Resources

- Gamification of writing:

  https://www.4thewords.com

- 21 Suggestions for Writing Good Scientific Papers*:

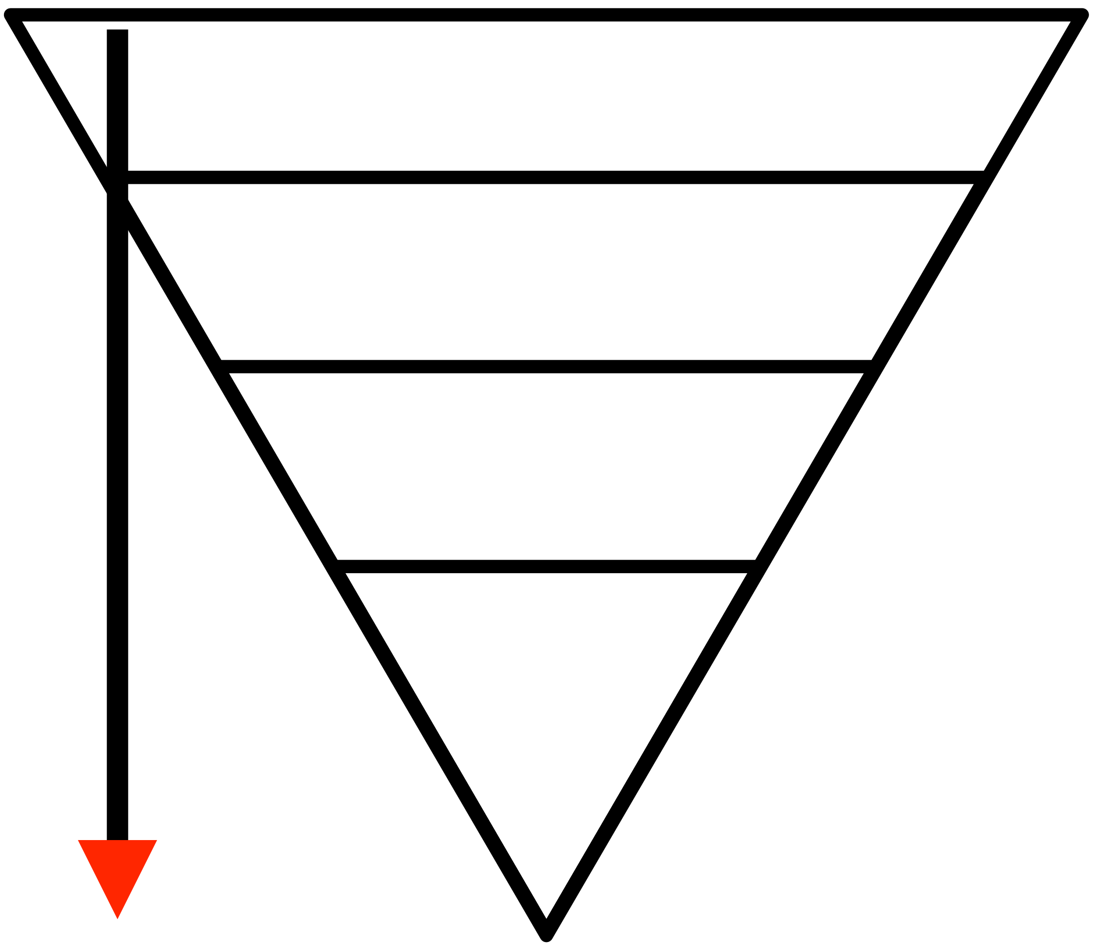
  https://www.scitechedit.com/images/21_writing_tips.pdf

*You have seen most of these in class, but not bad for a fast refresher in the future

Overview

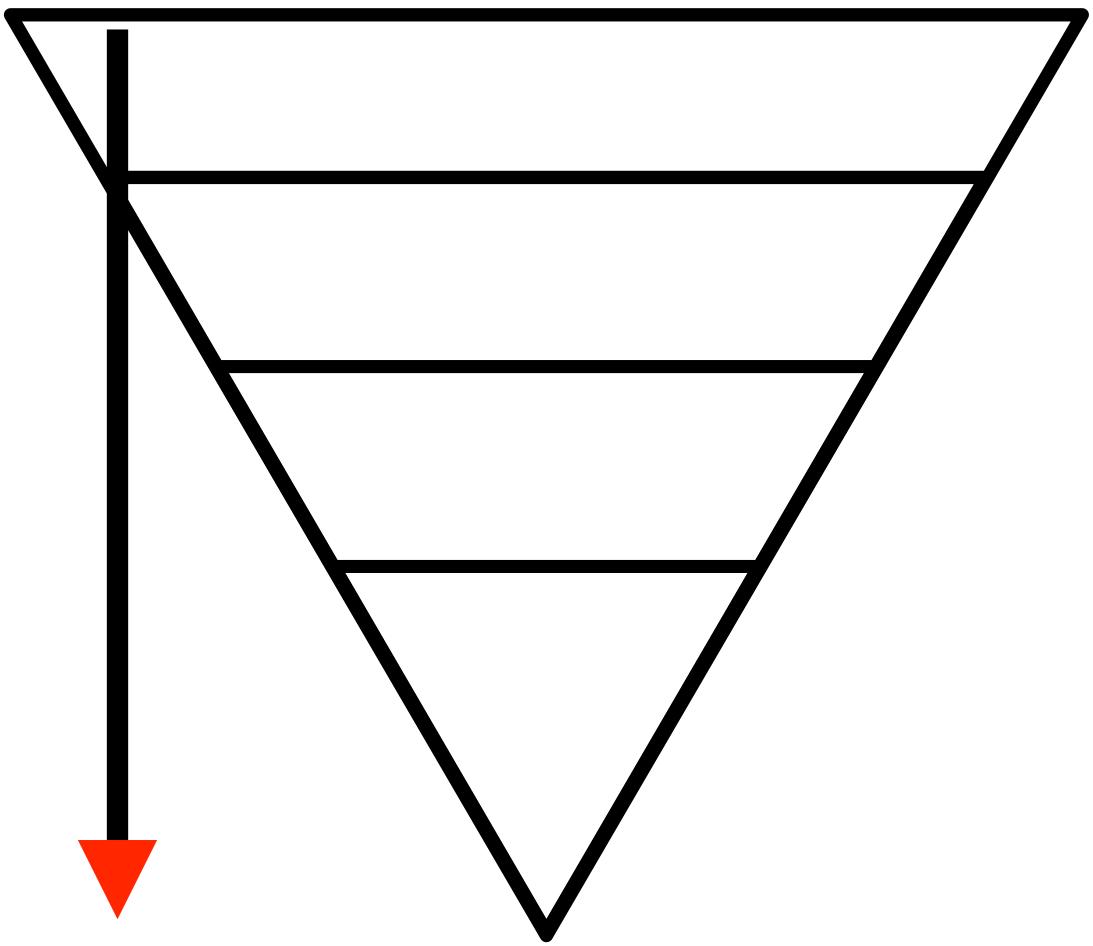
- Abstract
- Introduction
- Methods
- Results
- Discussion
- Conclusion
- Appendix
- Figures
- Tables

