Cloud Cosmology : Building the Web Interface for iCosmo

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ABSTRACT

Aims. Astronomy and cosmology have embraced the internet. We routinely and successfully use the internet as a repository for sharing code, publications and information, and as a computational resource. However the interactive nature of the web, for use as an alternative to downloading code has been largely overlooked. In this article we will outline a simple framework in which a cosmological code can be turned into an interactive web interface. This is presented as a result of creating www.icosmo.org which is a front-end for the open-source software iCosmo.

Methods. We explain how an HTML page can be created and how a cosmological code can be incorporated into a web environment using CGI scripts. We outline how plots and downloadable text can be made, and describe how help and documentation can be created.

Results. By using simple HTML and CGI scripts a basic web interface for any cosmological code can be created easily. We provide a worked example of the methods outlined, which can be used as a simple template by any researcher who wants to share their work online.

Key words. cosmology – observables – numerical methods

1. Introduction

The internet has begun to revolutionise the way that astronomical research is conducted. Online paper archives (e.g. the arXiv) have allowed for the dissemination of articles and results, and data (e.g. SDSS Adelman-McCarthy et al., 2006) are routinely made publicly available online for anyone to analyse. We of course use the internet to communicate via email, voice and video connections. More recently there have been some efforts to use the resources of the internet to aid in the calculation of a specific suite of scientific results; for example the Galaxy Zoo (Lintott et al. 2008) and cosmology@home (www.icosmo.org) both of which solve particular problems of concern for the authors and simultaneously serve as remarkable outreach programmes.

The open source code made available through the internet has enabled cosmologists to use this code, saving their time to do further research. Of particular note are the CMB power spectrum codes CMBfast (Zaldarriaga & Seljak, 2000) and CAMB (Lewis et al., 2000) and some likelihood analysis codes for example COSMOMC (Lewis & Bridle, 2002) and BAYESYS.

However there have been relatively few online resources that cosmologists can use in their research as a replacement to downloading code. Notable and excellent exceptions include the CMB LAMBDA toolbox, and the impressive online data reduction interface AstroWISE there are also some basic cosmology calculators (e.g. Wright, 2006). The use of the internet in this fashion heralds the move away from using the internet as a computa-
resources for cosmology and the probes used to measure cosmology.

In this article, we will not describe all possible ways that a web interface could be created. We will present the process from the perspective of cosmologists (who are not experts in web design) who want to make their code easily accessible to a wide audience and want an easy and quick way to make code available. We will begin by describing the requirements that a working cosmologist may need from an interactive web interface. Then we will describe the particular solution that we have used, along with some alternatives that we have investigated along the way. This will be written in a pedagogical style from the point of view of a non-expert in computer science.

The iCosmo HTML and CGI will be released in iCosmo v1.2 (http://icosmo.pbwiki.com). A description of the interactive features of the website are given in Appendix A.

2. Web solutions

The needs of the cosmological community are not entirely unique to science but are fairly representative in terms of the types of product that are required from a useful web interface. We will explain the requirements that we need as cosmologists and then step through the solutions that we have found.

2.1. Requirements from Cosmology

To be a true replacement to downloading code the web interface must be able to perform the majority of the actions, and create all the products, that one may wish to make using the code.

A user must be able to change the inputs easily. In cosmology these are commonly values of cosmological parameters. There are also some numerical limits and resolutions of particular variables on which cosmological functions depend; for example redshift \( z \), wavenumber \( k \), and azimuthal wavenumber \( \ell \).

The two most useful end-point products are the plot (or graph) that can be used to visually represent some functional behaviour, and a table of the data in the graph in a format that can then be used in subsequent programmes. The graphical interface should be flexible enough that any aspect of the graph can be tailored online to the users needs. In cosmology we often need to plot functions for multiple values of cosmological parameters including error bars.

The iCosmo code (Refregier et al., 2008) is a low-redshift, dark Universe, cosmology tool that allows a user to create cosmological functions, observables and parameter forecasts for arbitrary cosmologies and experimental designs. Our task was to turn this into an interactive web interface.

A simple demonstration of the procedures covered in this Section are shown on

- http://www.icosmo.org/WebPaper.html
- http://www.icosmo.org/cgi-bin/WebPaper.cgi

and in Appendix B, these examples can be used as a template to create new cosmological web interfaces.

2.2. HTML

HTML (HyperText Markup Language) is the language in which web pages are written. A website consists of a group of pages, usually in some directory structure. HTML is akin to the familiar Latex typesetting language in which a script is written and then compiled to create a document. In this case however it is the web browser that does the compiling when a particular page is loaded. HTML pages can be created in most word-processing or text based programmes (e.g. MS Word, Emacs, etc.) and just save the file with the extension .html. The webpage can then be viewed by typing in the path to the file. Note that when a browser calls a webpage it does so as an external user, so permissions on any files need to be such that a global user can execute the HTML code (e.g. in UNIX using the chmod command). In general one must be careful about permissions, if a file is writable by a global user then a malicious user could turn such a file into a virus. However if a file is writable but not executable this makes such an attack much more difficult, in developing iCosmo we followed the guidelines set out on this webpage http://www.oucs.ox.ac.uk/webfaq/index.xml.ID=safeperl.

A very simple HTML page is shown here:

```html
<html>
<head>
<title>Hello World</title>
</head>
<body>
<font color="yellow">Hello World</font>
</body>
</html>
```

The first line declares that this is an HTML code, and the last line is the end the code. The head contains information that will not appear on the page itself but may affect its attributes. The body contains information that will appear on the page, here there is a simple style change made to the font of the text shown. We have found that the following pages were particularly useful in documenting the HTML syntax

- http://www.w3schools.com/html/DEFAULT.asp
- http://www.htmlgoodies.com/
- http://www.htmlcodetutorial.com/
- http://en.wikipedia.org/wiki/HTML

though this is by no means an exhaustive list and typing in HTML and a problem into any search engine usually results in finding the solution very quickly. To check that the HTML page that you have written is valid (no bugs) there is an online HTML compiler that will highlight any problems or inconsistencies at http://validator.w3.org/– to use this the website needs to be online.

Writing ‘bare’ HTML allows the webpage to be exactly tailored to your needs, however it is a time consuming activity and the syntax needed to create complex displays can become cumbersome. Thankfully there are some very good website creators available that allow websites to be created in much the same way that a “Power Point” (or Keynote) presentation is made e.g. creating texboxes, changing fonts and colours, adding pictures etc. For the front end of the iCosmo site we used iWeb for Mac OSX, for Windows there is FrontPage, and there are even online webpage creators such as Google Sites.

