# "OCAR" Structure

- Opening
- Challenge
- Action
- Resolution

Opening (O): Whom is the story about? Who are the characters? Where does it take place? What do you need to understand about the situation to follow the story? What is the larger problem you are addressing?

Challenge (C): What do your characters need to accomplish? What specific question do you propose to answer?

Action (A): What happens to address the challenge? In a paper, this describes the work you did; in a proposal, it describes the work you hope to do.

Resolution (R): How have the characters and their world changed as a result of the action? This is your conclusion—what did you learn from your work?

# The Challenge

- Opening
- Challenge
- Action
- Resolution

You want to set up a challenge that will *engage* a variety of readers

# The Challenge

Effective “challenges” highlight scientific questions/mysteries

Ineffective “challenges” focus more on writer’s goals than potential reader’s goals.

# The Challenge

Effective "challenges" highlight scientific questions/mysteries

*"Why are some galaxies able to hold so much more gas without turning it into stars?"*

# The Challenge

*Ineffective* “challenges” focus more on writer’s goals than potential reader’s goals.

*“We wanted to characterize the gas-rich galaxies in our sample”*

# Ineffective Challenges

## Frames "objectives" rather than "questions"

| "What information will we gather?" | "What will we learn/explain/resolve?" |
|---|---|
| *Ineffective* | *Effective* |

# Ineffective Challenges

## Frames “objectives” rather than “questions”

| “We wanted to characterize the gas-rich galaxies in our sample” | “Why are some galaxies able to hold so much more gas without turning it into stars?” |
| --- | --- |
| *Ineffective* | *Effective* |

# Ineffective Challenges

## Why "objectives" are less effective than "questions"

- Weakens both science & storytelling
- Doesn't engage reader's curiosity
- Presupposes that reader shares your objectives

# Effective Challenges

Framed so that reader has a stake in the eventual resolution

# Effective Challenges

How to make sure the reader has a stake in the eventual resolution

- Provide enough context & background to appreciate puzzle
- Is straightforward to grasp
- Can be resolved by what you did.

# Effective Challenges

Makes use of readers' existing schema

"Schema" = The mental model that a typical reader will hold about your topic

# Effective Challenges

Makes use of readers' existing schema

An effective challenge should be compelling within that schema

# Effective Challenges

Makes use of readers' existing schema

"For years, people have thought X, but new data Y suggests everyone is wrong! What a puzzle!"

Surprises & mysteries are good!

# Effective Challenges

Makes use of readers' existing schema

"Everyone knows that X is a problem. Did you know that this thing I did can help?"

Leverages something readers are already invested in.

# Effective Challenges

Makes use of readers' existing schema

Even if *your* schema has evolved, due to your deep work and insights, you still have to start where the *reader's* schema is.

# Effective Challenges

Makes use of readers' existing schema

"For years, people have thought X, but new data Y suggests Z. Given this new picture we do Q."

You need to shift the schema before building on it.

# Effective Challenges

You need to shift the schema before building on it.

Huge issue for proposals!
You can *at most* teach the reviewer one new thing — it is very hard to shift someone's schema.

# Returning to "OCAR" Structure

- Opening
- Challenge
- Action
- Resolution

Opening (O): Whom is the story about? Who are the characters? Where does it take place? What do you need to understand about the situation to follow the story? What is the larger problem you are addressing?

Challenge (C): What do your characters need to accomplish? What specific question do you propose to answer?

Action (A): What happens to address the challenge? In a paper, this describes the work you did; in a proposal, it describes the work you hope to do.

Resolution (R): How have the characters and their world changed as a result of the action? This is your conclusion—what did you learn from your work?