Structuring the Introduction



From last time: Move from the largest context, to the specific details of the paper

Structuring the Introduction



Intro should set up the structure of the paper

Overall Paper Structure

"OCAR" from "Writing Science*"

Josh Schimel

- Opening
- Challenge
- Action
- Resolution

*Much of today's class is drawn from this book

- 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?

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- Challenge
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- Resolution

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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.

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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?

Good for research papers

- 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?

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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?

But, other structures can work for proposals or writing for outreach

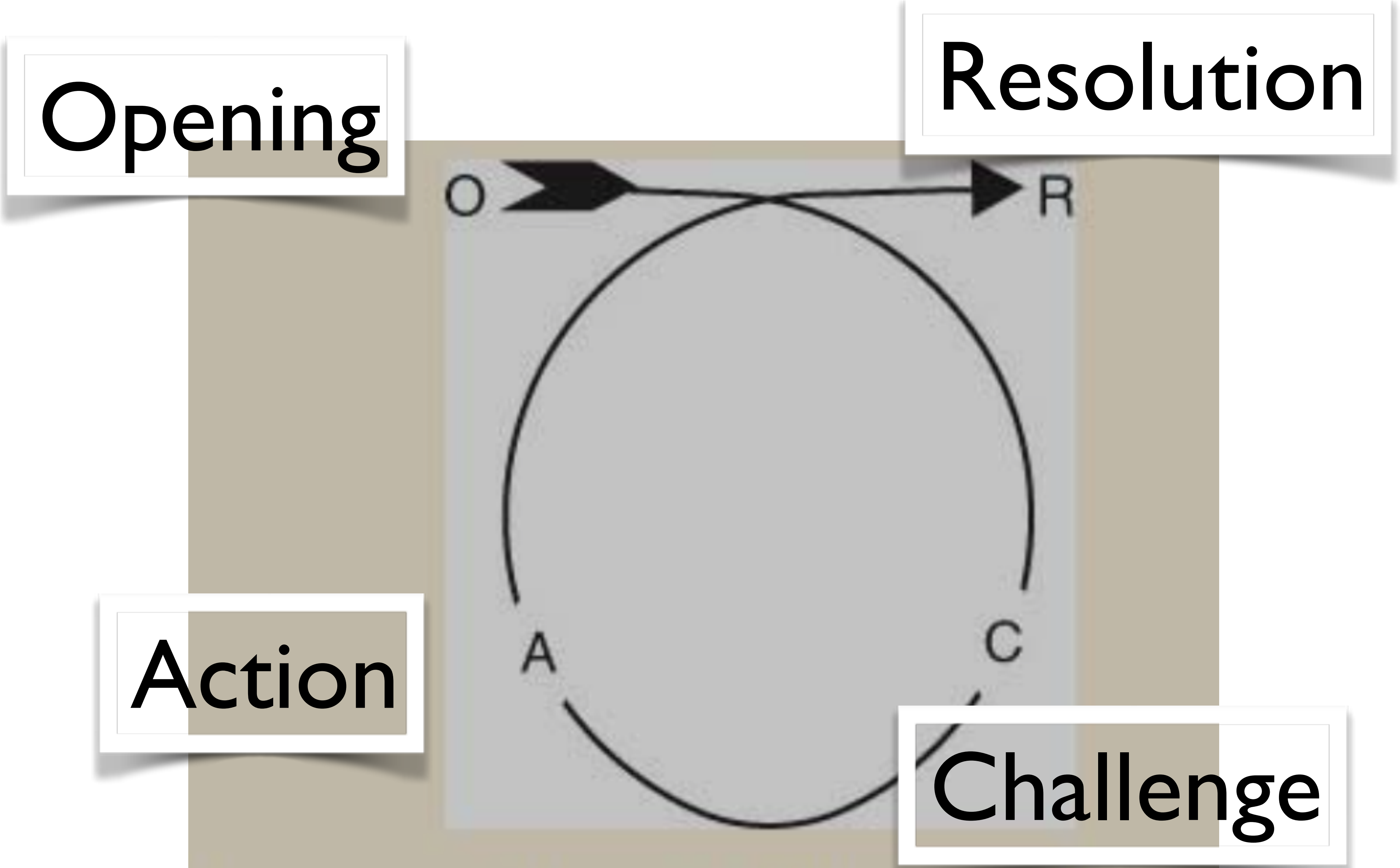


Figure 4.1. How an OCAR story makes a spiral: the story comes back to its starting point, but that point has moved.

