Vidarbha Youth Welfare Society's
Bar.Ramrao Deshmukh Arts, Smt. Indiraji Kapadiya Commerce and
Ny. Krushnarao Deshmukh Science College, Badnera Distt. Amravati (Maharashtra) 444 701
(Accredited by NAAC with B++ grade)
Ph. 0721-2681232, FAX : 0721- 2681232,
email : rdik128@sgbau.ac.in, website : www.rdikandnkd.org

Ref.No. 614/23-24 Date : 14/03/2024

DVV Clarification For

Document: 1

3.1.1 Grants received from Government and non-governmental agencies for research projects / endowments in the institution during the last five years (INR in Lakhs)

Vidarbha Youth Welfare Society's
Bar.Ramrao Deshmukh Arts, Smt. Indiraji Kapadiya Commerce and
Ny. Krushnarao Deshmukh Science College, Badnera Distt. Amravati (Maharashtra) 444 701
(Accredited by NAAC with B++ grade)
Ph. 0721-2681232, FAX : 0721- 2681232,
email : rdik128@sgbau.ac.in, website : www.rdikandnkd.org

Ref.No. 614/23-24 Date : 14/03/2024

DECLARATION

This is to declare that the information, photos, reports, true copies, numerical data, etc. furnished in this file as supporting documents is verified by IQAC and found correct.

Dr. N.A.Deshmukh
IQAC Co-Ordinator
Dr. Nakul A. Deshmukh
IQAC Co-Ordinator
R.D.I.K. & K.D. College, Badnera

Dr. R.D.Deshmukh
Principal
PRINCIPAL
Bar Ramrao Deshmukh Arts
Smt Indiraji Kapdiya Commerce
and Ny.Krusnarao Deshmukh
Science College,BADNERA.

Bar. Ramrao Deshmukh Arts, Smt.Indiraji Kapadiya Commerce and Ny.Krushnarao Deshmukh Science College
BADNERA
AMRAVATI

Vidarbha Youth Welfare Society, Amravati

Bar. Ramrao Deshmukh Arts, Smt. Indiraji Kapadiya Commerce and Ny.

Krushnarao Deshmukh Science College,

Badnera Dist. Amravati (M.S) 444701

SUPPORTING DOCUMENTS

Vidarbha Youth Welfare Society, Amravati

Bar. Ramrao Deshmukh Arts, Smt. Indiraji Kapadiya Commerce and Ny. Krushnarao Deshmukh Science College, Badnera Dist. Amravati (M.S) 444701

Metric No. 3.1.1

INDEX

Grant received from CSIR

Name of scholar : **Vishal Mahadev Ingle**

Scheme : Junior and Senior Research fellowship

Date of joining : 1st December,2017

Financial Year : 1st April 2018 to 31st March 2019

S.No.	Month	JRF/SRF Fellowship (Rs.)	HRA	Contingency	Total Amount (Rs.)
1	Apr-18	25000	0	1000	26000
2	May-18	25000	0	1000	26000
3	Jun-18	25000	0	1000	26000
4	Jul-18	25000	0	1000	26000
5	Aug-18	25000	0	1000	26000
6	Sep-18	25000	0	1000	26000
7	Oct-18	25000	2500	1000	28500
8	Nov-18	25000	2500	1000	28500
9	Dec-18	25000	2500	1000	28500
10	Jan-19	31000	2480	1000	34480
11	Feb-19	31000	2480	1000	34480
12	Mar-19	31000	2480	1000	34480
Total Amount (Rs.)		**318000**	**9982**	**12000**	**310460**

Bar Ramrao Deshmukh Arts, Smt. Indiraji Kapadiya Commerce & Nya Krushnarao Deshmukh Science College BADNERA AMRAVATI

Dr. R. D. Deshmukh
Principal
Bar.Ramrao Deshmukh Arts &
Smt.Indiraji Kapadiya Commerce
Naya. Krushnarao Deshmukh Science
College HSC Voc. Badnera Rly.
Dist- Amravati

Financial Year : 1st April 2019 to 31st March 2020

S.No.	Month	JRF/SRF Fellowship (Rs.)	HRA	Contingency	Total Amount (Rs.)
1	Apr-19	31000	2480	1000	34480
2	May-19	31000	2480	1000	34480
3	Jun-19	31000	2480	1000	34480
4	Jul-19	31000	2480	1000	34480
5	Aug-19	31000	2480	1000	34480
6	Sep-19	31000	2480	1000	34480
7	Oct-19	31000	2480	1000	34480
8	Nov-19	31000	2480	1000	34480
9	Dec-19	31000	2480	1000	34480
10	Jan-20	31000	2480	1000	34480
11	Feb-20	31000	2480	1000	34480
12	Mar-20	31000	2480	1000	34480
Total Amount (Rs.)		**372000**	**29760**	**12000**	**413760**

Financial Year : 1st April 2020 to 31st March 2021

S.No.	Month	JRF/SRF Fellowship (Rs.)	HRA	Contingency	Total Amount (Rs.)
1	Apr-20	31000	2480	1000	34480
2	May-20	31000	2480	1000	34480
3	Jun-20	31000	2480	1000	34480
4	Jul-20	31000	2480	1000	34480
5	Aug-20	31000	2480	1000	34480
6	Sep-20	31000	2480	1000	34480
7	Oct-20	31000	2480	1000	34480
8	Nov-20	3866	2500	3250	9616
9	Dec-20	4000	2500	6250	12750
10	Jan-21	35000	2500	6250	43750
11	Feb-21	35000	2500	6250	43750
12	Mar-21	35000	2500	0	37500
Total Amount (Rs.)		**329866**	**29860**	**29000**	**388726**

Financial Year : 1st April 2021 to 31st March 2022

S.No.	Month	JRF/SRF Fellowship (Rs.)	HRA	Contingency	Total Amount (Rs.)
1	Apr-21	35000	2500	0	37500
2	May-21	35000	2500	0	37500
3	Jun-21	35000	2500	0	37500
4	Jul-21	35000	2500	0	37500
5	Aug-21	35000	2500	0	37500
6	Sep-21	35000	20	0	35020
7	Oct-21	35000	20	0	35020
8	Nov-21	35000	2500	6250	43750
9	Dec-21	35000	2500	0	37500
10	Jan-22	35000	2500	0	37500
11	Feb-22	35000	2500	0	37500
12	Mar-22	35000	2500	6250	43750
Total Amount (Rs.)		**420000**	**25040**	**12500**	**457540**

Financial Year : 1st April 2022 to 31st November 2022

S.No.	Month	JRF/SRF Fellowship (Rs.)	HRA	Contingency	Total Amount (Rs.)
1	Apr-22	35000	2500	6250	43750
2	May-22	35000	2500	0	37500
3	Jun-22	35000	2500	0	37500
4	Jul-22	35000	2500	6250	43750
5	Aug-22	35000	2500	0	37500
6	Sep-22	0	2500	0	2500
7	Oct-22	35000	2500	0	37500
8	Nov-22	35000	2500	0	37500
Total Amount Rs.)		**245000**	**20000**	**12500**	**277500**

Dr. R. D. Deshmukh
Principal
Bar.Ramrao Deshmukh Arts &
Smt.Indiraji Kapadiya Commerce
Naya. Krushnarao Deshmukh Science
College HSC Voc. Badnera Rly.
Dist- Amravati

Total Grant received from CSIR

S. No.	Financial Year	JRF/SRF Fellowship (Rs.)	HRA	Contingency	Total Amount (Rs.)
1	1st April 2018 to 31st March. 2019	318000	9982	12000	310460
2	1st April 2019 to 31st March 2020	372000	29760	12000	413760
3	1st April 2020 to 31st March 2021	329866	29860	29000	388726
4	1st April 2021 to 31st March 2022	420000	25040	12500	457540
5	1st April 2022 to 31st Nov.2022	245000	20000	12500	277500
Total Amount (Rs.)		**1684866**	**114642**	**78000**	**1847986**

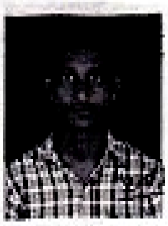
Dr. R. D. Deshmukh
Principal
Bar.Ramrao Deshmukh Arts &
Smt.Indiraji Kapadiya Commerce
Naya. Krushnarao Deshmukh Science
College HSC Voc. Badnera Rly.
Dist- Amravati

SPEED-POST/REGISTERED

वैज्ञानिक तथा औद्योगिक अनुसंधान परिषद्
COUNCIL OF SCIENTIFIC & INDUSTRIAL RESEARCH
मानव संसाधन विकास समूह, परीक्षा एकक
Human Resource Development Group, Examination Unit
सी.एस.आई.आर. कॉम्पलेक्स, लाईब्रेरी एवेन्यू, पूसा, नई दिल्ली- 110 012
CSIR Complex, Library Avenue, Pusa, New Delhi-110 012

Sr.No. 2061641218
Ref. No: 19/06/2016(i)EU-V

Dated 28/02/2017



ROLLNO: 427262
SH. VISHAL MAHADEV INGLE
S/O MAHADEV SUKHADEO INGLE
C /O N P GOMASE SHIV NAGAR
WARD NO 1 JALGAON JAMOD ROAD MANDURA
TQ NANDURA DIST BULDHANA MAHARASHTRA
443404

Sub: - Joint CSIR-UGC Test for Junior Research Fellowship and Eligibility for Lectureship (NET) held on 19-06-2016.

Dear Candidate,

CSIR is pleased to inform you that you have been declared successful in the above examination for award of **JUNIOR RESEARCH FELLOWSHIP** and **secured 149/0637 rank** in the subject **MATHEMATICAL SCIENCES** under UGC Fellowship scheme. Further, you have also been declared qualified for eligibility for **Lectureship (NET)** in the above subject area, **subject to fulfilling the eligibility criteria laid down by the UGC.**

The fellowship is tenable w.e.f. 01.01.2017. It will be governed by the terms and conditions of the UGC Junior Research Fellowship. In order to accept this offer you may contact UGC at the address given overleaf. Your dossier is being forwarded to UGC.

While considering for fellowship /appointment, the Supervisor/Guide/Fellowship awarding Authority/ Lectureship appointing Authority ***must verify the original record/certificates of the candidate*** regarding eligibility criterion & caste /PH/VH certificate (if applicable) for this test. The details regarding the eligibility criterion for this test is given overleaf.

This letter may be treated as a certificate.

Kindly acknowledge the receipt.

Yours sincerely,

D. Vijayalakshmi 28/02/17

Deputy Secretary (Exam)

डी. विजयलक्ष्मी / D. VIJAYALAKSHMI
उप सचिव (परीक्षा) / Deputy Secretary (Exam)
वैज्ञानिक तथा औद्योगिक अनुसंधान परिषद्
Council of Scientific & Industrial Research
सी. एस. आई. आर. कॉम्पलेक्स, पूसा, नई दिल्ली-110012
CSIR Complex, Pusa, New Delhi-110012

UNIVERSITY GRANTS COMMISSION
BAHADURSHAH ZAFAR MARG,
NEW DELHI- 110021.
SA-I SECTION

ANNEXURE-II

JOINING REPORT

JRF IN SCIENCES, HUMANITIES AND SOCIAL SCIENCES

Name of Fellow : **VISHAL MAHADEV INGLE**

Award letter number and date or UGC circular number and **Dated: 28/02/2017**

Sr.No. 2061641218. Ref.No .19/06/2016(i)EU-V

This is to certify that **VISHAL MAHADEV INGLE** has joined the Department of **MATHEMATICS in RDIK & NKD College Badnera, Amravati** for doing **Ph.D.**in the subject of **MATHEMATICS** under the above scheme of **JRF in MATHEMATICAL SCIENCE** students of University Grant Commission with effect from **01/12/2017(F.N./~~A.N.~~)**. He belongs to **O.B.C** category. He will be provided with all necessary facilities during his/her tenure of award. The terms and conditions of the offer are acceptable to the awardee.

Also certified that the Fellow shall not accept/hold any emoluments, paid or otherwise, or receive emoluments, salary, stipend etc. from any other source during the tenure of the award.

Signature of awardee:
NAME: **VISHAL MAHADEV INGLE**
Ph.No: 8605680630
MOBILE : 8605680630
E.Mail : vishalinglevmi@gmail.com
***Bank A/C NO* : 4310101007747**
IFAS CODE : CNRB0001083
MICR Code : 444015101
Aadhar NO : 254409529717

Signature:
NAME : **Dr. V.G.Mete**
GUIDE/SUPERVISOR
(SEAL)
Dr. V. G. Mete
Associate Professor & Head,
Department of Mathematics,
R.D.I.K. & K.D. College Badnera-Amravati

Signature:
NAME: **Dr. V.G.Mete**
Head of Deptt.
(SEAL **Dr. V. G. Mete**
Associate Professor & Head,
Department of Mathematics,
R.D.I.K. & K.D. College,Badnera-Amravati

01/03/18

Signature **PRINCIPAL**
NAME : **Dr. R. D. Deshmukh**
Register/Director/Principal
(Seal of university/Institution/College)
Bar. Ramrao Deshmukh Arts
Smt. Indiraji Kapadiya Commerce &
Nyaymurti Krishnarao Deshmukh
Science College, Badnera

12-digit unique (aadhaar) number, if you have:254409529717

ANNEXURE-III

UNIVERSITYGRANTSCOMMISSION
BAHADURSHAH ZAFAR MARG
NEW DELHI –110002

SA-I SECTION

CONTINUATION CERTIFICATE

JRF in Science, Humanities & Social Sciences

This is to certifythat **Mr. Vishal Mahadev Ingle**
Has continuously working the Department of **Mathematics** ,RDIK & NKD College Badnera , Amravati in the subject under the above scheme for the quarter from 01/12/2017 to 28/02/2018

Signature	Signature	Signature
Name of Awardee : Vishal M.Ingle	Name : Dr.V.G.Mete	Name : Dr. R.D.Deshmukh
Date :	Date:	Date:
	Head of the Deptt.	(Registrar /Director/Principal)

Dr. V. G. Mete
Associate Professor & Head,
Department of Mathematics,
R.D.I.K. & K.D. College,Badnera-Amravati

PRINCIPAL
Shri. Ramrao Deshmukh Arts
Smt. Indiraji Kapadiya Commerce &
Nanasaheb Kapadiya
Science College, Badnera.

H. R. A. Certificate ANNEXURE-II

Certificate No. 2

Certificate that **Mr. VISHAL MAHADEV INGLE** is staying independently and, therefore, is eligible to draw House ResentAllowanceofRs.5000 minimum admissible to a lecturer as per university rules. Form 01/12/2017 to 28/02/2018

Registrar/Director/Principal

If, as a result of a check or audit objection, some irregularity is noticed at a later stage, action will be taken to refund, adjust or regularize the objected amount.

Signature	Signature	Signature
Name of Awardee: Vishal Mahadev Ingle	**Name**: Dr.V.G.Mete	**Name**: Dr.R.D.Deshmukh
	Head of Deptt.	**Registrar/Director/Principal**
Date	Date	Date
	(seal)	(seal)

Dr. V. G. Mete
Associate Professor & Head,
Department of Mathematics,
R.D.I.K. & K.D. College,Badnera-Amravati

PRINCIPAL
Sir. Ramrao Deshmukh Arts
Smt. Indiraji Kapadiya Commerce &
Nyaymurti Krushnarao Deshmukh
Science College, Badnera.