# Note that this structure is a classic story arc

- Opening
- Challenge
- Action
- Resolution

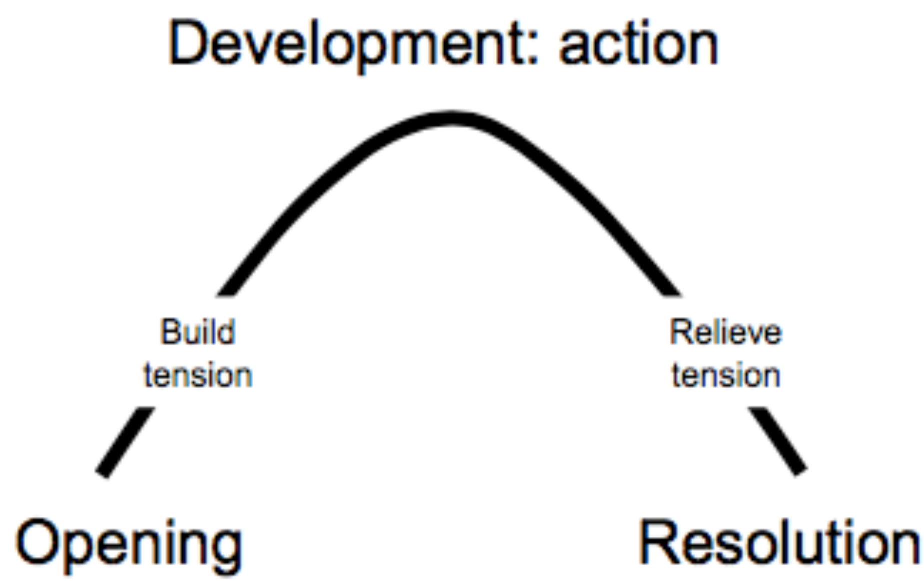


**Figure 10.1.** A story arc.

# You start the overall story in the introduction

- Opening
- Challenge
- Action
- Resolution

Background to set up challenge

Plan to reach resolution

# In proposals, you start this in the first *paragraph*.

- Opening
- Challenge
- Action
- Resolution

Background to set up challenge

Plan to reach resolution

# However, this arc should be used *throughout*

- Opening
- Challenge
- Action
- Resolution

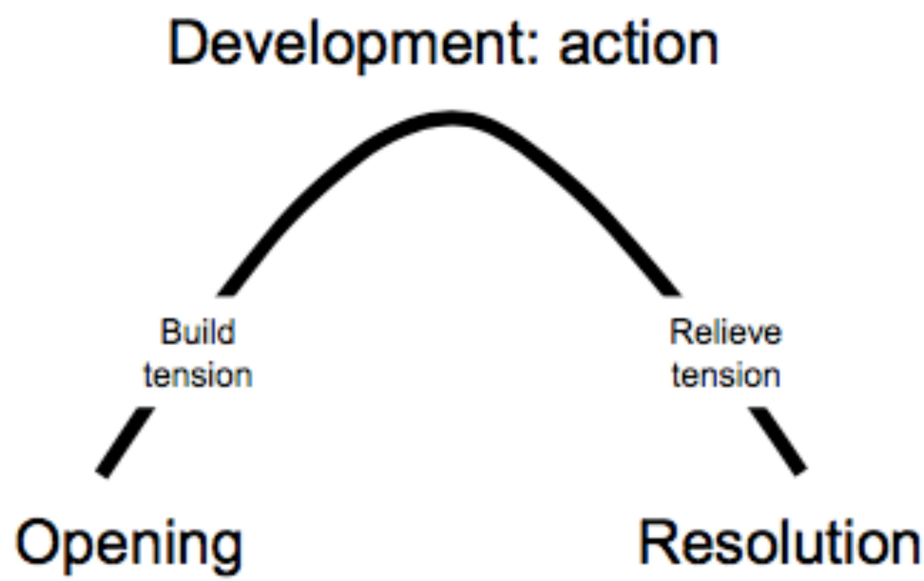


**Figure 10.1.** A story arc.

# This same structure repeats on small scales *within* the paper

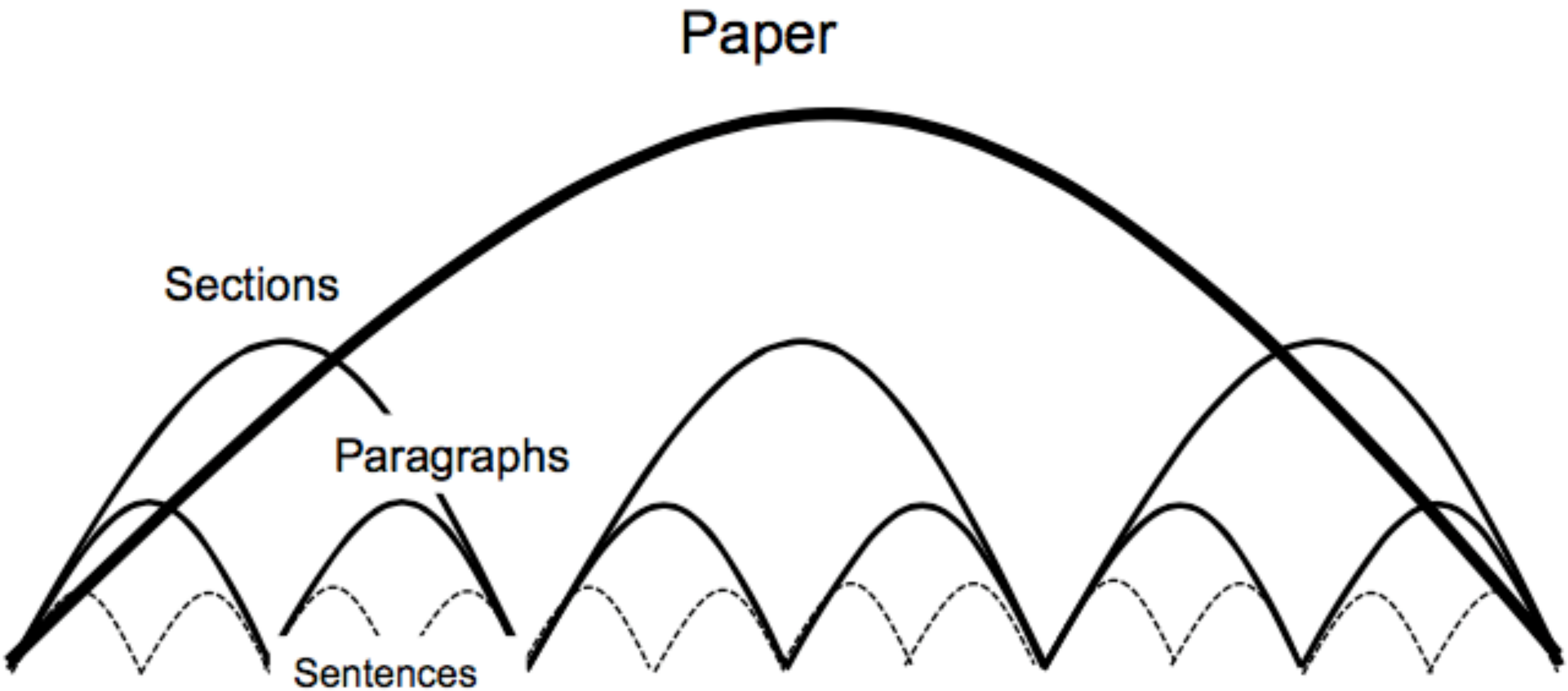


**Figure 10.2.** A story is a set of nested arcs.

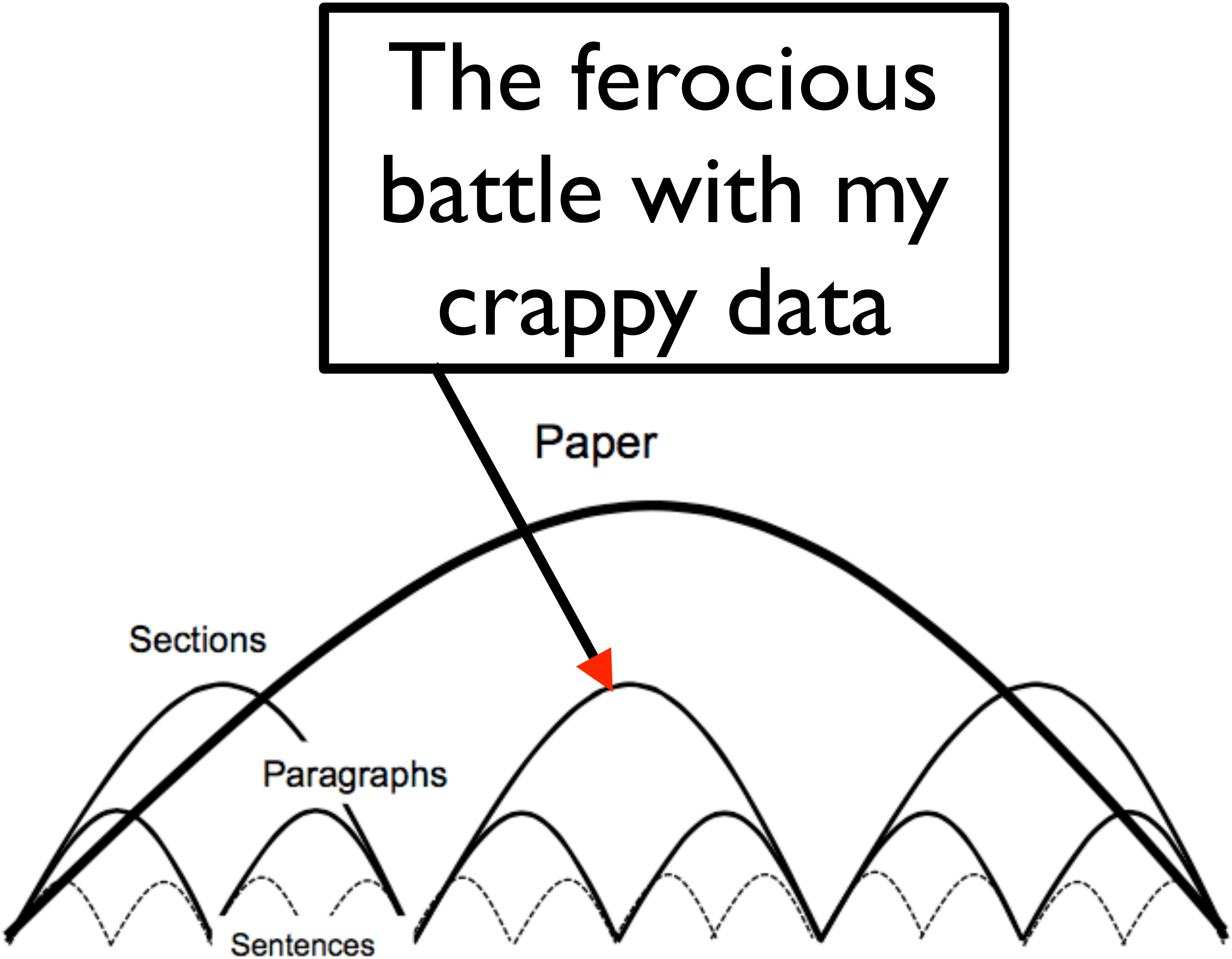


**Figure 10.2.** A story is a set of nested arcs.

# The drama of flux calibration

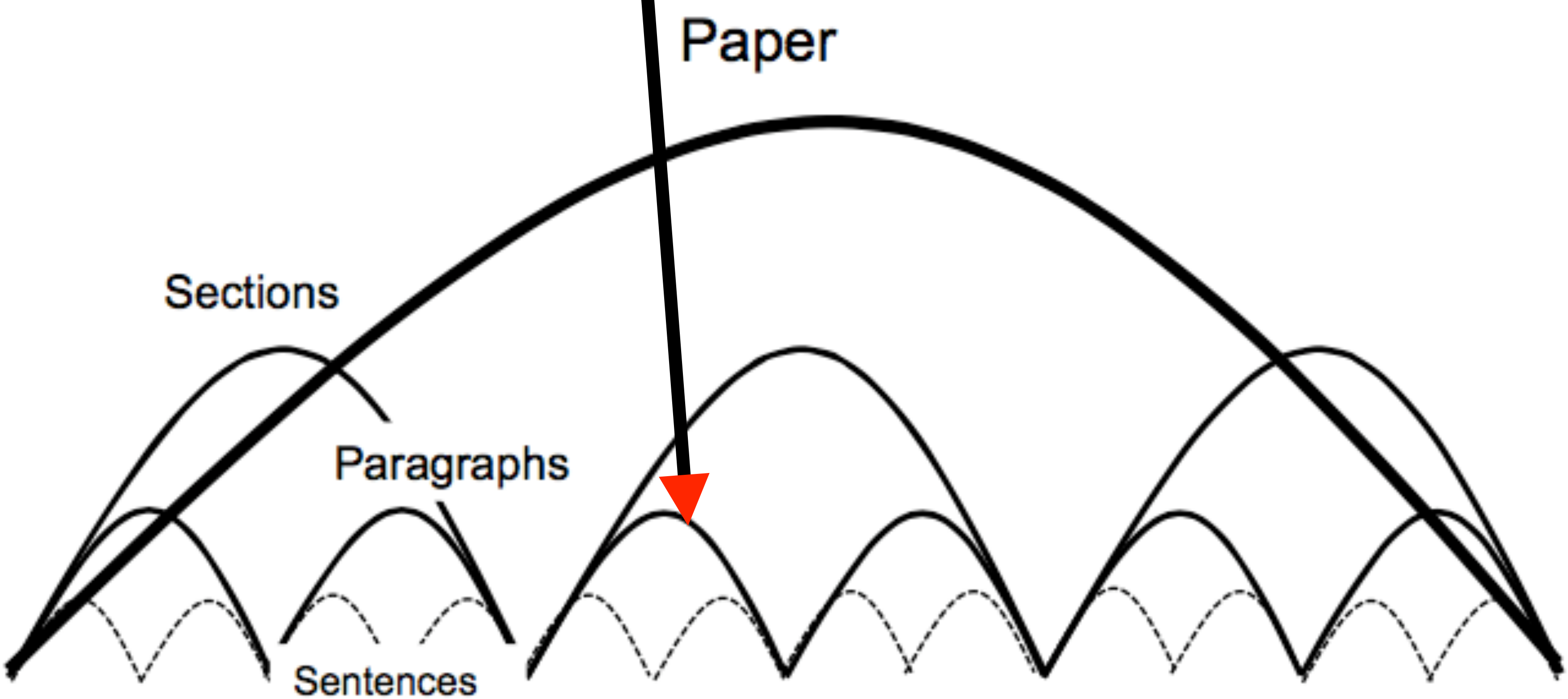


**Figure 10.2.** A story is a set of nested arcs.

After flat-fielding, we flagged CRs in the calibrated WFC3 images. The calibrated WFC3/IR images are essentially free of CRs, as expected due to the many non-destructive reads taken during data collection. However, the WFC3/UVIS images, which contain only two exposures in each filter, were plagued by CRs. We attempt to mitigate the CR effects by running all WFC3/UVIS exposures though the IDL routine `lacosmic` (van Dokkum 2001), as was done for the short ACS guard exposures. We also process the images through the PyRAF routines `tweakshifts` and `multidrizzle` using the `minmed` algorithm to flag CR-affected pixels.

