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Mobile applications and Virtual Observatory

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ABSTRACT

Within a few years, smartphones and Internet tablets have become the devices to access Web or standalone applications from everywhere, with a rapid development of the bandwidth of the mobile networks (e.g. 4G). Internet tablets are used to take notes during meetings or conferences, to read scientific papers in public transportation, etc. A smartphone is for example a way to have your data in the pocket or to control, from everywhere, the progress of a heavy workflow process. These mobile devices have enough powerful hardware to run more and more complex applications for many use cases. In the field of astronomy it is possible to use these tools to access data via a simple browser, but also to develop native applications reusing libraries (written in Java for Android or Objective-C/Swift for iOS) developed for desktops/laptops. We describe the experiments conducted in this domain, at CDS and IUCAA, considering a mobile application as a native application as well as a Web application.

1. Introduction

Some members of the IVOA[1] (International Virtual Observatory Alliance), developing mobile applications since several years, have now skills in native iOS and Android developments, Web development (especially HTML5, JavaScript, CSS3[2]) and conversion tools (e.g. PhoneGap[3]). Development in HTML5/JavaScript/CSS3 is promising and it has the advantage of allowing developments independent from the evolution of the mobile platforms ("write once, run everywhere").

Our approach was to perform testing of hardware, to develop prototypes but also operational applications or services. Compared to traditional developments one of the biggest change comes from human/computer interaction that is radically modified by the multitouch use. This interaction requires a redesign of the interfaces to take advantage of new features (simultaneous selections in different parts of the screen, etc.). In the case of native applications, the distribution is usually done through on-line stores (App Store, Google Play), which give a visibility to a wider audience. As the frontier is becoming thin between a native application and a Web application we use mobile application as a generic expression in this paper. To simplify, we use also desktop to designate both desktops and laptops. In this paper we give an overview of the experiments we have conducted and the applications we have developed. Mobile devices are not restricted to Android and iOS but we have focused our efforts on the most popular. For those wishing to achieve this kind of development, we give also technical information (development frameworks, languages, etc.).

2. Mobile application for the Virtual Observatory

2.1. Motivation

The IVOA does not develop specific standards for mobile devices, its aim is to work on interoperability of applications and services based on the definition of standard data models, data access layers, registries, etc. Mobile devices and their applications benefit from these standards and also from previous developments. It is for example possible to reuse libraries, developed for desktops, in mobile applications. The high improvements in the network bandwidth now allows to use a smartphone to launch jobs on servers, to store or move data on clouds or on large dedicated storage spaces like VOSpace (Graham et al., 2011). VOSpace is the IVOA interface to distributed storage. It specifies how VO agents and applications

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1 http://www.ivoa.net/.
2 Cascading Style Sheet version 3.
3 http://www.phonegap.com/.

http://dx.doi.org/10.1016/j.ascom.2015.03.006
2213-1337/

can use network attached data stores to persist and exchange data in a standard way.

Concerning the Web developments, it is now necessary to take into account the diversity of devices to implement a responsive Web design (the user interface changes automatically following the device display characteristics). The possibilities are also broader with a mobile device because it brings new features. It is for example possible to use gyroscope, accelerometer and GPS (Global Positioning System) to point an object in the sky. The IVOA has an Interest Group dedicated to Education. This domain should also be a good experimentation field for mobile applications. When possible, a VO service should be accessible from everywhere and on every device.

2.2. The use cases

CDS and IUCAA have not joined forces for developments, but have decided to share their experiences.

IUCAA was interested by the development of mobile applications mainly for Education (for example Stat-Lite) and its experiments were based only on Android. This choice is motivated by the percentage of people with an Android device and the effort at the Ministry level to furnish Android Internet tablets.

CDS was interested by the R&D aspects to learn how to develop mobile applications in several ways and to find use cases in connection with its services and tools. The survey visualization application was based on HEALPix[4] which is now widely used at CDS. The proof of concept concerning the use of an Internet tablet as a remote control is now used in the frame of a European project, for its outreach.

We give more details directly in the concerned sections.

3. How to develop a mobile application?

We have explored three ways to build applications for mobile devices.

