://drive.google.com/file/d/1CFhO3oA9tSUQ01nI-r5kxIL4_jinUUfE/view)

* Introduction: value proposition and structure/format of the PyaR tutorial **— Raja**
* Jupyter notebook 1 **— Antara**
* Structure of an astrophysics journal article (Dorman et al. 2015); astrophysics background: Andromeda galaxy, PHAT dataset **— Doug and Raja**
* Jupyter notebook 2 **— Antara**
* Q&A about notebook 1 and 2 (Slack+Zoom) **— Doug**
* Astrophysics background: magnitudes, colors, stellar evolution, color-magnitude or Hertzsprung-Russell diagrams, mass-luminosity relation **— Raja**
* Jupyter notebook 3 **— Amanda**

Session 2021B2 (Wed, June 9, 2021: 9 AM–12 noon PDT / 1600–1900 GMT / 2130–0030 IST)

[**Zoom video recording**](https://drive.google.com/file/d/10p9mFFMJGoSP23uR4dUDP3oUeka3yC3F/view)

[**Zoom chat recording**](https://drive.google.com/file/d/13y4EXZDOrJw-RXlU2JvJsF08TdEoOIm0/view)

* Astrophysics background: Stellar spectra and Doppler shift **— Maddy and Raja**
* Jupyter notebook 4 **— Antara**
* Astrophysics background: galaxy mergers **— Raja**
* Jupyter notebook 5 **— Amanda**
* Q&A about notebook 4 and 5 (Slack+Zoom) **— Maddy**
* Astrophysics background: galaxy disk kinematics, viewing geometry, statistical concept of standard deviation **— Raja**
* Jupyter notebook 6 **— Amanda**
* Closing the loop: conclusions of the Dorman et al. (2015) article **— Raja**

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***Recording and schedule of the February 2021 (2021A) PyaR Zoom sessions***

[Mentors: Amanda Quirk, Antara Bhattacharya, Kevin McKinnon, Philip Cherian, Raja GuhaThakurta]

* [**Session 2021A1 (February 20, 2021 – 8:00–11:00 AM PST) Notebooks 1, 2, and 3**](https://drive.google.com/file/d/1u5kQPUlooJAe9ly8U-WbwEhJsKGKrxRS/view)
* [**Session 2021A2 (February 27, 2021 – 8:00–11:00 AM PST) Notebooks 4, 5, and 6**](https://drive.google.com/file/d/1NO8dVAZuicdzF9l40MPj1o804_59MT0_/view?usp=sharing)

***Recording and schedule of the September/October 2020 (2020C) PyaR Zoom sessions***

[Mentors: Antara Bhattacharya, Caelum Rodriguez, Raja GuhaThakurta]

* [**Session 2020C1 (September 26, 2020 – 9:00–11:00 AM PDT) Notebooks 1 and 2**](https://drive.google.com/file/d/1UTQXB4FRic0WQ-QAaBXhqFitKG0x8gs2/view?usp=sharing)
* [**Session 2020C2 (October 3, 2020 – 9:00–11:00 AM PDT) Notebooks 3 and 4**](https://drive.google.com/file/d/1Ohu30_5z4rHVkearP5y9y9ZGXVlHGAmD/view?usp=sharing)
* [**Session 2020C3 (October 10, 2020 – 9:00–11:00 AM PDT) Notebooks 5 and 6**](https://drive.google.com/file/d/1EPvORvU4689cg3bgxhsdErZqpEiUcd3l/view?usp=sharing)

***Recording and schedule of the June 2020 (2020B) PyaR Zoom sessions***

(sorry the video and chat for the first two sessions are in pieces because of lost connections)