Unfortunately, even after these techniques are applied, the WFC3/UVIS data still contain some obvious CRs. More aggressive CR rejection was found to eliminate central pixels of stars, and thus we cannot pursue more aggressive CR rejection at the image-processing level. Instead of risking degradation of photometry for real stars, we cull CR artifacts from our photometric catalogs, since they have poor fits to the PSF model and are anomalously "sharp." We are therefore able to cleanly remove CR-affected photometric measurements in our post-processing, as will be detailed in our description of photometry. Thus, while the residual CRs result in less attractive looking images, they do not affect our final photometry catalogs significantly. We plan to continue to experiment with ways to generate cleaner WFC3/UVIS images as the survey continues.

A complete arc about "eliminating cosmic rays (CR)"

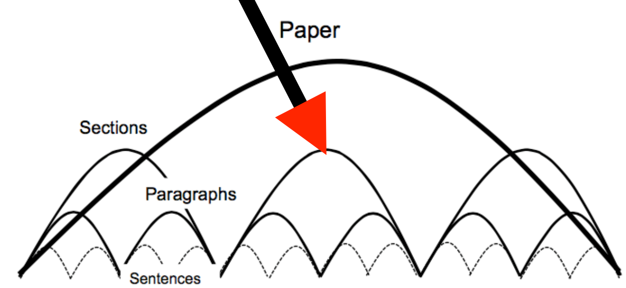

**Figure 10.2.** A story is a set of nested arcs.

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A paragraph-level arc about "special treatment of the worst cosmic rays"

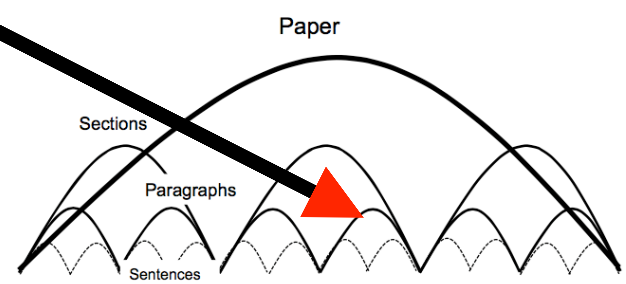



**Figure 10.2.** A story is a set of nested arcs.

# “Compartimentalized” structure allows story arcs to *end*!

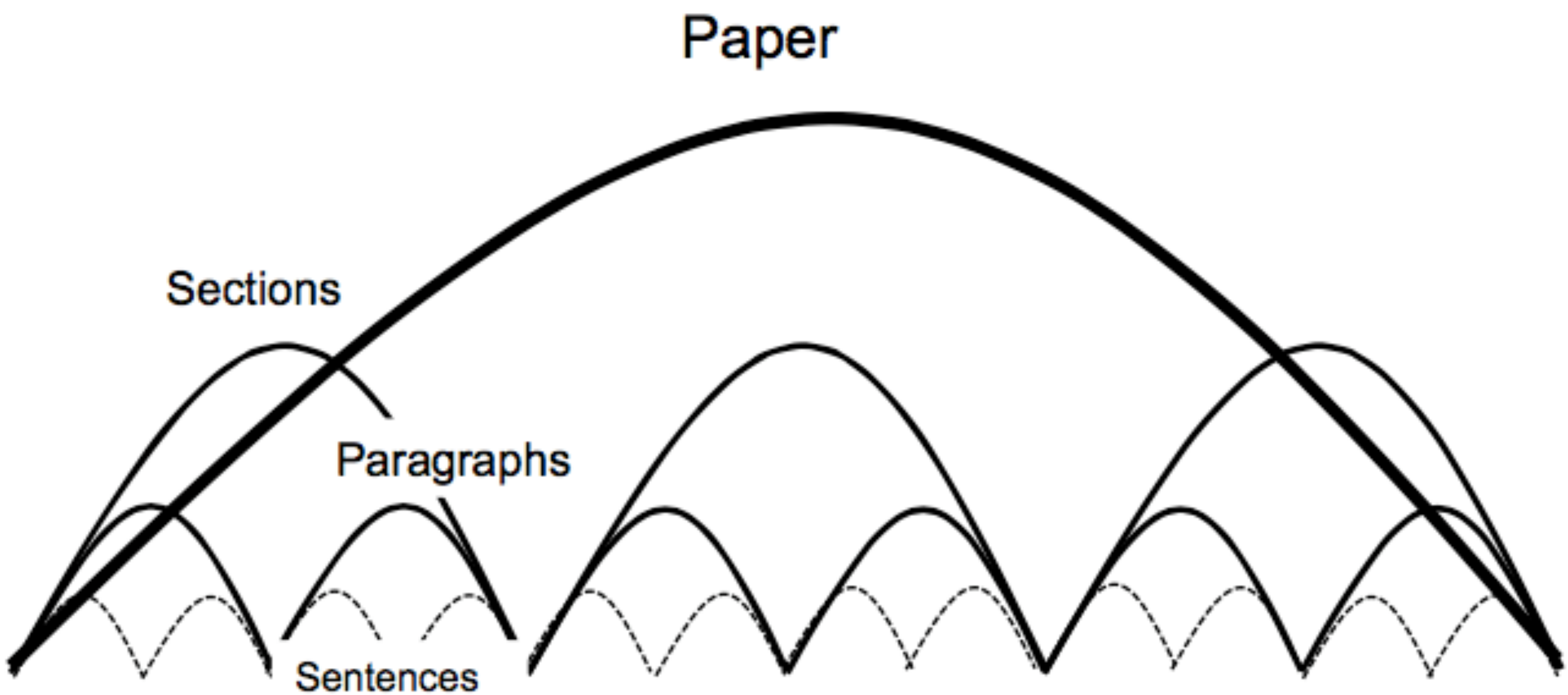



**Figure 10.2.** A story is a set of nested arcs.

# A good "compartimentalized" paragraph from an earlier class

It is instructive to understand which aspects of the model are driving agreement with the data. The normalization of the model predictions depend on the evolution of $\phi^*$, the redshift-dependent normalization of the stellar mass function, while the shapes depends on $\alpha^*$ and $M^*$, although the latter two dependencies are much weaker than the first. Recall that we have tuned the evolution of $\phi^*$ to reproduce the normalization of the SFR$-M_{\rm star}$ relations, but not the shape of these relations. The shape is thus a robust prediction of our approach, while the normalization agrees with the data by construction.

**After this paragraph, no longer need to talk about anything but its conclusions**

# “Compartamentalized” structure keeps ideas separated so they don’t interfere.

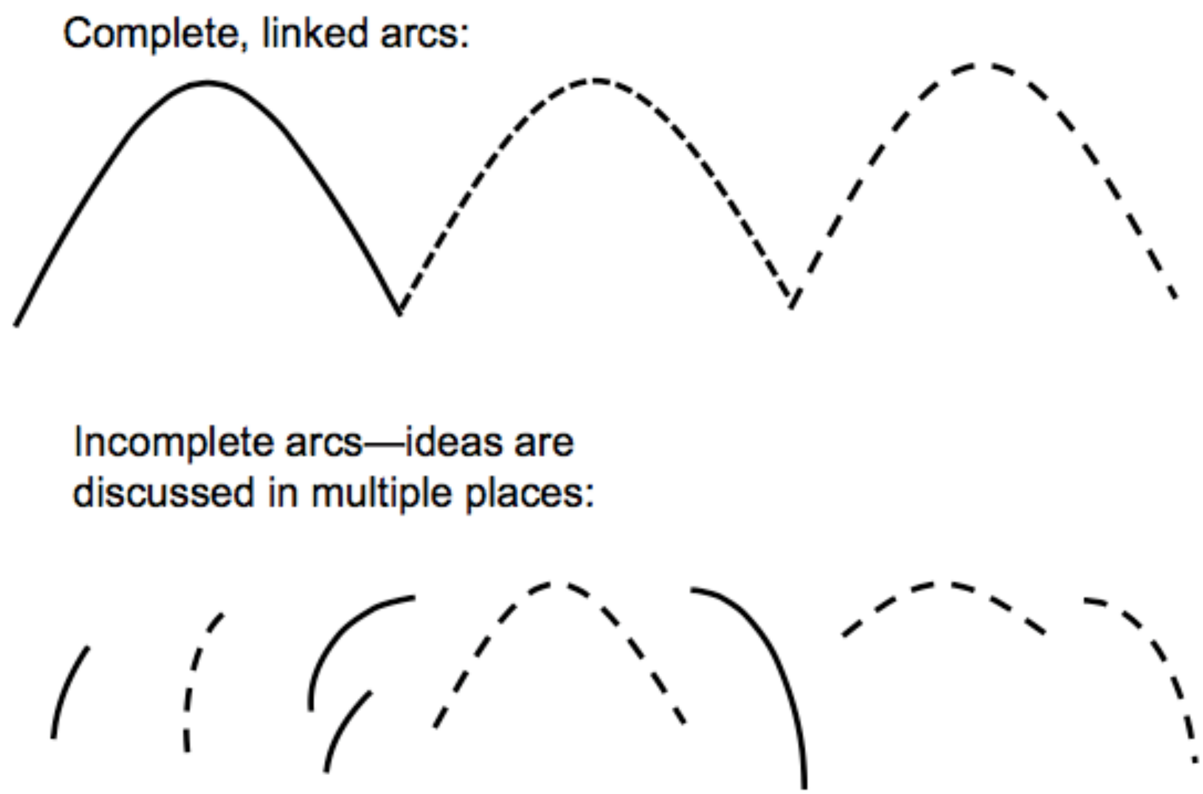



**Figure 10.3.** Complete versus broken story arcs: beginnings and endings are power positions.

# One paragraph = One topic helps enforce this naturally on small scales

# Structure of Papers

You've probably read >100 papers.