N.B: For any correspondence in this regard, the Commission's letter number and date may please be quoted without fail.

H. R. A. Certificate ANNEXURE-II

Certificate No. 2

Certificate that **Mr. VISHAL MAHADEV INGLE** is staying independently and, therefore, is eligible to draw House Resent Allowance of Rs.5000 minimum admissible to a lecturer as per university rules. Form 01/03/2018 to 31/05/2018

Registrar/Director/Principal

If, as a result of a check or audit objection, some irregularity is noticed at a later stage, action will be taken to refund, adjust or regularize the objected amount.

Signature	Signature	Signature
Name of Awardee: Vishal Mahadev Ingle	**Name**: Dr.V.G.Mete	**Name**: Dr.R.D.Deshmukh
	Head of Deptt.	**Registrar/Director/Principal**
Date	Date	Date
	(seal)	(seal)

Dr. V. G. Mete
Associate Professor & Head,
Department of Mathematics,
R.D.I.K. & K.D. College,Badnera-Amravati

N.B: For any correspondence in this regard, the Commission's letter number and date may please be quoted without fail.

H. R. A. Certificate **ANNEXURE-II**

Certificate No. 2

Certificate that **Mr. VISHAL MAHADEV INGLE** is staying independently and, therefore, is eligible to draw House Resent Allowance of Rs.5000 minimum admissible to a lecturer as per university rules. Form 01/06/2018 to 31/08/2018.

Registrar/Director/Principal

If, as a result of a check or audit objection, some irregularity is noticed at a later stage, action will be taken to refund, adjust or regularize the objected amount.

Signature	Signature	Signature
Name of Awardee:	Name: Dr.V.G.Mete	Name: Dr.R.D.Deshmukh
Vishal Mahadev Ingle	Date:	Date:
	Head of Deptt.	**Registrar/Director/Principal**
	(seal)	**(seal of univ./institution/college)**

Dr. V. G. Mete
Associate Professor & Head,
Department of Mathematics,
R.D.I.K. & K.D. College,Badnera-Amravati

N.B: For any correspondence in this regard, the Commission's letter number and date may please be quoted without fail.

Vidarbha Youth Welfare Society's
Bar.Ramrao Deshmukh Arts, Smt. Indiraji Kapadia Commerce &
Nya. Krishnarao Deshmukh Science College,Badnera-Amravati (Maharashtra) 444 701
(Accredited by NAAC - 2004)
Ph. 0721-2681232, FAX : 0721- 2681232,
email : rdik128@sgbau.ac.in, web site : www.rdikandnkd.org

Ref.No. 585/18-19

Date : 11 / 01 /2019

Authority letter

This is to certify that **Dr.V.G.Mete,** is serving in this college from 16th March, 1992 as a Associate Professor & Head Department of Mathematics. I have given authority to handle the website **scholarship.canarabank.in** as both maker & checker for Scholarship/Fellowship purpose.

Hence certified.

Dr.R.D.Deshmukh
PRINCIPAL
Bar. Ramrao Deshmukh Arts
Smt. Indiraji Kapadiya Commerce &
Nyaymurti Krushnarao Deshmukh
Science College, Badnera

ANNEXURE-VII

UNIVERSITY GRANTS COMMISSION
SELECTION & AWARDS BUREAU BAHADURSHAH ZAFAR MARG
NEW DELHI- 110 002.

THREE MEMBER ASSESSMENT COMMITTEE REPORT FOR UPGRADATION FROM JRF TO SRF UNDER THE SCHEME OF JRF IN SCIENCES, HUMANITIES AND SOCIAL SCIENCES.

Assessment for up gradation of Mr./Mrs. Vishal Mahadev Ingle JRF working at the Department of Mathematics University /Institution /College Bar. Ramrao Deshmukh Arts, Smt. Indiraji Kapadia Commerce & Nya. Krishnarao Deshmukh Science Collage, Badnera-Amravati (Maharashtra) on completion of two years on date 1st December 2019

CONSTITUTION OF THE COMMITTEE
(Name and Designation) (ONE OUTSIDE EXPERT OF CONCERNED SUBJECT)

1. Dr. V. G. Mete (Professor and Head, Department of Mathematics RDIK and KD collage Badnera-Amravati)
2. Dr. R. D. Deshmukh (Principal RDIK and KD collage Badnera-Amravati)

3 Dr. V. B. Raut (Associate Professor and Head, Department of Mathematics Mungsaji Maharaj Mahavidyalaya Darwha-Yawatmal)

Date of Joining:	1st December 2017
Ph.D. registration No.:	SGBAU/Ph.D./Mth/728/2021 w.e.f. 01.09.2019
Date of Meeting:	04.10.2021
Time:	11.00 am.

VENUE OF ASSESSMENT/INTERVIEW: Room no. 27, Department of Mathematics, RDIK & KD College Badnera-Amravati

The committee assessed the progress of the candidate through their presentation followed by interview and recommended as follows

(Satisfactory/Good/Very Good/Excellent) (Strike out whichever is not applicable)

In view of the ~~outstanding~~/ very good/~~satisfactory~~ performance of the JRF, and also the fact that he/she has published work to his/her credit the committee makes the following recommendations.

Mr./Mrs./Ms Vishal Mahadev Ingle may be upgraded from JRF to SRF w.e.f 02/11/2020

Signature:
Date: 4.10.21
Name of the: Dr. V. G. Mete
Supervisor

Signature:
Date: 4.10.21
Name: Dr. V. G. Mete
Head of Department
(Seal)
Dr. V. G. Mete
Professor & Head
Department of Mathematics,
R.D.I.K. & K.D. College, Badnera-Amravati

Signature:
Date: 4.10.2021
Name: Dr. R. D. Deshmukh
~~Registrar~~/~~Director~~/Principal
(Seal of ~~university~~/~~Institution~~/College)
PRINCIPAL
Bar. Ramrao Deshmukh Arts
Smt. Indiraji Kapadiya Commerce &
Nyaymurti Krushnarao Deshmukh
Science College, Badnera

Signature of Subject Expert:
Date: 4.10.2021
Name of the Expert: Dr. V. B. Raut

Vidarbha Youth Welfare Society's
Bar.Ramrao Deshmukh Arts, Smt. Indiraji Kapadia Commerce &
Nya. Krishnarao Deshmukh Science College,Badnera-Amravati (Maharashtra) 444 701
(Re-accredited by NAAC with B⁺⁺ grade)
Ph. 0721-2681232, FAX : 0721- 2681232,
email : rdik128@sgbau.ac.in, website : www.rdikandnkd.org

Ref.No. RDIKKD/2021-22 Date : 25/09/2021

Certificate

This is to certify that **Dr.V.B.Raut**, Professor & Head, Department of Mathematics, Mungsaji Maharaj Mahavidyalaya, Darwaha, Dist. Yavatmal, attended a three-member assessment committee for **upgradation from JRF to SRF under the scheme of JRF** in science, Humanities and social sciences as an external subject expert to evaluate the research work of a research fellow held on 04/10/2021.

Dr.R.D.Deshmukh
PRINCIPAL
Bar. Ramrao Deshmukh Arts
Smt. Indiraji Kapadiya Commerce &
Nyaymurti Krushnarao Deshmukh
Science College, Badnera

SANT GADGE BABA AMRAVATI UNIVERSITY

Tele (O) : 0721 2668220
Email : drphdecell@sgbau.ac.in

No. SGBAU/PhD/155 /2021,
Dated : 12.04.2021

To,

Director/Principal/Head of Department/ Chairperson of RAC
Br RDIK. Mv., Badnera

This is to inform you that the Research Proposal of the students mentioned in column No.3 under the Supervisor as mentioned in column No.4 has been accepted by the Research and Recognition Committee under Section 37(2)(a)(i) of M.P.U. Act, 2016 for the Subject Mathematics Science in the Faculty of Science & Technology held on 10.04.2021

Sr No	Centre / College Code	Name of Students	Name of Supervisor	Subject/ Faculty	Topic	Registration No. & Remark
1	2	3	4	5	6	7
1	128	Ku Vishakha N Asatkar	Dr V G Mete	Mathematics/ Science & Technology	STUDY OF SOME COSMOLOGICAL PARAMETERS FOR HOLOGRAPHIC DARK ENERGY MODELS IN THEORIES OF GRAVITATION	SGBAU/Ph.D./Mth/ 727/2021 w.e.f. 01.09.2019 subject to the condition that, one revised copy of synopsis with change in title shall be submitted as per suggestions of RRC within ten days. STUDY OF SOME PHYSICAL PARAMETERS FOR HOLOGRAPHIC DARK ENERGY MODELS IN THE VARIOUS ALTERNATIVE THEORIES OF GRAVITATION
2	128	Shri Vishal M Ingle	Dr V G Mete		DYNAMICS OF ANISOTROPIC UNIVERSE IN MODIFIED THEORIES OF GRAVITATION	SGBAU/Ph.D./Mth/ 728/2021 w.e.f. 01.09.2019 subject to the condition that, one revised copy of synopsis shall be submitted as per suggestions of RRC within ten days
3	128	Ku Minakshi T Sarode	Dr V G Mete	Mathematics/ Science & Technology	STUDY OF SOME COSMOLOGICAL MODELS IN f (Q.T.) THEORY OF GRAVITY	SGBAU/Ph.D./Mth/ 748/2021 w.e.f. 01.09.2020 subject to the condition that, one revised copy of synopsis shall be submitted as per suggestions of RRC within ten days.
4	128	Ku Vrinda S Deshmukh	Dr V G Mete	Mathematics/ Science & Technology	HIGHER DIMENSIONAL STUDY OF TOPOLOGICAL DEFECTS IN THEORIES OF GRAVITATION	SGBAU/Ph.D./Mth/ 749/2021 w.e.f. 01.09.2020 subject to the condition that, one revised copy of synopsis with change in title shall be submitted as per suggestions of RRC within ten days STUDY OF TOPOLOGICAL DEFECTS IN HIGHER DIMENSIONAL THEORIES OF GRAVITATION

Your registration is subject to compliance with following conditions:

1. The provisions of the Ordinance No.01./2016 as amended by the University from time to time shall be applicable.
2. Verification of all documents of qualification/eligibility at any time during the period of registration.
3. Scholar shall have to submit the yearly progress report of research in the prescribed format through RAC. To the university on or before 31st August along with the yearly retention fee of Rs.3000/-. If the scholar fails to submit the progress report consecutively for two years the registration shall stand cancelled.
4. The duration of PhD. programme including course work shall be minimum three years to maximum six years from the date of admission. However, extension for a period of maximum one year may be granted on the recommendation of the RAC and with the approval of the RRC. Provided, the person with disability (more than 40% disability) may be allowed a relaxation up to two years.
   Provided, the lady scholar may be allowed relaxation of up to the period equal to maternity leave/ child care leave once in the entire duration of PhD. Programme.
5. The scholar shall be allowed to submit the draft Ph.D. thesis for pre-defense to the concerned Research Centre not earlier than two years from the date of registration.
6. The Ph.D. scholar shall have to submit final thesis to Research Centre through the supervisor within three months from the date of pre-defense.
7. Please read carefully the provisions of Ordinance No.1/2016 before submission of thesis.

Assistant Registrar(PhD Cell),
SBG Amravati University.

Copy to,
1) All Concerned Supervisor.
2) All Concerned Students.

Welcome! VISHAL MAHADEV INGLE | Logout

Canara Bank

University Grants Commission

Home | My Profile | Payment Schedule | Online Confirmation Marking | Submit Guide Details | Change Password | Grievance | Academic-Milestone | Help |

VISHAL MAHADEV INGLE | 427262-ACTIVE

Account/IFSC: XXXXXXXXX7747 / CNRB0001083

Benificiary Code: BININ01167853 Accepted

Guide Details: Please Submit Guide details.

Aadhaar Updation Status:

Paid Details*

DATE	DESCRIPTION	AMOUNT	TXN ID	STATUS
21/07/2018	FELLOWSHIP-	25000 C	C071810651219	SUCCESS
21/07/2018	FELLOWSHIP-	25000 C	C071810651220	SUCCESS
21/07/2018	FELLOWSHIP-	25000 C	C071810651221	SUCCESS
21/07/2018	FELLOWSHIP-	25000 C	C071810651222	SUCCESS
21/07/2018	FELLOWSHIP-	25000 C	C071810651223	SUCCESS
21/07/2018	FELLOWSHIP-	25000 C	C071810651224	SUCCESS
09/08/2018	FELLOWSHIP-	25000 C	C081804148236	SUCCESS
09/08/2018	FELLOWSHIP-	25000 C	C081804148237	SUCCESS
26/09/2018	FELLOWSHIP-	25000 C	C091800735453	SUCCESS
16/10/2018	FELLOWSHIP-	25000 C	C101800745196	SUCCESS
02/11/2018	FELLOWSHIP-	25000 C	C101818819639	SUCCESS
11/12/2018	JRF FELLOWSHIP-	25000 C	C111815744776	SUCCESS
19/03/2019	JRF FELLOWSHIP-	25000 C	C031909662268	SUCCESS
19/03/2019	CONTINGENCY-	3000 C	C031909662263	SUCCESS
19/03/2019	CONTINGENCY-	3000 C	C031909662264	SUCCESS
19/03/2019	CONTINGENCY-	3000 C	C031909662265	SUCCESS
19/03/2019	CONTINGENCY-	3000 C	C031909662266	SUCCESS
19/03/2019	JRF FELLOWSHIP-	25000 C	C031909662267	SUCCESS
08/05/2019	JRF FELLOWSHIP-MAR2019	25000 C	C041902985249	SUCCESS
08/05/2019	CONTINGENCY-MAR2019	3000 C	C041902985248	SUCCESS
07/06/2019	JRF FELLOWSHIP-FEB2019	25000 C	C051917309607	SUCCESS
25/07/2019	JRF FELLOWSHIP-MAR2019	6000 C	C061932028543	SUCCESS
25/07/2019	JRF FELLOWSHIP-FEB2019	6000 C	C061932028542	SUCCESS
25/07/2019	JRF FELLOWSHIP-JAN2019	6000 C	C061932028541	SUCCESS
06/08/2019	HRA-JUL2019	2480 C	C081901658707	SUCCESS