In typical research papers:

- Opening
- Challenge
- Action
- Resolution

Introduction

In typical research papers:

- Opening
- Challenge
- Action — Methods/Analysis
- Resolution

In typical research papers:

- Opening
- Challenge
- Action
- Resolution

Discussion/
Conclusion

The Opening

- Opening
- Challenge
- Action
- Resolution

First sentence and/or paragraph can frame entire paper, when done well.

The Opening

Let's compare two papers' content (via their abstracts) to their choice of opening paragraphs.

An effective opening: Paper content

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

The effective opening paragraph:

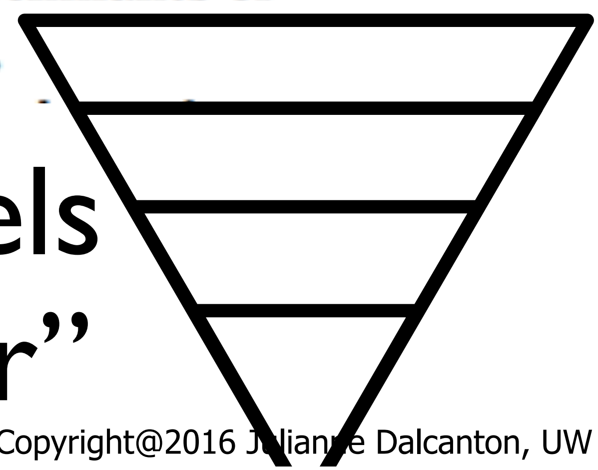
http://xxx.lanl.gov/pdf/1802.04798

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

1. INTRODUCTION

Once thought to be a simple evolutionary sequence, the pathways leading galaxies from the star-forming blue cloud to the quiescent red sequence have been revealed to be incredibly diverse (Barro et al. 2014; Schawinski et al. 2014). The cessation of star formation appears to happen on vastly different timescales, strongly dependent on a galaxy's growth history (Martin et al. 2007). A class of unique objects called post-starbursts galaxies (PSBs) appear to be the remnants of the most violent of such "quenching" events.

Note how efficiently it funnels down to the main "character"



The effective opening paragraph:

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1. INTRODUCTION

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

Note the hooks: "unique", "most violent"

The effective opening paragraph:

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1. INTRODUCTION

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

Opening sentence is also a good hook: suggests a rapidly-evolving subfield that yields surprises.

A less effective opening: Paper content

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.

FYI, this paper has nice results. I'm only quibbling with presentation choices.

The less effective opening paragraph

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).

Has the "main character" been introduced?
Would you guess it correctly?

The less effective opening paragraph

1 INTRODUCTION

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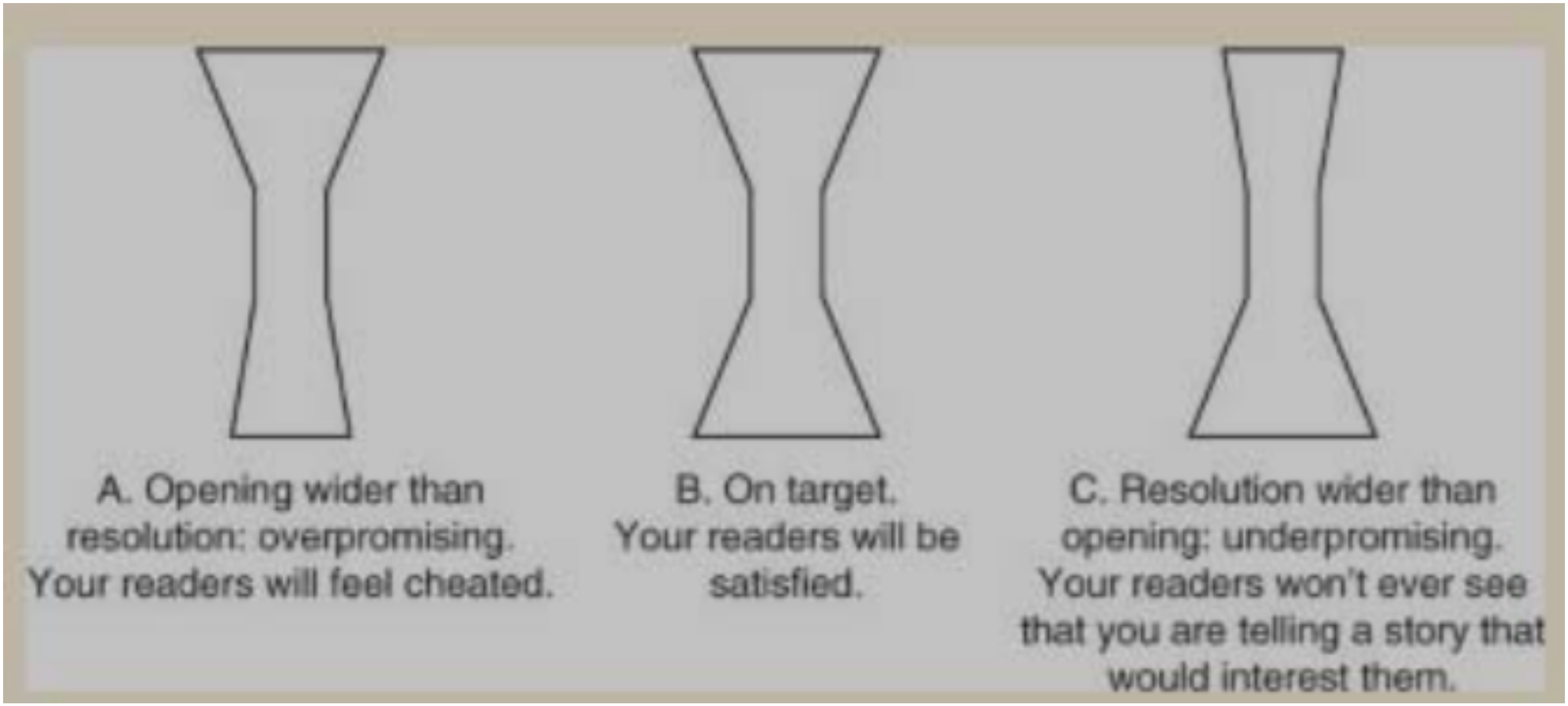
Is there even a hint of a puzzle?