So, this won't be news.

# Overview

- Abstract
- Introduction
- Methods
- Results
- Discussion
- Conclusion
- Appendix
- Figures
- Tables

# Overview

- Abstract
- Introduction
- Methods
- Results
- Discussion
- Conclusion
- Appendix
- Figures
- Tables

Setting challenge

# Overview

- Abstract
- Introduction
- Methods
- Results
- Discussion

Sometimes merged

- Conclusion
- Appendix
- Figures
- Tables

# Overview

- Abstract
- Introduction
- Methods
- Results
- Discussion
- Conclusion

Sometimes merged

- Appendix
- Figures
- Tables

# Overview

- Abstract
- Introduction
- Methods
- Results
- Discussion
- Conclusion
- Appendix
- Figures
- Tables

# Abstract

Abstracts should be interesting, concise, and forceful.

*Favors simple, direct, highly-edited sentences*

# Abstract

You cannot assume people will know why your result is interesting*.

*Convey the big picture, but without writing an introduction.*

*You want the casual reader to decide "This is something worth knowing…"

# Abstract

99% of your readers will *only* read the abstract.

*Tell the essentials of the entire story.*

# Example Abstract: Hogg & Lang 2012

*Exponential, de Vaucouleurs, and Sersic profiles are simple and successful models for fitting two-dimensional images of galaxies. One numerical issue encountered in this kind of fitting is the pixel rendering and convolution (or correlation) of the models with the telescope point-spread function (PSF); these operations are slow, and easy to get slightly wrong at small radii. Here we exploit the realization that these models can be approximated to arbitrary accuracy with a mixture (linear superposition) of two-dimensional Gaussians (MoGs). MoGs are fast to render and fast to affine-transform. Most importantly, if you have a MoG model for the pixel-convolved PSF, the PSF-convolved, affine-transformed galaxy models are themselves MoGs and therefore very fast to compute, integrate, and render precisely. We present worked examples that can be directly used in image fitting. The MoG profiles we provide can be swapped in to replace the standard models in any image-fitting code; they sped up model fitting in our projects by an order of magnitude; they ought to make any code faster at essentially no cost in precision.*

# (1) States problem/issue

*<u>Exponential, de Vaucouleurs, and Sersic profiles are simple and successful models for fitting two-dimensional images of galaxies. One numerical issue encountered in this kind of fitting is the pixel rendering and convolution (or correlation) of the models with the telescope point-spread function (PSF); these operations are slow, and easy to get slightly wrong at small radii.</u> Here we exploit the realization that these models can be approximated to arbitrary accuracy with a mixture (linear superposition) of two-dimensional Gaussians (MoGs). MoGs are fast to render and fast to affine-transform. Most importantly, if you have a MoG model for the pixel-convolved PSF, the PSF-convolved, affine-transformed galaxy models are themselves MoGs and therefore very fast to compute, integrate, and render precisely. We present worked examples that can be directly used in image fitting. The MoG profiles we provide can be swapped in to replace the standard models in any image-fitting code; they sped up model fitting in our projects by an order of magnitude; they ought to make any code faster at essentially no cost in precision.*

# (2) States Solution

*Exponential, de Vaucouleurs, and Sersic profiles are simple and successful models for fitting two-dimensional images of galaxies. One numerical issue encountered in this kind of fitting is the pixel rendering and convolution (or correlation) of the models with the telescope point-spread function (PSF); these operations are slow, and easy to get slightly wrong at small radii. <u>Here we exploit the realization that these models can be approximated to arbitrary accuracy with a mixture (linear superposition) of two-dimensional Gaussians (MoGs). MoGs are fast to render and fast to affine-transform. Most importantly, if you have a MoG model for the pixel-convolved PSF, the PSF-convolved, affine-transformed galaxy models are themselves MoGs and therefore very fast to compute, integrate, and render precisely.</u> We present worked examples that can be directly used in image fitting. The MoG profiles we provide can be swapped in to replace the standard models in any image-fitting code; they sped up model fitting in our projects by an order of magnitude; they ought to make any code faster at essentially no cost in precision.*

# (3) Explains value of result

*Exponential, de Vaucouleurs, and Sersic profiles are simple and successful models for fitting two-dimensional images of galaxies. One numerical issue encountered in this kind of fitting is the pixel rendering and convolution (or correlation) of the models with the telescope point-spread function (PSF); these operations are slow, and easy to get slightly wrong at small radii. Here we exploit the realization that these models can be approximated to arbitrary accuracy with a mixture (linear superposition) of two-dimensional Gaussians (MoGs). MoGs are fast to render and fast to affine-transform. Most importantly, if you have a MoG model for the pixel-convolved PSF, the PSF-convolved, affine-transformed galaxy models are themselves MoGs and therefore very fast to compute, integrate, and render precisely. <u>We present worked examples that can be directly used in image fitting. The MoG profiles we provide can be swapped in to replace the standard models in any image-fitting code; they sped up model fitting in our projects by an order of magnitude; they ought to make any code faster at essentially no cost in precision.</u>*

# Let's return to earlier abstract (1) States problem/issue

AFTER THE FALL: THE DUST AND GAS IN E+A POST-STARBURST GALAXIES

A. Smercina[1,2], J.D.T. Smith[2,3], D.A. Dale[4], K.D. French[5,6,#], K.V. Croxall[7], S. Zhukovska[8], A. Togi[9], E.F. Bell[1], A.F. Crocker[10], B.T. Draine[11], T.H. Jarrett[12], C. Tremonti[13], Yujin Yang[14], A.I. Zabludoff[6]

ABSTRACT

The traditional picture of post-starburst galaxies as dust- and gas-poor merger remnants, rapidly transitioning to quiescence, has been recently challenged. Unexpected detections of a significant ISM in many post-starbursts raise important questions. Are they truly quiescent and, if so, what mechanisms inhibit further star formation? What processes dominate their ISM energetics? We present an infrared spectroscopic and photometric survey of 33 SDSS-selected E+A post-starbursts, aimed at resolving these questions. We find compact, warm dust reservoirs with high PAH abundances, and total gas and dust masses significantly higher than expected from stellar recycling alone. Both PAH/TIR and dust-to-burst stellar mass ratios are seen to decrease with post-burst age, indicative of the accumulating effects of dust destruction and an incipient transition to hot, early-type ISM properties. Their infrared spectral properties are unique, with dominant PAH emission, very weak nebular lines, unusually strong $H_2$ rotational emission, and deep [C II] deficits. There is substantial scatter among SFR indicators, and both PAH and TIR luminosities provide overestimates. Even as potential upper limits, all tracers show that the SFR has typically experienced a more than two order-of-magnitude decline since the starburst, and that the SFR is considerably lower than expected given both their stellar masses and molecular gas densities. These results paint a coherent picture of systems in which star formation was, indeed, rapidly truncated, but in which the ISM was *not* completely expelled, and is instead supported against collapse by latent or continued injection of turbulent or mechanical heating. The resulting aging burst populations provide a "high-soft" radiation field which seemingly dominates the E+As' unusual ISM energetics.

http://xxx.lanl.gov/pdf/1802.04798

# (2) States approach

## ABSTRACT

The traditional picture of post-starburst galaxies as dust- and gas-poor merger remnants, rapidly transitioning to quiescence, has been recently challenged. Unexpected detections of a significant ISM in many post-starbursts raise important questions. Are they truly quiescent and, if so, what mechanisms inhibit further star formation? What processes dominate their ISM energetics? We present an infrared spectroscopic and photometric survey of 33 SDSS-selected E+A post-starbursts, aimed at resolving these questions. We find compact, warm dust reservoirs with high PAH abundances, and total gas and dust masses significantly higher than expected from stellar recycling alone. Both PAH/TIR and dust-to-burst stellar mass ratios are seen to decrease with post-burst age, indicative of the accumulating effects of dust destruction and an incipient transition to hot, early-type ISM properties. Their infrared spectral properties are unique, with dominant PAH emission, very weak nebular lines, unusually strong $H_2$ rotational emission, and deep [C II] deficits. There is substantial scatter among SFR indicators, and both PAH and TIR luminosities provide overestimates. Even as potential upper limits, all tracers show that the SFR has typically experienced a more than two order-of-magnitude decline since the starburst, and that the SFR is considerably lower than expected given both their stellar masses and molecular gas densities. These results paint a coherent picture of systems in which star formation was, indeed, rapidly truncated, but in which the ISM was *not* completely expelled, and is instead supported against collapse by latent or continued injection of turbulent or mechanical heating. The resulting aging burst populations provide a "high-soft" radiation field which seemingly dominates the E+As' unusual ISM energetics.

# (3) States findings

ABSTRACT

The traditional picture of post-starburst galaxies as dust- and gas-poor merger remnants, rapidly transitioning to quiescence, has been recently challenged. Unexpected detections of a significant ISM in many post-starbursts raise important questions. Are they truly quiescent and, if so, what mechanisms inhibit further star formation? What processes dominate their ISM energetics? We present an infrared spectroscopic and photometric survey of 33 SDSS-selected E+A post-starbursts, aimed at resolving these questions. We find compact, warm dust reservoirs with high PAH abundances, and total gas and dust masses significantly higher than expected from stellar recycling alone. Both PAH/TIR and dust-to-burst stellar mass ratios are seen to decrease with post-burst age, indicative of the accumulating effects of dust destruction and an incipient transition to hot, early-type ISM properties. Their infrared spectral properties are unique, with dominant PAH emission, very weak nebular lines, unusually strong $H_2$ rotational emission, and deep [C II] deficits. There is substantial scatter among SFR indicators, and both PAH and TIR luminosities provide overestimates. Even as potential upper limits, all tracers show that the SFR has typically experienced a more than two order-of-magnitude decline since the starburst, and that the SFR is considerably lower than expected given both their stellar masses and molecular gas densities. These results paint a coherent picture of systems in which star formation was, indeed, rapidly truncated, but in which the ISM was *not* completely expelled, and is instead supported against collapse by latent or continued injection of turbulent or mechanical heating. The resulting aging burst populations provide a "high-soft" radiation field which seemingly dominates the E+As' unusual ISM energetics.

