From Astrophysicist to Data Scientist in Three Acts:
navigating an academic career with a short attention span

Jill P. Naiman
Teaching Assistant Professor, iSchool
astronaiman.com

Act I: Astronomy & Astrophysics

Act II: Data Visualization

Act III: Information Scientist?

Act I: Astronomy & Astrophysics

Earth is ~ here

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IllustrisTNG Simulations

Moving mesh (AREPO)

1 Mpc ~ 3.1×10^{22} meters

Credit: Nelson 2015

Naiman et al. 2018

Run	Alt. Name	Total NumPart (DM)	Chunks per Snapshot	Full Snapshot Size	Avg Groupcat Size	Total Data Volume
L35n270TNG	TNG50-4	19,683,000	11	5.2 GB	20 MB	0.6 TB
L35n270TNG_DM	TNG50-4-Dark	19,683,000	4	1.2 GB	10 MB	0.1 TB
L35n540TNG	TNG50-3	157,464,000	11	44 GB	130 MB	7.5 TB
L35n540TNG_DM	TNG50-3-Dark	157,464,000	4	9.4 GB	50 MB	0.6 TB
L35n1080TNG	TNG50-2	1,259,712,000	128	350 GB	860 MB	18 TB
L35n1080TNG_DM	TNG50-2-Dark	1,259,712,000	85	76 GB	350 MB	4.5 TB
L35n2160TNG	TNG50-1	10,077,696,000	680	2.7 TB	7.2 GB	~320 TB
L35n2160TNG_DM	TNG50-1-Dark	10,077,696,000	128	600 GB	2.3 GB	36 TB
L75n455TNG	TNG100-3	94,196,375	7	27 GB	110 MB	1.5 TB
L75n455TNG_DM	TNG100-3-Dark	94,196,375	4	5.7 GB	40 MB	0.4 TB
L75n910TNG	TNG100-2	753,571,000	56	215 GB	650 MB	14 TB
L75n910TNG_DM	TNG100-2-Dark	753,571,000	8	45 GB	260 MB	2.8 TB
L75n1820TNG	TNG100-1	6,028,568,000	448	1.7 TB	4.3 GB	128 TB
L75n1820TNG_DM	TNG100-1-Dark	6,028,568,000	64	360 GB	1.7 GB	22 TB
L205n625TNG	TNG300-3	244,140,625	16	63 GB	340 MB	4 TB
L205n625TNG_DM	TNG300-3-Dark	244,140,625	4	15 GB	130 MB	1 TB
L205n1250TNG	TNG300-2	1,953,125,000	100	512 GB	2.2 GB	31 TB
L205n1250TNG_DM	TNG300-2-Dark	1,953,125,000	25	117 GB	810 MB	7.2 TB
L205n2500TNG	TNG300-1	15,625,000,000	600	4.1 TB	14 GB	235 TB
L205n2500TNG_DM	TNG300-1-Dark	15,625,000,000	75	930 GB	5.2 GB	57 TB

tng-project.com

Run	Alt. Name	Total NumPart (DM)	Chunks per Snapshot	Full Snapshot Size	Avg Groupcat Size	Total Data Volume
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- Data “chunking”
- Python in parallel on supercomputers/multi-core computers (5-50 CPUs)

tng-project.com

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Thousands of Milky Way-like (our galaxy) star formation histories

Naiman et al. 2018

tng-project.com

Act II: Data Visualization

Scientists have lots of data

IllustrisTNG: Tens of TB

Scientists have lots of data

Sloan Digital Sky Survey: ~ 120TB (already)

Dark Energy Survey: ~200GB/night, ~PB last decade

Large Synoptic Survey Telescope - 200PB/decade

Square Kilometre Array: 1000PB/year

The Data is in weird formats

Blender

- 3D modeling and animating program (free Maya)
- used by 3D graphics folks and a few astronomers
- Python API