06/08/2019	JRF FELLOWSHIP-MAY2019	31000 C	C081901658704	SUCCESS
06/08/2019	CONTINGENCY-JUN2019	3000 C	C081901658702	SUCCESS
06/08/2019	JRF FELLOWSHIP-APR2019	31000 C	C081901658703	SUCCESS
06/08/2019	JRF FELLOWSHIP-JUL2019	31000 C	C081901658706	SUCCESS
03/09/2019	JRF FELLOWSHIP-AUG2019	31000 C	C081921978107	SUCCESS
03/09/2019	HRA-AUG2019	2480 C	C081921978108	SUCCESS
14/11/2019	HRA-	2480 C	C101924790170	SUCCESS
14/11/2019	HRA-	2480 C	C101924790172	SUCCESS
14/11/2019	HRA-	2500 C	C101924790173	SUCCESS
14/11/2019	HRA-	2500 C	C101924790174	SUCCESS
14/11/2019	HRA-	2500 C	C101924790175	SUCCESS
14/11/2019	HRA-	2480 C	C101932680510	SUCCESS
14/11/2019	HRA-	2480 C	C101924790169	SUCCESS
14/11/2019	HRA-	2480 C	C101924790168	SUCCESS
14/11/2019	HRA-	2480 C	C101924790171	SUCCESS
14/11/2019	JRF FELLOWSHIP-	31000 C	C101932679469	SUCCESS
14/11/2019	CONTINGENCY-	3000 C	C101932679468	SUCCESS
14/11/2019	HRA-	2480 C	C101932679470	SUCCESS
15/11/2019	JRF FELLOWSHIP-	31000 C	C101932683247	SUCCESS
15/11/2019	HRA-	2480 C	C101932683248	SUCCESS
14/02/2020	JRF FELLOWSHIP-	31000 C	C012030243174	SUCCESS
14/02/2020	HRA-	2480 C	C012029905038	SUCCESS
14/02/2020	JRF FELLOWSHIP-	31000 C	C012029905037	SUCCESS
14/02/2020	HRA-	2480 C	C012030243175	SUCCESS
14/02/2020	CONTINGENCY-	3000 C	C012029915096	SUCCESS
14/02/2020	JRF FELLOWSHIP-	31000 C	C012029915097	SUCCESS
14/02/2020	HRA-	2480 C	C012029915098	SUCCESS
24/04/2020	JRF FELLOWSHIP-APR2020	31000 C	C042025186165	SUCCESS
24/04/2020	HRA-APR2020	2480 C	C042025186166	SUCCESS
01/06/2020	HRA-MAY2020	2480 C	C052013564531	SUCCESS
01/06/2020	JRF FELLOWSHIP-MAY2020	31000 C	C052013564530	SUCCESS
14/07/2020	JRF FELLOWSHIP-JUN2020	31000 C	C062034505484	SUCCESS
14/07/2020	HRA-JUN2020	2480 C	C062034505485	SUCCESS
29/08/2020	JRF FELLOWSHIP-JUL2020	31000 C	C072019598645	SUCCESS
29/08/2020	HRA-JUL2020	2480 C	C072019598646	SUCCESS
12/11/2020	JRF FELLOWSHIP-	31000 C	C092040771957	SUCCESS
12/11/2020	HRA-	2480 C	C092040771958	SUCCESS
12/11/2020	JRF FELLOWSHIP-	31000 C	C082016968062	SUCCESS
12/11/2020	HRA-	2480 C	C082016968063	SUCCESS
07/12/2020	JRF FELLOWSHIP-	31000 C	C122008617342	SUCCESS
07/12/2020	HRA-	2480 C	C122008617343	SUCCESS
07/01/2021	HRA-	2480 C	C012100872826	SUCCESS
07/01/2021	JRF FELLOWSHIP-	31000 C	C012100872825	SUCCESS
15/01/2021	JRF FELLOWSHIP-	31000 C	C012114127101	SUCCESS

15/01/2021	CONTINGENCY-	3000 C	C012114127099	SUCCESS
15/01/2021	CONTINGENCY-	3000 C	C012114127100	SUCCESS
15/01/2021	JRF FELLOWSHIP-	31000 C	C012114127102	SUCCESS
15/01/2021	HRA-	2480 C	C012114127103	SUCCESS
15/01/2021	HRA-	2480 C	C012114127104	SUCCESS
12/10/2021	JRF FELLOWSHIP-	31000 C	C102115809992	SUCCESS
12/10/2021	CONTINGENCY-	3000 C	C102115809991	SUCCESS
12/10/2021	HRA-	2480 C	C102115809993	SUCCESS
04/11/2021	CONTINGENCY-	3250 C	C112104428157	SUCCESS
04/11/2021	SRF FELLOWSHIP-	3866 C	C112104428158	SUCCESS
04/11/2021	SRF FELLOWSHIP-	4000 C	C112104428159	SUCCESS
04/11/2021	SRF FELLOWSHIP-	35000 C	C112104428160	SUCCESS
04/11/2021	SRF FELLOWSHIP-	35000 C	C112104428161	SUCCESS
04/11/2021	SRF FELLOWSHIP-	35000 C	C112104428162	SUCCESS
04/11/2021	SRF FELLOWSHIP-	35000 C	C112104428163	SUCCESS
04/11/2021	SRF FELLOWSHIP-	35000 C	C112104428164	SUCCESS
04/11/2021	SRF FELLOWSHIP-	35000 C	C112104428165	SUCCESS
04/11/2021	HRA-	20 C	C112104428181	SUCCESS
04/11/2021	SRF FELLOWSHIP-	35000 C	C112104428167	SUCCESS
04/11/2021	SRF FELLOWSHIP-	35000 C	C112104428168	SUCCESS
04/11/2021	SRF FELLOWSHIP-	35000 C	C112104428169	SUCCESS
04/11/2021	HRA-	2500 C	C112104428173	SUCCESS
04/11/2021	HRA-	2500 C	C112104428170	SUCCESS
04/11/2021	HRA-	2500 C	C112104428171	SUCCESS
04/11/2021	HRA-	2500 C	C112104428172	SUCCESS
04/11/2021	HRA-	2500 C	C112104428174	SUCCESS
04/11/2021	HRA-	2500 C	C112104428175	SUCCESS
04/11/2021	HRA-	2500 C	C112104428176	SUCCESS
04/11/2021	HRA-	2500 C	C112104428177	SUCCESS
04/11/2021	HRA-	2500 C	C112104428178	SUCCESS
04/11/2021	HRA-	2500 C	C112104428179	SUCCESS
04/11/2021	HRA-	20 C	C112104428180	SUCCESS
04/11/2021	CONTINGENCY-	6250 C	C112104428155	SUCCESS
04/11/2021	CONTINGENCY-	6250 C	C112104428154	SUCCESS
04/11/2021	CONTINGENCY-	6250 C	C112104428156	SUCCESS
04/11/2021	SRF FELLOWSHIP-	35000 C	C112104428166	SUCCESS

Important Messages

Disclaimer: The above details are provided only for the General information of the concerned. The amount which is due will be credited to the respective accounts only after the files are Digitally Signed by UGC through PFMS(M/o Finance).

Designed and Developed By - Canara Bank

खाता सं A/c No. 4310101007747

तारीख Date	विवरण Particulars	चेक संख्या Ch No.	निकासी Withdrawals	जमाराशियाँ Deposits	शेष Balance	आद्याक्षर Initials
04/03/2022	TD Initial Payin FD14 [illegible]10610 /1 VISH AL INGLE TD Initial P ayin FD	33095382	200000.00		120575.40	
	AL INGLE TD Initial P ayin FD					
	Balance B/F				120575.40	
05/03/2022	IB-IMPS-DR//SBIN/**78 03//05/03/2022 23:24: 40	23356147	10000.00		120575.40 110575.40	
05/03/2022	ATM Txn done in other bank ATM / IMPS Char ges	23356147	5.90		110569.50	
06/03/2022	IB-IMPS-DR//SBIN/**78 03//06/03/2022 17:25: 18	17468864	50000.00		60569.50	
06/03/2022	ATM Txn done in other bank ATM / IMPS Char ges	17468864	11.80		60557.70	
20/03/2022	SMS ALERT CHARGES NEW		18.00		60539.70	
01/05/2022	SBINT FOR THE PERIOD FROM01-FEB-22 TO 30-A PR-22			1571.00	62110.70	
02/05/2022	ATM Cash-MNS8029-KAML ESHKUMARKANTILALNANDU RAMHIN-02/05/22 10:25 :54/9268	10305580	4000.00		58110.70	
18/05/2022	ATM Cash-MNS8029-KAML ESHKUMARKANTILALNANDU RAMHIN-18/05/22 21:51 :33/9268	21305635	3000.00		55110.70	
20/05/2022	ECS 24235900122FC0522 35	42022052		35000.00	90110.70	
20/05/2022	ECS 24235900122HC0522	42022052		2500.00	92610.70	
20/05/2022	ECS 24235900222FC0522	42022052		35000.00	127610.70	

खाता सं A/c No. 4310101007747

तारीख Date	विवरण Particulars	चेक संख्या Ch No.	निकासी Withdrawals	जमाराशियाँ Deposits	शेष Balance	आद्याक्षर Initials
20/05/2022	ECS 24235900222HC0522 35	42022052		2500.00	130110.70	
	Balance B/F				130110.70	
20/05/2022	ECS 24235901121FC0522 35	42022052		35000.00	165110.70	
20/05/2022	ECS 24235901121HC0522 35	42022052		2500.00	167610.70	
20/05/2022	ECS 24235901221CC0522 35	42022052		6250.00	173860.70	
20/05/2022	ECS 24235901221FC0522 35	42022052		35000.00	208860.70	
20/05/2022	ECS 24235901221HC0522 35	42022052		2500.00	211360.70	
26/05/2022	ATM Cash-MNS8029-KAML ESHKUMARKANTILALNANDU RAMHIN-26/05/22 20:23 :06/9268	20305638	4000.00		207360.70	
19/06/2022	SMS ALERT CHARGES NEW		18.00		207342.70	
16/07/2022	MB-IMPS-DR/VISHAL MAH ADEO/SBIN/**7803/tran sfr/16/07/2022 18: 39:47	13271966	100000.00		107342.70	
16/07/2022	ATM Txn done in other bank ATM / IMPS Char ges	13271966	9.44		107333.26	
17/07/2022	MB-IMPS-DR/VISHAL MAH ADEO/SBIN/**7803/Tran sfer/17/07/2022 18: 23:23	18505798	30000.00		77333.26	
17/07/2022	ATM Txn done in other bank ATM / IMPS Char ges	18505798	9.44		77323.82	
31/07/2022	SBINT FOR THE PERIOD [illegible] UL-22			1132.00	78455.82	
					78455.82	

खाता सं A/c No.

क्रम सं. Sl. No.	तारीख Date	विवरण Particulars	चेक संख्या Ch No.	निकासी Withdrawals	जमाराशियाँ Deposits	शेष Balance	आद्याक्षर Initials
01							
02		4310101007747					
03							
04		Balance B/F				78455.82	
05	01/08/2022	DEBIT CARD ANNUAL CHA		148.00		78307.82	
06		RGES XXXXXXXXXXXX9268					
07	24/09/2022	SMS ALERT CHARGES NEW		18.00		78289.82	
08	12/10/2022	ECS 31570080522FC1022	92022101		35000.00	113289.82	
09		16					
10	12/10/2022	ECS 31570080522HC1022	92022101		2500.00	115789.82	
11		16					
12	12/10/2022	ECS 31570080622CC1022	92022101		6250.00	122039.82	
13		16					
14	12/10/2022	ECS 31570080322CC1022	92022101		6250.00	128289.82	
15		16					
16	12/10/2022	ECS 31570080322FC1022	92022101		35000.00	163289.82	
		16					
	12/10/2022	ECS 31570080322HC1022	92022101		2500.00	165789.82	
17							
18		16					
19	12/10/2022	ECS 31570080422FC1022	92022101		35000.00	200789.82	
20		16					
21	12/10/2022	ECS 31570080422HC1022	92022101		2500.00	203289.82	
22		16					
23	12/10/2022	ECS 31570080622FC1022	92022101		35000.00	238289.82	
24		16					
25	12/10/2022	ECS 31570080622HC1022	92022101		2500.00	240789.82	
26		16					
27	01/11/2022	SBINT FOR THE PERIOD					
28		FROM01-AUG-22 TO 31-O			831.00	241620.82	
29		CT-22					
30	04/11/2022	ECS 33480820722FC1122	18202211		35000.00	276620.82	
31	04/11/2022	ECS 33480820722HC1122	18202211		2500.00	279120.82	
32							
33							
34							
35							

00

खाता सं A/c No.

क्रम सं. Sl. No.	तारीख Date	विवरण Particulars	चेक संख्या Ch No.	निकासी Withdrawals	जमाराशियाँ Deposits	शेष Balance	आद्याक्षर Initials
						314120.82	
01							
02							
03		4310101007747					
04							
05		Balance B/F				314120.82	
06	04/11/2022	ECS 33480820822HC1122	18202211		2500.00	316620.82	
		00					
07	04/11/2022	ECS 33480820922CC1122	18202211		6250.00	322870.82	
08		00					
09	04/11/2022	ECS 33480820922FC1122	18202211		35000.00	357870.82	
10		00					
11	04/11/2022	ECS 33480820922HC1122	18202211		2500.00	360370.82	
12		00					
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
28							
29							
30							
31							
32							
33							
34							
35							

STATEMENT OF ACCOUNT

CANARA BANK
Account Branch : 1083-AMRAVATI 444601 DATE: 30-09-23 15:20:35 PM
IFSC : CNRB0001083
MICR : 444015101

Account No : 4310101007747
Product Name : CANARA SB GENERAL
Customer ID : 113184797
Customer Name : Mr VISHAL INGLE
Address : NANDURA
DIST BULDHANA

NANDURA
MAHARASHTRA
IN
443404
Nominee Reference num : 108300007758
Nominee Name : not given
Account Title : VISHAL INGLE
Joint Holder's/Authorised Person's Name :

Period : 01-12-2022 To 30-11-2023
Name Currency : INDIAN RUPEES
Swift code: CNRBINBBBFD

TRANS DATE	VALUE DATE	BRANCH	REF/CHQ.NO	DESCRIPTION	WITHDRAWS	DEPOSIT	BALANCE
01-DEC-22	01-DEC-22	0		B/F ...	0.00	360,370.82	360,370.82
31-JAN-23	31-JAN-23	1083		SBINT FOR THE PERIOD FROM01-NOV-22 TO 31-JAN-23	0.00	2,606.00	362,976.82
02-FEB-23	02-FEB-23	611		TD INITIAL PAYIN FD140082400944 /1 VISHAL INGLE TD INITIAL PAYIN FD	200,000.00	0.00	162,976.82
02-FEB-23	02-FEB-23	33	303312195068	MB-IMPS-DR/VISHAL MAHADEO/SBIN/**7803 /TO SELF/02/02/2023 12:34:28	1,000.00	0.00	161,976.82
26-MAR-23	26-MAR-23	1083		SMS CHARGES ON ACTUAL BASIS	1.00	0.00	161,975.82
30-MAR-23	30-MAR-23	1083	000000000000	ECS 53898621022FC032383	0.00	35,000.00	196,975.82
30-MAR-23	30-MAR-23	1083	000000000000	ECS 53898621022HC032383	0.00	2,500.00	199,475.82
30-MAR-23	30-MAR-23	1083	000000000000	ECS 53898621122FC032383	0.00	35,000.00	234,475.82
30-MAR-23	30-MAR-23	1083	000000000000	ECS 53898621122HC032383	0.00	2,500.00	236,975.82
30-APR-23	30-APR-23	1083		SBINT FOR THE PERIOD FROM01-FEB-23 TO 30-APR-23	0.00	1,352.00	238,327.82
12-JUL-23	12-JUL-23	1083		MB NEFT DR P193230253722100 VISHAL MAHADEO INGLE SBIN0002166 32402857803 TO SELF	20,000.00	0.00	218,327.82
12-JUL-23	12-JUL-23	1083		MB NEFT DR P193230253726638 VISHAL MAHADEO INGLE SBIN0002166 32402857803 NULL	1.00	0.00	218,326.82
14-JUL-23	14-JUL-23	33	319509027671	ATM CASH-S1AWBA02-NANDURABRANCHBU	3,000.00	0.00	215,326.82

TRANS DATE	VALUE DATE	BRANCH	REF/CHQ.NO	DESCRIPTION	WITHDRAWS	DEPOSIT	BALANCE
				LDHANAMHIN-14/07/23 09:52:50/8179			
31-JUL-23	31-JUL-23	1083		SBINT FOR THE PERIOD FROM01-MAY-23 TO 31-JUL-23	0.00	1,706.00	217,032.82
23-SEP-23	23-SEP-23	1083		SMS CHARGES ON ACTUAL BASIS	1.00	0.00	217,031.82

Statement Summary :

Opening Balance	Total Debit Amount	Total Credit Amount	Debit Count	Credit Count	Closing Balance	Unclear Balance	Sweep-in Balance as on 30-09-23 15:20:35 PM
360,370.82	224,003.00	80,664.00	7	7	217,031.82	0.00	0.00

UNLESS THE CONSTITUENT BRINGS TO THE NOTICE OF THE BANK ANY DISCREPANCIES / OMMISSION/ ERRORS/ UNAUTHORISED DEBITS IMMEDIATELY,
THE ENTRIES IN SUCH PASS SHEET SHALL BE DEEMED AS CORRECT AND SHALL BIND THE CONSTITUENT FOR ALL PURPOSE AND INTENTS .
BEWARE OF PHISHING ATTACKS THROUGH EMAILS AND FAKE WEBSITES.