A first way is to develop a Web application in HTML5/JavaScript/CSS3 like for desktops and with dedicated JavaScript libraries like jQuery[5] Mobile which are optimized for mobile devices. jQuery Mobile is a HTML5-based user interface system designed to make responsive Web sites (the user interface is adapted following the device display characteristics) for smartphone, tablet and desktop devices. At CDS, a significant part of the developments is based on these technologies and the developers have de facto the skills to learn quickly how to develop applications for mobile devices through this way.

A second way is to develop a native application in Java for Android and Objective-C/Swift for iOS. In astronomy it is now relatively common to develop in Java but probably not in Objective-C/Swift. For this reason, in the second case the maintenance and the evolution will be more random. A native development could be motivated by the re-use of existing libraries to gain time rather than re-develop in an other language, above all if it implies a scientific expertise. This is often the case in astronomy.

The last way is to develop Web applications in HTML5/JavaScript/CSS3 and to convert them in pseudo native code through converters like PhoneGap. It is not a true conversion in Java or Objective-C/Swift but an execution in a Virtual Machine.

We have not experimented an other solution based on the conversion from a language (for example Java) to an other one like Objective-C/Swift. A few frameworks do it like J2ObjC[6] which converts just the Java code (data access, etc.) but not the GUI side which must be still developed in the native language.

4 http://healpix.jpl.nasa.gov/.

5 http://jquerymobile.com/.

6 https://code.google.com/p/j2objc/.

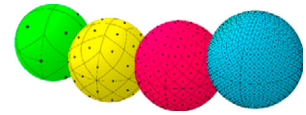

Fig. 1. HEALPix principle.

4. Experiments and developments at CDS

4.1. Introduction

The CDS started to develop for mobile devices in early 2010 (Schaaff et al., 2013). We give here on overview of the most significant experiments and developments done in the frame of R&D (Schaaff et al., 2014), more information is available on the CDS Developer's corner.[7] We often refer to Aladin Sky Atlas,[8] a portal of the Virtual Observatory, developed at CDS.

4.2. HEALPix viewer

HEALPix[9] (Hierarchical Equal Area isoLatitude Pixelization) offers a way to display large image surveys through a pixelization of the sky (cf. Fig. 1 for the principle). The number of HEALPix (Górski et al., 2005) surveys is growing and a few HEALPix visualizer are available like Aladin through the Allsky mode (Fernique et al., 2010). This mode runs well on a desktop with good performances and it was a real challenge to develop a HEALPix visualizer for smartphones and Internet tablets in 2011.

We decided to develop it (Fig. 2) on Android to reuse a part of Aladin Java code. We used Eclipse[10] and ADT[11] (Android Developer Tools) plugin for Eclipse to develop this application. A tablet linked to the development platform was mandatory as the emulation device was unable to execute the application. The emulation device worked fine only for small developments requiring few resources.

First tests were not really good due to the hardware capabilities (in 2011) compared to desktops. With 1.5 FPS[12] it was not usable. For a good user experience the number of FPS should be at least 30.

Aladin was not using OpenGL[13] (Open Graphics Library) but this graphical library was available on almost all the mobile devices. OpenGL is a cross-language, multi-platform application programming interface (API) for rendering 2D and 3D vector graphics. The new prototype, called SkySurveys (Schaaff et al., 2013), implementing this library was between thirty and forty times faster with 45 to 60 FPS. It was sufficient to provide a fluid multitouch interaction.

All the surveys available and added in the future in Aladin will also be available in SkySurveys. We consider this application as an advanced prototype for Android devices. We will not develop the same application for iOS devices because the porting of Aladin HEALPix Java libraries needs resources to do it and to test. It involves also OpenGL which is not trivial to manipulate. The maintenance of an application for both Android and iOS has also a cost we cannot assume. A solution could be to switch from OpenGL to WebGL[14] and thus to develop with HTML5/Javascript/CSS3. An effort is on going concerning the visualization with HTML5 canvas.

7 http://cds.u-strasbg.fr/resources/doku.php.

8 http://aladin.u-strasbg.fr/.

9 http://healpix.jpl.nasa.gov/.

10 https://eclipse.org/.

11 http://healpix.jpl.nasa.gov/.

12 Frames per second.

13 https://www.opengl.org/.

14 https://www.khronos.org/webgl/.

Fig. 2. SkySurveys—navigation in a HEALPix survey (Spitzer survey, credits: JPL/NASA).