Monday, June 8 (2020B1)—

* Video part A: [https://drive.google.com/open?id=1IgIsKzQceBx1-IvkOCpu16GVTj4RFwUb](https://slack-redir.net/link?url=https%3A%2F%2Fdrive.google.com%2Fopen%3Fid%3D1IgIsKzQceBx1-IvkOCpu16GVTj4RFwUb)
* Video part B: [https://drive.google.com/open?id=1ntKCYSGUfcoZhErGisq1C9Z5rGsiH3\_I](https://slack-redir.net/link?url=https%3A%2F%2Fdrive.google.com%2Fopen%3Fid%3D1ntKCYSGUfcoZhErGisq1C9Z5rGsiH3_I)
* Video part C: [https://drive.google.com/open?id=1lPZ22qC8mv6E-9QUZzf6TjkpggqYV8KG](https://slack-redir.net/link?url=https%3A%2F%2Fdrive.google.com%2Fopen%3Fid%3D1lPZ22qC8mv6E-9QUZzf6TjkpggqYV8KG)
* Video part D: [https://drive.google.com/open?id=1LPb9ZkBUMHwLcFXkaHEH0zJiEL\_e9y-e](https://slack-redir.net/link?url=https%3A%2F%2Fdrive.google.com%2Fopen%3Fid%3D1LPb9ZkBUMHwLcFXkaHEH0zJiEL_e9y-e)
* Chat part A: [https://drive.google.com/open?id=1D\_iYKpXJYDiz6SA-mhtFHIRUU608d65p](https://slack-redir.net/link?url=https%3A%2F%2Fdrive.google.com%2Fopen%3Fid%3D1D_iYKpXJYDiz6SA-mhtFHIRUU608d65p)
* Chat part C: [https://drive.google.com/open?id=1nyA8Yo1jaJCVzmWIPCer2pvU5gGILkhv](https://slack-redir.net/link?url=https%3A%2F%2Fdrive.google.com%2Fopen%3Fid%3D1nyA8Yo1jaJCVzmWIPCer2pvU5gGILkhv)
* Chat part D: [https://drive.google.com/open?id=1JKrqEPVF-HcuUphVgQJujVtpDJ-H\_3Qg](https://slack-redir.net/link?url=https%3A%2F%2Fdrive.google.com%2Fopen%3Fid%3D1JKrqEPVF-HcuUphVgQJujVtpDJ-H_3Qg)

Tuesday, June 9 (2020B2)—

* Video part A: <https://drive.google.com/open?id=144GONaCgjp4v2BQwVld7WX-8JDMykBxT>
* Video part B: <https://drive.google.com/open?id=1F3LFFHRFnp6wnVCk4h1zw_DboqZaRjxd>
* Chat part A: <https://drive.google.com/open?id=1K5pWxF7J7FUzWr3IIYDoq8LAgSvYF3QS>
* Chat part B: <https://drive.google.com/open?id=1iu-km2OXBggR6-qAEbgbWtuyWGJhjrkJ>

Thursday, June 11 (2020B3)—

* Video: <https://drive.google.com/open?id=1awPrWn0l01GEFKMk9sg85up1FmJhbno_>
* Chat: <https://drive.google.com/open?id=1UHVV5OPrmfNiUPqNHB_Ze6ANYTpdu45m>

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***Recording and schedule of the February/March 2020 (2020A) PyaR Zoom sessions***

[Mentors: Amanda Quirk, Antara Bhattacharya, Raja GuhaThakurta]

February 15, 2020 – 8:00–10:00 AM PST – Session 2020A1

(part A)

[https://drive.google.com/file/d/1kbrTR5dDbTdQvFOWSp0FblTeoWS7pf7n/view?usp=sharing](https://slack-redir.net/link?url=https%3A%2F%2Fdrive.google.com%2Ffile%2Fd%2F1kbrTR5dDbTdQvFOWSp0FblTeoWS7pf7n%2Fview%3Fusp%3Dsharing)

(part B)

[https://drive.google.com/file/d/1onQjbBxGimfoE6IDxqODZ-iuHe4-NQ5l/view?usp=sharing](https://slack-redir.net/link?url=https%3A%2F%2Fdrive.google.com%2Ffile%2Fd%2F1onQjbBxGimfoE6IDxqODZ-iuHe4-NQ5l%2Fview%3Fusp%3Dsharing)

February 29, 2020 – 8:00–10:00 AM PST – Session 2020A2

[https://drive.google.com/file/d/1Y2DrodXZE-1ulMyWZ1fsdl3P0U8pgCqz/view?usp=sharing](https://slack-redir.net/link?url=https%3A%2F%2Fdrive.google.com%2Ffile%2Fd%2F1Y2DrodXZE-1ulMyWZ1fsdl3P0U8pgCqz%2Fview%3Fusp%3Dsharing)

March 7, 2020 – 8:00–10:00 AM PST – Session 2020A3

<https://drive.google.com/file/d/1TuHjbxP7zucok0yvcZeQeKdgLKE_MjAU/view?usp=sharing>

***Schedule—***

We will offer the PyaR tutorial **in February/March 2020** – this next offering of the tutorial will consist of a set of three 2-hour long Zoom video conferences on the following dates:

* **(2020A) February 15, February 29, and March 7 (2020) 8–10 AM Pacific time (PST)**
* ~~(D) October 5, 12, and 19 (2019) 9–11 PM Pacific time (PDT)~~