Naiman et al. 2016

Houdini™

PIXAR ANIMATION STUDIOS

DIGITAL DOMAIN

Disney

UBISOFT

weta DIGITAL

EA™

double negative visual effects

DREAMWORKS ANIMATION SKG

Visualization with the Advanced Visualization Lab (NCSA)

http://www.ncsa.illinois.edu/enabling/vis/cadens/documentary/beginning_of_time

Naiman et al. 2017

ytini.com/blog.html

“Raw”

ytini

ytini

Borkiewicz et al. 2019

Scientific Visualization as an Educational Tool

Workshops/Short courses:

https://www.astroblend.com/ba2016/

https://www.astroblend.com/ba2017/

https://jnaiman.github.io/csci-p-14110_su2020/

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https://uiuc-ischool-dataviz.github.io/is445_spring2022/

Act III: Information Science?

(Digitization? Curriculum development? Visualization analytics? Science nomad?)

Impact Analysis with NLP on AVL Documentaries

Based on Rezapour & Diesner 2017
With iSchool students: Alistair Nunn, Anuska Gami, Shriya Srikanth
& in collaboration with the AVL

Positive shift in **knowledge**	“Very educational...learned a lot”
Negative shift in **knowledge**	“This is the biggest lie”
Positive **interest** in science topic	“My heart warms as we uncover the most unique and fascinating secrets of the universe”
Negative **interest** in science topic	“A waste of time and resources”
Positive **engagement** with film	“I like the piano”
Negative **engagement** with film	“Man this narrator gets pretty annoying after 7-10 min”
Impersonal report	“From the intro, none of this exists yet”
Personal opinion	“Their will be a time when they all will be face to face with the creator of the universal”

Table from Anushka Gami (Oct 11th SPIN talk)

Eric Jensen
Brinson Civic Science Fellow
Assoc. Prof. University of Warwick, Sociology

ILLINOIS
NCSA | National Center for Supercomputing Applications
AVL | Advanced Visualization Lab

Kalina Borkiewicz

Jeff Carpenter

Stuart Levy

ILLINOIS
School of Information Sciences

Jill Naiman

(Slides brazenly stolen from Kalina)

Digitizing Science: Indexing the Astronomical Literature

Jill P. Naiman
+ Peter Williams & Alyssa Goodman (Harvard, Seamless Astronomy)
+ Ishita Ghosh. Toby Tao, Shantanu Pagare, Ayesha Baweja, Linh Pham (iSchool)

The Dataset

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WR40		19 May 1994	[OIII]	2100	4b
WR75	HD147419	17 May 1994	Hα	2700	1a
WR75		17 May 1994	[OIII]	2700	1b
WR85	HR6392B	18 May 1994	Hα	900	5

* uses the nomenclature of van der Hucht et al. (1981).

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In this paper, we provide new, deep imaging of a number of multiple rings observed around WR stars in an optical narrow-band survey made of WR stars in the southern skies. We discuss their possible implications for WR evolution and postulate what further information they may provide about the evolution of massive stars with closer investigation.

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3.1 Bipolar Shells

Figures 1(a) and 1(b) show new, deep images of the nebula RCW 104 in both Hα and [O III] which surrounds the WR star WR75. This is the only object in our sample to show a bipolar morphology in Hα. However, close inspection of Fig. 1 of Marston *et al.* (1994) shows that the nebula NGC 2359 around the star WR6 has a diffuse outer, bipolar shell, which extends to approximately 20′ from the central star. The bright shell in the center is only 5′ across. NGC 2359 has been shown to have multiple velocity components which may be associated with multiple ejections (Goudis *et al.* 1994). Ejected material appears to be interacting with the diffuse bipolar materials as well as a nearby molecular cloud (Marston 1991; Schneps *et al.* 1981). The shell around WR75 shows similar multiple components. An outer bipolar flow is outlined by strong Hα filaments in the central regions while fainter lobes are observed to the north and south, extending to around 15′ from the central WN6 star. An inner ring of [O III] emitting material is observed entirely within the bipolar outflow and is only 10′ in diameter. The outer filaments of RCW 104 have been spectroscopically observed by Esteban *et al.* (1990), who suggest their abundances are similar to that expected from the enhanced abundances in a RSG wind. We might interpret our observations of these two bipolar nebulae as being the RSG ejecta outer filaments and relatively young WR winds interacting with the ejecta to form central cavities. The expansion of the cavities has not yet reached the edge of the RSG ejecta.