4.3. SkyObjects, pointing the sky

We have developed SkyObjects, an Android application using the CDS name resolver Sesame,[15] to retrieve basic information (coordinates, identifiers, etc.) about an astronomical object. The added-value of this small application is to access to the basic information about an astronomical object from everywhere and also to provide a pointing capability using the compass, gyroscope and GPS of the mobile device. It becomes possible to point all the astronomical objects resolved by Sesame. This additional feature gives a fun dimension to the application that gives it therefore also an interest for the general public (Fig. 3, the application is available in French and in English).

4.4. SkyTouch, a remote control of Aladin

The initial idea was to experiment the possible interaction between a desktop application and a mobile device. A typical use case was to use it during a demo of Aladin and to allow people to interact with Aladin without particular skills concerning this tool. Another idea was to provide several scenarios to fit to the level of education and knowledge of the public. Aladin is able to interact with other VO applications through the IVOA SAMP (Simple Application Messaging Protocol) protocol (Taylor et al., 2012). Thus we decided to base on this protocol the communication between Aladin and the remote device. The SAMP hub[16] implemented a protection allowing the communication between applications only on the same device. Mark Taylor, developer of the Java SAMP hub provided us a new version with an optional protection.

SkyTouch (Fig. 4) is a Web development (HTML5, JavaScript, CSS3) using a conversion tool (PhoneGap) in association with Xcode[17] (the Apple IDE). This is very quick and allows trying the application on different platforms. The technologies also corresponded better to the developer skills. Compared to Aladin, the capabilities were limited to an object request, the zooming, the multi-view management and a few other basic functionalities like the setting of the reticle. The aim was to let the general public play with a remote control as simple as possible.

4.5. SkyTouch as a proof of concept for ARCHES outreach

SkyTouch was a prototype and its original concept (a tablet used as a remote control, Fig. 5) is now used in the frame of the development of Arches Walker (Fig. 6), the outreach part of the European project ARCHES[18] (Astronomical Resource Cross-matching for High Energy Studies). Arches Walker will be available at the end of the project as a documented package for ARCHES participants, planetariums, schools, etc.

Tools are developed in the frame of ARCHES for cross-correlation with extensive archival resources to produce well-characterized multi-wavelength data in the form of SEDs (Spectral Energy Distributions) for large data sets of objects. The

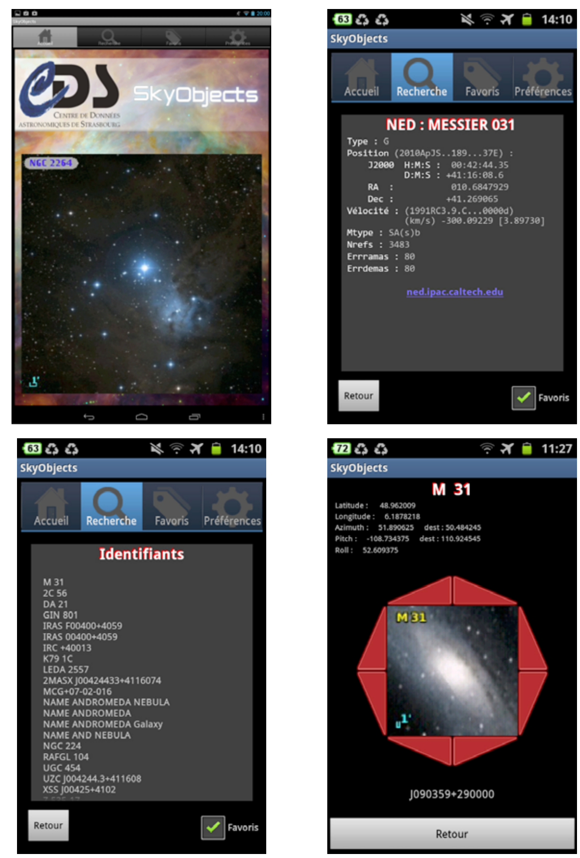

Fig. 3. SkyObjects—the first screen with a random image, result search for MESSIER 31, the identifiers and the pointing capability.

15 http://cds.u-strasbg.fr/cgi-bin/Sesame.

16 http://www.star.bris.ac.uk/~mbt/jsamp/.