IMB FACILITY USERS ARE REQUESTED TO NOTE THAT CANARA BANK DOES NOT SEEK ANY INFORMATION THROUGH EMAIL. DO NOT CLICK ON ANY LINK
WHICH HAS COME THROUGH EMAIL FROM UNEXPECTED SOURCES. IT MAY CONTAIN MALICIOUS CODE OR COULD BE AN ATTEMPT TO "PHISH".
ALWAYS LOGIN THROUGH WWW.CANARABANK.IN . PLEASE BEWARE OF PHISHING.
CHANGE IN THE ADDRESS OF ACCOUNT HOLDER/PA HOLDER , IF ANY, MAY PLEASE BE INFORMED TO THE BRANCH ALONG WITH ADDRESS PROOF.

"DO NOT SHARE ATM PIN NUMBER, ACCOUNT DETAILS, OTP TO OUTSIDERS, EMAILS ETC"

Fort Glacis

Details of Ombudsman : Centralized Receipt and Processing Centre (CRPC)
Office of Banking Ombudsman
Reserve Bank of India
4th Floor,Central Vista,Sector-17
CHANDIGARH
160017
Tel: 14448 / Fax:
E-mail: https://cms.rbi.org.in

ARE YOU A MERCHANT/ TRADER / RETAILER / SMALL VENDOR . USE DIGITAL PAYMENT CHANNEL TO RECEIVE PAYMENTS FROM YOUR CUSTOMERS. CONTACT MANAGER FOR MORE DETAILS. GO CASHLESS / CARDLESS.
COMPUTER OUTPUT DOES NOT REQUIRE SIGNATURE.

******END OF STATEMENT******

S. P. M. Science & Gilani Arts, Commerce College

Ghatanji, Dist. Yavatmal, Maharashtra 445301-India

(Affiliated to Sant Gadge Baba Amravati University, Amravati)

Organized

International Conference on Multi-disciplinary Research & Studies

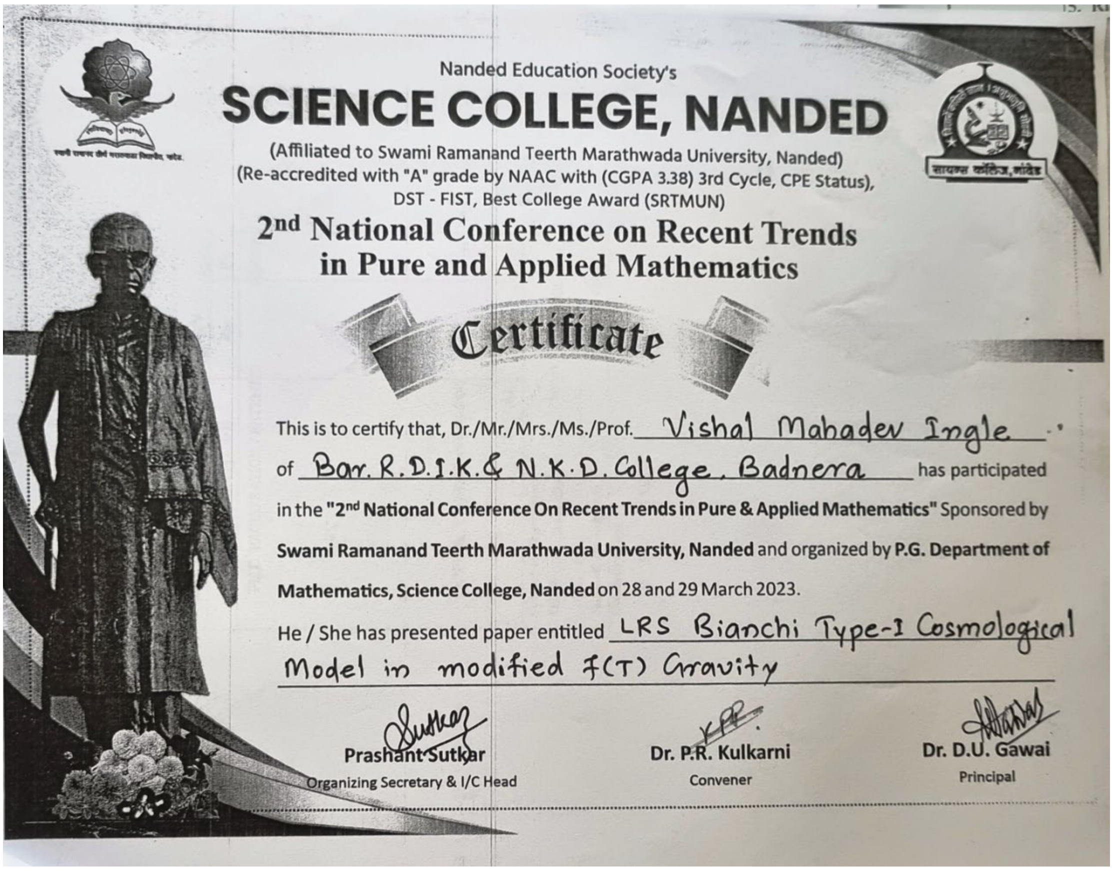
Certificate

This is to certify that,
Prof./Dr./Mr./Mrs./Ms. Vishal Mahadev Ingle
of R.D.I.K. & K.D. college, Badnera has actively participated / presented / published a research paper / article entitled Dynamics of Anisotropic Universe in Modified f(R,T) gravity in the International Conference on Multi-disciplinary Research & Studies (ICMRS23) on 21St January 2023.

Dr. Tushar M. Kotak
Convenor

Vivek K. Jagtap
Organizing Secretary

Dr. M. A. Shahezad
Principal / Chief Organizer



Nanded Education Society's

SCIENCE COLLEGE, NANDED

(Affiliated to Swami Ramanand Teerth Marathwada University, Nanded)
(Re-accredited with "A" grade by NAAC with (CGPA 3.38) 3rd Cycle, CPE Status),
DST - FIST, Best College Award (SRTMUN)

2nd National Conference on Recent Trends in Pure and Applied Mathematics

Certificate

This is to certify that, Dr./Mr./Mrs./Ms./Prof. Vishal Mahadev Ingle
of Bar. R.D.I.K. & N.K.D. College, Badnera has participated in the "2nd National Conference On Recent Trends in Pure & Applied Mathematics" Sponsored by Swami Ramanand Teerth Marathwada University, Nanded and organized by P.G. Department of Mathematics, Science College, Nanded on 28 and 29 March 2023.

He / She has presented paper entitled LRS Bianchi Type-I Cosmological Model in modified f(T) Gravity

Prashant Sutkar
Organizing Secretary & I/C Head

Dr. P.R. Kulkarni
Convener

Dr. D.U. Gawai
Principal

Sant Gadge Baba Amravati University, Amravati

NAAC Re- accredited with 'B++' grade

UNIVERSITY LEVEL WORKSHOP ON RESEARCH IN MATHEMATICS

CERTIFICATE

This is to certify that Prof./Dr./Mr./Ms. Vishal M. Ingle

of R.D.I.K & K.D College, Badnera.

has actively participated in University Level Workshop on Research in Mathematics, organized by the Department of Mathematics and IQAC, Sant Gadage Baba Amravati University, Amravati in collaboration with Department of Mathematics, R.D.I.K. & K. D. College Badnera ;Adarsh Science, J.B. Arts & Birla Commerce Mahavidyalaya, Dhamangaon (Rly.) and Shri. Dr. R.G Rathod Arts & Science College, Murtizapur, held on August 06, 2022.

He/ She has delivered a Lecture on ________

Dr. P.A. Pawar
Associate Professor & I/c Head Department of Mathematics
Sant Gadge Baba, Amravati Univeristy, Amt.

Dr. T.R. Deshmukh
Registrar
Sant Gadge Baba Amravati University, Amravati.

Yavatmal Zilla Akhil Kunbi Samaj Dwara Sanchalit

GOPIKABAI SITARAM GAWANDE MAHAVIDYALAYA UMARKHED

DIST. YAVATMAL

Re-accredited by NAAC with Grade B++ (CGPA 2.79, Third Cycle)

Organized National Conference

on

Recent Advances In Science And Technology

(RAISAT-2019)

5^{th} and 6^{th} March, 2019

Certificate

This is to certify that Prof / Dr / Mr / Mrs / Miss **V. M. Ingle**

Of R D I K and K D College Badnera *has actively participated in the conference held on 5^{th} and 6^{th} March, 2019 and chaired the session / worked on the panel of the session / has presented the research paper (oral / poster) in the subject* Mathematics *entitled* Plane Symmetric Universe Filled with Electromagnetic Filed in)(Rf Theory of Gravity"

during technical session of the conference.

Dr. S. R. Vadrabade
Convener

Dr. M. N. Gaikwad
Principal & Organizer

Article

LRS Bianchi Type-I Cosmological Model in Modified *f*(*R*, *T*)

V. G. Mete[*1], V. M. Ingle[1] & A.T. Valkunde[2]

[1]Department of Mathematics, R.D.I.K.& K.D. College, Badnera, India
[2]Department of Science, Government Polytechnic, Khamgaon, India

Abstract

In this paper, we have studied LRS Bianchi type-I cosmological model for $f(R,T)$ gravity. In order to present simplest mode of evolution, here we discussed in the background of a generic viable non-minimally coupled $f(R,T)=\alpha_1 R^m T^n+\alpha_2 T(1+\alpha_3 T^p R^q)$ gravity model. Here we used the case $f(R,T)=R+\alpha_2 T$. The exact solution of the field equations in respect of LRS Bianchi type-I space time filled with perfect fluid in frame work of $f(R,T)$ gravity are derived. The physical and kinematical behaviors of the model are also studied.

Keywords: LRS Bianchi type-I, perfect fluid, *f(R,T)*, modified gravity.

1. Introduction

Currently, observational experiments show that the Universe is undergoing an accelerated expansion [1-10]. The "dark energy" (DE) which makes a negative pressure and thus gives rise to the accelerated expansion of the Universe. The Wilkinson Microwave Anisotropy Probe (WMAP) satellite experiment suggests that 73% content of the Universe is in the form of dark energy, 23% is in the form of non-baryonic dark matter and rest 4% is in the form of usual baryonic (normal) matter as well as radiation Cosmologists have proposed many candidates for dark energy to fit the current observations such as cosmological constant, Tachyon, quintessence, phantom and so on. There are two major approaches to tackle this problem of cosmic acceleration either by introducing a dark energy component in the Universe and study its dynamics or by interpreting it as a failure of general relativity and consider modifying Einstein's theory of gravitation termed as modified gravity approach.

Modified theories of gravitation are used to explain the mysterious nature of dark energy. The modification of Einstein-Hilbert action may be the correct approach to explain the evolution of the universe. Noteworthy amongst them are f(R) modified theory of gravity formulated by Nojiri and Odintsov [11]. Recently, Harko et al. [12] developed f (R, T) modified theory of gravity,

*Correspondence: V. M. Ingle, Department of Mathematics, R.D.I.K.& K.D. College ,Badnera- 444701, India.
E-mail: vishalinglevmi@gmail.com

where the gravitational Lagrangian is given by an arbitrary function of the Ricci scalar R and of the trace T of the stress-energy tensor. They have obtained the gravitational field equations in the metric formalism, as well as, the equations of motion for test particles, which follow from the covariant divergence of the stress-energy tensor.

Now by considering the metric-dependent Lagrangian density L_m, the corresponding field equation for $f(R,T)$ gravity is obtained from the Hilbert–Einstein variation principle in the following manner. The action for $f(R,T)$ theory of gravity is

$$S=\int\sqrt{-g}\left(\frac{1}{16\pi G}f(R,T)+L_m\right)d^4x, \tag{1}$$

where L_m is the usual matter Lagrangian density of matter source, $f(R,T)$ is an arbitrary function of Ricci scalar R and the trace T of the energy–momentum tensor T_{ij} of the matter source, and g is the determinant of the metric tensor g_{ij} . The energy–momentum tensor T_{ij} from Lagrangian matter is defined in the form

$$T_{ij}=-\frac{2}{\sqrt{-g}}\frac{\delta(\sqrt{-g}L_m}{\delta g^{\mu\nu}}, \tag{2}$$

and its trace is $T=g^{ij}T_{ij}$.Here, we have assumed that the matter Lagrangian L_m depends only on the metric tensor component g_{ij} rather than its derivatives. Hence, we obtain

$$T_{ij}=g_{ij}L_m-\frac{\partial L_m}{\partial g^{ij}}. \tag{3}$$

The *f(R, T)* gravity field equations are obtained by varying the action S with respect to metric tensor ($g_{\mu\nu}$).

$$f_R(R,T)R_{ij}-\frac{1}{2}f(R,T)g_{ij}+[g_{ij}\nabla^i\nabla_i-\nabla_i\nabla_j]f_R(R,T)=8\pi T_{ij}-f_T(R,T)T_{ij}-f_T(R,T)\theta_{ij}, \tag{4}$$

where

$$f_R=\frac{\delta f(R,T)}{\delta R},f_T=\frac{\delta f(R,T)}{\delta T},\Theta_{ij}=g^{\alpha\beta}\frac{\delta T_{\alpha\beta}}{\delta g^{ij}}.$$

Here ∇ is the covariant derivative and T_{ij} is usual matter energy-momentum tensor derived from the Lagrangian L_m.It is mentioned here that these field equations depend on the physical nature of the matter field. Many theoretical models corresponding to different matter contributions for *f(R, T)* gravity are possible; However, Harko et al.[12] gave three classes of these models

$$f(R,T)=\begin{cases}R+2f(T),\\ f_1(R)+f_2(T),\\ f_1(R)+f_2(R)f_3(T)\end{cases} \tag{5}$$

The individual field equation for $f(R,T)$ gravity is given as

1. $f(R,T)=R+2f(T)$.