You should match the scope of the opening to the resolution



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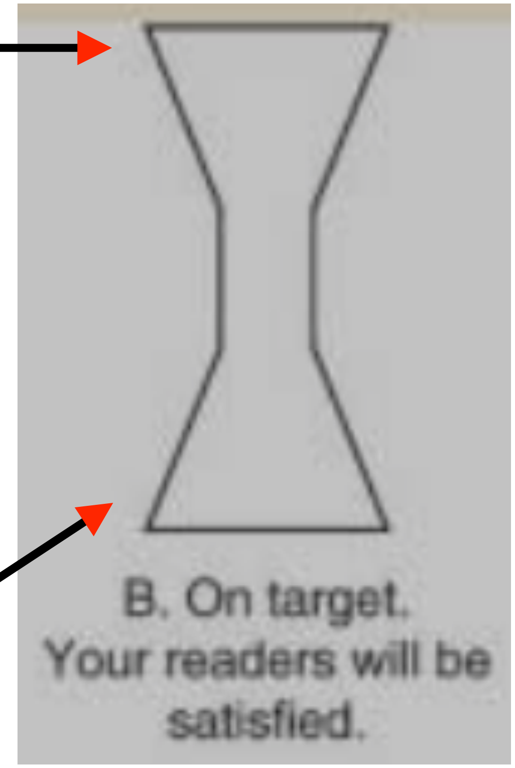
Once thought to be a simple evolutionary sequence, the pathways leading galaxies from the star-forming blue cloud to the quiescent red sequence have been revealed to be incredibly diverse (Barro et al. 2014; Schawinski et al. 2014). The cessation of star formation appears to happen on vastly different timescales, strongly dependent on a galaxy's growth history (Martin et al. 2007). A class of unique objects called post-starbursts galaxies (PSBs) appear to be the remnants of the most violent of such "quenching" events.



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.

Well-matched in scope, and even foreshadowed "timescales"!

The less effective opening paragraph:

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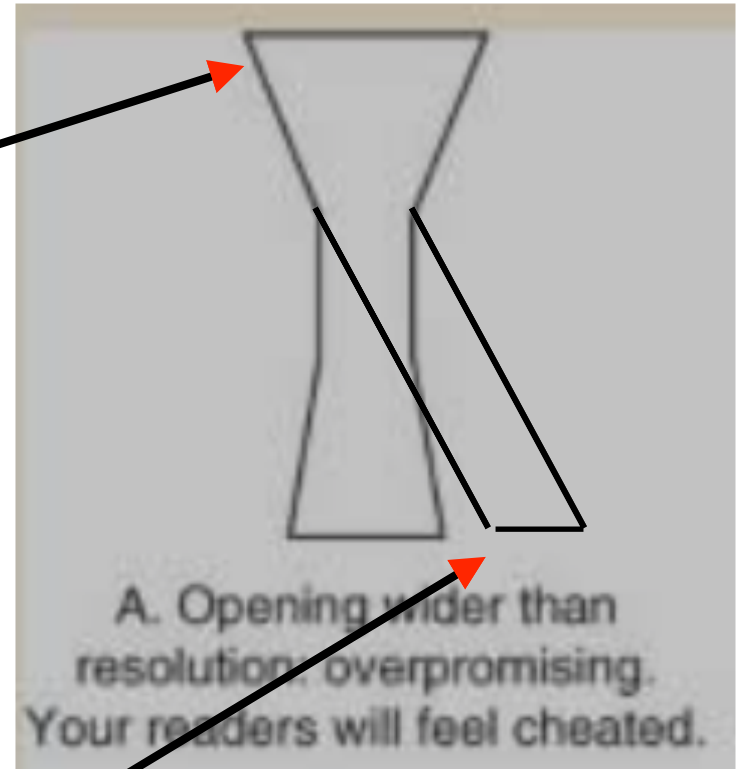


most HIX galaxies live in higher-spin haloes than most control galaxies. These results suggest that HIX galaxies are H I-rich because they can support more H I against gravitational instability due to their high specific angular momentum. The majority of the

Very different in scope, and not well-matched in topic (went somewhere quite different)

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?” instead of “what will we learn/explain/resolve?”
- 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

- Provide enough context & background to appreciate puzzle
- Engages with existing "schema" that readers hold, and possibly leverages them to create surprise
- Is straightforward to grasp
- Can be resolved by what you did.