~~[4–6 AM (0400–0600) UTC on October 6, 13, and 20]~~

* ~~(C) June 17, 18, 19, and 20 (2019) 9–11 AM Pacific time (PDT)~~

~~[4–6 PM (1600–1800) UTC on June 17–20]~~

* ~~(B) May 4, 11, and 18 (2019) 8–10 AM Pacific time (PDT)~~

~~[3–5 PM (1500–1700) UTC on May 4, 11, and 18]~~

* ~~(A) March 9, 16, and 23 (2019) 8–10 PM Pacific time (PST/PDT);~~

~~[4–6 AM (0400–0600) UTC on March 10 and~~

~~3–5 AM (0300–0500) UTC on March 17 and 24]\*\*~~

\* The ***same*** material that was covered in the 2019 sessions (March A1–A3 sessions, the May B1–B3 sessions, the June C1–C4, and October D1–D3 sessions) will be covered in the 2020A1–2020A3 sessions.

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***Step-by-step instructions (and accompanying videos)—***

* Tasks to be completed ***before*** session 1 (A1/B1/C1/D1):Participants are expected to have: (1) installed Anaconda Python 3.6 or 3.7 on their computers, and (2) run Jupyter notebooks 1 and 2 of the PyaR tutorial and tried to edit lines of code in them.
* Tasks to be completed ***before*** session 2 (A2/B2/C2/D2):Participants are expected to have completed (or at least tried to complete) Jupyter notebooks 3 and 4 of the PyaR tutorial.
* Tasks to be completed ***before*** session 3 (A3/B3/C3/D3):Participants are expected to have completed (or at least tried to complete) Jupyter notebooks 5 and 6 of the PyaR tutorial
* Videos of Zoom sessions D1, D2, and D3 from Antara, Rachel, and Raja’s October 5, 12, and 19, 2019 offering of the PyaR tutorial:
  + Session D1 (October 5, 2019) video —

[**https://drive.google.com/file/d/10MkoB6RwCgBwDtDIKo3irp3Er4JRvf6Q/view**](https://drive.google.com/file/d/10MkoB6RwCgBwDtDIKo3irp3Er4JRvf6Q/view)

* + Session D2 (October 12, 2019) video —

[**https://drive.google.com/file/d/1YavgkwNgU3UlP5QEwq6Rdft6ra1EpCxn/view**](https://drive.google.com/file/d/1YavgkwNgU3UlP5QEwq6Rdft6ra1EpCxn/view)

* + Session D3 (October 19, 2019) video —

[**https://drive.google.com/file/d/12pHg2U3LzANTtpU5EEPzbiiPYIIYtW7w/view**](https://drive.google.com/file/d/12pHg2U3LzANTtpU5EEPzbiiPYIIYtW7w/view)

* Video of Zoom sessions B1 and B2 from Amanda, César, and Raja’s May 4 and 11, 2019 offering of the PyaR tutorial:
  + Session B1 (May 4, 2019) video —

[**https://drive.google.com/file/d/1EQqQeKAuPHv9aQsV0ovG31aTC78MfVjy/view**](https://drive.google.com/file/d/1EQqQeKAuPHv9aQsV0ovG31aTC78MfVjy/view)

* + Session B2 (May 11, 2019) video —

[**https://drive.google.com/file/d/1xhKU20bk0-g2Uf7uEXKY\_L9VOoZGyNEi/view**](https://drive.google.com/file/d/1xhKU20bk0-g2Uf7uEXKY_L9VOoZGyNEi/view)

* Video of Zoom session A1 from Amanda, César, and Raja’s March 9, 2019 offering of the PyaR tutorial:
  + Session A1 (Mar 9, 2019) video —

[**https://drive.google.com/file/d/1YLNh5uZUa2XhQR5DBQPkark0WyRqwdlk/view**](https://drive.google.com/file/d/1YLNh5uZUa2XhQR5DBQPkark0WyRqwdlk/view)

* Video of Zoom sessions 1, 2, and 3 from Amanda and Raja’s November 16, 23, and 30, 2018 offering of the PyaR tutorial:
  + Session 1 (Nov 16, 2018) video —

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

* + Session 2 (Nov 23, 2018) video —

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

* + Session 3 (Nov 30, 2018) video —

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

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***Key links—***

* Pre-tutorial preparations: Summary of Anaconda Python (version 3.7 or 3.8) installation and other pre-tutorial tasks such as getting ready to connect via Zoom and Slack (courtesy: Philip Cherian, Ashoka University, Sonipat, India – November 2018):

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

* Google drive link containing a compilation of PyaR tutorial materials (courtesy: Philip Cherian, Ashoka University, Sonipat, India – November 2018):

[**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/)