17 https://developer.apple.com/xcode/.

18 http://www.arches-fp7.eu/.

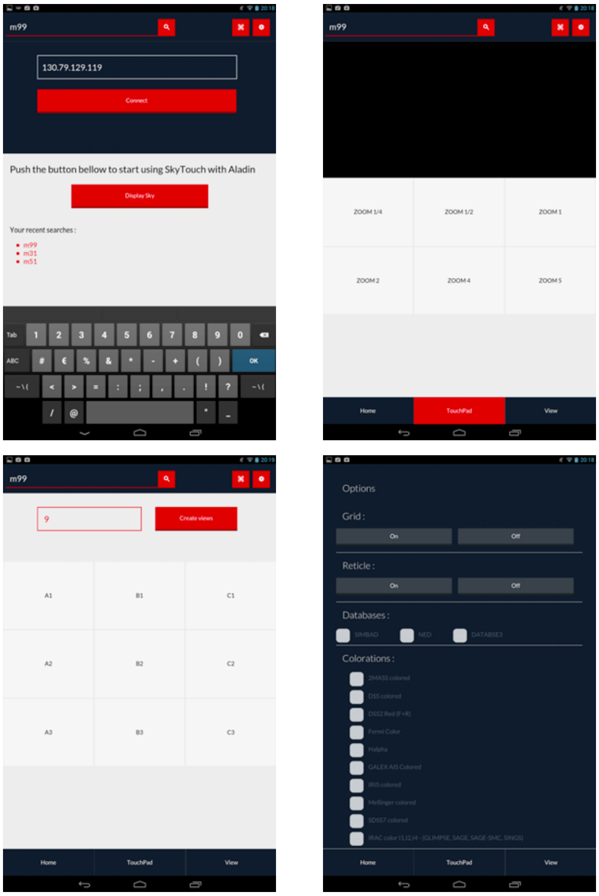

Fig. 4. SkyTouch—the connexion to the server hosting Aladin, a search of m99 in Aladin, request for a multiview in Aladin and possibility to select one of the 9 views.

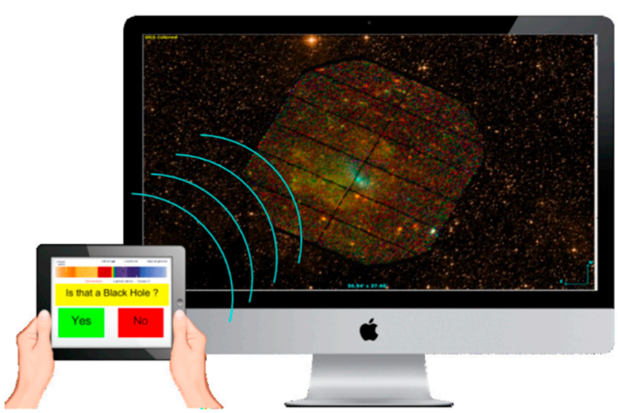

Fig. 5. Arches Walker concept—a tablet used as a remote control.

XMM-Newton (X-ray Multi-Mirror, an X-ray satellite mission)[19] catalog can be considered as one of the richest astrophysical resources available at ESAC (European Space Astronomy Centre)[20] and has been chosen as the main focus of the ARCHES project and the base catalog for multi-wavelength products creation.

The aim of Arches Walker is to promote XMM results for a wide audience (kids, general audience, students) and to make SEDs attractive.

The discovery mode:

- the mobile device communicates with the display station with a had hoc Wi-Fi or a Bluetooth connexion
- the display station hosts a local database with the whole data corpus, it can work without the network
- a Java application is running on the display station and controls the Aladin Sky Atlas and the viewers (images, html, pdf, etc.) used to display additional information to Aladin
- the user navigates in the Android application (Fig. 6, left part), selects the type of object (Galaxy, Star, etc.), he selects for example Galaxy and he can then select a particular galaxy and change the wavelength, display the SED, etc.
- the Java application running on the display station understands the user requests and interacts with Aladin or with the viewers to provide the correct action in Aladin or in the viewers.

On the technical side, this application was developed with AndroidStudio,[21] the official Android IDE (Integrated Development Environment). It was our first use of this IDE and we had a better experience than with Eclipse. It is hard to test his application with Eclipse without a tablet or a smartphone linked to the development platform. On its side, AndroidStudio offers a good embedded simulation device.