The Introduction

- Opening
- Challenge
- Action
- Resolution

Background to set up challenge

Plan to reach resolution

Note that this structure is a classic story arc

- Opening
- Challenge
- Action
- Resolution

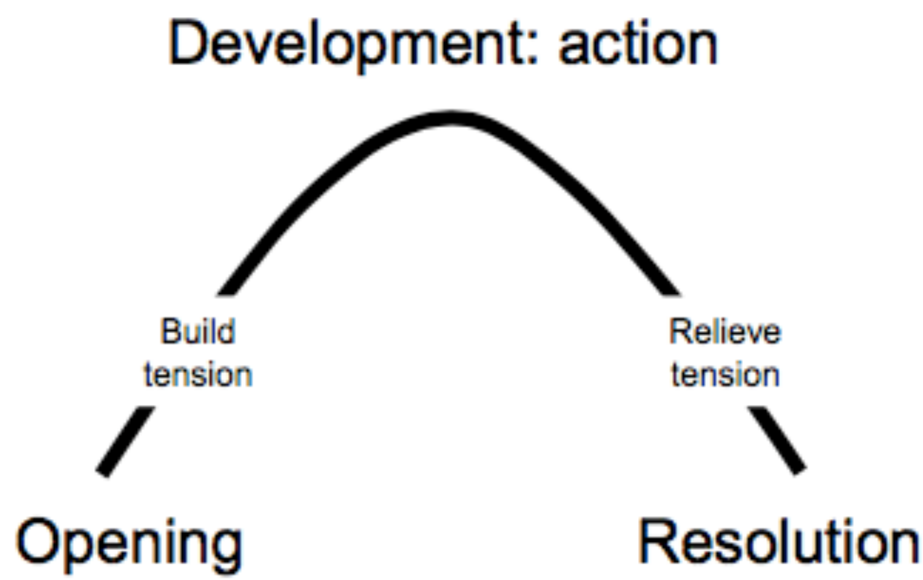


Figure 10.1. A story arc.