To enable more advanced features in a webpage one has to use scripts. There are different types of script, those that can be run within HTML itself and those that cannot. In iCosmo we have used some in-HTML JAVA scripts to enable some advanced features, for example the tabbed environment (see Appendix A) and some more simple things like allowing all checkboxes to be selected at once (see Section 2.6). These in-HTML scripts...
are defined in the <head> section of the HTML and are initialised using <script language=javascript> and ended using </script>, there are many open-source javascript widgets which can be copied and pasted from the web into any HTML page.

2.3. Running Scripts

In creating a web interface for cosmology one will inevitably have to run some sort of programme that will take inputs (say cosmological parameters) and perform a cosmological calculation. Running an executable, or script, can be done either on the side of the server (where the webpage is stored, see Section 2.4) or can be done through the browser itself on the ‘client’ side. We opted for, and recommend, the server-side approach since cosmological calculations can be complex (a client’s computational power may be minimal) and server side scripts are safer for the client (they do not need to run a potentially dangerous code on their personal machine).

There are a number of ways which we encountered that allow scripts to be run. Most simply any C code can be compiled which can be run in a browser by typing the executable name into the command line, though creating an entire webpage out of a C code quickly becomes complex. Alternatively one can use JAVA 1 and then create a “Applet” (although this is a client side solution). Other alternatives include PHP and API which are additions to HTML that allow scripts to be run from within HTML. An example C code, compiled like gcc test.c -o test.cgi is given below:

```c
#include <stdio.h>
2 int main(void) {
3 float p,q,r;
4 p=2.*2.;
5 q=2.*2.*.2;
6 r=p+q;
7 printf("Content-Type: text/plain;
charset=us-ascii\n%n");
8 printf("Hello world\n\n%n");
9 printf("2^2+2^3=%f\n",r);
10 return 0;
11 }
```

The easiest solution that we have found is to use CGI (Common Gateway Interface) scripts. These are executable scripts (akin to a more complicated version of a shell script) that can be written in a variety of different code languages. When a CGI script’s URL is called the server runs the CGI script, that creates a webpage which is then displayed. The most common language in which CGI scripts are written, and the one which we have chosen for iCosmo, is PERL 2 for iCosmo we chose PERL over Shell scripts because PERL is a full programming language with many available libraries, and as such is somewhat more flexible. An example PERL CGI script is shown here:

```perl
#!/usr/bin/perl
print<<<HTML;
<title>Hello World</title>
<head>
<body>
<script language=javascript>
Hello World
</script>
</body>
</HTML>
```

The first line declares that this is a PERL script. The print<<HTML then says “the following is HTML” where the header is created. Calculations can then be done in PERL and displayed on the webpage, in this very simple example we calculated $2^2 + 2^3$. We also show here an example CGI shell script:

```bash
#!/bin/sh
2 # xmltest.sh
3 # XML-based "Hello World"
4 echo Content-type: text/xml
5 echo
6 echo "<message>"
7 echo "<text>Hello World!</text>"
8 echo "</message>"
9 echo "</message>"
10 exit 0
```

2.4. Servers, URLs, IP Addresses

A webpage is hosted on a server which, as far as we are concerned, is essentially a computer with some specific software installed that allows CGI scripts to be run, and on which the web site resides. When you click on the URL of any webpage the browser will be redirected to a server, for a simple webpage the browser will download the webpage HTML from the server and display it, for a CGI script the server will run the script and then send the HTML created to the users browser. Servers are nothing more than a normal computers with extra software installed, indeed even a laptop can become a server (this is actually very easy with some recent operating systems e.g. Mac OSX Leopard, where server software is included as standard). The most common form of server software is Apache 3. A webpage on a server typically consists of a number of folders: one containing the static pages (front page of website etc.), one containing the CGI scripts, one containing some shared files.

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1 [http://java.com/en/](http://java.com/en/)
2 [http://www.perl.com](http://www.perl.com)
3 [http://www.apache.org/](http://www.apache.org/)
For iCosmo we developed the site using Apache installed on a MacBook laptop, to turn the laptop into a server all one needs to do is turn on “web sharing” once Apache is installed. Later we transferred the site to a dedicated server.

Every computer and every server connected to the internet has a unique numerical identifier called an IP (Internet Protocol) address. To connect to a servers website from a browser the IP address of the server needs to be known. The key thing to realise here is that IP addresses (computers/servers) use ports, through which they communicate. When two computers interact the IP address says where the machine is, the port says what type of interaction will occur. HTML web pages use port 80. So the server needs to have port 80 open to allow IP addresses to access HTML pages stored on the server.

If a computer is connected to a network then it may have an internal IP for the network and the router will have an external IP address. When developing a website at home, through a router for instance, the routers software should be changed to open port 80. There is a very useful website here that will provide a step-by-step guide to do this for almost any router available http://www.PortForward.com the router then needs to re-route any incoming traffic from the port to the internal IP of the machine. Once port 80 is open then typing in the external IP to a web browser will take the browser to your servers webpage.

A URL (Uniform Resource Locator) is an alpha-numeric replacement for an IP address. When developing a website you will be able to use the IP as an address for the webpage e.g. typing http://193.168.0.1 will take you to your webpage. If you want to create a URL instead of using the IP address then DNS (Domain Name System) server can be used which will reroute any incoming traffic using a given URL to your IP address. There are a number of free services that do this, when developing iCosmo we used DynDNS www.dyndns.com which is a dynamical DNS server. Dynamical servers are particularly useful if your IP address may change over time, this is almost always the case for a home computer that is linked to the internet via an ISP (Internet Service Provider). Later, once your website is at a mature stage more suitable domain names can be bought, for iCosmo we used the common service http://www.123reg.com

2.5. Language Choice

When developing a web interface, and an open source software package, the choice of a coding language is important. iCosmo is written in IDL, which immediately created some obstacles to creating a web interface since IDL cannot be run directly from within a CGI script. Languages which are more conducive to web interface programming are C (which can be run directly within a browser), JAVA, PERL and python. One option for iCosmo was therefore to re-code the entire package into something like JAVA or C, however this would have meant losing the features for which we chose IDL in the first place – easy syntax, vast scientific libraries, easy plotting routines.