In both cases of bipolar morphology, a wind-blown (W)

(a)

(b)

FIG. 1. (a) Hα image of the filamentary, bipolar nebula RCW104 surrounding the WR star WR75. (b) Deep [O III] image of the wind-blown bubble at the center of RCW104.

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FIG. 1. The HRI data (contours) are overlaying the optical image of NGC 1961 from the digitized sky survey. The X-ray data have been smoothed with a Gaussian with σ=10″ and the contour levels are (6.66, 7.77, 8.88, 9.98, 11.09, 12.20, 13.31, 14.42, 15.53, 16.64) $\times 10^{-3}$ counts s^{-1} arcmin^{-2}.

37″) centered on the peak of the emission from the northwest quadrant of the galaxy, we determine the count rate is 5.58 $\times 10^{-3} \pm$ 0.73$\times 10^{-3}$ counts s^{-1}, which corresponds to an X-ray luminosity of 7.26$\times 10^{41}$ erg s^{-1}. The count rate from the nuclear region is 2.58$\times 10^{-3} \pm$ 0.32 $\times 10^{-3}$ counts s^{-1} which corresponds to an X-ray luminosity of 3.2$\times 10^{41}$ erg s^{-1} in a 22″ circular aperture. This implies that the X-ray luminosity from the disk of this galaxy is at least 7.9 $\times 10^{41}$ erg s^{-1}.

3. OPTICAL DATA

Images in a variety of passbands and spectral data were acquired for both galaxies to trace both young and old stellar components. Narrow-band images, with filters (of typical bandwidth 60 Å) isolating Hβ, [O III] λ5007, Hα+[N II] λ6583, and [S II] $\lambda\lambda$ 6717+6731 at each galaxy's redshift, along with adjacent continuum bands at 5125 and 6600 Å for continuum subtraction, were obtained at the KPNO 2.1 m telescope with the video-camera system in 1983 October. The field of view was 140 arcsec, well matched to the size of NGC 2276 and requiring two pointings for NGC 1961 (so that only the central part was observed in the Hβ, [O III], and [S II] passbands). Additional broad-band images were obtained with CCDs for NGC 2276 (in *B* at the KPNO 2.1 m and *BVRI* at the Lowell 1.1 m) and NGC 1961 (*BRI* and narrow band for Hα). The Video Camera data used a combination of internal quartz and night-sky flat fields, with geometric distortions produced by the image-tube chain corrected after flat-field division. Since this corrects to constant surface-brightness (rather than point-source) response, the H II region fluxes required a modest correction (reaching 25% only at the extreme corners) to recover accurate integrated fluxes. The correction (which amounts to the Jacobean of the local coordinate transformation) was derived from observations of photometric standard stars in NGC 2419. The device was quite stable for these observations, with none of the Moire patterns which sometimes plagued such data.

FIG. 2. The azimuthally averaged X-ray profile of NGC 1961 (triangles) along with the azimuthally average profile of a stellar object from the same image (circles). NGC 1961 has excess emission from 0′.25 to ~0′.7.

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tions in the *x*-*y* plane are vertical lines whose uneven spacing belies the presence of volume currents associated with the *z*-component of the field. For $\alpha > \pi$ the field topology changes, with cells containing field lines whose projections are closed loops overlying an arcade. We will not be concerned further with these topologically distinct solutions, except to note that they do not arise until α exceeds π, with the $\alpha = \pi$ straight-line solution separating them from the simple arcade solutions like that shown in Figure 1.