$$R_{ij}-\frac{1}{2}Rg_{ij}=8\pi T_{ij}-2f'(T)T_{ij}-2f'(T)\theta_{ij}+f(T)g_{ij} \tag{6}$$

2. $f(R,T)=f_1(R)+f_2(T)$.

$$f_1'(R)R_{ij}-\frac{1}{2}f_1(R)g_{ij}+[g_{ij}\nabla^i\nabla_i-\nabla_i\nabla_j]f_1'(R)=8\pi T_{ij}-f_2'(T)T_{ij}-f_2'(T)\theta_{ij}+\frac{1}{2}f_2(T)g_{ij}. \tag{7}$$

If $L_m=p$ then $\theta_{ij}=-2T_{ij}-pg_{ij}$. (8)

We can see that the result depends on the choice of *f (R, T)* model. So we need to choose a viable *f(R,T)* model in order to represent our results in a meaningful way. The $f(R,T)$ model which we have selected for discussion by Sharif and Zubair [13]

$$f(R,T)=\alpha_1R^mT^n+\alpha_2T(1+\alpha_3T^pR^q) \tag{9}$$

where $\alpha_i' s$ are positive real numbers , whereas *m, n, p, q* assumes some value greater than or equal to 1. We will analyze our results considering different cases of above mentioned model and we will precede our further discussion under following three cases

1. $f(R,T)=R+\alpha_2T$ for $\alpha_1=1,\ m=1, n=0,\ \alpha_3=0$ (10)

2. $f(R,T)=\alpha_1R+\alpha_2T+\alpha_4T^2$ for $m=1,n=0,\ \alpha_4=\alpha_1\alpha_3, p=1, q=0$ (11)

3. $f(R,T)=\alpha_1R+\alpha_2T(1+\alpha_3T\ \ R^2)$ (12)

Using equations (6), (7) and (8) along with equations (10), (11) and (12) , we have

Model-I: $f(R,T)=R+\alpha_2T$ for $\alpha_1=1,\ m=1, n=0,\ \alpha_3=0$

$$R_{ij} - \frac{1}{2} R g_{ij} = [8\pi + \alpha_2] T_{ij} + \left[p\alpha_2 + \frac{1}{2}\alpha_2 T \right] g_{ij} \quad . \tag{13}$$

This theory of gravity has attracted a lot of research interest in recent times [14-19]. Sahoo and his collaborators have extensively investigated different aspects of this modified gravity theory and have reconstructed some $f(R,T)$ cosmological models for anisotropic universes [20-25]. Houndjo [26] have investigated the cosmological reconstruction in the $f(R,T)$ modified theory of gravitation. Reconstruction of cosmological models in the $f(R,T)$ theory of gravitation is also studied by Jamil et al. [27]. $f(R,T)$ gravity has been extensively studied in the literature by several eminent researchers [28-47].

Motivated by the above work, the present paper aims to study dynamics of LRS Bianchi type I cosmological model in $f(R,T)$ theory of gravitation.

2. Metric, Field Equations and Solutions

Bianchi type cosmological models are important in the sense that these are homogeneous and anisotropic, from which the process of isotropization of the universe is studied through the passage of time. Moreover, from the theoretical point of view anisotropic universe has a greater generality than isotropic models. The simplicity of the field equations and relative ease of solutions made Bianchi space times useful in constructing models of spatially homogeneous and anisotropic cosmologies.

The LRS Bianchi type-I line element is

$$ds^2 = -dt^2 + A^2 dx^2 + B^2 (dy^2 + dz^2), \tag{14}$$

where A and B are the scale factors and function of cosmic time t only [48-49]. We have assumed the stress energy tensor of matter as

$$T_{ij} = (p + \rho) u_i u_j + p g_{ij}, \tag{15}$$

where $u_i = (0,0,0,1)$ is the four-velocity vector in co-moving coordinate system satisfying $u_i u_j = -1$.

2.1 Model: $f(R,T) = R + \alpha_2 T$ for $\alpha_1 = 1,\ m = 1, n = 0,\ \alpha_3 = 0$.

Using equations (10), (13) and (14), the field equations are obtained as

$$\frac{2\ddot{B}}{B} + \frac{\dot{B}^2}{B^2} = [8\pi + \frac{7}{2}\alpha_2]p - \frac{1}{2}\alpha_2 \rho \ , \tag{16}$$

$$\frac{\ddot{A}}{A} + \frac{\ddot{B}}{B} + \frac{\dot{A}\dot{B}}{AB} = [8\pi + \frac{7}{2}\alpha_2]p - \frac{1}{2}\alpha_2 \rho , \tag{17}$$

$$\frac{2\dot{A}\dot{B}}{AB} + \frac{\dot{B}^2}{B^2} = \frac{5}{2}\alpha_2 p - [8\pi + \frac{3}{2}\alpha_2]\rho , \tag{18}$$

where dot represents derivatives with respect to time. The deceleration parameter is defined as

$$q = -\frac{a\ddot{a}}{\dot{a}^2} \ , \tag{19}$$

where a is the average scale factor. We have three equation's (16)-(18) involving four parameters as *A, B, p,* ρ.In order to solve these equations, we assume the time varying deceleration parameter as $q = -1 + \frac{\beta}{1 + a^{\beta}}$, where $\beta > 0$ is a constant. Bearing in mind the relation between scale factor and redshift, we have $a(t) = \frac{1}{(1+z)}$, which yields $q = \frac{\beta}{\left(\frac{1}{z+1}\right)^{\beta} + 1} - 1$

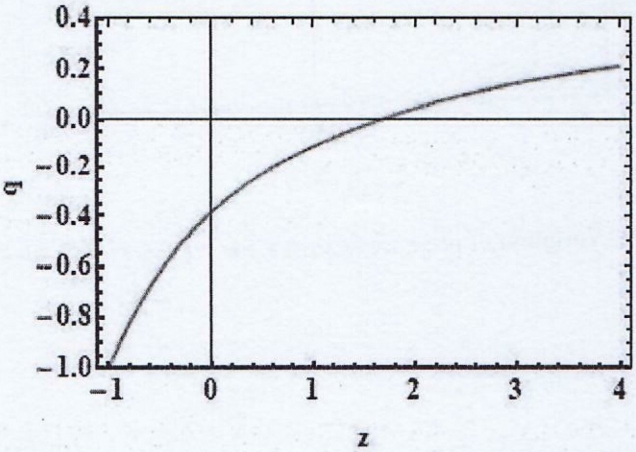


Fig. 1. Variation of q against z for $\beta = 1$.

We can see good agreement with recent observations where $t \to \infty$. Also, in our model, $q = -0.5$ as $z = 0$ while the current value of q is expected to be around -0.55 [50]as depicted in figure 1.

The scale factor and metric potentials are expressed as

$$a=\left[e^{\beta t}-1\right]^{1/\beta} \tag{20}$$

$$A=\left[e^{\beta t}-1\right]^{2/\beta}\ ,\ B=\left[e^{\beta t}-1\right]^{1/2\beta} \tag{21}$$

The energy density is obtained as

$$\rho=\frac{-[18\pi+6\alpha_2]-[18\pi+\frac{5}{2}\beta\alpha_2+6\alpha_2][2(1+z)^{3\beta}+(1+z)^{2\beta}]+\frac{5}{2}\beta\alpha_2[(1+z)^{\beta}]}{4[16\pi^2+10\pi\alpha_2+\alpha_2{}^2]}. \tag{22}$$

The pressure is found to be

$$p=\frac{6\pi+[6\pi-8\pi\beta-\frac{3}{2}\alpha_2\beta][2(1+z)^{3\beta}+(1+z)^{2\beta}]+[8\pi+\frac{3}{2}\alpha_2]\beta[(1+z)^{\beta}]}{4[16\pi^2+10\pi\alpha_2+\alpha_2{}^2]}. \tag{23}$$

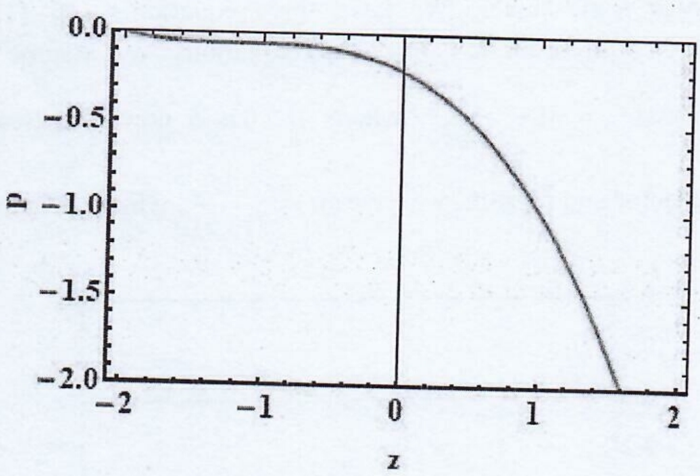


Fig. 2. Variation of pressure against **z** for $\alpha_2=-15$ and $\beta=1$

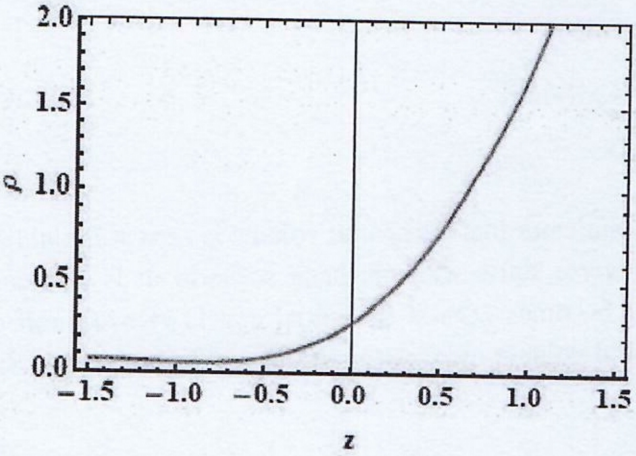


Fig. 3. Variation of energy density against **z** for $\alpha_2 = -15$ and $\beta = 1$.

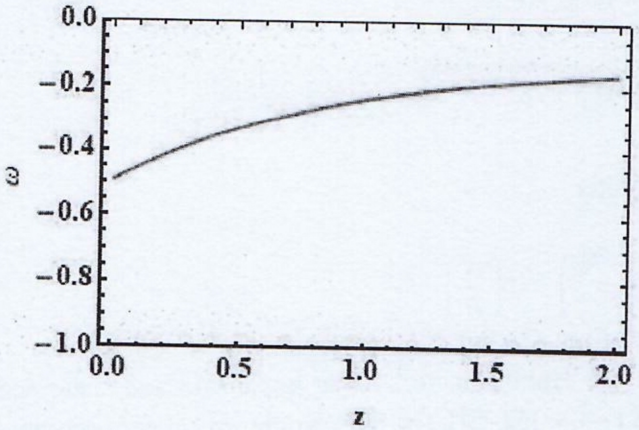


Fig. 4. Variation of EoS parameter against z for $\alpha_2 = -15$ and $\beta = 1$.

It is clear from Fig. 2 that the energy density of the Universe is an increasing function of redshift (z) and tends to a constant value in the future (i.e. $z \to -1$). For pressure (see Fig. 3), it is a decreasing function of redshift (z) and takes negative values throughout cosmic evolution. At the beginning of time it starts with very large negative values and later it approaches zero. The negative pressure is evidence of an accelerating phase of the Universe as shown by recent observations, and thus the validity of our model. The value of the EoS parameter for dark energy, or what is called in modified theories of gravity by cosmic acceleration, is negative. From this figure 4, we see that the behavior of the EoS parameter is similar to the quintessence model i.e. $-1 < \omega < -1/3$.

3. Physical properties

The spatial volume is given by

$$V = a^3 = AB^2 \tag{24}$$

The above equation indicates that the spatial volume is zero at initial time t = 0. It shows that the evolution of our universe starts with big bang scenario. It is further noted that from (24) the average scale factor becomes zero at the initial epoch. Hence, both models have a point-type singularity. The spatial volume increases with time. The Hubble's parameter *H*, expansion scalar and shear scalar are

$$H = \frac{1}{3}(H_x + H_y + H_z) = \frac{e^{\beta t}}{\left[e^{\beta t} - 1\right]} \tag{25}$$

$$\theta = 3H = 3e^{\beta t}\frac{1}{[e^{\beta t} - 1]} \tag{26}$$

$$\sigma^2 = \frac{1}{2}\left(H_x^2 + H_y^2 + H_z^2 - \frac{\theta^2}{3}\right) = \frac{3}{4}e^{2\beta t}\frac{1}{[e^{\beta t} - 1]^2} \tag{27}$$

The anisotropy parameter

$$\Delta = \frac{1}{3}\sum_{x=1}^{3}\left(\frac{H_x - H}{H}\right)^2 = 6\left(\frac{\sigma}{\theta}\right)^2 = \frac{1}{2} \tag{28}$$

We can observe that the Hubble factor, scalar expansion and shear scalar diverge at t = 0 and they become finite as t → ∞ [51-54].The anisotropic parameter becomes constant for our models. From the above mentioned equation, it can be observed that our models are expanding and accelerating the universe, which starts at a big bang singularity.

4. Jerk parameter

The jerk parameter is considered as one of the important quantities for describing the dynamics of the universe. Jerk parameter is dimensionless third derivative of scale factor *a* with respect to cosmic time *t* and is defined as

$$j = \frac{a^2}{\dot{a}^3}\frac{d^3a}{dt^3} \tag{29}$$

$$j = q + 2q^2 - \frac{\dot{q}}{H} \tag{30}$$

Hence we have,

$$\Rightarrow j = 1 - \frac{3\beta}{(1+z)^{-\beta}+1} + \frac{\beta^2}{(1+z)^{-\beta}+1} + \frac{\beta^2}{[(1+z)^{-\beta}+1]^2}. \tag{31}$$

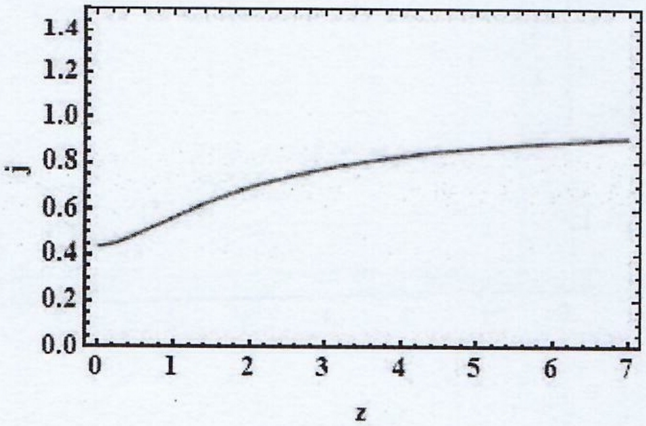


Fig. 5. Behavior of jerk parameter j versus z with $\beta = 1.5$

Jerk is a positive parameter. This denotes a quickening of growth. It's interesting to note that the jerk parameter never reaches unity at $z = 0$, which obviously contradicts the ΛCDM model.