# (4) Contextualizes results

ABSTRACT

The traditional picture of post-starburst galaxies as dust- and gas-poor merger remnants, rapidly transitioning to quiescence, has been recently challenged. Unexpected detections of a significant ISM in many post-starbursts raise important questions. Are they truly quiescent and, if so, what mechanisms inhibit further star formation? What processes dominate their ISM energetics? We present an infrared spectroscopic and photometric survey of 33 SDSS-selected E+A post-starbursts, aimed at resolving these questions. We find compact, warm dust reservoirs with high PAH abundances, and total gas and dust masses significantly higher than expected from stellar recycling alone. Both PAH/TIR and dust-to-burst stellar mass ratios are seen to decrease with post-burst age, indicative of the accumulating effects of dust destruction and an incipient transition to hot, early-type ISM properties. Their infrared spectral properties are unique, with dominant PAH emission, very weak nebular lines, unusually strong $H_2$ rotational emission, and deep [C II] deficits. There is substantial scatter among SFR indicators, and both PAH and TIR luminosities provide overestimates. Even as potential upper limits, all tracers show that the SFR has typically experienced a more than two order-of-magnitude decline since the starburst, and that the SFR is considerably lower than expected given both their stellar masses and molecular gas densities. These results paint a coherent picture of systems in which star formation was, indeed, rapidly truncated, but in which the ISM was *not* completely expelled, and is instead supported against collapse by latent or continued injection of turbulent or mechanical heating. The resulting aging burst populations provide a "high-soft" radiation field which seemingly dominates the E+As' unusual ISM energetics.

# What about the other abstract?

**ABSTRACT**

By analysing a sample of galaxies selected from the HI Parkes All Sky Survey (HIPASS) to contain more than 2.5 times their expected HI content based on their optical properties, we investigate what drives these HI eXtreme (HIX) galaxies to be so HI-rich. We model the H I kinematics with the *T*ilted *R*ing *F*itting *C*ode TiRiFiC and compare the observed HIX galaxies to a control sample of galaxies from HIPASS as well as simulated galaxies built with the semi-analytic model DARK SAGE. We find that (1) H I discs in HIX galaxies are more likely to be warped and more likely to host H I arms and tails than in the control galaxies, (2) the average H I and average stellar column density of HIX galaxies is comparable to the control sample, (3) HIX galaxies have higher H I and baryonic specific angular momenta than control galaxies, (4) most HIX galaxies live in higher-spin haloes than most control galaxies. These results suggest that HIX galaxies are H I-rich because they can support more H I against gravitational instability due to their high specific angular momentum. The majority of the HIX galaxies inherits their high specific angular momentum from their halo. The H I content of HIX galaxies might be further increased by gas-rich minor mergers.

Does not tie to a science question. The "investigation" is very self-referential ("why is my sample like this"?)

# What about the other abstract?

**ABSTRACT**

By analysing a sample of galaxies selected from the HI Parkes All Sky Survey (HIPASS) to contain more than 2.5 times their expected HI content based on their optical properties, we investigate what drives these HI eXtreme (HIX) galaxies to be so HI-rich. We model the H I kinematics with the *T*ilted *R*ing *F*itting *C*ode TiRiFiC and compare the observed HIX galaxies to a control sample of galaxies from HIPASS as well as simulated galaxies built with the semi-analytic model DARK SAGE. We find that (1) H I discs in HIX galaxies are more likely to be warped and more likely to host H I arms and tails than in the control galaxies, (2) the average H I and average stellar column density of HIX galaxies is comparable to the control sample, (3) HIX galaxies have higher H I and baryonic specific angular momenta than control galaxies, (4) most HIX galaxies live in higher-spin haloes than most control galaxies. These results suggest that HIX galaxies are H I-rich because they can support more H I against gravitational instability due to their high specific angular momentum. The majority of the HIX galaxies inherits their high specific angular momentum from their halo. The H I content of HIX galaxies might be further increased by gas-rich minor mergers.

This a reasonable conclusion, but doesn't tie into a larger question/issue.

# What about the other abstract?


**ABSTRACT**

By analysing a sample of galaxies selected from the HI Parkes All Sky Survey (HIPASS) to contain more than 2.5 times their expected HI content based on their optical properties, we investigate what drives these HI eXtreme (HIX) galaxies to be so HI-rich. We model the H I kinematics with the *T*ilted *R*ing *Fi*tting *C*ode TiRiFiC and compare the observed HIX galaxies to a control sample of galaxies from HIPASS as well as simulated galaxies built with the semi-analytic model DARK SAGE. We find that (1) H I discs in HIX galaxies are more likely to be warped and more likely to host H I arms and tails than in the control galaxies, (2) the average H I and average stellar column density of HIX galaxies is comparable to the control sample, (3) HIX galaxies have higher H I and baryonic specific angular momenta than control galaxies, (4) most HIX galaxies live in higher-spin haloes than most control galaxies. These results suggest that HIX galaxies are H I-rich because they can support more H I against gravitational instability due to their high specific angular momentum. The majority of the HIX galaxies inherits their high specific angular momentum from their halo. The H I content of HIX galaxies might be further increased by gas-rich minor mergers.


Its impact is also lost because it’s followed by a couple more (somewhat random) sentences that blunt it being in a stress position.

# How to construct a *Nature* summary paragraph

Annotated example taken from *Nature* 435, 114–118 (5 May 2005).

One or two sentences providing a **basic introduction** to the field, comprehensible to a scientist in any discipline.

Two to three sentences of **more detailed background**, comprehensible to scientists in related disciplines.

One sentence clearly stating the **general problem** being addressed by this particular study.

One sentence summarizing the main result (with the words "**here we show**" or their equivalent).

Two or three sentences explaining what the **main result** reveals in direct comparison to what was thought to be the case previously, or how the main result adds to previous knowledge.

One or two sentences to put the results into a more **general context**.

Two or three sentences to provide a **broader perspective**, readily comprehensible to a scientist in any discipline, may be included in the first paragraph if the editor considers that the accessibility of the paper is significantly enhanced by their inclusion. Under these circumstances, the length of the paragraph can be up to 300 words. (This example is 190 words without the final section, and 250 words with it).

During cell division, mitotic spindles are assembled by microtubule-based motor proteins[1,2]. The bipolar organization of spindles is essential for proper segregation of chromosomes, and requires plus-end-directed homotetrameric motor proteins of the widely conserved kinesin-5 (BimC) family[3]. Hypotheses for bipolar spindle formation include the 'push–pull mitotic muscle' model, in which kinesin-5 and opposing motor proteins act between overlapping microtubules[2,4,5]. However, the precise roles of kinesin-5 during this process are unknown. Here we show that the vertebrate kinesin-5 Eg5 drives the sliding of microtubules depending on their relative orientation. We found in controlled *in vitro* assays that Eg5 has the remarkable capability of simultaneously moving at ~20 nm $s^{-1}$ towards the plus-ends of each of the two microtubules it crosslinks. For anti-parallel microtubules, this results in relative sliding at ~40 nm $s^{-1}$, comparable to spindle pole separation rates *in vivo*[6]. Furthermore, we found that Eg5 can tether microtubule plus-ends, suggesting an additional microtubule-binding mode for Eg5. Our results demonstrate how members of the kinesin-5 family are likely to function in mitosis, pushing apart interpolar microtubules as well as recruiting microtubules into bundles that are subsequently polarized by relative sliding. We anticipate our assay to be a starting point for more sophisticated *in vitro* models of mitotic spindles. For example, the individual and combined action of multiple mitotic motors could be tested, including minus-end-directed motors opposing Eg5 motility. Furthermore, Eg5 inhibition is a major target of anti-cancer drug development, and a well-defined and quantitative assay for motor function will be relevant for such developments.

# Abstract

In short, it is worth investing in substantial, careful editing of your abstract to maximize its impact

If the abstract is the *only* thing that someone reads about your work, will they appreciate it?

# A few more points about abstracts:

Warning:
If a result isn't in the abstract, it's lost forever.

Thanks a LOT, ADS.