The same concept can be easily reused for other domains of astronomy. The investment (a desktop + screen and/or projector + an internet tablet) is low and it is probably more fun than just a touchscreen, as it provides a larger field of view and thus introduces a more collaborative participation. The evaluation in real condition is on going to improve it.

5. Developments at IUCAA

5.1. Introduction

During mid-2010 Virtual Observatory—India (VOI) started working on Virtual Observatory (VO) projects based on International Virtual Observatory Alliance (IVOA) standards. During that time VOI started developing some basic Android tools like the Name Resolver and the Cosmological Calculator. After a few years, in 2014, VOI developed two more Android applications namely Cone Search and Stat-Lite which were designed for high school and undergraduate students. All the developments were done for android platform as it is the most common. The development framework was Eclipse with the ADT suite.

5.2. Name resolver

The Name Resolver Application (Fig. 7) allows the user to input the name of celestial object and returns basic information such as RA/Dec values associated with provided object. In addition it also provides other information like redshift, proper motion, parallax, etc. All the information is retrieved from the object name resolver services provided by NED[22] (NASA/IPAC Extragalactic Database) and Simbad[23] (set of Identifications, Measurements and Bibliography for Astronomical Data).

5.3. Cosmological calculator

This application (Fig. 8) installed on an Android device (locally), allows the user to input user-selected values of the

19 http://xmm.esac.esa.int/.
20 http://www.esa.int/About_Us/ESAC.
21 http://developer.android.com/tools/studio/index.html.
22 http://ned.ipac.caltech.edu/.
23 http://simbad.u-strasbg.fr/simbad/.

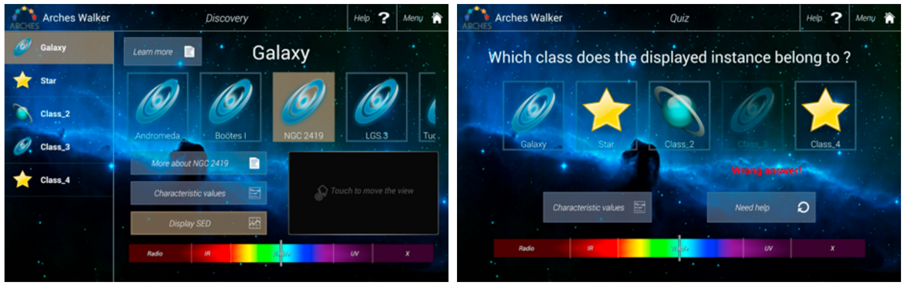

Fig. 6. Arches Walker—a discovery mode and a quiz mode.

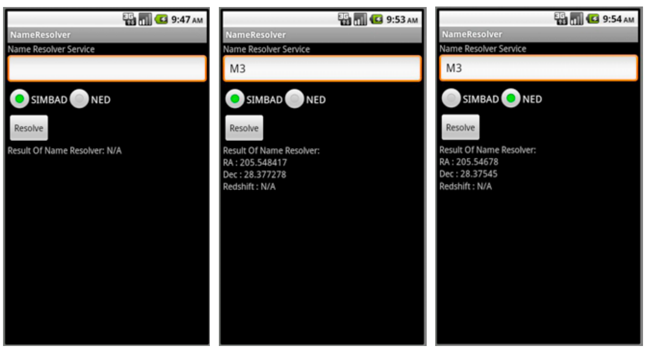

Fig. 7. Name resolver—the main screen, a request concerning M3 in Simbad, a request concerning M3 in NED.

Hubble constant, Omega (matter), Omega (Vacuum) and the redshift (x). Depending on these values it returns the current age of the Universe, the co-moving radial distance and volume, and the luminosity distance. It also provides the flexibility to choose between "Open(Omega(vacuum) = 0)", "Flat(Omega (total) = 1.0)", "general (arbitrary combination of Omega(matter) and Omega(vacuum)) universe". This application does not need any Internet access for generating these values. This calculator has been adapted from "Ned Wright's Cosmology Calculator".