When developing iCosmo we found a way to call any programme from within a PERL CGI script. IPC::Open3 (or Open2) creates a “child” process from the main PERL script which then runs (on the command line) and can return values to the PERL script. An example is given below:

```perl
#!/usr/bin/perl
use IPC::Open3;
$ENV{'PATH'} = '/Applications/itt/idl70/bin/';
$progName = "idl";
open3(WRITEIDL,READIDL,ERRORIDL, $progName);
print WRITEIDL "print,x
"
print WRITEIDL "x=2ˆ2+2ˆ3+2ˆ4 \n"
$y =<READIDL>; 
print<HTML;
2<sup>2</sup>+2<sup>3</sup>+2<sup>4</sup>=$y
HTML

#end the HTML

</body>
</HTML>

HTML
close(WRITEIDL);
close(READIDL);
close(ERRORIDL);
exit;
```

In this example an IDL script is initialised by the Open3 command, when the command WRITEIDL is called (which is named as the input to the IDL) actual IDL command lines can be entered which can then be read back into the PERL script using READIDL. The result can then be printed into an HTML page in the usual way. Note that any code package could be run in this way; we use IDL as an example.

You may want to run some code on a machine that is not the server. For example this may occur if you cannot install some particular library or if more computing power is needed. The IPC::Open command can be used so that when a particular CGI script is run the server can ssh into a machine that has the required software, perform the calculation on that machine and then output the results to the webpage. This is done by stacking the commands on the $progName line e.g. $progName = "ssh server@machine 'cd WebServer/CGI-Executables; command'" which connects to a machine under the username server, changes directory to the CGI folder and then runs some command. Most servers should come with some common software already installed, although installing some complex astronomical software may be difficult.

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[11] http://www.perl.com/doc/manual/html/lib/IPC/Open3.html
2.6. Input and Output

We have now outlined how to create a simple webpage and a CGI script that can run a particular cosmology code and output results to a webpage in a text format. Here will discuss how inputs can be taken from a webpage and put into a CGI script.

The key to web interactivity is the HTML form. Forms allow a web user to input information into a webpage which can then be read by the server. You will find forms on almost every webpage (from online shops to airline bookings). A form is basically a set of inputs and a ‘submit’ button (forms can also be automatically submitted – using javascript) when a form is submitted a new script is run which is given the variables input as arguments. The following example would create some boxes in which numbers could be input and then sent to the new CGI script.

```html
<form action="cgi-bin/newscript.cgi">
  <input type="text" name="omega_m" size="5" value="0.3">
  <input type="text" name="omega_de" size="5" value="0.7">
  <input name="submit" type="submit" value="Begin Calculations">
</form>
```

The variables \( \omega_m \) and \( \omega_{de} \) are submitted to newscript.cgi (the variables can be seen in the URL delimited by &’s or can be hidden using METHOD="POST" in the first line). There are many types of form input the most common are

- text: input a text value, numerical or alphabetical
- checkbox: a tick-box which can take one of two values depending on whether it is selected or not
- radio: an exclusive 'or' i.e. value can take a number of different values
- select: a drop-down box is created which gives a number of exclusive options

There is extensive online help for all these types of form input.

In iCosmo to read form data into a CGI script we used the ReadParse PERL command which works in the following way

```perl
&ReadParse(*input);
$omm = $input'omega_m';
$omv = $input'omega_de';
```

which would read in the submitted variables from above into the new PERL script as the variables \$omm and \$omv.

To create plots using PERL we used the common PGPLOT\[12\] software (we installed this for use in PERL using the excellent astronomical suite of tools provided by SciKARL\[13\]). Within PERL a plot can easily be created using the following syntax or similar

```perl
#Create a graph:
$ENV{'PGPLOT_PSBBOX'} = "MAX";
pbegin(0,"icosmo_plot.gif/gif",1,1);
pubplot($xmin,$xmax,$ymin,$ymax,0);
#black-on-white plots:
pgscr(0, 1.0, 1.0, 1.0);
pgscr(1, 0.0, 0.0, 0.0);
pgsci($linecolour);
pline($number, @x, @y);
pgend;
```

This would create a gif showing the data in the arrays @x and @y. To display this on a webpage the HTML img command can be used

```html
<img src="icosmo_plot.gif" width="500px" alt=""/>
```

To create a downloadable text file the following PERL syntax would write the structures $x and $y to a file

```perl
$file="file.txt";
open (MYFILE, $file);
for($start=1;$start<$number;$start++){
  $valueF=$x[$start];
  printf MYFILE "$valueF \n";
  $valueF=$y[$start];
  printf MYFILE "$valueF \n";
}
```

The following HTML would create a link to file.txt

```html
<a href='file.txt'> Download Text Output</a>
```

2.7. Browsers and Styling

When creating a web interface one must always be careful with respect to browser compatibility. Issues can arise from even simple things such as choosing a font such that it will appear the same in each browser (we found this website particularly useful [http://dustinbrewer.com/fonts-on-the-web-and-a-list-of-web-safe-fonts/](http://dustinbrewer.com/fonts-on-the-web-and-a-list-of-web-safe-fonts/), there are only a handful of fonts available) to an entire page appearing incorrectly.

Incompatibility issues are usually created when obsolete HTML methods are used, this means that some new browsers will not recognise certain HTML commands and will render them in a different way than intended. The most up-to-date (c. 2008) standard for writing browser-proof HTML is to use styles.

Styles are essentially small scripts that can be written separately (in the header) or within certain basic HTML commands that tell the browser how to render the object in question - that could be some text, a table, an image etc. An simple example is given below

```html
<a href="http://www.icosmo.org"><font color="#66000">iCosmo</font></a>
```

```html
<a style="color: #660000" href="http://www.icosmo.org">iCosmo</a>
```

These two lines ostensibly do the same thing (create a red
coloured hyperlink to iCosmo) but the first line does not use styles and as such may appear incorrect in some browsers.

Other problems can occur if, for example, a tables width is defined in %, which some browsers recognise, whereas it should be defined in terms of pixels (px). When writing a web interface you should constantly check that whatever changes are made are accurately reproduced in all browsers. This can be done manually by installing some of the most common browsers (Firefox, Opera, Safari, Internet Explorer) or by using an online browser checker - we found this site particularly useful http://browsershots.org/

2.8. Version Tracking
When creating a web interface keeping track of different versions, and what changes have been made is important so that the site can be restored to any point in its creation if things go wrong. There are many commercially available and open source ways which can back up websites and code, the most commonly used is SVN (SubVersion).