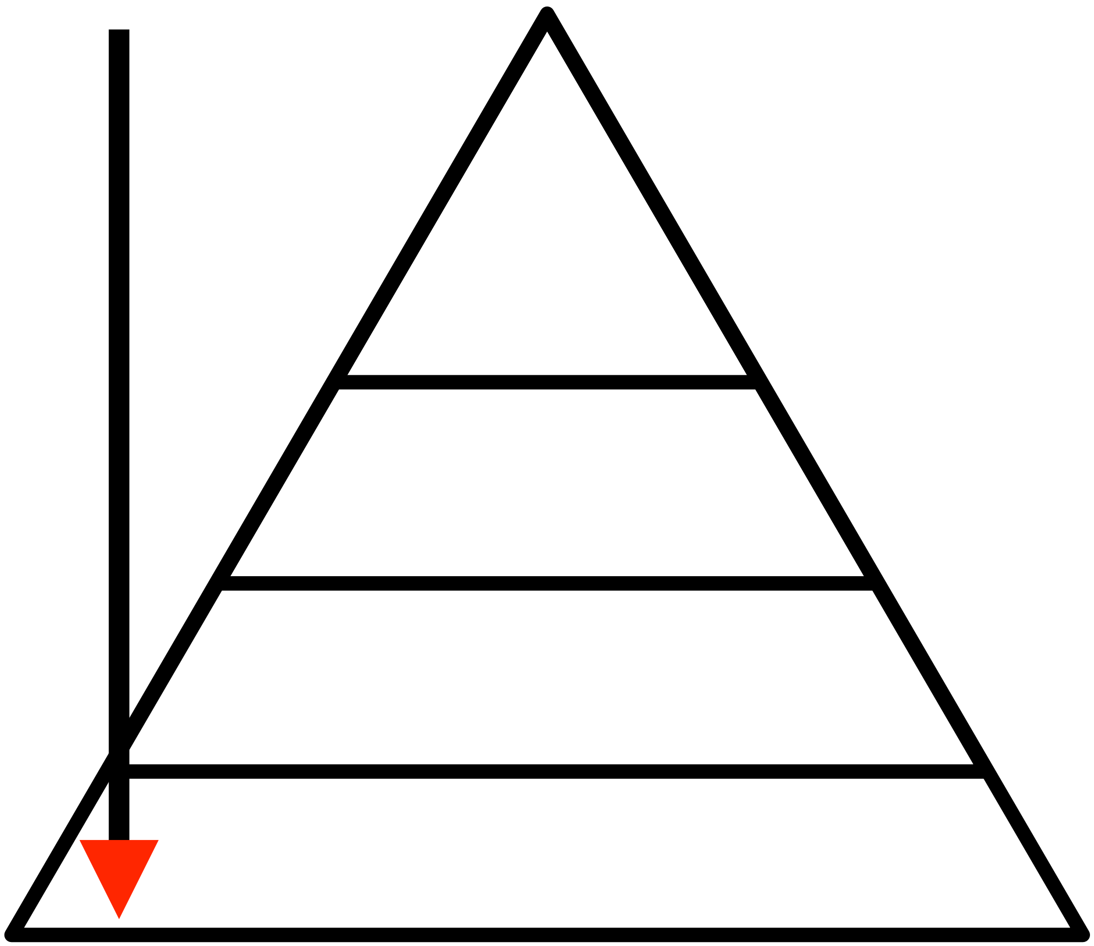
# A few more points about abstracts:

It is frequently helpful to have a collaborator draft the abstract, so it's in a different voice

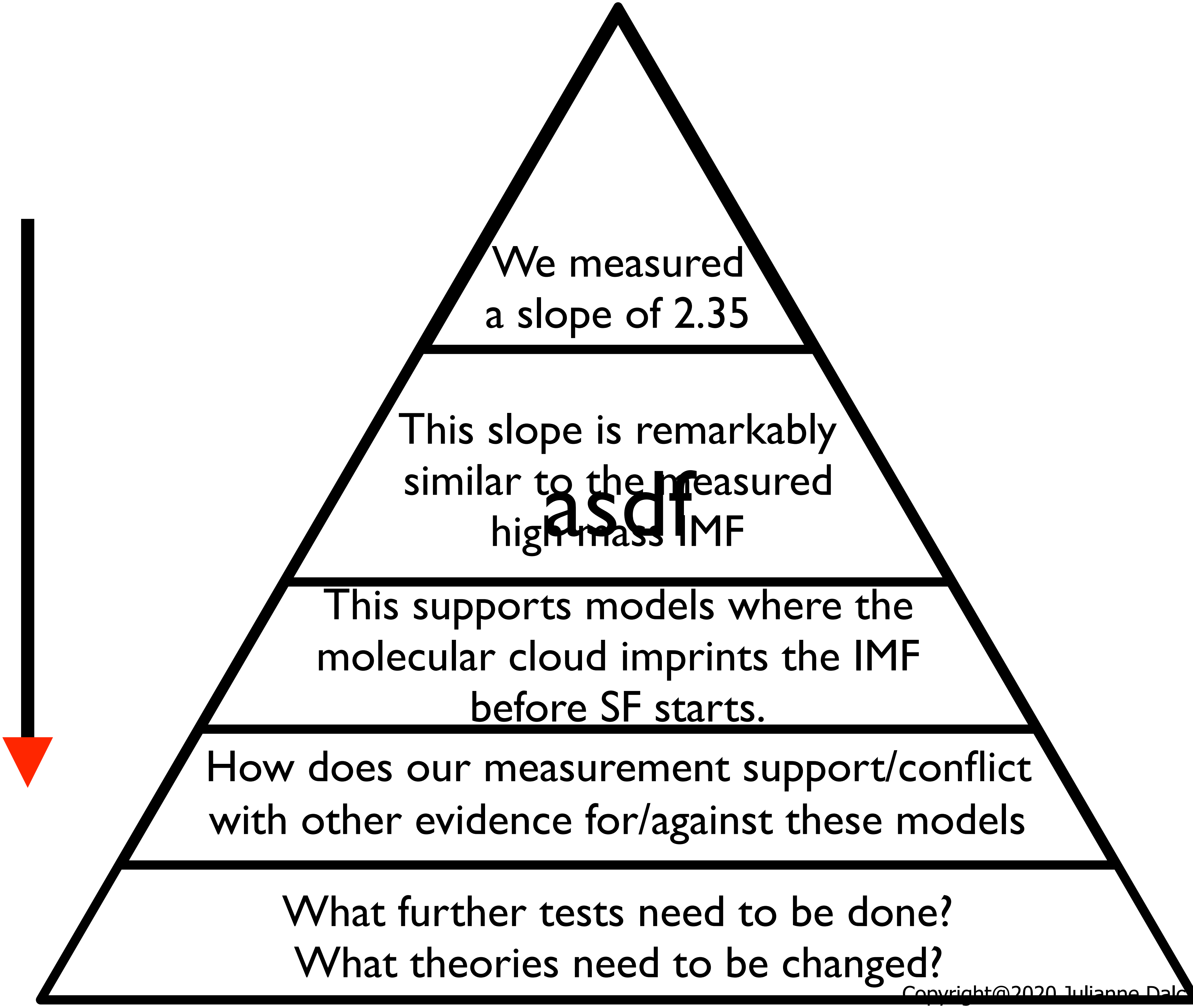
# Overview

- Abstract
- Introduction
- Methods
- Results
- Discussion
- Conclusion
- Appendix
- Figures
- Tables

# Discussions have almost the opposite structure as introductions



Move from your specific result, to the larger implications


We measured
a slope of 2.35
This slope is remarkably
similar to the measured
high mass IMF
asdf
This supports models where the
molecular cloud imprints the IMF
before SF starts.
How does our measurement support/conflict
with other evidence for/against these models
What further tests need to be done?
What theories need to be changed?

# Discussion

This is your chance to *explicitly* tell your story

Do not assume that your reader knows what to make of your result.

# Discussion

Number one problem:
Rushing

# Discussion

Make sure you take the time to explain the full implications of your result.

# Discussion

Make sure you take the time to ~~explain~~ the full implications of your ^*understand* result.

# Discussion

## Number two problem: Reluctance to "hold forth"

*"It's obvious."*
*"It's boring."*
*"Everyone knows this."*
*"No one would care."*

# Discussion

If this is an issue, change your mental frame from "*holding forth*" to "*patiently teaching*"

# Discussion

This is also the section where the reader can get the clearest view of how you think.

# Discussion

Being clear, thorough, and balanced builds respect for you as a scientist

# Overview

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# Methods/Analysis

Three main goals.

# Methods/Analysis

Goal One:
Give enough information that someone could reproduce your result*

*within reason.

# Methods/Analysis

The level of detail should be higher where there are ambiguous choices

*Which solar abundance pattern?*
*Which UV background model?*
*Which photometry version?*

# Methods/Analysis

The level of detail should be higher where the choices could easily affect the result

Example: *Which of the many SFR indicators did you adopt (each of which has different associated biases & timescales) and why?*

# Methods/Analysis

Your work involved many choices.

Make sure you help the reader understand why you made specific choices.

# Methods/Analysis

"We adopted the X prescription because it is insensitive to dust"

"The Y algorithm proved to be more robust to outliers than Z, based on our tests with mock data"

# Methods/Analysis

Goal Two:
Contextualize information to build your reader's intuition

*within reason.

# Methods/Analysis

Contextualize numbers whenever possible.

People remember quantities better by "feel" rather than by value*.

Don't make your reader do the work.

*e.g. "Milky Way mass" vs "$10^{10}$ $M_{sun}$"

# Methods/Analysis

"We adopted a cluster mass of $10^6$ $M_{sun}$, comparable to that of Omega Cen"

"Model A's mass was 50% smaller than that of Model B ($5 \times 10^9$ $M_{sun}$ vs $10^{10}$ $M_{sun}$)"

# Methods/Analysis

Goal Three:

Build credibility

# Methods/Analysis

You are signaling that you:

- Pay attention to details
- Think through implications
- Are careful
- Evaluate your own work critically & with skepticism

# Methods/Analysis

- Pay attention to details
- Think through implications
- Are careful
- Evaluate your own work critically & with skepticism

Signaling these traits is equivalent to actually *doing* them. Which is *science*.

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# Aside #1

## The amount that you write should be proportional to:

- it's importance to your story.
- it's importance to the reader's understanding.
- ~~the amount of time you spent doing it or understanding it.~~

# Aside #2

Do not hesitate to remind your reader of why you're doing something*.