5.4. Cone search

It (Fig. 9) provides the VO facility on Android platforms allowing the user to query catalogs from the VO registry (Benson et al., 2011) based on the Ra/Dec values and the radius of the object. These values can be resolved by integrated "Android Name Resolver" application (using Simbad/NED or users can provide the values themselves). This cone search works similarly to a typical VO cone search for desktops. The application also allows user to view or save data onto their Android device in the form of VOTable. Further due to limited resources we are able to display only the first few records at a time and as the user pans through the screen other pages are loaded accordingly (like pagination).

5.5. Stat-Lite

This application (Fig. 10) provides an interactive and easy introduction to the concepts of Descriptive Statistics and Curve Plotting. It also includes few basic features like loading VOTable (Ochsenbein et al., 2011) and ASCII data set and performing some basic statistical analysis such as correlation tests, and summary statistics. Some of the novel features include graphs with multitouch gesture support the user can pan and zoom to study specific areas, ability to study effect of outliers on regression fits by adding them using a simple interface, etc. The interface and the content have been designed for high school and undergraduate students. The curve-plotting module, apart from having all the major

Fig. 8. Cosmological calculator—the main screen and successively general, Open and Flat universe options.

categories of pre-defined functions, has the ability to plot any arbitrary mathematical function by writing it down as combination of functions in the existing library.

There are approximately 15 applications on the Google Play Store that provide the kind of analysis we make available in our application. In most of these applications there is no provision to evaluate the correlation and causation between two or more variables. Further, none of the applications allow the user to load an IVOA standard data files. We looked at various plotting applications available on this store, the major flaw in majority of the applications were they did not handle the curves with inflection points (curves with infinite values) properly. Another major problem with these applications is that sometimes graph gets distorted while zooming or panning. Although some of them allow user to plot even 3D graphs, yet the major problem with them is that User interface is too cluttered.

A motivation for developing Stat-Lite was also to spread scientific awareness among the Indian students with the help of Aakash tablet. These tablets have been launched and distributed in India with the support of Ministry of Human Resource Development, Government of India, along with a British-Canadian company Data Wind as part of its initiative to modernize teaching and learning systems in schools, colleges, and universities across India. These tablets have a hardware configuration of 4 GB storage, 512RAM and 1 GHz cortex processor and run on Android Operating System.

6. Conclusion

Our several experiments represent a significative development effort which should be seen as an investment for the future. The desktops will probably become less used than today. Especially in the outreach domain, we will have great opportunities to develop mobile applications and services. The Virtual Observatory offers a way to access a large amount of data through standardized protocols and added-value services developed on top of these data (e.g. efficient cross-match services). All these data sources and all these services will be easily reached from everywhere through the mobile devices. The mobile applications can be seen as light interfaces able to access to a large variety of data and services. The future of the Virtual Observatory is probably in the pocket!

Fig. 9. Cone search—search around sirius with a radius of 2° and a VOTable format result.

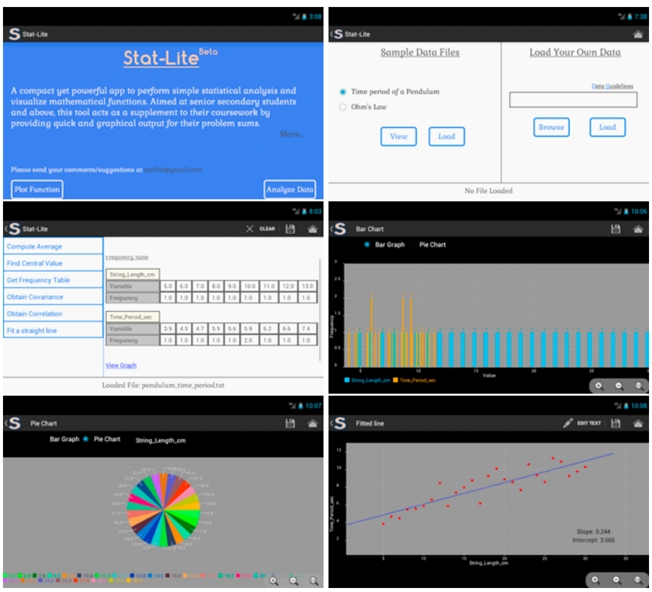

Fig. 10. Stat-Lite—introduction page, sample data files or own data, functions, Bar chart, Pie chart, Fitted line.

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[24] http://voi.iucaa.ernet.in/.