For iCosmo, creating a web site in collaboration, we found that using a self-made wiki page was the optimal solution. We used the public wiki pages http://www.pbwiki.com and on our iCosmo wiki page created a “Blockbuster” style table. If one person wanted to edit the site they “checked out” the code (downloaded as a zipped file), and made a note on the wiki. They would then “check in” and upload a new version. All versions are stored on the wiki page and this prevented multiple people working on the same code simultaneously as well as saving the old versions for backup.

2.9. Help Solutions and Documentation
When creating a web interface for cosmology, and following the ‘transparent box’ approach that we have taken with iCosmo, sufficient material should be provided and links to relevant publications made (at the very least links to other sites that contain good material should be added).

For iCosmo we have made a multi-layered suite of help resources. The simplest is to add help directly as text to the webpages in question. Links can easily be made to publications available on online archives. The next layer is to create more information on a different page and make this an evolving and interactive document. The most common forms of these interactive documents are wiki pages and online word processors (e.g. GoogleDocs). For iCosmo we have used http://www.pbwiki.com to create a number of wiki pages that are edited and updated by a group of experts in each field we have covered. The GREAT08 challenge (Bridle et al., 2008; http://www.great08challenge.info) has made good use of GoogleDocs to provide online documentation.

The next layer of interactivity is to provide an online forum for users of your site to discuss the science, results and the webpage. In cosmology we are fortunate to have http://www.cosmocoffee.info For iCosmo we have provided a discussion forum hosted by cosmocoffee.

To make posting a website onto network sites (e.g. Facebook, MySpace) and bookmark sites (e.g. Twitter, Digg) easy for a user it is common to add small links at the bottom of a page that will automatically post to these websites. For iCosmo we used the free service provided by http://www.sharethis.com which provides a snippet of HTML that once pasted into a website compresses all the posting links into one button.

Finally video (or audio) tutorials can be provided in addition to text based and interactive help. Video tutorials can allow the web site to be demonstrated to the user and for all the aspects of the site to be presented. For iCosmo we choose YouTube to host the videos online - YouTube also allows videos to easily be embedded directly into HTML. Alternatively you can host your own videos, or publish audio as a pod- cast. To record on-screen video and audio there are many cheap software options available; we chose iShowU for Mac.

2.10. A Worked Example
As a worked example we have provided some simple templates of an HTML page and a CGI page in Appendix B. Working versions of these can be found on

- http://www.icosmo.org/WebPaper.html
- http://www.icosmo.org/cgi-bin/WebPaper.cgi

In these examples we show how each of the components described in this Section can be brought together to create a simple cosmology interface. We show how styles and forms are used as well as some other HTML tricks, for example inserting an image, creating Greek letters and making lists. In the CGI example we take some data from the HTML page and use this data to perform a calculation using the iCosmo IDL software.

We have outlined how to create a web interface for cosmology calculations from scratch. This can be done by through the following 3 steps:

- Create a static HTML site to collect user input. This can be done using the forms discussion in Section 2.2 or the template provided http://www.icosmo.org/WebPaper.html
- Write a CGI script to run your program (e.g. an IDL .pro file). This is discussed in Section 2.6 and an example can be found at http://www.icosmo.org/cgi-bin/WebPaper.cgi
- Create an interface for displaying the results. See http://www.icosmo.org/cgi-bin/WebPaper.cgi for an example

Some users may wish to simply extend the capability of an existing site, such as iCosmo, this can be done by using the templates provided. The iCosmo website source code will be released in iCosmo v1.2 (http://icosmo.pbwiki.com).

3. Online Cosmology
The internet has been harnessed in astronomy and cosmology as a communication tool and as a source of processing power for individual calculations. The move towards using the interactivity of the internet advocated here is similar in motive and result to cloud computing where computational processes are not performed locally but within the cloud (remote, anonymous, machines on the internet). We refer to the use of the internet in this fashion, for cosmological calculations, as cloud cosmology.

It may appear strange to an expert in web design or cloud computing that we are using the relatively well known CGI approach to writing webpages as an example of cloud computing. However the definition of cloud computing does not stipulate the method by which the cloud is contacted. We advocate the use of CGI scripts because of their simplicity, easy-of-use and the vast amount of scientific libraries that are available for them.
Other recent suggestions for using the interactivity of the internet to increase productivity in astronomy and cosmology are 3D environments and the virtual observatory. 3D environments (e.g. Hut, 2007) can be used for outreach activities and as visualisation tools for complex data sets. The concept of the virtual observatory (e.g. Szalay & Brunner, 1999) is that astronomers can access vast libraries of pre-observed data, where any desired observation has a high probability of already existing, thus making the need for a new observation redundant.

We have outlined the particular solutions that we have found that will enable cosmologists to turn their code into a web interface. Looking ahead we envisage a move to a more open culture that will enable cosmologists to turn their code into a web interface.

Here we define a number of tiers possible of involvement:

- As a minimum one can publish the code, related to an article, online.
- Secondly the code can be published as part of a coherent software package e.g. iCosmo. In this case, in order to become integrated into the package both the code and the science need to be refereed to some degree to ensure consistency.
- Thirdly the code can be published and turned it into a web interface, this could be as an extension of an existing interface (e.g. http://www.icosmo.org) or as a stand alone interface.

The iCosmo source code itself (Refregier et al., 2008) is an example of the third tier, both open source and web interactivity. Kitching et al. (2008) (a cosmological systems investigation) is an example of the second tier, some source code which has been integrated into an existing software package as an additional module.

iCosmo can be used as a platform for all three tiers. The source code is very modular and can easily be extended, and because iCosmo is an existing software package new add-on modules can be published in each new release. Finally the methods outlined in this article show how an iCosmo module can be turned into an interactive webpage. New interactive webpages could either be entirely independent or could be incorporated in the main site.

4. Conclusion

Cosmology had made good use of the internet so far as either a public repository for articles and code, or as a large-scale computational farm. However the interactive potential of the web, that can allow cosmologists to perform complex calculations online, has thus far been largely overlooked.

We envisage a move towards cloud cosmology in which computationally demanding and complex processes can be performed non-locally.