5. Statefinder diagnostic

The statefinder parameters are important to discuss the cosmological aspects of models which are introduced in Refs. [55-56], originally. The state-finder pair {r, s} is defined as

$$r = \frac{\ddot{a}}{aH^2}, \quad r = 1 + \frac{3\dot{H}}{H^2} + \frac{\ddot{H}}{H^3}, \quad s = \frac{r-1}{3(q-\frac{1}{2})} \tag{32}$$

The values of the state-finder parameter for our model are

$$r = 1 - \frac{3\beta}{(1+z)^{-\beta}+1} + \frac{\beta^2[(1+z)^{-\beta}+2]}{[(1+z)^{-\beta}+1]^2}. \tag{33}$$

$$s = \frac{1}{\{6\beta - 9[(1+z)^{-\beta} + 1]\}[(1+z)^{-\beta} + 1]}\{2\beta^2((1+z)^{-\beta} + 2) - 6\beta[(1+z)^{-\beta} + 1]\}. \quad (34)$$

We get different dark energy models for different combinations of r and s: For ΛCDM → (r = 1, s = 0) For SCDM → (r = 1, s = 1) For HDE → (r = 1, s = 2/3) For CG → (r > 1, s < 0) For Quintessence → (r < 1, s > 0). Our model satisfies the ΛCDM scenario of the universe.

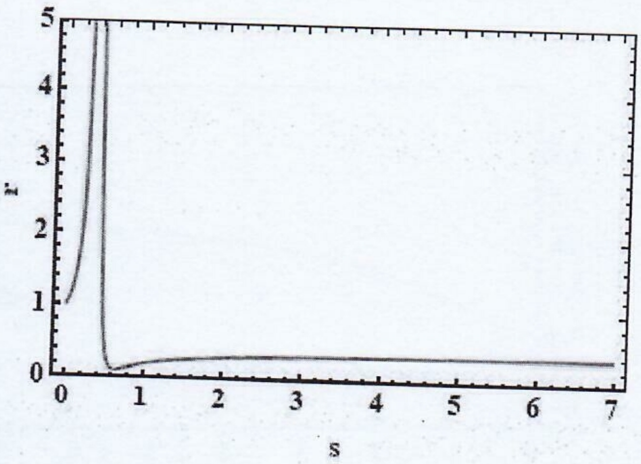


Fig. 6 : r vs s.

6. Conclusion

In this paper, we have considered LRS Bianchi type-I cosmological model in the presence of perfect fluid and generic viable non-minimally coupled

$$f(R,T) = \alpha_1 R^m T^n + \alpha_2 T(1 + \alpha_3 T^p R^q)$$

gravity model, where the gravitational Lagrangian is given by an arbitrary function of Ricci scalar (*R*) and of the trace of the stress-energy tensor (*T*). In this paper, the gravitational field equation has been established by taking $f(R,T) = f_1(R) + f_2(T)$ .The cosmic acceleration in *f(R, T)* gravity results not only from a geometrical effect, but also from a matter contribution. The deceleration parameter describes the rate of expansion and acceleration or deceleration of the universe. If q > 0, the universe is at a decelerated phase, else q < 0 corresponds to an accelerated phase.

The deceleration parameter depicts a transition from positive in the past to negative in the present showing the current accelerated expansion of the universe One can observe that the energy density is positive throughout the universe whereas the pressure is always negative. The negative pressure indicates the expanding accelerated phase of the universe. It is observed that the EoS parameter remains in the quintessence phase supporting the acceleration in the universe.

Received August 20, 2023; Accepted September 30, 2023

References

1. Riess, A. G., Filippenko, A. V., Challis, P., Clocchiatti, A., Diercks, A., Garnavich, P. M., ... & Tonry, J. (1998). Observational evidence from supernovae for an accelerating universe and a cosmological constant. *The Astronomical Journal, 116*(3), 1009.

2. Perlmutter, S., Aldering, G., Goldhaber, G., Knop, R. A., Nugent, P., Castro, P. G., ... & Supernova Cosmology Project. (1999). Measurements of Ω and Λ from 42 high-redshift supernovae. *The Astrophysical Journal, 517*(2), 565.

3. Riess, A. G., Kirshner, R. P., Schmidt, B. P., Jha, S., Challis, P., Garnavich, P. M., ... & Zhao, P. (1999). BVRI light curves for 22 type Ia supernovae. *The Astronomical Journal, 117*(2), 707.

4. Spergel, D. N., Verde, L., Peiris, H. V., Komatsu, E., Nolta, M. R., Bennett, C. L., ... & Wright, E. L. (2003). First-year Wilkinson Microwave Anisotropy Probe (WMAP)* observations: determination of cosmological parameters. *The Astrophysical Journal Supplement Series, 148*(1), 175.

5. Tegmark, M., Strauss, M. A., Blanton, M. R., Abazajian, K., Dodelson, S., Sandvik, H., ... & York, D. G. (2004). Cosmological parameters from SDSS and WMAP. *Physical review D, 69*(10), 103501.

6. Abazajian, K., Adelman-McCarthy, J. K., Agüeros, M. A., Allam, S. S., Anderson, K. S., Anderson, S. F., ... & York, D. G. (2004). The second data release of the sloan digital sky survey. *The Astronomical Journal, 128*(1), 502.

7. Abazajian, K., Adelman-McCarthy, J. K., Agüeros, M. A., Allam, S. S., Anderson, K. S., Anderson, S. F., ... & Yocum, D. R. (2005). The third data release of the sloan digital sky survey. *The Astronomical Journal, 129*(3), 1755.

8. Spergel, D. N., Bean, R., Doré, O., Nolta, M. R., Bennett, C. L., Dunkley, J., ... & Wright, E. L. (2007). Three-year Wilkinson Microwave Anisotropy Probe (WMAP) observations: implications for cosmology. *The Astrophysical Journal Supplement Series, 170*(2), 377.

9. Komatsu, E., Dunkley, J., Nolta, M. R., Bennett, C. L., Gold, B., Hinshaw, G., ... & Wright, E. L. (2009). Five-year wilkinson microwave anisotropy probe* observations: cosmological interpretation. *The Astrophysical Journal Supplement Series, 180*(2), 330

10. .Komatsu, E, et al. Astrophys. J. Suppl.192 (2011) ,18.

11. Nojiri, Shin'ichi, and Sergei D. Odintsov. "Modified gravity with negative and positive powers of curvature: Unification of inflation and cosmic acceleration." *physical Review D* 68, no. 12 (2003): 123512.

12. Harko, T., Lobo, F. S., Nojiri, S. I., & Odintsov, S. D. (2011). f (R, T) gravity. *Physical Review D, 84*(2), 024020.

13. M. Sharif and M. Zubair, Gen. Relativ. Gravit., vol. 46, no. 6, pp. 1–30, (2014).

14. Myrzakulov, R. (2012). FRW cosmology in f (R, T) gravity. *The European Physical Journal C, 72*(11), 1-9.

15. Sharif, M., & Zubair, M. (2012). Anisotropic universe models with perfect fluid and scalar field in f (R, T) gravity. *Journal of the Physical Society of Japan, 81*(11), 114005.

16. Houndjo, M. J. S., & Piattella, O. (2012). 2150024H. vol. 21. *Int. J. Mod. Phys. D*, 1250024.

17. Alvarenga, F. G., Houndjo, M. J. S., Monwanou, A. V., & Orou, J. B. C. (2012). Testing some f (R, T) gravity models from energy conditions. *arXiv preprint arXiv:1205.4678.*

18. Barrientos, J., & Rubilar, G. F. (2014). Comment on "f (R, T) gravity". *Physical Review D, 90*(2), 028501.

19. Vacaru, S. I., Veliev, E. V., & Yazici, E. (2014). A geometric method of constructing exact solutions in modified f (R, T)-gravity with Yang–Mills and Higgs interactions. *International Journal of Geometric Methods in Modern Physics, 11*(10), 1450088.

20. Sahoo, P. K., & Sivakumar, M. (2015). LRS Bianchi type-I cosmological model in f (R, T) theory of gravity with Λ (T). *Astrophysics and Space Science, 357*(1), 1-12.

21. Sahoo, P. K., Mishra, B., & Tripathy, S. K. (2016). Kaluza–Klein cosmological model in f (R, T) gravity with Λ (T). *Indian Journal of Physics, 90*(4), 485-493.

22. Sahoo, P. K., Mishra, B., Sahoo, P., & Pacif, S. K. J. (2016). Bianchi type string cosmological models in f (R, T) gravity. *The European Physical Journal Plus, 131*(9), 1-12.

23. Sahoo, P. (2016). LRS Bianchi type-I string cosmological model in gravity. *Fortschritte der Physik, 64*(4-5), 414-415.

24. Singh, G. P., Bishi, B. K., & Sahoo, P. K. (2016). Scalar field and time varying cosmological constant in f (R, T) gravity for Bianchi type-I universe. *Chinese journal of physics, 54*(2), 244-255.

25. Singh, G. P., Bishi, B. K., & Sahoo, P. K. (2016). Cosmological constant Λ in f (R, T) modified gravity. *International Journal of Geometric Methods in Modern Physics, 13*(05), 1650058.

26. Houndjo, M. J. S. (2012). Reconstruction of f (R, T) gravity describing matter dominated and accelerated phases. *International Journal of Modern Physics D, 21*(01), 1250003

27. Jamil, M., Momeni, D., Raza, M., & Myrzakulov, R. (2012). Reconstruction of some cosmological models in f (R, T) cosmology. *The European Physical Journal C, 72*(4), 1-6.

28. Singh, C. P., & Kumar, P. (2014). Friedmann model with viscous cosmology in modified $$ f (R, T) $$ f (R, T) gravity theory. *The European Physical Journal C, 74*(10), 1-11.

29. Adhav, K. S. (2012). LRS Bianchi type-I cosmological model in f (R, T) theory of gravity. *Astrophysics and space science, 339*(2), 365-369.

30. Mishra, B., & Sahoo, P. K. (2014). Bianchi type VI h perfect fluid cosmological model in f (R, T) theory. *Astrophysics and Space Science, 352*(1), 331-336.

31. Reddy, D. R. K., Naidu, R. L., & Satyanarayana, B. (2012). Kaluza-Klein Cosmological Model in f

(R, T) Gravity. *International Journal of Theoretical Physics*, *51*(10), 3222-3227.

32. Samanta, G. C. (2013). Kantowski-Sachs universe filled with perfect fluid in f (R, T) theory of gravity. *International Journal of Theoretical Physics*, *52*(8), 2647-2656.
33. Samanta, G. C. (2013). Holographic dark energy (DE) cosmological models with quintessence in bianchi type-V space time. *International Journal of Theoretical Physics*, *52*(12), 4389-4402.
34. Samanta, G. C., & Dhal, S. N. (2013). Higher dimensional cosmological models filled with perfect fluid in f (R, T) theory of gravity. *International Journal of Theoretical Physics*, *52*(4), 1334-1344.
35. Shukla, B. K., Shukla, S. N., & Singh, A. (2022). Late Time Acceleration of the Expanding Universe in the Framework of f (R, T) Gravity. *Prespacetime Journal*, *13*(1).
36. Ahmed, N ., & Pradhan, A. (2014). Bianchi type-V cosmology in f (R, T) gravity with Λ (T). *International Journal of Theoretical Physics*, *53*(1), 289-306.
37. Pradhan, A., Ahmed, N., & Saha, B. (2015). Reconstruction of modified f (R, T) with Λ (T) gravity in general class of Bianchi cosmological models. *Canadian Journal of Physics*, *93*(6), 654-662.
38. Katore, S. D., & Baxi, R. J. (2016). On Dynamical Instability of Kantowski-Sachs Space-Time in f (R) Theory of Gravitation. *Prespacetime Journal*, *7*(16).
39. Rao, V. U. M., & Jaya Sudha, V. (2015). Bianchi type-V dark energy model in Brans-Dicke theory of gravitation. *Astrophysics and Space Science*, *357*(1), 1-4.
40. Pawar, D. D., & Shahare, S. P. (2019). Dynamics of tilted Bianchi type-III cosmological model in f (R, T) gravity. *Journal of Astrophysics and Astronomy*, *40*(4), 1-7.
41. Rao, V. U. M., & Papa Rao, D. C. (2015). Bianchi type-V string cosmological models in f (R, T) gravity. *Astrophysics and Space Science*, *357*(1), 1-5.
42. Rao, V. U. M., Neelima, D., & Sireesha, K. V. S. (2013). Cosmological Models in a Modified Theory of Gravity. *Prespacetime Journal*, *4*(3).
43. Shaikh, A. Y., & Bhoyar, S. R. (2015). Plane Symmetric Universe with Λ in f (R, T) Gravity. *Prespacetime Journal*, *6*(11)..
44. Zubair, M., Sardar, I. H., Rahaman, F., & Abbas, G. (2016). Interior solutions of fluid sphere in f (R, T) $ f (R, T) $ gravity admitting conformal killing vectors. *Astrophysics and Space Science*, *361*(7), 1-6.
45. Pawar, D. D., & Arawal, P. K. (2015). Dark energy cosmological model in f (R, T) theory of gravity. *Prespacetime Journal*, *6*(3).
46. Momeni, D., Moraes, P. H. R. S., & Myrzakulov, R. (2016). Generalized second law of thermodynamics in f (R, T) $ f (R, T) $ theory of gravity. *Astrophysics and Space Science*, *361*(7), 1-6.
47. Shaikh, A. Y., Gore, S. V., & Katore, S. D. (2020). Holographic Dark Energy Cosmological Models in f (G) Theory. *New Astronomy*, *80*, 101420.
48. Pacif, S. K. J., Myrzakulov, R., & Myrzakul, S. (2017). Reconstruction of cosmic history from a simple parametrization of H. *International Journal of Geometric Methods in Modern Physics*, *14*(07),

1750111.

49. Shaikh, A. Y. (2021). Diagnosing Renyi and Tsallis Holographic Dark Energy Models with Hubble's Horizon Cutoff. *arXiv preprint arXiv:2105.04411.*

50. Hatkar, S. P., & Katore, S. D. (2022). Decelerating Kasner Bianchi Type I Viscous Cosmological Models in f (R, T) Theory. *Prespacetime Journal, 13*(3)..

51. Mete, V. G., Umarkar, V. M., & Pund, A. M. (2012). Two-Fluid Cosmological Models in Bianchi Type-V Space-Time in Higher Dimensions. *Prespacetime Journal*, *3*(2).

52. Mete, V. G., Murade, P. B., & Bansod, A. S. (2018). Interacting Dark Fluids in LRS Bianchi Type-II Universe. *Open Access Library Journal*, *5*(10), 1-15.

Available Online

JOURNAL OF
SCIENTIFIC RESEARCH

Publications

J. Sci. Res. **15** (3), 571-581 (2023)

www.banglajol.info/index.php/JSR

Bianchi Type-I Cosmological Model with Perfect Fluid in Modified $f(T)$ Gravity

V. G. Mete [1*], P. S. Dudhe[2], V. M. Ingle[3]

[1]Department of Mathematics, R. D. I. K. & K. D. College, Bandera-Amravati (M. S.), India

[2]P. R. M. I. T & R, Badnera-Amravati (M. S.), India

[3]R. D. I. K. & K. D. College, Bandera-Amravati (M. S.), India

Received 14 October 2022, accepted in final revised form 11 June 2023

Abstract

In this paper, the Bianchi type I cosmological models with perfect fluid is investigated in the framework of $f(T)$ theory of gravitation. The functional form of the function $f(T)$ such as $f(T) = T + \beta T^2$ is used for investigation. The physical and kinematical properties of the models are obtained and analyzed. We obtained an accelerating and expanding universe.