This is particularly important in "drier" method sections

*although do not belabor it. Too much repetition can be irritating.

# Aside #3

## Do not abandon the principles of paragraph structure

- Topic sentence.
- Supporting detail.
- Closing sentence should help signal next topic sentence.

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# Conclusions

In the era where most
papers are skimmed,
a bulleted list of results is
a good idea.

If this is the only thing that is read,
will you be satisfied with what the
reader learned?

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# Appendices

These are good places to put useful information that would otherwise interrupt your story

# Appendices

But, if you're putting in an Appendix, evaluate if that information needs to be present at all.

Tradeoff between "completeness & posterity" vs "lard"

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# Figures

Many papers are only "read" via the figure captions.

(Think "CApheine")

# Figures

Every caption should include the *explicit conclusion* you want the reader to draw.

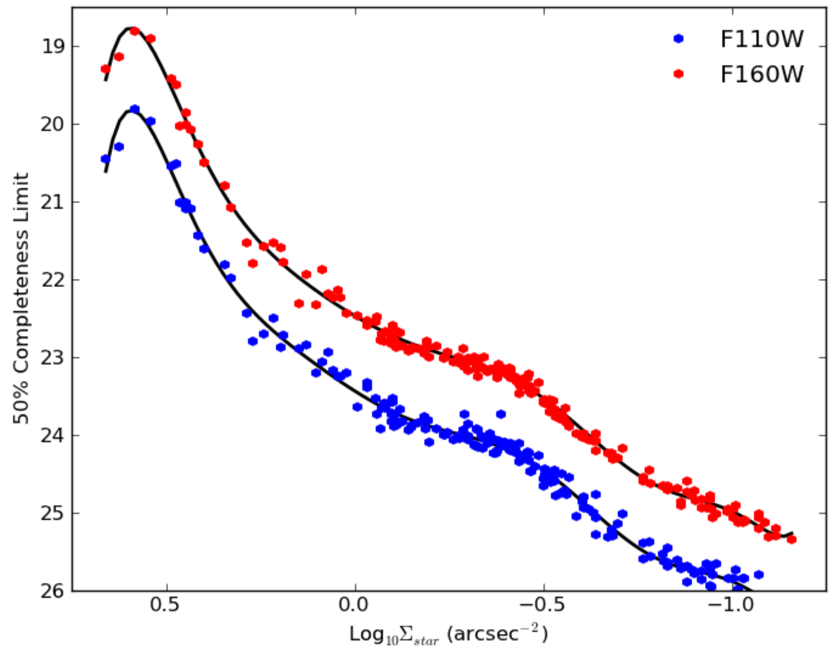



FIG. 4.— The depth of the photometry as a function of radius. The blue and red points show the 50% completeness limit $m_{50}$ as a function of $\log_{10}$ of the local stellar surface density in bright RGB stars, for the F110W and F160W filters, respectively. The solid lines show 10th order polynomial fits to the data, used to interpolate to an appropriate limiting magnitude at each position in the galaxy. The PHAT photometry is crowding-limited, and thus the limiting magnitude is a strong function of the local stellar surface density. The apparent roll-off in the inner disk (at high surface densities in the left side of the plot) is an artifact of the extraordinarily high crowding levels in the inner bulge, which lead to biases in the photometry; while we include these regions for completeness here, we do not actually analyze their $A_V$ distributions.

# First part describes the "logistics"

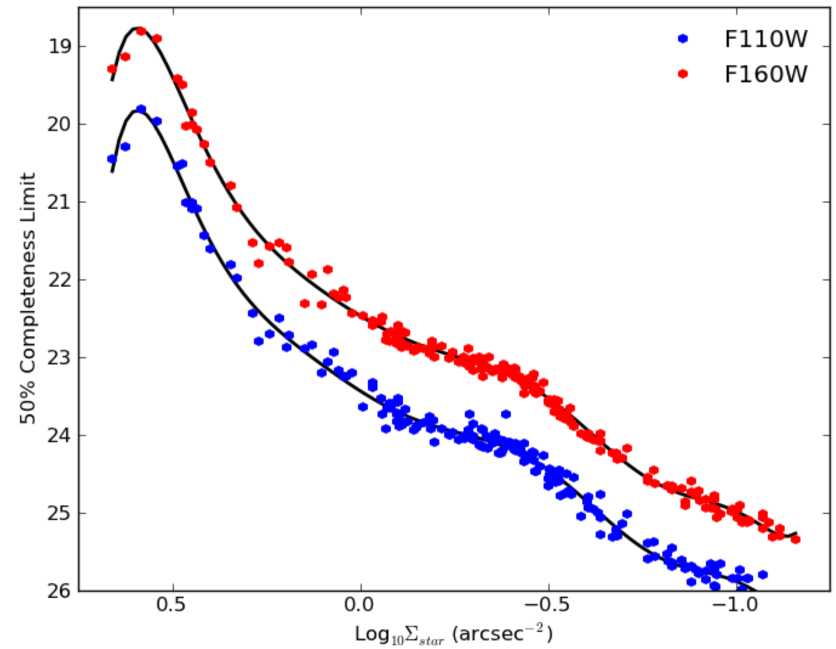



FIG. 4.— The depth of the photometry as a function of radius. The blue and red points show the 50% completeness limit $m_{50}$ as a function of $\log_{10}$ of the local stellar surface density in bright RGB stars, for the F110W and F160W filters, respectively. The solid lines show 10th order polynomial fits to the data, used to interpolate to an appropriate limiting magnitude at each position in the galaxy. The PHAT photometry is crowding-limited, and thus the limiting magnitude is a strong function of the local stellar surface density. The apparent roll-off in the inner disk (at high surface densities in the left side of the plot) is an artifact of the extraordinarily high crowding levels in the inner bulge, which lead to biases in the photometry; while we include these regions for completeness here, we do not actually analyze their $A_V$ distributions.

# The second part gives *what the reader should learn*

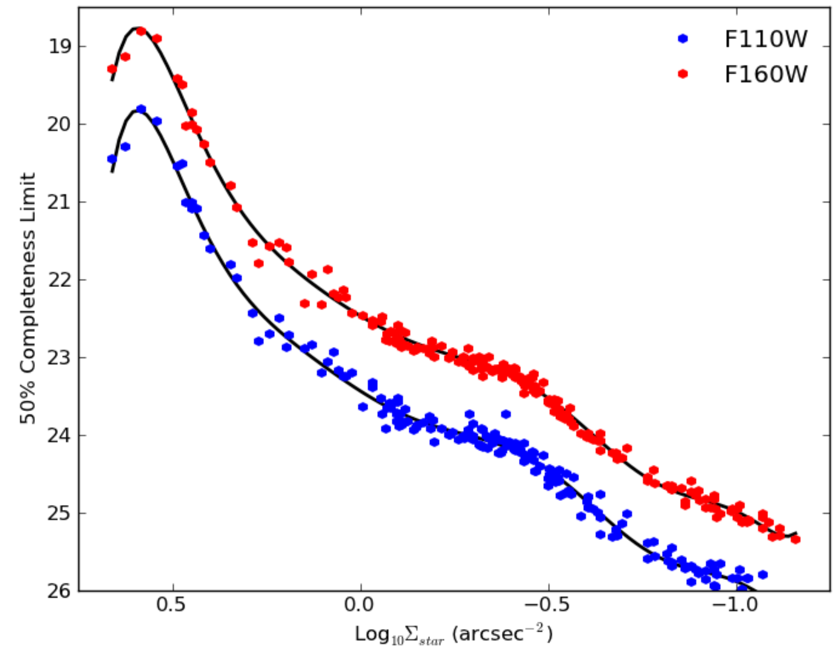



FIG. 4.— The depth of the photometry as a function of radius. The blue and red points show the 50% completeness limit $m_{50}$ as a function of $\log_{10}$ of the local stellar surface density in bright RGB stars, for the F110W and F160W filters, respectively. The solid lines show 10th order polynomial fits to the data, used to interpolate to an appropriate limiting magnitude at each position in the galaxy. The PHAT photometry is crowding-limited, and thus the limiting magnitude is a strong function of the local stellar surface density. The apparent roll-off in the inner disk (at high surface densities in the left side of the plot) is an artifact of the extraordinarily high crowding levels in the inner bulge, which lead to biases in the photometry; while we include these regions for completeness here, we do not actually analyze their $A_V$ distributions.