In this article we have outlined the some simple processes that we have learnt in the creation of an online, interactive, low-redshift (dark Universe) cosmology calculator. We have outlined how a simple web page is created, and hosted, and shown how cosmological code can be turned into an interactive web site. Throughout we have used the example of the interactive web site http://www.icosmo.org which is powered by the open source software iCosmo – for a description of the interactive features on this site see Appendix A.

Finally we described three levels integration that could be adopted by a cosmologist wanting to make their code easily accessible online.

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Appendix A: User Guide for http://www.icosmo.org

In this Appendix we describe the interactive features of iCosmo, the products available from the website and how to access the main features of the web interface.

A.1. Beginning Calculations

The iCosmo interactive website allows you to calculate cosmological functions, cosmology observables and Fisher matrices. These are summarised in Table A.1. We always calculate the Fisher matrices. The three different calculation scopes will be described in more detail in Section A.6.

Throughout all calculations we use the following set of cosmological parameters \( \Omega_m, \Omega_\Lambda, \Omega_B, \sigma_8, \Omega_K, h \) and the spectral index \( n_s \). The curvature density \( \Omega_K \) is determined through...
Table A.1. The range of products available on the website. Cosmology Functions are always calculated. The user can investigate the effect of changing cosmological parameters in the case of Cosmology Functions and Cosmology Observables.

| Scope                  | Products                                      |
|------------------------|-----------------------------------------------|
| Cosmology Functions    | Distances, $H(z)$, Growth Factor              |
|                        | Linear Power Spectrum, Non-Linear Power Spectrum |
| Cosmology Observables  | Lensing Power Spectrum, Baryon Distance Scales |
|                        | Supernovae Type-Ia Magnitude Distance Relation |
| Cosmology Errors       | Lensing Fisher Matrix                          |
|                        | BAO Fisher Matrix, Supernovae Type-Ia Fisher Matrix |

Fig. A.1. The Front Page of the iCosmo web site. The QuickStart Calculator panel can be seen on the right hand side. To access the stepwise interactive pages click on the “Cosmology Tools” link or on the “Tools” link in the navigation bar across the top of the page.

The choice of $\Omega_m$ and $\Omega_{DE}$ where $\Omega_K = 1 - \Omega_m - \Omega_{DE}$ at all times.

There are two ways in which the interactive part of the iCosmo web site can be accessed. Either though the QuickStart panel on the front page or through a step-by-step process that allows the user to customise the exact scope and details of calculations required.

A.2. QuickStart

You will find the QuickStart panel on the front page of the iCosmo website, see Figure A.1. To start simply fill in the values of the cosmological parameters and click on “QuickStart Cosmology”. You will be taken to a waiting page whilst the calculations are performed. When the calculations are completed you will be redirected to the Cosmology Functions interactive tab described in Section A.6.

A.3. Step-by-Step

To start your calculation and to choose Cosmology Observables and Errors options from the beginning the user can begin a stepwise customisation of the calculations needed. This is reached by clicking on any of the links to “Tools” on the front page, Figure A.1 and then clicking on “Interactive Web Tool”. Throughout the stepwise process the user will only be shown options relevant to the calculations requested, for example if the lensing power spectrum or lensing Fisher matrices are not required the user will never see any lensing-related options. The structure of this flow is outlined in Figure A.2.

Step 1 allows the user to specify the cosmology, or cosmologies (see Section A.3) that they wish to use in the calculation. In this step the range of products that will be calculated is also chosen, the products are arranged into the three scopes detailed in Table A.1. To advance to the next stage the user clicks on “Begin Calculations”.

Step 2 will show some further options relevant to the products chosen in Step 1. The baseline options for the Cosmology Functions are the minimum and maximum redshift for the distance, Hubble parameter and growth factor calculations. For the matter power spectrum the minimum and maximum k-range as well as the functional form used in the calculations can be chosen. The types of option available are shown in Table A.2. For the matter power spectrum the linear form can be calculated using either Eisenstein & Hu (1997) (with or without baryon oscillations) or Bardeen et al. (1986). The non-linear power spectrum can be calculated using either Peacock & Dodds (1996) or Smith et al. (2003).

If either Cosmology Observables or Cosmology Errors were chosen in Step 1 then the choice of survey will be given in Step 2. If “Make Custom” is chosen then the user will be taken to a further Step where the survey parameters relevant to the type of probe required can be customised. Alternatively a pre-defined survey can be chosen, the available pre-defined options are detailed in Section A.4.

Step 3 will appear if “Make Custom” is selected in Step 2. In Step 3 the user will be shown survey parameters specific to the type of probe that is required, either lensing, baryon acoustic oscillations (BAO) or type-Ia supernovae. The details of the options available for each of the probes are:

Lensing:
- The area of the survey in square degrees
- The number $n$ of tomographic redshift bins used to construct lensing power spectra, $m(n + 1)/2$ spectra will be calculated. Note that the bin boundaries will be chosen such that the number of galaxies in each bin is approximately constant
- The surface number density of galaxies in galaxies per square arcminute that can be used for a cosmic shear analysis
- The intrinsic variance in the measured ellipticity of galaxies, here we use the convention that the variance in measured shear is $\sigma_e = \sigma_r/2$ as explained in Bartelmann & Schneider (2001)
- The uncertainty $\delta_e(z)$ in the redshift of each galaxy, using the common $(1 + z)$ scaling $\sigma_e(z) = \delta_e(z)(1 + z)$. A typical broad band photometric redshift survey should have $\sigma_e(z)/(1 + z) \sim 0.02$ to 0.05 whereas a spectroscopic survey may have $\sigma_e(z)/(1 + z) < 0.001$.
- The median redshift for the number density distribution of galaxies. We employ the commonly used Smail et al. (1994) formula
Supernovae:
- The area of the survey in square degrees that is multiply imaged to allow supernova studies
- The surface number density of supernovae in supernovae per square arcminute. Note that this depends on the total time of the survey, the depth of the survey (magnitude limit) and the intrinsic efficiency of a galaxy in producing supernovae
- The intrinsic variance in supernovae apparent magnitude, this is typically \( \sigma_m \sim 0.15 \).
- The uncertainty \( \delta_m \) in the measured apparent magnitude of a given supernovae, this value will depend on the particular instrument that is used in the observations. For a space-based instrument \( \delta_m \sim 0.02 \) and for a ground-based instrument the uncertainty may be \( \delta_m \sim 0.05 \).
- The minimum and maximum redshifts for the number density of supernovae. Note that for simplicity we will assume that the number of supernovae in each redshift bin is constant in redshift. To calculate the number of redshift bins we set the shot noise uncertainty on the apparent magnitude in a given bin to be 1/1000 the intrinsic magnitude dispersion as is typically assumed Tegmark et al. (1998) and Huterer & Turner (2001).