The footpoint shear $\Delta\alpha$ for the constant-α solution is readily calculated. Equation (7) shows that the value of A on the field line whose footpoints are located at $\pm x_f$ is simply $\cos \pi x_f$. Then the equation for this field line can be written $\cos \pi x_f = \cos \pi x e^{-\sqrt{\pi^2-\alpha^2}\,y}$, so y as a function of x on the field line is given by

$$y_0(x) = \frac{\ln(\cos \pi x/\cos \pi x_f)}{\sqrt{\pi^2 - \alpha^2}}, \quad (8)$$

where again the subscript 0 designates the constant-α solution. Using this result for y in the term $\partial A/\partial y$ that appears in equation (5) then gives a very simple result for the shear $\Delta\alpha$ expressed as a function of the footpoint coordinate x_f:

$$\Delta\alpha(x_f) = \frac{2\alpha}{\sqrt{\pi^2 - \alpha^2}}\, x_f = \lambda x_f\,, \quad (9)$$

where we have defined λ by

$$\lambda \equiv \frac{2\alpha}{\sqrt{\pi^2 - \alpha^2}}. \quad (10)$$

Thus the shear is a simple linear function of footpoint location, a fact shown graphically in Priest (1982, Fig. 3.8) and again in our Figure 5.

FIG. 3.—Field lines projected into the *x*-*y* plane for the nonlinear solution $A = A_0 + \epsilon A_1$, with $\epsilon = 0.2$ and $\alpha = 3.02$. In this case the current enhancement is great enough to lead to magnetic islands, a situation that would be impossible in the temporal evolution of an ideal MHD system. Although the figure illustrates qualitatively what a closed-loop solution looks like, the assumptions leading to the perturbation expansion $A = A_0 + \epsilon A_1$ are violated before closed loops appear (see Fig. 4).

FIG. 2.—Plot of the perturbation solution $A_1(x, y)$, for $\alpha = 0.5$. The single maximum corresponds to a region where current density is enhanced over the constant-α solution.

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to which it is subject in consequence of the attraction of the sun and moon and as modified by the resulting distortion of the body of the earth. But this may be furnished with any desired degree of accuracy by the changes in the position of the level of a liquid surface which is necessarily normal to the resultant of all the forces acting. If from these we can eliminate all but the gravitational forces the problem is solved.

FIG. 1.—Microscope and gauge

A very sensitive method of measuring the changes in level is furnished by the interferometer; and a method of carrying this into practice was devised and the apparatus constructed[1] in 1910.

But before attempting to utilize so delicate an appliance it was deemed advisable to make these preliminary experiments with the microscope. Accordingly a 6-inch pipe, 500 feet long, was half filled with water,[2] the level of which could be read off through the glass sides of the end vessels, as shown in Fig. 1.

[1] An interference apparatus for this purpose was independently devised by Professor A. G. Webster.

[2] The vessels at the ends were at first connected by a pipe filled with water, but with this arrangement temperature changes produced enormous disturbances in the level.

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FIG. 95.—Same as Fig. 9 for NGC 5907

YOUNG ET AL. (see 98, 228)

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FIG. 3.—Sequence of magnetograms made at Kitt Peak. Solar north is top, with west to the right. The north-south dimension in each of the magnetograms is 4X3.

ATHAY, JOHNS, AND ZIRIN (see page 878)

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The Dataset

The Astrophysics Data System (ADS): https://ui.adsabs.harvard.edu/

The Idea

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The Idea

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WR30	-	19 May 1994	[OIII]	2100	3b
WR40	HD96548	18 May 1994	Hα	1950	4a
WR40	-	19 May 1994	[OIII]	2100	4b
WR75	HD14749	17 May 1994	Hα	2700	1a
WR75	-	17 May 1994	[OIII]	2700	1b
WR85	HR6392B	16 May 1994	Hα	900	5

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Fig

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WR40	-	19 May 1994	[OIII]	2100	4b
WR75	HD14749	17 May 1994	Hα	2700	1a
WR75	-	17 May 1994	[OIII]	2700	1b
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Fig

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Get locations of physical objects

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Fig

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The Idea : How do we do this?