Keywords: Bianchi type-I space-time; Theory of gravity; Perfect fluid.

doi: http://doi.org/10.3329/jsr.v15i3.62228 J. Sci. Res. **15** (3), 571-581 (2023)

1. Introduction

Recent cosmological observations indicate that the present observable universe is undergoing an accelerated expansion. It is generally accepted that dark energy, whose origin is still a mystery in modern cosmology, is the reason for this cosmic acceleration. The discovery of the universe's swift expansion shows that it is almost spatially flat and contains roughly 75 % DE, which causes cosmic acceleration. The universe is fairly equally divided throughout with this mysterious energy, which is physically identical to vacuum energy. Many theories have been developed to explain why the cosmic acceleration begins. The most prominent gravitational modification theory is $f(T)$ gravity. The construction of viable modified teleparallel gravity models has developed as an alternative to general relativity, and in recent years, the cosmological applications of this theory have attracted considerable attention in the literature. We still don't fully comprehend the nature of the origin of dark energy. Einstein-Hilbert action is modified by substituting the function of the Ricci scalar for R. These theories come under the purview of $f(R)$ theories of gravitation. Recently proposed modified theories of gravity include $f(G), f(R,G)$and $f(R,T)$. Metric $f(R)$ formalism was used to study the dark energy scenario by Hatkar *et al.* [1]. In the modified $f(G)$ theory of gravitation, FRW domain walls were studied by Katore *et al.* [2]. Another significantly modified theory of

* *Corresponding author*: vmete5622@gmail.com

gravitation is called $f(T)$, where T is a torsion scalar. It is based on Weitzenbock's geometry. The expression of the torsion scalar T in the cosmological background does not include the time derivative of the Hubble parameter H, in contrast to the curvature scalar R of standard general relativity. We note that tetrad components are derived with the Weitzenbock connection in teleparallelism, and metric components are derived with the Levi-Civita connection in the framework of general relativity. This feature offers a significant advantage in the reconstruction procedure of $f(T)$ gravity compared $f(R)$ gravity.

As a result, general relativity is replaced by the teleparallel gravity scenario employing the transformation of the tetrad components to the metric components. To put it differently, the curvature term R from general relativity is transformed into a torsion term T in the teleparallel scenario, and its modified form is transformed from T to $f(T)$ by an arbitrary function in the associated action, known as the $f(T)$ cosmology theory. In this theory, gravitation is attributed to the torsion of a zero-curvature space-time, which acts as a force. Bianchi type-I spatially homogenous models, whose spatial sections are flat, are the most straightforward anisotropic models typically employed to describe the anisotropic effect. An advantage of adopting anisotropic models is their important role in the description of the early stage of the universe. Chirde *et al.* [3] explored the accelerating universe, dark energy, and exponential $f(T)$ gravity. Bianchi type-I homogeneous and anisotropic space-time has been taken into consideration by several researchers. Katore *et al.* [4] studied a higher dimensional Bianchi type-I inflationary universe in general relativity. The study of dark energy in $f(T)$ theories were done by Bamba *et al.* [5], Bianchi type-I metric with massive string was presented by Pradhan *et al.* [6] in general relativity. The accelerating Bianchi-type dark energy cosmological model with cosmic string in $f(T)$ gravity has been studied by Chirde *et al.* [7]. Pawar *et al.* [8] constructed perfect fluid and heat flow in the $f(R,T)$ theory. The Bianchi type-III charged fluid universe in the Brans-Dicke theory of gravitation was examined by Mete *et al.* [9]. Recently Chirde *et al.* [10,11] explored various types of cosmological models in the context of $f(T)$ gravity. Bhoyar *et al.* [12] studied Kantowaski-Sachs cosmological model with bulk viscous and cosmic string in the context of $f(T)$ gravity. Lambat *et al.* [13] investigated Bianchi type VI_0 inflationary model with scalar field and flat potential in the context of Lyra geometry. Brahma *et al.* [14] explored Bianchi type-V dark energy cosmological model with the electromagnetic field in Lyra based on $f(R,T)$ gravity. Mete *et al.* [15] constructed a five-dimensional cosmological model with a one-dimensional cosmic string coupled with zero mass scalar field in the context of the Lyra manifold.

Motivated by the above discussion, we present a cosmological power law solution for the universe's acceleration based on the teleparallel equivalent of general relativity modified as previously mentioned. The functional form of the function $f(T)$ such as $f(T) = T + \beta T^2$ is used and investigated this theory using the cosmic power law scale factor solution. Because this type of solution offers a framework for determining the behavior of more general cosmological solutions in various eras of our universe, such as radiation-dominant, matter-dominant, or dark energy-dominant eras, we are aware that power law solutions play a significant role in standard cosmology.

In this paper, we examine Bianchi type-I space-time with perfect fluid within the framework of $f(T)$ gravity. Preliminary definitions of $f(T)$ gravity is introduced in Section 2. In Section 3, we explore the field equations together with solutions and some physical and kinematic parameters. The conclusions are given in Section 4.

2. Preliminary Definitions and Equation of Motion of $f(T)$ Gravity

In this section, a concise explanation of $f(T)$ gravity, and a thorough derivation of its field equations is given. Let us define the Greek and Latin notations of the Latin subscript as those connected to the space-time coordinates and the tetrad field, respectively. We can define the line element for a general space-time metric as

$$ds^2 = g_{\mu\nu}dx^\mu dx^\nu, \tag{1}$$

where $g_{\mu\nu}$ are the components of the metric which is symmetric and possesses ten degrees of freedom. The theory can be expressed either in space-time or in tangent space, allowing us to rewrite the line element that can be transformed into the tetrad described by Minkowski (which represents the dynamic fields of the theory) as follows.

$$ds^2 = g_{\mu\nu}dx^\mu dx^\nu = \eta_{ij}\theta^i\theta^j \tag{2}$$

$$dx^\mu = e_i^\mu\theta^i, dx^\nu = e_i^\nu\theta^j, \tag{3}$$

where $\eta_{ij} = diag[1,-1,-1,-1]$ is Minkowski metric, $e_i^\mu e_\nu^i = \delta_\nu^\mu$ or $e_i^\mu e_\mu^j = \delta_i^j$. The square root of the metric determinant is given by $\sqrt{-g} = det[\,e_\mu^i] = e$ and the tetrads e_μ^α represent the dynamic fields of the theory. The Weitzenbocks connection components for a manifold, where the Riemann tensor part without the torsion terms is null (contribution of the Levi-Civita connection) and only the nonzero torsion terms exist, are defined as follows

$$\Gamma_{\mu\nu}^\alpha = e_i^\alpha\partial_\nu e_\mu^i = -e_\mu^i\partial_\nu e_i^\alpha \tag{4}$$

which has a zero curvature but nonzero torsion. The main geometrical objects of space-time are constructed from this connection. Through the connection, the components of the tensor torsion are defined by the anti-symmetric part of this connection as

$$T_{\mu\nu}^\alpha = \Gamma_{\mu\nu}^\alpha - \Gamma_{\nu\mu}^\alpha = e_i^\alpha(\partial_\mu e_\nu^i - \partial_\nu e_\mu^i). \tag{5}$$

Also, define the components of the so-called con-torsion tensor as

$$K_\alpha^{\mu\nu} = (-\tfrac{1}{2})(T_\alpha^{\mu\nu} - T_\alpha^{\nu\mu} - T_\alpha^{\mu\nu}). \tag{6}$$

To make clearer the definition of the scalar equivalent to the curvature scalar of Riemannian geometry, we first define a new tensor $S_\alpha^{\mu\nu}$, constructed from the components of the torsion and contortion tensors as

$$S_\alpha^{\mu\nu} = \frac{1}{2}(K_\alpha^{\mu\nu} - \delta_\alpha^\mu T_\beta^{\beta\nu} - \delta_\varepsilon^\nu T_\beta^{\beta\mu}) \quad (7)$$

Now, we can be able to construct a contraction that is equivalent to the scalar curvature in general relativity. We define then the torsion scalar as

$$T = T_{\mu\nu}^\alpha S_\alpha^{\mu\nu} \quad (8)$$

Now, we define the action by generalizing the teleparallel gravity, i.e., $f(T)$ theory as

$$S = \int [T + f(T) + L_{Matter}] e d^4 x. \quad (9)$$

Here, $f(T)$ denotes an algebraic function of the torsion scalar T. Making the functional variation of the action (9) with respect to the tetrads, we get the following equations of motion

$$S_\mu^{\nu\rho} \partial_\rho T f_{TT} + [e^{-1} e_\mu^i \partial_\rho (e e_i^\alpha S_\mu^{\nu\rho}) + T_{\lambda\mu}^\alpha S_\alpha^{\nu\lambda}] f_T + \frac{1}{4} \delta_\mu^\nu f = 4\pi T_\mu^\nu \quad (10)$$

The field equation (10) is written in terms of the tetrad and partial derivatives and appears very different from Einstein's equation,

where T_μ^ν is the energy-momentum tensor, $f_T = {df(T)}/{dT}$, $f_{TT} = {d^2 f(T)}/{dT^2}$ and by setting $f(T) = a_0 =$ constant, the equations of motion (10) are the same as that of the teleparallel gravity with a cosmological constant, and this is dynamically equivalent to general relativity. These equations clearly depend on the choice made for the set of tetrads.

3. Field Equations for the Bianchi Type-I Model

The line element of homogeneous anisotropic Bianchi type-I is given by

$$ds^2 = dt^2 - A^2(t)dx^2 - B^2(t)(dy^2 + dz^2), \quad (11)$$

where the metric potentials A and B be functions of cosmic time t only.
Let us choose the following set of diagonal tetrads related to the metric (11)

$$[e_\mu^\nu] = diag[1, \rightleftarrows A, B, B] \quad (12)$$

The determinant of the matrix (11) is

$$e = AB^2 \quad (13)$$

The components of the tensor torsion (5) for the tetrads (11) are given by

$$T_{01}^1 = \frac{\dot{A}}{A}, T_{02}^2 = \frac{\dot{B}}{B}, T_{03}^3 = \frac{\dot{B}}{B} \quad (14)$$

The components of the tensor $S_\alpha^{\mu\nu}$ in (7), are given by

$$S_1^{10} = \frac{\dot{B}}{B}, S_2^{20} = \frac{1}{2}\left(\frac{\dot{A}}{A} + \frac{\dot{B}}{B}\right), S_3^{30} = \frac{1}{2}\left(\frac{\dot{A}}{A} + \frac{\dot{B}}{B}\right) \quad (15)$$

The corresponding torsion scalar (8) is given by

$$T = -2\left(2\frac{\dot{A}\dot{B}}{AB} + \frac{\dot{B}^2}{B^2}\right) \quad (16)$$

Here we take a more general perfect fluid stress-energy tensor in the following form.

$$T_{ij} = (p+\rho)u^{\nu}u_{\mu} - p\delta^{\nu}_{\mu}, \tag{17}$$

where u^{ν} is the four-velocity vector, while ρ and p are the energy density and pressure of the fluid, respectively.

Now, the field equations for space-time (11), in the framework of $f(T)$ gravity, is obtained as

$$f + 4f_T\left(2\frac{\dot{A}}{A}\frac{\dot{B}}{B} + \frac{\dot{B}^2}{B^2}\right) = 16\pi\rho \tag{18}$$

$$f + 4f_T\left(\frac{\dot{A}}{A}\frac{\dot{B}}{B} + \frac{\dot{B}^2}{B^2} + \frac{\ddot{B}}{B}\right) + 4\left(\frac{\dot{B}}{B}\right)\dot{T}f_{TT} = -16\pi p \tag{19}$$

$$f + 2f_T\left(3\frac{\dot{A}}{A}\frac{\dot{B}}{B} + \frac{\dot{B}^2}{B^2} + \frac{\ddot{A}}{A} + \frac{\ddot{B}}{B}\right) + 2\left(\frac{\dot{A}}{A} + \frac{\dot{B}}{B}\right)\dot{T}f_{TT} = -16\pi p, \tag{20}$$

where the dot (.) denotes the derivative with respect to time t.

Finally, here we have three differential equations with five unknowns, namely, A, B, f, ρ, p. The solution of these equations is discussed in the next section. In the following, we define some important physical quantities of space-time.

We assume the analytic relation between the metric coefficients as

$$A = B^n \tag{21}$$

some kinematical space-time quantities, average scale factor (a), and volume (V), respectively are defined as

$$a = \sqrt[3]{AB^2}, V = a^3 \tag{22}$$

The generalized mean Hubble parameter (H), which describes the volumetric expansion rate of the universe, is

$$H = \frac{1}{3}(H_1 + H_2 + H_3), \tag{23}$$

where H_1, H_2, H_3 are the directional Hubble parameters.

Eqns. (22) and (23), reduced to

$$H = \frac{1}{3}\frac{\dot{V}}{V} = \frac{1}{3}(H_1 + H_2 + H_3) = \frac{\dot{a}}{a} \tag{24}$$

We discuss the mean anisotropy parameter (A_m) of the form to analyze whether the model approaches isotropy or not.

$$A_m = \frac{1}{3}\sum_{i=1}^{3}\left(\frac{H_i}{H} - 1\right)^2 \tag{25}$$

The expansion scalar (θ) and the shear scalar (σ^2) are defined as

$$\theta = u^{\mu}_{;\mu} = 3H \tag{26}$$

$$\sigma^2 = \frac{3}{2}A_m H^2 \tag{27}$$

3.1. *Physical and kinematical parameters*

Model-I: We consider the value of the average scale factor corresponding to the model of the universe as

$$a = t^{\frac{b}{3}} \tag{28}$$

The value of the deceleration parameter is given for the mean scale factor in Eqn. (28) as

$$q = -1 + \frac{3}{b} \tag{29}$$

It is crucial to remember that to determine the values of metric functions, the average scale factor *a(t)* must be known. Since they define how the cosmos works, the deceleration and Hubble parameters are essential for developing cosmological theories. According to recent discoveries, the universe was previously decelerating and is currently accelerating. The value of the deceleration parameter is, therefore, commonly taken to have both a constant and a time-dependent form. Many researchers have found various average scale factor forms and recommended various time-dependent deceleration parameter forms for the model.

For this model, the associated metric coefficients A and B become

$$A = t^{\frac{bn}{n+2}} \tag{30}$$

$$B = t^{\frac{b}{n+2}} \tag{31}$$

Using Eqns. (30) and (31), we get

$$ds^2 = dt^2 - t^{\frac{bn}{n+2}} dx^2 - t^{\frac{b}{n+2}} (dy^2 + dz^2) \tag{32}$$

The Torsion scalar *(T)* becomes

$$T = \frac{4(2n+1)b^2}{(n+2)^2 t^3} \tag{33}$$

The spatial volume (V) is given as

$$V = t^b \tag{34}$$

The mean Hubble parameter (*H*) and the expansion scalar (θ) turn out to be

$$H = \frac{b}{3t} \tag{35}$$

$$\theta = \frac{b}{t} \tag{36}$$

The average scale factor and spatial volume disappear with time $t \to 0$. As time $t \to 0$, the model begins to expand with a zero volume; when time increases expansion scalar decreases, and as the time $t \to 0$, the mean Hubble parameter is initially large and zero at time $t \to 0$,

The expansion scalar $\theta \to 0$ as time $t \to \infty$, which indicates that the universe is expanding with an increase with time *t*.