BAO:
- The area of the survey in square degrees
- The number of redshift bins in which to measure the BAO scale. Note that the bin boundaries will be chosen such that the number of galaxies in each bin is approximately constant
- The median redshift for the number density distribution of galaxies. We employ the commonly used Smail et al. (1994) formula

A.4. Surveys

Both the observables and the Fisher matrix parameter error predictions depend on the design of the experiment. The user will find on Step 2 that for each lensing observable and Fisher matrix required we have provided the choice of either a custom survey or a current/future survey. The references for the surveys shown are:
- Dark Energy Survey (DES): DES Collab (2005)
- Dark UNiverse Explorer (DUNE): Refregier et al. (2008b)
- Large Synoptic Survey Telescope (LSST): Tyson et al. (2006), Ivezic et al. (2008)
- Panoramic Survey Telescope & Rapid Response System (Pan-STARRS 1): Kasier et al. (2004)
- SuperNovae Acceleration Probe (SNAP) : SNAP Collab (2005), Huterer et al. (2005)

The suite of surveys available will continually be updated and any suggestions can be sent to help@icosmo.org

A.5. Multiple Cosmologies

In Step 1 the user can choose between one or two cosmologies. This feature is to enable the sensitivity of cosmological functions and observables to certain cosmological parameters (or combination or parameters) to be investigated. By selecting two cosmologies from the drop down button on Step 1 the user can fill in the values of each cosmological parameter. On the interactive pages the user will then see two lines, one for each cosmology, above either the cosmological functions or observables being plotted.

After the last Step (either Step 2 or Step 3 depending on the products and level of customisation needed) the user is taken to a waiting page whilst the calculations are performed. Note that there are certain ‘illegal’ values of the cosmology parameters and customisable variables such as \( \Omega_m < 0 \) or \( k_{\text{min}} > k_{\text{max}} \) that the iCosmo source code will not accept. If an illegal value is passed to the interactive calculator the waiting page will display
The results tabs are all arranged using a common template which be seen in Figure [A.4]. This template is split into a number of regions. The top region is dedicated to the input cosmology used, the survey parameters (in the case of the Cosmology Observables and a Cosmology Errors tab). The user can click on any tab and change between tabs in any order or combination. In addition the navigation bar at the top of the page allows the user to link to other iCosmo pages.

The options that are given on each tab are shown in Table [A.2] where an “&” means that each option can be shown simultaneously and an “OR” means that the options are mutually exclusive.

The results tabs are all arranged using a common template which be seen in Figure [A.4]. This template is split into a number of regions. The top region is dedicated to the input cosmology used, the survey parameters (in the case of the Cosmology Observables and Errors tabs) and the options available for the particular tab.

Associated with each cosmological parameter is a box containing the current fiducial value. To change the fiducial value the user can simply enter an alternative value and click on “Change Cosmology”. The user will then be redirected to calculation page where the cosmological products will be re-calculated using the new cosmology.

The central part of each tab is the graphical window. When any of the options in a tab are changed the plot will be automatically updated. The plot is provided on screen in gif format, to save the plot as a gif most browsers provide a save option when an image is right-clicked. In addition to the gif format we provide an encapsulated postscript version of every plot, this can be downloaded by clicking on the plot.

In every tab, to the left of the plot, there are the options that are given on each tab are shown in Table [A.2] where an “&” means that each option can be shown simultaneously and an “OR” means that the options are mutually exclusive.

The format of the ascii file is shown to the right of the link and a message detailing the values that are discrepant and display a button with which the user can return to the previous step. After the calculations the user will be redirected to the Interactive results pages described in the next Section [A.6].

A.6. Interactive Pages

In this Section we will describe the Interactive results web pages. When the user arrives at the interactive results page they will be presented with a number of tabs one can change between any of the tabs simply by clicking on the relevant headers. The Cosmology Functions tab will always be present, since these are always calculated, in addition there may also be a Cosmology Observables and a Cosmology Errors tab. The user can click on any tab and change between tabs in any order or combination. In addition the navigation bar at the top of the page allows the user to link to other iCosmo pages.

The options that are given on each tab are shown in Table [A.3] where an “&” means that each option can be shown simultaneously and an “OR” means that the options are mutually exclusive.

Below the plot, in each tab, is a “Download Text Output” link. By clicking on this link the user can download the data plotted at the present time in an ascii table format for later use. The format of the ascii file is shown to the right of the link and is updated so that it is always relevant to the particular function being plotted.

To the right of the plot in each tab are the options that are relevant to the particular products that are being plotted, we will now explain each tab in turn.

A.6.1. Cosmology Functions Tab

The cosmology functions tab presents the calculations of the basic cosmology functions, and will always be present in the interactive section. To change between the functions the user can click on the relevant button. When the button is changed the “Cosmology Options” on the righthand side of the graph will change to reflect the new options available to the user.

Distances When the distances button is selected the angular diameter, luminosity, comoving and light travel distances can be plotted. Any combination of these distances can be plotted by selecting the relevant checkboxes – colours for each function can also be chosen independently using the drop down menu. These functions can be plotted as a function of: redshift $z$, scale factor $1/(1 + z)$ or look-back time.

| Product(s)                                      | Options                                                                 |
|------------------------------------------------|-------------------------------------------------------------------------|
| Distances, Hubble Parameter, Growth Factor     | $z_{\text{min}} - z_{\text{max}}$                                      |
| Matter Power Spectrum                          | $k_{\text{min}} - k_{\text{max}}$                                      |
| Lensing Power Spectrum or Lensing Fisher Matrix| Linear: Eisenstien & Hu (1997) (with or without baryon oscillations)   |
| BAO Distance Measure or BAO Fisher Matrix      | Non-Linear: Peacock & Dodds (1996) or Smith et al.(2003)                |
| Supernovae Magnitude-Distance or Supernovae Fisher Matrix| Survey                   |

Table A.2. The options given in Step 2 relevant for each of the products chosen in Step 1.
Evolution: Hubble Parameter, Growth, Angular Size When the cosmological evolution button is selected the Cosmology Options will change to allow the growth factor, Hubble parameter and angular size of galaxies to be plotted. The user can change the graphical output by selecting the relevant button, and change the colour of the line accordingly. All of these functions can be plotted as a function of redshift, scale factor or look-back time. The angular size is simply a modification of the angular diameter distance, we included it in this button (cosmological evolution) since it is not strictly a distance measure but a derived quantity that changes as a function of redshift. It is also a quantity that is of use to for some observational proposals. The growth factor is found by solving the growth factor differential equations.