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

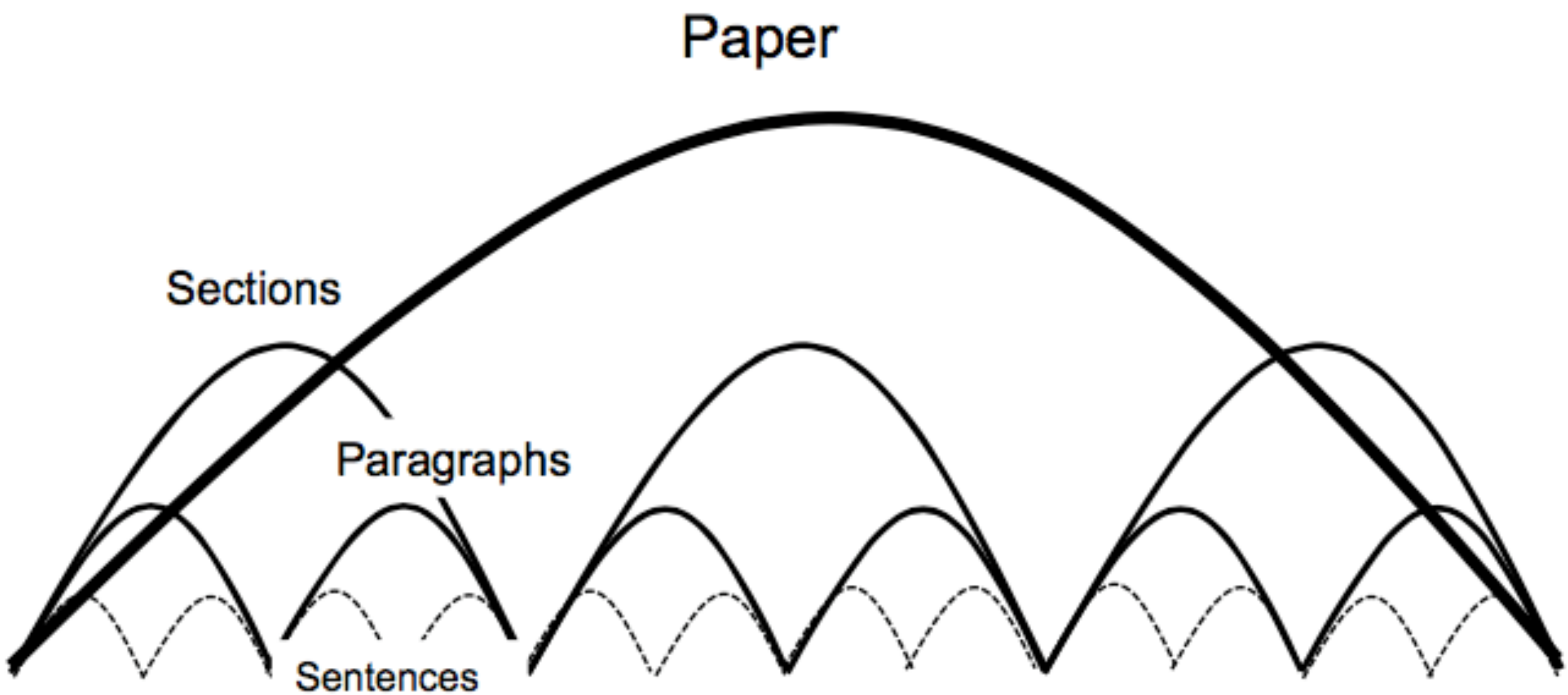
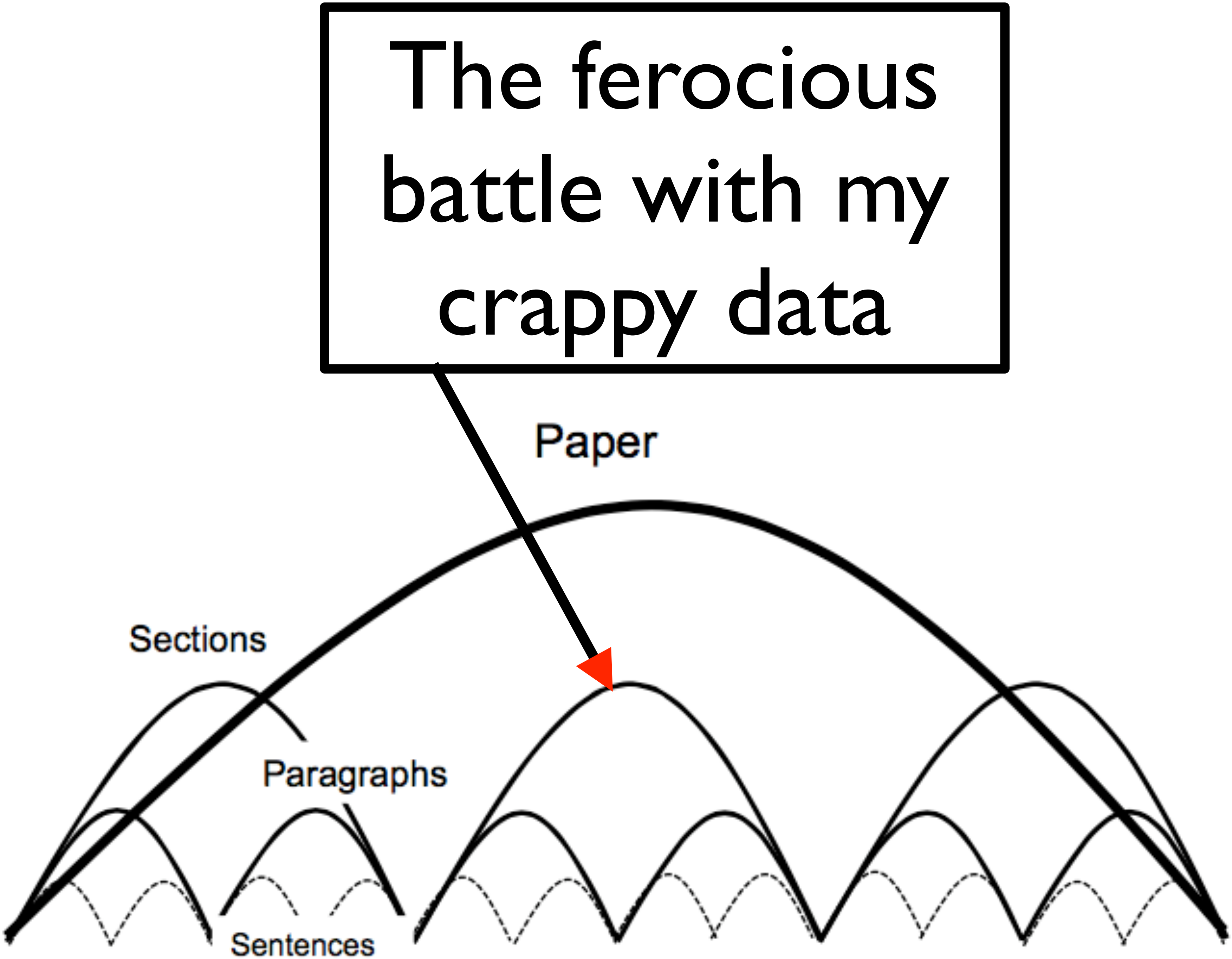


Figure 10.2. A story is a set of nested arcs.