The mean anisotropy parameter (A_m) and shear scalar (σ^2) are given by

$$A_m = \frac{2(n-1)^2}{(n+2)^2} \tag{37}$$

$$\sigma^2 = \frac{(n-1)^2 b^2}{3(n+2)^2 t^2} \tag{38}$$

It has been found that the spatial volume vanishes at starting time $t = 0$, expands with time, and becomes infinitely massive at $t = \infty$. Compared to the shear scalar, which is time-dependent and decreases with time as the universe expands, the mean anisotropy parameter is independent of time t and remains constant throughout the universe's evolution from early to infinite expansion. This indicates how the universe is expanding with the flow of time while slowing its growth rate to a constant value, showing how the universe began to expand at an infinite rate.

The exact general solution for a viable $f(T)$ a model with a quadratic correction term $f(T) = T + \beta T^2$, will be derived in this section. In particular, considering the basic and usual ansatz $f(T) = T + \beta T^2$ is a good approximation in all realistic cases, and we can use data from planetary motions to constrain β. Houndjo and Momeni [16] investigated cylindrical solutions in modified $f(T)$ gravity with the given function.

$$f(T) = T + \beta T^2, f_T = 1 + 2\beta T, f_{TT} = 2\beta$$

The value of energy density and pressure become,

$$\rho = \frac{1}{\chi^2}\left\{\frac{2(2n+1)b^2}{(n+2)^2 t^2}\left[1 - \frac{6\beta(2n+1)b^2}{(n+2)^2 t^2}\right]\right\} \tag{39}$$

$$p = -\frac{1}{\chi^2}\left\{\begin{array}{l}\frac{4(2n+1)b^2[(n+2)^2 t^3 + 4\beta(2n+1)b^2]}{(n+2)^4 t^6} + \frac{3[(n+2)^2 t^3 + 8\beta(2n+1)b^2](b^2-b)(n+2)^2 t}{(n+2)^4 t^6} \\ - \frac{24\beta(2n+1)(3+n)b^3(n+2)t}{(n+2)^4 t^6}\end{array}\right\} \tag{40}$$

In the power law expansion of the universe, the energy density (39) is always positive and decreases as cosmic time t grows. The energy density of the cosmos is infinitely massive at first, but it diminishes with expansion and disappears entirely at very great expansion, as seen in Fig. 1. It is evident that pressure (40) takes on a negative value during the period of the cosmic time development displayed in Fig. 2. Negative pressure is necessary to produce an antigravity effect and to propel the acceleration, as is clear from observational evidence.

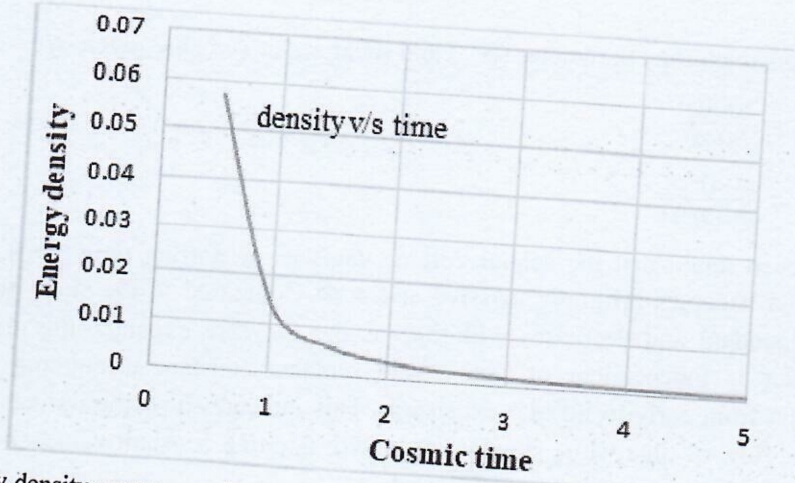


Fig. 1. Energy density versus cosmic time.

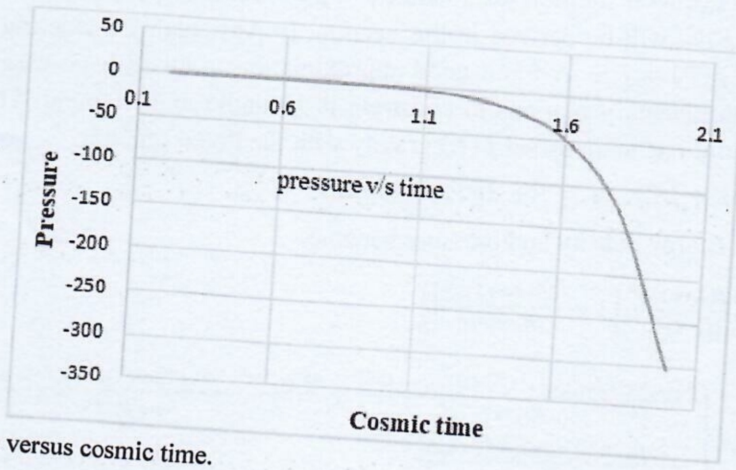


Fig. 2. Pressure versus cosmic time.

Model II: We consider the value of the average scale factor corresponding to the model of the universe as

$$a = (e^{bt} - 1) \tag{41}$$

The value of the deceleration parameter is given for the mean scale factor in Eq. (41) as

$$q = -1 + \frac{1}{e^{bt}} \tag{42}$$

The associated metric coefficients A and B for this model become

$$A = (e^{bt} - 1)^{\frac{3n}{n+2}} \tag{43}$$

$$B = (e^{bt} - 1)^{\frac{3}{n+2}} \tag{44}$$

Using Eqns. (43)and (44), we get

$$ds^2 = dt^2 - (e^{bt} - 1)^{\frac{3n}{n+2}} dx^2 - (e^{bt} - 1)^{\frac{3}{n+2}} (dy^2 + dz^2) \tag{45}$$

The Torsion scalar *(T)*becomes

$$T = \frac{-18(2n+1)b^2}{(n+2)^2(1-e^{-bt})^2} \tag{46}$$

The spatial volume (V)becomes

$$V = a^3 = (e^{bt} - 1)^3 \tag{47}$$

The mean Hubble parameter (H) and the expansion scalar (θ) turn out to be

$$H = \frac{b}{(1-e^{-bt})} \tag{48}$$

$$\theta = 3H = \frac{3b}{(1-e^{-bt})} \tag{49}$$

The spatial volume disappear with time $t \to 0$. At time $t \to 0$, the model begins to expand with a zero volume. The mean Hubble parameter is initially large and zero as time $t \to \infty$. The expansion scalar $\theta \to 0$ as time$t \to \infty$, which indicates that the universe is expanding with increases with time.

The mean anisotropy parameter (A_m) and shear scalar (σ^2) are given by

$$A_m = \frac{2(n-1)^2}{(n+2)^2} \tag{50}$$

$$\sigma^2 = 3\frac{(n-1)^2 b^2}{(n+2)^2(1-e^{-bt})^2} \tag{51}$$

It has been found that the spatial volume vanishes at starting time = 0, expands with time, and becomes infinitely massive at $t = \infty$. Compared to the shear scalar, which is time-dependent and decreases with time as the universe expands, the mean anisotropy parameter is independent of time t. It remains constant throughout the universe's evolution from early to infinite expansion. This indicates how the universe is expanding with the flow of time while slowing its growth rate to a constant value, showing how the universe began to expand at an infinite rate.

The energy density and pressure become,

$$\rho = \frac{1}{\chi^2}\left\{\frac{18(2n+1)b^2}{(n+2)^2(1-e^{-bt})^2}\left[1 - \frac{54\beta(2n+1)b^2}{(n+2)^2(1-e^{-bt})^2}\right]\right\} \tag{52}$$

$$p = -\frac{1}{\chi^2}\left\{\begin{array}{l}\frac{-18(2n+1)b^2[(n+2)^2(1-e^{-bt})^2-18\beta(2n+1)^2b^2]}{(n+2)^4(1-e^{-bt})^4}\\ +\frac{12b^2\rightleftarrows[(n+2)^2(1-e^{-bt})^2-36\beta(2n+1)b^2][3n+3+(3-(n+2)e^{-bt})]}{(n+2)^4(1-e^{-bt})^4} - \frac{864\beta(2n+1)b^4e^{-bt}}{(n+2)^4(1-e^{-bt})^4}\end{array}\right\} \tag{53}$$

The energy density (52) actions for a suitable selection of constants are shown in Fig. 3. The energy density is a function of time t and decreases. According to Fig. 4, it is evident that pressure (53) takes on a negative value as cosmic time progresses. As observational evidence shows, negative pressure is necessary to produce an antigravity effect and drive the acceleration.

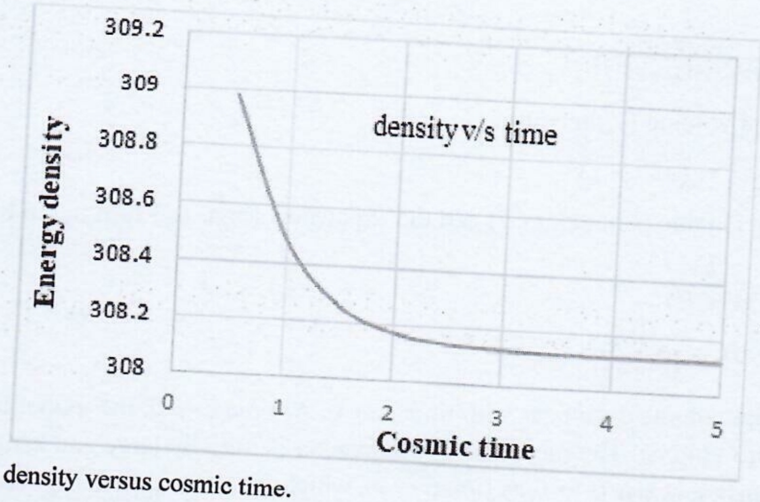


Fig. 3. Energy density versus cosmic time.

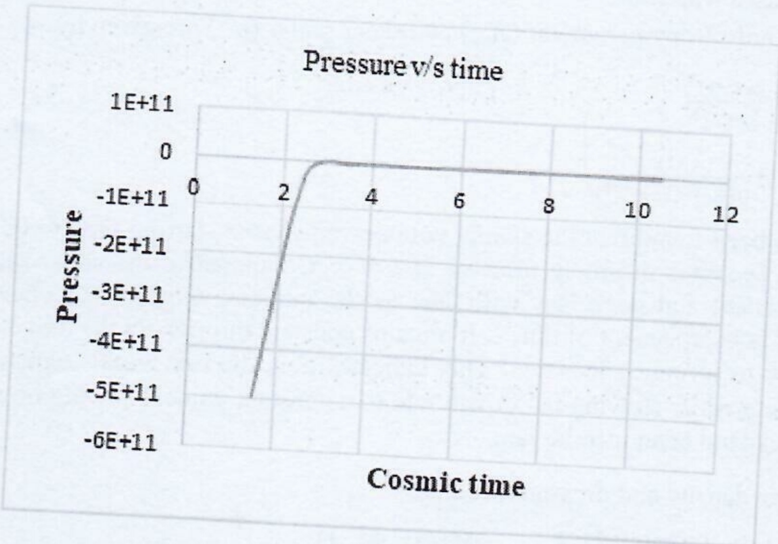


Fig. 4. Pressure versus cosmic time.

4. Conclusion

In this paper, we have presented the solution of spatially homogeneous and anisotropic Bianchi type-I cosmological model in the presence of perfect fluid in $f(T)$ theory of gravity. We have derived the exact general solution for a viable $f(T)$ a model with a quadratic correction term $f(T) = T + \beta T^2$. For this purpose, we use scale factor $a = t^{\frac{b}{3}}$,$a = (e^{bt} - 1)$ and $f(T) = T + \beta T^2$. We have evaluated some physical parameters for this solution, such as H, θ, A_m, σ^2. The Hubble parameter is decreasing function of time, i.e., the expansion rate decreases as time increases. It is important to note that in both cases, q is negative. Therefore, the universe is accelerating. For these physical parameters, from both the models, we find that energy density is very large initially, and at a later time, it decreases gradually; for the universe to expand, density must decrease. Pressure assumes a negative value throughout the evolution of cosmic time. As evident from observational data, negative pressure is required to provide an antigravity effect and drive the acceleration.

References

1. S. P. Hatkar, P. S. Dudhe, and S. D. Katore, Found. Phys. **49**, 1067 (2019). https://doi.org/10.1007/s10701-019-00302-x
2. S. D. Katore, S. P. Hatkar, and P. S. Dudhe, Grav. Astrophys. **64**, 103 (2021). https://doi.org/10.1007/s10511-021-09672-5
3. V. R. Chirde and S. H. Sheikh, The Afr. Rev. Phys. **10**, 145 (2015).
4. S. D. Katore, K. S. Adhav, V. G. Mete, and A. Y. Shaikh, Pramana **78**, 101 (2012). https://doi.org/10.1007/s12043-011-0208-y
5. K. Bamba, C. Q. Geng, C. C. Lee, and L. W. Luo, J. Cosmo. Astroparticle Phys. **2011**, ID 021 (2011). https://doi.org/10.1088/1475-7516/2011/01/021
6. A. Pradhan and D. S. Chouhan, Astrophys. Space Sci. **331**, 697 (2011). https://doi.org/10.1007/s10509-010-0478-8
7. S. H. Sheikh, V. R. Chirde, Astrophys. Space Sci. **365**, 1 (2020). https://doi.org/10.1007/s10509-020-03772-y
8. D. D. Pawar, R. V. Mapari, and J. L. Pawade, Pramana **95**, 1 (2021). https://doi.org/10.1007/s12043-020-02058-w
9. V. G. Mete, K. R. Mule, and V. M. Ingle, Int. J. Sci. Res. Phys. Appl. Sci. **6**, 57 (2018). https://doi.org/10.26438/ijsrpas/v6i5.5761
10. V. R. Chirde, S. P. Hatkar, and S. D. Katore, Int. J. Modern Phys. D **29**, ID 2050054 (2020). https://doi.org/10.1142/S0218271820500546
11. V. R. Chirde and S. H. Sheikh, Afr. Rev. Phys. **10**, 475 (2016).
12. S. R. Bhoyar, V. R. Chirde, and S. H. Shekh, J. Sci. Res. **11**, 249 (2019). http://dx.doi.org/10.3329/jsr.v11i3.39220
13. P. M. Lambat and A. M. Pund, J. Sci. Res. **14**, 435 (2022). http://dx.doi.org/10.3329/jsr.v14i2.55557
14. B. P. Brahma and M. Dewri, J. Sci. Res. **14**, 721 (2022). http://dx.doi.org/10.3329/jsr.v14i3.56416
15. V. G. Mete and V. S. Deshmukh, J. Sci. Res. **15**, 351 (2023). http://dx.doi.org/10.3329/jsr.v15i2.61442
16. M. J. S.Houndjo, D. Momeni, and R. Myrzakulov, Int. J. Mod. Phys. D **21**, ID 1250093 (2012). https://doi.org/10.1142/S0218271812500939