(contents: overview, press release about main scientific discovery, scientific journal article, “blank” and completed Jupyter notebooks, videos of past mentored sessions)

* Some helpful notes about PyaR Jupyter notebooks 1 and 2 (courtesy: Antara Bhattacharya):

[**https://docs.google.com/document/d/1kNOu-S1TXkU8H43dKr5acKmskn3R5MZ63wgkqKFbY5c**](https://docs.google.com/document/d/1kNOu-S1TXkU8H43dKr5acKmskn3R5MZ63wgkqKFbY5c)

* Zoom conference link: [**https://ucsc.zoom.us/j/284472579**](https://ucsc.zoom.us/j/284472579)

(same link for all three D1–D3 sessions)

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

(We will use the same Slack channel for future offerings of the PyaR tutorial, so participants are advised to leave the Slack channel after their session is complete.)

* Video of Raja GuhaThakurta’s description of the PyaR tutorial (~1 hour): [**https://www.youtube.com/watch?v=wpSpE2uVG2Q&feature=youtu.be**](https://www.youtube.com/watch?v=wpSpE2uVG2Q&feature=youtu.be)

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Hi October 2019 PyaR participants,

Looking forward to seeing all of you on Zoom and Slack in a few hours' time (9 PM PDT). The mentoring session will run for 2 hours (9–11 PM PDT). We will be covering the last two Jupyter notebooks (#5 and #6) in today’s session. Please go through these two notebooks on your own before the mentoring session.

Please read the rest of this message carefully!

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— PyaR Zoom conference call link:

[**https://ucsc.zoom.us/j/284472579**](https://ucsc.zoom.us/j/284472579)

— PyaR Slack #general channel link:

[**https://pyar-workshop.slack.com/messages/CDMR8FZAQ/**](https://pyar-workshop.slack.com/messages/CDMR8FZAQ/)

All those who have registered for the October PyaR tutorial by filling out the Google form have been emailed an invitation to join the PyaR Slack channel. ***Please join the Slack channel if you haven’t done so already!***

— Before the session, please make sure you have completed the Anaconda installation of Python 3 on your computer. Link to instructions for Anaconda installation and other pre-tutorial preparatory steps (courtesy: Philip Cherian):

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

— Website that contains the blank Jupyter notebooks that we will use for the PyaR tutorial (download and unpack item 5 named JupyterNotebooksBlank.zip) and other relevant materials:

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

— Some helpful notes about PyaR Jupyter notebooks 1 and 2 (courtesy: Antara Bhattacharya):

[**https://docs.google.com/document/d/1kNOu-S1TXkU8H43dKr5acKmskn3R5MZ63wgkqKFbY5c**](https://docs.google.com/document/d/1kNOu-S1TXkU8H43dKr5acKmskn3R5MZ63wgkqKFbY5c)

— Main PyaR Google doc link:

[**https://docs.google.com/document/d/16QuhwolhX0URjpyPZ7sfWy107aBuvq3E9-LPyT8Nz68/edit?usp=sharing**](https://docs.google.com/document/d/16QuhwolhX0URjpyPZ7sfWy107aBuvq3E9-LPyT8Nz68/edit?usp=sharing)

— Link to video recordings of first two October 2019 sessions:

+ October 5, 2019 (session D1) —

[**https://drive.google.com/file/d/10MkoB6RwCgBwDtDIKo3irp3Er4JRvf6Q/view**](https://drive.google.com/file/d/10MkoB6RwCgBwDtDIKo3irp3Er4JRvf6Q/view)

+ October 12, 2019 (session D2) —

[**https://drive.google.com/file/d/1YavgkwNgU3UlP5QEwq6Rdft6ra1EpCxn/view**](https://drive.google.com/file/d/1YavgkwNgU3UlP5QEwq6Rdft6ra1EpCxn/view)

+ October 19, 2019 (session D3) —

[**https://drive.google.com/file/d/12pHg2U3LzANTtpU5EEPzbiiPYIIYtW7w/view**](https://drive.google.com/file/d/12pHg2U3LzANTtpU5EEPzbiiPYIIYtW7w/view)

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Please send a message on PyaR Slack #general channel or email Raja (raja@ucolick.org) if you have any questions.

Raja

***Explanation of the cross-correlation technique*** (relevant for Jupyter notebook 4)

A standard spectroscopic data analysis technique known as “cross correlation” is used to automate the measurement of Doppler shifts of stellar absorption line spectra. Here is a brief summary of how the cross correlation method is typically applied to spectra:

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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 ***CCF*** which is a function of ***v*** of course: ***CCF***(***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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