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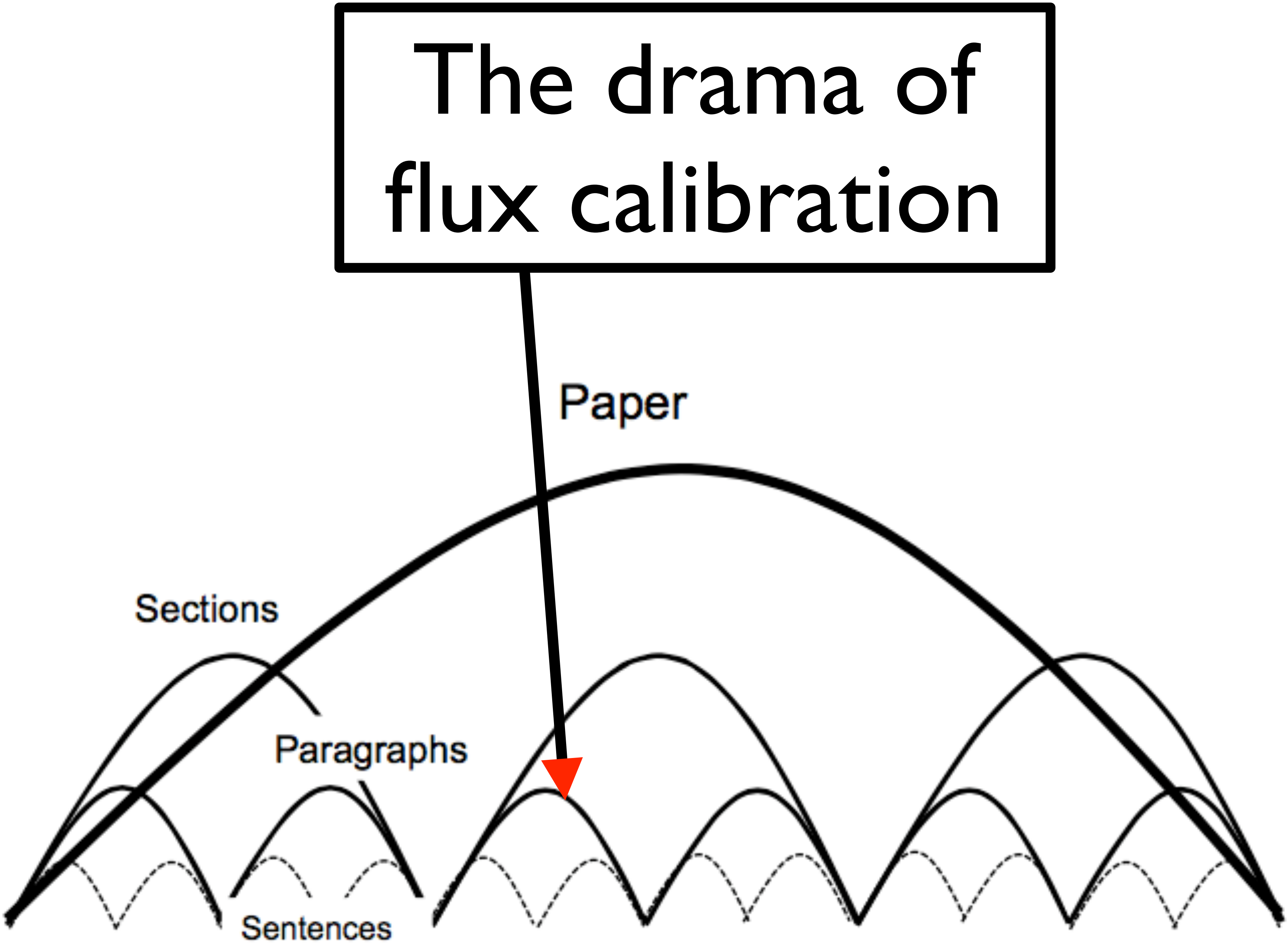
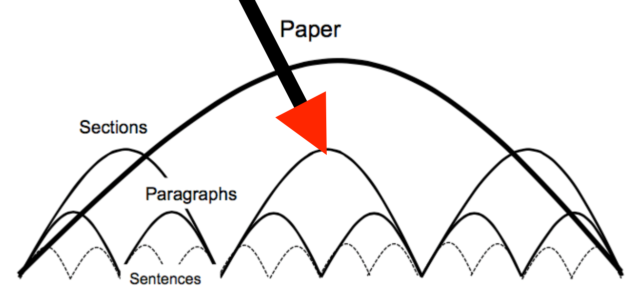


Figure 10.2. A story is a set of nested arcs.

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)"



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

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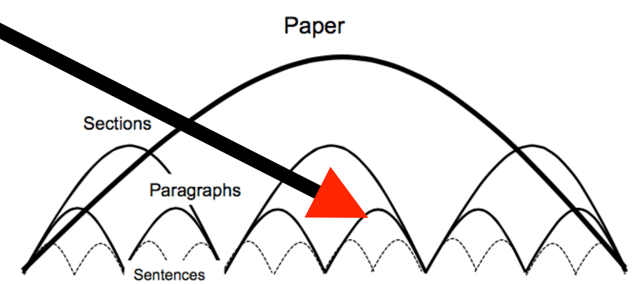

Figure 10.2. A story is a set of nested arcs.