NASA Astrophysics Data Analysis Program (20-ADAP20-0225)

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Results of our method

Naiman et al. (any day now)

Tesseract/pytesseract
OpenCV

GROBID
pdffigures2
MakeSense.ai/Zooniverse

OpenCV
Pillow
Tensorflow, Keras

Results of our method

	ScanBank No PP		ScanBank w/PP		detectron2* No PP		detectron2* w/PP		Ours No PP		Ours w/PP	
	fig	cap	fig	cap	fig	cap†	fig	cap†	fig	cap	fig	cap
TP	69.9	29.0	69.3	52.8	72.0	46.4	81.0	80.9	58.2	23.2	85.7	86.7
FP	71.4	28.8	43.6	8.7	41.8	68.2	27.1	22.4	45.3	82.3	13.7	8.6
FN	1.7	42.8	2.5	40.7	0.6	1.6	1.2	4.9	3.1	5.1	3.5	6.0
Prec	49.5	50.2	61.4	85.9	63.3	40.5	74.9	78.3	56.2	22.0	86.2	90.9
Rec	97.6	40.4	96.5	56.5	99.2	96.6	98.5	94.3	95.0	81.9	96.1	93.6
F1	65.7	44.8	75.0	68.1	77.2	57.1	85.1	85.6	70.6	34.7	90.9	92.2

Naiman et al. (any day now)

Results of our method

fig = figure cap = figure caption

	ScanBank No PP		ScanBank w/PP		detectron2* No PP		detectron2* w/PP		Ours No PP		Ours w/PP	
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True Positive TP	69.9	29.0	69.3	52.8	72.0	46.4	81.0	80.9	58.2	23.2	85.7	86.7
False Positive FP	71.4	28.8	43.6	8.7	41.8	68.2	27.1	22.4	45.3	82.3	13.7	8.6
False Negative FN	1.7	42.8	2.5	40.7	0.6	1.6	1.2	4.9	3.1	5.1	3.5	6.0
Precision Prec	49.5	50.2	61.4	85.9	63.3	40.5	74.9	78.3	56.2	22.0	86.2	90.9
Recall Rec	97.6	40.4	96.5	56.5	99.2	96.6	98.5	94.3	95.0	81.9	96.1	93.6
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1840 A. R. MARSTON: RINGS AROUND WR STARS 1840

TABLE 1. Multiple ring nebulae observed.

WR star[a]	HD Number	Date observed	Filter	Exposure (secs)	Figure
WR16	HD86161	16 May 1994	Hα	1800	2
WR30	HD94305	15 May 1994	Hα	900	3a
WR30	-	19 May 1994	[OIII]	2100	3b
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WR75	-	17 May 1994	[OIII]	2700	1b
WR85	HR6392B	16 May 1994	Hα	900	5

[a] uses the nomenclature of van der Hucht et al. (1981).

ejection events. This uses a similar line of argument to that proposed by Balick *et al.* (1992) for using the extended halos of planetary nebulae to distinguish the characteristics of the red giant stellar winds that existed prior to their formation.

In this paper, we provide new, deep imaging of a number of multiple rings observed around WR stars in an optical narrow-band survey made of WR stars in the southern skies. We discuss their possible implications for WR evolution and postulate what further information they may provide about the evolution of massive stars with closer investigation.

2. OBSERVATIONS

Narrow-band imaging, using Hα (λ=6563 Å, Δλ=12 Å) and [O III] (λ=5006 Å, Δλ=44 Å) filters was performed using a Thomson 1024×1024 CCD chip at the *f*/3 focus of the 0.6 m Curtis Schmidt at Cerro Tololo Interamerican Observatory (CTIO) during the nights of 15–19 May 1994. The sample objects were taken from the lists of Marston *et al.* (1994) and Marston & Yocum (in preparation). It was intended that all possible shells associated with the WR stars would be identified as well as information on relative sizes and morphologies. A full listing of observations used in this paper are supplied in Table 1.

3. RESULTS ON MULTIPLE RINGS

Images of the multiple ring systems of our sample are shown in Figs. 1–5. These r
gies allow a classification in
bipolar shapes in an outer e
spherical outer shells. Table 2 lists the ring type (after Chu 1991) and apparent sizes of the multiple shells.