Matter Power Spectrum By clicking on the matter power spectrum button the page will be updated with options relevant to the matter power spectrum. If the QuickStart button was used then the linear power spectrum will have been calculated using the Eisenstein & Hu (1997) formulae with baryon oscillations included, and the non-linear correction using Smith et al. (2003). The choice of linear and non-linear power spectrum (Table A.2, Step 2) will be shown in the bottom right-hand corner of the tab. Both the linear and non-linear power spectrum can be plotted, in addition the redshift of the power spectrum can be chosen from a grid of 50 finely spaced redshifts between 0 ≤ z < 5.

A.6.2. Cosmology Observables Tab

The Cosmology Observables tab will appear if some observables have been selected for calculation. Below the standard cosmology parameters will appear buttons that match to each of the observables requested. For every observable the 1-σ error bars for the survey chosen can be shown (or suppressed) at any time by selecting (de-selecting) the show errors checkbox. Naturally for any of the displayed functions the colour of the line drawn is always given as an option.

Lensing Power Spectrum The lensing power spectrum in fact consists of multiple individual spectra, for n tomographic bins there will be n(n + 1)/2 spectra. These are the auto-correlation of the cosmic shear signal in each redshift bin, and the cross correlation of the cosmic shear signal between redshift bins. The auto-correlation for the lowest redshift bin is initially shown, the drop down box labelled “Cℓ Bins” allows the user to plot any of the spectra calculated for the cosmic shear survey (the number available will depend on the number of redshift bins chosen).

Baryon Wiggles The baryons oscillation distance scale can be measured in either the radial direction (parallel to the line-of-sight) or in the tangential direction (perpendicular to the line-of-sight). The user can show either of these distance measures using the Cosmology Options buttons. For a recent discussion of baryon oscillations see Rassat et al. (2008).

Supernovae Magnitude-Distance The supernovae magnitude-distance option shows the predicted apparent magnitudes of Type-Ia supernovae as a function of redshift.

A.6.3. Cosmology Errors Tab

The cosmology errors tab will appear if Fisher matrices have been requested in Step 1 (see Section A.3). Fisher matrices calculate the expected marginal errors for a given cosmological probe and survey design. The cosmology errors tab will show either one or two sets of errors depending on the number of Fisher matrices requested. The 1-σ marginal errors are shown under each cosmological parameter at the top of the tab, these take into account all the degeneracies that exists between all of the parameters shown.

Some cosmological probes are only sensitive to particular parameters, in the case that neither Fisher matrix can constrain a parameter it will not be shown. In the case that the first Fisher matrix is sensitive to more parameters than the second then any parameters to which the second is insensitive will be given a “–” in place of a marginal error. We also show the dark energy equation of state pivot redshift error wp, this is the minimum error on function w(z) which we parameterise using w0 and wa (Chevallier & Polarski, 2001; Linder, 2003). We also show the Dark Energy Task Force (Albrecht et al., 2006) Figure of Merit (FoM) which is proportional to the reciprocal of the area constrained by the wp and wa ellipse FoM= 1/(Aw aAw p).

| Tab | Button | x-axis | y-axis |
|-----|--------|--------|--------|
| Cosmology Functions | Distances | redshift, scale factor, look-back time | Angular Diameter Distance & Luminosity Distance & Light Travel Distance & Comoving Distance |
| Evolution | | redshift, scale factor, look-back time | Hubble Parameter OR Growth Factor OR Angular Size |
| Matter Power Spectrum | | wavenumber, k | Linear & Non-Linear, Redshift |
| Cosmology Observables | Lensing Power Spectrum | azimuthal wavenumber, ℓ | Cross or auto correlation spectra, Survey Error Bars |
| | Baryon Oscillation Distance Scale | redshift | Radial OR Tangential modes, Survey Error Bars |
| | Supernovae Magnitude-Distance Relation | redshift | Survey Error Bars |
| Cosmology Errors | Fisher Matrices | | Cosmological Parameters, Display Fisher 1 & Fisher 2 & Combined |

Table A.3. The options for each tab and button on the interactive webpages.
A prior represents the extra (or a priori) knowledge that one may have on a particular parameter, allowing the user to add a Gaussian prior to any parameter. To add a prior to any parameter, the user can simply fill in the boxes under the parameter in the “Gaussian Prior” row at the top of the tab and click on “Add Prior.” The prior will be added to all Fisher matrices shown (one, two, or combined), and the marginal errors and graphical window will be automatically updated.

We graphically display the predicted marginal errors as contour plots. The graph can show the 1-σ marginal error contours for any of the parameters to which methods are sensitive. The contours will always be ellipses since in all Fisher matrices we have assumed Gaussian distributed data (Tegmark et al., 1997). The user can choose between any parameter combination by using the drop-down menus under Cosmology Options. In addition to changing the color of the line drawn, the ellipses can also be filled with a color chosen from the drop-down menus. To show a Fisher matrix (or suppress it) the check box to the left of the Fisher matrix description can be selected (or de-selected).

If two Fisher matrices have been calculated, the user will now have the further option of combining the constraints. This is done by selecting the check box to the left of “Combined Fisher” under the Cosmology Options. When the Fisher matrices are combined, there will now be an additional row of marginal errors shown at the top of the tab and an additional constraint drawn in the graphical window.

The Fisher matrices are calculated using the formalism outlined in following publications. For lensing we use Amara & Refregier (2007), this calculation has been extensively tested and found to be in agreement with a number of independent codes, these include codes written by: Sarah Bridle, Filipe Abdalla, Jiayu Tang, Shaun Thomas, Peter Schneider, Martin Kilbinger, Jan Hartlap and Benjamin Joachimi as well as a 3D cosmic shear code (Heavens, 2003; Heavens et al. 2006). For the BAO calculation we use the formalism for spectroscopic surveys developed by Blake et al. (2006), this has been tested against, and found to be in agreement with independent codes written by Martin Kunz, Francesc Castander as well as the DETFfast website, for a description of these implementations see Rassat et al. (2008). For supernovae we use the Fisher matrix formalism described in Tegmark et al. (1998) and Hutner & Turner (2001).