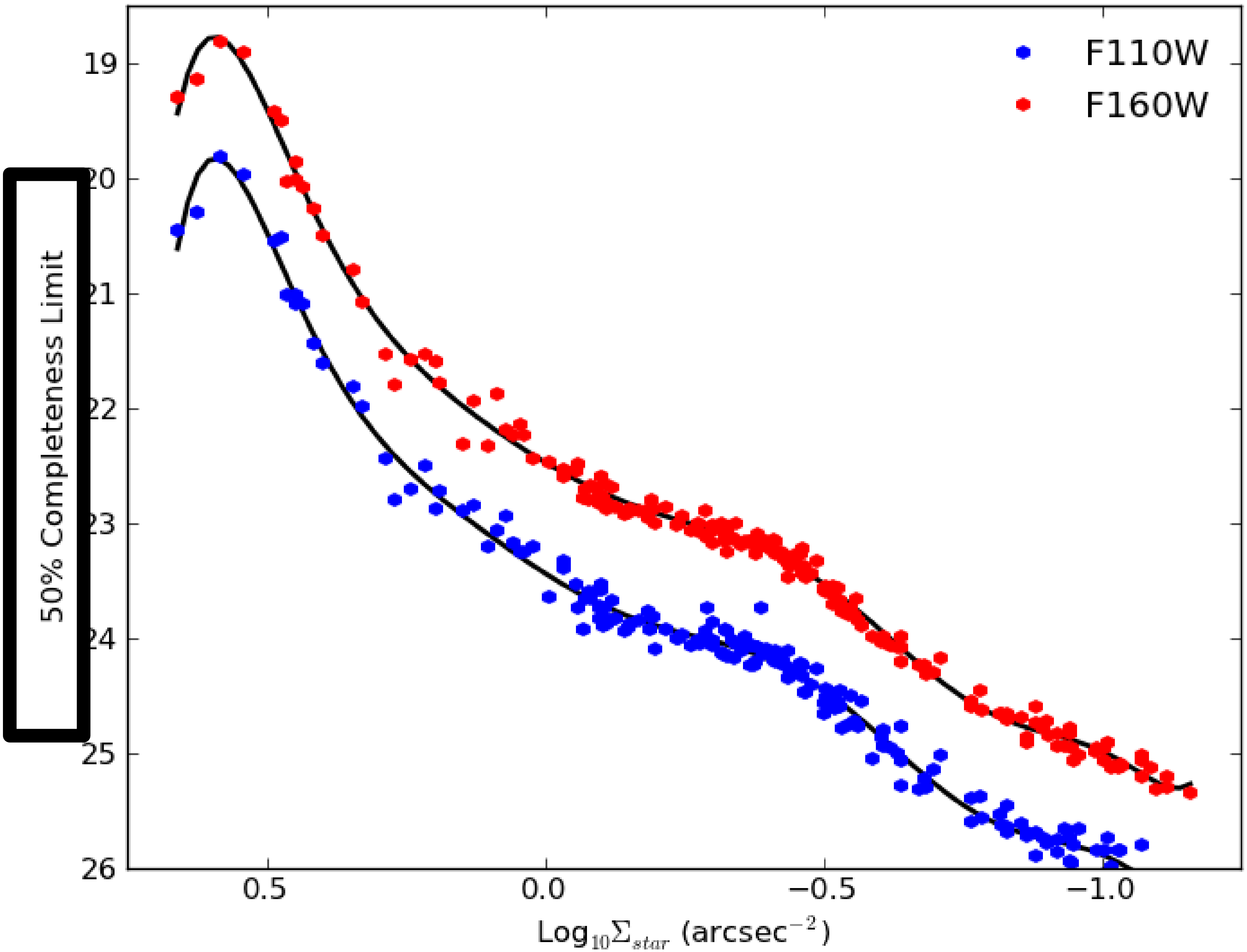
# Figures

## Use words in addition to symbols, in captions & axis labels

"$\alpha$ *versus* $M_C$"

is not as useful as

"*The IMF slope* $\alpha$ *versus the cluster mass* $M_C$"




# This is more informative than $m_{50}$

# Figures

Legends are good*.

The more of the figure that can be understood *without reading the caption*, the better.

*Though, clutter is bad. So, it's a tradeoff.

# Figures

Ask:

*"Would this figure work well in a talk, without modification?"*

Some papers are more highly cited than others *solely* because they had the better figure for talks.

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# Tables

Use table notes to define column headers, even if the definitions are elsewhere in the text

# Random

1. Variables should be in math mode

2. Software routines in {\tt }

3. Describe routine by more than its name* — needs to stand test of time.

*e.g. “The PACKAGENAME implementation of an MCMC sampler””

# In-class exercise

**ABSTRACT**
By analysing a sample of galaxies selected from the HI Parkes All Sky Survey (HIPASS) to contain more than 2.5 times their expected HI content based on their optical properties, we investigate what drives these HI eXtreme (HIX) galaxies to be so HI-rich. We model the H I kinematics with the *T*ilted *R*ing *F*itting *C*ode TiRiFiC and compare the observed HIX galaxies to a control sample of galaxies from HIPASS as well as simulated galaxies built with the semi-analytic model DARK SAGE. We find that (1) H I discs in HIX galaxies are more likely to be warped and more likely to host H I arms and tails than in the control galaxies, (2) the average H I and average stellar column density of HIX galaxies is comparable to the control sample, (3) HIX galaxies have higher H I and baryonic specific angular momenta than control galaxies, (4) most HIX galaxies live in higher-spin haloes than most control galaxies. These results suggest that HIX galaxies are H I-rich because they can support more H I against gravitational instability due to their high specific angular momentum. The majority of the HIX galaxies inherits their high specific angular momentum from their halo. The H I content of HIX galaxies might be further increased by gas-rich minor mergers.

This paper is based on data obtained with the Australia Telescope Compact Array (ATCA) through the large program C 2705.

**Key words:** galaxies – evolution, galaxies – formation, galaxies – kinematics and dynamics, galaxies – ISM

## 1 INTRODUCTION

The gaseous and stellar content of galaxies is tightly related through the galactic gas cycle. Atomic hydrogen (H I) condenses to form molecular gas ($H_2$) clouds. These clouds are the birth places of stars. When comparing the amount of available H I to the current star formation rate in local galaxies, Kennicutt (1998) and Schiminovich et al. (2010) find that their H I reservoirs would be consumed within ≈ 2 Gyr. Hence, galaxies need to replenish their gas reservoir in order to remain active starformers in the future (Sancisi et al. 2008, Sánchez Almeida et al. 2014 and references therein).

Gas–rich mergers and smooth accretion from the circumgalactic medium are suggested as avenues for gas replenishment (White & Rees 1978). Observations of local galaxies do not find evidence for enough gas rich mergers to sustain star formation (Di Teodoro & Fraternali 2014; Sancisi et al. 2008; Sánchez Almeida et al. 2014). This leads to the the conclusion that smooth accretion is the dominant channel of gas accretion. This might be the reaccretion of gas previ-



ously ejected by feedback mechanisms together with pristine halo gas, which is dragged along (à la the "Galactic Fountain", see e. g. Oosterloo et al. 2007; Fraternali et al. 2011). Cosmological simulations suggest accretion occurs through the cooling of hot halo gas or through the delivery of cold gas through filaments (Birnboim & Dekel 2003; Kereš et al. 2005; Dekel & Birnboim 2006; van de Voort et al. 2011). In the local Universe, gas-phase metallicity gradients / inhomogeneities (Moran et al. 2012), warps (Roškar et al. 2010) and lopsided discs (Bournaud et al. 2005) may be interpreted as observations of cosmological accretion but may also result from tidal interactions with other galaxies.

The HALOGAS survey (Heald et al. 2011) has previously searched for signs of accretion in deep H I observations of nearby galaxies (distance < 11 Mpc). Through detailed modelling of the H I kinematics, the HALOGAS team has found a few high velocity clouds, thick H I discs, and warps in their samples galaxies (Gentile et al. 2013; Zschaechner et al. 2011, 2012; de Blok et al. 2014). In the Milky Way, high velocity clouds are thought to contribute to gas accretion (Putman et al. 2012). The thick disc component, which is usually lagging in rotation velocity with respect to the thin disc, is interpreted as a sign of the Galactic Fountain (Oosterloo et al. 2007; Fraternali et al. 2011). However, the total rate of detected H I accretion in the HALOGAS observations is not sufficient to fuel star formation in their sample galaxies (Heald 2015).

The H I eXtreme (HIX) galaxy survey examines a sample of H I-rich galaxies to understand how they accumulate and maintain their gas reservoirs. In Lutz et al. (2017), we found that HIX galaxies are less efficient at forming stars than a control sample. The most extreme galaxy in the HIX sample (ESO075-G006) has built its massive H I disc through a combination of a lower star formation efficiency ($SFE_{HI} = SFR/M_{HI}$), due to a high specific baryonic angular momentum, and likely some accretion of pristine gas (as probed by gas-phase metallicity gradients).

So the gas-rich galaxies of the HIX survey are not necessarily gas-rich due to recent gas accretion but could also be inefficient at using their available gas for star formation. Simple models describing the H I based star formation efficiency ($SFE_{HI} = SFR/M_{HI}$) find a strong dependence of the SFE on the stability of the disc (Wong et al. 2016). Maddox et al. (2015) suggests that the upper envelope of the stellar – H I mass relation at high stellar masses is defined by the halo spin parameter. That is galaxies with a high H I mass for their stellar mass tend to live in higher spin haloes. A high angular momentum can reduce the star formation efficiency in two ways: (1) accreted gas can not be transported to the denser, inner parts of the galaxy (Kim & Lee 2013; Forbes et al. 2014), where the star formation efficiency would be higher (Leroy et al. 2008); (2) the disc is stabilised against star formation (Toomre 1964; Obreschkow et al. 2016).

In this paper, we extend the analysis of the relation between the H I content and kinematic properties to the entire HIX sample and an accompanying control sample. We make use of observations of our sample galaxies with the Australia Telescope Compact Array (ATCA), which provide spatially resolved H I distributions and kinematics.

This article is structured as follow. In Sec. 2, we discuss the selection of the HIX and control samples and present the data used in this paper. In Sec. 3, we present the results of the analysis of H I kinematics and distribution. We then compare our results to the semi-analytic model DARK SAGE of galaxy evolution in Sec. 4. The results are discussed in Sec. 5. We then conclude in Sec. 6.

Throughout the paper we will assume a flat ΛCDM cosmology with the following cosmological parameters: $H_0 = 70.0\,\mathrm{km\,Mpc^{-1}\,s^{-1}}$, $\Omega_m = 0.3$. All velocities are used in the optical convention (cz).

## 2 SAMPLES AND DATA

# Analyze and save this introduction