3.1 Bipolar Shells

Figures 1(a) and 1(b) show new, deep images of the nebula RCW 104 in both Hα and [O III] which surrounds the WR star WR75. This is the only object in our sample to show a bipolar morphology in Hα. However, close inspection of Fig. 1 of Marston *et al.* (1994) shows that the nebula NGC 2359 around the star WR6 has a diffuse outer, bipolar shell, which extends to approximately 20′ from the central star. The bright shell in the center is only 5′ across. NGC 2359 has been shown to have multiple velocity components which may be associated with multiple ejections (Goudis *et al.* 1994). Ejected material appears to be interacting with the diffuse bipolar materials as well as a nearby molecular cloud (Marston 1991; Schneps *et al.* 1981). The shell around

Fig

(a)

Fig

(b)

Fig Caption

FIG. 1. (a) Hα image of the filamentary, bipolar nebula RCW104 surrounding the WR star WR75. (b) Deep [O III] image of the wind-blown bubble at the center of RCW104.

WR75 shows similar multiple components. An outer bipolar flow is outlined by strong Hα filaments in the central regions while fainter lobes are observed to the north and south, extending to around 15′ from the central WN6 star. An inner ring of [O III] emitting material is observed entirely within the bipolar outflow and is only 10′ in diameter. The outer filaments of RCW 104 have been spectroscopically observed by Esteban *et al.* (1990), who suggest their abundances are similar to that expected from the enhanced abundances in a RSG wind. We might interpret our observations of these two bipolar nebulae as being the RSG ejecta outer filaments and relatively young WR winds interacting with the ejecta to form central cavities. The expansion of the cavities has not yet reached the edge of the RSG ejecta.

In both cases of bipolar morphology, a wind-blown (W)

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anBank w/PP		detectron2* No PP		detectron2* w/PP		Ours No PP		Ours w/PP	
fig	cap	fig	cap†	fig	cap†	fig	cap	fig	cap
3	52.8	72.0	46.4	81.0	80.9	58.2	23.2	85.7	86.7
6	8.7	41.8	68.2	27.1	22.4	45.3	82.3	13.7	8.6
5	40.7	0.6	1.6	1.2	4.9	3.1	5.1	3.5	6.0
4	85.9	63.3	40.5	74.9	78.3	56.2	22.0	86.2	90.9
5	56.5	99.2	96.6	98.5	94.3	95.0	81.9	96.1	93.6
0	68.1	77.2	57.1	85.1	85.6	70.6	34.7	90.9	92.2

Naiman et al. (any day now)

= 0.9

Results of our method

Naiman et al. (any day now)

Tesseract/pytesseract
OpenCV
→ Campus cluster for large batch

GROBID
pdffigures2
MakeSense.ai/Zooniverse
→ Zooniverse scaled for citizen scientists
(Automatically tag machine learning method vs citizen science)

OpenCV
Pillow
Tensorflow, Keras
→ AWS

Summary & Useful links

astronaiman.com

Astrophysics
- https://www.astronaiman.com/publications.html
- https://www.tng-project.org/

Data Viz
- https://www.astronaiman.com/vizualization.html
- https://www.astroblend.com/ (Blender+Astro Data, hasn't been updated in a while)
- ytini.com
- https://yt-project.org/ (scientific data analysis)
- https://www.sidefx.com/ (Houdini)
- https://avl.ncsa.illinois.edu/ (Advanced Visualization Lab, NCSA)
- https://uiuc-ischool-dataviz.github.io/is445_spring2022/ (this semester's Data Viz course)
- Other courses:
  - https://www.astroblend.com/ba2016/ & https://www.astroblend.com/ba2017/
  - https://jnaiman.github.io/csci-p-14110_su2020/
  - https://jnaiman.github.io/csci-p-14110_su2019/

Digitization
- https://www.astronaiman.com/digitization.html
- https://github.com/ReadingTimeMachine (public with paper publishing)
- Review of document layout analysis: https://www.mdpi.com/2076-3417/11/12/5344

Thank you!

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