A.6.4. Extending the Calculation & Help

The final tabs on the interactive website allow the user to change the calculation from what they have already calculated and get some more Help.

**Help** If any extra help is needed we provide some short pragmatic < 1 minute clips where particular aspects of the interactive tabbed environment are demonstrated. These are hosted on an external YouTube channel [http://www.youtube.com/icosmology](http://www.youtube.com/icosmology).

**Extend Calculations** On the extend calculation tab the user will find a copy of Step 1 (see Section A.3) but with the values and scope already calculated filled in with the currently selected products and variables. The user can then change the options in any way just like Step 1, either extending or simplifying the calculation or just changing some of the parameters. By clicking on “Extend Calculation” the user is taken to Step 2.
Appendix B: A Worked example

**HTML Example.** Here is an HTML script that can be used to create the page [http://www.icosmo.org/WebPaper.html](http://www.icosmo.org/WebPaper.html), we also display this HTML on the page itself.

```html
<html>
<head>
<title>A Simple Cosmology HTML Page</title>
<style type="text/css">
htest
{
font-family: arial;
font-size: 10px;
color: \#660000
}
</style>
</head>
<body>
<h1>Welcome!</h1>
<p>This HTML page accompanies the paper <em>Cloud Cosmology: Building the Web Interface for iCosmo</em>. Here we will demonstrate some simple HTML syntax including forms, styles and images.
We could not possibly give examples of all possible HTML syntax here, for extensive tutorials follow these links:
</p>
<ul>
<li>(This is also an example of how to make a list and hyperlinks)</li>
<li><a href="http://www.w3schools.com">w3 schools</a></li>
<li><a href="http://www.htmlcodetutorial.com/">html tutorial</a></li>
</ul>
<p>The HTML used for this page is shown at the bottom of this page, or can be viewed by using the <em>show source code</em> option in most browsers.</p>
<h2>Styles</h2>
<p>There are two ways in which the style of text can be changed.</p>
<p style="font-family:verdana;font-size:15px">Either within the paragraph declaration, as is done here</p>
<h2>Images</h2>
<p>This is how to insert an image:</p>
<img src="http://www.icosmo.org/icosmo\_logo.jpg" alt="iCosmo logo">
<p>And turn an image into a hyperlink:</p>
<a href="http://www.icosmo.org">img src="http://www.icosmo.org/icosmo\_logo.jpg" alt="iCosmo logo"></a>
<h2>Forms</h2>
<p>Here is an example of a simple HTML form that will collect some information and submit it to CGI script. This CGI script will then perform a cosmological calculation using iCosmo and the information provided. (this example also shows how to make Greek letters and subscripts)</p>
```
Please enter some cosmological parameters

<form action="/cgi-bin/WebPaper.cgi">
\(\Omega_m\) <input type="text" name="OmegaM" size="10" value="0.3">
\(\Omega_{DE}\) <input type="text" name="OmegaL" size="10" value="0.7">
<input name="reset" type="reset" value="Reset Default">
<input name="submit" type="submit" value="Calculate">
</form>

CGI Example. Here is the PERL code that is used to create the CGI script on http://www.icosmo.org/cgi-bin/WebPaper.cgi the code is also displayed at the bottom the online page.

```perl
#!/usr/bin/perl
require "cgi-lib.pl";
&ReadParse(*input);
#If not already set then set defaults:
$omega_m=0.3;
$omega_l=0.7;
#Reads in the values from the webpage
$omega_m = $input{\'OmegaM\'} if (exists $input{\'OmegaM\'});
$omega_l = $input{\'OmegaL\'} if (exists $input{\'OmegaL\'});
print "Content-type: text/html;\n\n;";
print <<HTML;
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN" "http://www.w3.org/TR/xhtml1/DTD/xhtml1-transitional.dtd">
<html>
<head>
<title>A Simple Cosmology CGI Page</title>
</head>
<body>
<h1>Welcome to the CGI Page!</h1>
<p>This CGI page accompanies the paper <em>Cloud Cosmology : Building the Web Interface for iCosmo</em> and has been called from the HTML page <a href="http://www.icosmo.org/WebPaper.html">http://www.icosmo.org/WebPaper.html</a>.</p>
<p>This CGI page is written in PERL, it has read in the values you submitted. These are printed below:</p>
<ul>
<li>\(\Omega_m\)=\$omega_m\</li>
<li>\(\Omega_{DE}\)=\$omega_l\</li>
</ul>
<p>Now we will start an IDL session and do some very simple calculations (use the densities to determine whether the Universe is open or closed)</p>
HTML
```
use IPC::Open3;
$ENV{'PATH'} = '/Applications/itt/idl70/bin/'; $progName = "ssh wwwicosm@machine ’cd WebServer/CGI-Executables; idl’";
open3(WRITEIDL,READIDL,ERRORIDL, $progName) or die "Could not begin "$progName" ";

#IDL command line arguments can now be done using the following syntax:

print WRITEIDL "omega_total=$omega_m+$omega_l \n";
print WRITEIDL "print,omega_total \n";
$omega_T=<READIDL>;

print "The total density is &Omega;_T=$omega_T so";
if ($omega_T <= 1.0) {
    print " the Universe is open. ";
} else {
    print " the Universe is closed. ";
}
print " This calculation was done in IDL. ";
print " Now we will use an iCosmo routine to perform a simple cosmological calculation. ";

#load the iCosmo routines:
print WRITEIDL "restore,file='comp_fisher.sav' \n";
#set fiducial and run mk_cosmo (without matter power spectrum):
print WRITEIDL "fid=set_fiducial() \n";
print WRITEIDL "fid.cosmo.omega_m=0.3 \n";
print WRITEIDL "fid.cosmo.omega_l=0.7 \n";
print WRITEIDL "cosmo=mk_cosmo(fid,/nopk) \n";
#extract some variables:
print WRITEIDL "print,cosmo.evol.z[200] \n";
$z=<READIDL>;
print WRITEIDL "print,cosmo.evol.da[200] \n";
$da=<READIDL>;

print<<HTML;<p style="font-family:arial;">At a redshift of $z the angular diameter distance is $da Mpc.</p>
HTML

#end of the web page:
print<<HTML;
<html>
</html>
HTML

#close the child IDL session:
close(WRITEIDL);
close(READIDL);
close(ERRORIDL);
exit;