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

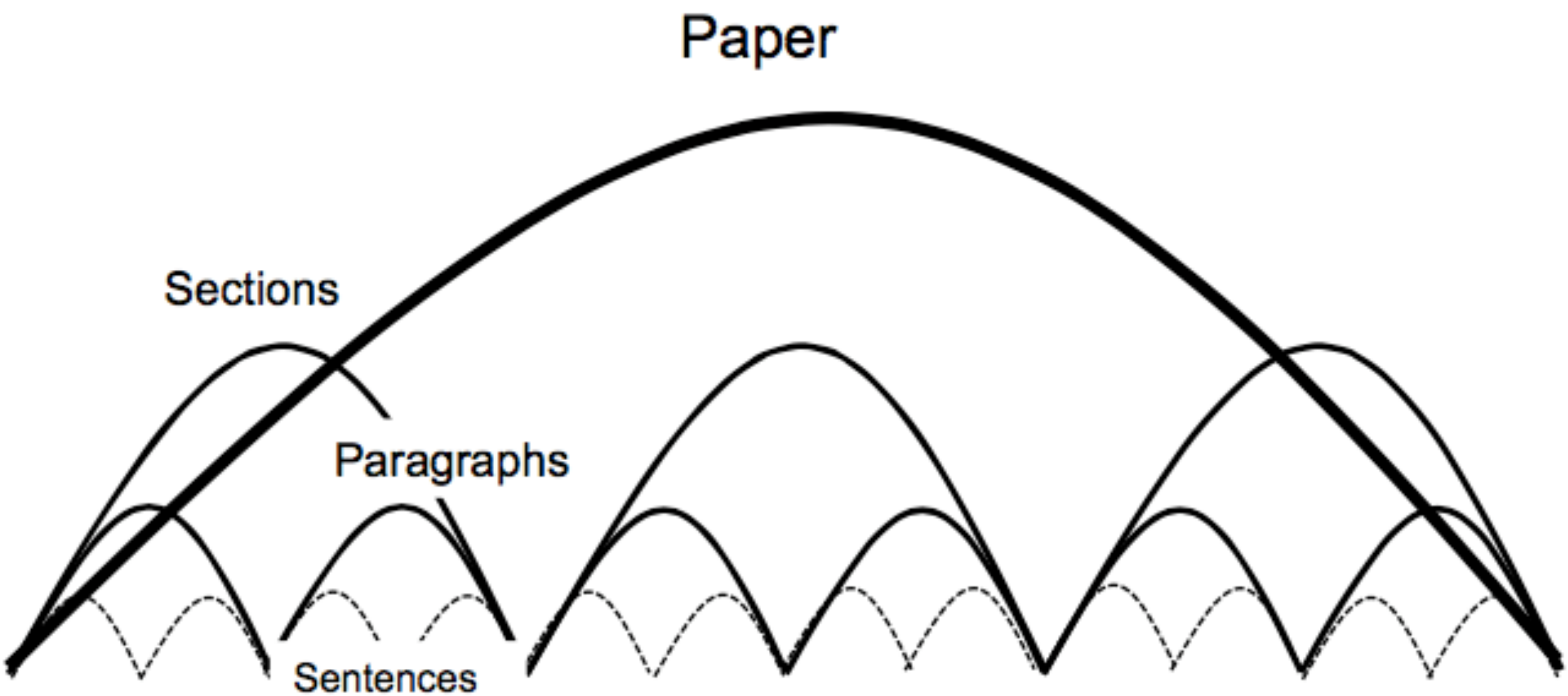

Figure 10.2. A story is a set of nested arcs.

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 ϕ^*, the redshift-dependent normalization of the stellar mass function, while the shapes depends on α^* and M^*, although the latter two dependencies are much weaker than the first. Recall that we have tuned the evolution of ϕ^* 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.

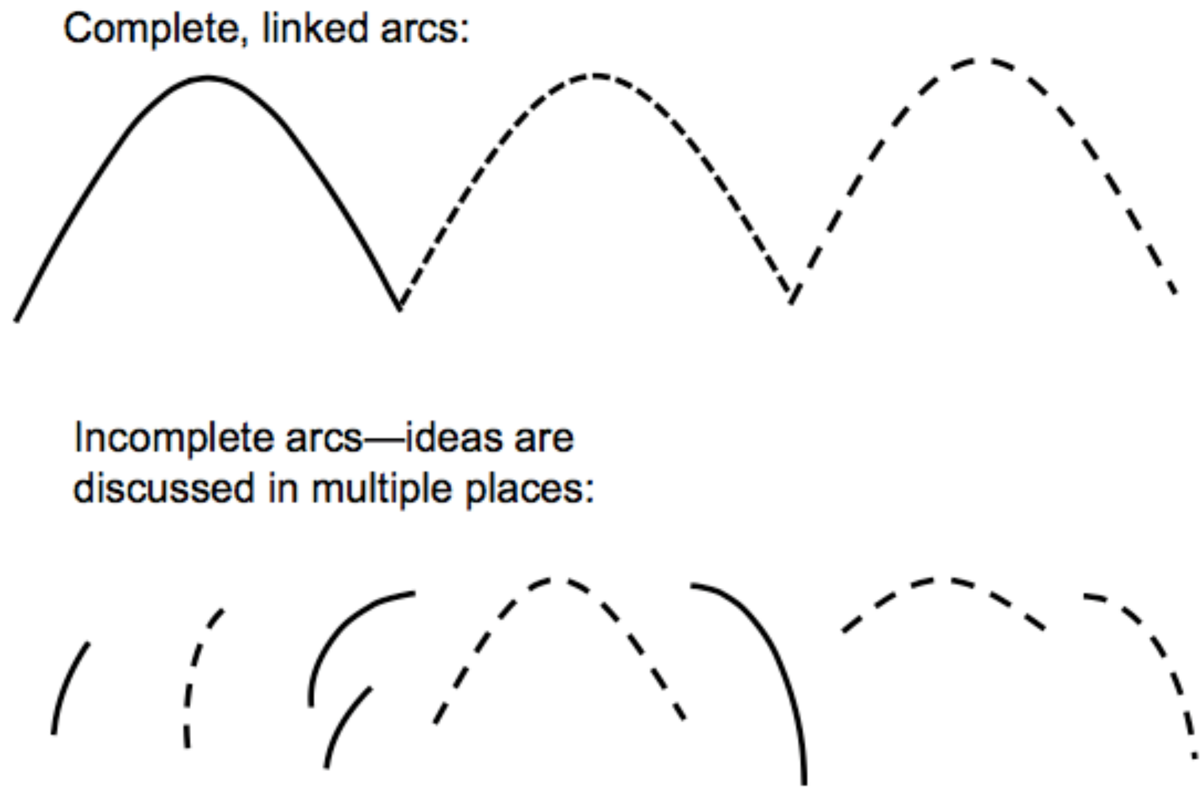

Figure 10.3. Complete versus broken story arcs: beginnings and endings are power positions.

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

The Introduction
Proposals

- Opening
- Challenge
- Action
- Resolution

Background to set up challenge

Plan to reach resolution

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